Impact of Irrigation on Poverty and Environment in Ethiopia

Draft Proceeding of the Symposium and Exhibition held at Ghion Hotel, Addis Ababa, Ethiopia
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Acronyms and Abbreviations

ADA	Austrian Development Agency
ADB	African Development Bank
ADLI	Agricultural Development-led Industrialization
AHFSI	Aggregate Household Food Security Index
AIP	Amibara Irrigation Project
AMU	Arba Minch University
ARC	Austrian Research Centers
ARIS	Annual Relative Irrigation Supply
ARWS	Annual Relative Water Supply
BOKU	University of Natural Resources and Applied Life Sciences
CA	Comprehensive Assessment
CSA	Central Statistical Authority
CGIAR	Consultative Group on International Agricultural Research
DAP	Diammonium Phosphate Fertilizer
DPPC	Disaster Prevention and Protection Commission
EARO	Ethiopian Agricultural Research Organisation
EIA	Environmental Impact Assessment
EIAR	Ethiopian Institute of Agricultural Research
EPA	Environmental Protection Authority
ESDA	Ethiopian Sugar Development Agency
FAO	Food and Agriculture Organization of the United Nations
FDRE	Federal Democratic Republic of Ethiopia
FFW	Food-for-Work
GDP	Gross Domestic Product
GMs	gross margins
GSDID	Gobu Seyo District Irrigation Desk
HU	Haramaya University
IAR	Institute of Agricultural Research
IDP	Irrigation Development Program
IDP	Irrigation Development Strategy
IFAD	International Food and Agricultural Development
IIPE	Impact of Irrigation on Poverty and Environment
IWMI	International Water Management Institute
MoA	Ministry of Agriculture
MoARD	Ministry of Agriculture and Rural Development
MoFED	Ministry of Finance and Economic Development
MoWR	Ministry of Water Resources

MSI	Medium Scale Irrigation
NDVI	Normalized Difference Vegetation Index
OIDA	Oromia Irrigation Development Authority
PA	Peasant Association
PASDEP	Plan for Accelerated and Sustained Development to End Poverty
PRSP	Poverty Reduction Strategy Paper
REST	Relief Society of Tigray
RWH	Rain Water Harvesting
SNNPR	Southern Nation and Nationalities People Region
SSI	Small Scale Irrigation
TUs	Tertiary Units
UNDP	United Nation Development Project
USDA	United States Department of Agriculture
WDR	Water Delivery Ration
WSDP	Water Sector Development Program

Acknowledgement

This proceeding is the output of three days symposium and exhibition organized by International Water Management Institute (IWMI), University of Boku, ARC Sieberdorf, Haramaya University (AU), Arbaminch University (AMU), and Ethiopian Institute for Agricultural Research (EIAR). There were over 126 participants representing institutions from Government, NGOs, private sector, irrigators and students supported by the project who have contributed to the success of this symposium.

The International Water Management Institute is thankful to Austrian Government for allocating the necessary resource to undertake this research which will provide comprehensive and valuable input to the irrigated agriculture sub sector in Ethiopia in particular and Sub Saharan Africa in general.

The authors and co-authors who presented pepares during this symposium also acknowledge the support and assistance provided by various parties in the successefull accomplishment of their respectieve research work.

Welcoming address

Seleshi B. Awulachew

Head, International Water Management Institute (IWMI)
East Africa and Nile Basin, Addis Ababa, Ethiopia

Your Excellency Ato Adugna Jebessa, State Minister, Ministry of Water Resources

Representatives of partner institutions for Impact of Irrigation on Poverty and Environment from Univeritaet Bodunkultur Wien, ARC Sibersodrf, Arba Minch University, Haramaya University, Ethiopian Institute of Agriculture

Delegates from various federal and regional government offices
Academic and research institutions

International donor communities
International and regional institutions
Non governmental organizations
Private sector representatives
Irrigation scheme operators

Ladies and gentlemen:

Thank you very much for accepting our invitation on the Impact of Irrigation on Poverty and Environment symposium and poster exhibition and welcome. The symposium and exhibition are organized towards the final period of the project which has been implemented during the last three and half years

The three days symposium and exhibition are organized in order to share the generated knowledge by the researchers to the wider audience and stakeholders in the irrigation sector.

The symposium is organized with the objectives of:

- Bring together and share experiences among government (policy makers, technical experts), NGOs, private sector, international donors and financial institutions and related stake holders that are working on irrigation, socio-economy and environment;
- Disseminate and Share the results generated during the project implementation period;
- Carry out focused discussion to explore opportunities and mechanisms through which the uptake of knowledge, application, and dissemination and out scaling of findings could be enhanced.

The symposium is organized under four themes that include:

1. *Statues quo analysis, Characterization and Assessment of Performance of irrigation in Ethiopia:*
2. *Irrigation Impact on Poverty and Economy*
3. *Irrigation Policy, Institutions and Support Services)*
4. *Environmental and Health Impact of Irrigation*

In total 28 papers will be presented. In addition a number of posters will also be exhibited. We will be having a number of plenary discussions and group work deliberations. You have the details of the program in your bags.

It is my hope that you will enjoy this event and we can make useful discussions that can lead to a good synthesis of knowledge building on the result of the project and wealth of experience and wisdom of the participants towards the support of sustainable development irrigation in Ethiopia.

In order to start and officially open the symposium I will like to request the representative of the various institutions sitting on the podium to make opening remarks. After the opening remarks, his Excellency Ato Adugna Jebessa will make an official opening speech of the symposium.

Accordingly, first I will like to invite:

- Prof. Willibald Loiskandl, BOKU
- Prof. Belay Kassa, HU
- Dr. Tarkegn Tadessa, AMU
- Dr. Solomon Assefa, EIAR
- Dr. Akissa Bahri, IWMI

Thank you!

Welcoming address

Akissa Bahri, IWMI

Head, International Water Management Institute (IWMI)
Africa Region, Accra, Ghana

Your excellency, Mr. Ato Adugna Jebessa, State Minister of Ministry of Water Resources

Dr. Leopohld Moll, Director, Austrian Development Cooperation

Prof. Willibald Loiskandl, Universität für Bodenkultur Wien

Distinguished representatives of partner institutions for Impact of Irrigation on Poverty and Environment from Universität für Bodenkultur Wien, ARC Siebersdorf, University of Natural Resources and Applied Life Science, Arba Minch University, Haramaya University, Ethiopian Institute of Agriculture

Ladies and gentlemen,

It is with great pleasure that I welcome you all on behalf of the International Water Management Institute and on my own behalf to this symposium on "Impact of Irrigation on Poverty and Environment in Ethiopia" and to this opening session.

This two-day symposium is the output of a collaborative research project sponsored three years ago by the Austrian Development Agency (ADA) and implemented by the International Water Management Institute (IWMI), Austrian Institutions, Universität für Bodenkultur Wien (BOKU, Vienna), Austrian Research Centers (ARC Siebersdorf), the University of Natural Resources and Applied Life Science and Ethiopian Institutions: Arba Minch University (AMU), Haramaya University (HU), the Ethiopian Institute of Agricultural Research (EIAR), the Ministry of Water Resources (MoWR), the Ministry of Agriculture and Rural Development (MoARD) and the Regional Bureaus for Irrigation and Agriculture.

The International Water Management Institute, member of the CGIAR system, is the leading international scientific research organization on water, food and environment, with an overall mission of "improving the management of water and land resources for food, livelihoods and nature". In Africa, IWMI conducts research in three sub-regions; the Nile Basin and East Africa, West Africa and Southern Africa. Water scarcity, poverty, low productivity, health issues, water quality, endemic droughts and floods and transboundary conflicts in water management, along with land degradation are some of the critical issues Africa faces. IWMI works closely with Africa-wide sub–regional organizations and many national and agricultural research systems to study the land and water management challenges facing poor rural communities and to develop innovative approaches, tools and interventions that can improve food security, livelihoods, health and ecosystem services.

Improved land and water management is essential for sustainable development and poverty reduction in sub-Saharan Africa including Ethiopia. I would therefore like to mention two key research programs, the Comprehensive Assessment of Water Management in Agriculture (the CA) (Comprehensive Assessment of Water Management in Agriculture. 2007) and the

Investment in Agricultural Water for Poverty Reduction and Economic Growth in Sub-Saharan Africa (a collaborative program of the World Bank, FAO, IFAD, ADB and IWMI, in partnership with NEPAD, 2007) whose findings should be considered along the results of the present project.

- The CA has critically evaluated the benefits, costs and impacts of the past 50 years of water development, the water management challenges communities are facing today, and solutions people have developed. The results of the CA will support better investment and management decisions in water and agriculture in the near future and over the next 50 years.

- The synthesis report of the Agricultural Investment Study analyses the contribution to date of agricultural water management to poverty reduction and growth in the sub-Saharan Africa, the reasons for its slow expansion and apparently poor track record, as well as the ways in which increased investment in agricultural water management could make a sustainable contribution to further poverty reduction and growth.

Investment in irrigation is needed to reduce poverty in rural areas. Eighty-five percent of sub-Saharan Africa's poor live in the rural areas and depend largely on agriculture for their livelihoods. The Nile basin is home to an estimated 175 million people and more than 330 million people live in the NBEA sub-region. The Nile Basin and East Africa sub-region is far from being homogenous in terms of agro-ecology, socio-economic development, historical and political background. The Sub-region, despite having significant water and land resources, has the highest proportion of people living below the poverty line and is the most food insecure sub-region in the world. Dependence on rainfed agriculture, coupled with high rainfall variability, is one of the main causes of food insecurity. Drought is a frequent and recurrent event throughout much of the region, the impacts of which are made worse by HIV-AIDS and war. The majority of the people, over 70%, depend on subsistence agriculture. However, the resource base of land and water is not well utilized, nor appropriately managed, and is degrading very rapidly. Water-related diseases are common and a major cause of the relatively low life expectancy in the region.

Agricultural growth is therefore clearly key to poverty reduction; it can also help drive national economic growth. Ethiopia relies on agriculture for a large part of its GDP (44%). Raising agricultural productivity is the most viable option for reducing poverty, and irrigation development can enhance economic development. Irrigation schemes can facilitate multiple uses of water that combine agriculture with livestock, fisheries, and other income-generating activities to enhance rural incomes and sustainability. Investment in irrigation is also needed to keep up with global demand for agricultural products and adapt to changing food preferences and societal demands, to adapt to urbanization, industrialization, and increasing allocations to the environment and to respond to climate change. Climate variability and extreme events will require water resources development, large water storage facilities, further irrigation development, and changes in the operation of existing schemes.

Your excellency,
Distinguished participants,
Ladies and gentlemen,

I hope that at the end of this symposium, we would gain insights into how various irrigation strategies have impacted on agricultural output and hence the reduction of poverty as well as improvement in the environmental conditions of Ethiopia. This should then help us to better understand the role that irrigation can play in Ethiopia's development process and hence improve rural poverty, achieve gender equity and protect Ethiopia's environment.

It is my hope that this symposium will constitute a major step that will lead to better natural resources management in Ethiopia.

On behalf of IWMI, I would like to thank you all for coming and look forward for a fruitful and rewarding symposium.

Thank you

Opening Address

H.E Dr. Leopohld Moll

Director, Austrian Development Cooperation
Addis Ababa, Ethiopia

His Excellency Dr. Leopohld Moll, Director Austrian Development Cooperation in his oral speech said that the Austrian Government is pleased to support t the Government of the Federal Republic of Ethiopia in its effort to fight poverty and improve the well being of its people. The Austrian government recognizes the significance of irrigated agriculture in mitigating the impacts of climate variability and attaining food security in Ethiopia. He said, it is my sincere belief that the out puts of the research results of the IIPE project provides veritable information that can assist policy makers to make appropriate policy related decsions in the subsector.
Finally, he wished participants a successful two days deliberation.

Opening Address

H.E Ato Adugna Jebessa

State Minister, Ministry of Water Resources
Addis Ababa, Ethiopia

Dear delegates of government and non governmental organizations

Representatives of academic and research organizations

Dear invited guests and participants

Ladies and Gentlemen,

It is indeed my great pleasure to be here with you today for the opening of this important workshop on **impact of irrigation on poverty and environment research** in Ethiopia.

As you all know there is a global consensus to fight poverty and improve human well being through appropriate measures that can target the issues related to poverty. Accordingly, in the year 2000 the MDG have set quantitative targets to be achieved by the year 2015 for the reduction of poverty, i.e. improvement in health, education, and the environment and other dimensions of human well being, particularly in sub-Saharan Africa where about 25% of the world poor live.

The economy of Ethiopia is significantly agricultural based. Access to reliable water is a fundamental factor in influencing poverty and economy. In this country, recurrent droughts have caused serious failures in agricultural production that have resulted in mass starvation and loss of human and animal life, not to mention the devastation of the natural environment. A more satisfactory outcome can be achieved through the development of the country's water resources for growth of productivity and irrigation, wherever opportunities exist.

Population explosion and food insecurity are serious twin problems that must be addressed simultaneously on priority basis. Despite several attempts to address the situation, the problem of environmental degradation, agricultural productivity and food shortage remains critical. Unless they are seriously tackled they are threats to the country and can worsen poverty in the face of the rapidly growing population.

The Ministry of Water Resources in an effort to develop and utilize the countries water resources in a systematic way has prepared policy, strategy and development plans for effective and efficient water use. Through the river basin master plan studies all the potentials for irrigation developments are identified and there exists over about 3.5 million hectares of land suitable for irrigation development. In addition, improving water management in the rain fed systems as well has significant scope to increase productivity of agriculture

Recognizing these facts, while small scale irrigation and rainfed agriculture water management are undertaken by regional government, medium and large scale irrigation developments have been given significant attention by the federal government and the Ministry of Water Resources in it's development program. Accordingly, 487,000 ha of land are planned to be irrigated during the PASDEP period (2009/10) in addition to the existing one. Some of these projects are ready for detail design and construction and some are already under construction. This clearly shows, substantial investment in irrigated agriculture is needed to meet targets for poverty alleviation, food security and economic growth. I would like to also stress that some of the large and medium scale irrigations are and will be designed to benefit the smallholder farmers, as the government of Ethiopia strongly committed to eradicate the rural poverty. Notable example is the Koga irrigation development which is designed to develop about 6,000ha with over 7,000 (?) beneficiaries. As the development of large schemes for small holders is new experience for the country, it is important for research institutions to support such endeavors by undertaking adoptive and applied research which can support this and future development in sustainable manner

While many Sub-Saharan countries and Ethiopia alike committed to water infrastructure development, lending for irrigation in Sub-Saharan Africa has declined considerably over the past few decades. But still, there are reports that indicate many Bank-financed irrigation projects had produced satisfactory outcomes and the outputs of this particular research are expected to prove that the benefits of investment have reached the poor. However, it is clear that there are issues to be addressed and constraints to be overcome if investments in agricultural water or irrigation development are to achieve viability and sustainability.

Among other factors, capacity building stands as a key factor to obtain diversified expertise and to increase knowledge that is required for sustainable irrigation and drainage. There are pertinent issues with regard to technology, material and equipment selection and even methodologies in engineering design of irrigation projects. In this regard, researchers are expected to contribute significantly towards scientific, practical, and multidisciplinary solution for the prevailing irrigation development constraints and be able to advice decision makers. At this juncture, I would like to mention the MOU signed with International Water Management Institute (IWMI) is having such an objective of initiating conceptual and practical research on high priority areas in collaboration with Ethiopian partners, including issues that would have impact on the development.

Another important area is to ensure that all the partners public, private, civil society as well as donor/lending partners, have sufficient information from our data base to allow them understand the benefits of irrigation development from both social and economic perspective. I hope studies like the Impact of Irrigation on Poverty and Environment for which this symposium is organized can help to enhance such understanding and synthesize the new knowledge generated.

Finally, I would like to thank IWMI, BOKU, ARC Sieberdorf, and Ethiopian Institutions such as Arba Minch University, Haramaya University and Ethiopian Institute of Agricultural Research and other collaborating institutions for the initiative that they have taken in support of irrigation development in general and conducting the related research. The Ministry of Water Resources would like to reiterate its commitment to collaborate and closely work with all stakeholders that are interested in promoting and developing the water resources of this country.

Finally, for those of you who came from abroad wishing you a pleasant stay in Addis Ababa, I wish you all, success in your deliberation and I declare the workshop open.

Good bless you
I thank you

Theme one:

Status Quo Analysis, Characterization and Assessment of Performance of Irrigation in Ethiopia

Papers

1. Status quo analysis, characterization and assessment of performance of irrigation in Ethiopia
2. Comparison of irrigation performance based on management and cropping types
3. Irrigated and rainfed crop production systems in Ethiopia
4. Baseline survey of irrigation and rainfaid agriculture in Ethiopian part of Nile Basin

Statues quo analysis, Characterization and Assessment of Performance of Irrigation in Ethiopia

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Abstract

This paper first looks in to the background on major challenges of Ethiopia with respect to poverty. It discuses the root cause of poverty and its vicious cycle nature, the interlink of population growth, the scarcity of land and natural resources, the extension of agriculture in to marginal land, the decreasing productivity, inability to invest and deepening of poverty and further aggravation as a result of various shocks such as drought, flood, war, etc. The paper also looks in to the importance of the broad agricultural water management in general and irrigation in particular with respect to increasing productivity and capability to break the vicious cycle and opportunity to reverse in to virtuous cycle that can help eradicate poverty and develop the poor economy. The paper also looks in to how poor management of water resources and impacts of variability of rainfall and related drought affecting the socio-economy and the overall wellbeing of the country to the extent that significant population became dependent on imported food. Results of broad assessment of water resources, database of irrigation development and potential, characterization by typology and major performance in Ethiopia are presented. Key water resources information related to each of the 12 river basins in Ethiopia is summarized. Details of existing irrigation and future potential are also captured in the paper. A geographic information system (GIS) database describing irrigation by typology, region and location, scheme size, type of structures, water source, number of beneficiaries, investment cost, etc, are some of the important attributes of the database. In addition, schemes that are operational and failed are identified in the database. Based on the broad database, performances of the schemes are highlighted. Furthermore, the various sites that are used in the detail study and the selection criteria for the impact of irrigation on poverty and environment project and the specific characteristics of these sites are described.

Key words: poverty, water scarcity, database, GIS, irrigation, water resources.

1. Introduction

Ethiopia is mainly agrarian nation and the rainfed system has always played a central role in Ethiopian society. Dependency on rainfed system has put more than 80% of the society at the mercy of meteorological variability.

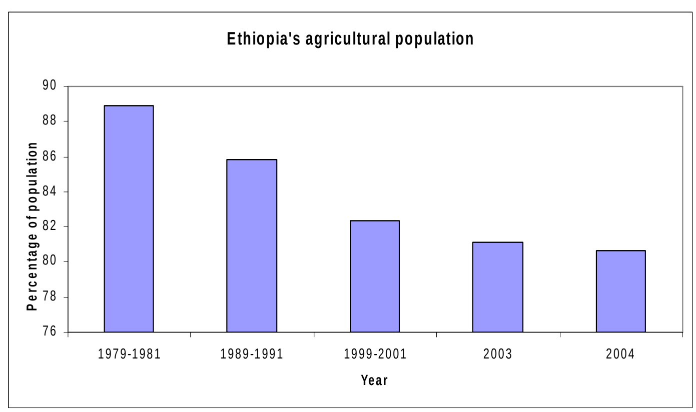

Figure 1: Ethiopia's agricultural population (data extracted from the World Bank Development Indicator WB 2006b)

Figure 1, shows the dependency of Ethiopian population on agriculture and in 25 years the agricultural population reduced only from 89% to 81%. Agriculture in Ethiopia is dominated by small holder production of cereals under rainfed condition, accounting a total area of approximately 10 million hectares. According to Central Statistics Authority [CSA, 1995-1999], within agriculture, some 60 percent of the output is from crops, with livestock and forestry producing 30 percent and 7 percent respectively. Crop production by area is predominantly cereals (84.55 percent) followed by pulses (11.13 percent) and others (4.32 percent). Five crops account for almost all cereal production: maize (15.75 percent), teff (*Eragrostis tef*) (25.78 percent), barley (12.29 percent), sorghum (12.39 percent) and wheat (10.76 percent). According to Mulat et al (Mulat et al 2004), agriculture remains the main activity in the Ethiopian economy. It is the most important contributor to the country's GDP: accounted, on the average, 65.5%, 52.7% and 47.1% of the GDP during 1960-1973, 1974-1991 and 1992-2002, respectively.

Despite the above mentioned facts, there are a number of factors that led to failure of achieving food security in Ethiopia. The major causes for food insecurity in Ethiopia can be associated to the following:

- Population growth and associated inadequate resource base to support
- Lack of growth of production and productivity
- Vulnerability to climatic variability
- Political instabilities and war
- and poverty

The main development objective of the Ethiopian Government is poverty eradication. Hence, the country's development policies and strategies are geared towards this end (MOFED: PASDEP 2006). As Ethiopia's economy and majority of people's livelihood is dependent on Agriculture, to develop the socio-economy of Ethiopia and eradicate poverty, the policy and interventions should focus on Agriculture as entry point. The current rural development policy and strategy of the government clearly stipulates this as priority.

Building further on the above factors, the poverty situation in Ethiopia is a vicious cycle in nature and requires key entry points for intervention. The following figure is a schematic example showing poverty is linked to and aggravated by various demographic, biophysical, production system, productivity and other socio-economic factors.

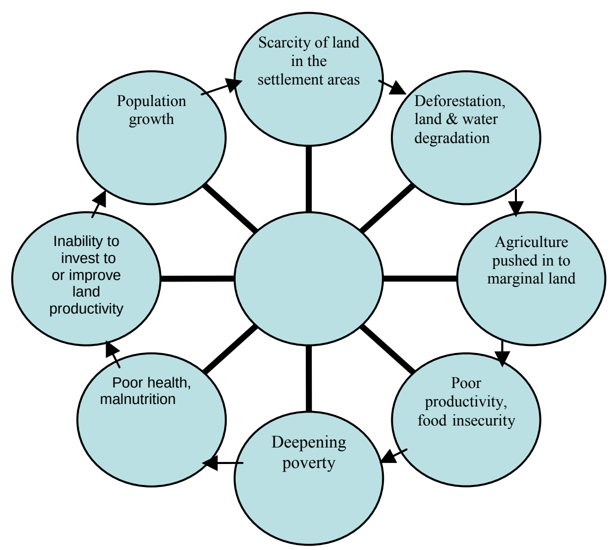

Figure 2: The vicious cycle of poverty and aggravating factors in Ethiopia

Socioeconomic development and civilization of human being is closely associated to ability to utilize and control water resources. Water serves as a positive input for many activities and play negative roles. Positively, it serves essential biological needs, as basic element of social and economic infrastructure, and as a natural amenity contributing psychological welfare. Water also serves in negative roles such as flooding and diseases transmission. In Ethiopia, as in all societies, there has always been a struggle to reduce the negative/destructive impacts of water and enhance its positive/productive impacts, but with limited focus and capacity. These efforts have been increased since the past three to four decades and more so during the last few years. However, the ability to use and enhance the positive role of water and to reduce its negative impacts, in Ethiopia in general has been low.

2. The Importance of Agricultural Water Management and Irrigation in Ethiopia

It is essential to increase agricultural productivity in order to eradicate poverty, improve the economy, and reduce degradation. Irrigation and improved agricultural water management practice is important in Ethiopia for the following major reasons:

- Population in Ethiopia is rapidly increasing (over 80,000,000 currently), land holding size particularly in highland areas is decreasing substantially. Intensification and increasing productivity of land and labour is essential to produce enough food, particularly from the limited available land.
- Agriculture is primarily rain fed dependent. Unless the rain fed system is upgraded through improved water management, recurrent drought and dry spell continue to affect productivity and hamper agricultural production
- Ethiopia's economy is strongly dependent on rain fed based agriculture, and rainfall variability impact costs the economy significantly. Therefore, unless agriculture is de-linked from the strong linkage to rainfall variability, the economy of the country will continue to be severely affected. Particularly, this could be more severe under the strong impact of climate change and variability. WB (2006) and IWMI (2007) describe the impact of costs 1/3rd of growth potential of Ethiopian economy. The impact of this can be shown from the recent information. According to MOFED (MoFED 2006), GDP Growth of Ethiopia in 2002/3 was -3.3% during the drought year while the previous and latter years were positive. In 2004/5, GDP growth was 11.9% and 2005/6 was 10.6%, which brings the three year average down to 6.4%.
- Improved agricultural water management and irrigation can increase productivity of land, water and labor. The following figure based on Central Statistical Authority data and Mulat et al (2004) shows the crop productivity and productivity growth for the period of the last two decades for major crops in Ethiopia. However, recent data of 2004/5 onwards and predicted productivity data according to MOFED (2006) shows there has been increase in productivity of cereals. The increase is mainly attributed to increased input use (seed, fertilizers, and pesticides) and improved water management for agriculture in certain areas. The strategy to achieve the future targeted result focuses to use intensification (irrigation, vertisol management, seed, fertilizer, pest control) and expansion.

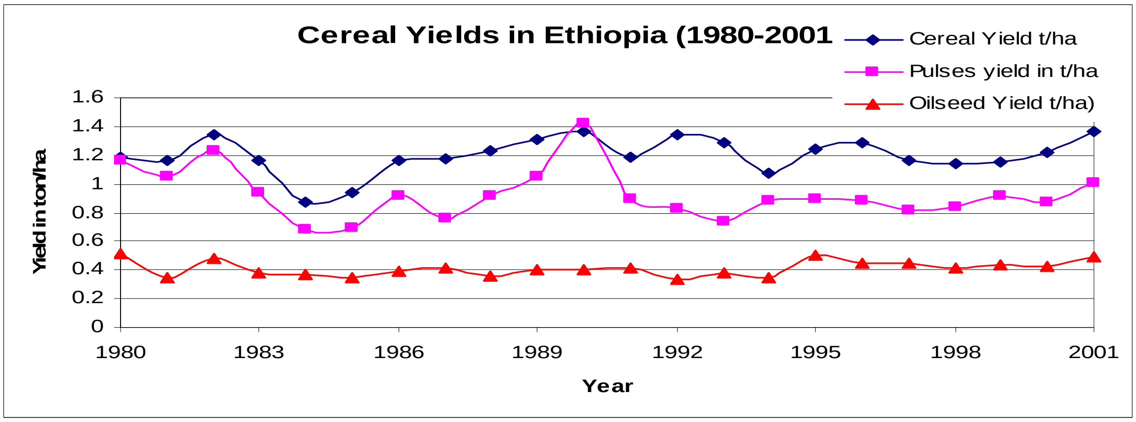

Figure 3: Crop yield in Ethiopia for the period of 1980-2001 (Data source: Mulat 2004)

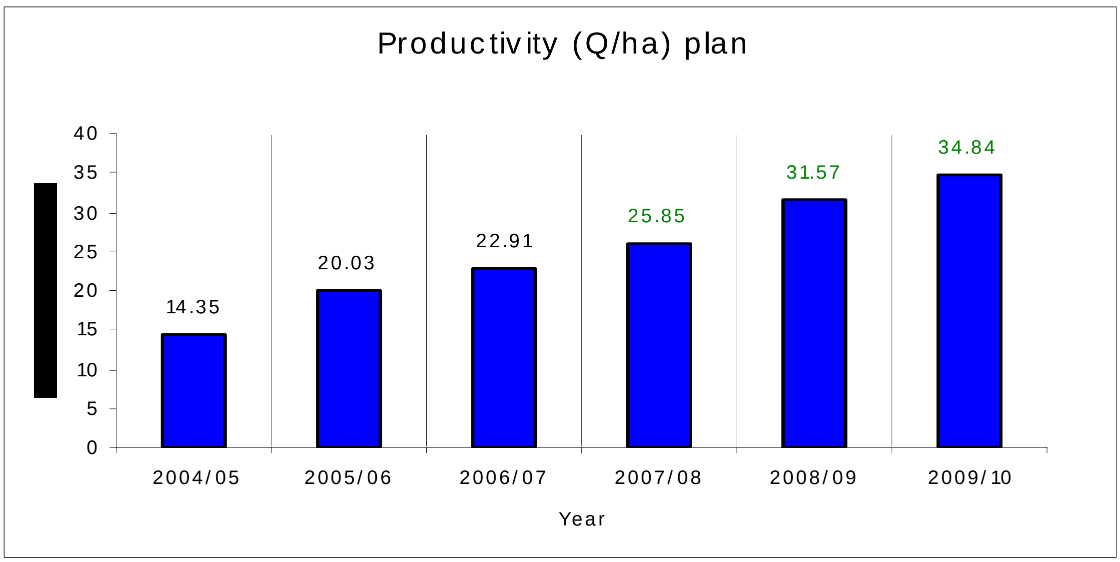

Figure 4: Cereal productivity and productivity Plan of Ethiopia (Data source: MOFED, PASDEP 2006)

- Contrary to the first bullet above, there are considerable land and water resources in various relatively remote parts of the country. The constraining factors for development however are low infrastructure that includes accessibility such as roads, and communication; unregulated water resources; no settled people to develop the resources; lack of capital; and lack of knowledge and capacity. Improving on these can enhance development of these resources. Particularly, the irrigation development through improved infrastructure is an important measure that may be pursued in Ethiopia to cope with complex problems

leading to poverty and insufficient food production

The major sources of growth for Ethiopia is still conceived to be the agriculture sector, as it is expected to be insulated from drought shocks through enhanced utilization of the water resource potential of the country (through development of small scale irrigation, water harvesting, and on-farm diversification), coupled with strengthened linkages between agriculture and industry (agro-industry), thereby creating demand for agricultural output (MOFED 2006).

Irrigation development, including large and medium scale irrigation development, as public schemes, commercial farming and for small holders are getting importance under the current government, particularly since 2004.

3. Irrigation Status in Ethiopia

3.1 History

There is no documented history of water management for agriculture. Remnants of millennium old water storage structures for non-agricultural use around Axum in Tigray show the oldest usage of water in a controlled manner. Certain, non-irrigation related technologies to conserve water and soil have been practiced by Konso people in the South, at least for the last four hundred years. However, there is no well-documented resource material on water use for irrigation in Ethiopia. Modern irrigation development in Ethiopia is not having centuries old history. There is no written history on how Ethiopia has used irrigation technologies to secure agricultural production, as the vast country with small population had adequate natural resources base and rainfall to produce the food requirements without the need to develop irrigation.

Private concessionaires who operated farms for growing commercial crops such as cotton, sugarcane and horticultural crops started the first formal irrigation schemes in the 1950s in the upper and lower Awash Valley. In the 1960s irrigated agriculture was expanded in all parts of the Awash Valley and in the Lower Rift Valley. The Awash valley saw the biggest expansion in view of the water regulation afforded by the construction of the Koka dam and reservoir that regulated flows with benefits of flood control, hydropower and assured irrigation water supply. In addition, the construction of the tarmac Addis-Assab road opened the Awash Valley to ready markets in the hinterland as well as for export (Metaferia, 2004). Although certain aspects of the development during the pre-Derge era have wrong doings in terms of property and land rights, there has been remarkable emergence of irrigation development and establishment of agro industrial centers. Teshome (2003) has reviewed and discussed the land tenure system in the various regimes in Ethiopia. These establishments were highly motivated private sectors, which are both export and domestic market oriented.

During the Derge era, all private farms were nationalized to establish the so-called state farms, thereby ending the embryonic private sector. The government pursued the development of medium and large-scale irrigation schemes in a number of river basins in addition to expansion in the Awash Valley. The Amibara Irrigation Project in the Middle Awash, Alwero Irrigation Project in Gambella, Gode-West Irrigation near Gode town, the Omorrate Irrigation scheme in Southern Omo, the Tana Beles, the Fincha Suger State, etc are some of the expansions, most of which are suspended currently.

Following the downfall of the Derge, the current government withdrew from the expansion of State Farms and further construction of medium and large-scale irrigation (Metaferia, 2004). This has been the trend until the aftermath of the 2002/3 severe drought that has caused about 15 Million population under extreme food shortage. Not only the government hesitated to expand medium and large scale irrigation but also it has interrupted finalization of the above 5 major irrigation projects started in the former regime. On the other hand, the government indeed provided certain attention on small scale irrigation mostly in the food insecure areas. Nevertheless, in the water sector development program (WSDP) it was identified to expand large and medium scale irrigation by about 147,000 ha and small scale irrigation by about 127,000 ha. As strategy of developing irrigation sector, the plan of the government targets to develop a total of additional 274,612 ha of land which brings the total irrigated area of about 478,000 ha by 2015. Despite ignoring the medium and large-scale sector for a decade long, recently after the development of the water sector development program, there is a growing attention to the irrigated agricultural sector. The revised strategy even plans to put more irrigated land in short period of time.

3.2 Water Resources, Irrigation Typology and Existing Schemes

Ethiopia has 12 river basins. The total mean annual flow from all the 12 river basins is estimated at about 122 BMC (WRMP, 1999); Figure 5 and Table 1 show the river basins and distributions of water resources in various basins. The water resources distribution shows slightly higher values as extracted from recent master plan studies.

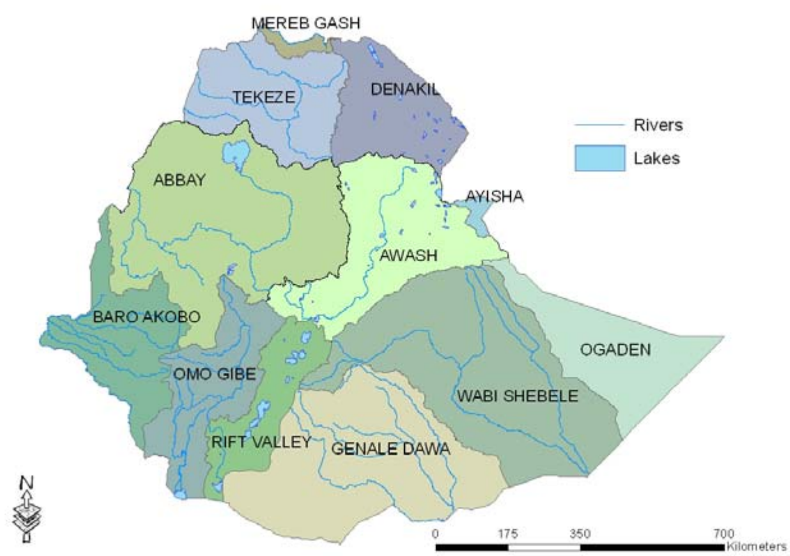

Figure 5: Ethiopia’s River Basins

Table 1: Water resources distribution by river basins of Ethiopia

River Basin	Area (Km^2)	Runoff (Bm^3)	Estimated ground water potential (Bm^3)
Tekeze	82,350	8.2	0.20
Abbay	199,812	54.8	1.80
Baro-Akobo	75,912	23.6	0.28 0.13 Rech/yr
Omo-Ghibe	79,000	16.6	0.42 (.10) Rech /yr
Rift Valley	52,739	5.6	0.10
Mereb	5,900	0.65	0.05
Afar /Denakil	74,002	0.86	-
Awash	112,696	4.9	0.14
Aysha	2,223	-	-
Ogaden	77,121	-	-
Wabi-Shebelle*	202,697	3.16	0.07
Genale-Dawa*	171,042	5.88	0.14
Total	1,135,494	124.25	**2.86**

Source: IWMI Working paper 123 (Awulachew et. al, 2007)

In addition, Ethiopia has also 11 fresh and 9 saline lakes, 4 crater lakes and over 12 major swamps or wetlands. Majority of the Lakes are found in the Rift Valley Basin. For details refer Awulachew et al (2007). The total surface area of these natural and artificial lakes in Ethiopia is about 7,500 km2, representing about 0.67% of area of Ethiopia. Most of the lakes except Ziway, Tana, Langano, Abaya and Chamo have no surface water outlets, i.e. they are endhoric. Lakes Shala and Abiyata have concentrations of chemicals.

3.2 Irrigation Typology

The irrigation schemes in Ethiopia are divided according to the following typology:

- Small scale: These are schemes less than 200ha. Two major categories under this are modern schemes which usually have fixed or improved water control/diversion structures and water users associations that have by laws and traditional schemes – developed and managed by community tradition and usually characterized by non fixed structures and practiced traditionally.
- Medium scale: Schemes exceeding 200ha but less than 3,000ha
- Large scale: schemes exceeding 3,000ha

The latter two are mostly public schemes, owned and managed by the government, and in certain cases by large communities.

There are also irrigation typologies that are not clearly captured in policy and strategy documents. These are

- Water harvesting based irrigation; e.g. Household based minute irrigation;
- Ground water irrigation;
- In-situ Agricultural Water Management.

3.3 Existing Irrigation Schemes

One of the objectives of impact of irrigation on poverty and environment project is to develop GIS database of irrigation schemes to understand the spatial distributions and their characteristics. Accordingly, a database have been developed for about 790 modern irrigation schemes having various attributes such as name, administrative locations, georefenece, type of irrigation, typology, etc. For details refer Awulachew et al (2007).

Based on this the following map is one of the products of the database, showing irrigation distribution in Ethiopia based on attribute of typology and regions. Note also that the map is not showing the complete list of the irrigation schemes, as some of the geo-referencing information is missing and the map represents 107 schemes of complete large and medium scale irrigation and some small-scale irrigation.

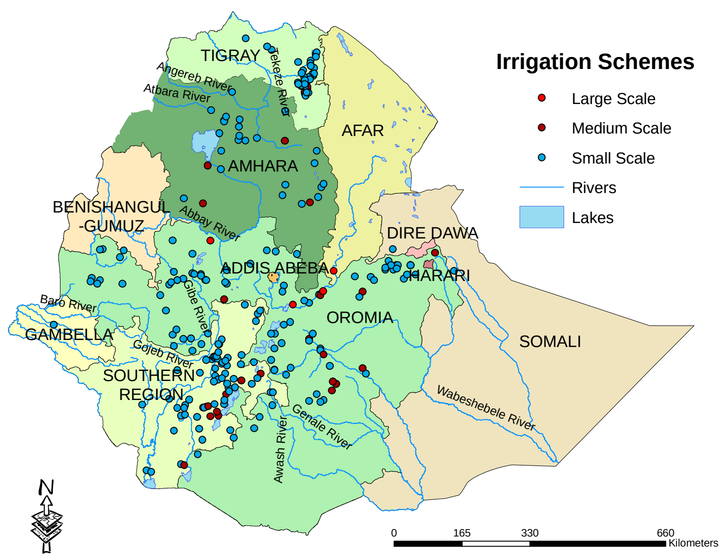

Figure 6: Existing Irrigation schemes distributed in the regional states of Ethiopia

According to MOFED (2006), with respect to irrigation development, within the program period of PASDEP 2004/2005 to 2009/2010, pre-design studies will be carried out for 17,988 hectares, full-fledged design studies will be undertaken on 464,051 hectares, and construction works will be completed for 430,061 hectares. Currently, actual implementation projects at Tendaho and Kessem totaling about 90,000 ha in the Awash Valley, 7,000ha Koga irrigation development in Blue Nile River Basin are actually near completion. There are also many additional scale development projects under construction invested by regional governments, donors and NGOs and private sector.

3.4 Irrigation Potentials by River Basins

In Ethiopia, under the prevalent rain fed agricultural production system, the progressive degradation of the natural resource base, especially in highly vulnerable areas of the highlands coupled with climate variability have aggravated the incidence of poverty and food insecurity. Water resources management for agriculture includes both support for sustainable production in rain fed agriculture and irrigation (Awulachew et al 2005).

Currently, the MoWR has identified 560 irrigation potential sites on the major river basins. The total potential irrigable land in Ethiopia is estimated to be around 3.7 million ha (Awulachew et al 2007). Table 2 and Figure 7 show the irrigation development potential by river basins in Ethiopia. Detail characterization of the potentials by basins is provided in Awualchew et al (2007).

Table 2: Irrigation Potential in the River Basins

Basin	**Catchment Area (Km^2)**	**Irrigation potentials (Ha) (Respective recent master plan studies)**				**WAPCOS, 1995**		
		Small scale	**Medium scale**	**Large scale**	**Total**	**Total Drainage Area (km^2)**	**Irrigable Area (Ha)**	**% Irrigable Area of the Country**
Abbay	198,890.7	45,856	130,395	639,330	815,581	201,346	1001000	27
Tekeze	83,475.94	N/A	N/A	83,368	83,368	90,001	317000	8.5
Baro-Akobo	76,203.12	N/A	N/A	1,019,523	1,019,523	74,102	985000	26.5
Omo-Ghibe	79,000	N/A	10028	57900	67,928	78,213	445000	12
Rift Valley	52,739	N/A	4000	45700	139,300	52,739	139000	3.7
Awash	110,439.3	30,556	24,500	79,065	134,121	112,697	205000	5.5
Genale-Dawa	172,133	1,805	28,415	1,044,500	1,074,720	117,042	423000	11.4
Wabi-Shebele	202,219.5	10,755	55,950	171,200	237,905	102,697	200000	5.4
Danakil	63,852.97	2,309	45,656	110,811	158,776	74,102	-	-
Ogaden	77,121				-	77,121	-	-
Ayisha (Gulf of Aden)	2,000				-	2,000	-	-
Total	1,118,074.53				3,731,222	982,060	3,715,000	100

Note: The national water resources master plan (WAPCOS, 1995) was a desk study without significant field investigation.

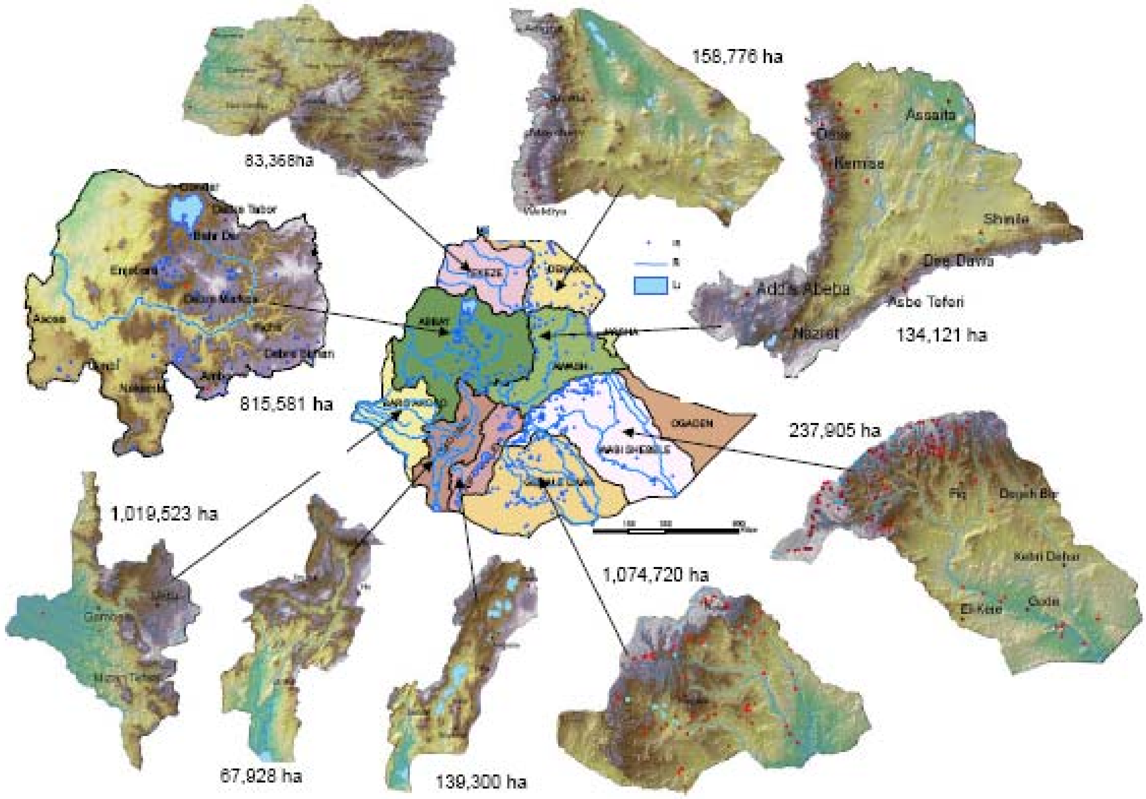

Figure 7: Irrigation Potentials in Ethiopia by River Basins

The complete database is developed for existing irrigation development and irrigation potential. We trust that this database creates important information system and a foundation for complete and comprehensive database that can be updated continuously for irrigation development in Ethiopia. The database is also made available to regional irrigation development bureaus and federal institutions for use and further updating. This information system establishes a public good and any interested institution or individual can receive a copy. The available formats for sharing include GIS products, Microsoft Excel or Microsoft Access database categorized per typology, river basins and regions.

4. General performance of the irrigated systems

The performances of the existing irrigation schemes are highly variable. Some of the schemes from all typologies in terms of water use efficiency, productivity, sustainability are performing very well, while some are not performing efficiently, interrupted while under construction, abandoned after implementation, or transferred from public to private or community and their performances are not known. Many successful schemes are providing increased income, higher productivity, significant job opportunity and considerable contribution to the economy. The existing irrigated schemes are estimated at about 2% of the total agricultural land but contribute over 5% of the agricultural production. On the other hand, there are also a number of schemes with critical problems leading to complete abandonment or under performance, missing the targets of performance in terms of land area developed, number of beneficiaries or sustainability. The assessment related to the database development, see also Awulachew et al (2007) reveals that 17% to 22% of schemes in the Amhara, SNNPR, Oromia and Tigray, particularly small scale irrigation schemes fall under this category.

A number of medium and large irrigation schemes, with a total area of 44,050 hectares, that were under construction, during the previous government, were suspended by the present one. The underlying reason seems to be the policy of market economy precluding government involvement in such economic activities added with the complexity of the projects that were under establishment at remote areas with low infrastructure, insufficient labor and market linkage. However, the wisdom of the decision, for abandonment of development schemes on which hundreds of million have been invested, remains to be questionable. It might be wiser to finalize the schemes and settle smallholders of the area and/or encourage private operators to take over under an attractive/ acceptable arrangement. On the contrary, private initiatives to takeover and finish some of the schemes - Meki-Zeway, Belbela & Wedecha, Alwero - either have not been accepted or have failed of their own accord until recently whereby the former two have attracted the attention of flower farmers. According to MCE (2004) some of the schemes have been turned over to party affiliated companies with limited success. These projects represent priority schemes for rehabilitation and completion.

Besides the suspended schemes a total of 26,347 ha are transferred from public to private or communal developers. The operation of this transferred schemes are variable. Some are successful, some are failed after transfer and the performances of some are not known. MCE (2004) and Awulachew et al (2007) discuss these.

5. Conclusion

This paper, which is related to the wider impact of irrigation on poverty and environment research project, provided information and database on the water resources of Ethiopia, potential of development, extent of existing development focusing on irrigation development. It also discussed irrigation development categorized by various river basins and regions. Discussions were also made on schemes that are non-operational or transferred to community and private sector and their implication on performance.

Specific database is also developed for existing irrigation schemes having a number of attributes. The developed database has information about the existing irrigation schemes and potentials. The database under GIS environment, maps their spatial distribution using point maps from those schemes for which geo-refenced data is available.

It is obvious that Ethiopia is extremly dependent on rain fed agriculture; its majority of population are dependent on agriculture without limit to move out of the sector, agriculture being at low productivity, rapid population growth and lack of innovation to maximize the benefit of the combination of population, land and water. Hence, most of the population are poor and agriculture and overall economy is vulnerable and remains very weak against the shocks of the climatic variability.

The last five years attentions towards development taking the rural development policy and strategy, the water sector policy, the irrigation development strategy, the PASDEP actions are encouraging and hoped to accelerate development endeavors. Ethiopia's challenges towards development are immense and require significant actions and efforts addressing the various problems from various sectors that speed up rapid development.

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Comparison of irrigation performance based on management and cropping types

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Abstract

Although performance evaluation of irrigated agriculture has gained momentum since late 1980s worldwide such attempt is rarely carried out in Ethiopia. The aim of this study was to assess the performance of 7 irrigation schemes some of which are expected to contribute much to the national economy. Sugar cane is grown by three of these schemes whereas cotton is grown by three schemes and the remaining single scheme grows tobacco. With regards to management types both government agency and community managed schemes are considered. The scheme level values of water supply performance indicators show that there was no constraint of water availability and supply at scheme level. In general, schemes that grow sugar cane were found to have attained higher outputs per units of land and water used which ranges from 7794 – 10834US$/ha and 0.24 – 0.55 US$/m^3 respectively. On the other hand, whether state farm or community managed, schemes that grow cotton have shown low output per units of land and water, i.e. 310 – 385 US$/ha and 0.01 – 0.05 US$/m^3 respectively. Large productivity performance differences have been observed between irrigation schemes with same cropping and management types. From scheme level performance values it is not simple to identify the area where and what is going wrong which is responsible for low performance. Generally, problems casing low productivity derive both in management and deterioration of physical structures. Hence investment on improvements of physical structures, management and operation of the system at all levels will bring substantial improvement in the performances of cotton producing schemes.

1. Introduction

Irrigation is highly expected to play a major role in the realization of Ethiopian food security and poverty alleviation strategy. Irrigation enhances agricultural production and improves the food supply, income of rural population, opening employment opportunities for the poor, supports national economy by producing industrial crops that are used as raw materials for value adding industries and exportable crops. From this important viewpoint irrigation projects are widely studied, planed and implemented throughout the country. However, little or no attention is given to the monitoring and evaluation of the performance of already established irrigation schemes. Whether traditional or modern, public agency or community managed many of the existing irrigation systems are deteriorating in their physical structures, operation and management.

Performance assessment is used to identify the present status of the scheme with respect to the selected indicators and will help to identify 'why the scheme is performing so' which in turn imply means of improvement. Of course performance evaluation needs relevant and reliable data which is rarely measured in Ethiopia.

According to Clemmens, A.J. and Molden. D.J. (2007) two major approaches to performance evaluation are to consider, how well service is being delivered and the outcomes of irrigation in terms of efficiency and productivity of recourses use. To measure these performances a number of indicators have been proposed and tested in different parts of the world (Molden, D. et al. 1998; Kloezen W.H., 1998; Burton, M. et al. 2000; Lorite, J. et al. 2004, Bos, M.G. et al. 2005, Vandersypen et al., 2006). IWMI's minimum sets of performance indicators were used by many researchers to compare different irrigation schemes. Comparison helps to identify 'who is doing what right' and what lesson can be learnt or who can be a benchmark for a particular activity. The objective of this study was to assess the performance of 7 irrigation schemes in Ethiopia based on management and cropping types using IWMI's performance indicators.

2. Technical background on performance assessment

Performance can be simply defined as "the level of achievement of desired objectives" (Mohtadullah, K., 1993). Indicators are used to measure performance. An indicator is some number that describes the level of actual achievement in respect of one of the objective of irrigation system. Indicators are used to simplify the otherwise complex internal and external factors affecting the performance of irrigated agricultural system. Performance can be measured from process and output points of view. Process measures of performance relate to a system's internal operations and procedures whereas output measures of performance examine the quality and quantity of the system's final output (Small, L. and M. Svendsen, 1990). While quoting the value of certain indicators, at a particular irrigation system and time, it means that all other factors and processes are ignored or neglected. The fact that an indicator services as a guideline for further decision making it should be carefully chosen, measured and interpreted.

Irrigation performance, whether bad or good, is the result of verities of activities such as planning, design, construction, operation of facilities, maintenance and proper application of irrigation water and agronomic activities (Small L. and Svendsen M. 1990). Facilitation and execution of these activities requires proper coordination of six functional processes of irrigation, i.e. personnel management and support, equipment management, financial management and accounting, and resources mobilization. Planning, design and construction of irrigation schemes are mainly dealing with creation of physical infrastructure to facilitate the capturing of water from its source and transportation up to the farm level. These physical facilities need to be properly operated to ensure the capturing, allocation and delivery of water at the right time and adequate quantity. Maintenance activities are designed to ensure the capabilities of physical infrastructure to deliver the intended amount of water over the project life time. Application of water to the field is the core activity of irrigation which is designed to disperse the incoming stream from higher level canal over the field thereby storing in the crop root zones. Substantial improvements in the performance of such a complex system is not possible by making big improvements at only one level within the system (Clemmens A.J. & Molden D.J., 2007). Physical or management improvements may need to be made at all levels before substantial improvements in the performance can result.

Gorantiwar S.D. and I.K. Smout (2005) have summarized performance measures proposed by various researches into allocation type and scheduling types. Allocation types performance measures are those which need to be attained primarily during the allocation of the resources at the planning and operation stages. Productivity and equity are performance measures under allocation type category. Scheduling type performance measures consists of irrigation scheduling, i.e. temporal and spatial distribution of irrigation water to the users. This measures adequacy, reliability, flexibility, efficiency and sustainability.

Scheduling should be such that water deliveries need to be adequate both in planning and operation, reliable, flexible and sustainable. The same authors grouped these two categories of performance measures into: economic (productivity), social (equity), environmental (sustainability) and management (reliability, adequacy, efficiency and flexibility).
Conveyance efficiency is used to compare the amount of water delivered at the turnouts of the main irrigation conveyance network to the total amount of water delivered into the irrigation scheme. Its measurement is important in that water allocation plans are developed using estimated efficiencies of water flow at various stages and time. Deterioration of efficiency over the years will reduce the performance of the irrigation scheme over this period. Gorantiwar and I.K. Smout (2005) categorized the importance of efficiency in two ways: Firstly, appropriate optimum allocation plans cannot be developed if proper consideration is not given to efficiency. Inaccurate or simplified estimates also have a major influence on other performance parameters such as productivity, adequacy, equity and reliability. Secondly, the inspection of efficiencies over space and time at different levels enables the irrigation authorities to learn which part of the scheme is inefficient, where it is inefficient and how it is deteriorating.

Productivity is related to output from the system in response to the input added to the system and there are several indicators of productivity. The primarily output of the scheme is the total crop yield or its economic equivalence per units of land or water used. Hence, most often the productivity is expressed in terms of land or water supplied to produce a certain level of output. Water productivity deals with the amount of production (mass or monetary equivalent) per water supplied to the scheme during the season. Land productivity on the other hand is production per unit of land cultivated.

3. Materials and Methods

3.1. Description of the schemes

This study uses six government owned irrigation schemes for detail investigations which are believed to have large contribution to national income and one community managed irrigation schemes. The schemes are geographically located in south, east and central parts of the country. Table 2 gives brief information on the schemes. For details on the characteristics of the schemes, see Girma and Awulachew (2007).

3.2. Performance indicators

The performance indicators adopted in this study are:

1. ***Irrigation water delivery performance***
    a. Conveyance efficiency (E_C)
    b. Annual relative water supply (ARWS)
    c. Annual relative irrigation supply (ARIS)
    d. Water delivery performance or water delivery ration (WDR)

2. ***Output performance indicators***
    a. Output per harvested area (tons/ha)
    b. Output per harvested area (US$/ha)
    c. Output per command area (US$/ha)
    d. Output per water supplied (US$/$m^3$)

These indicators were measured using the following mathematical descriptions:

$$E_C = \frac{Water\ flowing\ out\ of\ the\ system}{Water\ flowing\ into\ the\ system} \quad (1a)$$

$$ARWS = \frac{Total\ volume\ of\ water\ supplied}{Total\ volume\ of\ crop\ water\ demand} \quad (1b)$$

$$ARIS = \frac{Total\ volume\ of\ irrigation\ water\ diverted}{Total\ volume\ of\ irrigation\ water\ demanded} \quad (1c)$$

$$WDR = \frac{Volume\ of\ water\ actually\ delivered}{intended\ volume\ of\ water\ to\ be\ delivered} \quad (1d)$$

$$Outpout\ per\ harvested\ area\,(tons/ha) = \frac{Production\,(tons)}{Irrigated\ cropped\ area\,(ha)} \quad (2a)$$

$$Outpout\ per\ harvested\ area\,(US\$/ha) = \frac{Local\ value\ of\ production\,(US\$)}{Irrigated\ cropped\ area\,(ha)} \quad (2b)$$

$$Outpout\ per\ command\ area\,(US\$/ha) = \frac{Local\ value\ of\ Production\,(US\$)}{Command\ area\,(ha)} \quad 2c)$$

$$Outpout\ per\ water\ supplied\ (US\$/m^3) = \frac{Local\ value\ of\ Production\,(US\$)}{Diverted\ irrigation\ supply\,(m^3)} \quad (2d)$$

Data used in this study are emanating from different sources. Sugar estates have their own records regarding annual production, water diverted to the schemes and meteorological data.

Table 1: Sources of important data

Data	Irrigation schemes					
	Metahara	Wonji	Finchaa	Hare	Sille	Bilate
Metro Data	Estate	Estate	Estate	NMSA	NMSA	Tessema, 2006
Production	Estate	Estate	Estate	Belete, 2006	Aklilu, 2006	Tessema
Water supply	Estate	Estate	Estate	Belete	Aklilu	
ARWS	calculated	calculated	calculated	Belete	Aklilu	Tessema
ARIS	calculated	calculated	calculated	Belete	Aklilu	Tessema
Efficiency	measured	measured		Belete	Aklilu	

Table 2: Characterization of selected irrigation schemes

Scheme name	**Hare**	**Sille**	**Bilate**	**Metahara**	**Wonji**	**Finchaa**
Latitude	6º 30´ to 6 º 38´ N	5º 49' to 5º 55' N	6^{0}48' to 6^{0}50'N	8º 21' to 8º 29' N	8º 21' to 8º 29' N	9º 30' to 9º 60' N
Longitude	37 º 33´ to 37º 37´ E	37º 26' to 37º 29' E	38^{0}4' to 38^{0}5' E	39º 12' to 39º 18' E	39º 12' to 39º 18' E	37º 10' to 37º 30' E
Average annual rainfall (mm)	830.7	748	734	659.6	832	1300
Average annual ET_o (mm)	1651.2	1540		1958	1596.5	
Predominant soil types	Sandy loam to clay soil	Silty loam and clay loam	Sandy to loam	Sand to clay loam	Clay, light soil	black heavy clay
Water source	Hare River	Sille River	Bilate River	Awash River	Awash River	Finchaa River
Water availability	Scarce in some periods	Scarce in some periods	sufficient	abundant	abundant	abundant
Irrigated area (ha)	1962	1082	870	11058	7279.8	8500
Main crops	Banana, cotton, maize, fruit trees, sweet potato, vegetables	Banana, cotton, maize	Tobacco, maize	Sugar cane	Sugar cane	Sugar cane, horticultural crops
Year first operational	1996	1957	1962	1966	1954	1991
Type of management	community	government	Government/ private	government	government	government
Land ownership	private	government	Government	government	government	government
Method of water abstraction	Gravity (inundation, weir)	Gravity (inundation)	Gravity (barrage)	Gravity (weir)	Pump	Gravity/ weir
Water delivery infrastructure	Open channel	Open channel	Open channel/ pipelines	Open channel	Open channel	Open channel/pipe
Predominant on-farm water application method	Furrow, basin	Furrow, basin	furrow	furrow	Furrow	Sprinkler/ furrow

4. Results and Discussions

4.1. Water delivery performance

Water delivery performances considered are conveyance efficiency, annual relative water supply, and annual relative irrigation supply and water delivery ratio. The results of conveyance efficiency measurements given in Fig. 1 show that there is a high water loss especially in community managed Hare irrigation scheme. Through filed measurements it was evidenced that the canal losses more than 50% of water over 5 km canal distance from the diversion point. As the physical conditions of canal in Hare irrigation scheme is bad, the losses are mainly attributed to seepage from the canals. Moreover, even if they are closed, points of unauthorized water turnouts contribute also to low conveyance efficiency because of leakages.

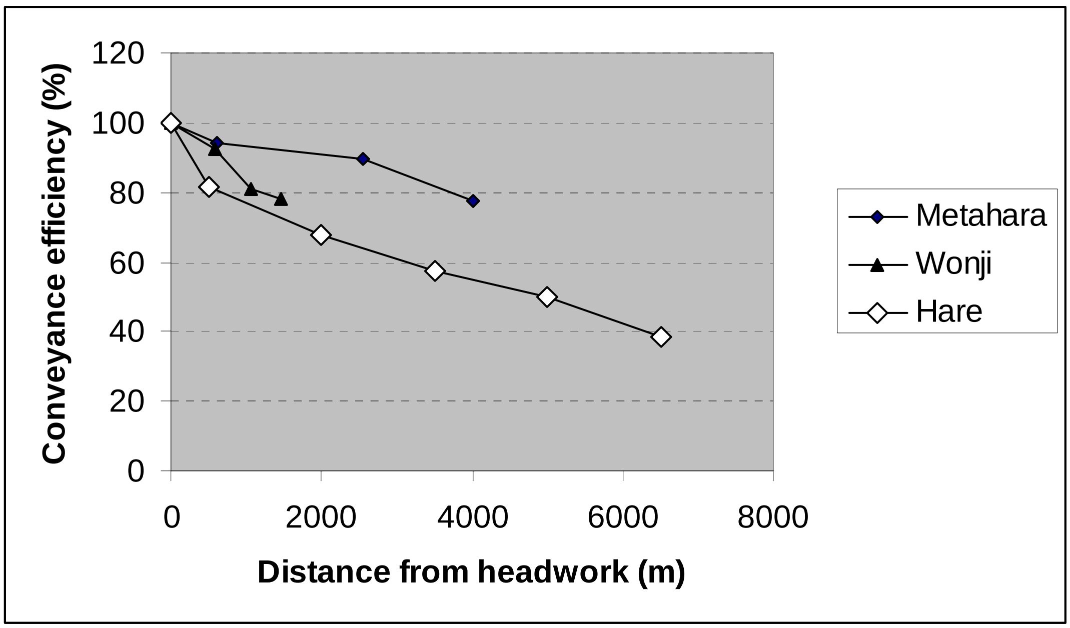

Fig. 1: Variation of conveyance efficiency along the canals of some schemes

Conveyance efficiency underlies spatial variations based on the conditions of the canal and management system. Farm units which are located along the canal segment with low conveyance efficiency tend to suffer from unreliable and untimely supply of water.

These problems have been observed in community managed irrigation schemes such as in Hare. To this effect, farmers located at tail-end of the canal (>7km) are limited in their crop diversification and forced to grow relatively water stress resistant crops such as cotton and sweet potato. Not only bad conditions of physical structures but also leakage through unofficial points of water turnouts are observed to be reasons for rapid decline of conveyance efficiency in Hare irrigation schemes

Previous studies in Wonji indicated that seepage losses in the tertiary canals account to about 40% and contributed to rising of groundwater level to 0.94m below the surface (Habib, 2005).

The values of water delivery performance, i.e. annual relative water supply (ARWS) and annual relative irrigation supply (ARIS) are given in table 3. These indicators are evaluated as optimal if their values would be equal to one. Less or greater than one would mean under or over supply of water respectively. ARWS relates the total volume of water applied (irrigation plus total rainfall) to the volume of water required by the crops. It can also be used both as a measure of adequacy and seasonal timelines (Levine 1982 and Meinzen D., 1995, In: Kloezen W.H & G.-R. Carlos, 1998).

The annual relative irrigation supply (ARIS) on the other hand is the ratio of the volume of irrigation water delivered to the volume of irrigation water demanded (net irrigation water requirement). It indicates also the extent to which the water supplied was adequate to satisfy the water demand. The value of this indicator is nearly unity in Wonji irrigation scheme and range from 1.46 to 2.05 incase of other schemes indicating that the amount of water supplied at scheme level exceeded the estimated crop water requirement.

Table 3: Values of water delivery performance indicators (2005/06)

Scheme name	Values of water supply performance		
	ARWS	**ARIS**	**WDR**
Hare	1.22	2.05	1.07
Sille	1.66	1.46	0.95
Bilate	1.86	2.00	1.30
Metahara	1.45	1.59	1.03
Wonji	1.11	0.95	0.62

The water delivery ration (WDR) is an indicator that relates the amount of water delivered to the amount of water needed to be delivered, i.e. total water supplied to the scheme divided by gross irrigation water requirement. According to the values of this indicator, Wonji and Sille irrigation schemes were found to have delivered less amount of water than theoretically forecasted. Wonji scheme is characterized by lower values of all water supply and delivery performance indicators compared to other schemes. The cost involved in pump diversion might have contributed to efficiency of resources use in Wonji

4.2. Production per unit area

Values of crop production per units of harvested land in the studied irrigation schemes are presented in Table 4 and figures 2-4. As can be seen from table 4, production varies from 122 to 174 tons per hectare in sugar cane producing irrigation schemes and from 0.50 to 3.56 tons per hectare in cotton producing schemes. The productivity of tobacco varied between 0.45 to 1.55 tons per hectare. The average sugar cane production in Metahara, Wonji and Finchaa is respectively 162.3, 147.1 and 136.5 tons per hectare. This shows that Metahara has produced more cane per units of area.

With a standard deviation of 13.7, the productivity variation is higher in Finchaa followed by Metahara and Wonji sugar estates. Huge differences between minimum and maximum productions in table 4 show inconsistencies that exist in the management practices as well as practically attainable level of productivity under the existed condition. Compared to sugar cane producing schemes, large coefficients of variation (Cv) in cases of cotton and tobacco producing schemes have been observed indicating high productivity variation from year to year. The reasons could be inconsistencies in the agricultural practices, management system and input supplies.

Table 4: Output per units of harvested land (from 1998/99 – 2005/06 except for Hare scheme)

Scheme name	Crop grown	productivity (tons/ha)				Cv (%)
		minimum	maximum	mean	SD	
Metahara	Sugar cane	152.6	173.8	162.3	9.3	5.6
Wonji	Sugar cane	137.2	152.8	148.1	5.6	3.4
Finchaa	Sugar cane	123.5	169.0	138.3	13.4	9.7
Average (sugar cane)		137.2	165.2	148.6	9.52	6.5
Hare[1]	Cotton	0.70	2.20	1.30	0.65	50
Sille	Cotton	0.50	2.40	1.09	0.79	72
M. Sedi	Cotton	1.57	3.56	2.51	0.67	26.7
Average (cotton)		0.92	2.72	1.67	0.65	43
Bilate	Tobacco	0.47	1.55	0.90	0.33	36.9

1. Compared between different villages in the scheme

The productivity of cotton presented in this study, when compared to the optimum yield, i.e. 5.4 tons/ha (Aklilu, 2006), it is evident that there is a room for improvement. Melka Sedi was found to perform better than other cotton producing farms.

To compare the outputs of schemes and productivity of different crops per units of land and water supplied, monetary equivalents of the production during the season 2005/06 have been considered. This type of calculation was made taking into account the farm gate unit price of sugar, cotton and tobacco in the year 2005/06 as 491.2, 1069.77 and 1962.79 US$ per tons respectively. The results presented in figures 2 and 6 show that outputs per units of land and water are by far large in sugar producing schemes than cotton and tobacco farming schemes.

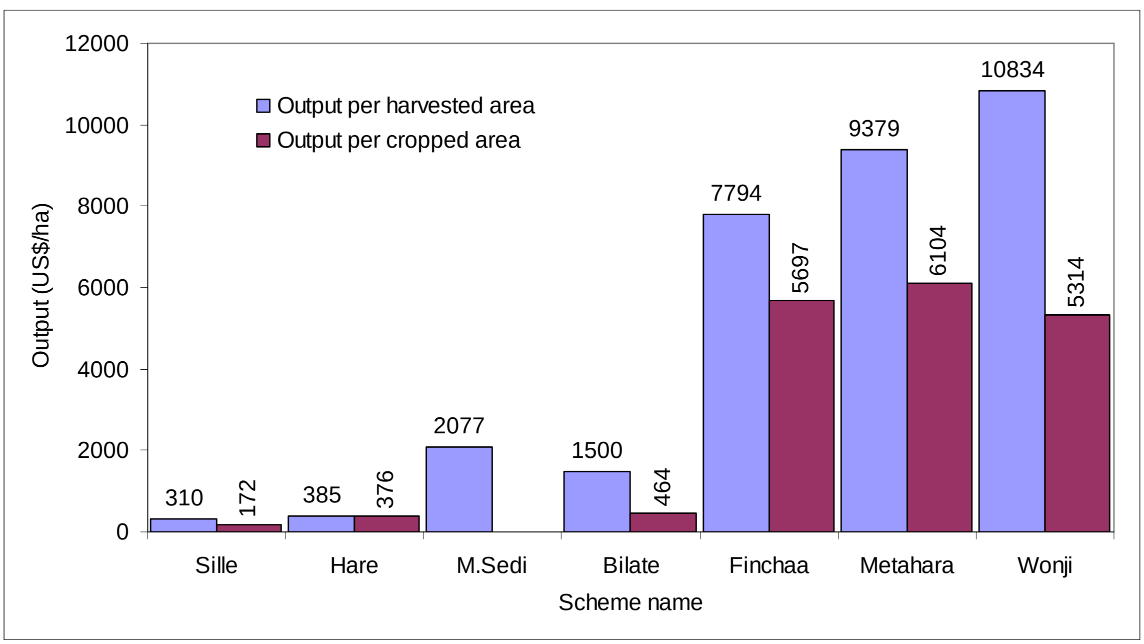

Fig. 2: Output per units of harvested and irrigable area (2005/06)

The difference between schemes in terms of output per irrigable area is less compared to output per harvested area. In the year 2005/06, the proportions of harvested to total cultivated area in Wonji, Metahara and Finchaa are 49, 65 and 73% respectively.

Even if the cane production per harvested area in 2005/06 was higher in Metahara (Fig. 4) than other cane producing schemes output per units of harvested land (US$/ha) was higher in case of Wonji than Metahara (Fig. 2). This is because the end sugar productivity was higher in Wonji than others, i.e. 21.92, 15.98 and 15.77 tons of sugar per hectare of harvested area respectively in Wonji, Metahara and Finchaa. Sugar produced per hectare per month was also greater in Wonji followed by Metahara and Finchaa which may be attributed to the differences in the cutting ages of the cane.

Fig. 3 shows the relationships between the size of area harvested and the corresponding cane production during the last 8 years (1998/99 – 2005/06).

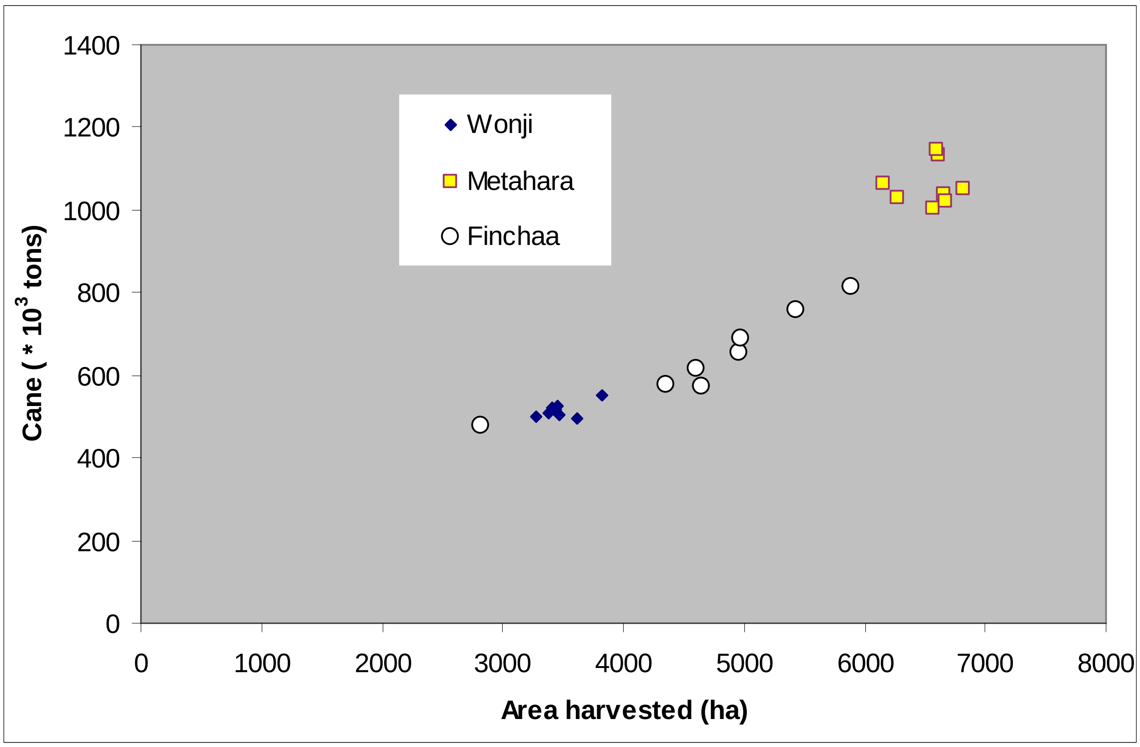

Fig. 3: Comparison of harvested area and cane production (1998/99 – 2005/06)

Annually harvested area and hence total cane production is greater in Metahara sugar estate followed by Finchaa and lowest in Wonji. The regression coefficients (r^2) of the relations given in figure 3 are 0.36, 0.004 and 0.88 for Wonji, Metahara and Finchaa respectively. This shows that both harvested area and cane production was not significantly increased in Metahara and Wonji. In case of these schemes, the points showing the relationships between areas harvested and cane production are concentrated at almost same area. Within the period 1998/99 – 2005/06 the total cropped area has increase from 9911.5 ha to 10145.9ha in Metahara. This is an increment of about 2.4%. However, the size of harvested area was variable from year to year without showing linear increase.

Figure 4 and 5 show the deviation of annual production of sugar cane and cotton from the overall average production of the schemes involved in producing the same crop during the last 9 years. While the productivity of Wonji is consistently close to the average line, the productivity of Metahara scheme is greater than the average and that of Finchaa scheme is lower than the mean productivity of the schemes.

From the two cotton producing schemes, Melka Sedi was found to consistently produce more than average production. On the contrary the productivity of Sille scheme is below average in all 9 years considered except in one year, i.e. 2001/02 (Fig. 5). Although both belongs to the state farms, government managed, the management setup and conditions of physical structures under which they are operating is different. The more than 40 years old irrigation infrastructure in Sille farm and less motivated and unskilled staff as well as low input services are contributed to low productivity of the farms.

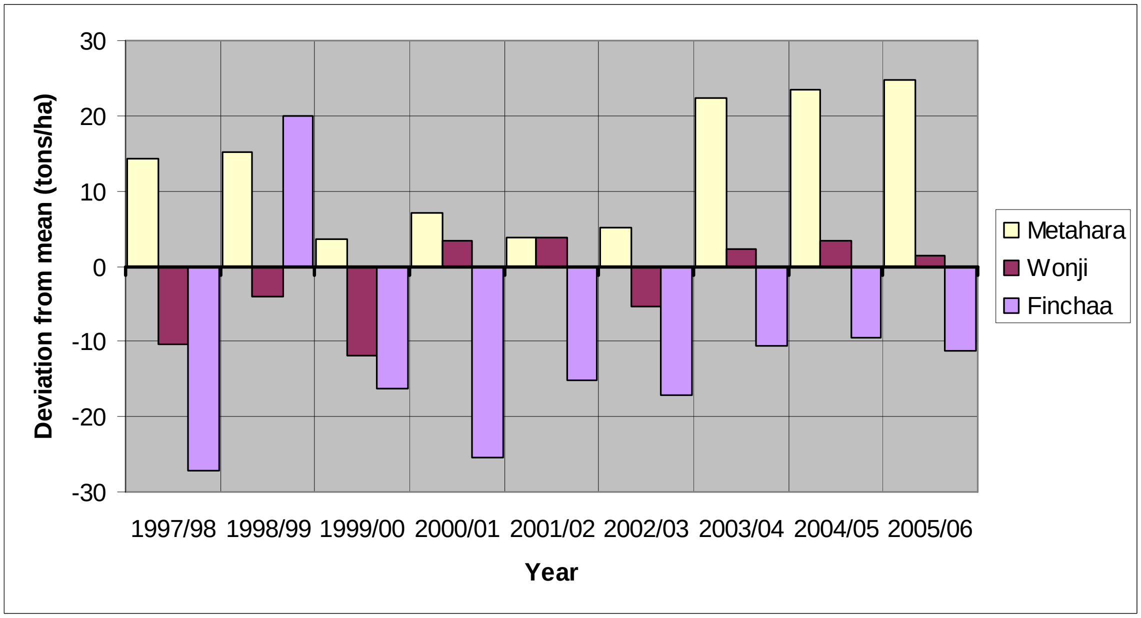

Fig. 4: Deviation of annual sugar cane production from mean, i.e. 149 tons/ha

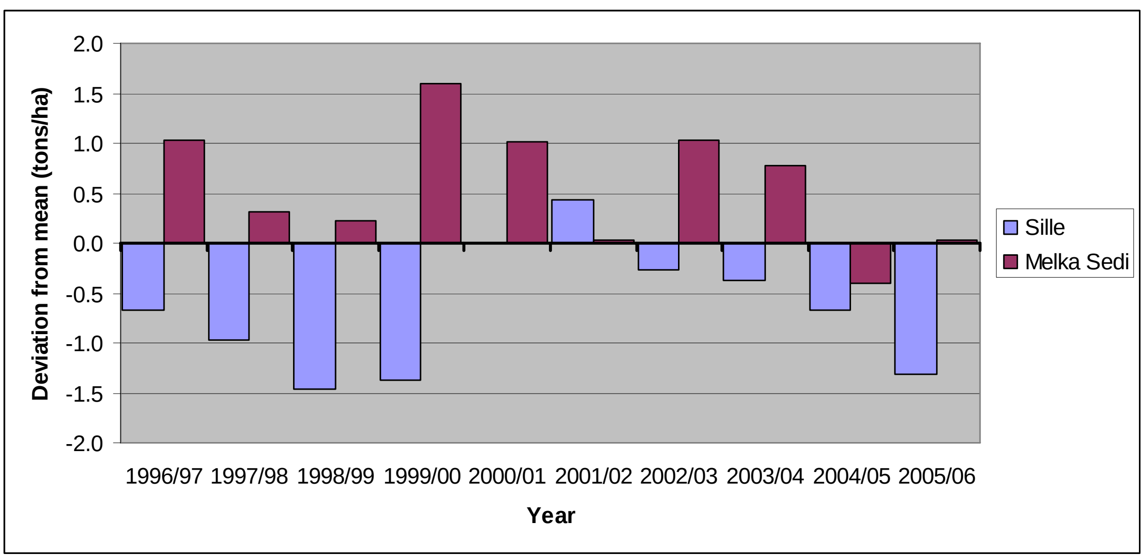

Fig. 5: Deviation of annual cotton production from mean, i.e. 1.97 tons/ha

Although adequate or more water than required is supplied to the scheme, the output obtained in Sille and Hare schemes are very low. It may not be the total amount of water diverted to the scheme which is so important to evaluate the influence of irrigation water on production rather adequacy and uniformity of its distribution on the cropped field.

4.3. Output per units of water supply

Water productivity has been defined as the amount of output produced per unit of water involved in the production, or the value added to water in a given circumstance (Molden et al. 1998). It was calculated by dividing the value of agricultural production obtained from a unit area of land by volume of irrigation water supplied during the production season. Fig. 6 shows the productivity of water for different irrigation schemes.

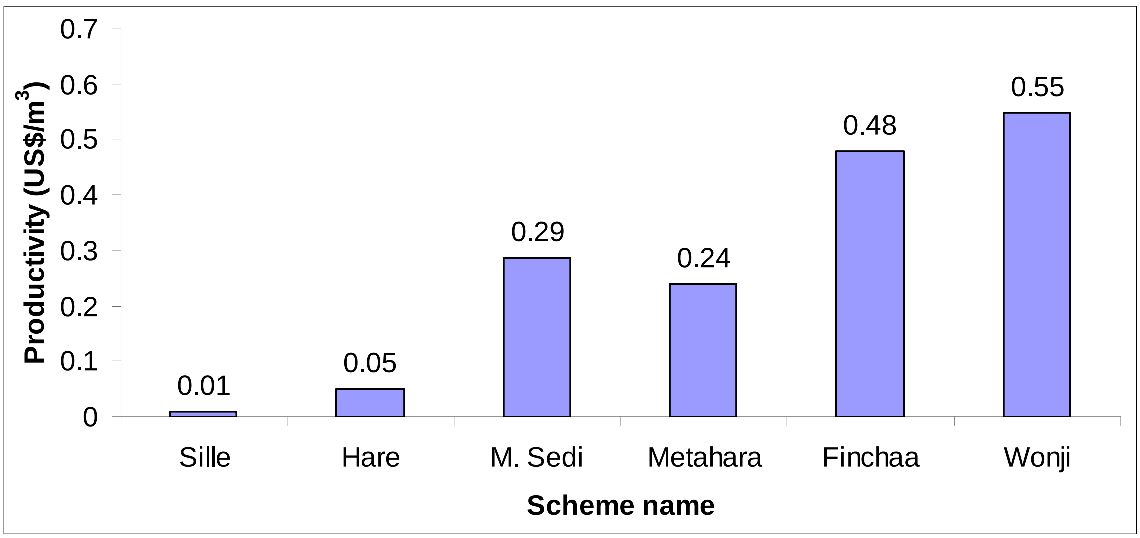

Fig. 6: Output per unit water supplied

Output (US$) per units of water supply (m^3) varies between 0.01 in Sille, 0.05 in community managed scheme and 0.55 US$ in government managed irrigated sugar cane farm. Water productivity in other areas was found to be 0.04 – 0.56 US$ (Merdun, 2004), 0.03 – 0.91 US$ (Molden et al. 1998). Differences have also observed not only between different schemes, cropping and management types but also between the same cropping and management type in different schemes. The results indicate that Wonji irrigation scheme was found to be efficient in economical use of irrigation water followed by Finchaa and Metahara. In terms of cane productivity Metahara was found to produce more. However, sugar gained is more in case of Wonji. This may be due to the differences in the cutting ages adopted by the schemes. Results given in Fig. 6 are also influenced by the value of crops grown, irrigation management and weather conditions such as contribution of rainfall. Proper irrigation scheduling that takes into account the contribution of rainfall during growing season will have improving effect on water productivity. The difference in the water productivity between sugar cane producing scheme is attributed to the management practices. Despite adequate water deliveries at the scheme level (Table 3) in Sille and Hare irrigation schemes, both land and water productivity is low compared to Melka Sedi scheme, producing the same crop, i.e. cotton. It is not the total amount of water diverted to the scheme which so important to influence the production, rather its adequacy, uniformity and proper spreading over the cropped field.

5. Summary and Conclusion

The assessment of irrigation performance in seven irrigation schemes using output and water supply performance showed that there is a tremendous difference between the schemes in their output performance. This is true even for the same cropping and management types. Government agency managed schemes that grow sugar cane have got higher productivity that ranges 123.5 - 173.8 tons/ha, 7794 – 10834 US$ per harvested area and 0.24 – 0.55 US$/$m^3$. On the other hand schemes that grow cotton have relatively low productivity that ranges from 310 US$/ha in community managed scheme to 385 US$/ha in state farm. The water productivity of these schemes is respectively 0.05 and 0.01 US$/$m^3$. It is evident that as the management setup, staffing, capacity, and availabilities of resources are different, not all schemes under similar management and cropping types have similar performance. Then, there is a huge difference in the attainment of the primary objective of irrigation, i.e., increased outputs.

The scheme level values of water supply performance indicators (ARWS and ARIS) revealed that there were no water supply constraints during the season. That means the water supplied during the season (2005/06) could meet the forecasted crop and irrigation water demand in all schemes considered. However, it should be noted that the scheme level values does not give any clue how efficiently, adequately, uniformly, timely and reliably the water was distributed within the farms. It is evident that measuring these indicators requires intensive field data which need to be generated from field level measurements.

Government agency managed schemes that grow sugar cane have got higher productivity that ranges from 123.5 - 173.8 tons per hectare of harvested area, 7794 – 10834 US$ per harvested area (2005/06) and 0.24 – 0.55 US$/$m^3$ of water supplied (2005/06). On the other hand schemes that grow cotton have relatively low productivity and high variations that ranges from 310 – 2077 US$/ha in community managed and state farm. Output per units of water supplied varied from 0.01 – 0.29 US$/$m^3$ of water supplied to the scheme.

Cotton growing schemes are characterized by high productivity variations between seasons. This could be due to inconsistencies in the management systems, input services and inability to minimize the influences of climate conditions through adoption of effective irrigation scheduling. Huge variations between outputs of same crop type in different schemes reveal that there is a room for improvement in the productivity of land and water. However, answer to the question, ‘which one is doing what better and why?’ need the examination of internal process indicators.

Low productivity of irrigated agriculture in schemes such as Hare and Sille is possibly attributed to poor conditions of the irrigation infrastructure, inadequate management capacity and skills, lack of proper operation and on-farm water management practices and procedures, lack of incentives and hence low motivation to improve performance. Investment on improvements of physical structures, management and operation of the system at all levels will bring substantial improvement of performances of these schemes.

Scheme level values of water delivery and supply performance indicators presented in this paper are based on data sets of one year. It doesn’t show also how adequately, uniformly, efficiently and timely the water distributed over the field and field units throughout the season. Hence the scheme level performance indicators are of use for strategic thinking and don’t serve as such operational purpose, because they don’t indicate exactly where the problems responsible for low performance of the system lie. The next study should focus on assessment of performance based on internal processes indicators such as adequacy, uniformity, reliability, efficiency and sustainability.

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Irrigation and Rain-fed Crop Production System in Ethiopia

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Abstract

Crop production is a function of water, nutrient, climate and soil environment. Provided that all other requirement are satisfactorily for proper growth and production, rainfall rarely meets the time with required amount of water application for plant growth. As a result average yield of agricultural crops under rain-fed agriculture is low compared to irrigated agriculture. This study assesses irrigation and rain-fed agriculture system in connection to its potential productivity under existing practice. While the rain-fed areas considered in this study are the aggregate at the national level, five systematically selected Medium and large scale irrigation schemes were selected based on cropping patter, geographic and agro ecological representation These are Fincha'a, MAAE, Metehara, Sille, and UAAIE which are located at three river basins, viz, Nile (Abbay), Awash and the Rift valley basins. Data were collected using pre-formulated checklists, through series of interviews and discussions; and from published and unpublished documents. The result indicated that crop production was undulating under rain-fed agriculture and as a result the performance of rain-fed productivity remained low and stable for most crops. Although crops grown by small-holder private farmers are different, cereals occupy about 74 per cent followed by pulses and oil seeds with small proportion. During the last one decade, the maximum and minimum cultivated land by small-holder peasant farmers at the national level was 10.7 and 6.6 M ha, respectively. Increased cultivable area by private small-holder farmers could not seem to contribute to the increased production. Total irrigated land by private peasant farmers ranged between 66 and 147 thousand hectares for the last one decade. During the last decade the area under irrigation was steadily increasing for most of the large scale schemes. Particularly Fincha'a and Metehara farms are significantly increasing while MAAE farm has shown only a slight increase. At UAAIE farm, crop production shows a decreasing trend. Productivity of banana at Sille farm was decreasing despite its increasing in land area.

Key words: Irrigation, Rain-fed, crop production, productivity, large scale scheme, private small-holder

1. Introduction

Crop production is a function of water, nutrient, climate and soil environment. Complex relationship existed between these factors and the crop as a consequence of the involvement of biological, physiological, physical and chemical processes. However, efficient crop production and optimum yield can be achieved only when the water supply is precisely in fine tune with the biological needs provided that the crop is well supplied with the required nutrients and well adapted to the prevailing environment. On the other

hand, there is no crop without water, what so ever needs are in place. Therefore, timely supplied with an adequate amount of precipitation and/or irrigation could play a major role in increasing agricultural crop production.
Rainfall rarely meets the time with required amount of application for plant growth. As a result average yield of agricultural crops under rain-fed agriculture is low compared to irrigation, which is the application of controlled amount of water at specified time of application. In Ethiopia, traditional rain-fed agriculture is the dominant form of farming in which the peasant farm households contribute the largest proportion of the total agricultural production. Out of the total land area of 112.3 M ha, about 16.4 M ha are suitable for the production of annual and perennial crops. Of the estimated arable land, presently about 10 M ha is used annually for rain-fed crops (CSA, 2006).

The pattern and intensity of rainfall in the country is quite variable in which most of the highlands receive between 510 to 1530mm of rain annually and in typical arid and semi-arid areas generally receive less than 500mm to about 750mm rain, respectively. However, rainfall in most cases is unreliable and erratic and moreover, productivity is constrained by several interlinked factors such as unpredictable climate (flood, frost, pest etc.) small and fragmented land holding, land degradation, limited technological inputs, etc. About 80 percent of the population lives in the highlands. Over population in these area caused shortage of land and thereby pushing the farmers onto lands with fragile soils and steep slopes in which the land becomes exposed to erosion and eventually turns out to unproductive state. On the other hand there is a huge tract of arable land in the low lands which could be utilized for agricultural production. However, rainfall is either not sufficient or not dependable in amounts and timing. As a result, crops suffer from severe soil moisture stress and drought.

The dependence on rain has significantly affected the life of the people in particular and economic development of the country in general. Improving this sector contributes to improve the productivity of agriculture and thus the generation of higher incomes, promotion food self-sufficiency and improving health condition of the people. It also increases and diversifies production of raw materials for industries and promotion of export item.

Irrigation is one means for a good farm husbandry, better land utilization and stable and higher crop production. Sustained growth and dynamism in agriculture is a fundamental necessity to meet the increasing demand for food and other products in view of the growing population. Irrigated agriculture will play a major role in reaching the broader development vision of the country in achieving food security, poverty alleviation and improvement in the quality of life. The main objective of irrigated agriculture is to provide plants with sufficient water to prevent stress that may cause reduced yields or poor quality of harvest (Haise and Hagan, 1987; Tayler, 1965).

Ethiopia is one of the few African countries endowed with relatively abundant water resources, favorable climate and potentially huge irrigable land. The annual stream flow and groundwater resources are estimated around 122 and 2.6 billion m^3, respectively. About 83 percent of the total runoff is found in the basins of large rivers such as the Abbay (Blue Nile), the Baro Akobo, the Omo Gibe and the Tekez (MoWR, 2002).

While the potential benefits of irrigation are great, the actual achievement in many irrigated areas of the country is substantially less than the potential. According to MoWR (2005), Ethiopia is estimated to have 3.7 M ha of potentially irrigable area with the available surface water resources and the land irrigated through the development of traditional and modern irrigation schemes are estimated to be about 386,603 hectares, which is about 10 per cent of potentially irrigable land. According to the report, in the modern irrigation there were 466 small, 102 medium and 9 large irrigation schemes with the total area coverage of 28,939, 71,924 and 49,675 ha, respectively have been developed by Government, nongovernmental organizations and private investors. However, the major crops produced with irrigation are industrial and cash crops with small proportion of food crops. The major part of food crops produced in the country come from rain-fed agriculture.

This gross underdevelopment has spurred the Irrigation Development Program (IDP) to put additional hectares of land under irrigation within its 15-year plan period of 2002-2016 (MoFED, 2006). Therefore, a strategy that ensures economically profitable, ecologically sustainable and socially acceptable use of the available resources (land, water, climate, labor, finance) is of paramount importance. This presumes that the limited resources are efficiently used so that the benefits per unit out puts are optimized. Therefore, this study was aimed to assess irrigation and rain-fed agriculture system in connection to its potential productivity under existing practice.

2. Study Area

The study area encompasses rain-fed areas in the country in general and five systematically selected Medium and large scale irrigation schemes based on cropping patter, geographic and agro ecological representation These are Fincha'a, MAAE, Metehara, Sille, and UAAIE which are located at three river basins, viz, Nile (Abbay), Awash and the Rift valley basins. The main features of the study sites are presented in Table 1.

Table 1 Main features of selected irrigation schemes

	Irrigation Schemes				
Features	Fincha	MAAI	MSF	UAAIE	Sille SF
River basin	Abbay	Awash	Awash	Awash	Rift valley
Latitude	9° 18'N	9° 46'N	8° 52'N	8° 37'N	6° 1'N
Longitude	37° 14'E	40° 38'E	39° 54'E	39° 43'E	37° 37'E
Altitude (m)	1450	750	950	1100-1200	1280
Tmax (^{0}C)	24	34	33.1	32.6	32
Tmin (^{0}C)	7.4	18	17.2	15.3	17
Rainfall (mm)	1300	500	550	500	729.6
Crops	Sugarcane	Cotton	Sugar (fruits)	vegetables and fruits	cotton, maize and banana
Source of water	Fincha'a River	Awash River	Awash River	Awash River	Sille River
Method of irrigation	Sprinkler	Surface (furrow)	Surface (furrow)	Surface (furrow and basin)	Surface (furrow)

3. Methodology

In this study status of rain-fed and irrigated agriculture in terms of area, production and productivity will be assessed at national and River basin level. Primary data (crop production and productivity, irrigated and rain-fed area etc) were collected using pre-formulated checklists for time span of at least ten years. Series of interviews and discussions were held with different stakeholders including; representatives of water user associations and beneficiaries, subject matter specialists from zonal and district BoARD (agronomists, irrigation and natural resource experts, extension personnel etc) for the small scale irrigation schemes and the corresponding rain-fed agriculture system. Similarly interviews and discussions were also held with enterprise, farm and unit managers of the selected large scale irrigation schemes. In addition, published and unpublished documents (series of agricultural sample survey reports (CSA) were reviewed and analyzed.

4. Results and Discussion

Rain-fed Farming System

Ethiopian farming is mainly dependant on rain-fed smallholder agriculture system as a means of food and income for its population. Virtually all food crops come from rain-fed agriculture system. The farming societies are principally private peasant. Crops grown under rain-fed farming system were diverse and many within a cropping season. However, the agriculture system is dominated by cereal based productions since it was produced in large quantity as compared to other crops (Fig. 1). Pulses and oil seeds occupy small proportion in contrast to cereals. The major cereal crops gown were maize, sorghum, tef, wheat and barley.

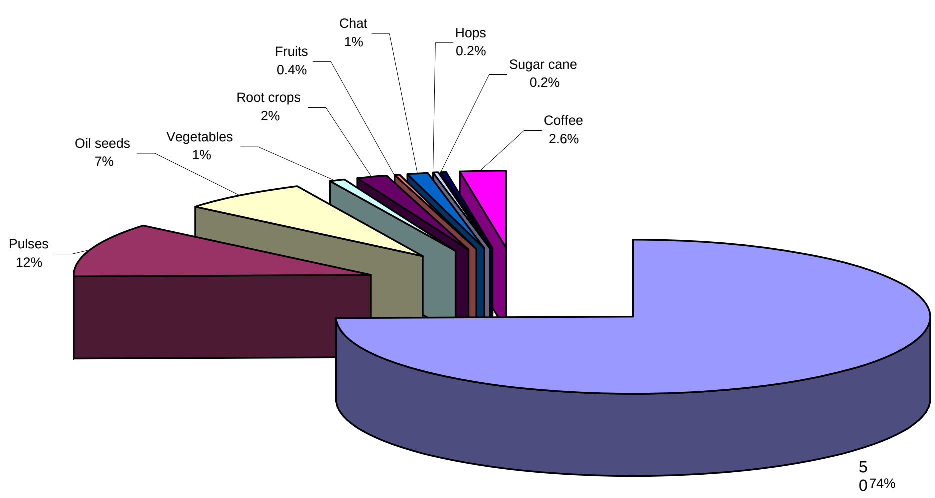

Fig. 1 Area coverage of rain-fed crops

Cereal production and productivity under rain-fed agriculture is shown in figure 2. The crop production was undulating reaching low during 1995/96 and 2005/06; and pick during 2001/02. As shown in Fig. 3, area under rain-fed agriculture was highest during 2005/06 cropping season and where as production is low as compared to 200/01 cropping season.

During the last one decade, the maximum and minimum cultivated land by small-holder peasant farmers at the national level was 10.7 and 6.6 M ha, respectively (fig. 3). Agricultural production could be increased through increasing cultivable area or using improved seed and cultural practices (fertilizer, irrigation etc). The increased cultivable area during 2005/06 by private small-holder farmers could not seem to contribute to the increased production. The production rather seems to fall as the area increased. There can be several reasons for low production. Simple reason for increased crop production during 2001/02 could be due to an increase in cultivable area along with the favorable conditions including adequate rainfall that might have occurred during the cropping season. Moreover, visual observation elucidated that the occurrence of sufficient rainfall (adequacy and reliability) through-out the growing season enables the private peasant farmers to get bumper harvest, indicating rain-fed agriculture to depend strongly on rainfall availability. In absence of sufficient rainfall, there is always low agricultural production thereby creating food shortage and food insecurity for its population and also dipping poverty. Consequently, the performance of rain-fed agricultural production and productivity remained low and stable for most of the years. The low level of performance of rain-fed agriculture could not only be attributed to erratic nature of rainfall but also deteriorating soil fertility and slow adoption and/or lack of appropriate technologies.

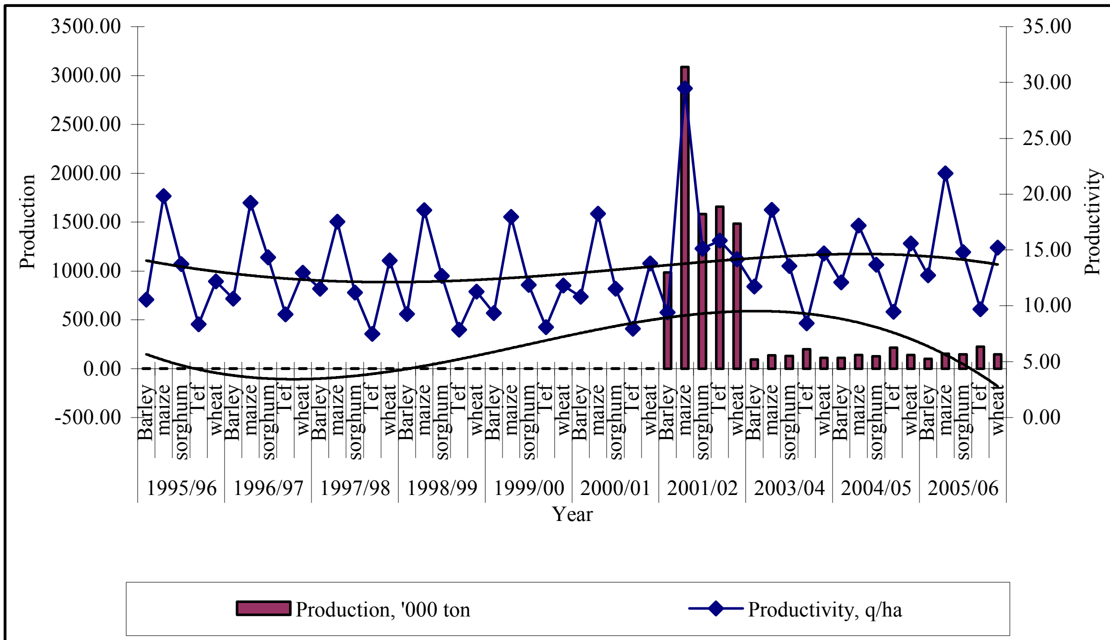

Fig. 2 Production and productivity of rain-fed agriculture

The above statements generally point out that those small-holder private farmers survived with uncertainty of rainfall and low level of technology aggravating the occurrence of poverty and food insecurity. With the existing rate of production and productivity, it is going to be a challenge and threat to the country to feed the ever rapidly growing population. Therefore, due attention should be given to improve the production system to alleviate poverty and secure food self-sufficiency.

Irrigation Farming System

Irrigation enables farmers to improve crop production and intensification thereby sustaining and improving livelihoods and food security. In Ethiopia, private peasant farmers use irrigation at small scale level to enable them increase crop production and as a means of raising income. Small scale irrigation not only increase crop production, but also improves cropping intensity and reduces the effect of erratic rainfall. The practice of irrigation may not be possible for every farmer and could not be possible to expand the area. As shown in figure 3, during the last one decade, the total irrigated land by private peasant farmers ranged between 63 and 175 thousand hectares which is 0.8 to 1.8 per cent of the total area covered under rain-fed agriculture, respectively.

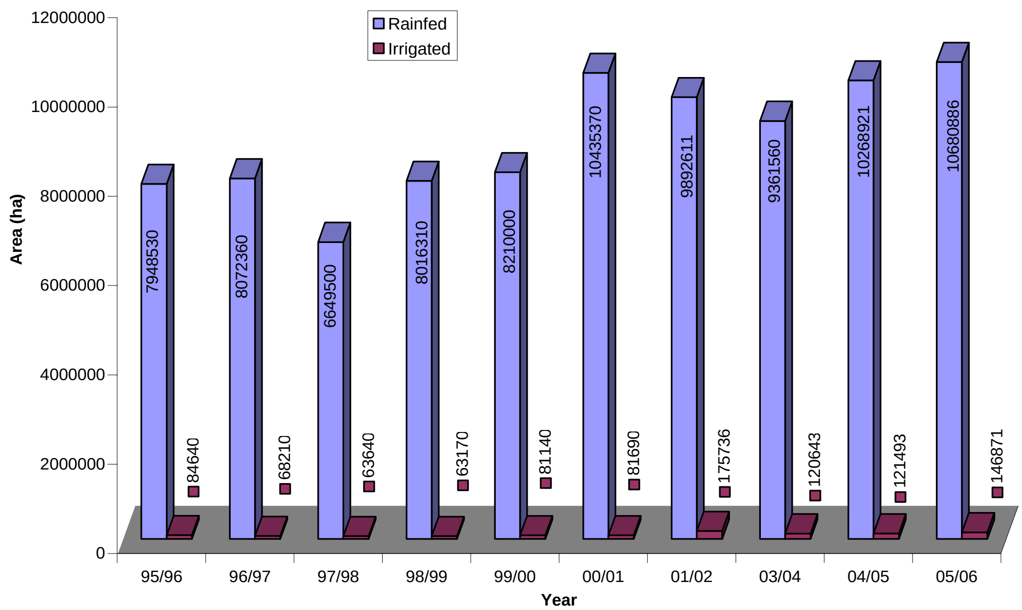

Fig. 3 Rain-fed and irrigated area under small-holders

The area under small scale irrigation has been appreciably expanding, particularly

after 2001/02 though apparently shown to decline during 2003/04.

Table 2. Irrigated area under small-holder private farmers (ha)

Year	Cereals									Permanent crops
	Teff	Barley	Wheat	Maize	Sorghum	Total	Pulses	Oil seeds	Others	
2005/06	7895	7441	6116	35586	15596	73509	3950	1740	30170	37502
2004/05	7756	7212	4614	29407	9756	59052	6832	1915	16143	34361
2003/04	7835	5647	3805	32573	11199	61406	5217	927	21578	31516
2001/02	12447	8016	4750	53838	12778	93615	9896	726	35855	33359
2000/01	5650	3680	1330	18960	15910	45770	3880	290	9240	22500
1999/00	5230	4630	1780	18560	11510	42850	2890	430	13390	21580
1998/99	2890	3580	2570	13650	7240	30110	2660	**	8830	21350
1997/98	11540	4230	2540	12140	3690	34560	1920	**	7350	18860
1996/97	4790	**	800	13690	18970	39220	**	**	3650	21470
1995/96	4490	1400	1890	21810	**	55050	5300	**	4890	1933

****** not reported

The main agricultural produces under small scale irrigation includes cereals, pulses, oil seeds and permanent crops like fruits, chat, coffee, hopes and sugarcane. Permanent crops occupy the largest share next to cereals. Pulses and oil seeds occupy (5 %) insignificant part compared to permanent crops. The major irrigated pulse crops include field pea, horse bean, haricot bean and chick pea. Major irrigated oil seeds include neug, linseeds and sesame. Others like vegetables and root crops are produced in small proportion. Among cereals crops, maize covers the maximum area under small scale irrigation followed by sorghum, tef, barley and wheat (Table 2).

In contrary to small scale irrigation, Medium and large scale irrigation schemes in the country has been found to produce mainly cash and industrial crops. The schemes considered this in study are government owned enterprises. Medium and large scale irrigation schemes are usually expected to contribute to the national economic growth and alleviation of poverty and food security. However, the contribution of these schemes to food crops production is almost none. The major crops grown under medium and large scale irrigation include Sugarcane, cotton, fruits and vegetables. Figures 4 to 6 show area, production and productivity of Medium and large scale irrigated agriculture schemes. During the last one decade the area under irrigation was steadily increasing for most of medium and large scale schemes (Fig.4). Particularly Fincha'a and Metehara farms are significantly increasing while MAAE farm has shown only a slight increase. Mainly due to re-occupation of part of the lands by the local people, Sille farm has shown a decline in irrigated land area. . Similarly, crop production, has shown an increasing trend for most of the irrigation schemes (Fig. 5). Sugar cane production is increasing significantly at Fincha'a and Metehara while banana production is increasing significantly at Sille farm. However at UAAIE farm, crop production shows a decreasing trend. At Sille farm cotton production shows a decreasing trend mainly the replacement of some of the cotton field by banana. This was attributed mainly to market problems since there are no competent purchasers of the products in the area, and transportation cost is too high to move to other areas. Consequently, the farm has become price recipient, instead of negotiating for a reasonable price.

Productivity is increasing better at MAAE farm only while at Metehara and sille farms the trend is stable. Productivity has been declining at UAAIE and Fincha farms, but attempts are made to compensate by increase in cultivated land area. While the productivity of banana at Sille farm was decreasing despite its increasing in land area, the overall productivity of Sille farm is unstable, which may be among the reasons for continuous change of crop types.

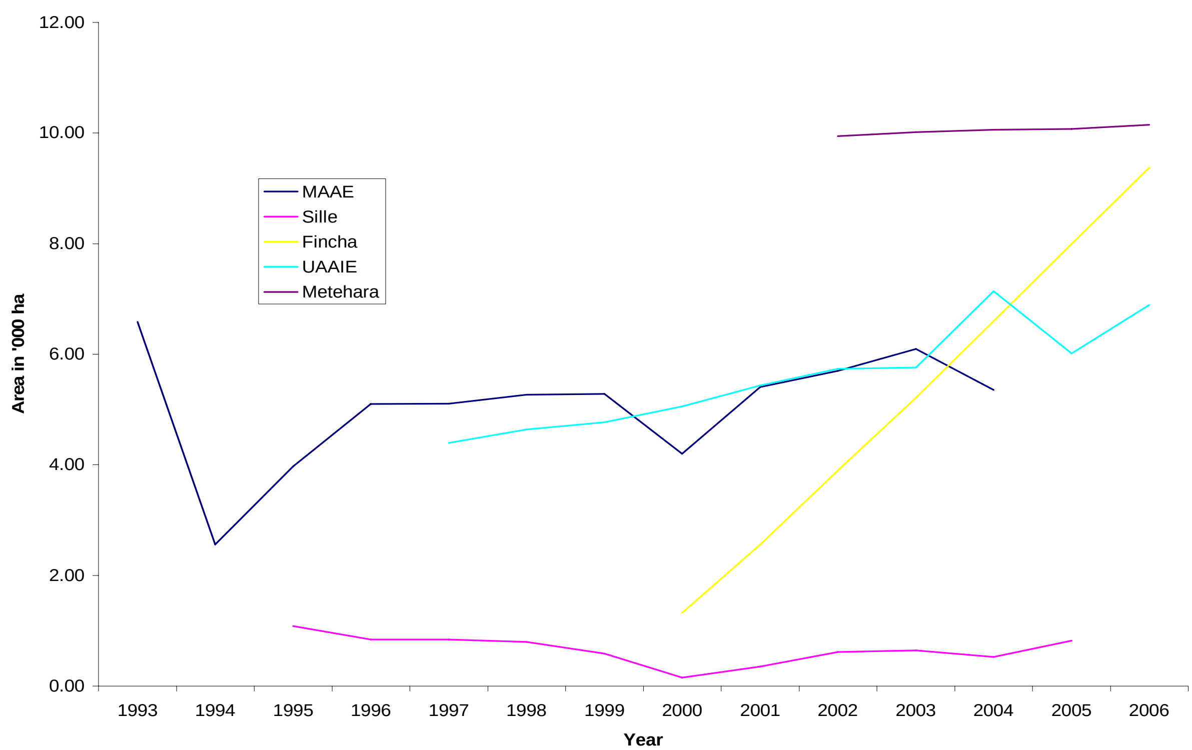

Fig. 4 Trend of irrigated area under medium and large-scale irrigation schemes

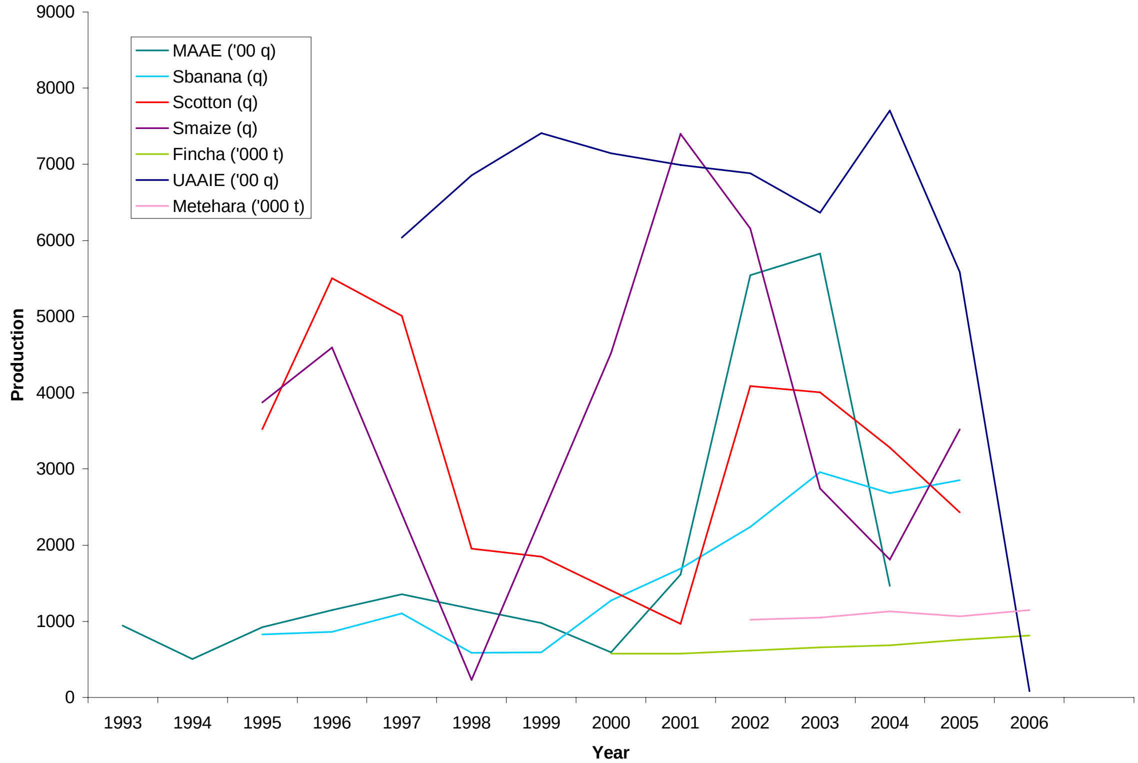

Fig. 5 Trend of agricultural production under medium and large-scale irrigation schemes

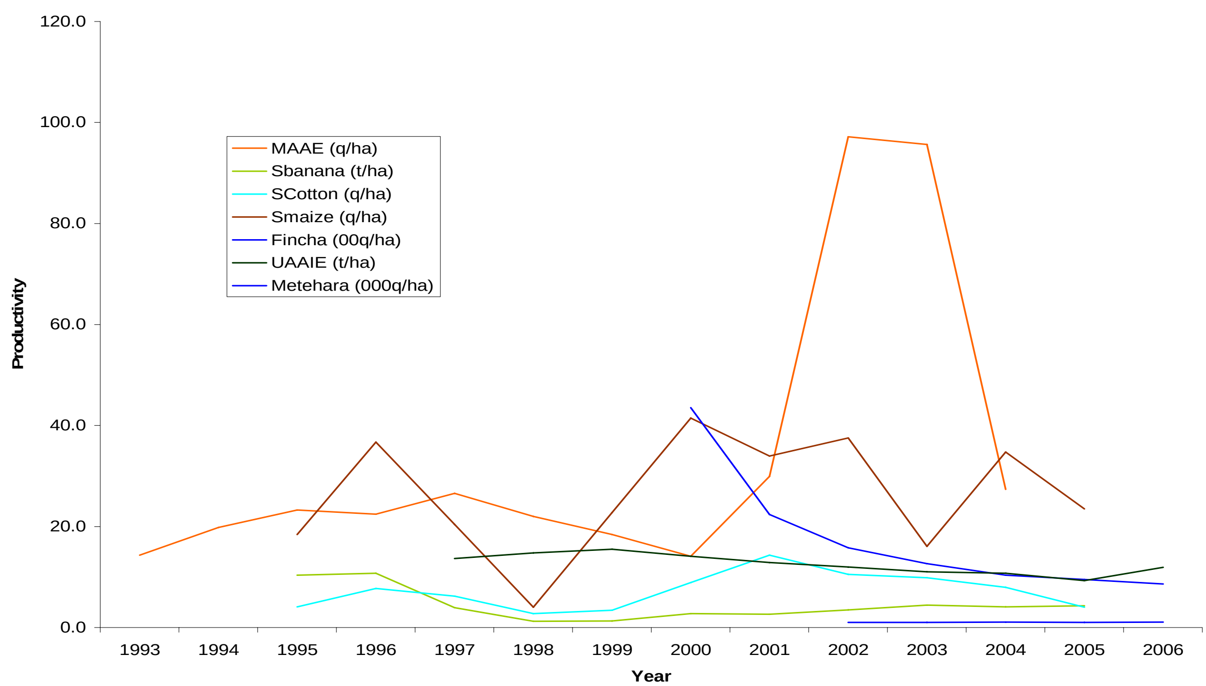

Fig. 6 Trend of productivity of irrigated agriculture under medium and large-scale schemes

5. Conclusion

In Ethiopia, crop production is dominated by traditional rain-fed agriculture. However, rainfall is unreliable and erratic in nature. As a result, production and productivity is low and stable. During the last one decade, the maximum and minimum cultivated land by small-holder peasant farmers at the national level was 10.7 and 6.6 M ha, respectively. Crops grown are mainly cereals occupying about 74 per cent followed by pulses and oil seeds in small proportion. The major cereal crops gown were maize, sorghum, tef, wheat and barley. However, rain-fed agriculture does not seem to meet the ever rising demand for food as population increased. Hence, requires special focus on ways of increasing production and productivity.

Private peasant farmers use irrigation at small scale level to enable them increase crop production and as a means of raising income. Area under small scale irrigation has been appreciably expanding, particularly after 2001/02. During the last one decade, the total irrigated land by private peasant farmers ranged between 63 and 175 thousand hectares which is 0.8 to 1.8 per cent of the total area covered under rain-fed agriculture, respectively. Cereals and permanent crops occupy the major part followed by vegetables and root crops.

The contribution of medium and large scale irrigation to food crops is almost negligible. The schemes produce mainly industrial, exportable and cash crops of which sugarcane, cotton, fruits and vegetables are the major once. In most cases, the area under medium and large scale irrigation schemes was steadily increasing except at MAAE and Sille farm. At UAAIE production and productivity were declining while Sille farm production is generally declining and productivity was unstable. Crop productivity was declining at Fincha'a farm, better at MAAE farm and stable at Metehara.

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Basline Servey of Irrigation and Rainfed Agriculture in Blue Nile Basin

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Abstract

This paper discusses issues and challenges of agricultural developments in the Blue Nile Basin of Ethiopia. The crop land in the basin can not sustain the population unless agricultural productivity increases. Due to climatic factors and low yield rainfed agriculture can not support the high population in the basin. Up to date the land under irrigation is very small. Like most Nile Basin countries though agriculture dominates the economy of Ethiopia much was not done in the irrigation agricultural resources development.

Irrigated agriculture is the largest draw on the waters of the Nile in Egypt and Sudan. But the others 8 Nile countries agriculture is mainly rainfed and they are not using even 2% of Nile water. Ethiopia is contributing more than 85% of the Nile water annual discharge and yet is not using even 1 % of it. In near future the water scarcity in agricultural development of the Nile Basin can be affected by ever increasing population, unpredictable climate, soil infertility, uncertainty of surface water allocations, unexplored groundwater resources, low water availability, infrastructure etc. Agriculture is by far the main user of water in the Nile basin and therefore requires due attention in future investments. Ethiopia does not achieve food security until it utilizes Nile water for irrigation.

1. Background

The Nile river basin covers an area of approximately 3.1 million square kilometers and with a total population of around 370 million people. The Nile basin countries are Burundi, the Democratic Republic of Congo, Egypt, Eritrea, Ethiopia, Kenya, Rwanda, Sudan, Tanzania and Uganda.

The FAO-ITALY supported project "Information Products for Nile Basin Water Resources Management" is implementing a basin wide survey of current and future water use in rainfed and irrigated agriculture. The Project "Information Products for Nile Basin Water Resources Management" is intended to strengthen the ability of the governments of the ten Nile countries to take informed decisions with regard to water resources policy and management in the Nile basin. The project is supported by the Government of Italy and carried out under the umbrella of the Nile Basin Initiative, of which Italy is a full partner. The project will make extensive use of regional expertise. It will also draw on the specific experience and knowledge residing at FAO, especially in the fields of agricultural water use and water productivity.

2. Objectives

The survey is intended to provide stakeholders and decision makers in the Nile Basin with a thorough assessment of the linkage between agriculture and water in the basin. The survey is expected to address the following issues:

- What are the opportunities for enhancing productivity in agriculture?
- Create Agricultural production database at district level providing information on area, yield, and production for the main commodities for a baseline year from (2000);
- Analysis of the current agricultural productivity under rainfed and irrigated conditions;

- Rapid export growth through production of high value agricultural products;

- Decentralization to shift decision making closer to community to improve responsiveness and service delivery;
- Increase proper and modern water resources utilization.

3. Rainfed Agriculture

- A baseline survey (for the year 2000 and onwards) of agricultural water use covering all aspects of agriculture is in progress. The survey includes a detailed review and maps of population, land use, cropping patterns, estimate of water use in rainfed and irrigated agriculture, and an assessment of current water development facilities.

- Projections for 2030 of demand for food and other produce in the basin, with estimates of arable land expansion in irrigated and rainfed agriculture, yields of major crops, cropping patterns, and cropping intensities will be executed. Results of a set of scenarios on water development for agriculture will be based on analysis by administrative units.

- The study will focus at national and sub-national levels with particular attention to the main crop production systems. Agricultural water productivity will be analyzed at district level. Results will be aggregated to country level with the aim to build up a comparable picture of water productivity in rainfed and irrigated agriculture across the basin.

rain fed agriculture is the major livelihood of the country, which is characterized by low productivity associated with underdeveloped, low input systems and highly degraded natural resources. peasant agricultural lands on the plateaus of the northern and south-central part of ethiopia have been degraded because of over-utilization for centuries. one cannot hope that ethiopia can maintain her food production through the traditional farming method of highland agriculture. absolute dependence on rainfed agriculture and low productivity associated with underdeveloped, low input systems of production and degraded natural resources base has rendered these areas highly vulnerable to even minor shocks. irrigated crop production is insignificantly low in these areas. different agro ecological considerations might lead to the improvement of agricultural production. the following map shows the main agro ecological zones of the basin. one can see clearly the topography in the east is not easy for farming (figure 1). regional specialization based on suitability and provisions of compatible packages for the different agro ecologies that will lead to the improvement of small-scale agricultural production are the basic development directions.

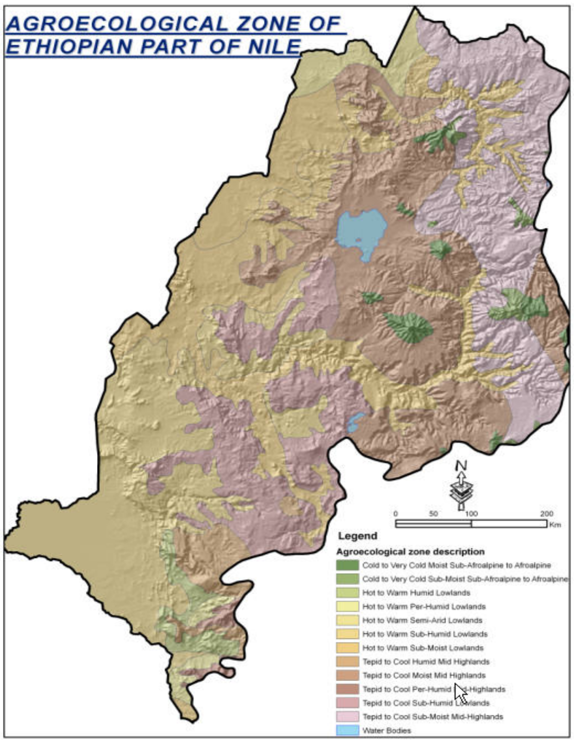


Figure 1. Agroecological Zone of the Blue Nile Basin

Production and productivity are very low in the basin and the use of improved productivity enhancing inputs and technologies is extremely low. The expansion of irrigated agriculture is among other factors is constrained by the rugged topography and terrain. Most of the regions have poor market access due to underdevelopment of infrastructure as whole and agricultural markets in particular. Natural resources degradation (soil erosion and deforestation) are extremely sever in the basin, which makes it a necessity for all development interventions to be oriented towards sustainable natural resources management as a matter of priority.

3.1 Crop yield distribution of Blue Nile Basin

Crop data from rain fed and irrigated agriculture was collected from Nile Countries through national consultants. Major crops were provided in terms of crop production, acreage and yield.
The only district based agricultural survey was carried out in the year 2001/02 (1994 Ethiopian Calendar). However the survey data from 1994 (1987 Ethiopian calendar) provides also useful information on area, production and productivity even if this survey was zone based.

The crop production data is for both seasons ("Meher" and "Belg") for all holdings. The "Meher" is the major season while the "Belg" is the small season. Crops harvested between the months of September and February are considered "Meher" crops while those harvested between the months of March and August are considered "Belg". Private peasant holding is predominant while large-scale commercial production is negligibly very little. In this rainfed production dominated small scale farming system, the share of irrigated agriculture is also very little. The distribution of some major crops yield was displayed on (Figure 2,3,4). Countries like Egypt, Kenya have higher yield than Ethiopia. Especially Egypt which has used all its crop land for irrigation agriculture attains the highest yield in the Nile Basin. The yield for Blue Nile of Ethiopia is quite low in the range of 0.3 ton/hectare to 1.5 ton/hectare for major cereal crops.

The following maps present the spatial distribution of the dominant crops found in the Basin. It aims to provide insight in the cropping distribution of the farming systems, in particular in relation to the natural conditions determined by topography and climate.

The data presented are the result of an intensive database compilation on reported cropping statistics. As such they combine findings from multiple data sources. After a process of quality control, data were eventually selected as per the principle "best data source so far available around the reference year 2000". All data are presented as they are and occasionally represent different time periods. It is to expresses types and distribution of cropping systems. Map of major crops (teff, wheat, maize etc).

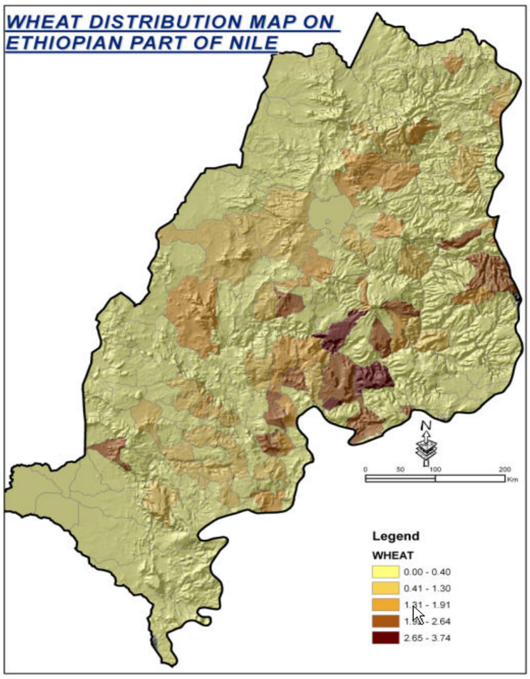


Figure 2. Wheat distribution of the Blue Nile Basin

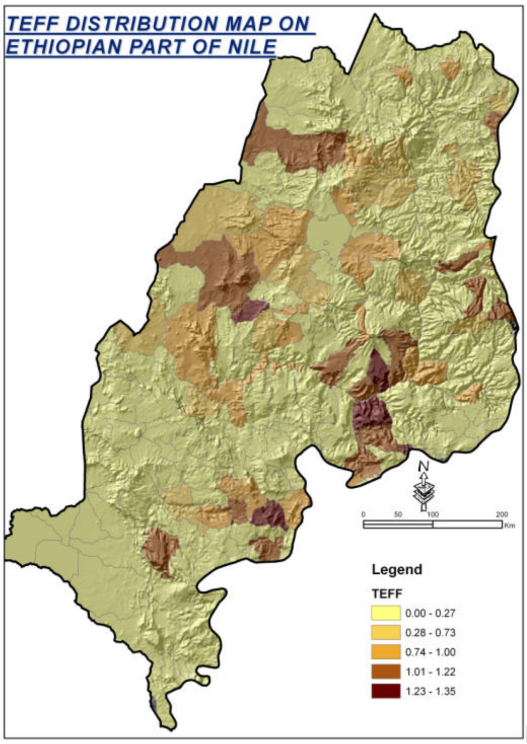


Figure 3. Teff Distribution of the Blue Nile Basin

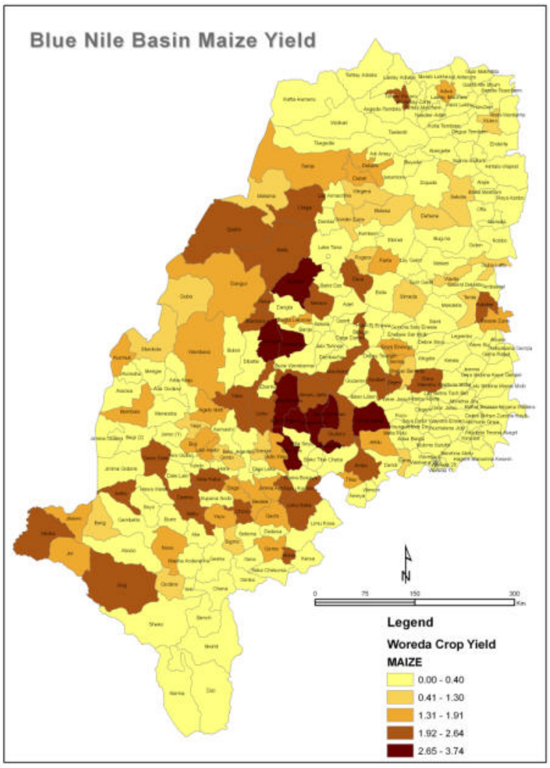


Figure 4. Maize Distribution of the Blue Nile Basin

4. Potential and Existing Irrigation Schemes

The fundamental goal of achieving sustainability irrigation Agricultural system is complex and initiates many new questions that require further studies, which in turn requires multi-disciplinary collaboration and funding. The investigation and further study programs would be essential for development of improved methods and technology for improving agricultural productivity, and to alleviate future scarcity of water. The assessment of methodologies for sustainable development is also quiet essential. In addition, the goal requires continuing research and gathering field data to assess management approaches. So this project output supports and benefit the Nile Countries to some extent.

Blue Nile of Ethiopia covers an area of about 367,000km2 and a population of 31 millions according to 2005 UNPD figure. The Nile Basin in Ethiopia stretches over a very wide geographic area with diverse agro ecological conditions. The Nile basin comprises of the following contributing basins:

- The Abay river basin
- The Tekeze river basin
- The Baro Akobo river basin
- The Mereb river basins (partially)

The Nile Basin of Ethiopia known as Blue Nile contributes more than 85% of the annual discharge of the Nile being a big contributor, Ethiopia to date use only 1% of it.

According to the Master Plan Studies of Ministry of Water Resources, Blue Nile Basin has 165 Potential irrigation sites with total area of 2,126,700ha. The existing irrigation schemes have been collected as point data and it is difficult to calculate the area.

4.1 Blue Nile and GIAM

According to Global Irrigated Area Map (GIAM) most irrigation lands are situated in Egypt and Sudan. The rest upper Basin countries have minor land under irrigation. Ethiopia Blue Nile land under irrigation is so small compared to its potential area. According to the Master Plan Studies of Ministry of Water Resources, Existing irrigation is 57,561 ha and the potential is 1,774,676 ha. Ethiopia in order to feed her fast growing population the irrigation potential of the country has to be developed.

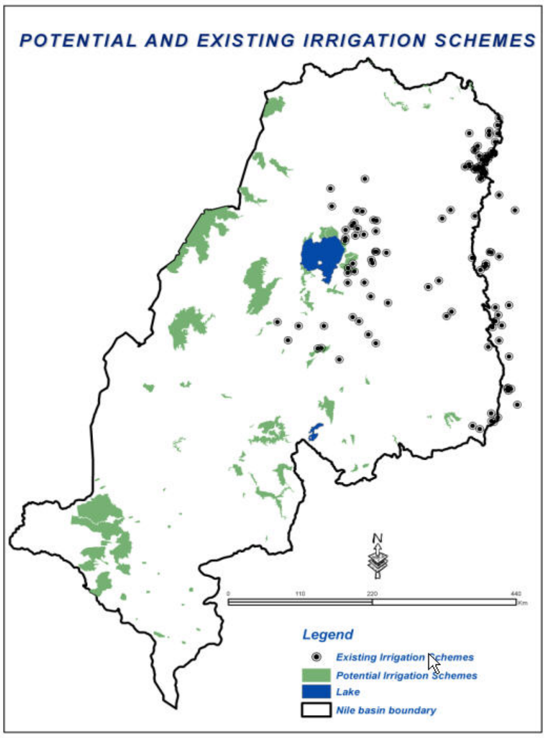


Figure 5. Potential and Existing Irrigation Schemes of the Blue Nile Basin

Table 1. Existing and potential irrigation Summary in the basin

Sub-basin	Administrative Units	Area (km2)	Mean Water Resources (*106 m3/yr)	Existing Irrigation (ha)	Potential Irrigation (ha)
Blue Nile (Abbay)	Amhara, Benishangul Gumuz, Oromia	199,812	49,000	37,347	719,088
Baro Akobo	SNNPR, Oromia, Gambella, Benishangul Gumuz	75,912	23,237	12,315	486,299
Tekeze/Atbara	Tigray, Amhara	86,510	8,191	7,899	569,289
Total		362,234	80,428	57,561	1,774,676

The irrigation potential of Ethiopia is estimated between 1.8 (Blue Nile Basin) and 3.7 (for the whole country) million hectares out of which only 5% is under irrigation (Irrigation in Africa by Food & Agriculture of the UN programme latter called AQUASTAT). As it is displayed in (Figure 5) Evapotranspiration map in general the west marginal area which is in reddish brown color though it is flat and convenient for irrigation, it has high evaporation. The eastern and central part of the basin with bluish color is characterized by low evapotranspiration and rugged topography. But there are some pocket areas which have potential for irrigation.

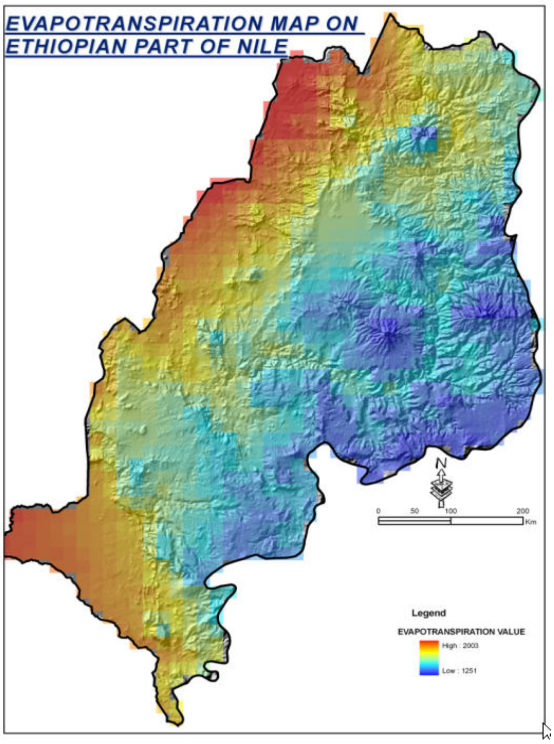


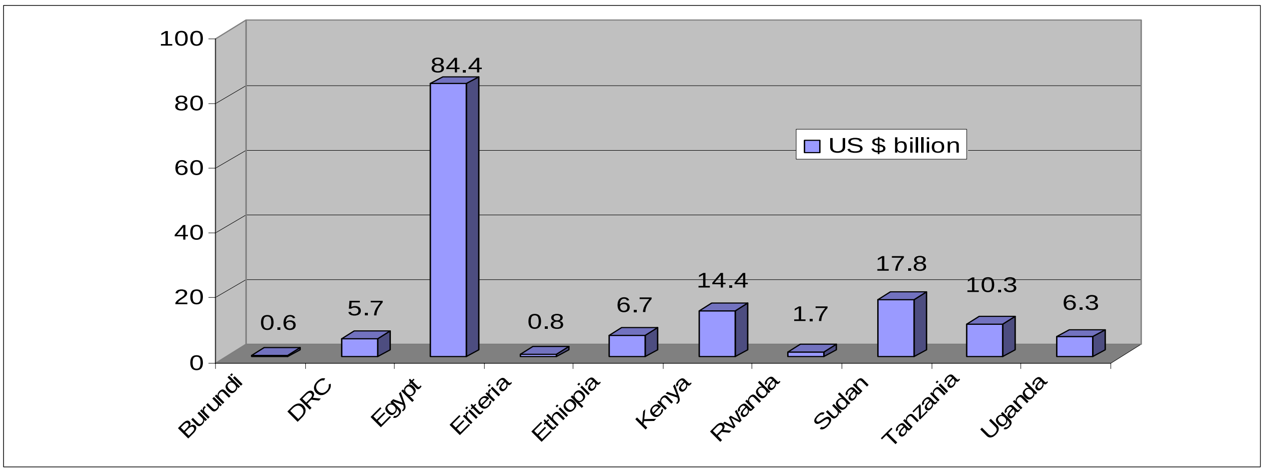
Figure 6. Evapotranspiration Map of the Blue Nile Basin

5. Agricultural Trade of Nile Basin countries

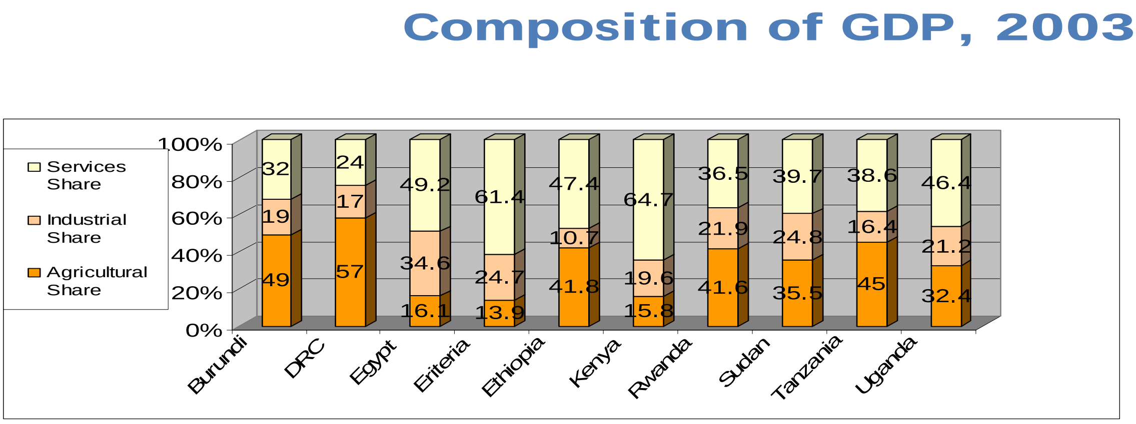
Agriculture dominates the economies of most African countries, providing jobs, income exports. A stronger performing agricultural sector is fundamental for Africa's overall economic growth. A constantly growing agricultural sector is crucial for addressing hunger, poverty and inequality. More than 70 percent of the total population and the majority of the extreme poor and undernourished live in rural areas. A healthy agriculture sector means more jobs, more income and more food for the poor.

Nile Countries mainly depend on export of primary agricultural products. The gross domestic product (GDP) of Nile Countries is very low as compared to other developing countries. Among the Nile Countries Egypt has a GDP of greater than 80 billion USD while the rest have a GDP of less than 20 billion USD according to African Development Report (Graph 1). When we see the composition of the GDP for countries like Democratic republic of Congo, Brundi, Tanzania, Ethiopia and Rwanda agriculture contributed above 40% of the GDP (Graph 2).

Gross Domestic Product (GDP), 2003



Graph 1 Gross Domestic Product (GDP)



Graph 2 Composition of GDP

For Egypt, Eritrea, DRC and Rwanda the import of agricultural commodities is higher than export of agricultural commodities. For Countries like Ethiopia and Sudan the difference between export and import of agricultural commodities is not so much even though import is a little bit high. For Kenya, Uganda, Tanzania and Brundi their export of agricultural commodities is higher than importing (Figure 7).

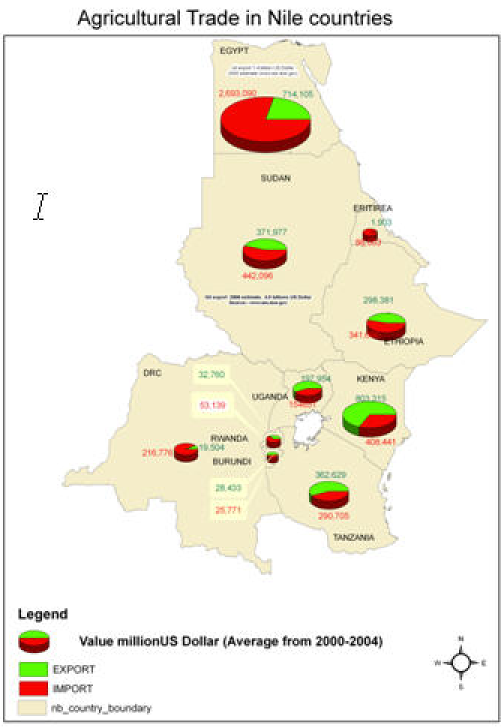
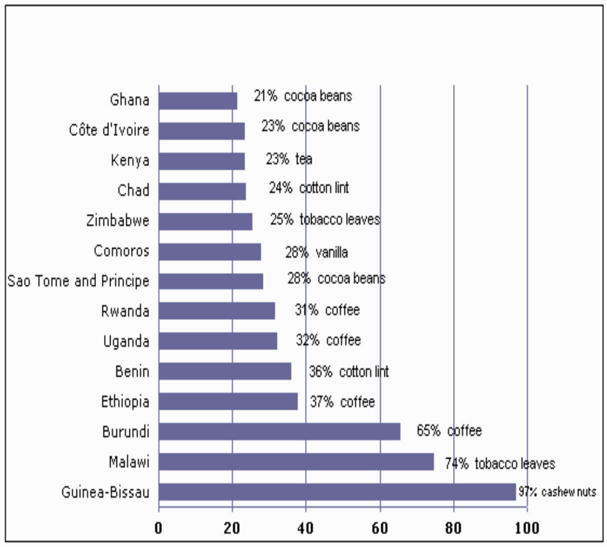


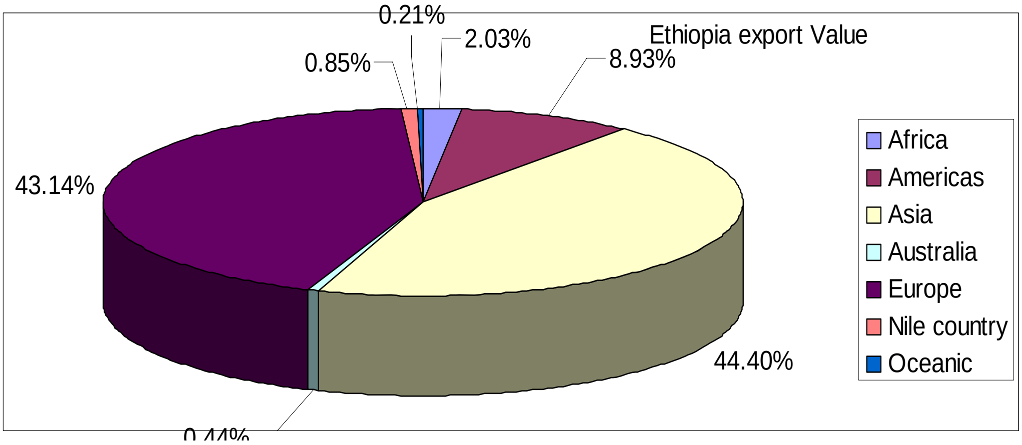
Figure 7. Agricultural trades in the Nile countries



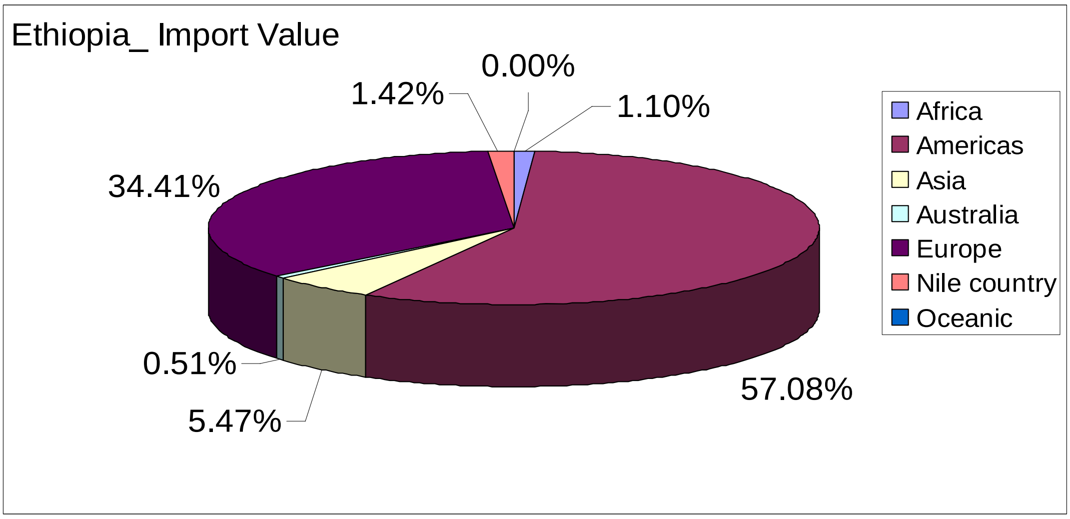
Graph 3. African Countries are highly dependant on single agricultural commodity

At present, a characteristic of too many African countries is a relatively undiversified economy with little industry and manufacturing and exports dominated by one or two raw commodities (Graph 3). Often a single, primary agricultural commodity is the major source of export earnings, creating a source of uncertainty because of their low income elasticity of demand and their declining and volatile terms of trade. Overall, Africa's agricultural sector accounts for about 20 percent of total merchandise exports, declining from more than 50 percent in the 1960s

Over the past 30 years, agricultural imports have outstripped agricultural exports, making the region a net agricultural importer since 1980, Indeed, as population growth in Africa outpaces food production, imports and food aid are required to make up the difference In the mid-1990s, out of the world total of 32 million victims of disasters receiving relief assistance from the World Food Programme (WFP), 21.5 million were living in Africa. In 2000 Africa received 2.8 million tones of food aid, which is more than a quarter of the world total. In 2001, the number of people suffering from food emergencies ranged between 23 and 28 million.



Graph 4. Ethiopian agricultural import is mainly from America and Europe. The import from Africa and within Nile Countries is insignificant



Graph 5. Ethiopian agricultural export is mainly to America and Europe. The export to Africa and within Nile Countries is insignificant

Increasing trade and market opportunities locally, regionally and internationally contribute to agriculture's ability to grow expand incomes and reduce poverty and food insecurity. Trade often introduces new, more productive and more sustainable production technologies, processing systems and related services. Trade provides opportunities to produce higher value products. For many producers, expanding agricultural trade opportunities locally and within the region is an important first step for taking advantage of potential new access international markets. However, according to a recent paper, [1] trade continues to be marked by overwhelming dependence on traditional overseas markets in industrial countries, although (admittedly from a low base), there has been substantial growth in intra-regional trade within Africa. If we exclude unrecorded, often informal-sector, trade across the porous borders, on average, only 10 percent of exports of countries belonging to each African Regional Economic Organization are destined within itself.

6. Recommendations

Unless the level of food production increases it will be hard to sustain the ever increasing population

- Increase export growth through production of high value agricultural products to get foreign earnings

Rather than depending on single commodity it is advantages to diversify raw commodities.
The potential area in the Blue Nile Basin need to be developed before water shortage becomes an issue.

Community based irrigation projects should be encouraged by the government

7. Major sources of information and data for the survey

7.1 Irrigation (potential) in Ethiopia both existing and possible schemes, FDRE, Ministry of water resources, September 2005, Addis Ababa

7.2 Tana Beles Integrated rural development project rehabilitation and restructuring study, December 1993

7.3 Tekeze basin integrated development master plan project second phase report, vol. No. 4, June 1997

7.4 Ethiopian Agricultural sample enumeration 2001/2002 (1994 E.c), Federal democratic republic of Ethiopia, central, Agricultural Census commission (Amhara, Tigray, Oromia & Benishangul gumuz regions)

7.5 Abby River basin master plan study.

7.6 Tekeze river basin master plan study.

7.7 Baro Akobo river basin master plan study

7.8 National statistical survey 1994/95 (1987 Eth. Cal.)(Estimates of area, production and yield)

7.9 Agro ecological zones Ministry of Agriculture and natural resources ----

7.10 Woody biomass inventories and strategic planning project (WBISPP)

Assessment of Design Practices and Performance of Small Scale Irrigation Structures in South Region

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Abstract

Uneven distribution of rainfall in the country in general and in South region in particular makes irrigation the best way to enhance food production. Development of small-scale irrigation schemes is the best alternative as they require minimum investment & their gestation period is comparatively low. The southern region as part of the country has been implementing such schemes. Despite remarkable achievements, some of the implemented schemes have totally failed and some are performing below their capacity. A case study considering 26 existing small scale irrigation works (about 1/3rd of the total schemes) in the south region is carried out for this research work and attempt is made to understand the causes of the major problems that are related to the design consideration of the different components of the structure and identify the gap in knowledge between the current design practices and performance of the structures. The pre and post construction institutional aspects, planning aspects, social aspects, economic aspects, operation & utilization aspects are also given due attention. Some of the physically observed problems of the existing irrigation structures considered for analysis are: main canal siltation (50%), sedimentation of the headwork (42%), problem of seepage through foundation (4%), main canal seepage (33%), scouring of downstream bank (8%), drying of rivers (12%), damage on impervious and flexible apron(19%), change of river course(12%), damage of under sluices(27%) and damage on CD works(4%). Likewise, some of the planning, institutional & operation problems are lack of adequate community participation, water right conflict among up streamers and down streamers (12%), market outlet problems (8%), proper handing over problem (31%), lack of proper training and the like. During the time of the study, 18 % the irrigation schemes of the region were not operational because of aforementioned and related reasons.

Key Words: Small scale irrigation; Performance of Structures; Design Practices

1. Introduction

The majority of population of Ethiopia is dependent on rain fed agricultural production for its livelihood. However, estimated crop production is not close to fulfill the food requirements of the country.
One of the best alternatives to consider for reliable and sustainable food security development is expanding irrigation development on various scales (whether small, medium or large) and options (diversion, storage, gravity, pumped, etc). For countries like Ethiopia where the principal component of project development (finance) is a constraint to incur huge investment for irrigation, small scale irrigation can be an alternative solution to enhance food production. This is of course without undermining the strategic importance of developing medium to large scale irrigation schemes to feed the expanding population in the foreseeable future. Development of small scale irrigation through river diversion, constructing micro dams, water harvesting structures, etc may

be considered as pragmatic approach in the contemporary Ethiopia for ensuring food self-sufficiency.

Small scale irrigation structures, owing to their relatively small investment cost, ease of construction, simplicity of operation & maintenance have been a strategic target of the country for achieving sustainable food security and self sufficiency. A number of such schemes have been designed and constructed in the previous years. However, while some schemes are performing successfully, it has been observed in various reports that some of the schemes have failed to serve the purpose for which they are intended. In line with this, recent study report for the Amhara region (Asfaw, 2004) has been used as a bench mark to conduct related study in the southern region.
To this end, this research aims to evaluate the design practices and performances of small scale irrigation structures in Southern Nations Nationalities and Peoples Regional Government. In addition to the hardware problems, institutional, planning, social and economic problems contributing to the failure are also highlighted.
The out puts of the research are believed to highlight the problems of the existing irrigation schemes and show future direction for planning, design and operation of irrigation projects.

2. Objectives

2.1 General objective

The primary objective is to investigate the cause of failure of existing small scale irrigation schemes of the region to learn a lesson and generate knowledge on practices and performances for future practical application and compile set of recommendations for planning, design, implementation and operation of irrigation schemes.

2.1.1 Specific objectives

- To conduct inventory on the success and failure cases of small scale irrigation schemes in the region.
- To categorize irrigation structures based on different problem parameters
- Investigate the causes of failure for selected structures in the region with regard to hydrologic, hydraulic design, structural design & implementation aspect.
- Investigate the existing schemes with reference to planning, institutional and operational problems
- Formulate a systematic database on attributes of irrigation structures in the region using dBASE format and Arc View GIS software. The database is basically important for efficient follow up, evaluation of projects and to assess what has been done in the subject so far.
- Investigate selected successful structures in the region and draw lessons from their success (i.e. whether any unique design practice had been adopted or not)
- Investigate failed structures and draw lessons to devise better design practices and suggest methods of rehabilitation.

3. Methodology of data collection and analysis

In this research, desk study is made on existing small scale irrigation systems and practical field visits were conducted to 15(Fifteen) sites found in the region. In the desk study, the available relevant data on 11(eleven) existing irrigation structures and post implementation review reports on the status of existing schemes in the south region is collected from the regional irrigation authority. From the study and design reports, the current design practice for irrigation structures is examined and from the practical visits undertaken on 15 sites, the extent and frequency of hardware and software problems on the schemes is assessed. In the analysis, the frequency of each problem among the sites, type of problem in each site and problem ranking has been done. Better insights on hardware and software aspects of the problems have been acquired via interviews with community and technical personnel using relevant structured questionnaire.

To help build the geographic database, inventory is made, missing coordinates were recorded using GPS instrument, inserted in spreadsheets as dBASE (dbf-IV) and imported to the drainage and rainfall maps

4. Results and Discussion

4.1 Main Canal Siltation

Out of the 26 sites considered for the analysis, 13 are observed to have main canals highly charged with sediment. In other words, 50% of the sites are seen to suffer from the problem. The problem prevalence indicates the level of attention to be given. The silt load is observed to come either along with the river water (suspended and bed load) or as a run off from upstream nearby catchement.
The figure below shows a lined canal completely filled with sediment.

of the region geo-referenced and digitized for the same purpose.

Some canals like the one shown in the figure do not have proper design. In this case, the canal does not have a sustaining bed slope and it also does not have side berms.

Fig-1 Silted main canal of Satame irrigation project

Sustaining bed slopes should be provided by conducting proper profile leveling activities.
The soil bank immediately beside the canal is frequently washed by the rain water and deposited in to the canal. Hence, deposition of large soil mass should not be allowed beside the canals and adequate berms should be provided.
As additional solutions to the problem, proper procedures of design of de-silting basins are also forwarded along with FORTRAN program written for the same purpose. Vortex vanes and excluder tunnels are also recommended in the context of experimentation and further research.

4.2 Headwork Sedimentation

This was observed at 11 of the 26 sites. Accordingly, some 42% of the sites are affected with this problem. Headwork sedimentation refers to the overall submergence of the weir proper, wing walls and appurtenant structures such as gates due to settlement of sediment and the bed level rise of the river channel. Since the phenomenon results in the course change of rivers, in some cases like Hao diversion it is seen that the main canal is completely washed away by the river water changing its course.
To minimize the problem with headwork sedimentation especially with high flow conditions and movement of sediment laden water, provision of simple intakes of gabion or rock fill may provide a solution (Novak et al, 2001). Similar recommendation has been forwarded in the study at Amhara region

(Asfaw, 2004). Despite the failure, the Lenda project of Bilate river is an example characterized by bends, locating the intake at the external bend will give better performance (Arved et. al, 1993). This is mainly owing to the reason that the inner sides of bends are liable to deposition of sediment. The figure below illustrates the case:

Fig-2 Failed Hao diversion weir

4.3 Main Canal Seepage

The problem of main canal seepage is observed on 9 of the 26 schemes considered for the purpose of the analysis. This means that the problem is prevalent on 35% of the schemes.

The seeping water is seen to ooze through the underneath of the soil and hence significant quantity of irrigation water is lost prior to arriving to the distributing watercourses. Besides the loss of valuable diverted water, the seepage moisture in the vicinity houses is also a serious problem in the area. According to the key informants of Gidabo and Gelana irrigation schemes, the schemes have never been meaningfully used for irrigation since their construction 10 years back. This is mainly because of the reason that community members living along side of the main canals do not allow diversion of water due to the excessive seepage flow in to their living houses.

of side intake with simple masonry obstruction across the river. If the stream is It is recommended to practice use of clay lining and plastic lining to reduce the seepage of irrigation water at the canal. However, this may not always be successful as it has been tried and failed in Wamole irrigation project of Sidama Zone.

The issue of canal seepage can be managed by giving due emphasis to the properties of the soil along the canal route & command area. In line with this, proper techniques of clay lining and plastic lining should be tried to reduce seepage problems in irrigation canals.

The coefficient of permeability is the most important factor that should be taken in to consideration. According to the USBR recommendation, canal lining should be carried out for soils with permeability coefficient value greater than 0.8m/day (EVDSA, 1990).

4.4 Seepage through Foundation

The foundation seepage is also observed in the region as being one of notable problems. The analysis of water seepage under the foundation is very important and must be given due attention. Failure to apply the proper sub- surface flow theories and practices may result in complete failure of the structure (Garg, 1989). During the survey, 1 of the 26 sites (4%) is seen to fail due to this problem. At the observed site, the water is totally flowing beneath the foundation of the structure resulting in the total failure of the scheme. As physically observed, the structure does not even have up stream and downstream cut offs to control the sub surface flow which induce failure due to uplift pressure or failure due to piping or undermining. The figure below shows the situation:

Fig-3 Failed Hazembara diversion weir

4.5 Damage on Intake gate and Sluice gates

Out of the 26 sites considered for the analysis, 8 are observed to have highly damaged and broken intake gates. In other words, around 31% of the sites are seen to suffer from the problem. Similarly, 7 of the 26 sites (27%) have damaged sluice gates.
The figures possibly indicate how the schemes are performing under difficult condition. The cause for the problem of gates can be mainly attributed to improper scheme operation. Provision of adequate training, proper handing over and follow up of the users is indispensable. In addition, users organized in water user association should take initiatives to generate some resource to carry out some maintenance works of this sort.

4.6 Damage on Headwork

Damage of the weir proper is observed in 1 of the 26 sites that is Lenda (4%) and 2 sites (8%) are observed to have damaged wings and eroded banks.
The following figure taken from Lenda irrigation project constructed across the Bilate river may depict the phenomena.

Fig-4 Failed Side intake constructed on Bilate River

The stability of the weir proper can be ensured by correctly following the proper procedures of the structural analysis after identifying the various forces acting on the structure.

In some cases like Lenda, it was observed that irrigation structures with in earth quake prone areas are designed with out considering the earth quake forces. The force due to earthquake should be considered where necessary for the stability analysis.
The most important forces to consider are: Forces due to surface flows, forces due to sub surface flows, forces due to self weight and external forces like earth quake and silt pressure.
The downstream wing walls can be failed due to excessive downstream bed and bank erosion which results because of excessive energy carried by the water coming from upstream. In addition, as seen at Lenda project, outflanking of protection structures can also cause failure of wing walls. Hence proper estimation of the magnitude of flood, proper geological investigation and proper protection measures are vital in this case.

4.7 Damage on Downstream Bed

This problem is observed on 5 of the 26 (19%) of the surveyed sites and it is attributed to improper hydraulic design that arises from poor knowledge of the energy dissipation and impact of sediment on the structure (Baban, 1995 & Novak et. al, 2001). The impervious floor is designed in all cases to reduce the surface flow action that causes scouring due to unbalanced pressure in the hydraulic jump trough. Generally speaking, except very few sites, end sills are not seen at the constructed structures. These could have played significant role in controlling receding jumps and hence reducing erosive power of the flowing water (Chow, 1959). In the diversion schemes where this problem prevails, abrasion and scouring of the impervious floor is commonly observed. In addition, flexible aprons are seen to be completely washed away by the energy of flowing water. The prolonged occurrence of abrasion and scouring of downstream portion of the structure may end up in the total collapse of the structures.
Accordingly, proper design of both impervious and pervious aprons are required to control the excessive upstream energy and control structures should be provided to manage the problem of receding jump. The figure below shows the phenomena:

Fig-5 Failed Goche diversion weir

4.8 Drying of River Flows

Drying out of flow was observed at the 3 of the 26 sites considered for the analysis. In other words, about 12% of the schemes were seen having no water in their river channels. Some of the sites such as Balle have got seasonal rivers. One of the reasons causing drying out of flows is improper estimation of lean flows. The current design practice follows the procedure of float method to estimate the lean flow. It may not be wrong to use the method for preliminary works. However, the method is approximate enough to over estimate the actual flow in the river and is not reliable for important works with considerable investment. In case of over estimation, the actual flow may not be obtained to satisfy the CWR and downstream water demands which may result in complete diversion of water in to irrigation canals letting the downstream dry.

The caseof Ufute may be taken as a good example for this situation. During the survey, people living downstream of the scheme were seen complaining because of shortage of water for their livestock. However, interviews revealed that some other sites like Jelaka became dry due to significant water use far upstream from the irrigation scheme. This situation has created some level of conflict among the far up streamers & irrigators and the phenomena showed lack of adequate social work during feasibility study and follow up. The river drying problem can be observed in the following figure:

Fig-6 Jelaka Diversion Weir

4.9 Damage on CD Works

CD- works are structures carrying discharges of a natural stream across a canal intercepting the stream. When a canal is to be taken to the watershed, it crosses a number of natural streams in the distance between the headwork and command area. As one of CD structures, an aqueduct is observed at Lenda project site. However, design was not prepared for the structure and was just constructed based on experience of masons. Hence serious scouring is observed both at up stream and downstream bed and bank of the structure. The following figure depicts the case:

Fig-7 Scouring problem on an aqueduct at Lenda Project

The features of design of cross drainage works can be summarized in the following main categories (Arora, 1996):

A. Hydraulic Design

This usually involves the following:

- Determination of the maximum flood discharge and high flood level
- Fixation of water way of the drain
- Determination of canal water ways
- Determination of uplift pressure on the floor of drain
- Design of bank connections

B. Structural Design

This usually involves the following:

- Design of the cross section of the aqueduct trough
- Design of piers and abutments
- Design of foundations

At Lenda, the calculation of the adequate water way is not carried out to allow safe passage of the drainage water beneath the main canal. This could be carried out using the formula forwarded by Lacey. For large drains, the wetted perimeter may be taken equal to the width of the river; however, for small drains like that of Lenda a contraction of up to 20% can be allowed (Arora, 1996).
However, failure to carryout the calculation of the waterway may endanger the entire structure and in extreme case may even flood the nearby areas.

In the case of Lenda, determination of waterway, protection works of bed and bank, design of foundation and consideration of scour conditions are totally ignored resulting in serious erosion problems as indicated in figure-7 above.
Accordingly, it is recommended to do detail hydraulic and structural design of cross drainage works rather than simply deploying masons to build the structure.

5. Planning, Institutional, Social & Economic Problems

The above problems with such schemes are not only attributed to problems of design and construction. The software aspects of planning, institutional social & operational and economic problems are also crucially important. In the following section the highlights of each problem are presented:

5.1 Planning Problems

The planning process in the development of irrigation projects can be viewed in the light of community willingness and participation. Accordingly, good performance of the schemes is directly related to the level of involvement of community members in the planning process.
In line with this, the schemes in the region can be categorized in to two:

- Schemes implemented with due involvement of stakeholders
- Schemes implemented with out(less) participation of stakeholders

As observed during field visits, strong community participation was involved at Ufute and Doje schemes that are implemented by WVE in Kembata zone. The schemes are functioning satisfactorily and users are also happy with them. Community interview revealed that the beneficiaries clean silt from main canals with out the orders given by leaders of user association. From the very beginning, the beneficiaries adequately involved in the implementation process by providing labour and local materials and have already developed sense of ownership.
On the other hand, the situation at Goche scheme of Hadiya zone is the opposite of what has been discussed. Practically, the users had no involvement with the implementation of the project and a sort of induced development or top down development is observed there. The intended beneficiaries did not show any interest with the scheme mainly because it is not addressing their real problem. They were requesting for development of a nursery at the place where the major portion of the command area of the scheme is found. Accordingly, the scheme has now failed to fulfill the purpose to which it is intended and simply the structure is located there.
Similarly, less participation of intended beneficiaries is also observed at Ameka irrigation scheme in Hadiya zone. The beneficiaries could not participate adequately in all the phases of planning, implementation and operation mainly for reasons of location of the command area far away from their village and unsuitability of the command area soil. The location of the command area at distant place and high plasticity of the command area soil developed reluctance among intended users of the scheme. Hence, although the project is completed, no one in the area is interested to use it. The implementing government agency should have repeatedly consulted the local people starting from the project inception and site selection rather than implementing the scheme with out their involvement. In addition to this, suitability of the command area soil should have been tested in laboratory during the feasibility study.

5.2 Institutional Problems

In the implementation of irrigation schemes, various institutions are involved in the process of planning, design, implementation and operation & evaluation.
However, in some of the schemes built by NGOs and GOs the expected level of participation of various institutions is not

observed. Schemes of Satame, Hazembara, Lezembara, Hao, Jelaka & Goche can be cited as projects having no design and handing over documents. Preparation of proper design is the due responsibility of the implementing institution (WVE) and the regional irrigation authority. The absence of proper design document also resulted in creating problem to proper completion and handing over of the schemes to concerned stakeholder institutions. At this point, it is worth to mention that the main reason not to handover irrigation schemes built by WVE at Omosheleko wereda in Kembata zone is absence of proper design documents. The implementing institution may phase out from the area up on completion of agreement period and if the schemes are not handed over to the stakeholders, they may totally abandon.

It is clearly seen that the handing over problem largely results because of failure of concerned institutions to discharge their due responsibilities.

Like wise, the cooperative promotion office as an institution at zone or wereda level has a responsibility to properly organize the irrigation water users and follow up the collection of periodic contributions by users to conduct maintenance works and help sustain the project. However, almost in all the visited projects irrigation water users are just aware of this but have not yet started contributions.

The institutional problem is also manifested by the absence of follow up during the operational phase of the implemented schemes. The performance evaluation of irrigation projects built by NGOs is the duty of zonal disaster prevention and preparedness office and the woreda council. In addition to periodic reports given to these offices, these government institutions should observe the field level situation of individual schemes and should try to curb problems prior to total failure of the projects.

5.3 Social and Operational Problems

The planning and institutional problems can also be reflected in the proper operation and utilization of the implemented schemes. Establishing WUA is a task to be carried out during the planning process or right at the beginning of implementation. This important activity is carried out by the implementing institution and the respective cooperative promotion office. Failure to establish legally instituted WUA and elect leaders results in problem of proper operation of schemes. Some older projects implemented by LWF & WVE can be cited as examples where strong WUA is not established. At such schemes, activities of silt cleaning from main canal and minor maintenance on gates could not be carried out because of lack of community and resource mobilization in organized manner.

In some projects like Jelaka, social problems like conflict were also observed due to water rights. In the following sections, the issue of conflict is discussed in general and specific terms.

Conflicts due to water rights are of two types:

- ♦ Conflict among irrigators, which is not common in the region
- ♦ Conflict among irrigators and up stream settlers or down stream settlers. The conflict with up stream settlers is mainly due to diversion of same river or tributary for other irrigation or some other purpose as seen at Jelaka scheme. The riparian law that says 'first come first served' does not seem to work well in such conditions. The conflict with down stream settlers mainly occurs during low flow seasons when irrigators completely divert the stream flow to fields. This case is observed in Ufute scheme.

The issue of downstream water rights is something that should be discussed in detail during the feasibility study and failure of doing these results in creating operation and utilization problems discussed above.

5.4 Economic Problems

Most users of visited irrigation schemes in the region are characterized by low income condition at household level. Users are usually heard of complaining against the high rates of costs of production inputs such as fertilizers and seeds. As indicated in the table below, 25 schemes of the 26 considered in the analysis generate no resource to help sustainability of schemes by conducting minor maintenance and rehabilitation activities. The reason for this is partly economic problem. However, this does not mean that irrigation schemes are not changing the life of beneficiary households. As an example, in cash crop producing areas of the region such as Sidama, users are observed to fetch considerable amount of money. During interview with beneficiaries of kedoboga irrigation scheme, it was revealed that an individual is earning up to Birr 2000 per quarter of a hectare of land per one season of cash crop.

Generally speaking, the country's food situation is characterized by food insecurity at both micro and macro levels. The major area of concern is the availability of food at household level. The country is even not able to produce most of its food requirements in normal years.

Ethiopia's national target is to achieve food security both at national and household levels. To achieve this, specific programmes are needed to address the two sides of the food security equation: availability of food through increased production and storage, and access to food through family production, purchasing on the market and through effective food transfer programme.

Small scale irrigation can lead to availability of food at household level through increased productivity, stable production and hence increases income leading to alleviation of economic problems at household level. It also appears that development of small scale irrigation schemes helps the country attain food self sufficiency at national level

6. Inventory and GIS based database building

Regional level inventory has been made to collect the information on existing schemes. The information is collected from field survey & study and design reports and other reports concerning the topic. All the information pertaining to the irrigation projects are inserted in spreadsheet as dBASE and then attached to regional maps using Arc-View GIS [Fig-8 below].

The most important advantage of the digitized maps is that they can be used as tools to store and retrieve information in Arc-View GIS windows. Information of an individual scheme can be easily accessed by clicking on the point theme representing the scheme. Like wise, any additional information can be stored in the spreadsheets attached with the point themes.

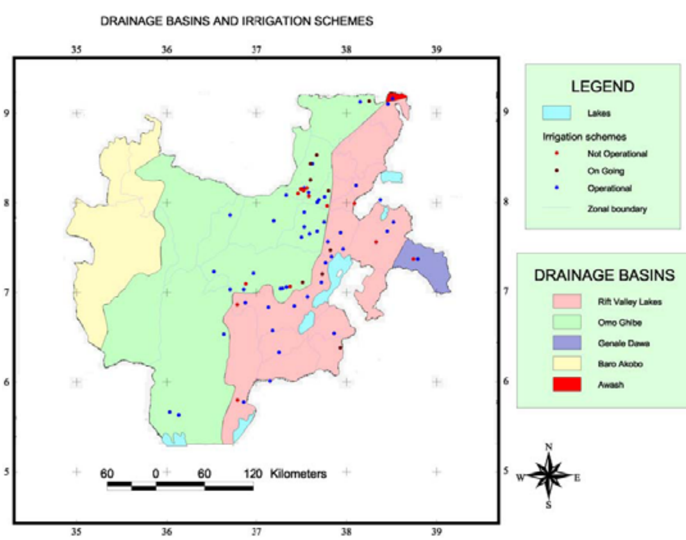

Fig-8 Distribution of irrigation schemes and drainage basin

7. Overall Conclusion

In the past, a considerable effort has been exerted by government and various agencies to promote irrigation development in the south region. However, what this research has revealed is that a considerable number of schemes (18%) have already totally failed because of the various problems discussed in the preceding sections & a significant number are performing below their capacity.

Accordingly, the government and various other agencies involved in the subject need to revise the approach towards irrigation development by:

- Integrating local research with modern irrigation development by creating mutual relationship between research and irrigation development
- Promoting irrigation development activities based on local knowledge and community participation
- Building the capacity of the technical personnel involved in the subject so that better skills can be gained in planning, design and implementation of projects
- Integrating software and hardware aspects of irrigation schemes rather than focusing largely on design and construction alone as hardware components

Failure to consider these elements may result in subsequent failure of other schemes.

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Across System Comparative Assessment of irrigation performance of community managed scheme in Southern Ethiopia

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Abstract

The water users located at the upstream of the irrigation system have more access to water than those located at the downstream of the system. Moreover, the irrigation activity of tail-enders is seriously affected in both water scarce and water abundant periods due to under and over irrigation respectively. Not only water but also the situation of landholding affects the productivity and income of the farming community. The goal of this study was to assess the spatial variation of irrigation performance and to evaluate its effects in terms of performance of agricultural production (intensification and productivity), income and resources base as well as the environment. Across-system performance assessment study sponsored by International Water Management Institute (IWMI) was done on the basis of simple illustration of the approach followed for the assessment and different levels of water accessibility along the canal reaches. The level of availability of irrigation water or accessibility to the farm is affected by the proximity of the farm to the water source or to the water carrying canals. The study confirmed that as one gets away from both the water source and the canal the accessibility of water becomes less and less, unless proper system for water allocation is in place and practiced. In view of that, six zones can be differentiated based on the condition of water accessibility. These are highly accessible, moderately accessible, less accessible, very less accessible, poorly accessible and water scarce zones. Sometimes the tail-end, which is characterized by water scarce zone, is also found to be affected by water logging. Since, available water and demand for water are not continuously monitored and managed, the situation outlined paves the path for potential conflicts among water users in response to visible livelihood differences. Despite disruption of downstream users from irrigating their field, significant loss of scarce resource by the upstream users have resulted in detectable environmental threat such as water logging, sodicity (10.44meq/l, k (H.C.) 0.00279cm/hr) and salinity problems in the area.

1. Introduction

There is a common perception that water users located at the upstream of the irrigation system have more access to water than those located at the downstream of the system. Moreover, the irrigation activity of tail-enders is seriously affected in both water scarce and water abundant periods due to under and over irrigation respectively. In Hare irrigation scheme there are three diversion sites very close to each other which are planned to serve a wide range of users. Before the establishment of the scheme, only limited numbers of farmers which are close to the water source were using traditional methods to irrigate their lands. It is common that after the establishment of irrigation scheme the number of population in the command area increases through migration of peoples from elsewhere. Intended is to get the benefit of irrigation that the early settlers are enjoying. Land acquisition of new comers is most likely possible at downstream of the canal reaches in the system. Not only these late settlers will become the victims of water shortage but also the whole irrigation system will get under pressure because initially designed capacity may not met the increased demand through time. Unless the available water and demand for water are continuously monitored and managed, the situation outlined above could be one of the potential causes of conflict among water users.

There are complaints among four involved Kebeles regarding unequal distribution of water among the users in the scheme. Especially, during dry seasons Kolla Shara Kebele which is served by the upstream diversion structure is diverting water without considering the share of three other Kebeles (Chano Dorga, Chano Chalba and Chano Mile) that are feed by the rest two downstream diversions. There are visible livelihood differences among the beneficiaries of the scheme. On the other hand there are poor and food self-insufficient households living in the system.

Not only water but also the situation of landholding affects the productivity and income of the farming community. Provided that water is sufficiently available, the direct benefits of irrigation, in terms of increased farm output, will tend to accrue in proportion to the size of landholdings, with large holders benefiting more than smallholders, and smallholders benefiting more than the landless.

The objective of this study was to assess the spatial variation of irrigation performance in Hare community managed irrigation scheme in southern region of Ethiopia. The specific objectives are:

- to assess the water distribution performance of the scheme
- to evaluate the effect of being at the upstream, midstream or downstream regions of irrigation canal system in terms of performance of agricultural production (intensification and productivity), income and resources base

2. Description of the irrigation scheme

2.1. Hydrometeorology of the area

The climate of the area is characterized by mean maximum and minimum temperature of 30.3 and 17.4^{0}C respectively, annual rainfall of 843mm and potential evapotranspiration of about 1644mm. Mean monthly distribution of these parameters are shown in Table 1. The rainfall distribution pattern is bimodal with first and maximum peak in April to March and second peak in October. The area is characterized by high potential evapotranspiration rate that ranges from 112mm in July to 180mm in March. Consequently, except in April and May, the evaporative demand of the area is greater than the amount of natural rain. This means that there is a negative climatic water balance in the area. This calls for supplementary water application to the crop fields through irrigation to sustain crop production. The warmest months of the year are February and March while the coldest are November and December.

The maximum flow hydrograph of Hare River which is the source of water for the scheme shows also two distinct peaks that occur in May (5.60m^3/ s) and October (4.53m^3/s). The low flow hydrograph between the two peak rainfall periods, i.e. from May to October, is almost consistent ranging from 1.26 to 1.62m$^{3/}$s. The low flow declines during the months from December to April.

Table 1: Mean monthly values of hydro-meteorological parameters

	Rainfall (mm)	PET (mm)	Temperature (^{0}C)		Hare River Flow (m^3/s)	
			Maximum	Minimum	Maximum	Low flow
January	28.1	139.5	31.7	16.3	1.31	0.69
February	27.9	140.0	32.9	17.1	1.49	0.64
March	64.0	179.8	33.0	18.3	1.95	0.63
April	144.1	141.0	30.8	18.2	4.06	0.85
May	140.5	136.4	28.9	17.9	5.59	1.33
June	63.1	120.0	28.1	17.9	3.79	1.25
July	43.4	111.6	27.7	17.9	3.81	1.26
August	53.2	124.0	28.5	18.0	3.54	1.31
September	78.1	135.0	30.1	17.8	4.26	1.33
October	110.6	136.4	29.8	17.7	4.53	1.62
November	59.3	138.0	30.6	16.0	2.65	1.16
December	31.1	142.6	31.1	15.7	2.13	0.93
Total/Mean	843.2	1644.3	30.3	17.4	3.26	1.09

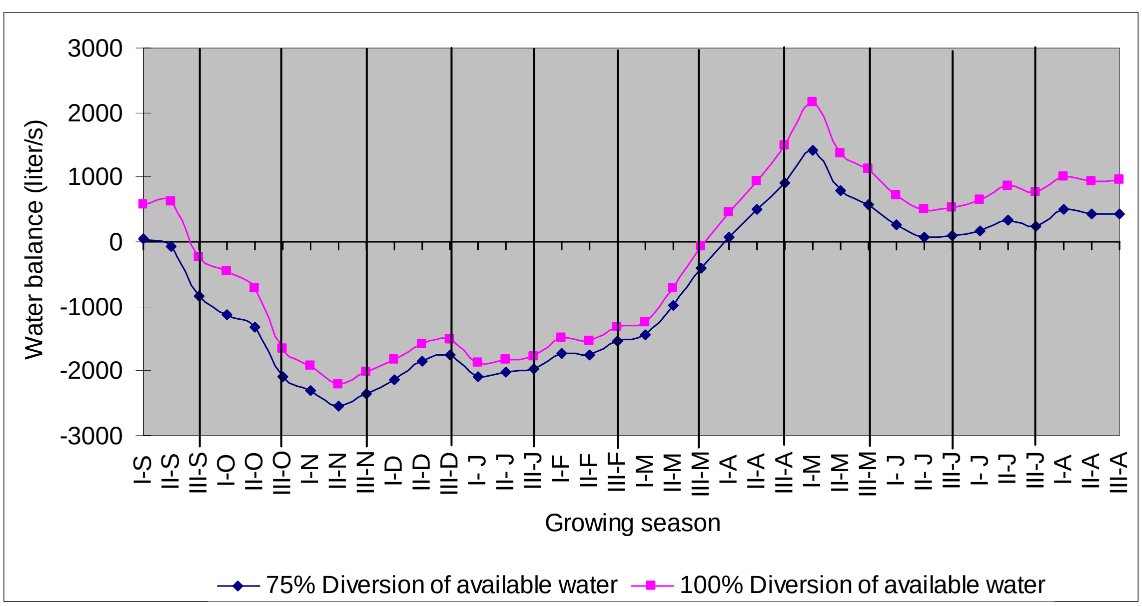
To see the relationship between demand and available water two scenarios have been considered; (i) with 75% dependable diversion and (ii) with 100% diversion of the available water. The results are presented in Fig.1. In both scenarios the available water cannot meet the water demand for irrigation during seven consecutive months of the year viz. from late September to March. Feedback from the users also revealed that these identified periods to be water scarce times. Total diversions of water from the river course to the canals have been observed in the months of December and January. The available water in these months can only irrigate an area which is 24% of actually irrigable land (2224 ha). As the river pass through diversified bushes to end in Abaya Lake which is located downstream of the scheme (Fig. 2), its total diversion will likely have negative effects on these ecosystems. The water balance (water supply minus demand) is positive from April to August.

Fig. 1: Mean decade water balance (water demand minus available water from the source) from September to August.

2.2. Background of Hare irrigation scheme

2.2.1 Irrigation Scheme

Hare irrigation scheme encompasses three diversion systems the upstream diversion with control gate, the midstream traditional diversion and downstream diversion weir. These diversion points are respectively designated as D1, D2 and D3 (Fig. 1).
The upstream and midstream diversions and



their delivery systems were established in the year 1993 while the downstream diversion weir was implemented in 1996. It was meant to serve four villages which are locally called "Kebele", viz. Kola Shara, Chano Dorga, Chano Chelba and Chano Mille. Fig. 2 shows the diversion points and the canal systems delivering water to the respective Kebeles.

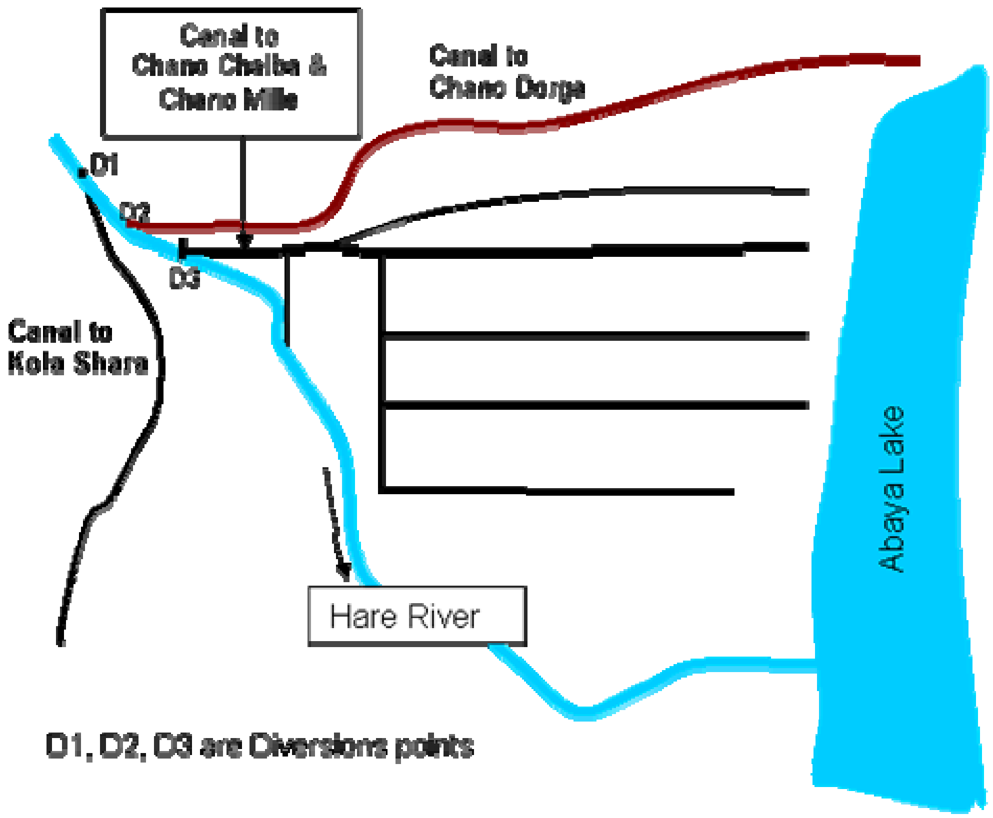


Fig. 2: Layout of Hare Irrigation Scheme

The upstream diversion (D1) of water is accomplished by simple concrete intake structure. The earthen unlined canal is receiving water from the intake structure to irrigate Kolla Shara command area. The 6km long main canal was initially trapezoidal in shape and now it is irregular. The canals pass through villages and are subjected to damages by human and animals which resulted in bank breaks, overtopping, weed growth, accumulation of silt and wastes in the canals.

Downstream of D1 is D2 the point at which traditional diversion of water is practiced. That means there is no headwork and water diversion is accomplished by a simple open cut in to the river bank which is supported by diagonally arranged temporary barrier (stones, plant rests) and act as divide wall. Unlined earthen canal which is running on the left bank of the river takes water from this diversion point to irrigate Chano Dorga area. The main canal runs over 7.1 km distance and has got irregular shapes. In some areas the canal bed has developed to gorges while in other locations shallow depth and wide surface areas are the characteristics of the canal. There is not as such well designed secondary canal. Hence field channels arranged by the community take of water which is directly used to irrigate the corresponding fields. There are about more than 60 major outlet points along the main canal. Since there is not control structure at the head some farm fields are affected by flood during rainy seasons.

Downstream of the above mentioned intake points (D2) there is a diversion weir (at D3) to convey water it to a partially masonry type lined main canal. The structure was provided with a flow control mechanism though its performance has deteriorated from time to time. The weir and its delivery infrastructure were constructed by technical and financial support of Chinese government. It was planned to serve large portion of Chano Mille and some part of Chano Chalba irrigable areas. The construction of the weir was started without feasibility study and awareness of the users. Hence it was accompanied by complaints from the users and even from local and regional authorities. The reasons were luck of awareness, imbalanced weir location, and demand for small dam that could ensure the balance between water supply and demand over the growing season. During construction phase the communities have realized that the implementation of the system will bring about the dissections of their farming field for delivery systems and for the access roads etc. and became more reluctant. In spite of these resistances the Chinese contractors have implemented the diversion weir.

While the construction work was under final phase, some parts had started to give partial services but the discontented farmers partly started destroying the irrigation channels, particularly plowing over the secondary and tertiary canal systems and dismantling of the structures. But gradually the community realized that they have made a lot of mistakes during construction while they have observed a lot of positive impacts in their life due to the intervention. Particularly, the primary user of this weir, Chano Chalba, is the leading Kebele with respect to their production competence as well as the significant change in their standard of living.

Those who complained and protected the irrigation canal from reaching their field at that time are now the one who are straggling to bring the water to their field are still relatively poorer.

The main canal taking of water from the weir is of two types. A certain length is masonry rectangular canal and the major portion of the main canal is trapezoidal pitching. The other irrigation infrastructures such as the turn outs, the division boxes, the road crossings, the drops, the head and cross regulators are all constructed with masonry and reinforced concrete, all are lined and plastered except in some area pointing work. The main canal has got a length of 5.33 km. There are 7 secondary canals which when totally summed have got a length of 12.95 km. The longitudinal slope of the canal alignment is 0.1 % which was ensured through 13 drops.

Group of farmers take water from secondary canals to their field plots through the outlet structures prepared for same purpose. The excess water from the canals and from the runoff joins the main drainage system. Part of the drainage water joins the Hare River and the remaining flows in to Lake Abaya. It is only the main drainage canal which is functional at present and serves to remove immense amount of excess water at the down stream section of the irrigation scheme.

As far as water allocation is concerned there is a water users committee (WUC) which is responsible for fair distribution of water among the users. WUC also organizes maintenance activities. Whenever irrigation is required, each water users group submit request for water to the WUC. Once the request is made to the WUC, then this committee prepares a tentative time schedule up on which irrigation can be made.

2.2.2 Socioeconomics

Prior to construction of irrigation scheme in the area local farmers used to irrigate their lands on their own traditional ways. This accounts to only some 300 hectares. After the implementation of first and second phase construction in 1993 1996 respectively more than 1031 ha and 1336 ha of land have been developed. The number of beneficiaries has also increased from time to time.

The principal crops grown in the command area are banana, maize, mango, avocado, sweet potato and also cotton. Those farmers who have better access to water have preference of growing banana mainly due to its marketability on central market. As it is suitable for fruits trees the area is known for the provision of fruits such as mango, avocado, papaya to the central market. Farmers grow crops such maize and sweet potato for own consumption. Cotton is an alternative crop for tail-enders as it withstands water stress conditions.

Table 2: Demographic feature of Hare irrigation scheme

Name of Villages	Number of Households			Number of Population		
	Male	Female	Total	Male	Female	Total
Kola Shara	800	164	964	2358	2474	4832
Chano Dorga	413	20	433	1403	1363	2766
Chano Chalba	751	175	926	2339	2713	5052
Chano Mile	821	102	923	3950	3074	7024
Total	2785	461	3246	10050	9624	19,674

As per the information in 2006 the total number of beneficiary households is about 3246 out of which 14% are female headed. The relative proportion of female and male of the total population in the command area is almost equal. More female households are found in the command areas of upstream and modern diversion canals viz. in Kola Shara and Chano Chalba commands. The number of households is almost equally distributed in the three of the Kebeles except in Chano Dorga which has the least number of households (Tab. 2).

Table 3 shows the land use patterns of the command area. From the total irrigable area of 2224ha in the scheme the highest proportion is in Chano Mille (32.2%) followed by Chano Chalba (29.2%), Kola Shara (27.7%) and Chano Dorga (10.9%).

Table 3: Land use patterns in the command area

Type of land use	Kola Shara	Chano Dorga	Chano Chalba	Chao Mille	*Total*
Total area, ha	800	745	799	900	*3244*
Cropped area (annual), ha	251	282	199	496	*1228*
Cropped area (perennial), ha	391	120	450	400	*1361*
Total cropped area, ha	642	402	649	716	*2409*
Irrigable area at the moment, ha	617	242	649	716	*2224*
Irrigated area at the moment, ha	617	242	649	454	*1962*
Area occupied by infrastructures, ha	100	43	90	164	*489*
Forest area, ha	20	200	40	10	*270*
Grassland, ha	38	100	20	10	*188*
Average landholding, ha	*0.97*	*1.50*	*1.50*	*1.25*	*1.42*

Except in Chano Dorga Kebele, the largest proportion of cropped area is covered by Perennial crops such as Banana and other fruit trees. Irrigable areas in the first three Kebeles have already been developed under irrigation. However in Chano Mille which is relatively far from the headwork, the irrigated area is only 63% of irrigable land.

2. Methodology

Like other schemes in the country, there is no any kind of record available in Hare community managed irrigation scheme. Hence, useful information for the execution of this study was generated through measurements, observations and interviews. Discussions have been held with water development committee, community elder groups Kebele administration member, development agent/extension agent, farmers, female headed households etc. The scheme has been frequently visited to examine the operations, the conditions and functions of irrigation systems, agronomic practices of farmers, cropping patterns etc. These visits were conducted with the accompany of different water users and operators group, viz. water development committee members, administrators, local elders, model farmers, male and female farmers. An attempt was made to understand the system and collect data necessary to measure the performance indicators.

The main canal and the secondary canal, tertiary canals and field canals including the drainage lines of all the three schemes have been inspected. The capacities of the canal systems have been measured at different reaches.

More than 800 GPS points has been taken for evaluating the scheme performance with respect to its proximity to the watercourse and main canal reach.

Measurements of flows in the canals have been conducted after the canals are maintained, i.e. after the removal of sediments, weeds and other barriers in the canals. Since this study was conducted during the out set of the rainy season right after they maintained the canal section to start irrigation, while they were not yet opened their many illegal outlets particularly the canal of traditional diversion to Chano Dorg. Accordingly, the measurements for this diversion have been only taken along the canal at 5 points (300, 1804, 3802, 5390 & 6730 m). Then again, for the other two diversions, measurements have been taken safely in both directions along the canal and laterally at several points. For instance, for the u/s diversion, Kola Shara along the canal at 370, 1600, 3290, 4190 & 4889 m positions, while for modern diversion 334, 1100, 2230, 2810, 3860, 4030, 5560 & 5890m. For the lateral flow performance investigation, the traditional diversion was not considered as it has no as such properly managed or working secondary canals. Thus, the other two diversions lateral canal performance was evaluated in two categories that is comparison between the secondary lined canal and the secondary earthen canal of the Modern versus the secondary earthen canal of the Modern Cum Traditional.

It is common to measure the discharge at the intake and the application point to estimate the losses. Even though such method is capable of giving the general nature of the water conveying structures performance, by this study we assumed such methods are really less important as it hardly locate the apparent position of the significant loss. In contrast the method we applied here, measuring within short interval and projecting the loss per unit length found to be a relevant technique to get the desired result. Accordingly by linking the actual efficiency and the distance from the intake point the linear correlation coefficients have been obtained.

Across-system performance assessment was done on the basis of illustration given in figures 3 and 4. The level of irrigation water availability or accessibility to the farm is affected by the proximity of the farm to the water source or to the water carrying canals. As one gets away from both the water source and the canal the accessibility of water becomes less and less unless proper system for water allocation is in place and practiced. According to figure 4, seven zones can be differentiated based on the condition of water accessibility. These are highly accessible zone, moderately accessible, less accessible, very less accessible, poorly accessible and water scarce area. Some times the tail-end which is characterized by water scarce zone can also be affected by water logging.

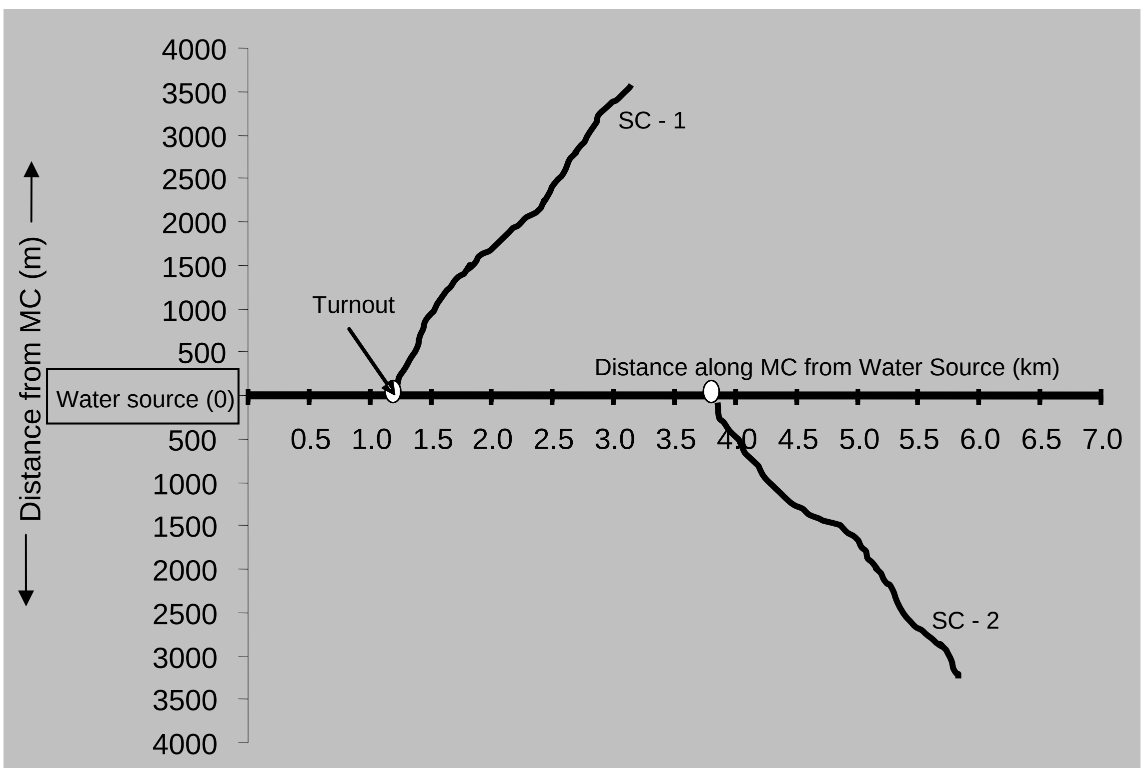


Fig. 3: Simple illustration of the approach followed for the assessment

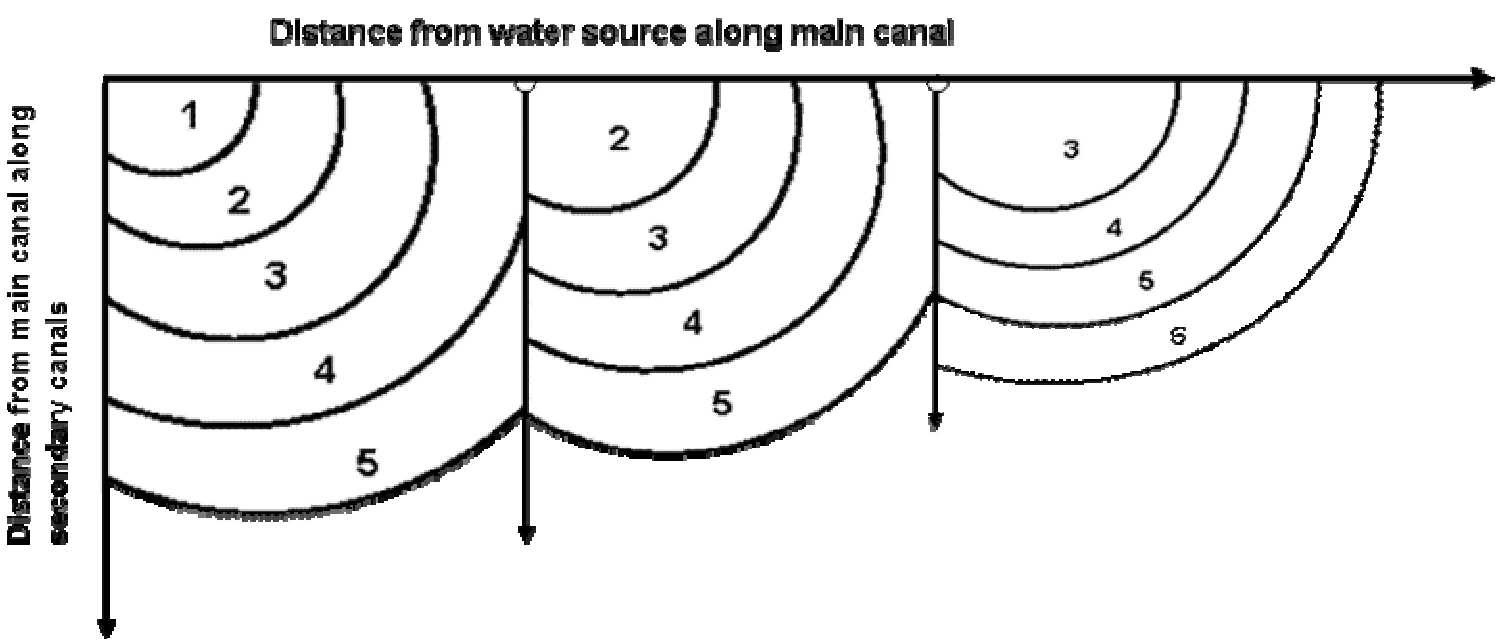
All relevant data were collected along main canal (MS) and secondary canals (SC) that are functional during the season. Accessibility of water to a farm unit which is measured in amount and timely delivery is defined in this case with respect to proximity to water source that decreases from the head to tail end of the canal systems. The assessment was carried out following two directions (Fig. 3), i.e., (i) along the main canal that receives water from the main source and (ii) along secondary canals that takeoff from the main canal. The hypothesis here is that the secondary canal 1 (SC-1) have more access to water than secondary canal 2 (SC-2) due to its relative closeness to the water source along the main canal. Likewise there are differences along the secondary canal itself as one goes from head to tail.

Table 3: Summary of information in Fig. 4

Zones	Distance ranges (m) along		Water accessibility
	Main canal	Secondary canal	
1	0 - 500	0 - 250	high
2	500-1000	500-750	moderate
3	1000-1500	570-1000	less
4	1500-2000	1000-1250	Very less
5	2000-2500	1250-1500	Poorly accessible
6	2500-3000	1500-1750	Water scarce

Areas that fall in the regions of poorly available and water scarce zone are characterized by critically limited water availability and hence depend more on rainfall. Water logged areas are located at end of the systems. The owners of such lands are suffering from shortage of water during irrigation and flooding during off-irrigation periods. These areas are covered by cotton which is relatively water stress resistant compared to common crops grown in the area.

Fig. 4: Simple illustration for different levels of water accessibility along the canal reaches



4. Results and Discussions

4.1. General Practices

One of the most important problems that exist in and around the small- and medium-scale irrigation schemes in the country is discrepancies between design specifications of the systems and expectations from the same. No reference is usually made, if at all available, to the design documents while operating and managing the schemes.

With increasing number of population the size of the landholdings in an area becomes smaller and smaller. This is exactly what is observed around successful irrigation schemes. The main advantages of irrigation practice lay on provision of opportunity for intensification of cropping. Under decreasing size of landholdings in irrigated agriculture, intensification of cropping coupled with productivity improvement is the way to enhance food production. No doubt that better access to inputs and technologies contribute to improvement of productivity. Intensification of cropping is mainly determined by the type of crops selected and availability of water.

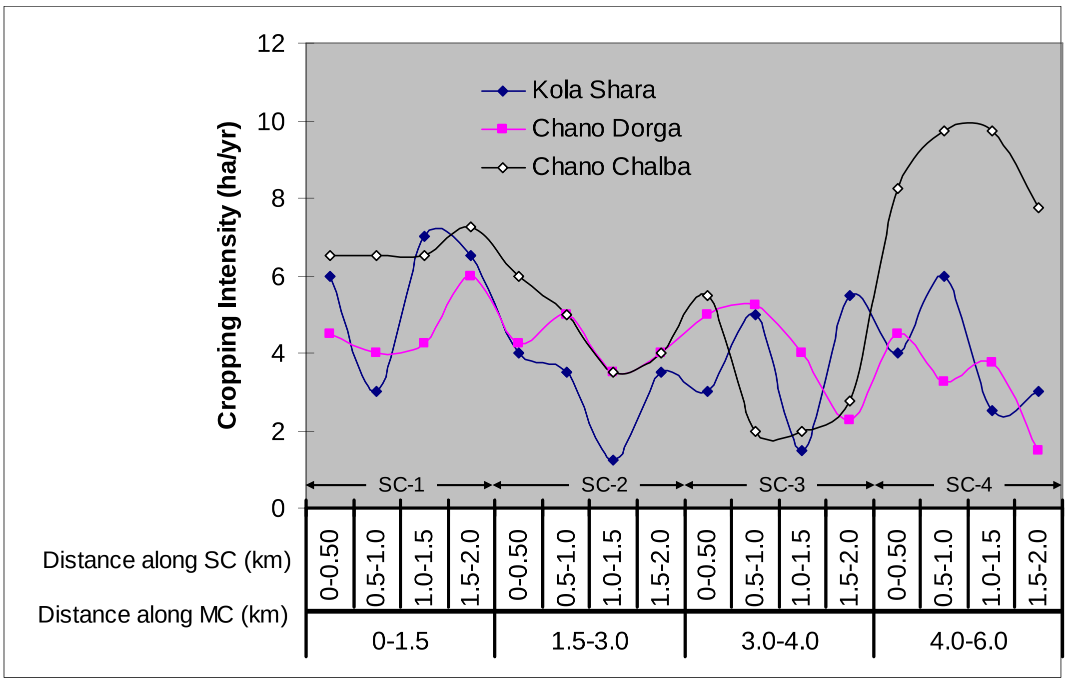


Fig. 4.1: Cropping intensity along the canal reaches (the product of average area cultivated per season and frequency of harvest per season)

Figure 4.1 shows the spatial variation of mean cropping intensity that was practiced by one household. It is evident that the intensity of cropping decreases along the main canals from upstream to downstream incase of communities in Kola Shara and Chano Dorga which are served by the upstream and midstream diversions respectively. On the contrary, there is slight decreasing trend of intensity as one goes down along the secondary canals. Under Chano Chalba condition, the trend of the curve coincides with the previous two up to a certain distance beyond which rapid raise is taking place. Farmers located here, i.e., 4 – 6 km away from the diversion point along this canal, are practicing higher crop intensification compared to those located in the middle and head regions of the canal. These framers are trying to convert the challenges of flooding and shallow groundwater depths in the tail regions of the canals to opportunities in that they are adopting multi-cropping system or intercropping.

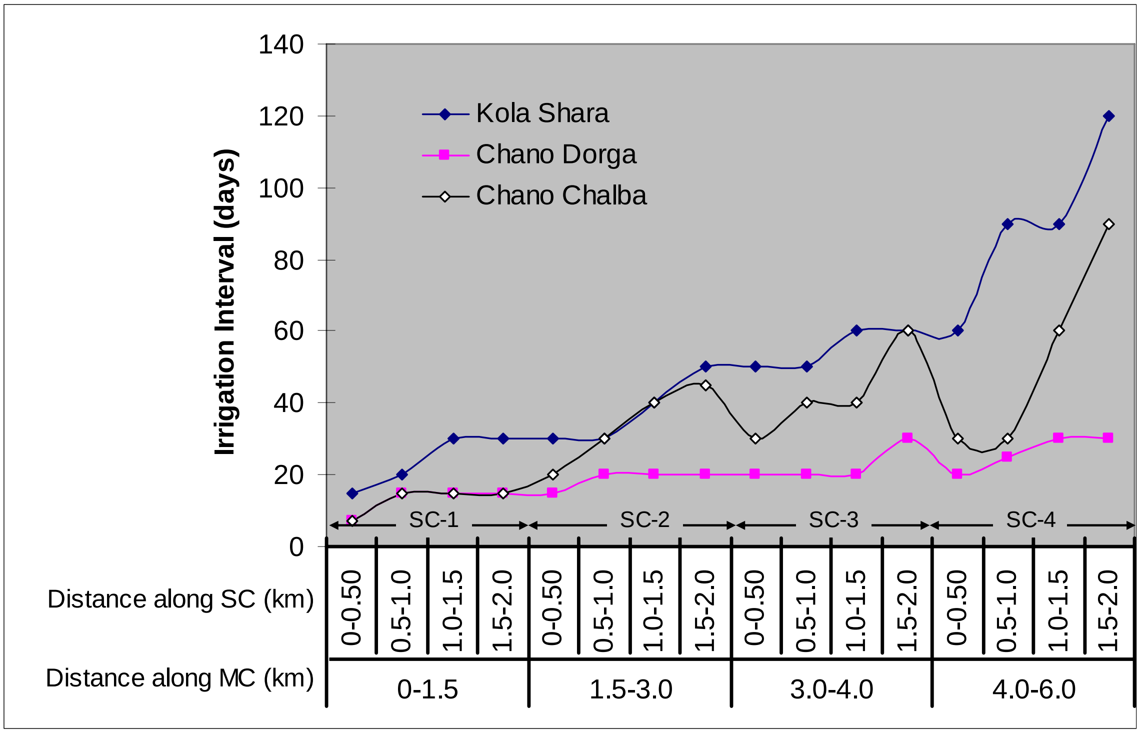


Fig. 4.2: Irrigation Interval (days the users have to wait until the arrival of the next irrigation water)

As can be viewed from Fig. 4.2 the frequency of getting water by the users decreases from head to tail-ends of all canal systems. It varies from 7 – 30 days, from 7 – 90 days and from 15 – 120 days in Chao Dorga, Chano Chalba and Kola Chara respectively. Irrespective of the location of diversion point with respect to each other, those users close to water source get frequent access to water. The communities using traditional diversion get frequently water compared to Kola Shara and Chano Chalba that use respectively simple diversion structure and diversion weir.

4.2. Water delivery performance

The values of some performance indicators are given in the table 4.1. As far as most of these indicators are concerned, Chano Dorga which is served by traditional diversion (D2) is found to perform better than others. The productivity of land and water is higher in Kola Shara followed by Chano Dorga. The later is characterized by greater values of water supply performance indicators, i.e. RIS, RWS and WDR.

Table 4.1: Values performance indicators

Performance Indicators	Kola Shara	Chano Dorga	Chano Chelba
Output per water consumed (birr/m^3)	0.56	0.44	0.35
Output per cropped area (birr/ha)	4400	3464	2736
Water delivery ratio (WDR)	0.56	1.09	0.71
Relative irrigation supply (RIS)	1.40	2.70	1.78
Relative water supply (RWS)	1.18	1.79	1.36

Community in Kola Shara, Chano Dorga and Chano Chalba are served by the upstream, midstream and downstream diversions respectively.

4.3. Output performance

According to figure 4.3 the productivity of banana decreases from upstream to midstream rapidly in Kola Shara and Chano Dorga command areas. From midstream to downstream no decreasing trend both along main canal and secondary canals rather variation among the canals in terms of productivity is visible. The lower areas of tail ends are usually characterized by shallow groundwater tables (o.6 – 2m below the surface) which are likely to contribute to the water requirements of perennial crops.

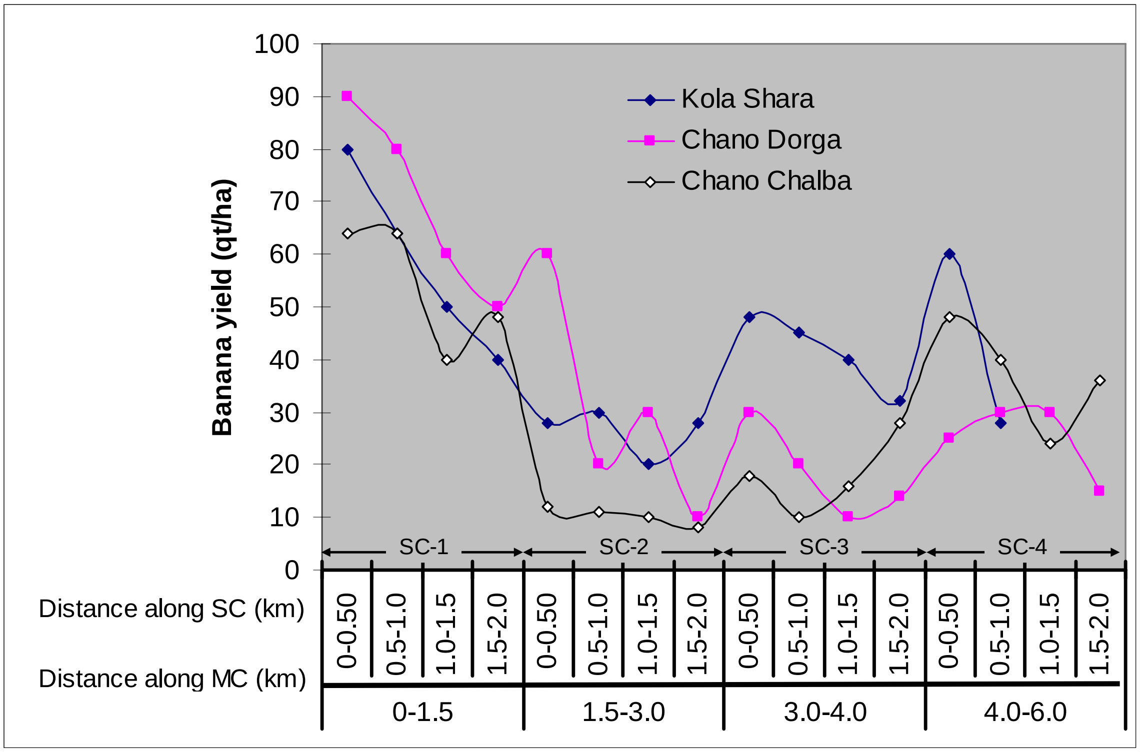


Fig. 4.3: Productivity variation of banana along the canal reaches

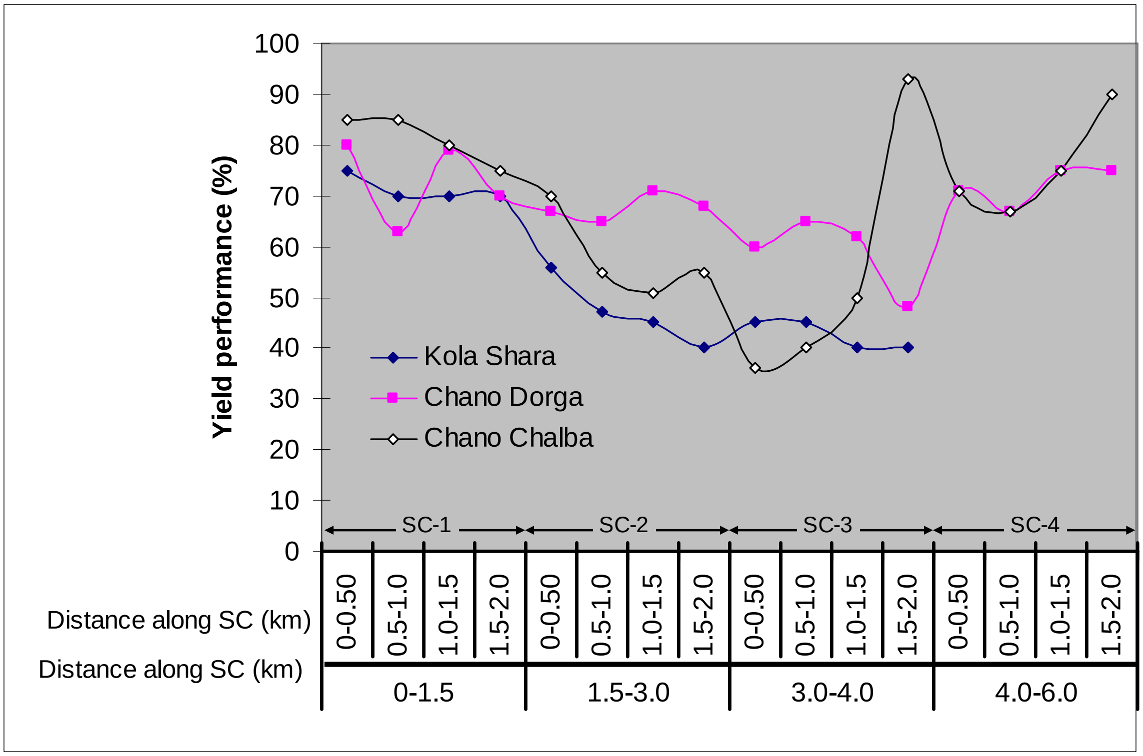


Fig. 4.4: Yield performance (actual yield/potential yield) irrigation along the canal reaches

Yield performance which is the ratio of actually harvested yield to potentially harvestable yield of crop varieties can be an indication for how agronomic practices and other inputs (water and agrochemicals) were effective to exploit the yielding potentials of the crops selected. The indicator shows also a decreasing tendency towards midstream. Almost equal yield performance is observed in Chao Dorga which is located in the command area of traditional diversion. It shows more variation between upstream, midstream and downstream in Chano Chalba that is found in command area of modern weir diversion. Except Chano Chelba the yield performance of the other villages is the reflection of irrigation intervals (Fig. 4.2). Those villages that have got water in shorter intervals have registered better yield performed than villages with longer irrigation intervals.

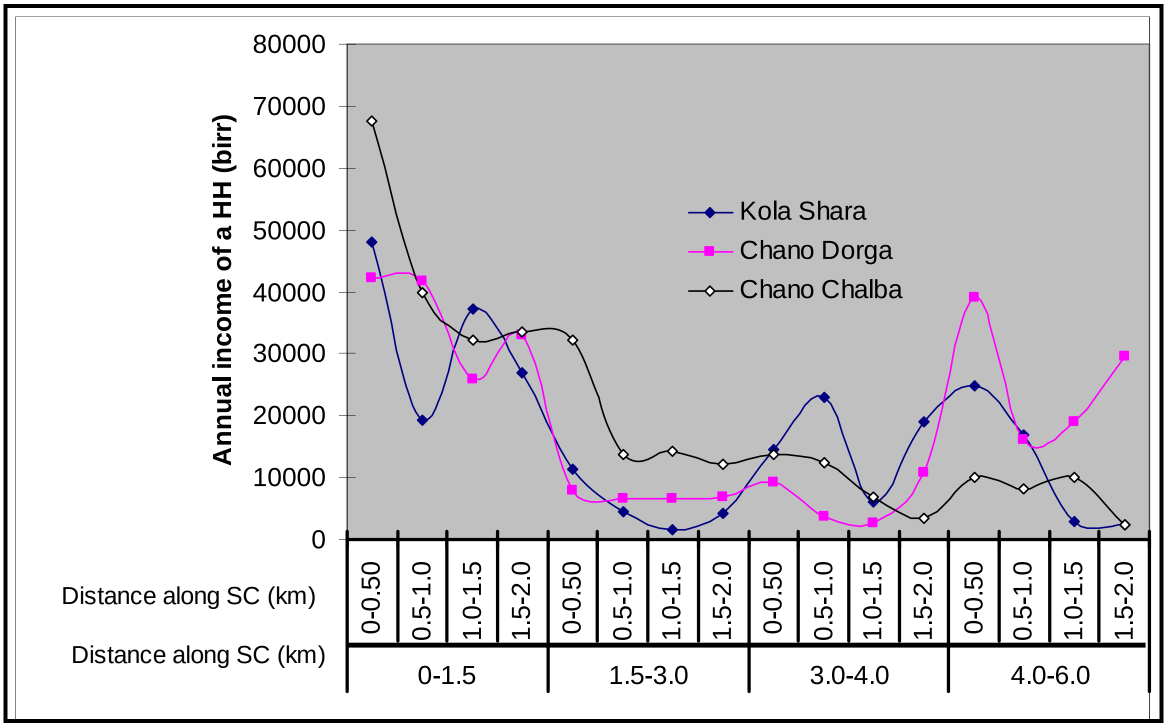


Fig. 4.5: Average annual income of Household along the canal reaches

The ultimate goal of irrigation development is to improve the livelihood of the farming community. Its achievement is largely depends on integration and coordinated operation of nested systems of irrigation which was indicated by Small and Svendsen (1992). As the production increases the income of the farmers is likely to increase. Other factors such marketability of the produce and market access influences the total income of the households. The annual income of households which have year round access to water be it from canal or groundwater is greater than farmers with limited access to water (Fig. 4.5). Annual income of households in Kola Shara and Chano Dorga command areas is variable irrespective of proximity to the canal. Most often, resources are efficiently and effectively utilized when they become scarce. Similarly households that have less access to water tend to use it more efficiently than those having access to abundant water resources.

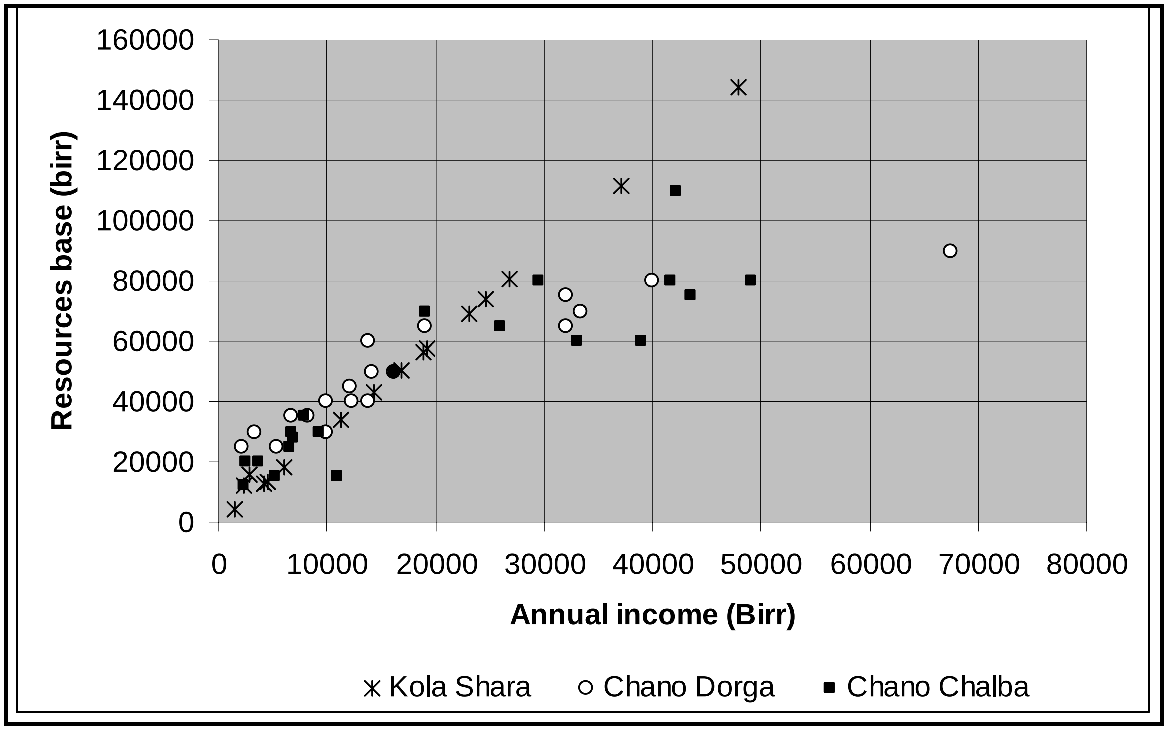


Fig. 4.6: Relationship between annual income from agricultural production and resources base (monetary values of important possessions; example house, chattels etc.)

Improved agricultural production coupled with remunerative selling of the production will result in improved income of the farming community. This together with better social facilities enhances the betterment of farmers' welfare. Fig. 4.6 shows how the resources base of a household improves with the level of income. There are farmers who have managed to construct house in the nearby towns, buy taxis and small transporters etc.

Table: Chemical properties of the soil of different Kebeles

	EC (µmohs/cm)	PH (meq/l)	SAR (meq/l)	ESR (meq/l)	ESP (%)	Texture	K cm/hr
Kola Shara	2060.8	8.35	10.44	5.87	85.44	Clay	0.00279
Chano Dorga	166.4	7.82	6.94	6.94	71.61	Sandy Clay Loam	0.015
Chano Chalba	147.2	7.69	5.3	1.63	61.94	Loam	0.0882
Chano Mile(D)	170.24	7.47	0.5	0.49	32.7	Clay	0.00576

4.5. Environmental Indicators

From suitability aspect based on FAO frame work, the soil of Kola Shara with its SAR, 10.44meq/l value and the soil of traditional irrigation users, SAR value of 8.84 both appear within 8 to 18meq/l hence characterized in moderately suitable range (i.e. class 2 level). However, along with its clayey nature and very small hydraulic conductivity value calculated, that is 0.00279cm/hr, which is quite less than threshold level of 5cm/hr, hence the soil category as per critical limit for sodium tolerance could be n2 (that is permanently not suitable range). Nevertheless, salinity level (EC, 2060.8 µmohs/cm) that is sufficiently less than10, 000 µmohs/cm) preserved the area soil in the moderate suitability range. Still, the soil is categorized under good to injurious, suitable only permeable soils and moderate leaching coupled. The extent with in this range is harmful to more sensitive crops. This has been also confirmed from the actual survey done in the area; they grow mostly cotton which is salt tolerant crop. From acidity and alkalinity point of view also, the soil of Kola Shara is categorized under alkaline category as its pH value, 8.35 is greater than 8, which has a potential to cause depletion of the important micro nutrients such as iron, manganese, and zinc

4.6. Social Problems

Although there are official rules and agreements that regulate water distribution among the users, there exist unofficial diversions, unauthorized use of water, vandalism and stealing of water by the upstream user kebeles particularly by Kola Shara as the controlling mechanisms are the local river materials that can easily be subjected for deviation. Non-permanent control materials instead they use stones and plant rests, as they are easily shifted from their initial position (see figure 4.14) along with the absence of observers assigned to oversee the proper functioning of the delivery system aggravated the disruption of the downstream users from irrigating their field. Such problem of unlawful diversion also exists by Chano Chalba KA, the one using the modern diversion, because of such gateway mentioned above the downstream users Chano Mile KA are highly disrupted to irrigate their field.

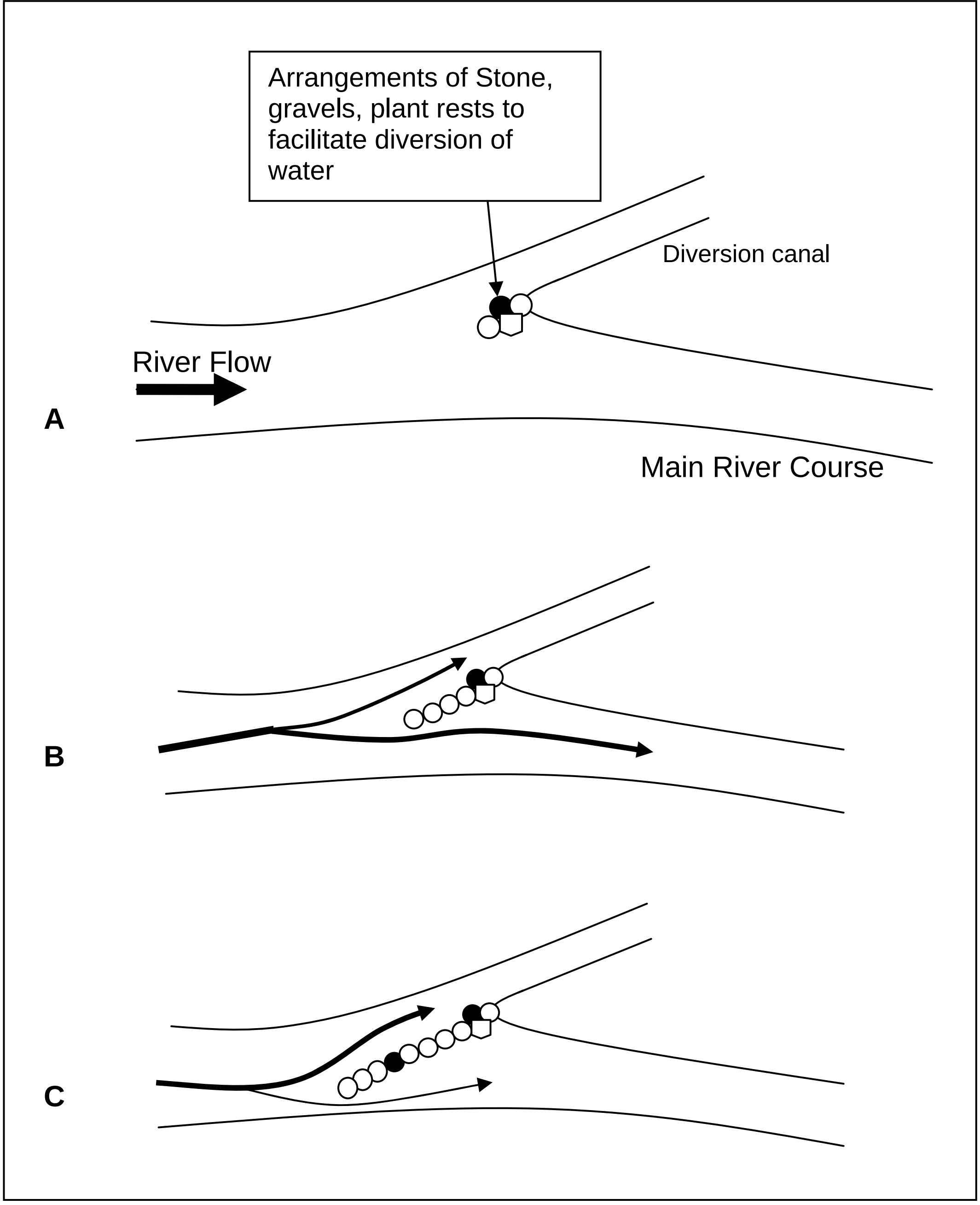


Fig. Simple illustration showing how farmers manipulate the arrangements of traditional water diversions based on the conditions of water availability (with decreasing availability of water in the rivers and increasing demand for water the adopted diversion arrangement by farmers shift from A to B and to C

5. Conclusion

At Hare irrigation scheme, it has been identified that the availability of water, the poor water management and high demand are the main actors. From the water availability versus demand analysis undertaken within ten days interval for the whole year, out of P=38, f (D>Q, 0.00)= 20 times, s (D<Q yield, 1.00)=18, thus, it is possible to articulate, with the current system of use, Hare river cannot supply the required demand, i.e. failure, f=54.05%.

The water availability analysis revealed that, the diverted water is noticeably lesser than the demand during the dry season, in contrast, the available water is very much surplus during the wet period. Owing to this, those located far away from the diversion site and main canal, plant their crops anticipating rainfall. Irrigation is hardly possible in these periods to the farthest area yet the potential irrigable area has not yet achieved by the users. Some of the key findings for less performance are the skew ness in distributions, simultaneous extraction of the available water, and very poor performance of delivery structures particularly the traditional ones.

The results in conveyance efficiency determination at different delivery point has disclosed supplying equal amount of water, the traditional one finish the water after 7750 meter; the modern diversion with traditional delivery finish its water after 8019 meter. But the modern irrigation with its earthen secondary canal goes up to 13, 074 meters; nearly double distance compared to the traditional one. The results depicted that the two schemes total instantaneous loss of the allocated water compared to the modern scheme is 37%.

Another critical social problem is continued inconsiderate use of irrigation water at upstream i.e. ample loss of water which is disrupting downstream users from irrigating their field, as well as visible environmental threat to the up stream irrigators themselves such as water logging coupled with continual malaria out break and other waterborne diseases, sodicity (SAR, 10.44meq/l, clayey soil, hydraulic conductivity calculated, 0.00279cm/hr) of their soil (in permanently not suitable range (n2)) and salinity problem, mainly at Kola Shara KA looking into FAO frame work and the facts in the area.

Thus, in order to maximize the resourceful use of the present water supply at Hare irrigation scheme, a matched and designed better water management of the irrigation scheme is not only capable of reducing the effect of naturally occurring low flow and subsequent yield reduction, but also the increased efficiency augments the production substantially.

Analysis of irrigation systems using comparative performance indicators: A case study of two large scale irrigation systems in the upper Awash basin

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Abstract

This research was conducted to introduce the concept of evaluating the countries large scale irrigation systems and using the IWMI's minimum set of indicators for the same purpose. This was done by selecting two irrigation systems in the Upper Awash Basin. NuraEra state and Wonji estate farm were selected for their relatively better organization and management, nearness to weather station and their representative nature of the large scale irrigation systems in the country.

The necessary primary and secondary data to calculate the nine indicators were collected which are measurement of canal capacity and pump capacity, and total yields, farm gate prices of irrigated crops, area irrigated per crop per season or per year, crop types, production per season or per year, incomes generated from water fee and cropping pattern.

The indicators used are output per cropped area, output per command area, output per irrigation diverted, output per water consumed, relative water supply, relative irrigation supply, water delivery capacity, financial self sufficiency and gross return on investment.

The result of the analysis shows that the ratio of RWS, RIS and WDC for NuraEra are 4.8, 6.6 and 1.4, for Wonji estate 1.36, 1.4 and 0.77 respectively. The four agricultural indicators; output per cropped area, output per command, output per irrigation supply and output per water consumed are in the order of 21017.44, 23791.21, 0.74 and 2.3 for NuraEra and 20074.97, 13916.03, 1.4 and 1.2 for Wonji, respectively. .

NuraEra spent 0.36 percent of its income in the year of analysis and that of Wonji is 0.17 percent for operation and maintenance of the delivery system. FSS was 100% for both of the farms. And gross return on investment was 84.7% for NuraEra and 76.8% for Wonji.

Background

Rapid increases in the world's population have made the efficient use of irrigation water vitally important, particularly in poorer countries, where the greatest potential for increasing food production and rural incomes is often to be found in irrigated areas. It has therefore become a matter of serious concern in recent years that, despite their very high costs, the performance of many irrigation schemes has fallen far short of expectations (FAO, 1986).

The country's irrigation efficiencies are generally low, of the order of 25 to 50%, and problems with rising water tables and soil salinisation are now emerging. As is usually the case, these problems only emerge some 10 to 15 years after project inception. More detailed information on the long-term operational behavior of the existing schemes often results in optimum design at the planning stage of the new schemes, leading to lower capital and lower overall costs, the avoidance of costly remedial works in the long term and achieving maximum returns on water (Woodroofe, 1993).

State run farms, which include large-scale irrigation systems, were reiterated as major components of efforts to develop the country's agricultural sector, notably in the Awash Valley. However, productivity of these top–down managed systems over the decades has been disappointing—the farms have been beset by a number of environmental**,** technical and socio-economic constraints. The large scale systems in the Awash basin and elsewhere suffer from water management practices that have resulted in rising ground water tables and secondary soil salinisation where large tracts of land have gone out of production (EARO 2001; Paulos).

Even if evaluating the existing irrigation systems is an old phenomenon in the other parts of the world; it has not been tried in Ethiopian large-scale farms. Hence, this study attempts to introduce the concept of comparative performance indicators as a tool to evaluate the performance of large-scale irrigations in the Upper Awash valley.

The indicators

Nine indicators are developed related to the irrigation and irrigated agricultural system. The main output considered is crop production, while the major inputs are water, land, and finances.

Indicators of Irrigated Agricultural Output

The four basic comparative performance indicators relate output to unit land and water. These "external" indicators provide the basis for comparison of irrigated agriculture performance. Where water is a constraining resource, output per unit water may be more important, whereas if land is a constraint relative to water, output per unit land may be more important.

Output per unit of irrigation water supplied and output per unit of water consumed are derived from a general water accounting framework (Molden et al, 1998). The water consumed in equation 4 on page 21 is the volume of process consumption, in this case evapotranspiration. It is important to distinguish this from another important water accounting indicator—output per unit total consumption, where total consumption includes water depletion from the hydrologic cycle through process consumption (ET), other evaporative losses (from fallow land, free water surfaces, weeds, trees), flows to sinks (saline groundwater and seas), and through pollution.

We are interested in the measurement of production from irrigated agriculture that can be used to compare across systems. If only one crop is considered, production could be compared in terms of mass. The difficulty arises when comparing different crops, say wheat and tomato, as 1 kg of tomato is not readily comparable to 1 kg of wheat. When only one irrigation system is considered, or irrigation systems in a region where prices are similar, production can be measured as net value of production and gross value of production using local values.

$$Output\ per\ cropped\ area = \frac{Production}{Irrigated\ Cropped\ area} \quad (1)$$

$$Output\ per\ unit\ command\ area = \frac{Production}{Command\ area} \quad (2)$$

$$Output\ per\ irrigation\ \text{supply} = \frac{Production}{Diverted\ irrigtion\ \text{supply}} \quad (3)$$

$$Output\ per\ unit\ water\ consumed = \frac{Production}{Volume\ of\ water\ consumed\ by\ ET} \quad (4)$$

Where,

Production is the output of the irrigated area in terms of gross or net value of production measured at local or world prices,

Irrigated cropped area is the sum of the areas under crops during the time period of analysis,

Command area is the nominal or design area to be irrigated,

Diverted irrigation supply is the volume of surface irrigation water diverted to the command area, plus net removals from groundwater, and

Volume of water consumed by ET is the actual evapotranspiration of crops.

Five additional indicators were identified in this minimum set for comparative purposes. These are meant to characterize the individual system with respect to water supply and finances.

Relative water supply and relative irrigation supply are used as the basic water supply indicators:

$$\text{Re}\,lative\ \ water\ \ \text{supply} = \frac{Total\ \ water\ \ \text{supply}}{Crop\ \ demand}$$

(5)

(6)

Where:

Total water supply

= Surface diversions plus net ground water draft plus rainfall.

Crop demand

= Potential crop ET, or the ET under well-watered conditions.

Irrigation supply

= only the surface diversions and net groundwater draft for irrigation.

Irrigation demand

= the crop ET less effective rainfall.

Relative irrigation supply is the inverse of the irrigation efficiency Molden et al (1998). The term *relative irrigation supply* was presented to be consistent with the term relative water supply, and to avoid any confusing value judgments inherent in the word *efficiency*.

Both RWS and RIS relate supply to demand, and give some indication as the condition of water abundance or scarcity, and how tightly supply and demand are matched. Care must be taken in the interpretation of results: an irrigated area upstream in a river basin may divert much water to give adequate supply and ease management, with the excess water providing a source for downstream users. In such circumstances, a higher RWS in the upstream project may indicate appropriate use of available water, and a lower RWS would actually be less desirable. Likewise, a value of 0.8 may not represent a problem; rather it may provide an indication that farmers are practicing deficit irrigation with a short water supply to maximize returns on water.

$$Water\ delivery\ capacity(\%) = \frac{Canal\ capacity\ to\ deliver\ water\ at\ system\ head}{Peak\ consumptive\ demand}$$

(7)

Where:

Capacity to deliver water at the system head

= the present discharge capacity of the canal at the system head, and

Peak consumptive demand
= the peak crop irrigation requirements for a monthly period expressed as a flow rate at the head of the irrigation system.

Water delivery capacity is meant to give an indication of the degree to which irrigation infrastructure is constraining cropping intensities by comparing the canal conveyance capacity to peak consumptive demands. Again, a lower or higher value may not be better, but needs to be interpreted in the context of the irrigation system, and in conjunction with the other indicators.

Financial Indicators

The two financial indicators are:

$$Gross\ return\ on\ Investment\ (\%) = \frac{production}{Cost\ of\ irrigation\ structure} \quad (8)$$

$$Financial\ self\ sufficiency = \frac{\mathrm{Re}venue\ from\ irrigation\ service\ fee}{Total\ O\ \&\ M\ \exp enditure} \quad (9)$$

Where,

Cost of irrigation infrastructure considers the cost of the irrigation water delivery system referenced to the same year as the SGVP,

Revenue from irrigation, is the revenue generated, either from fees, or other locally generated income, and

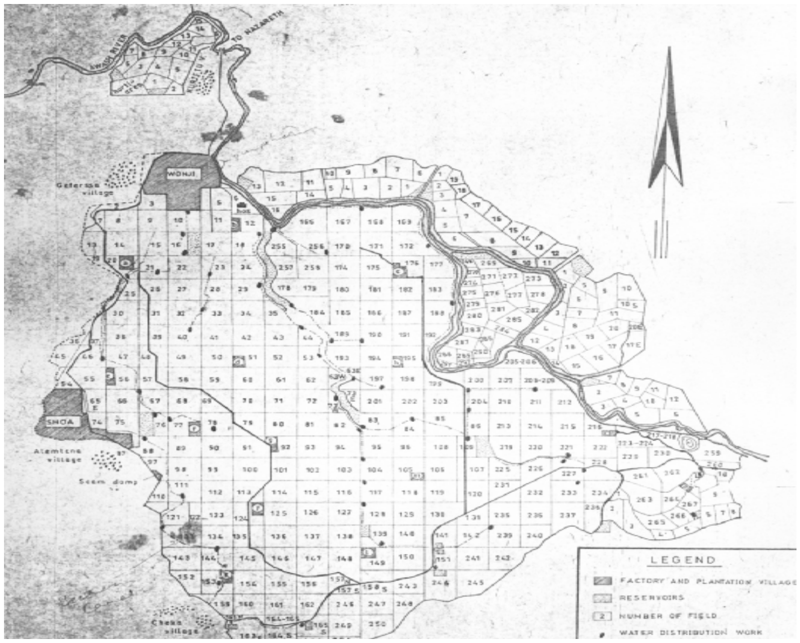
Total O & M expenditure is the amount expended locally through operation and management

Description of the Study Area

The mean annual rainfall of Awash Basin varies from about 1600mm at Ankober; in the highlands north east of Addis Ababa top 160mm at Asayta on the northern limit of basin. Addis Ababa receives 90% of its annual rainfall during the rainy period March to September. At Dubti the same over all proportion is received during the two rainy periods, distributed 30% and 60% respectively. The mean annual rainfall over the entire western catchment is 850mm and over the head waters of Awash, as gauged at Melka Hombole it is 1216mm.The annual and monthly rainfall are characterized by high variability (Halcrow, 1989).

Wenji Estate farm

The estate was constructed by HVA in the early 1960s .It comprises 5925ha of sugar and is operated by the ESC (Halcrow, 1989). The estate is located in the central east part of the main Ethiopia rift system, 107 km southeast of Addis Ababa. It is found between $8^0$30’ to $8^0$35’N and $39^0$20’E grid and at an altitude of 1540 m a.s.l Average Maximum and Minimum temperature are 27.6^{0}C and 15.30C, respectively. The surrounding topography is steep on all sides north and east being bound by river awash the west and the south by the border drain which protects the estate from the run off and sedimentation from those steep slopes (Mukherji, 2000). Irrigation supplies are provided by continuous electrical pumping from the Awash into a settling basin at the head of the main canal. Night storage reservoirs cover a surface area of 60ha (Halcrow, 1989).



Nuraera state farm

The farm is found in the eastern showa administration zone. It is divided in three sub farms. From the total land owned by the farm which is 3,277ha, 3,069 ha is covered by crops the remaining 208 ha by infrastructures. The farm has been developed on an adhoc basis over several years and water abstraction is by gravity.

Canals and irrigation layouts have not been formally designed so that their capacities are not listed.

Water use efficiencies would appear to be in the range of 20%-30% (Halcrow, 1989). Irrigation of citrus is generally by small basin around tree bases.

Main gate on the main canal at Nuraera

Diversion Weir at Nuraera

Abstraction is measured by staff gauges in the main canal from gravity offtakes irrigation is generally undertaken 24 hours a day. Wastage of water is inevitable but it appears that little, if any flow is returned to Awash. The northern end of the canal used to outfall into Lake Beseka. This has been stopped by a cut-off-drain which is partly constructed with the objective of leading the flows back to Awash.

Methodology

After reconnaissance survey and consulting the officials of the Upper Awash agro-industry enterprise, one farm was selected among the three farms of the enterprise. NuraEra farm was selected for its nearness to the weather station, relatively better organization and management and availability of secondary data. Moreover the other two farms are medium scale farms.

The other farm selected for its attributes of nearness to Addis Ababa and wheather station and the availability of data were Wonji sugare estate.

Secondary data collections were started in February 2005 in collaboration with the farm officials.

Primary data collection

The job of primary data collection which is measurement of canal capacity and pump capacity was started in April 2005 in collaboration with the department of hydrology in the Ministry of Water Resources.

The upper Awash Water Administration center installed a BOC on the main canal at around 200m from the diversion weir for the purpose of updating its rating curve for the reason that the flow characteristics changes due to high rate of sedimentation resulting in change of canal morphology.

The plotted rating curve was used to find out the total water diverted using the daily records of the gauge height taken by main gate operator who is an employee of the center.

But due to the shortage of material and manpower, the center has been using
the old rating curve for the purpose of knowing the total amount of water diverted. Due to the high siltation rate and the changing nature of the hydraulic condition in the main canal , it will be hard to get a reliable data using a rating curve plotted two years ago. For this reason it was decided to measure the discharge at various gage heights and take the average discharge to calculate the amount diverted for each season.

Maintaining the abandoned BOC took much of our time before engaging in the measurement.

Preparation for work at Nuraera

In the case of Wonji showa estate farm, the pumps in the main pump station are more than 40 years old. Their Design capacity went on reducing through these years. Therefore the current capacity of each pump should be measured. That can be done either by measuring the water depth over the cippoleti weir and use the formula to calculate the discharge or by measuring the flow on site.

The measurement was taken at 0.2*the depth of water over the weir crest measured from the surface of the water and the width of the crest was divided by 0.2m interval(see appendix B).

Measuring discharge from cippoleti weir at Wonji

Secondary data collection

The Secondary data included total yields, farm gate prices of irrigated crops, area irrigated per crop per season or per year, crop types, production per season or per year, incomes generated from water fee and cropping pattern.

Climatic data of Wonji farm were collected from the nearby station at wonji while that of NuraEra were collected from the head office of Ethiopian National Meteorological Agency in Addis Ababa.

Since both farms have a planning and program department run by skilled manpower, they kept good number of years record of the production and prices
of crops. For instance, wonji have a 50 year data of production.

The only problem in the case of the needed secondary data was the record of money spent for operation and maintenance of the irrigation systems

Results and Discussion

Nuraera

After measuring the discharge at various working gauge heights, the average discharge was estimated to be 3.1 m^3/s. And this discharge was used to estimate the amount of water diverted in the year 2003/04.

Based on the collected data of planting and harvest of each crop for the year of analysis, the agricultural practice of the farm is divided into two seasons. The first season of cropping goes from January to July, the amount diverted in these months was.

Season A 3.1*212*24*60*60 = 56,782,080 m^3

Season B 3.1*153*24*60*60 = 40,979,520 m^3

Total amount of water diverted for the year 2003/04 = 97,761,600m^3

Total output of NuraEra farm for the year 2003/04

Crop	Area (ha)	Production in Qt.	Unit price in birr/Qt.	Total Output in Birr
Orange	772	254,580.6	112	28,497,753.48
Manderine	181	35,844	87.50	3,133,836.55
Guava	55	1,307.2	32.20	42,038.27
grape Vine	11.18	538.3	400	215,304.00
Mango	40.35	9,395	117.75	1,106,250.65
Tomato	224.53	35,115	40.60	1,424,968.73
Onion	54.12	4,790	136.50	653,925.34
Green chilies	5.30	182.	134.60	24,494.91
Cabbage	0.55	23.6	40.60	959.31
Carrot	0.30	22.2	40	889.64
Beet root	0.45	36	40.00	1,444.40
Beans(local)	2.00	1,463.8	61	89,323.52

Bobbybeans(export)	149.50	6,221.8	1,383	8,604,265.49
Okra	0.60	3	172	532.92
Maize	350.00	17,002.6	120.20	2,043,368.86
Pop corn	58.60	385.7	483.30	186,411.74
Cotton	735.00	18,061.8	1,494.30	26,989,446.28
Total	2,640.5	384,973		73,015,214

As it is clearly seen the farm used wider cropping pattern. And based on the planting and harvesting dates of each crop, the whole year is divided into two seasons and their CWR and irrigation requirement was calculated using CROPWAT 4.2. The result is as shown below:

CWR and IR of each crop

	SEASON A			SEASON B		
Crop	Area(ha)	Crop water requirement (mm/season)	Net irrigation requirement (mm/season)	Area(ha)	Crop water requirement (mm/season)	Net irrigation requirement (mm/season)
Tomato	220.5	760.68	613.44	224.53	712.92	446.05
Onion	47	490.79	389.56	54.12	489.76	243.78
Vegetables	8.15	515.89	413.39	7	493.45	242.48
Beans	150	427	330.55	151	424.51	178.94
Maize	408.6	684.37	495.58	408.6	537.53	416.32
Cotton	735	999.13	634.58			
Citrus*	1008	1334.31	873.46			
Mango*	40.35	1973.22	1512.36			
Grape wine*	11.18	1057.43	596.58			
Total	2628.78			845.25		

* Perennial crops

To calculate the first four indicators grose production was taken instead of SGVP because of the fact that there is no price difference in the two irrigation systems and no common crop is grown in both the farms. Sugarcane is not grown in NuraEra farm but it is the only crop in Wonji sugar estate.

1. $Output\ per\ cropped area$

$$= \frac{production}{Irrigated cropped area}$$

= 73,015,214.08 / (2628.78+ 845.25)
= 73,015,214.08 / 3474.03
= 21,017.44 birr/ha

2. $Output\ per\ unit\ command\ area$

$$= \frac{production}{Command\ \ cropped\ \ area}$$

Out put per unit command area
= 73,015,214.08 / 3,069
= 23,791.21 birr/ha

3. $Output\ \ per\ \ irrigation\ \ \sup\ ply$

$$= \frac{production}{Diverted\ \ irrigation\ \ \sup\ ply}$$

= 73,015,214.08 /97,761,600
= 0.75 birr/m^3

Then, the net crop water requirement and the net irrigation requirement (IR) are computed for each irrigated crop and for each growing season (option 2 in CROPWAT main menu). The crop coefficients provided with CROPWAT program are used (input: planting dates and growth length in days). The outcomes were:

The total net crop demand for season A is (refer table 4.2):

CWR_{tomato}* (area $_{tomato}$ / area $_{total}$) + CWR_{onion}* (area $_{onion}$/ area $_{total}$) + etc. =

760.68* (220.5/2628.78) + 490.79* (47/2628.78) + 515.89* (8.15/2628.78) + etc.

= 1,030.70 mm/season

In the same way, the total net irrigation requirements are computed. The efficiency used is 40%. This percent was set basing the estimation of Halcrow(1989) and allowing for the improvements of the years between the year of study and the year of analysis.

SEASON	NCWR*	NIR**
A(Jan-July)	1,030.70	693.7
B(Aug.-Jan)	560.5	369.3
Total	1591.2	1063

*Net crop water requirement
**Net irrigation requirement

$$Output\ \ per\ unit\ \ water\ \ consumed$$
$$= \frac{\Pr oduction}{Volume\ \ of\ \ water\ \ consumed\ \ by\ \ ET}$$

Where *Volume of water consumed by ET* is the actual evapotranspiration of crops.

$= 73,015,214.08 / (1,030.70*2628.78+ 560.5*845.25)*10^{-3}*10^{4}$

= 2.3 birr/m3

5. *Relative water supply*
= (Irrigation derived + total precipitation) / CWR

Diverted irrigation in mm
Season A = 56,782,080 / 2628.78*10 = 2160 mm
Season B = 41,247,360 /845.25*10 = 4879.9
Total = 7039.9
RWS = (7039.9+566.9)/1591.2
= 4.8

6. *Relative* irrigation *supply*
= Irrigation applied / irrigation requirements
= 7039.92/1063
= 6.6

The scheme irrigation requirement was calculated with CROPWAT (option 4 in main menu) using the climate data, cropping pattern, planting dates, and area.
For 2003/04, the scheme irrigation requirements were:

Scheme irrigation requirement of NuraEra farm

	Jan.	Feb.	March	April	May	June	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
IR in l/s/ha	0.37	0.39	0.69	1.13	1.2	0.77	0.75	0.73	1.47	1.4	1.17	0.59

Peak irrigation requirements occur in September, 1.47 l/s/ha.
Peak demand is 1.47 * cropped area for that month =1.47 *2639.78= 3880.48 l/s.
As explained above the canal capacity was measured using bank operated cable. The result was 5.4 m^3/s

7. *Water delivery capacity*: 5,400 lit. / 3,880.48 lit. = 1.4 or 140%

8. *Gross return on investment =Production / cost of irrigation infrastructure*

The cost of the distribution system can either be estimated from original costs, or estimated by using present costs of similar types of infrastructure development. Since it was not possible to get the design documents of the two projects, the document of other projects with more or less similar structural condition were taken. After studying the documents of the similar irrigation projects in Awash Basin, the Angelele and Bolhamo design document were used for their better similarity and nearness to NuraEra and Wonji to estimate the cost of distribution system per hectare.

All the delivery system of the NuraEra farm is earth canals .Therefore the cost of earth canals per hectare in these documents is found to be 1497.9 4 birr
The formula to calculate the present worth is.

$$\Pr esent\ Net\ Worth(PNW) = (Initial\ \cos t / ha) \times (1 + r)^n$$

Where: *r* is interest rate, which is taken from the design document of Angelele Irrigation Project and *n* is years from construction time.

PNW = 1497.94(1+0.1) ^{30}
= 26138.2birr/ha

The cost of delivery system of NuraEra
= 26138.2 birr/ha *3069 ha
= 80,218,006 birr

Therefore Gross return on investment
= 73,015,214.08 birr/ 80,218,006birr
= 91%

9. Financial self-sufficiency
= Revenue from irrigation/Total O&M expenditure

Where, *Revenue from irrigation,* is the revenue generated, either from fees, or other locally generated income, and Total *O&M expenditures* are the amount expended locally through O&M plus outside subsidies from the government.

Even if the Upper Awash Water Administration Center collects water fee at the rate of 3 birr per 1000 m^3 of water, no money was spent for maintenance and operation in the year of analysis. Rather the farms perform some clearing and maintenance work whenever they feel necessary. Thus the income generated from the farms doesn't go to the purpose of operation and maintenance.

However the intent of IWMI indicator number 9 is to see how much of the cost of operation and maintenance work is generated locally. In this context we can say that both farms are 100 % self sufficient. It was learnt from the farm record that the amount of money spent for operation and maintenance of the delivery systems for the year 2003/'04 was 260,317.23 birr.
= 260,317.23/260,317.23
= 100%

In this respect, the management of these two farms is a little bit different to that of normally practiced. In order to have additional information for evaluating that part which is related to maintenance and operation, one more indicator is developed and added in this paper. This indicator atleast will give us additional insight on the relative focus given to the delivery systems.

$$Percent \quad allocated \quad to \quad O \,\&\, M = \frac{Total \quad O \,\&\, M \ \exp enditure}{\Pr oduction}$$

= 260,317.23/ 73,015,214.08
= 0.36 %

Wonji Sugar estate

The only crop grown in this farm is sugarcane. The kind of irrigation practiced at Wonji may be termed ''blocked end furrow irrigation system''. Water applied each furrow is cut off as it reaches the end of the furrow ,which is blocked ,and ponds up within the furrow .The furrow length for the part of the field (anjir) depends on the gradient available and three lengths 32m,48m,and 64m are being used currently. The advantages of this system are that there is no run off and the entire water applied to the field incorporated into the soil. As such, in addition to the infiltration characteristics of the soil, the size of the inflow stream and the gradient of the furrow become important variables to control the rate of advance of water front to the end of the furrow, which determines the cutoff time for the inflow. (Mukherij, 2000)

Production and area of Wonji estate for the year 2003/04

Command area(ha)	Irrigated area(ha)	Production(qtl.)	Farm gate price(birr/qtl.)	Income (birr)
5,929	4,110	7,446,581	11.08	82,508,117.5

The main pump station at Wonji has a total of eight pumps with a design discharge of (6*750+2*500)5500 lps .According to Mukherji the two vertical shaft pumps are working with overall efficiency of 68% and the other six horizontal shaft pumps with an efficiency of 50% of their designed capacity.

Crop water requirement mm/year	Irrigation requirement mm/year
1,667.1	1,054.33

The result of our measurement almost agrees with that of Mukherji, The current capacity of the two vertical shaft pumps is 240.3 lps and the horizontal shaft pumps are with a capacity of 488 lps. Therefore the maximum discharge that can be pumped for irrigation purpose is 3,165.34 lps allowing 10% for factory use.

1. Out put per cropped area
   = Out put / irrigated cropped area
   = 82,508,117.48 / 4,110
   = 20,074.97 birr/ha

2. Out put per command area
   = Out put / command area
   = 82,508,117.48/5929
   = 13,916.03 birr/ha

3. Out put per irrigation supply
   = Out put / irrigation diverted
   = 82,508,117.48/75320000
   = 1.1 birr/m^3

4. Out put per unit water consumed
   =out put/Volume water consumed by ET

Volume of water consumed by ET
= 1667.1*4110*10 m^3
= 68,517,810 m^3

Out put per unit of water consumed
= 82,508,117.48/68,517,810
= 1.2 birr/m^3

5. Relative water supply
= (Irrigation derived + total precipitation) / CWR
= (1,466.08 + 817.3)/1667.1

= 1.36

= 1,466.08/1,054.33
= 1.4

6. *Relative irrigation supply*
= Irrigation applied/ irrigation requirements

For 2003/04, the scheme irrigation requirements were:

IR in	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
l/s/ha	0.4	0.58	0.94	0.93	0.87	0.65	0.31	0.23	0.73	1	0.94	0.85

Peak irrigation requirements occur in October, 1 l/s/ha.
Peak demand is 1 * cropped area for that month = 1 * 4110 = 4110 l/s.

7. Water delivery capacity: 3,165.34/4110
= 0.77 or 77%

8. The same procedure was applied to Wonji to calculate gross return on investment except that irrigation structure costs are included since all the necessary structures are found in Wonji estate farm. The present initial cost per hectare of the delivery system is found to be 26137.5 birr.

Gross return on investment
= 82,508,117.5 birr / 235,727,927.5 birr
= 35%

9. Percent allocated to O&M
= 139,330.46/ 82,508,117.48
= 0.17%

Comparative analysis of the two irrigation systems

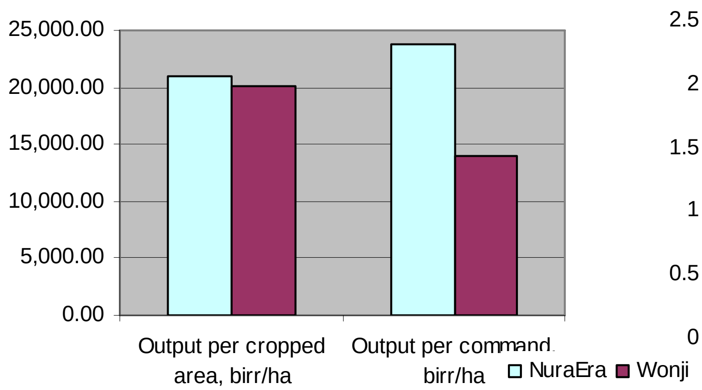
The four basic comparative performance indicators relate output to unit land and water. These "external" indicators provide the basis for comparison of irrigated agriculture performance (Molden, 1998).

The values of the four indicators for the respective farms are as tabulated below.

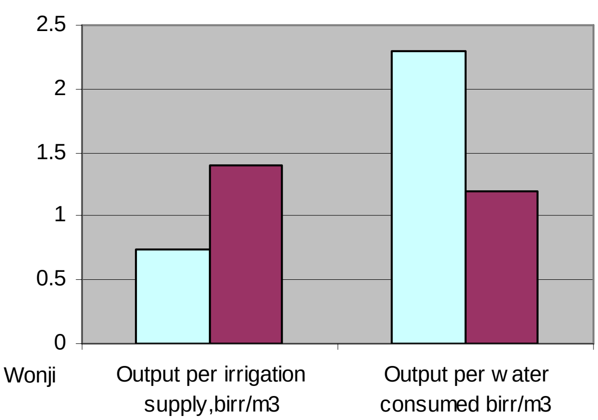
summary of the four indicators

Site	Output per cropped area, birr /ha	Output per command, birr/ha	Output per irrigation supply,birr/m^3	Output per water consumed birr/m^3
NuraEra	21,017.44	23,791.21	0.75	2.3
Wonji	20,074.97	13,916.03	1.4	1.2

output per cropped and command area



Output per irrigation supply and water consummed

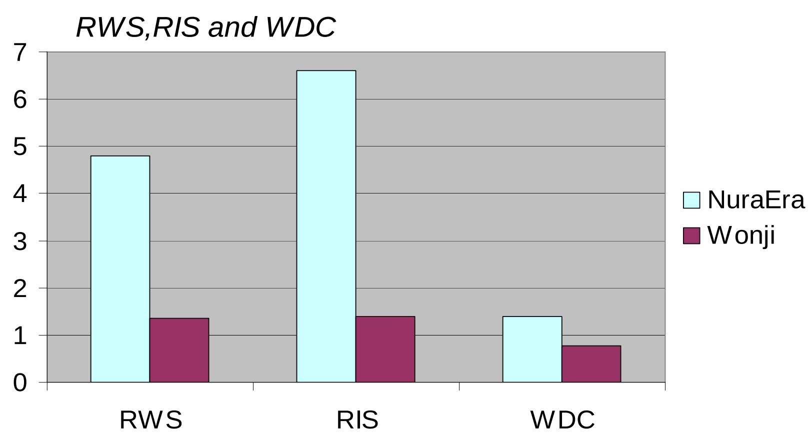


As clearly seen in the first table and chart, NuraEra is higher in output per cropped area and output per command. This is attributed to the high value and export crops grown in the farm and also the higher cropping intensity.

In the case of output per irrigation supply Wonji has the higher value (1.4) implying that Wonji is better in effective utilization of water. But as the indicators are comparative we can't say that Wonji achieved the required performance. NuraEra show a generous supply of water. Using the rainfall in a better way than that of the NuraEra contributes for this higher value of output per irrigation in Wonji. In other words NuraEra is better in land productivity and Wonji show better performance in water productivity.

Result of RWS and RIS

Site	Relative water supply	Relative irrigation supply	Water delivery capacity
NuraEra	4.8	6.6	1.4
Wonji	1.36	1.4	0.77



Higher values of RWS and RIS indicate a more generous supply of water (Molden, 1998). In our case, NuraEra show this fact which means productivity to land is more important. In the Wonji farm we have more constrained supply of water so that productivity per unit of water is more important. These two values can be minimized by adjusting the release of water from storage or diversion with the available rainfall.

The lower values of RWS and RIS of Wonji estate farm is not mainly the result of good management rather the decreasing capacity of the pumps limiting the supply. As the result of the measurement conducted showed, 35 and 52 percent decrease in the capacity of the horizontal and vertical pumps has been witnessed respectively. With this capacity, the pumps are not enough to satisfy peak irrigation demand. This will get worse unless a major rehabilitation work of the pump house is done.

On the other hand high value of RWS and RIS is of for NuraEra. This result was expected by the researcher at the end of reconnaissance survey of the area because of two main reasons: one the 34 km main canal is not well maintained and the absence of the necessary irrigation structures in the line of the canal expose the system for very low efficiency, second the farmers around the state farm steal water from the main canal. Consequently much water is lost through its way to the field.

Unauthorized diversion from the main canal at NuraEra

A high value of financial self-sufficiency does not automatically indicate a sustainable system as the O&M expenditures might be too low to meet the actual maintenance needs (Molden, 1998).Thus the high value of FSS of the two farms doesn't show that the expenditure satisfies the operation and maintenance needs. Rather as Molden et al. (1989) explained financial self-sufficiency tells us what percent of expenditures on O&M is generated locally. If government subsidizes O&M heavily, financial self-sufficient would be low, whereas if local farmers through their fees pay for most of the O&M expenditures, financial self-sufficiency would be high.

NuraEra and Wonji are 100% self sufficient meaning all the expenditures for operation and maintenance generated locally from the income of these two farms. Interms of percent allocated to operation and maintenance NurEra is better. This is because of high silt deposit rate in the delivery systems. With out frequent clearing of the system normal operation of the farm can't be carried out.

GRI of the NuraEra and Wonji are 84.7% and 76.8% respectively. NuraEra show a higher rate of return. This is mainly because of the lower investment cost and higher productivity of the farm. But it is hard to say that this system is better than that of Wonji because it is taking much money for its maintenance. Consequently its sustainability is in big question of such systems

Conclusion

The higher values in RWS and RIS combined with the lower ratio of output per water consumed in NuraEra shows that the availability of water is not a problem. In addition it can be inferred that the issue of water management is in jeopardy. The main reasons for this problem are the meager attention given by the farm for irrigation water management, the low water rate and the effect of unregistered users.

As to Wonji farm the low value of WDC can be early warning indicator. This is meant to say that the pump capacity is deteriorating and is not in position to satisfy peak irrigation demand. This problem may manifest itself by reducing production in near future. This has big implication on the production of sugar. WDC of NuraEra farm seems in a better position but the increasing sedimentation and the absence of silt excluders put its sustainability in question.

Both farms spent less than one percent of their income for operation and maintenance of delivery systems. This by itself shows the very low attention given to the irrigation systems. But in relative terms NuraEra was better.

The rate of gross return on investment is high for both of the farms.

Furthermore, as explained in the literature review part, there are varies types of institutional designs of the irrigation systems adopted in different part of the world. This part has not been given the proper attention in our country. As a result, the irrigation delivery systems are left unattended for many years. The case of the two irrigation systems is not an exception. The management of the farms, having their main objective on productivity, didn't give the proper attention for their irrigation delivery systems. This can be seen by the fact that the two farms have no separate irrigation department despite being very profitable ones. Moreover no permanent budget is allocated for irrigation system maintenance.

This research managed to show some of the problems that our large scale irrigation systems are in. The lack of awareness in the farm officials on one side and policy problem in the other left the irrigation systems with lots of problems. Water logging, deterioration of canal capacity and salinity are coming faster.

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Discussion on Theme 1: Status Quo Analysis, Characterization, and Assessment of Performance of Irrigation in Ethiopia

Chair person: Dr. Deboorah Bossio
Rapporture: Makonnen Loulseged

The chairman for this session introduced the theme and the floor was opened for questions, comments and suggestions.

Questions and Discussions

Marginal environments are means of living for people who are habitats of the area. Unless there are other means of income we can not avoid (stop them) growing crops on marginal lands. The environment has not been benefited from technologies promoted under optimum conditions. Then, how can we say agriculture in marginal environment causes poverty?

> **Ans**: Marginal lands with steep slopes are being farmed, on the other hand there is plenty of irrigation potential in low land areas where communities can make use of it.

The data base is organized for modern irrigation schemes. Do we have a plan to set up a data base for traditional irrigation schemes in Ethiopia? Please give attention in collecting GIS data for the traditional irrigation systems.

> **Ans**:IWMI is willing and interested to collaborate with other institutions in setting up the database for traditional irrigation.

When we talk about challenges in irrigation schemes, the impact of land degradation is not captured in the study? Why irrigation projects only focuses on the dam and command area but not the upper catchment; so also the research results?

> **Ans**: There are many intrinsic problems associated with irrigation and drainage. In SNNP alone there are about seventeen schemes that have failed. In line with the policy statement, future irrigation development should be undertaken in an integrated manner in order to ensure its sustainability.

Why the presenter did not see with respect to integrated watershed management.

> **Ans**: Irrigation schemes are operating within the environment of complex watershed activities. Sedimentation is the cause of failure in many schemes as a result of poor watershed management. Therefore, due attention should be given to sound watershed management practices.

Do you have bench marks from other countries for your comparison of performances of irrigation schemes in Ethiopia?

> **Ans**: As the conditions of irrigation schemes are different it will be un fare to compare their performance with other countries; for example a scheme in Ethiopia bench marked with a scheme located somewhere in US. Instead we can bench mark better performing schemes with in the country. For example Methara under the same environment with other scheme located somewhere in Ethiopia

The scope of irrigation development is beyond putting physical assets on the ground. This is about 25% of the tasks. The remaining 75% covers a complex and wide range of tasks that we need to put in place and achieves production and income objectives. The experience in the last 2-3 decades shows irrigation schemes are not fully or properly utilized due to inadequate attention being given to skill in O&M, skill in irrigation water and irrigation extension, markets, credit services, input supply, institutional arrangement in managing schemes, catchment treatment, etc. These issues were discussed in the past. However, policy makers and practitioners are not responsive to these complex issues. Now thanks to researchers (IWMI) and others that we have good evidence to feed into an informed decision to focus on the issues beyond construction. Future success in irrigation development will depends on willingness to draw lessons from our experiences and proactively engage in rectifying the issues mentioned above.

Ans: Acceptable suggestion

Attempt has been made to compare Melka Sedi irrigation scheme with Sile and perhaps with others. Because of differences in Climatic factors (rainfall, etc), soil salinity, age of the scheme. How about issues of management?

Ans: The performance of each scheme is identified in terms of its technical performance. However, the evaluation and establishment of indicators on the internal management process at scheme level has been found difficult. As a result comparison between schemes has not been easy.

Rainfed agriculture has low production and productivity due to erratic nature of rainfall in Ethiopia. But some downstream water users argue that poor farming practice and management is the main cause for low water productivity of rainfed agriculture in Ethiopia. The contribution of rainfall variability and poor farming practices to the low productivity of rainfed agriculture should be studied comparatively such study would have paramount contribution towards water allocation among competing water users.

Ans: Climate variability has a seasonal impact on the agricultural production depending on the timing and amount of rainfall in each season. Poor farming practice has also a negative impact on agricultural production. However their relative impact has not been studied in this project as it is beyond the scope of this study.

Why factors that are responsible for the performance at scheme level were not identified? What was the purpose of comparing number of irrigation schemes unless these factors are identified?

Ans: Factors that have contributed to low performances of community managed irrigation scheme (Hare) and state farm (Sille) are mainly management and deterioration of physical infrastructures. It is however, hardly possible to identify the details of indicators of external performance indicators such as output and water supply at scheme level. Instead we need to consider on farm process indicators (accepted international indicators).

Theme two:

Irrigation Impact on Poverty and Economy

Papers

1. Rural poverty in Ethiopia: Does small scale irrigation make a difference
2. An assessment of the financial viability and income impact of SSI in Ethiopia
3. Importance of irrigated agriculture to the Ethiopian Economy: Capturing the direct net benefits of irrigation
4. Investment in irrigation as a poverty reduction strategy: The case of SSI and its impact on poverty in Tigray, Ethiopia

Rural poverty and inequality in Ethiopia: does access to small-scale irrigation make a difference?

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Abstract

Ethiopia is an agrarian society in a land of drought and floods. Agricultural production, which is the source of livelihood for eight out of ten Ethiopians, is extremely vulnerable to climatic conditions. The causes of rural poverty are many including wide fluctuations in agricultural production as a result of drought, ineffective and inefficient agricultural marketing system, under developed transport and communication networks, underdeveloped production technologies, limited access of rural households to support services, environmental degradation and lack of participation by rural poor people in decisions that affect their livelihoods. However, the persistent fluctuation in the amount and distribution of rainfall is considered as a major factor in rural poverty. Cognizant of this reality the successive Ethiopian governments and farmers have made investments in small scale irrigation schemes. This paper aims to assess the efficacy of these investments in reducing poverty based on data obtained from a survey of 1024 farmers drawn from four major regional states of Ethiopia. The Foster, Greer and Thorbecke poverty measures were used to compare the incidence, depth and severity of poverty among groups of farmers defined by relevant policy variables including access to irrigation. In order to explore the correlates of rural poverty and their quantitative significance, logistic regression model was estimated. The main conclusion of the study is that the incidence, depth and severity of poverty is affected more by the intensity of irrigation use (as measured by the size of irrigated area) than mere access to irrigation. Alternatively, there seems to be an economy of scale in the poverty-irrigation relationship.

Key words: Rural poverty, FGT indices, Small scale irrigation

1. Introduction

Farmers in rural Ethiopia live in a shock-prone environment. Agricultural production, which is the source of livelihood for eight out of ten Ethiopians, is extremely vulnerable to climatic conditions. The causes of rural poverty are many including wide fluctuations in agricultural production as a result of drought, ineffective and inefficient agricultural marketing system, under developed transport and communication networks, underdeveloped production technologies, limited access of rural households to support services, environmental degradation and lack of participation by rural poor people in decisions that affect their livelihoods. However, the persistent fluctuation in the amount and distribution of rainfall is considered as a major factor in rural poverty. Small-scale farmers are the largest group of poor people in Ethiopia. Their average land holdings are smaller, their productivity is low and they are vulnerable to drought and other adverse natural conditions. Cognizant of this reality the successive Ethiopian governments and farmers have made investments in small scale irrigation schemes. Despite efforts to reduce poverty in the country over the past decade, farmers, herders and other rural people remain poor. Poor people in rural areas face an acute lack of basic social and economic infrastructure such as health and educational facilities, veterinary services and access to safe drinking water. Households headed by women are particularly vulnerable. Women are much less likely than men to receive an education or health benefits, or to have a voice in decisions affecting their lives. For them, poverty means high numbers of infant deaths, undernourished families, lack of education for children and other deprivations (IFAD).

The impact of drought on the overall macro-economy of Ethiopia is very significant. There is very strong correlation between hydrology and Ethiopia's GDP performance. It is widely accepted that the Ethiopian economy is taken hostage to hydrology due to the so far insignificant infrastructural development in the water sector (World Bank, 2006). Oftentimes, Ethiopia is ravaged by droughts, leading to dramatic slow downs in economic growth. The development of water storage facilities which could be used, among other things, to develop irrigation is seen as a way of reducing Ethiopia's dependence on the annual availability of rainfall (UNPD, 2006; World Bank, 2006).

In Ethiopia, the persistent correlation between rainfall and GDP growth is striking and troubling. The effects of hydrological variability emanate from the direct impacts of rainfall on the landscape, agricultural output, water-intensive industry and power production. These impacts are transmitted through input, price and income effects onto the broader economy, and are exacerbated by an almost complete lack of hydraulic infrastructure to mitigate variability and market infrastructure that could mitigate economic impacts by facilitating trade between deficit and surplus regions of the country.

Evidences from elsewhere indicate that initial investments in water resources management and multipurpose hydraulic infrastructure had massive regional impacts with very large multiplier effects on the economy. Therefore, it is possible that irrigation investments in Ethiopia may have contributed to poverty reductions among other people than the irrigators, who are direct beneficiaries of the investment. However, in this paper we limit ourselves to the poverty impact of small-scale irrigation development on the direct beneficiaries or farmers.

Definition of concepts

Before addressing the rural poverty and irrigation nexus, it is important to clarify the meaning of poverty. There is great variation in the manner in which poverty is being defined and measured in developing countries (May,2001). Poverty is a persistent feature of socioeconomic stratification through out the world. Over the last twenty five years the understanding of poverty has advanced and become more holistic. From having been understood almost exclusively as inadequacy of income, consumption and wealth, multiple dimensions of poverty and their complex interactions are now widely recognized. These include isolation, deprivation of political and social rights, a lack of empowerment to make or influence choices, inadequate assets, poor health and mobility, poor access to services and infrastructure, and vulnerability to livelihood failure.

Often distinction is made between absolute and relative poverty. Relative poverty measures the extent to which a household's income falls below an average income threshold for the economy. Absolute poverty measures the number of people below a certain income threshold or unable to afford certain basic goods and services. Absolute poverty is a state in which one's very survival is threatened by lack of resources. Consideration is also necessary of the dynamics of both chronic[1] and transient poverty, and of the processes which lead people to escape from or fall into and remain trapped in poverty (Carter et al. 2007). Another related concept is equity, which is usually understood as the degree of equality in the living conditions of people, particularly in income and wealth, that a society deems desirable or tolerable. Thus equity is broader than poverty and is defined over the whole distribution, not only below a certain poverty line. The meaning of equity encapsulates ethical concepts and statistical dispersion, and encompasses both relative and absolute poverty. Hence, ideally any

[1] Chronic poverty is an individual experience of deprivation that lasts for a long period of time. In this sense the chronic poor are those with per capita income or consumption levels persistently below the poverty line during a long period of time. Transient poverty is associated with a fluctuation of income around the poverty line.

assessment of how irrigation can affect poverty must consider impacts on these varied dimensions of poverty and their interactions. For example, it must consider whether changes are in absolute or relative terms, and whether they are long lasting or transient. Similarly, it must encompass the other dimensions of poverty beyond income, consumption and wealth. In order to understand the dynamics of poverty, one can draw on the notions of 'capabilities' and 'entitlements' that have received a good deal of attention (Sen 2000). Sen's work belies the idea that income shortfalls are the main attribute of poverty. He emphasises the importance of the bundle of assets or endowments held by the poor, as well as the nature of the claims attached to them, as critical for analyzing poverty and vulnerability.

Nevertheless, while recognizing that poverty is a multidimensional phenomenon consisting of material, mental, political, communal and other aspects, the material dimensions of poverty expressed in monetary values is too important an aspect of poverty to be neglected (Lipton 1997). Given the fact that there is 'a lack of consensus regarding the measurement of other forms of deprivation', the approach followed in this paper is ultimately grounded on the notion of some minimum threshold below which the poor are categorized (Lipton 1997). There is growing recognition that poverty may adequately be defined as private consumption that falls below some absolute poverty line. This is best measured by calculating the proportion of the population who fall below a poverty line (the headcount) and the extent of shortfall between actual income level and poverty line (the depth or severity of poverty). The poverty line is usually based on an estimated minimum dietary energy intake, or an amount required for purchasing a minimum consumption bundle.

This paper analyses the state of poverty and inequality among sample farm households with and without access to irrigation. It also analyses the correlates of poverty. Section two presents the data collection and analytical methods. Section three shows the results of poverty profiling, while section four assesses the determinants of poverty and their quantitative significance in predicting poverty. Section fives gives some policy conclusions and implications.

2. Methodological Issues

Data sources

This study is part of a comprehensive study on the impacts of irrigation on poverty and environment run between 2004 and 2007 in Ethiopia implemented by the International Water Management Institute (IWMI) with support from the Austrian government. The socio-economic survey data on which this paper is based is gathered from a total of 1024 households from eight irrigation sites in 4 Regional states involving traditional, modern and rain fed systems. The total sample constitutes 397 households practicing purely rainfed agriculture and 627 households (382 modern and 245 traditional) practice irrigated agriculture. These households operate a total of 4953 plots (a household operating five plots on average). Of the total 4953 plots covered by the survey, 25 percent (1,250 plots) are under traditional irrigation, 43 percent (2,137 plots) are under modern while the remaining 32 percent (1,566 plots) are under rainfed agriculture. The data was collected for the 2005/2006 cropping season.

Poverty indices

When estimating poverty using monetary measures, one may have a choice between using income or consumption as the indicator of well-being. Most analysts argue that, provided the information on consumption obtained from a household survey is detailed enough, consumption will be a better indicator of poverty measurement than income for many reasons (Coudouel et al. 2002). One should not be dogmatic, however, about using consumption data for poverty measurement. The use of income as a poverty measurement may have its own advantages. In this paper we estimate poverty using income adjusted for differences in household characteristics.
As for the poverty measures, we will be concerned with those in the Foster-Greer-Thorbecke (FGT) class. The FGT class of

poverty measures have some desirable properties (such as additive decomposibility), and they include some widely used poverty measures (such as the head-count and the poverty gap measures). Following Duclos et al. (2006), the FGT poverty measures are defined as

$$P(z;\ \alpha) = \int_0^1 \left(\frac{g(p;\ z)}{z} \right)^{\alpha} dp \qquad (1)$$

where z denotes the poverty line, and α is a nonnegative parameter indicating the degree of sensitivity of the poverty measure to inequality among the poor. It is usually referred to as poverty aversion parameter. Higher values of the parameter indicate greater sensitivity of the poverty measure to inequality among the poor. The relevant values of α are 0, 1 and 2.

At α =0 equation 1 measures poverty incidence or poverty head count ratio. This is the share of the population whose income or consumption is below the poverty line, that is, the share of the population that cannot afford to buy a basic basket of goods.

At α =1 equation 1 measures depth of poverty (poverty gap). This provides information regarding how far off households are from the poverty line. This measure captures the mean aggregate income or consumption shortfall relative to the poverty line across the whole population. It is obtained by adding up all the shortfalls of the poor (assuming that the non-poor have a shortfall of zero) and dividing the total by the population. In other words, it estimates the total resources needed to bring all the poor to the level of the poverty line (divided by the number of individuals in the population). Note also that, the poverty gap can be used as a measure of the minimum amount of resources necessary to eradicate poverty, that is, the amount that one would have to transfer to the poor under perfect targeting (that is, each poor person getting exactly the amount he/she needs to be lifted out of poverty) to bring them all out of poverty (Coudouel et al. 2002).

At $\alpha = 2$ equation 1 measures poverty severity or squared poverty gap. This takes into account not only the distance separating the poor from the poverty line (the poverty gap), but also the inequality among the poor. That is, a higher weight is placed on those households further away from the poverty line.

We calculated these indices using DAD4.4 (Duclos, J-Y et al., 2006)

Inequality indices

To assess the income inequality among the different farm household groups, we calculate the Gini coefficient of inequality and Decile ratios. **Gini coefficient of inequality** is the most commonly used measure of inequality. The coefficient varies between 0, which reflects complete equality, and 1, which indicates complete inequality (one person has all the income all others have none). The decile dispersion ratio presents the ratio of the average consumption or income of the richest 10 percent of the population divided by the average income of the bottom 10 percent. This ratio is readily interpretable by expressing the income of the rich as multiples of that of the poor.

In summary the analysis of poverty and inequality followed four steps. First, we have chosen household income as a welfare measure and this was adjusted for the size and composition of the household. Second, a poverty line is set at 1075 Birr (1USD=9.07Birr), a level of welfare corresponding to some minimum acceptable standard of living in Ethiopia (reference). The poverty line acts as a threshold, with households falling below the poverty line considered poor and those above the poverty line considered non-poor. Third, after the poor has been identified, poverty measures such as poverty gap and squared poverty gap were estimated. Fourth, we constructed poverty profiles showing how poverty varies over population subgroups (example irrigators Vs non-irrigators) or by characteristics of the household (for example, level of education, age, etc.). The poverty profiling is particularly important as what matters most to many policymakers is not so much the precise location of the poverty line, but the implied poverty comparison across subgroups or across time. Lastly, we analyzed income inequality among sample households.

3. Household income distribution

The income distribution differentiated by access to irrigation and irrigation use intensity is shown in table 1. A close scrutiny of the table shows the following interesting results:

- The mean per capita income of rainfed farmers is below the poverty line. Interestingly also the mean per capita income values up to the eighth income decile is lower than the assumed poverty line. However, the mean per capita income for irrigators and the overall sample is higher than the poverty line and the gap between mean per capita income and poverty line widens in proportion to the size of irrigated area.
- Comparison of the mean per capita income for the richest 10% of irrigators and non-irrigators shows that the mean per capita income for the former is almost doubles that of the latter group. The income difference widens with the size of irrigated area.
- Comparison of the per capita income for the lower 10% of income distribution for irrigators and non-irrigators shows that the per capita income for the irrigators is three times that of non-irrigators. This difference is also influenced by the size of cultivated area
- The gap in mean per capita income between poor and non-poor households is substantial irrespective of access to irrigation. Even though the mean per capita income of poor people with access to irrigation is higher than that of the poor without access to irrigation, the difference seems to be insignificant.
- The Gini index of income inequality values suggests that income inequality is higher among households with access to irrigation as compared to those with no access. The values for the decile ratios also indicate that income inequality is lower among the rain-fed farmers.

Table 1. Distribution of per capita income by income deciles for irrigators and non-irrigators

Deciles	Rainfed	Irrigators	Overall	1st quartile [a]	2nd quartile	3rd quartile	4th quartile
First	38.5	114.5	72.6	90.8	80.4	116.5	233.4
Second	166.8	331.0	236.4	274.6	242.6	362.9	520.0
Third	285.6	503.0	391.0	385.5	466.7	538.9	708.2
Fourth	401.6	648.2	526.8	509.3	584.3	658.8	960.2
Fifth	514.2	850.9	651.5	673.4	813.8	864.0	1268.3
Sixth	617.0	1127.9	842.0	827.0	1035.8	1270.1	1641.1
Seventh	774.2	1507.0	1099.5	1112.8	1245.2	1766.1	2295.2
Eighth	984.5	2067.9	1542.5	1481.8	1729.0	2506.7	3294.9
Ninth	1379.2	3231.7	2425.7	2033.6	2374.8	3889.2	4796.6
Tenth	4152.5	8736.3	7096.5	6395.6	7447.2	9352.3	10212.0
Mean	930.7	1908.3	1487.3	1369.6	1613.7	2230.9	2492.7
Poverty line	1075	1075	1075	1075	1075	1075	1075
poor	486.2	498.5	492.8	503.4	527.0	525.2	602.9
non-poor	2688.4	3497.1	3290.5	2980.4	3123.2	3998.4	3718.5
% poor	77.1	58.5	65.7	66.3	58.9	53.9	41.8
Gini coefficient	0.499	0.546	0.547	0.507	0.515	0.537	0.503
Deciles ratio	11.6	26.9	20.7	14.8	20.1	22.6	16.4

Given the assumed poverty line, the proportion of poor households among those households with no access to irrigation is higher than those who have access to irrigation. The poverty reduction impact of access to irrigation is very much influenced by the size or irrigated area. The relationship between poverty and irrigation and other relevant factors will be analyzed in more detail in the succeeding sections.

4. Poverty profile

Rural poverty and irrigation

Table 2 shows the incidence, depth and severity of poverty by access to irrigation, irrigation typology, and extent of irrigated area owned by those who have access to irrigation. As expected the poverty incidence, depth and severity values are lower for farmers that have access to irrigation. While the interpretation of the incidence values is straight forward (i.e., it indicates the proportion of poor people in the sample), that of the depth and severity is not. The depth of poverty for irrigators is about 0.322 as compared to 0.425 for those without access to irrigation. The interpretation is that the per capita income of farmers with access to irrigation needed to be increased on average by 32.2% to lift their per capita income level to the poverty line or alternatively to move them out of absolute poverty, while the income of rain-fed poor farmers should be increased by 42.5% to lift them out of poverty. The higher poverty severity value for rain-fed poor farmers also indicates that inequality among the poor rainfed farmers is higher when compared to irrigating poor farmers. Similar interpretations hold for tables 3 through 6 as well.

However, note that the incidence of poverty among the sample households is still higher irrespective access to irrigation. When comparing irrigation scheme types, the poverty situation is worse among irrigators belonging to traditional scheme. Poverty indices are also responsive to the size of irrigated area. Poverty incidence for households belonging to the first quartile of irrigated area is about 65.8%, which decreases to 40.3% for those in the fourth quartile.

Table 2.The effect of irrigation on incidence, depth and severity of poverty

Variables	Incidence ($\alpha = 0$)		Depth ($\alpha = 1$)		Severity ($\alpha = 2$)	
	value	SD	Value	SD	Value	SD
Access to irrigation						
Irrigators	0.585	0.0197	0.322	0.0140	0.226	0.0125
Non-irrigators	0.771	0.0211	0.425	0.0161	0.283	0.0144
Irrigation Scheme Type						
Traditional Schemes	0.661	0.0303	0.404	0.0234	0.297	0.0216
Modern Schemes	0.537	0.0255	0.270	0.0169	0.181	0.0148
Size of Irrigation area						
No irrigation	0.792	0.0191	0.466	0.0160	0.333	0.0154
1^{st} quartile (0.66)	0.658	0.0374	0.351	0.0259	0.230	0.0220
2^{nd} quartile (1.87)	0.586	0.0436	0.299	0.0298	0.203	0.0254
3^{rd} quartile (3.56)	0.524	0.0390	0.268	0.0246	0.171	0.0209
4^{th} quartile (7.92)	0.403	0.0450	0.177	0.0246	0.104	0.0181

It is true that the exact magnitude of the calculated poverty incidence, depth and severity values is influenced by the level of the chosen poverty line. This is particularly true when one considers the fact that the different regions of Ethiopia are expected to differ in the magnitude of poverty line due to several reasons (Coudouel et al.2002). To avoid the potential bias that might be created due to the use of in appropriate poverty line, we have plotted a graph depicting the relationship between all the realized income per capita and the corresponding poverty incidence values[1] and the results are shown in Figure 1 and 2.

Figure 1 shows that baring the results for the extreme low values of income per capita, at all of the realized per capita income (plausible poverty lines), the poverty incidence is higher among farmers with no access to irrigation. The vertical line indicates the assumed poverty line (1075 Birr).

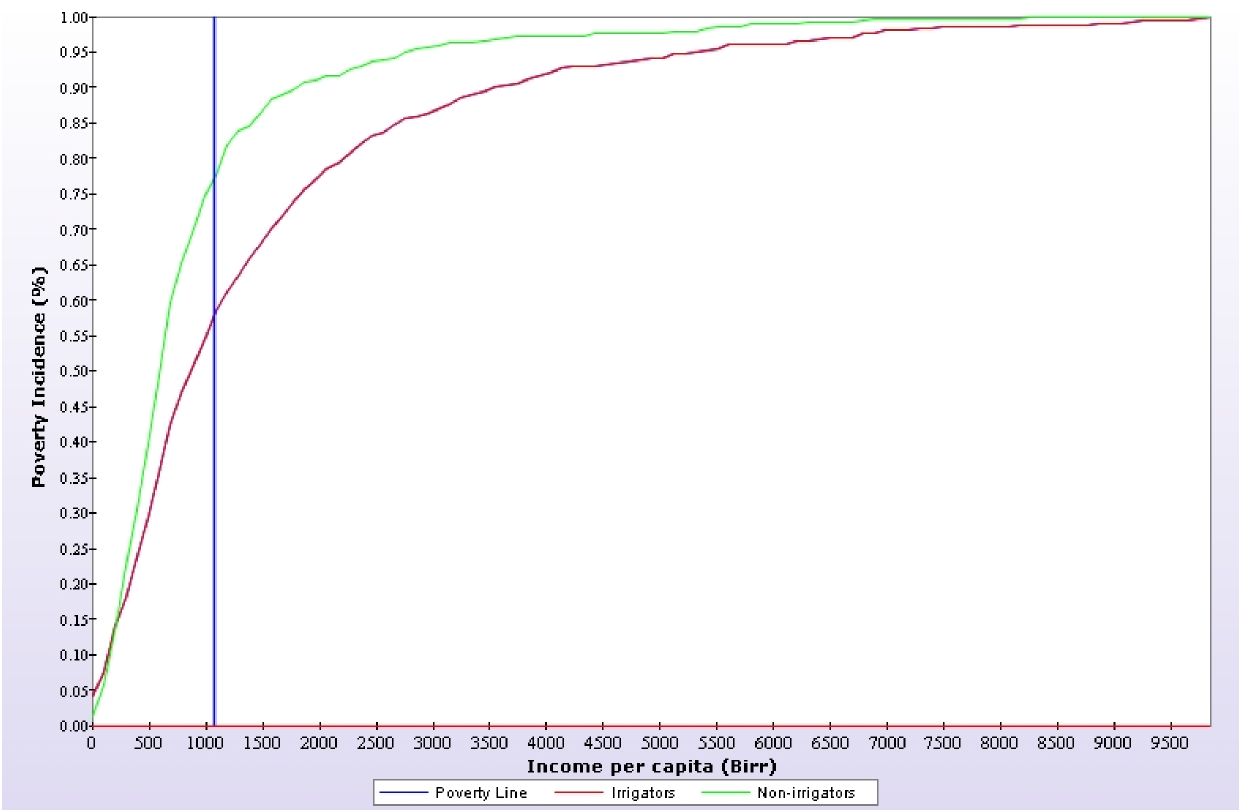
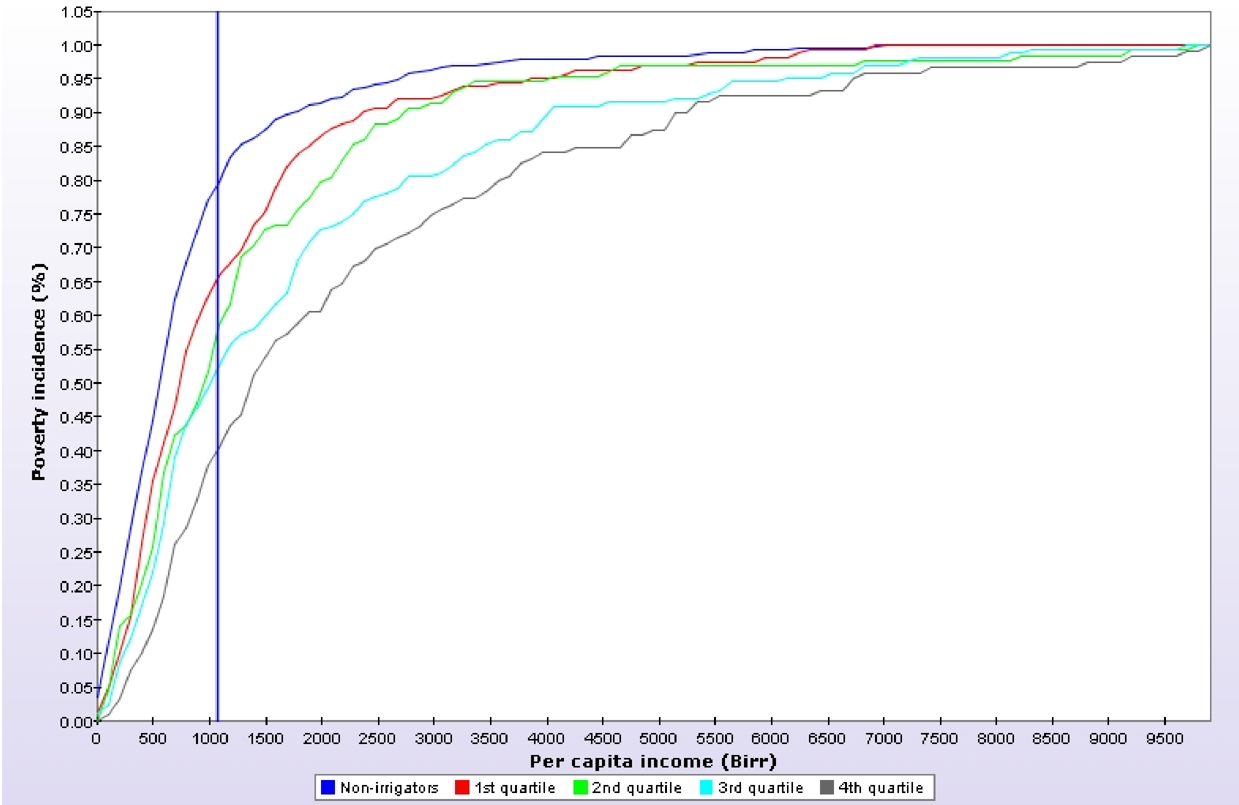


Figure 1. Poverty incidence curves for irrigators and non-irrigators under different poverty line assumptions.

1. We have used DAD 4.4 to generate these curves.

Figure 2 Shows poverty incidence for different irrigated area categories. The figure indicates that poverty incidence is very responsive to the size of irrigated area.



Poverty, farm size and livestock holding

The effect of farm size and livestock holding on the incidence, depth and severity of poverty is shown in table 3. The incidence depth and severity of poverty among farmers in the higher farm size category is significantly lower. However, it should be noted that the room for expanding farm size is limited in most parts of Ethiopia due to population pressure. Any farther expansion is possible only in fragile lands or important natural resources enclaves. The relationship between livestock holding and poverty is generally as expected: poverty incidence is lower among farmers with highest livestock holding.

Table 3. The effect of farm size and livestock holding on poverty incidence, depth and severity

Variables	Incidence ($\alpha = 0$)		Depth ($\alpha = 1$)		Severity ($\alpha = 2$)	
	Value	SD	Value	SD	Value	SD
Farm Size						
1st quartile	0.789	0.0249	0.524	0.0216	0.400	0.0211
2nd quartile	0.700	0.0288	0.360	0.0204	0.235	0.0181
3rd quartile	0.600	0.0313	0.291	0.0201	0.183	0.0164
4th quartile	0.531	0.0312	0.260	0.0194	0.163	0.0157
Livestock holding						
1st quartile	0.657	0.0230	0.407	0.0231	0.299	0.0217
2nd quartile	0.669	0.0295	0.383	0.0212	0.260	0.0182
3rd quartile	0.654	0.0299	0.353	0.0205	0.231	0.0172
4th quartile	0.607	0.0308	0.272	0.0190	0.164	0.0155

Poverty and cropping pattern

Table 4 depicts the influence of cropping pattern on poverty indices. It is interesting to note that as the proportion of cultivated area devoted to cereals increases the value of the FGT poverty indices increases. This is particularly important because most of the sample farmers grow low value staple cereal crops. On the other hand, the incidence, severity and depth of poverty is significantly lower among farmers whose substantial proportion of cultivated area is devoted to vegetables and root crops. This suggests that poverty among smallholders can be reduced through diversifying crop production by including high value crops such as vegetables. However, it is also important to note that most of the farmers who grow vegetables and root crops had access to irrigation.

Table 4. The effect of cropping pattern on poverty incidence, depth and severity

Variables	Incidence ($\alpha = 0$)		Depth ($\alpha = 1$)		Severity ($\alpha = 2$)	
	Value	SD	Value	SD	Value	SD
Crop area shares: cereals						
0.0 - 0.25	0.575	0.0319	0.385	0.0257	0.307	0.0239
0.25-0.50	0.630	0.0290	0.334	0.0196	0.218	0.0170
0.50-0.75	0.641	0.0303	0.290	0.0190	0.175	0.0152
0.75-1.0	0.780	0.0259	0.441	0.0203	0.299	0.0185
Crop area shares: vegetables						
No vegetables	0.766	0.0158	0.440	0.0126	0.308	0.0117
0.0 - 0.25	0.455	0.0399	0.178	0.0195	0.091	0.0130
0.25-0.50	0.368	0.0495	0.179	0.0313	0.125	0.0291
0.50-0.75	0.263	0.1011	0.096	0.0528	0.062	0.0440
0.75-1.0	0.258	0.0786	0.181	0.0603	0.145	0.0537
Crop area share: root crops						
No root crops	0.661	0.0161	0.366	0.0117	0.252	0.0105
0.0 - 0.25	0.645	0.0435	0.329	0.0291	0.210	0.0239
0.25-0.50	0.667	0.0786	0.411	0.0592	0.295	0.0518
0.50-0.75	0.0	0.0	0.0	0.0	0.0	0.0
0.75-1.0	0.0	0.0	0.0	0.0	0.0	0.0
Crop area shares: fruits						
No fruits	0.671	0.0176	0.351	0.0120	0.233	0.0109
0.0-0.25	0.523	0.0377	0.296	0.0257	0.203	0.0217
0.25-0.50	0.738	0.0480	0.471	0.0383	0.345	0.0351
0.50-0.75	0.625	0.1211	0.398	0.0930	0.297	0.0855
0.75-1.0	0.903	0.0531	0.668	0.0647	0.675	0.0672

Poverty and geographic characteristics

Table 5 shows poverty indices by geographic location of the sample households. The poverty incidence is generally higher in all of the Ethiopian regional states. It is relatively lower in Oromia and Tigray regional states and higher in Southern Nations Nationalities and Peoples states[2]. When comparing the zones included in the study, the lowest poverty incidence was observed in East Shewa and the highest in North Omo. The observed low poverty incidence rate in East Shewa is not surprising given the fact that the zone is relatively well developed in terms of services and infrastructure, thus providing relatively better marketing conditions and employment opportunities. We have also assessed poverty according to which basin the sample irrigation schemes or farm households

[2] However note the regional differences in poverty line and the non-representative ness of the sample

belong. It was found that poverty is significantly lower in Awash and Denakil basins.

Table 5. Headcount, depth and severity of poverty among sample households

Variable	Incidence ($\alpha = 0$)		Depth ($\alpha = 1$)		Severity ($\alpha = 2$)	
	value	SD	Value	SD	Value	SD
Sample total	0.657	0.0148	0.362	0.0107	0.248	0.0010
Zones						
North Omo	0.871	0.0285	0.626	0.0286	0.506	0.0302
Arsi	0.648	0.0460	0.268	0.0261	0.145	0.0222
Awi	0.717	0.0438	0.390	0.0325	0.264	0.0279
Raya Azebo	0.565	0.0351	0.299	0.0227	0.193	0.0178
East Shewa	0.455	0.0387	0.177	0.0192	0.092	0.0132
West Shewa	0.727	0.0347	0.417	0.0260	0.286	0.0227
West Gojam	0.664	0.0418	0.330	0.0277	0.207	0.0231
Basins						
Abay	0.707	0.0227	0.388	0.0166	0.262	0.0145
Awash	0.535	0.0301	0.219	0.0162	0.120	0.0127
Denakil	0.444	0.0500	0.272	0.0362	0.204	0.0310
Rift Valley	0.871	0.0284	0.626	0.0286	0.506	0.0302
Tekeze	0.704	0.0440	0.369	0.0302	0.235	0.0256
Region						
Amara	0.693	0.0299	0.368	0.0215	0.236	0.0188
SNNP	0.871	0.0285	0.626	0.0286	0.506	0.0302
Oromia	0.607	0.0233	0.293	0.0148	0.182	0.0123
Tigray	0.580	0.0343	0.323	0.0237	0.220	0.0200

The incidence of and severity of poverty is higher in rural than urban areas (52 per cent and 36 per cent, respectively). Poverty is uniformly distributed throughout the country's rural areas. An exception is the region of Oromiya, where the level and intensity of poverty is significantly lower.

Poverty and household demographic and socioeconomic characteristics

Table 6 presents the state of poverty among sample farmers by their demographic and socioeconomic characteristics. Education had a profound effect on poverty. In fact there are no poor people with post secondary education. Poverty is also highly associated with family size . The poverty incidence is almost 90% among households having 10 members or more. Contrary to our expectation, the poverty incidence is relatively lower among female headed households. Poverty incidence is also lower among younger households.

Table 6. Household socioeconomic and demographic characteristics

Variables	Incidence ($\alpha = 0$)		Depth ($\alpha = 1$)		Severity ($\alpha = 2$)	
	value	SD	Value	SD	Value	SD
Education						
No education	0.677	0.0186	0.364	0.0132	0.243	0.0114
Elementary	0.649	0.0295	0.356	0.0209	0.241	0.0182
Secondary	0.539	0.0465	0.295	0.0333	0.215	0.0311
Post secondary	0.0	NA	0.0	NA	0.0	NA
Household Size						
1 person	0.348	0.0703	0.177	0.0445	0.122	0.0390
2-4 persons	0.529	0.0278	0.277	0.0181	0.183	0.0153
5-9 persons	0.727	0.0183	0.399	0.0139	0.275	0.0126
10 + persons	0.885	0.0408	0.581	0.0401	0.435	0.0411
Gender						
Male	0.664	0.0162	0.368	0.0118	0.254	0.0105
Female	0.626	0.0370	0.330	0.0257	0.221	0.0220
Household age group						
15 through 24	0.561	0.0658	0.301	0.0463	0.212	0.0419
25 through 34	0.592	0.0347	0.310	0.0239	0.211	0.0215
35 through 44	0.665	0.0292	0.359	0.0412	0.245	0.0187
45 through 54	0.710	0.0320	0.315	0.0225	0.315	0.0225
55 through 64	0.680	0.0381	0.359	0.0268	0.236	0.0232
65 through 74	0.686	0.0460	0.358	0.0322	0.233	0.0278
75 +	0.646	0.0691	0.364	0.0491	0.248	0.0430

5. Determinants of rural poverty: the role of access to irrigation

Poverty and poverty changes are affected by both microeconomic and macroeconomic variables. Within a microeconomic context, the simplest method of analyzing the correlates of poverty is to use regression analysis to see the effect on poverty of a specific household or individual characteristic while holding constant all other characteristics, which is the focus of this section. In these regressions, the logarithm of consumption or income (possibly divided by the poverty line) is typically used as the left hand variable (Qiuqiong et al.2005). An alternative framework transforms the continuous income variable into binary variable using poverty line as a cutoff value (Anyanwu 2005). The resulting dummy variable indicates whether a household is poor (i.e., the household's income is less than the poverty line) or non-poor (i.e., household's income is more than the poverty line). In this paper we follow the later approach. The right-hand explanatory variables span a large array of possible poverty correlates, such as education of different household members, number of income earners, household composition and size, and geographic location. The regressions will return results only for the degree of association or correlation, not for causal relationships.

Empirical Model

The discussion in section 3 has relied largely on descriptive results, exploring relationships between variables without holding the effect of other factors constant. However, correlations among key variables potentially could obscure the relationship between poverty and a single factor of interest. Consequently it is useful to analyze the impact of the relevant variables on poverty holding all other factors constant. This implies the need to separate the effects of correlates. We approach this problem through the application of multivariate analysis, using logistic regression. The dependent variable is a discrete variable which takes a value equal to 0 for non-poor, if a household had per capita income equal to or more than 1075 Birr and 1 for poor if a household had a per capita income less than 1075 Birr (which is considered her as a poverty line).

The explanatory variables considered in the model were household heads' personal characteristics (age, gender, educational achievement, etc), household demographic characteristics (household size and its square), household wealth (farm size, livestock holding), the nature of farming system (share of grains in the total cultivated area, size of irrigated area), and location (zones to which the household belong). See table 7 for details of the variables included in the model.

In the model, the response variable is binary, taking only two values, 1 if the rural household is poor, 0 if not. The probability of being poor depends on a set of variables listed above and denoted as X so that:

$$\text{Prob}(\text{Y} = 1) = \text{F}(\beta' x)$$

$$\text{Prob}(\text{Y} = 0) = 1 - \text{F}(\beta' x) \quad (1)$$

Using the logistic distribution we have:

$$\text{Prob}(\text{Y} = 1) = (e^{\beta' x} / 1 + e^{\beta' x}) = \Lambda(\beta' x) \quad (2)$$

Where Λ represents the logistic cumulative distributions function. Then the probability model is the expression:

$$\text{E}[\text{y}/\text{x}] = 0[1 - \text{F}(\beta' x)] + 1[\text{F}(\beta' x)] \quad (3)$$

Since the logistic model is not linear, the marginal effects of each independent variable on the dependent variable are not constant but are dependent on the values of independent variables. Thus, to analyze the effects of the independent variables upon the probability of being poor, we calculated the conditional probabilities for each sample household. Once the conditional probabilities are calculated for each sample household, the partial effects of the continuous individual variables on household poverty can be calculated using

$$\frac{\partial \Lambda(\beta' X_i)}{\partial X_i} = \Lambda(\beta' X_i)[1 - \Lambda(\beta' X_i)]$$

The partial effects of the discrete variables will be calculated by taking the difference of the mean probabilities estimated for respective discrete variables at values 0 and 1.

Alternatively, we present the change of the odds ratios as the dependant variables change. The odds ratio is defined as the ratio of the probability of being poor divided by the probability of not being poor. This is computed as the exponents of the logit coefficients (e^{β}) and can be expressed in percentage as [100(e^{β} - 1)].

Before presenting the model results we wish to give a brief description of the variables included in the model (See table 7). There is significant association between poverty and access to irrigation. Irrigating households have also significantly higher farm size, family size, and years of schooling. They also devote significantly lower area to the cultivation of food grains than the non-irrigators. The proportion of female headed households is relatively higher among farmers without access to irrigation.

Table 7. Description of variables included in the model

Variables	Irrigators	Non-irrigators	t-statistic	χ^2
Proportion of poor (Y=1=poor, 0 other wise) (%)	56.8	76.6	NA	41.578***
Proportion of female (%) (X1)	14.8	19.6	NA	4.051*
Zones (Number) (X2)				
North Omo	55	55	NA	NA
Arsi	109	30	NA	NA
Awi	55	53	NA	NA
Raya Azebo	107	100	NA	NA
East Shewa	108	57	NA	NA
West Shewa	110	55	NA	NA
West Gojam	83	47	NA	NA
Irrigated area (Timmad) (X3)	3.02	NA	NA	NA
Farm Size (Timmad) (X4)	6.87	5.90	8.321***	NA
Area share of grains (%) (X5)	64.33	91.21	234.085***	NA
Livestock holding in TLU (X6)	3.78	4.20	2.708	NA
Family Size (number) (X7)	5.63	5.34	3.569*	NA
Age of household head (years) (X8)	45.99	44.84	1.386	NA
Years of schooling (X9)	2.34	1.65	11.389***	NA

The logistic regression analysis is fitted to strengthen and clarify the descriptive results of the preceding descriptive sections.

Empirical results

The model results are summarized in table 8. The likelihood ratio χ^2 statistic is used to test the dependence of rural poverty on the variables included in the model. Under the null hypothesis (Ho) where we have only one parameter, which is the intercept (β_o), the value of the restricted log likelihood function is -666.39, while under the alternative hypothesis (H_1) where we have all the parameters, the value of the unrestricted log likelihood function is -453.64. The model χ^2 statistic is highly significant, indicating that the log odds of household poverty is related to the model variables. With regard to the predictive efficiency of the model, of the 1024 sample households included in the model, 822 or 80.3% are correctly predicted.

The results of the parameter estimates of determinants of poverty generally agree with the descriptive results of the preceding section. Of the twelve variables included in the model, nine were found to have a significant impact on poverty. Increases in farm size, irrigated area and years of schooling significantly reduce the probability of being poor, while increases in family size and area share of food grains in the total cultivated area significantly increases the probability of being poor. The relationship between poverty and family size is non-linear. Family size increases the probability of being poor up to a certain point beyond which any successive addition of a family member contributes to the reduction of poverty. This confirms the usual inverse U relationship between poverty and family size (World Bank 1991, 1996; Lanjouw and Ravallion 1994; Cortes 1997; Szekely 1998, Gang et al. 2004). Livestock holding size, which is usually regarded as a measure of wealth (Shiferaw et al.2007), had the expected sign but not statistically significant. Contrary to our expectation female headed households had lower chance of being poor as compared to male headed households. Concerning location effects, the probability being poor for sample households from North Omo and West Shewa is significantly higher, whereas the probability of being poor for households from East Shewa and Raya Azebo zones is significantly lower.

We assess the magnitude of the effect of changes in statistically significant and policy relevant variables on household poverty based on the partial effects of the respective variables on conditional probabilities (Table 9). The partial effects of continuous variables were calculated using equation 4, while those of the discrete variables were calculated by taking the difference between the mean probabilities estimated at the respective values (0 and 1) of the discrete variables. The partial effects thus calculated from the logistic model show the effect of change in an individual variable on the probability of being poor when all other exogenous variables are held constant.

Table 8. Parameter estimates of determinants of poverty model

Variables	Estimate[a]	SE	e^{β}	$100(e^{\beta}-1)$
Constant	-1.018	0.915	0.361	-63.9
Size of irrigated area	-0.354***	0.117	0.702	-29.8
Area share of grains cultivation	1.942***	0.433	6.970	597
Irrigated area-by-area share of grain	0.291*	0.156	1.338	33.8
Farm size	-0.202***	0.026	0.817	-18.3
Livestock holding in TLU	-0.039	0.025	0.961	-3.9
Family size	0.724***	0.146	2.064	106.4
Square of family size	-0.022*	0.012	0.979	-2.1
Age of household head	-0.050	0.035	0.951	-4.9
Square of age of household head	0.001	0.000	1.001	0.1
Level of education of HH head	-0.116***	0.032	0.890	-11
Sex of the household head(=Male)	0.438*	0.246	1.549	54.9
Zones:				
North Omo	2.248***	0.440	9.470	847
Arsi	0.663*	0.378	1.940	94
Awi	-0.161	0.353	0.852	-14.8
Raya Azebo	-0.569*	0.296	0.566	-43.4
East Shewa	-1.353***	0.309	0.258	-74.2
West Shewa	1.107***	0.357	3.026	202.6
West Gojam (reference)				

Note:

Restricted log likelihood value [Log(L0)]=-666.3848

Unrestricted log likelihood value [Log (L1)]=-453.6428

Log likelihood value ($\chi^2_{(df=9)}) = -2[\log(L0) - (-\log(L_1))] = 425.4841$ ***

% of correct prediction=80.3

Number of observation=1024

[a] The parameters were estimated using maximum likelihood methods. They are un-weighted

***Statistically significant at p<0.01; **Statistically significant at p<0.05; *statistically significant at p<0.1.

In logit model analysis, it is marginal effect values and elasticities that have direct economic interpretation not the estimated coefficients. Looking at the marginal effect and elasticity values presented in table 8, the irrigation variable comes third or after area share of grains and family size variables in quantitative importance with respect to poverty reduction. Rural poverty is highly responsive to the cropping pattern. A unit increase in the proportion of area of grain crops increase the probability of being poor by 0.41% or a 1% increase in the proportion of area devoted to grain crops increase the probability of being poor by 0.44%. This implies that changing the crop mix managed by farmers towards high value crops such as vegetables would have a profound effect on rural poverty. Irrigation technology facilitates the cropping pattern shift process. A one *timmad* increase in irrigated area would reduce the probability of being poor by 0.075% . In other words, a 1% increase in irrigated area would reduce the probability of being poor by 0.2%. Increasing the household member by one person would increase the probability of being poor by 0.15%. Alternatively a 1% increase in the family size would increase the probability of being poor by 1.21%.

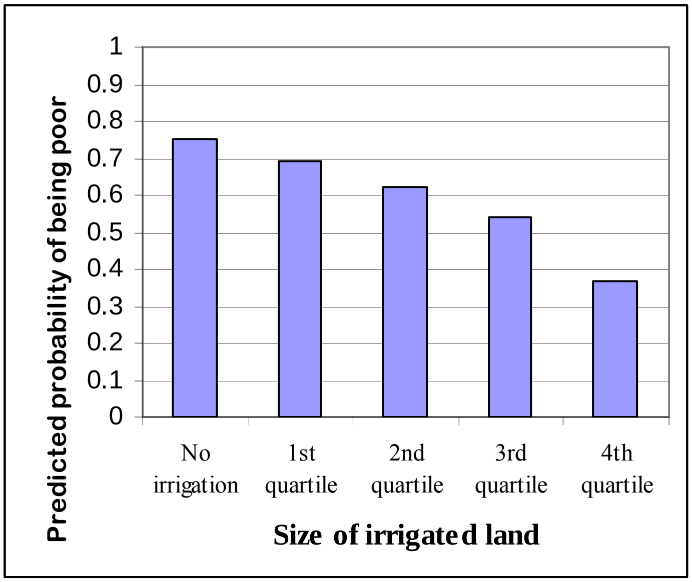
Another significant policy relevant variable is years of schooling. An unit increase in year of schooling decreases the probability of being poor by 0.0245.

Table 9. Marginal effects of the significant variables

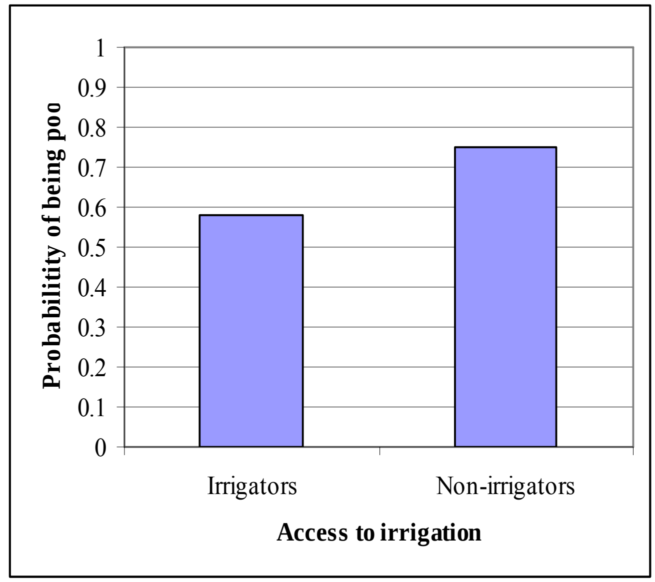
Determinants	Marginal effects	Elasticity
Irrigated area in Timmad	-0.0747	-0.20
Area share of grain crops	0.4089	0.44
Farm size in Timmad	-0.0426	-0.40
Family size	0.1526	1.21
Years of schooling	-0.0245	-0.07
Gender (Male)	0.0865	0.02
Zones		
North Omo	0.3113	0.06
Arsi	0.1240	0.02
Awi	-0.0346	-0.01
Raya Azebo	-0.1268	-0.04
East Shewa	-0.3156	-0.07
West Shewa	0.1948	0.05

The interesting results contained in table 10 can be graphically depicted. Poverty is more responsive to the size of irrigated area than mere access to irrigation (See panel a and b of Figure 3). In the past due mainly to the demand for irrigated land exceeding the supply and due to also partly to the egalitarian policies followed for rural development, the irrigated land is rationed in Ethiopia. In an effort to reach many people the irrigated plots distributed to farmers are often far below an economic size that is sufficient to warrant the full engagement of farmers in irrigated production business. Consequently, irrigated farming is considered as a second best option by farmers.

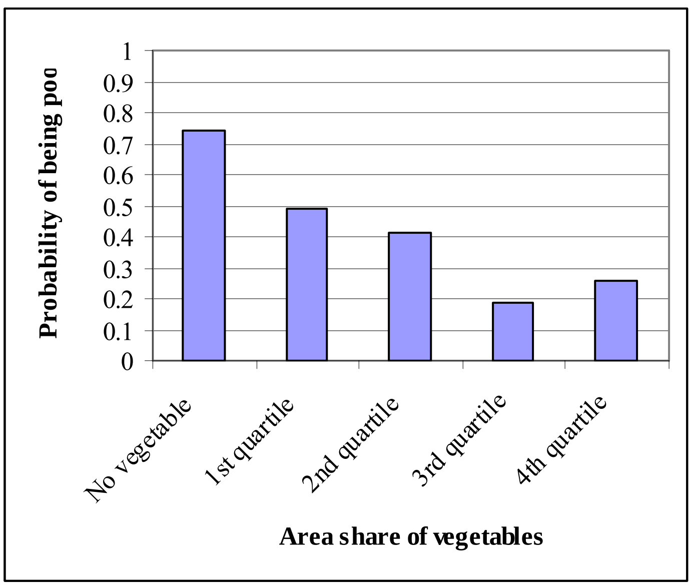
Rural poverty is also very responsive to cropping pattern changes (see panel c and d of Figure 3). Reductions in area share of food grains and increases in the area share of high value crops such as vegetables significantly reduces rural poverty. Two major variables that allow the change to high value crops are access to irrigation and proximity to the demand centers thus allowing easy marketing. Figure 4 (panel a and b)show that poverty is highly related to family size and level of education of the household head.



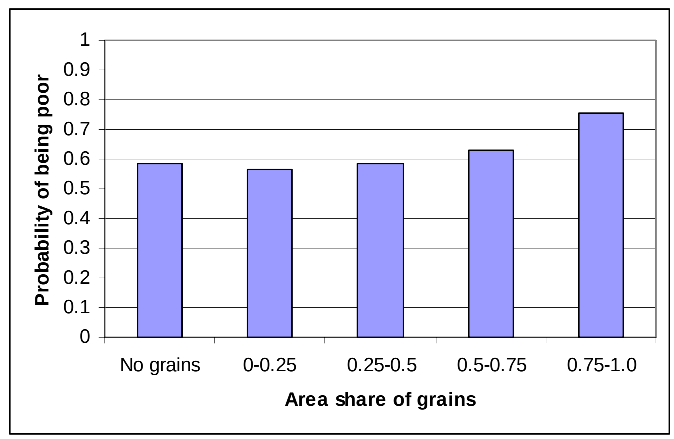
Panel a



Panel b

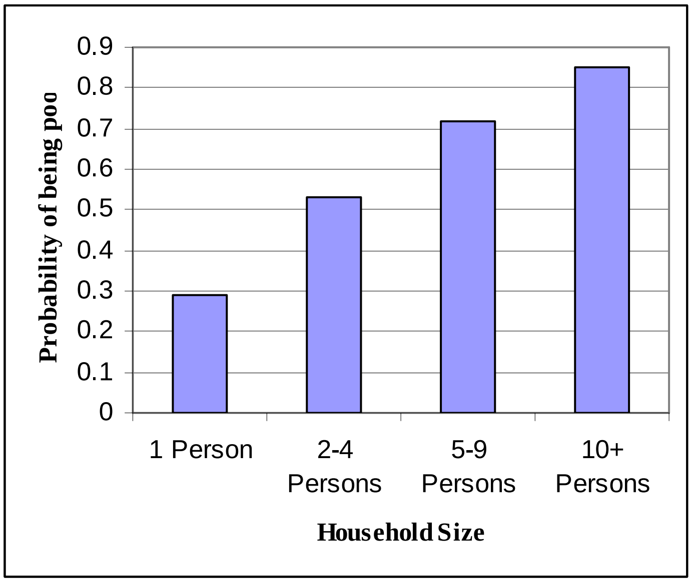


Panel c

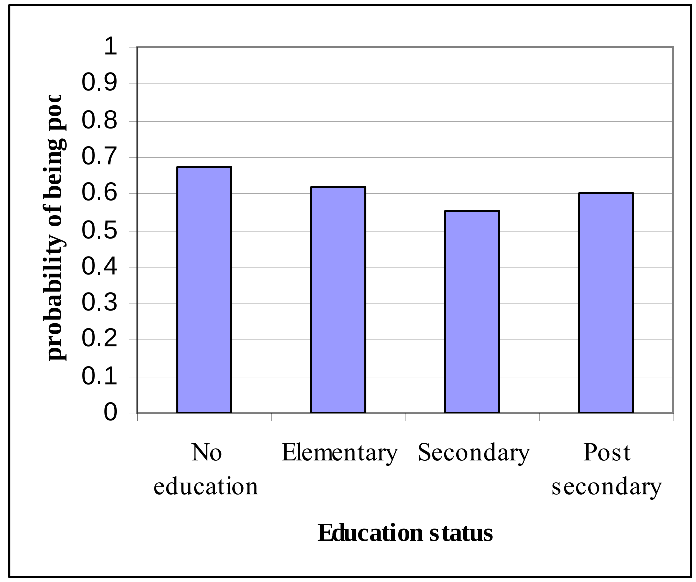


Panel d

Figure 3. Irrigation, cropping pattern and poverty



Panel a



Panel b

Figure 4. A graphical illustration of the influence of education and household size on poverty.

6. Conclusions and policy implications

In Ethiopia agriculture and even the performance of macro-economy is taken hostage by the amount and distribution of rainfall (Reference).The unreliable rainfall pattern in many parts of the country forced the farming population to adopt a risk-averse behavior, the behavior that limits the capacity of farmers to innovate and adopt farming technologies with potential of boosting yield and income. For instance, the successive Ethiopian governments have tried to enhance the productivity of agriculture through modest investments in agricultural research and extension, mainly focused on seed and fertilizer technologies[3]. Several evaluation studies of these programs have underlined that the seed and fertilizer technologies were mostly successful in areas endowed with relatively ample moisture (reference). It was based on this revelation that the government, NGOs and farmers have made investments in agricultural water management such as small-scale irrigation schemes to extricate the agricultural sector and the economy at large form the shackles of unreliable rainfall. The main goals of these investments in small-scale irrigation schemes were reducing food insecurity and incidence of rural poverty. This paper assessed whether the developed irrigation schemes have lived up to the expectation of significantly reducing rural poverty and also inequality.

The study was based on the extensive data set generated form a total of 11 small-scale irrigation schemes (i.e., 7 modern schemes and 4 traditional schemes), sampled from four major regional states of Ethiopia. For comparison purposes a sample of adjacent villages with no access to irrigation was also sampled. All in all 1024 farming households were randomly sampled from the selected irrigation schemes and rain-fed villages. It consisted of 627 irrigating households (of which 382 are modern scheme irrigators and 245 are traditional schemes irrigators) and 397 purely rain-fed farmers. It is to be noted that even those households with access to irrigation do manage rain-fed plots. Only few farmers were found to be purely irrigators.

From the results presented in this paper, the following conclusions may be made:

- There is significant difference in incidence, depth and severity of poverty between households with access to irrigation and those without. However, the poverty incidence among the sample households is still unacceptably high irrespective of access to irrigation, indicating that poverty deeply entrenched in rural Ethiopia.
- Poverty indices are responsive to irrigation typology and irrigation intensity. Among the irrigation the two irrigation typologies studied the poverty situation is relatively milder among modern irrigation scheme users.
- Poverty indices were found also to be responsive to the irrigation intensity as measured by the size of irrigated area. Poverty incidence is significantly lower among households with higher irrigated area size. Due to demand outstripping the limited supply of irrigation service and due to considerations for equity, irrigation plots are rationed in Ethiopia. The limited differentiation observed in the size of irrigated land among sample farmers is due to the prevalence of informal irrigable land markets. This calls for an investigation to determine a minimum irrigated area that needed to be allotted to a household for sustained poverty reduction and food insecurity eradication.
- Poverty incidence is also related to the cropping pattern, indicating that mere access to irrigation would not bring the desired results. Poverty situation is more sever among farmers devoting significant proportion of their cropping land to food grains (cereals, oil seeds and pulses) irrespective of access to irrigation. Vegetable growers are better off in terms of poverty situation. The implication is that irrigation project planners should consider the crop mix in future irrigation development plans.
- Income inequality among households with access to irrigation is worse than that of those with out access. The implication is that even though accesses to irrigation moves up the mean income, farmers have different capacity in making better use of the available irrigation water and therefore irrigation widens the income

[3] See for instance the evaluation reports of the recent Extension Package Projects

gap[4]. However, the main policy concern in Ethiopia is reducing absolute poverty at this moment.

- Finally, our study confirms that while the income inequalities among households without access to irrigation are lower, it was found that inequality among rainfed poor farmers is higher than those with access to irrigation!!!

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[4] See which studies agree with our findings and which ones do not?

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An Assessment of the financial viability and income impact of small scale irrigation in Ethiopia

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Abstract

Recently, there has been very little irrigation development in sub-Saharan Africa. The main reasons cited for this lack of interest in developing irrigation in sub-Saharan Africa is that irrigation projects are expensive and perform poorly compared to projects from other regions. However, when classified into success and failure projects, the sub-Saharan Africa success projects' investment costs are not significantly higher than from other regions. African countries like Ethiopia, which has embarked on an agricultural led development program, aspire to use irrigation as a development strategy with small scale irrigation playing a key role in rural development. This study evaluates the financial performance of small scale irrigation using O & M and investment recovery, and the ability to replicate the investments. It is concluded that the systems are financially viable and provide a low cost development option for rural areas.

1. Introduction

Recently, there has been very little irrigation development in sub-Saharan Africa (SSA). The main reasons cited for this lack of interest in developing irrigation in SSA is that it was believed that irrigation projects in SSA are expensive and perform poorly compared to projects from other regions (Inocencio et al., 2007). In a study of 314 schemes of which 45 were from SSA, 51 from Middle East and North Africa, 41 from Latin America and the Caribbean, 91 from South Asia, 68 from South East Asia and 18 from East Asia, Innocencio et al (2007) showed that when average costs are considered, establishment costs for irrigation projects in SSA were significantly higher at an estimated USD14, 455 per ha compared to USD6, 590 for non-SSA projects. They further analyzed establishment costs by defining "Success" and "Failure" projects. In defining these they used 10 percent economic internal rate of return as a cut off point. Those projects that achieved less than 10 percent economic internal rate of return were classified as "Failure' projects. The justification for using 10 percent was that this is the cut off point used for evaluating public projects.

After applying this classification, they found that for the "Failure" projects in SSA the establishment costs averaged USD 23,184 compared to USD 10,624 for non-SSA projects, whereas for the SSA "Success" projects the average was USD 5,726 compared to USD 4,603 for non-SSA projects. This difference was not statistically significant showing that for "Success" projects, the SSA projects are not more expensive than their non SSA counterparts. Their analysis also shows that the performance of both non SSA and SSA projects has improved over time. Commenting on this performance improvement, they conclude that: "The degree and speed of improvements have been deeper and faster in SSA than in non-SSA, so that the difference in unit cost and project performance between SSA and non-SSA, which used to be significant in earlier decades, has been reduced to the extent that there is no significant difference in the latest decade". (Inocencio et al, 2007; pp 42)

Some countries in Africa, have a renewed interest and some like Ethiopia have recently become interested in the role that irrigation can play in the development process. Agriculture plays a major role in Ethiopia contributing more than 44 percent to GDP over the period 1996 to 2006 (Government of the Republic of Ethiopia, 2006_a). Most of agriculture's contribution is based on smallholders who produce cereals under rainfed production. This leaves the performance of the Ethiopian economy exposed to the vagaries of nature by depending on how good the rainfall season is (World Bank, 2006). The Ethiopian government, in its agricultural led development program, aspires to use irrigation as a major development component. Currently less than 5 percent of the potentially 3.5 million ha of irrigable land is developed. The government of Ethiopia aspires to develop about 430,061 ha within the planning period of the Plan for Accelerated and Sustained Development to End Poverty (PASDEP) which spans the years 2005/05 to 2009/10 (Government of the Republic of Ethiopia, 2006_b). This planning document aspires to strongly develop and support small scale irrigation (SSI).

Irrigation development in Ethiopia is classified using two systems. The first classification system uses the size of command area irrigated as follows:

1. Small scale irrigation systems <200ha
2. Medium scale irrigation systems (200-3000ha)
3. Large scale irrigation systems (>3000)

The second classification uses a mix of the history of establishment, time of establishment, management system and nature of the structures as follows:

1. Traditional schemes: These are SSI systems which usually use diversion weirs made from local material which need annual reconstruction or from small dams. The canals are usually earthen and the schemes are managed by the community. Many are constructed by local community effort and have been functional for very long periods of time, some were recently constructed with the aid of NGOs and government.
2. Modern schemes: These are SSI systems with more permanent diversion weirs made from concrete hence no need for annual reconstruction and small dams. The primary and sometimes secondary canals are made of concrete. They are community managed and have recently been constructed by government.
3. Public: These are large scale operations constructed and managed by government. Sometimes, public schemes have out growers whose operations are partially supported by the large scheme.
4. Private: These are privately owned systems that are usually highly intensive operations.

Given our interest in SSI, which is distinguished from large scale irrigation by the farm level scale of operation, we therefore prefer to identify SSI irrigation systems using the second classification system and we study the first and second categories of this classification. Werfring (2004) describes the typology of SSI in Ethiopia in detail.

Given the strong support envisaged for SSI development during the PASDEP planning period, it is important to provide insights into the viability of SSI investment in order to inform investment decisions.

2. Objectives

The main objective of the study is to provide a contribution that can be used to partially answer the question whether investment in SSI is a viable option for the proposed agricultural led industrialization development strategy by assessing the financial viability of existing SSI. Supplementary to the main objective we also estimate the importance of agriculture to rural smallholders by estimating how much income is derived from agriculture compared to off farm sources. PASDEP aspires to develop and support SSI but the current farm level contribution of irrigation to the rural households is not known. This paper also aims to estimate the income impact of irrigation to smallholder producers

3. Methodology

The methodology we use is partially based on that used by Huang et al (2006) to evaluate benefits and costs of irrigation systems in China. We use gross margin analysis to estimate agricultural income for irrigators and non irrigators. Based on the gross margins, we estimate the income contribution of agriculture in general and irrigation in particular to the household.

In order to assess the financial viability of SSI we define three indices;

1. O & M index = GMI / O & M.
2. Financial performance index = GMI / (I + O& M.).
3. Replicability index = GMI – (I + O & M) / (I + O & M).

Where: GMI = Gross margin from irrigated production, O & M = Operation and maintenance costs, I = annual replacement cost all on a per ha basis. Annual replacement cost is computed as initial investment divided by project lifetime. Project lifetime is assumed to be 30 years (Innocencio, 2007). Verdier (1992) gives estimates of O & M for earth work (canals, drains, feeder roads with no tarmac) as 2 percent of investment, and concrete structures (river diversion, weir and inlet) as 1 percent of initial investment. In this study O & M is assumed to be 10 percent of annual replacement cost.

The first index shows farm level ability to recover O & M costs. If farmers cannot recover O & M, it renders the scheme non-financially viable. The second index shows whether farmers recover both initial investment and operation and maintenance costs. Ideally, in a financially viable scheme, both investment and O & M should be recovered. The third index shows whether farmers can recover both initial investment and operation and maintenance costs and still have the potential financial capacity to reinvest in a similar SSI system, in other words, could the schemes potentially financially perpetuate themselves.

4. Data collection

Data were collected on the initial investment or establishment costs for the small scale irrigation systems. During the growing season May 2005 to March 2006, plot level data were collected from ten SSI schemes. Data were collected on cropping patterns, areas under crops, yields, marketed output, inputs, and input and output prices. Since farmers usually grow at least two crops, sometimes three on the irrigated plots, the cropped area is summed across seasons. On each of the schemes, a random sample of 50 farmers was selected. A random sample of 50 non irrigating farmers was also selected from each site as a control. Data were also collected on non-agricultural income so as to estimate the contribution of agriculture and irrigation to household income.

During the summer most of SSI systems grow cereals like teff, maize and barley under supplementary irrigation given that it rains during the summer. During the winter farmers grow a variety of vegetables including onions, tomatoes, and leafy green vegetables like spinach under full irrigation. Rainfed farmers' production is primarily based on the staple cereals teff, wheat, barley and sorghum. Both rainfed and irrigating farmers also grow perennial crops like mango, banana, sugar cane which are sometimes intercropped with seasonal crops. Data were collected on all crops grown on a sampled farm.

During data collection we took cognizance of the fact that most of the cereal production is kept for home consumption. The computation of gross margins was based on data collected on yields and the prices of marketed output. For instance, if a farmer sold half of the wheat yield, we assumed that the prices realized in the market would have also been realized by the farmer if the rest had been sold. Although it is possible that if more produce is put on the market, prices tend to reduce we also argue that the shadow price attached to the retained output by the farmer has to be higher than the market price, assuming a rational farmer would sell if their shadow price is lower than the market price.

Most farmers, both irrigating and rainfed mainly grow seasonal crops but some do grow perennial crops. Data on the input-output relationships of seasonal crops were easier to collect than those of perennial crops. For instance, there could be some perennial crops intercropped and spaced within a seasonal crop. The area was better estimated for the seasonal crop than for the perennial crop. Even though in some cases of modern irrigation schemes where most the area was under a perennial crop like banana, the input-output relationships were still much easier and accurate for seasonal crops since the operations on the perennials are not as regular and consistent as on the seasonal crops. Based on these two observations, this analysis only includes the sites with seasonal crops.

5. Challenges in data collection

During the process of collecting the data on establishment costs, we realized that the data on small scale irrigation systems is not systematically collected and kept in a central location. The data, if available, could be found for different schemes in different locations, for instance in different ministries. Sometimes data were found in one location, like a ministry, but different departments. Furthermore, some data is kept at federal level, whereas other data are kept at regional and sometimes district level. Some regional authorities pass information to the federal level, for instance to the Ministry of Water Resources, but some simply do not. If a donor is involved in the project establishment, sometimes the donor keeps the records, if at all. This made the process of collecting establishment costs for even a small sample of SSI systems quite an arduous and time consuming task. Given this, even though we started off with 10 schemes, three traditional and 7 modern, we could only collect accurate investment information on all the modern schemes and only one traditional system. The Hare modern scheme was excluded from the sample for the reason of perennial crops as mentioned earlier so the final sample, for the financial viability analysis, was made up of one traditional and six modern schemes. Even though the data is still not centralized for modern schemes, the likelihood that it exists and that it can be accessed is higher for modern schemes than for traditional ones since the modern schemes are usually built with some form of government involvement at regional or federal level. The data for most traditional schemes is very difficult to come by. Bruns (1991) notes that there is a serious lack on information on SSI.

6. Income levels and dependence on agriculture and irrigation

Table 2 summarizes the cropped area and incomes for the sample farmers. The average irrigated area for all the sample irrigated systems is 0.71 ha, but is slightly higher for modern schemes at 0.76 ha while it averages 0.58 ha for traditional systems. The highest irrigated area is at Endris modern irrigation system at 1.07 ha while the lowest is at Haiba modern irrigated

system at 0.35 ha. Average cropped area for the rainfed farmers is 1.41 ha.
Table 2 also shows the extent to which the sample households depend on agriculture for income. In table 1, total income is the sum of agricultural income, irrigated and non

Table 1. Income dependence on irrigation for sample schemes.[1]

Region	**Site name**	**Site type** (Irrigation/Rainfed)	**Area (ha)** Irrigated[2]	Rainfed	**Income** Total[3] (USD)	Agricultural income % of total: Rainfed + irrigated	Irrigated
Oromia	Endris	Modern [n=42]	1.07 (1.20)	1.88 (1.46)	603 (975)	83	36
		Traditional [n=41]	0.65 (0.81)	1.40 (1.19)	471 (1198)	90	38
		Rainfed (n=55)	N/A	2.75 (1.47)	360 (288)	90	N/A
	Wedecha Belbella system	Modern [n=51]	0.46 (0.35)	1.13 (0.68)	771 (493)	92	44
		Traditional Filitino [n=52]	0.56 (0.41)	0.94 (0.47)	570 (404)	98	45
		Rainfed [n=57]	N/A	1.36 (0.59)	468 (315)	99	N/A
	Gologota	Modern [n=52]	0.96 (0.41)	N/A	713 (721)	88	86
		Rainfed [n=55]	N/A	1.39 (1.21)	304 (203)	71	N/A
Amhara	Zengeny	Modern [n=49]	0.85 (0.77)	0.76 (0.39)	552 (633)	91	58
		Rainfed [n=47]	N/A	0.81 (0.46)	261 (326)	90	N/A
	Tikurit	Traditional [n=55]	0.47 (0.49)	0.90 (0.86)	576 (639)	95	55
		Rainfed [n=42]	N/A	1.18 (0.76)	277 (164)	96	N/A
Tigray	Haiba	Modern [n=47]	0.35 (0.28)	0.73 (0.43)	346 (297)	82	34
		Rainfed [n=53]	N/A	0.72 (0.37)	240 (251)	80	N/A
	Golgol Raya (Kara Adishu)	Modern [n=26]	1.03 (0.60)	1.86 (1.15)	1100 (1071)	80	52
		Rainfed [n=22]	N/A	1.59 (0.89)	247 (320)	100	N/A
		All Modern [n=42]	0.76 (0.71)	1.16 (0.96)	650 (728)	87	53
		All Traditional [n=42]	0.58 (0.59)	1.09 (0.87)	536 (806)	95	45
		All Irrigated	0.71	1.13	616	89	50

[n=42]	(0.68)	(0.93)	(753)		
All rainfed	N/A	1.41	318	88	N/A
[n=42]		(1.12)	(278)		

1 ( ) = sdev; 2 = Gross irrigated area summed over the cropping seasons. 3= Total income (agricultural + non agricultural)

irrigated plus non agricultural income. Income from agriculture and that from irrigation is expressed as a percentage of total income to show the income dependence on agriculture and irrigation. For instance, the average annual income at Endris modern irrigation scheme is 603U SD. On average 83 percent of the 603 USD is derived from agriculture (irrigated and non-irrigated) and 36 percent of the 603 USD is derived from irrigated agriculture. Agricultural income at Endris modern irrigated system is about 500 USD and income from irrigated production is about 217 USD, meaning irrigated agriculture contributes slightly more than 43 percent of agricultural income, even though gross irrigated area is less than rainfed area. This makes agriculture a highly significant contributor to income for the smallholders, much more so than the dependence on agriculture depicted at national level. It also shows that irrigation, when made available, can play a significant role in contributing to the income of rural households particularly if we take into cognizance the small areas of irrigation developed per household.

For all irrigated systems, agricultural income constitutes about 90 percent of income, while it appears to contribute a slightly higher proportion on traditional irrigation systems. The lowest contribution of agricultural income is at Gologota rainfed system at 71 percent while it is highest for Golgol Raya rainfed farmers at 100 percent. This may be explained by the fact that Golgota is close to the capital city, several towns and public schemes which offer employment opportunities whereas Golgol Raya is several kilometers from the capital city and also has neither towns nor public schemes in its proximity, hence has limited off farm employment.

Irrigation contributes significantly to income at an average 50 percent for the whole irrigated sample while it appears to be slightly lower at traditional irrigated schemes at 45 percent. Given the significant contribution of irrigated agriculture to income, it is essential to establish if the systems are financially viable both in the long and short term.

One of the concerns raised by the World Bank (2006) is that, given the national dependence on rainfed agriculture, the performance of the economy is directly related to the quality of the rainfall season. We have demonstrated that this statement is even truer for rural smallholders whose incomes are a direct function of the quality of the rainfall season, given their high income dependence on agriculture. Irrigation, if it uses stored water, can be used to de-link the performance of the national economy, and more so the incomes of the rural poor smallholders from the quality of the rainfall season.

7. Investment levels for sample schemes

Table 2 summarizes the investment levels for the sample SSI schemes. Constant 2006 prices were used to make the figures comparable since the cropping data came from 2005/2006 growing season and the schemes were established at different times. The exchange rate of 1USD = 8.69 Birr which prevailed in 2006 (CIA, 2007) was used to convert the expenditures in Birr to USD. The average per ha initial investment cost is estimated at 2090 USD per ha. This estimate does not include possible contribution by the community on the form of labor and other materials. The data show that the systems are low financial investment irrigation projects as this is slightly under 40 percent of the figure quoted by Inocencio et al (2007) for success projects in SSA. Annual O & M costs were estimated as 10 percent of annual replacement costs.

Table 2. Investment levels for small scale irrigation schemes in constant 2006 prices

Region	Scheme name	Scheme type	Year established	Command area (ha)	Investment (USD/ha)		
					Initial Investment	Annual replacement	O&M
Oromia	Indris[1]	Modern	1980[4]	382	744.96[6]	24.83	2.48
	Gologota[1]	Modern	1962[4]	850	870.53[7]	29.02	2.90
	Wedecha	Modern	1990[5]	150	3436.89[8]	114.56	11.46
	Belbella system[2]	Traditional Filitino	1990[5]	85	2544.65[9]	84.82	8.48
Amhara	Zengeny[1]	Modern	1997[4]	270	1071.80[10]	35.73	3.57
Tigray	Haiba[2]	Modern	1997[4]	250	2087.52[11]	69.58	6.96
	Gol Gol Raya (Kara Adishu)[3]	Modern	2003[4]	104	3864.52[12]	128.82	12.88

Water source and delivery system: 1 River diversion and gravity, 2 Small dam and gravity, 3 Deep well and pressurized drip and sprinkler.

Year established: 4= actual, 5=based on feasibility study

Sources of Investment figures: 6. Indris Irrigation project. RID-OFFICE for C.Z. 1991. Porject proposal report. Information Brochure. Idris Irrigation Development project, 7. Average of sample modern schemes, 8. East Shoa Water Mineral and Energy Resources Department (1998). Goa Worka Small Scale irrigation Project Proposal Final Draft , 9. East Shoa Water Mineral and Energy Resources Department (1998). Filtino Small Scale irrigation Project Proposal Final Draft , 10. Personal communication Yenew Desalegn, Irrigation expert. Zengeny irrigation scheme, 11. Co-SAERT (1993).List of irrigation sites constructed by Co-SAERT from 1987-1992 E.C. Unpublished., 12. Raya Valley ground water Development report. Unpublished.

Note: Investment data for the traditional schemes at Endris and Tikurit t which are included in the income analysis, table 1, were not available.

Investment costs differ by site and region. It is beyond this paper to establish the reasons for the variations but this might partly depend on the water source and delivery system. The scheme with the highest establishment cost, Gol Gol Raya, has deep wells as water source and uses a pressurized drip and sprinkler system. We also note that for the two Wedecha Belbella systems, which are close to each other, the traditional system investment is lower, most likely reflecting less concrete infrastructure installed on the traditional system.

8. Assessing the financial viability of SSI

Table 3 summarizes the results of the financial viability analysis. Based on the

three indices defined above we get some insights into the financial viability of irrigated schemes. At the onset, we have to point out that this analysis only provides insights into the financial viability of these systems because it is based on one year's data. Given the variation of agricultural performance from year to year, ideally more than one year's data on gross margins would provide better insights. If more than one year's data is available, one could do many scenario analyses, one of which could be to use both the performance and replicability indices with a flow of gross margins and investment costs.

Table 3. Performance ratios for small scale irrigation systems

Region	Scheme name		Distribution within Performance Indices (%) Index Category	O & M	Financial	Replicability
Oromia	Indris		<0	5	5	11
			GE 0 < 1	0	5	14
			GE 1	95	90	74
			Mean	111	10	9
	Gologota		<0	10	10	10
			GE 0 < 1	0	0	2
			GE 1	90	90	88
			Mean	245	22	21
	Wedecha Belbella system	Modern	<0	2	2	8
			GE 0 < 1	0	6	10
			GE 1	98	92	82
			Mean	70	6	10
		Traditional	<0	0	0	4
			GE 0 < 1	0	4	12
			GE 1	100	96	84
			Mean	68	6	5
Amhara	Zengeny		<0	0	0	0
			GE 0 < 1	0	0	2
			GE 1	100	100	98
			Mean	141	13	12
Tigray	Haiba		<0	0	0	17
			GE 0 < 1	2	17	23
			GE 1	98	83	60
			Mean	65	6	5
	Gol Gol Raya (Kara Adishu)		<0	0	0	19
			GE 0 < 1	4	19	19
			GE 1	96	81	62
			Mean	39	4	3
	All Modern		<0	3	3	10
			GE 0 < 1	1	7	11
			GE 1	96	90	79
			Mean	119	11	10
	All		<0	2	3	9
			GE 0 < 1	1	6	11
			GE 1	97	91	80
			Mean	111	10	9

that takes into account the time value of money for both costs and returns flows in computing either an Internal Rate of Return and or Net Present Value. Alternatively, instead of computing an internal rate of return, one could also assume that farmers could borrow money at a certain interest rate, for instance the rate at which the government borrows for development projects, annualize the cost flows by the interest rate and then evaluate whether the farmers earn a return higher than the interest rate. We do understand that such analyses would be more informative than the one done here. However, we believe that in the absence of data to achieve such, our analysis is informative, even though at best, it gives us the performance of the systems for one year, say emulating the first year of the project.

In our suite of indices, the first index shows whether the systems recover operation and maintenance costs. If it is negative, irrigated income is less than O & M, if it lies between 0 and 1, O & M is only partially recovered and if it is greater than 1 O & M is fully recovered. The same interpretation applies for the financial performance ratio where instead of O & M the sum of annual replacement cost and O & M is used to determine cost recovery. The means for these indices shown in table 3 show that most of the schemes recover O & M. It is possible that we may have underestimated O & M, at 10 percent of investment, however, the degree to which most of the schemes recover O & M leaves a lot of room for O & M to increase substantially but still being recovered. The lowest O & M index mean value is 39 for Golgol Raya and the highest is 245 for Gologota. The low O & M index at Gologol Raya can be explained by the fact that the deep well water source combination with drip and sprinklers requires more maintenance than the diversion weir and gravity flow used in the other systems.

Of importance is also the percentage distribution of farmers between the ratios across systems. For instance, at Endris modern irrigation scheme, 95 percent of farmers fully cover their O & M costs, and 90 percent cover both investment and O & M costs. In comparison at Golgol Raya 96 percent fully cover O & M costs while 81 percent cover investment plus O & M costs. In general, at all the schemes, 90 percent or more cover O & M costs while the lowest percentage covering investment costs is at Golgol Raya at 81 percent. This shows that farmers have the ability to pay for both O & M and investment costs.

The replicability index asks the question if farmers were to pay for the current scheme and to concurrently invest in a similar one, could they manage it, in other words, could the systems potentially financially perpetuate themselves. The answer to this question is yes they could manage. The lowest percentage of farmers with this ratio greater than one is at Haiba with 60 percent, followed by Golgol Raya with 62 percent. We do understand that this analysis evaluates what could happen; otherwise the income earned from irrigation is subject to many competing family needs which generally do not include reinvestment. This is just a simple way of evaluating financial viability. From this simple analysis, the SSI systems are financially viable and could also potentially financially perpetuate themselves. Adams (1990) notes that, if they can be viable, SSI provide a low cost, low technology alternative to development.

9. Conclusions

The financial analysis shows that SSI projects in Ethiopia are very low investment ventures. From the three indices we used, we conclude that the systems are financially viable. However, it is important to note that only one year's data has been used in this analysis and therefore is missing the variability in returns that is characteristic of agricultural production. The financial viability performance is in line with the observations made by Inocencio et al (2007) of improved performance of recent irrigation projects in SSA. This makes investment in SSI a potentially viable low investment, development alternative.

We show the degree to which Ethiopian farmers depend on agricultural income, and specifically on irrigated income and how this varies by location. The analysis shows that SSI development has potential for improving the well being of the poor farmers through its significant impact on incomes.

It is important to note that all of the schemes evaluated in this study use diversion weirs, except one which uses underground water and another using a small dam, thus their performance dependends on the quality of the rainfall season. The schemes using diversion weirs although cheap to establish, cannot achieve one of the government's objectives of de-linking national economic performance and farmers' incomes from the quality of the rainfall season. The financial viability of these SSI systems however, provides insights into the fact that stored water could also be potentially used for SSI to de-link irrigation performance for the quality of the season. However, this needs to be evaluated against the investment costs for the stored water.

Finally, given the experience of collecting data on establishment costs for SSI, we conclude that data management and centralized systematic data collection of SSI investment and production data is definitely one area where there could be significant improvement in Ethiopia. Well organized data collection assists analyses that help inform decision making for policy makers.

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Importance of Irrigated Agriculture to the Ethiopian Economy: Capturing the direct net benefits of irrigation

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Abstract

Irrigation development is seen as one of the means to reduce poverty and promote economic growth. While a lot of effort is exerted towards irrigation development, little attempt is done to quantify the contribution of irrigation to national income in Ethiopia. This study is an attempt to quantify the actual and expected contribution of irrigation to the Ethiopian national economy for 2005/06 cropping season and 2009/10 using adjusted net gross margin analysis.

Our results show that irrigation in the study sites generates an average income of about USD 323/ ha. This compares to the calculated gross margin for rainfed which is USD 147/ha. This indicates that after accounting for annual investment replacement cost net gross margin from irrigation is more than twice higher than gross margin from rainfed agriculture. On the contribution of irrigation to national economy, in 2005/06 smallholder irrigated agriculture contributed about 262.3 million USD. This accounts for about 4.46 percent of the agricultural GDP in 2005/2006 and 1.97 percent of the total overall GDP. The total income earned from large scale schemes is estimated to be about 74.0 million USD. This accounts for about 1.26 percent of the agricultural and 0.5 percent of the total GDP respectively. Overall, the contribution of irrigation to agricultural and total national GDP was about 5.7 and 2.5 percent during the 2005/06 cropping season.

As a result of expansion, by the year 2009/2010 the expected contribution of

smallholder managed irrigation to national economy, assuming that exiting cropping pattern, and the average gross margin values for different crop categories are still valid, is expected to increase from USD 262.3 million in 2005/2006 to about USD 414.2 million in 2009/2010, which accounts to about 5.5 percent of the agricultural GDP and 2.3 of the overall GDP for the same year. On the other hand, the contribution coming from the large scale sugar growing estates in 2009/2010 is estimated to be USD 217.5 million which amounts to 2.9 and 1.2 percent of the agricultural and overall GDP respectively. Similarly the contribution coming from large scale commercial farms growing crops other than sugar cane is expected to increase to USD 35.8 million in 2009/2010 which accounts to 0.4 and 0.2 percent of the agricultural and overall GDP respectively. This implies that large scale commercial farms will contribute about 3.3 and 1.4 of the agricultural and overall GDP respectively. In summary, our results indicate that under conservative estimates the future contribution of irrigation to agricultural and overall GDP will be about 9 and 3.7 percent respectively.

When some of the assumptions related to cropping pattern, input and output prices,

and efficiency levels are relaxed, the contribution of smallholder managed irrigation to agricultural and overall GDP will vary between 4 to 6 and 1.8 to 1.9 percent respectively. Similarly, the contribution from large scale irrigation to agricultural and overall GDP will be in the range of 3 to 6 and 1.2 to 2.5 percent respectively. Overall, the future contribution of irrigation to agricultural GDP will be in the range of 7 to 12 percent while the contribution to overall GDP will be in the range of about 4 percent. To enhance the contribution of irrigation to national economy, besides increasing the presence of physical water infrastructure, however, there is a need to: i) improve provision of agricultural inputs, ii) promote high value crops through the extension system, iii) create good market conditions, and iv) increase the efficiency of small and large schemes.

1. Introduction

Unreliable rainfall, recurrent drought and limited use of the available water resources, coupled with heavy reliance on rain-fed subsistence agriculture, have contributed adversely to the economy of Ethiopia. In fact, the World Bank (2006) estimates that unmitigated hydrological variability currently costs the economy over one-third of its growth potential and leads to 25 percent increase in poverty rates. Hence, enhancing public and private investment in irrigation development has been identified as one of the core strategies aimed to de-link economic performance from rainfall and to enable sustainable growth and development (World Bank 2006; MoWRa, 2002; MoWR, 2002b; MOFED, 2006). In the government policy documents, irrigation development is identified as an important tool to stimulate sustainable economic growth and rural development and is considered as a corner stone of food security and poverty reduction (MoWRa, 2002; MoWR, 2002b; MOFED, 2006).

Ethiopia is said to have an estimated irrigation potential of 3.5 million hectares (Awulachew et al. 2007). However, the total estimated area of irrigated agriculture in the country in 2005/2006 was 625,819 ha, which in total constitutes about 18 percent of the potential (MOWR, 2007).

Irrigation is expected to contribute to the national economy in several ways. At the micro level, irrigation could lead to an increase in yield per hectare and subsequent increases in income, consumption and food security (Bhattarai and Pandy, 1997; Vaidynathanet al., 1994; Ahmed and Sampath, 1992; Lipton et al. 2003; Hussain and Hanjra, 2004). Furthermore, Hussain and Hanjra (2004), based on their studies in Asia, indicated that irrigation benefits the poor through higher production, higher yields, lower risks of crop failure, and higher and year round farm and non-farm employment. Irrigation enables smallholders to adopt more diversified cropping pattern, and to switch from low value subsistence production to high-value market-oriented production (Hagos et al., 2007).

Macro level impacts manifest themselves through agricultural impacts on economic growth. At the aggregate level irrigation investments act as production and supply shifters, and have a positive effect on economic growth. Studies in Asia show that agricultural growth serves as an “engine” of economic growth, and irrigation-led technological changes are the key drivers behind productivity growth in the agricultural sector (Hussain and Hanjra 2004; Alagh, 2001; Dhawan, 1988). Other effects of irrigation on changes in the environment and other social impacts have been reported in the literature such as on the economic value of wetlands (Barbier and Thompson, 1998); employment impact of irrigation (Berck and Hoffman, 2002) and non-farm sector benefits from irrigation investment (Bhattarai, et al. 2003).

The methodological approaches applied to capture these diverse impacts of irrigation varied from linear programming, to regression models, to partial equilibrium models, to economy–wide models such as input-output models, Social Accounting Matrices (SAM) and Computable General Equilibrium (CGE) Models. For instance, Bhattarai and Pandy (1997) used a linear programming technique to isolate the impact of irrigation from other factors (such as road and market) on crop production and productivity in Nepal. Vaidynathan et al. (1994) used regression analysis at the aggregate level to assess the difference in land productivity between irrigated and un irrigated lands in India. Ahmed and Sampath (1992) used a partial equilibrium model that incorporates demand and supply shifts to assess the impact of irrigation on efficiency and equity in Bangladesh. Makombe (2000) used a similar partial equilibrium model to estimate the impact of irrigation induced technological change in Zimbabwe. Bell and Hazel (1980) used SAM and a semi input-out model to measure the magnitude and incidence of regional downstream effects of the Muda irrigation project in Malaysia. While there are various studies that have tried to capture the diverse impacts of irrigation, there are, however, few studies that attempted to capture the direct contribution of irrigation to the national economy. One such study is by Doak et al., (2004) and Doak (2005) which develop a simple methodological framework to measure the economic value of irrigation to the New Zealand's National economy. Our study builds on the approach followed by Doak et al., (2004) and Doak (2005).

The objective of this study, hence, was to estimate the net contribution of irrigation to GDP at the farm gate. This study attempted only to capture the direct benefits of irrigation to national economy for a given year (2005/2006) using a farm gate value approach and made forecasts on its future contribution based on the projected annual growth-rate of irrigated areas in the National Irrigation Development Program (MoWR, 2002b; MOFED, 2006) and associated changes in cropping patterns. In so doing, we tried to determine how much irrigation is contributing and will contribute to national income relative to rain fed agriculture. This method of adjusted gross margin analysis accords with the System of Environmental and Economic Accounts (SEEA) recommendations (UN, 2003) and provides a "best estimate" of the change in GDP generated by irrigation at the farm gate (Doak, 2005). However, it should be noted that a large number of estimates and assumptions are required to estimate the impact on GDP, and the results should be interpreted with caution. In addition, the increased output from irrigated farms will have different multiplier effects in the wider economy, so the total impact of irrigation on GDP is likely to be higher than the farm gate impact.

For estimating the contribution of smallholder irrigation we relied on data collected during the 2005/6 season from eight smallholder irrigation schemes in four regional states in Ethiopia, namely Amhara, Oromia, Southern Nations Nationalities and Peoples Regional Government (SNNPR) and Tigray. The data collected included command area, actual cultivated area cropping pattern, output types and value, input use and input expenditure and information on the level of operation, (e.g. fully operational, medium, low or not operational). Moreover, we used secondary data gathered from selected large scale commercial farms in the Awash and Nile Valleys and price data and production data from the Central Statistical Authority (CSA).

The research report is presented as follows. Section two outlines the methodology used to value the contribution of irrigation to the national economy followed by presentation of data sources in section three. In section four we present an overview of the contribution of agriculture to national economy while section five outlines the hitherto irrigation development in Ethiopia followed by, in section six and seven, by presentation of agricultural production and cropping pattern, both rainfed and irrigated respectively. In section eight, we present the envisaged future expansion of irrigated agriculture based on the National Irrigation Development Program (IDP). Sections nine and ten present the results of the valuation, current and future, to national economy. In section eleven, we conduct sensitivity analysis to take account of possible changes in cropping patterns and crop cover, in input and output prices and improvements in efficiency levels. The final part concludes and draws some policy recommendations.

2. Methodology in valuing the contribution of irrigation for the national income

The methodology calculates the contribution of existing irrigation to gross domestic product (GDP) by taking into account the alternative rainfed production from the same area of land. The method adopted follows a "with minus without" irrigation approach, adjusted for changes in farm type and scale.

Following Doak (2005) the formula is:
Farm gate GDP due to irrigation = GDP with irrigation – GDP without irrigation.
*= (irrigated land use mix * (irrigated Gross Margin – fixed costs)) – (rainfed land use mix * (rainfed Gross Margin – fixed costs)).*

(1)

A gross margin is the total revenue associated with a particular production (income) less the costs that clearly vary in direct proportion to the level of production - the direct or variable costs associated with the enterprise. Gross margin analysis is an accepted tool commonly used in the evaluation of farming enterprises. It has been used for the evaluation of the costs and benefits of irrigation in cost benefit analysis. Assessing the change to the gross margin per unit area as a result of irrigation and then scaling this appropriately by the total affected area provides an initial estimate of the GDP change (at the farm gate) likely to occur as a result of irrigation.

In the Ethiopian context, farmers use full irrigation to grow crops during the dry season when crop production from rain is not possible. This implies that households get additional income from irrigation to that what farmers get during the main cropping season. Under small scale irrigation system, irrigation does not replace rain fed agriculture but supplements it. Large scale schemes, however, are under full irrigation throughout the year. We made adjustments in the methodology to take account of this difference between small and large scale irrigation. Hence, for a given farmer i under smallholder agriculture,

$$NetIncome_i = Netm\arg in_{irrig} + Netm\arg in_{rf} \qquad (2),$$

where the total income constitutes of income from rainfed and income from irrigation.

The gross margins (GMs) were determined for farm types in each of the schemes and aggregated to a scheme scale throughout Ethiopia based on the data obtained from the household surveys and secondary sources. The gross margins are those for the 2005/06 season and are defined as the revenue generated from the activity less the direct costs of producing the revenue. The Gross Margins were adjusted to account for the differences in overheads (fixed costs) of land uses with and without irrigation, and also for differences in shadow prices of labor and oxen in irrigated and rain fed systems (for the small scale schemes). Shadow prices of labor and oxen were estimated from the production data by first estimating labor elasticity, which was used to estimated the marginal value of labor, in a production function framework (for details see Jacoby, 1993).

The "without irrigation" land use is that which would now exist if irrigation had not been developed, rather than if irrigation was no longer available for that particular land. This was estimated based on GM of rain fed agriculture around the scheme or average GM value for all rainfed, if data for adjacent rainfed plots were not available. The value of irrigated production and the value of production from the rainfed use that would be most likely if there was no irrigation were derived from the survey data for each scheme. For the large scale schemes, we explored the dominant rainfed production type and estimated average gross margins per ha from the household survey.

The assumption here is that all of the now irrigated lands would have been under some sort of rain-fed farming had it not been converted to irrigation plots. There are also some other possible scenarios. It is possible that some of the current irrigated lands are hitherto uncultivated lands or new openings[5]. If this is true, the methodology we adopted may underestimate the true contribution of irrigation development without considering the environmental costs of such changes. It may be that the current irrigated land may have been used for grazing livestock[6]. The direction of bias on our estimation depends on whether the gross margin per unit area from livestock rearing is greater or less than the gross margin per unit area for cropping under rainfed. While a meaningful analysis should take account of these diverse scenarios, the lack of data on livestock productivity under pastoral production in Ethiopia and environmental costs of land use change made it impossible. Hence, the approach described above (in equations 1 and 2) was used to assess the current and future contribution of irrigation to the national economy.

For the fixed cost, we calculated an annual replacement cost all on per ha basis. Annual replacement cost was computed as initial investment divided by project lifetime (25 years) and O & M was assumed to be 10 percent of annual replacement for small scale schemes and 50 yrs and 5 percent for large scale schemes (Inocencio et al., 2007).

In estimating the future contribution of irrigation to national economy, we used information about the expected growth of the irrigation sector during 2005/2006 to 2009/2010 based on the country's Irrigation Development Program (IDP) (MoWR, 2006; World Bank, 2006; MOFED, 2006). These policy documents outline how irrigation is expected to develop over the planning period. The details are provided in section eight of this paper.

A complex issue related to the calculation of the future contribution of irrigation to the national economy is how to address the impact of increased output on price. Gross margin calculations generally assume that a change in output has no effect on prices. While for small-scale changes at the individual farm level this may well approximate the truth[7], the large-scale land use changes generated by irrigation on the national scale are believed to be sufficient to have some measurable effect on output prices. Lipton et al. (2003) state that if irrigation leads to increases in staples or non-staple food output then this may result in lower prices for staples and food in imperfectly open economies or if there are significant transport costs from food-surplus area to towns or food deficit areas. For crops that are largely dependent on the local market and for which there is little opportunity to develop large-scale export markets increases in production tend to have a dramatic effect on price (Doek, et al., 2004). A complicating factor in assessing the impact of future irrigation-driven increases in output on price is also that growers of annual crops are very flexible in the combinations of crops that they choose to grow (Doak et al., 2004). If, for example,

[5] The development of Finchaaa Sugar estate is a case in point.

[6] The development irrigation in the middle and lower Awash is a case in point.

[7] Even at the small scale, we observe increases in crop output of tomato and onion leading to crashes in prices.

potatoes are in over supply, growers would switch to another crop which proves more profitable. The farmer is, therefore, able to choose the most profitable product to produce, and to increase the value of the product e.g., by producing at a time of the year when price is highest, or by increasing the quality of the product (for example, through improved fruit size). There is also the possibility that as irrigation expands, it tends to get more government support e.g. extension and hence intensification can increase. This upside potential has by and large been included in the analysis. We suggested possible scenarios in changes in cropping patterns. However, it is difficult to exactly forecast the possible future changes in cropping patterns. The crop combinations and gross margins used in the analysis are, therefore, only indicative of a range of possible crops with similar outcomes.

To quantify the price effect of irrigation development we assumed different price scenarios based on certain assumptions about demand growth and output growth. In the light of all these considerations, we assumed different price changes in price of the major produce when assessing the impact of future irrigation driven increases in output. This is described in detail in section ten of this report.

Finally, there are a host of multiplier effects expected to manifest themselves with irrigation development, including expansion of the off-farm sector, provision of inputs to industry and better nutrition for rural households. These effects are not captured in this study. Our calculated GDP represents, at best, the return to producers' labor and capital (including capital tied up in land). It is also worth noting that the high income sector of irrigation (emerging flower farming and capital intensive commercial farms are not included in our assessment. Our method therefore underestimates the true contribution of irrigation to GDP.

3. Data sources

This study made use of both primary data on smallholder production collected from household surveys and data from various secondary sources. The household survey was part of a comprehensive nationwide study on the impacts of irrigation on poverty and environment run between 2004 and 2007 in Ethiopia. It was a component of the Impact of Irrigation on Poverty and Environment (IIPE) research project run by the International Water Management Institute (IWMI) with support from the Austrian government. The survey, which investigated the impact of irrigation on poverty and irrigation's contribution to national economy, addressed a total sample size of 1024 households from eight irrigation sites in 4 regional states involving traditional and modern and rainfed systems. The total sample comprised 397 households practicing purely rainfed agriculture and 627 households (382 modern and 245 traditional) practice irrigated agriculture. These households operate a total of 4,953 plots (a household operating five plots on average). The data collected include demographics, asset holdings, access to services, plot level production and sale and input use data (distinguished between irrigated and rain fed), constraints to agricultural production and household perceptions about the impact of irrigation on poverty, environment and health and other household and site specific data. The data were collected for the 2005/2006 cropping season. We used part of this comprehensive dataset for the analysis here.

We also used secondary data from various sources. From the large scale schemes we gathered data on investment cost/initial capital outlays, cost of production, output and revenue among others. From official documents such as the policy documents of the government (MoWR, 2006; World Bank, 2006; MoFED, 2006) we gathered developed and projected irrigation development plans and we used land utilization and crop cover data from the Central Statistics Agency (CSA, 2006). Furthermore, for specific data on future expansion and new development plans on sugar estates we used the revised master plan of the Ethiopian Sugar Development Agency (ESDA, 2007). The plans for the development of small scale irrigation are prepared by the regional governments and are compiled by the Ministry of Agriculture and Rural Development that oversees the development of the sub-sector.

4. Contribution of agriculture to national economy

Agriculture is the main stay of the Ethiopian economy. It is major contributor to the national economy both in terms of income, employment and generation of export revenue. Its contribution to GDP, although showing slight decline over the years, has remained very high, about 44 percent. From among the sub-sectors of agriculture, crop production is major contributor to GDP accounting for about 28 percent in 2005/06. The most important crops grown and their area coverage are described in section six and seven.

Table 1: Contribution of Agriculture to GDP (in 000 Birr) (1995/96-2005/06)

Year	GDP at Current Market Prices	Agricultural GDP	Crop GDP	Agri contribution to GDP	Crop contribution to GDP
1995/96	53,597,593	28,613,235	17,286,203	0.53	0.32
1996/97	55,520,011	28,767,766	16,764,422	0.52	0.30
1997/98	53,391,285	25,214,701	14,505,336	0.47	0.27
1998/99	57,368,203	25,397,662	15,500,013	0.44	0.27
1999/00	64,397,933	28,444,382	17,713,717	0.44	0.28
2000/01	65,687,343	27,750,560	16,333,285	0.42	0.25
2001/02	63,461,569	24,460,704	13,135,220	0.39	0.21
2002/03	68,898,037	26,207,930	14,963,341	0.38	0.22
2003/04	81,754,514	32,229,991	19,746,954	0.39	0.24
2004/05	98,397,946	42,196,370	27,349,050	0.43	0.28
2005/06	115,589,480	50,893,906	32,246,432	0.44	0.28

Source: FDRE (2006).

5. Overview of irrigation development in Ethiopia

Ethiopia is said to have an estimated irrigation potential of 3.5 million hectares of irrigation land (Awulachew et al. 2007)[8]. The total estimated area of irrigated agriculture in the country is about in 2005/2006 was 625,819 ha, out of which 483, 472 is from the traditional irrigation, 56032 ha is from modern small scale,

[8] Other estimates put it in the order of 3.7 million hectares (MoWR, 2002; World Bank, 2006).

86,612 ha is from modern medium and large scale schemes. Out of the total irrigated area, 197,250 ha is covered by the so-called modern schemes while the remaining area traditional schemes (MoWR, 2002). The total and modern irrigated area account for about 17 and 5 percent of the potential respectively. The total cultivated land area, rainfed included, in 2005/06 was about 12.28 million hectares (MOFED, 2006). The total current irrigated land area, hence, accounts for about 5 percent of the total cultivated land. When the traditional schemes are not considered, the irrigated land area covers a minimum of about 1.6 percent of the total cultivated area.

There is high spatial variability in water resources endowment and development in the country. Hence, ninety percent of the country's water resources development occurs in four river basins (World Bank, 2006). Much of the formal irrigation developments are located in the Awash Basin, where about 50 medium- and large scale irrigated farms are located (Fig. 1).

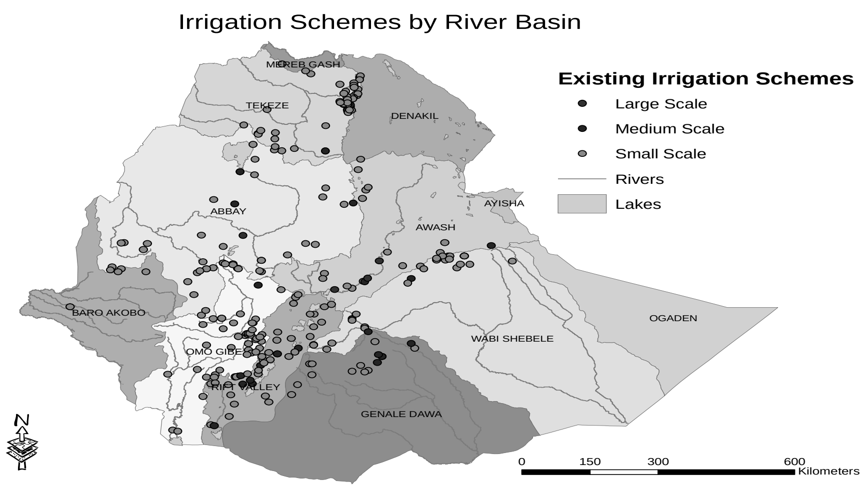

Fig.1: Existing Irrigation Schemes in various river basins in Ethiopia (Source: Awulachew, et al. 2007)

In terms of regional distribution, Afar and Oromia have the bulk of the share in irrigated agriculture accounting for 45 and 31 percent of the total irrigated area. Amhara, SNNPR and Tigray account for 8, 7 and 5 percent of the total irrigated area respectively (Awulachew, et al. 2007).

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6. Agriculture production and cropping pattern

Based on Central Statistics Agency's 2005/06 agricultural sample survey (CSA, 2006), the major crops during the main rainy season (a.k.a ***meher season***) are cereals, pulses, oilseeds, vegetables, root crops, fruit crops, stimulant crops[9] and sugar cane. Cereals are the dominant food crops covering 58 % of the land area[10] and 87 % of the volume of grain production[11] (See Fig 2). The major cereal crops include: teff (*Eragrostis tef*), barley (*Hordeum vulgare)*, wheat (*Triticum durum*), maize (*Zea mays)*, sorghum (*Sorghum bicolour*) and finger

[9] Stimulant crops consist of Chat, coffee and hops.

[10] Total cultivated land area during 2005/06 cropping season was estimated at 12.28 million hectares.

[11] Total volume of agricultural produce during 2005/06 cropping season was 133. 1 million quintals. A quintal is equivalent to 100 kgs.

millet (*Eleusine coracana*). Teff, maize, sorghum and wheat took up 22, 15, 14 and 14 percent of the grain crop area, respectively. Maize, wheat, Teff and sorghum made up 25, 17, 16 and 16 percent of the grain production in the same order.

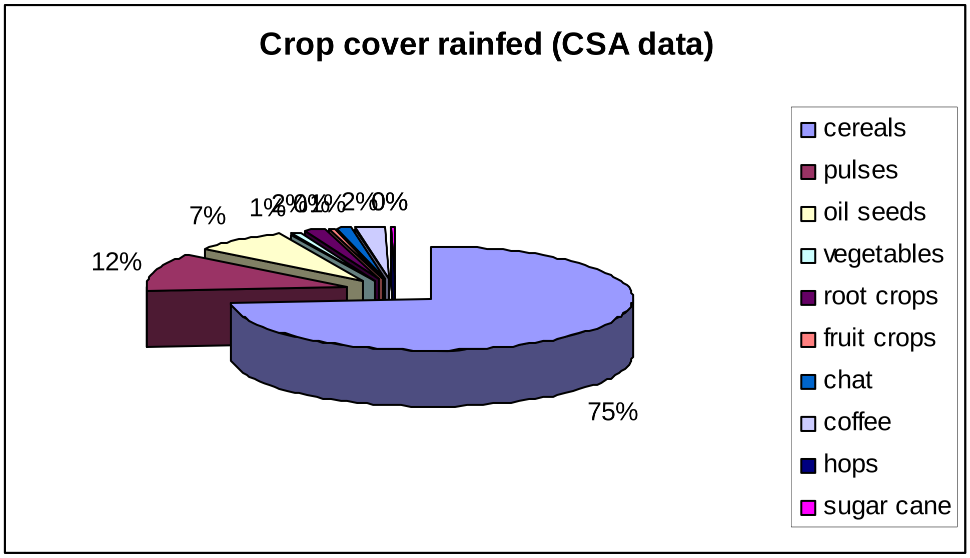


Fig 2: Crop cover during the ***Meher*** season of 2005/2006 (Source: CSA (2006))

Pulses grown in 2005/06 covered 12.7 % of the grain crop area and 9.5 % of the grain production. Faba beans (*Vicia faba*), field peas (*Pisum sativum)* and chick-peas (*Cicer arietinum*) were planted on 4.5, 2.29 and 1.98 percent of the grain crop area. The production obtained from the same crops was 3.8, 1.4 and 1.6 percent of the grain production.

Oilseeds comprised 7.8% of the grain crop area and 3.6% of the production to the national grain total. Neug (*Guizotia abyssinca*), linseed (*Linum sativum*) and sesame (*Sesamum indicum*) covered 3.0, 2.1 and 2.0 of the grain crop area and 1.1, 0.9 and 1.1 of the grain production.

Vegetables took up 1.1% of the area under all crops at national level. Of all the area under vegetables 69 and 19 percent was under red peppers and Ethiopian Cabbage (*Brassica carinata*), respectively. As to production of vegetables, 39.8 and 40.2 percent was that of the same crops.

Root crops covered more than 1.6% of the area under all crops in the country. Potatoes, sweet potatoes and taro covered 36.5, 29.7 and 15.1 percent of the area to the root crop total. The same crops and onion contributed 33.7, 30.6, 12.9 and 13.2 percent to the root crop production in the same order.

More than 45 thousand hectares of land is under fruit crops in Ethiopia. Bananas contributed about 62.4% of the fruit crop area followed by mangoes that contributed 12% of the area. Nearly 4.3 million quintals of fruits was produced in the country in 2005/2006. Bananas, Papayas, mangoes and oranges took up 49.4, 16.6, 12.8 and 11.8 percent of the fruit production, respectively.

The area and production of chat and coffee are larger than that of fruits since they earn a considerable amount of cash for the holders. Chat (*Catus adulis*) and coffee shared 1.24 and 2.39 percent of the area under all crops in the country and 1.2 and 1.7 million quintals of produce was obtained from these crops in the same agricultural year respectively.

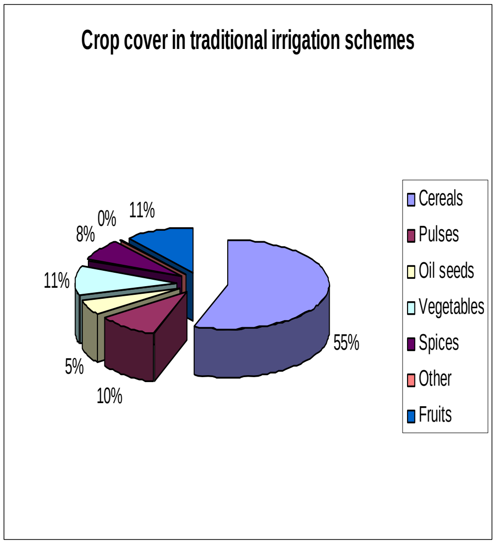
Sugar Cane is grown on about 19 thousand hectares of land in the country, yielding 16.1 million quintals of produce by the peasant holders.

7. Irrigation typologies and cropping patterns

In the Ethiopian context, the irrigation sub-sector is classified as small (less than 200 ha), medium (200 to 3000 ha) and large-scale (over 3000 ha) schemes (MoWR 2002a; Awulachew et al., 2005). Small scale irrigation schemes are considered as traditional if the diversion weirs are made from local material which needs annual reconstruction. The canals are usually earthen and the schemes are managed by the community. Many are constructed by local community effort and have been functional for relatively longer periods of time. On the other hand, small scale schemes are considered as modern schemes if they have more permanent diversion weirs made from concrete, and the primary and sometimes secondary canals are made of concrete. They are generally community managed and have recently been constructed by government or NGO. Werfring (2004) and Makombe et al. (2007) describe the typology of small scale irrigation in Ethiopia, the former in more detail. Small and medium scale schemes grow cereals as main crops. During the main rainy season most of small and medium scale irrigation schemes grow cereals like teff, maize and barley, with little or no supplementary irrigation, under rain fed conditions. During the dry season farmers grow cereals and a variety of vegetables including onions, tomatoes, and leafy green vegetables like lettuce under full irrigation. Farmers also grow perennial crops like mango, banana, sugar cane which are sometimes intercropped with seasonal crops.

From our survey data, we present below the composition of crops under irrigated and rain fed conditions. We made the distinction between traditional and modern irrigation schemes while looking into cropping composition. We clustered crops into different categories; namely, cereals, pulses, oil seeds, spices, vegetables, fruits and others and calculated area cover (as percentage of the total area) for these different crop categories in the different systems. The dominant crop categories under traditional irrigation system, in terms of the percentage area covered are: cereals (55%), vegetables (11%), fruits (11%), pulses (10%), spices (8%), oil seeds (5%), and others (0.2%) (Figure 3a). In the modern irrigation systems, in the order of importance, the dominant crops are: cereals (67%), vegetables (17%), fruits (4%), pulses (3%), spices (0.2%), oil seeds (0.4%), and others (5 %) (Figure 3b).

Under the rainfed agricultural system the dominant crops are: cereals (77%), pulses (16 %), vegetables (1.3 %), fruits (1%), oil seeds (1%), spices (0.4%), and others (3.3 %) (Figure 3c).



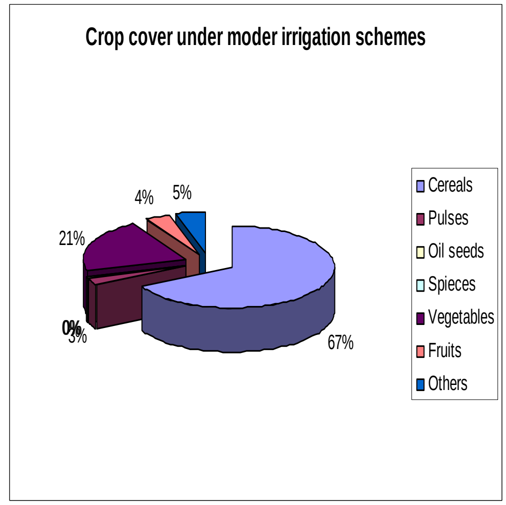


Fig. 3a: Dominant crops under traditional irrigation system (n= 1240) Fig. 3b: Dominant crops under modern irrigation system (n= 2092)

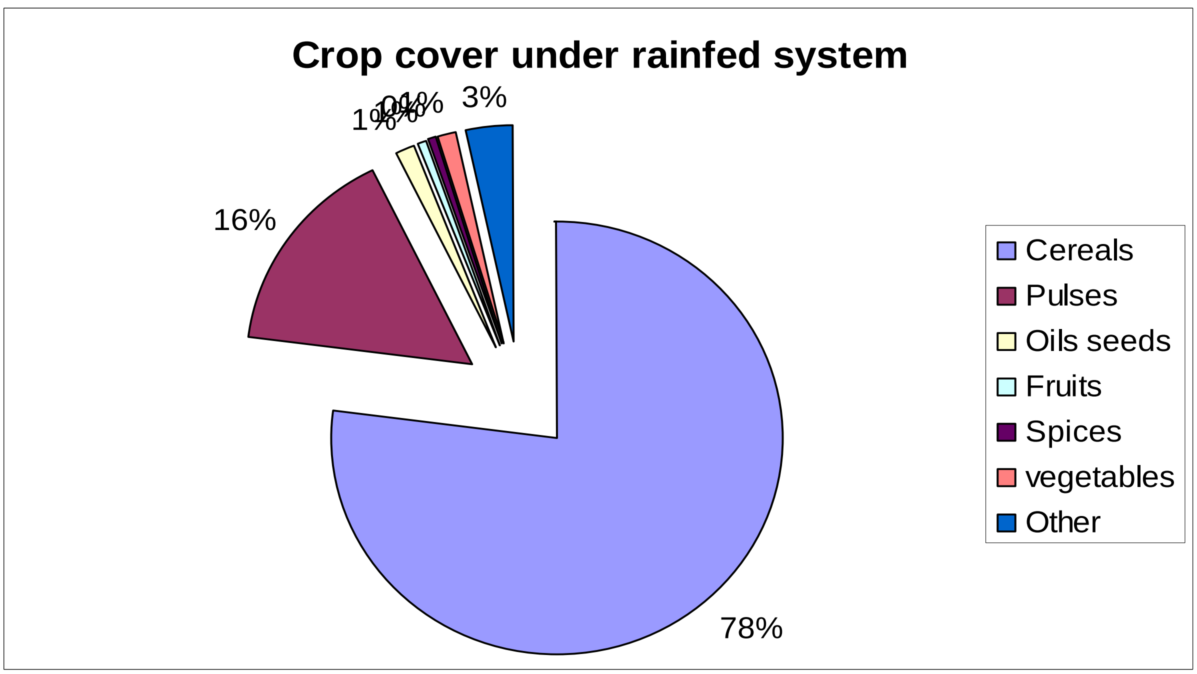


Fig. 3c: Dominant crops under modern rain fed system (n= 1533)

The figures above show that there is difference in the relative importance of the crop categories under different systems. Cereals and pulses are dominant under rainfed system while vegetables and fruits cover about 2 percent of the land area. While cereals still remain dominant under the irrigation systems, covering about 61 percent of the land area, vegetables and fruits become important under both traditional and modern systems. There is also noticeable difference in the share of land taken by vegetables and fruits between the modern and traditional irrigation systems. Vegetables take more land area under the modern systems compared to that of traditional systems while more land area is covered with fruit tress under the traditional system indicating perhaps the

difference in age between the two type of systems.
Large-scale irrigation schemes, on the other hand, grow mainly sugar cane, cotton and fruits and vegetables. Wonji/Shoa, Metehara and Finchaa schemes grow sugar cane, while the Amibara and Upper Awash schemes grow cotton and Fruits and vegetables respectively (see Table 2)

Table 2: Large scale schemes under irrigation and type of cropping

Region	Scheme name	Major crop	Area 2005/06 (in ha)
Afar	Amibara (Middle Awash)	Cotton	6448
Oromia	Finchaa sugar plantation	Sugar cane	7185
Oromia	Metehara sugar plantation	Sugar cane	10145.9
Oromia	Upper Awash	Vegetables & fruits	6017.34
Oromia	Wonji/Shoa sugar plantation	Sugar cane	4094

Source: ESDA (2007); MOFED (2006);

8. Future expansion of irrigation development in the country

The Irrigation Development Program (IDP) as set out in the government's Plan for Accelerated and Sustained Development to End Poverty (PASDEP) document (2005/06-2009/10) envisages the expansion of irrigation in the country by an additional 430,061 ha by the year 2010 (MoWR, 2006; MOFED, 2006). This will consist of mainly medium and large scale schemes. Accordingly, 39 significant irrigation projects are planned to be implemented during the PASDEP period. These include World Bank project around Tana (100,000 ha); Anger Negesso Project in Oromia (49,563 ha); Humera project in Tigray (42,965 ha); Kessem Tendaho in Afar (90,000 ha); Upper Beles in Benishangul Gumz (53,000 ha) and Ilo-Uen Buldoho (32,000 ha) in Somali (MOFED, 2006; MoWR, 2006). Most of these irrigation schemes will be community managed schemes to be used by small scale farmers. Exceptions are the schemes to be developed in the Awash basin which will mainly involve expansion of the already existing large scale schemes or development of new ones (see Table 3). About 90,000 ha of irrigation land will be developed in Kesem and Tendaho to grow sugar cane while there are planned expansions in the already existing sugar plantations. Overall, by the year 2010 there will an additional 122,000 ha of irrigated land developed to grow sugar cane (ESDA, 2007).

There are also parallel plans to develop 98,625 ha under small scale irrigation by the regional governments (Atnafu, 2007). The total extension to irrigated area by the year 2009/10 compared to 2005/2006 will be in the range of 528,686 ha. This implies that further development will extend the irrigated area to about cover 33 percent of the irrigated potential and about 9 percent of the total cultivated land area. These plans are used as indicative targets for future irrigation development for valuing the future contribution of irrigation to the national economy.

Table 3: Future development plans of large scale schemes

Region	Scheme name	Main crop	Future expansion/development until 2010 (in ha)
Oromia	Finchaaa	Sugar cane	12000
Afar	Kesem	Sugar cane	40000
Oromia	Metehara	Sugar cane	10000
Afar	Tendaho	Sugar cane	50000
Oromia	Wonji/Shoa	Sugar cane	10000

Source: ESDA (2007)

9. Value of irrigation to national economy

The contribution of agriculture to national economy is estimated on the basis of the estimated production during the ***Meher*** (main rainy season) and the ***Belg*** seasons (small rainy season) (BOFED, 2006). We assume that the contribution from irrigation is included in the production during the ***Belg season,*** although not explicitly stated in the document**.** Farmers use full irrigation to grow crops during the dry season when crop production using rain is not possible. This implies that household's get additional income from irrigation in comparison to farmers who can only grow during the main rainy season. Under small scale irrigation system, irrigation does not replace rainfed agriculture but supplements it. Large scale schemes, however, are under full irrigation through out the year.

Based on the net gross margin calculations (see table 4), irrigation in the study sites generates an average income of about Birr 2800 /ha, which is equivalent to USD 323/ ha[12]. This compares to the calculated gross margin for rainfed which is USD 147/ha. This indicates that after accounting for annual investment replacement cost, net gross margin from irrigation is more than two times higher than gross margin from rainfed agriculture.

When we disaggregate net income by irrigation typology, we also see a strong difference between the categories. Average income from small scale but modern schemes is about USD 355/ha while from small scale traditional is about USD 477/ha. This may sound counter intuitive in the sense that schemes with permanent structures and well lined canals should have led to better returns. The reason for higher margins for traditional schemes may have to do with high average investment cost of modern schemes compared to the traditional ones. The relatively longer irrigation experience and, hence, acquired improved irrigated crop management practices of farmers working and the composition of crops grown under traditional system may also contribute to this difference. The development of modern irrigation schemes is a recent phenomenon in Ethiopia.

There are also huge inter-scheme differences in income within the same typology which could be attributed to relative difference in irrigation experience and access to market. When it comes to medium scale irrigation schemes, the average income from modern irrigation schemes was USD 400/ha. We do not know the corresponding figure for a traditional medium scale scheme as we did not have such a scheme in our sample. We assumed in this study that the average net income from a traditional medium scale scheme is USD 400.

[12] 1 USD was equivalent to 8.67 ETB in 2005/06 prices.

Table 4: Gross margin calculation from small and medium scale irrigation schemes

Scheme name	**Scheme scale**	**Typology**	**Area (in ha)**	**AFC**	**GM/ha rain fed**	**GM/ha irrigated**	**GI minus FC**	**Total income**
Indris	Medium	Modern/ traditional	382	74	429	1850	1776	678571
Gologota	Medium	Modern	850	303	1068	7596	7293	6199193
WBS	Medium	Modern/ traditional	685	200	1485	2603	2402	1645656
Tikurit	Small	Traditional	102	91	1353	4140	4050	413081
Zengeny	Small	Modern	270	222	1971	3375	3152	851160
Haiba	Small	Modern	250	437	1585	2795	2358	589537
Golgol Raya	Micro irrigation	Modern	104	1372	1710	2240	868	90280
Hare	Medium	Modern/ traditional	1345	159	646	950	791	1064206

Source: Own calculation

Taking the average income from smallholder managed small and medium scale irrigation schemes in the country and the total hectarage for both categories, we calculated the total income driven from irrigation to be Birr 2.27 billion (about 262.3 million USD). This accounts for about 4.46 percent of the agricultural GDP in 2005/2006 and 1.97 percent of the total GDP.

Table 5: Gross margin calculation from large scale irrigation schemes

Scheme name	**Main crop**	**Area (in ha)**	**Average investment cost/ ha**	**Annual recovery cost/ ha**	**Total GM (in million)**	**GM per ha**	**Net income**	**Total income**
Amibara*	cotton	5358	11418	228	13.8	1212	984	5270343
Finchaa	sugar cane	7185	62672	1253	184.4	2943	1689	12137261
Metehara	sugar cane	10146	9303	186	303.7	32649	32463	32936660
Upper Awash	fruits & vegetables	6017	3793	76	62.9	16594	16518	99396889
Wonji/Shoa**	Sugar cane	4094	35987	720	439.3	12210	11490	47040510

* Based on 2004/2005 estimate
** Average investment cost for Wonji is taken as the average for Metehara and Finchaa

When it comes to valuation of the contribution from large scale schemes, we followed strictly the approach outlined in section two. Hence, in calculating net income from large scale schemes we deducted the contribution of rainfed from the net income obtained under irrigation to account for the income foregone for not using the land under rainfed production. The rationale behind this is that irrigation in the large scale schemes is full season devoid of any possibilities to practice rain fed agriculture. Before netting out the contribution coming from rainfed, the average income from large scale schemes was USD1456/ha. There are strong differences in GM between the schemes, however. As we did not have data from rainfed in and around the large scale schemes, we used rainfed data from the medium and small scale sites. The calculated average gross margin per ha from rainfed agriculture, as indicated earlier, was USD 147. Taking this value into account, the netted income from a hectare of irrigation under large scale schemes is USD 1308. When we differentiate the large scale schemes into sugar plantation and other crop growing plantations (i.e. predominantly vegetables and fruits and cotton growing schemes) the average net income is USD 1782.5 and USD 998.9 respectively. Taking the all large scale schemes in the country, differentiated by their cropping pattern, and the average income from the selected learning sites, the total income earned from large scale schemes amounts to Birr 641 million (ca 74.0 million USD). This accounts for about 1.26 percent of the agricultural GDP and 0.5 percent of the total GDP respectively. When only the improved system is considered, it contributed to about 1.26 and 0.5 percent of the agricultural GDP and GDP respectively. Overall, the contribution of irrigation to agricultural GDP and total national GDP was about 5.7 and 2.5 percent during the 2005/06 cropping season. This shows that the contribution of irrigation to national income is still very small compared to the 28 percent contribution of crop production. Regional comparisons could shed some light on this. In the Sudan, for instance, irrigation contributes about 50 percent of the crop production while almost all agriculture in Egypt is irrigated (FAO, 1997).

10. Projecting future contribution of irrigation

In this section we present the projected expansion of irrigated agriculture vis-à-vis rain fed agriculture and the contribution of the former to agricultural GDP. To set the future scenario we used cropping patterns as observed in our empirical results and projected cropping patterns of the PASDEP (2005/06-2009/10) document (see Table 7). The projected irrigation development, both small-and medium scale and large scale schemes is taken into account in setting the future scenario.

Table 6: Cropping pattern under different systems (% area covered by) by small and medium scale irrigation

Crop category	Area under Rain fed system (%)	Area under Traditional irrigation (%)	Area under Modern irrigation (%)	Average area Cover under irrigation (%)
Cereals	77	55	67	61
Vegetables	1	11	21	16
Perennials/fruits	1	11	4	7
Pulses	16	10	3	6
Oil seeds	1	5	0.4	3
Spices	0.5	8	0.3	4
Others	3	0.2	5	2.5

Source: Own calculation

In projecting future scenarios we assumed that the cropping pattern of the large scale sugar plantations to be the same. We ruled out reductions of irrigated land due to salinity or other environmental damages in those sugar plantation for lack of data that clearly shows the magnitude of the problem or how effective are the ameliorative measures undertaken by these schemes. On the other hand, we assumed that the cropping pattern in the smallholder managed large, medium and small scale irrigation schemes to be the same as depicted in Table 6. The land cover statistics of the irrigation, all typologies considered, and rainfed systems are also given in Table 7. We relaxed this assumption later in the sensitivity analysis as it is realistic that farmers will shift to high paying crops as they gain experience and the market situation likely to improve.

Table 7: Land use assumptions for future irrigated areas (2005/06-2009/2010)

Land use	**Area with irrigation (in 000 ha)**	**Area without irrigation (in million ha)**
Cereals	809.2	9.2
Pulses		1.6
Oil seed crops	119.4	1.2
Vegetables	212.2	
Fruits	99.5	0.419
Cotton		0.043
Sugar cane	122.0	0.060
Coffee		0.734
Floriculture	n.a.	0.002
Tea		0.0038
Other	86.2	0.039
Total	**1326.5**	**12.65**

Source: MOFED (2006) and own calculation; n.a.= no data available

The PASDEP document also outlines the projected development of the economy for the whole planning period. Accordingly, the Ethiopian economy is expected to grow at an average of 7.3 percent through out the PASDEP period. Agriculture, the major sector of the economy is also expected to grow at an average rate of 6.2 percent (MOFED, 2006, p. 55). Agriculture's share to the economy will show slight reduction from 46.2 percent in 2004/2005 to 43.9 percent at the end of the planning period. Taking the baseline situation (2005/06), Ethiopia's GDP will grow to Birr 153.2 billion while agricultural GDP will grow to Birr 64.7 billion both at 1999/00 constant basic prices.

For the assumptions about the IDP differentiated into small-medium scale & large scale we used MOFED (2006) and MoWR (2006), as indicated in section eight. As the national IDP indicates the country's irrigation coverage will increase from the current 625,819 ha to 1.15 Million hectares. Accordingly, there will be 638,129 ha of small scale irrigation, both traditional and improved, 328,485.9 ha of smallholder managed medium and large scale irrigation schemes and 122000 ha of large scale schemes dedicated for sugar plantations and 35511 ha of large scale commercial farms dedicated to growing of vegetables, fruits and cotton.

Taking all the envisaged areal expansion, crop cover assumptions as indicated in Tables 7 and 8 and the average gross margin by crop category (table 9), we calculated that the contribution of smallholder managed irrigation to national economy to increase from USD 262.3 million in 2005/2006 to about USD 414.2 million in 2009/2010, which accounts to about 5.5 percent of the agricultural GDP and 2.3 of the overall GDP for the same year. On the other hand, the contribution coming from the large scale sugar growing estates is in 2009/2010 is estimated to be USD 217.5 million which amounts to 2.9 and 1.2 percent of the agricultural and overall GDP respectively. Similarly the contribution coming from large scale commercial farms growing other crops other than sugar cane is expected to increase to USD 35.8 million in 2009/2010 which accounts to 0.4 and 0.2 percent of the agricultural GDP and overall GDP respectively. This implies that large scale commercial farms will contribute about 3.3 and 1.4 of the agricultural GDP and overall GDP respectively. This shows that the bulk of the contribution is expected to come from smallholder managed irrigation systems. In summary, this indicates that under conservative estimates the future contribution of irrigation to agricultural GDP and overall GDP will be in the range of 9 and 3.7 percent respectively. This estimation is based on the projected areal expansion, current cropping patterns and prices. These results are likely to change when some of the assumptions were allowed to change as shown below.

11. Sensitivity analysis

In projecting the future contribution of irrigation to national economy or agricultural GDP our assumptions were rigid: only a change in area expansion was assumed. However, it is realistic to assume that there will be various changes associated with irrigation expansion. For instance, given the significant difference in the gross margin between different crop categories, farmers will benefit economically from growing more vegetables and fruits than growing cereals. Hence it is realistic to assume that farmers will gradually shift to high value crops. Prices of inputs and outputs cannot be taken to remain constant. It is realistic to assume that there could be either upward or down ward movements in prices of agricultural inputs and outputs. Furthermore, the efficiency of farmers is also expected to improve with time as they gain irrigation experience and experiment with various technologies and combinations. Hence it is important to relax these assumptions and see the effect of these changes on irrigation's contribution to national income. This section presents the results of the sensitivity analysis.

11.1 Simulating changes in cropping patterns under smallholder managed irrigation schemes

To simulate the effect of such change in cropping pattern on the agricultural GDP we set the following scenarios: Scenario 1 involves 10 percent increase in area coverage of vegetables and fruits (10 percent decrease in area for cereals) while areas for pulses and oil seeds and other crops remain the same; Scenario 2 assumes 10 percent increase in area of vegetables and 5 percent in fruits (15 percent reduction in area for cereals *cetaris paribus*) and Scenario 3 assumes 10 percent increase in area for both vegetables and fruits (20 percent reduction in area for cereals) and finally scenario 4 assumes a 25 percent increase in area of vegetables and fruits (i.e. 25 percent reduction in area for cereals ceteris paribus). The outcomes of these scenarios were compared against the baseline scenario where we assumed that there will be only aerial expansion (Table 11).

Table 8: Estimated average gross margin for different crop categories

Average Gross margins by crop category	Birr/ ha - rain fed	Birr/ ha - irrigated
Cereals	1282.32	1720.84
Vegetables		3421.2
Fruits		2754.9
Pulses & oil seeds	1481.45	1558.19
Sugar cane		4528.7
Cotton		709.6
others (hops, chat, etc)	1254.8	2891.8

Source: Own calculation

As can be seen from Table 8 (See also Table 10a and 10b in Annex) there is significant difference in the gross margin between different crop categories. On average farmers get Birr 1720 per ha from growing cereals, Birr 3421 from vegetables, Birr 2755 from fruits, Birr 1558 from pulses and oil seeds, and Birr 1719 from growing other crops such as spices and stimulants.

Table 9: The effect of change in cropping pattern on the projected contribution of small holder managed irrigated agriculture to Agricultural GDP (Net gross margin in BIRR)

Crop type	Total NGM (in Million USD)	Contribution to AgGDP in 2009/2010 (%)	Contribution to GDP in 2009/2010 (%)	Relative change (%)
Baseline	315.2	4.22	1.78	
Scenario 1	327.9	4.39	1.85	17
Scenario 2	335.8	4.5	1.9	28
Scenario 3	340.6	4.56	1.92	34
Scenario 4	3.84.5	4.67	1.97	45

As can be seen from the simulation results, the contribution from smallholder managed irrigation schemes to Agricultural GDP increases to about 4.5 percent or even more when these various changes in cropping patterns are assumed. 15 and 10 percent increase in the area of vegetables and fruits (25 percent reduction in the area of cereals) lead to about 45 percent increase in the contribution of smallholder irrigation to agricultural GDP as compared to the baseline scenario. This is an important result indicating that the contribution of irrigation could be maximized if smallholder farmers shift their cropping pattern to high value crops. Hence, the extension system could play an important role in providing and promoting high value crops.

11.2 Simulating changes in crop prices

The factors that influence price change could be related to overall demographic change and improved economic performance (through increased demand) and increase in supply of output. It is reasonable to assume that the population of Ethiopia will continue to grow in the foreseeable future while there could be differences in opinion about the prospects of economic growth in the country. The prospects point towards improved economic performance, however. For this exercise, hence, we assumed that demand factors will play a more significant role in influencing the price of outputs.. To simulate the effect of these changes in prices of output on the contribution of irrigation to national economy, we set various scenarios: baseline scenario GM net of annual investment recovery cost; 10 percent increase in price of vegetables and fruits *ceteris paribus* (scenario 1); 15 percent increase in price of vegetables and fruits *ceteris paribus* (scenario 2); 10 and 15 percent increase in price of cereals *ceteris paribus* (scenarios 3 and 4); 10 and 15 percent increase in the price of pulses and oil seeds *ceteris paribus* (scenarios 5-6); and 10 and 15 percent increase in price of other crops *ceteris paribus* (scenario 7 and 8). The simulation results are reported in table 10 below.

These simulation results show that a 10-15 percent increase in the price of fruits and vegetables leads to 15-23 percent increase in the relative contribution of smallholder irrigation to agricultural GDP. An equivalent increase in the price of cereals leads to 22-32 percent increase in the relative contribution of the sub sector. One the other hand, the same level of increase in prices of pulses, oil seeds and other crops did not yield significant change in their contribution. The relative higher contribution from cereals comes from the bigger share cereals have on land cover claiming about 61 percent of the cultivated area under irrigation, Hence, vegetables and fruits are economically more attractive. This implies that an increase or decrease of prices of vegetables and fruits will have a stronger relative impact on the contribution of irrigation to national economy compared to the price change of cereals.

Table 10: the effect of change in output prices on the projected contribution of small holder managed irrigated agriculture to Agricultural GDP

Scenarios	Description	Contribution to AgGDP in 2009/2010 (%)	Contribution to GDP in 2009/2010 (%)	Relative change (%)
Baseline	GM net of investment recovery cost	4.22	1.8	
Scenario 1	10 % increase in price of vegetables & fruits	4.37	1.85	15
Scenario 2	15 % increase in price of vegetables & fruits	4.45	1.88	23
Scenario 3	10 % increase in price of cereals	4.44	1.87	22
Scenario 4	15 % increase in price of cereals	4.55	1.92	32
Scenario 5	10 % increase in price of pulses and oil seeds	4.25	1.79	3
Scenario 6	15 % increase in price of pulses and oil seeds	4.26	1.80	4
Scenario 7	10 % increase in price of other crops	4.25	1.79	3
Scenario 8	15 % increase in price of other crops	4.26	1.80	4

11.3 Simulating changes in input prices

Fertilizer is the most important input for smallholder farmers working under irrigation. The average cost of fertilizer varies by type of crop category. Cereals and vegetables are major consumers of fertilizer with average expenditure per hectare of Birr 287 and Birr 403 respectively. Pulses and oil seeds, other crops and fruits reported expenditure per hectare of Birr 238, 161 and 47 respectively. In projecting the impact of irrigation on national economy, one needs to consider the effect of changes in input prices on the gross margin. To simulate such an effect, we determined the impact of the following scenarios: 10, 15, 25 and 35 percent increase in the price of fertilizer. Given the current trends in fertilizer prices, it seems realistic to assume that fertilizer prices will increase.

Table 11: Effect of changes in fertilizer prices on contribution of smallholder contribution to agricultural GDP

Crop category	Contribution to AgGDP	Contribution to GDP	Relative change
Baseline	4.22	1.78	
Scenario 1	4.17	1.76	-5
Scenario 2	4.14	1.75	-8
Scenario 3	4.08	1.72	-14
Scenario 4	4.03	1.70	-19

As can be seen from the simulation results, the contribution from smallholder managed irrigation schemes to agricultural GDP does fall significantly compared to the baseline scenario if there is a 10 percent or more increase in price of fertilizer. A 35 percent increase in price of fertilizer, while assuming other things remain constant, for instance, leads to a 19 percent reduction in its contribution to agricultural GDP compared to the baseline scenario.

11.4 Improvement in efficiency of smallholder managed schemes

Besides exogenous changes in prices and changes in cropping patterns, farmers are also expected to gain irrigation experience and improve their efficiency in using land and water. This is also expected to lead to increase in gross margin. We, hence, explored what happens to irrigation's contribution if gross margin of smallholder agriculture increases to that of irrigators in the traditional schemes. The simulation results show that the contribution from smallholder managed irrigation will increase to about USD 475.5 million that accounts to 6.4 and 2.7 percent of the agricultural GDP and overall GDP in 2009/2010. This has also an important policy implication; government and extension support through education and training contributes to improved efficiency and increased contribution of irrigation to national economy.

11.5 Projecting the future contribution of large scale plantations

In projecting the future contribution from large scale commercial plantations, we tested various scenarios. First we need to differentiate between large scale smallholder managed and large scale commercial plantations. The former category was covered in the proceeding sections while in this section we focus on the large scale commercial production. The major expansion in the state owned commercial plantations involves predominantly growing of sugar cane for sugar production. There is no information on future expansion plans of fruits and vegetables and other crop growing large scale commercial farms. Our focus in this section, hence, will be on sugar plantations. Worth noting is that in the existing sugar plantations there is huge difference in annual investment recovery costs and net gross margin (see Table 5). These differences could be attributed to differences in structure of investment and management and, hence, efficiency of the schemes. The lack of relevant information on initial investment expenditure has also made the analysis difficult. In schemes where we couldn't get data on initial investment costs we used data related to initial capital outlays. The huge differences in annual investment recovery costs and net gross margin could partly be attributed to lack of reliable data.

In simulating the future contribution of large scale schemes, we set certain assumptions based on the differences in net gross margin between the three major sugar growing schemes. Since there will be emerging schemes, e.g. Kesem and Tendaho on 90000 ha of land, in sugar cane production, we need to set certain assumptions about these schemes performance. We first assumed that the net gross margin for Finachaa, Metehara and Wonjo/Shoa respectively applies to the new schemes (Scenario 1-3); Kesem & Tendaho perform on the average of the three exiting schemes (scenario 4); all schemes, existing and emerging, perform like Finachaa (scenario 5); all schemes perform like Metehara (scenario 6), all perform like Wonji/Shoa or all perform on the average of the three (scenarios 7 & 8) . Finally we assumed a 10 and 15 percent increase in the price of sugar while the average gross margin works in all schemes (scenarios 9 and 10). For details see Table 12 below. Following these scenarios, the contribution from large scale plantations to agricultural GDP, ranges from less than 1 percent for scenario 5 (worst scenario) to about 6 percent in scenario 2 (best scenario). The intermediate outcomes lie somewhere in between contributing about 3 percent to the agricultural GDP. These results show that the structure of investment and the way these schemes are managed may have a significant bearing on their contribution to national economy.

Table 12: Projected contribution of large scale sugar estates to Agricultural GDP

Scenarios	Description	Contribution to AgGDP	Contribution to GDP	% Change
Baseline	average NGM for LSS assumed	2.9	1.2	
Scenario 1	Kesem & Tendaho performs like Finchaa	1.5	0.65	- 140
Scenario 2	Kesem & Tendaho performs like Metehara	5.8	2.46	290
Scenario 3	Kesem & Tendaho performs like Wonji/Shoa	2.9	1.22	0
Scenario 4	Kesem & Tendaho achieves average performance	3.4	1.4	50
Scenario 5	All perform like Finchaa	0.32	0.13	-258
Scenario 6	All perform like metehara	6.1	2.5	320
Scenario 7	All perform like Wonji/Shoa	2.16	0.9	-74
Scenario 8	All perform like average	2.87	1.2	-3
Scenario 9	10 percent increase in baseline NGM	2.87	1.2	-3
Scenario 10	15 percent increase in baseline NGM	2.87	1.2	-3

Taking these scenarios into account the contribution of smallholder managed irrigation to agricultural and overall GDP will vary between 4 to 6 and 1.8 to 1.9 percent respectively. Similarly, the contribution from large scale irrigation to agricultural and overall GDP will be in the range of 3 to 6 and 1.2 to 2.5 percent respectively. Overall, the future contribution of irrigation to agricultural GDP will be in the range of 7 to 12 percent while the contribution to overall GDP will be in the range of about 4 percent.

12. Conclusions and recommendations

Irrigation development is quite a recent phenomenon in Ethiopia. While the country has huge potential for irrigation only about 5 percent of this potential is currently used. Irrigation development is identified as an important tool to stimulate sustainable economic growth and rural development and is considered as a corner stone for food security and poverty reduction in the country. To this effect a comprehensive national Irrigation Development Strategy (2005/06-2009-2010) has been developed and is being implemented with the aim of establishing small, medium and large scale irrigation schemes, either for use either under smallholder managed schemes or large scale commercial plantations. In spite of this, there is little attempt to measure the actual and expected contribution of irrigation to the national economy. Hence, the objective of this study was to estimate the net contribution of irrigation to GDP at the farm gate following an adjusted gross margin analysis approach. Studies of this kind could be instrumental in comparing the actual and expected direct benefits of irrigation with the actual and expected costs of irrigation expansion to guide policy makers in irrigation development. However, there is need for caution. This study does not capture the all the multiplier effects of irrigation. Doing that requires more data than is presently available. However, this first attempt can be extended to more precise analysis of economy wide effects of irrigated agriculture development.

Our results show that irrigation in the study sites generates an average income of about USD 323/ ha. This compares to the calculated gross margin for rainfed which is USD 147/ha. This indicates that after accounting for replacement cost, net gross margin from irrigation is more than twice higher than the gross margin from rainfed agriculture. When disaggregated by irrigation typology, average income from small scale modern systems is about USD 355/ ha while from small scale traditional systems it is about USD 477/ha. This difference in net income between the traditional and modern systems could be attributed to differences in the investment cost and relative irrigation experience. We also found huge inter-scheme differences in average income within the same typology which could be attributed to differences in relative irrigation experience and access to market. When it comes to medium scale irrigation schemes, the average income from modern irrigation schemes was USD 400/ha. Taking the average income from smallholder managed small and medium scale irrigation schemes in the country and the total hectarage for both categories, we calculated the total income driven from irrigation to be Birr 2.27 billion (about 262.3 million USD). This accounts for about 4.46 percent of the agricultural GDP in 2005/2006 and 1.97 percent of the total overall GDP.

On the other hand, the average income net of annual recovery cost from a hectare of irrigation under large scale schemes is USD 1,308. Taking the all large scale schemes in the country, differentiated by their cropping pattern, and the average income from the selected learning sites, the total income earned from large scale schemes is estimated to be Birr 641 million (ca 74.0 million USD). This accounts for about 1.26 percent of the agricultural and 0.5 percent of the total GDP respectively. Overall, the contribution of irrigation to agricultural and total national GDP was about 5.7 and 2.5 percent during the 2005/06 cropping season. When only the improved system is considered, it contributed to about 1.26 and 0.5 percent of the agricultural GDP and GDP respectively. Our result show that the bulk of the contribution to national economy comes from the smallholder managed irrigation schemes, most importantly from the traditional schemes. The same results also show that the contribution of irrigation to national income is still very small compared to the 28 percent contribution of crop production and role of irrigation to national economy in some countries such as the Sudan and Egypt where in the former irrigation contributes to about 50 percent of the crop production while in the latter almost all agriculture is irrigated.

Taking all the envisaged areal expansion, exiting cropping pattern, and the average gross margin values for different crop categories, the expected contribution of smallholder managed irrigation to national economy is expected to increase from USD 262.3 million in 2005/2006 to about USD 414.2 million in 2009/2010, which accounts to about 5.5 percent of the agricultural GDP and 2.3 of the overall GDP for the same year. On the other hand, the contribution coming from the large scale sugar growing estates in 2009/2010 is estimated to be USD 217.5 million which amounts to 2.9 and 1.2 percent of the agricultural and overall GDP respectively. Similarly the contribution coming from large scale commercial farms growing crops other than sugar cane is expected to increase to USD 35.8 million in 2009/2010 which accounts to 0.4 and 0.2 percent of the agricultural and overall GDP respectively. This implies that large scale commercial farms will contribute about 3.3 and 1.4 of the agricultural and overall GDP respectively. In summary, our results indicate that under conservative estimates the future contribution of irrigation to agricultural and overall GDP will be in the range of 9 and 3.7 percent respectively.

Furthermore, we also relaxed some of the assumptions to check the sensitivity of our results to model assumptions. We assumed various changes in cropping patterns, changes in input and output prices and improvement in levels of efficiency.

Our results from the simulation exercise in relation to shift in cropping patterns show that a 15 and 10 percent increase in the area of vegetables and fruits respectively (i.e. 25 percent reduction in the area of cereals) leads to about 45 percent increase in the contribution of smallholder irrigation to agricultural GDP as compared to the baseline scenario. This is an important result indicating that the contribution of irrigation could be maximized if smallholder farmers shift their cropping pattern to more high value crops. Hence, the extension system could play an important role in providing and promoting high value crops.

Likewise, simulation results on the effect of price change show that a 10-15 percent increase in the price of fruits and vegetables leads to 15-23 percent increase in the relative contribution of smallholder irrigation to agricultural GDP. An equivalent increase in the price of cereals leads to 22-32 percent increase in the relative contribution of the sub sector. One the other hand, the same level of increase in prices of pulses, oil seeds and other crops did not yield significant change in their contribution. The relatively higher contribution coming from cereals is attributed to the bigger share cereals have on land claiming about 61 percent of the cultivated area under irrigation. This implies that an increase or decrease of prices of vegetables and fruits will have a stronger relative impact on the contribution of irrigation to national economy compared to that of cereals. Hence, vegetables and fruits are economically more attractive and could yield more value to the economy if more a more land is shifted from cereal production to production of vegetables and fruits.

On the other hand, increase in price of fertilizer leads to reduction in the contribution of irrigation to national economy. Accordingly, a 35 percent increase in price of fertilizer, while assuming other things remain constant, for instance, leads to a 19 percent reduction in small holder irrigation's contribution to agricultural GDP compared to the baseline scenario.

Besides changes in prices and cropping patterns, improved efficiency is found to impact significant increased in the contribution of irrigation to national economy. Our simulation results show that the contribution from smallholder managed irrigation will increase to about USD 475.5 million, which is 6.4 and 2.7 percent of the agricultural and overall GDP in 2009/2010, when all smallholder irrigation farmers perform to the level of traditional irrigators. This has also an important policy implication: government and extension support through education and training contributes to improved efficiency and increased contribution of irrigation to national economy.

Furthermore, when we simulated the effect of changes in efficiency levels of existing and emerging large scale sugar plantations and changes in the price of sugar we found that the contribution from large scale plantations to agricultural GDP, ranges from less than 1 percent for worst scenario to about 6 percent in the best scenario. The intermediate outcomes lie somewhere in between contributing about 3 percent to the agricultural GDP. These results show that the structure of investment and the way these schemes are managed may have a significant bearing on their contribution to national economy.

In summary, taking these scenarios into account the contribution of smallholder managed irrigation to agricultural and overall GDP will vary between 4 to 6 and 1.8 to 1.9 percent respectively. Similarly, the contribution from large scale irrigation to agricultural and overall GDP will be in the range of 3 to 6 and 1.2 to 2.5 percent respectively. Overall, the future contribution of irrigation to agricultural GDP will be in the range of 7 to 12 percent while the contribution to overall GDP will be in the range of about 4 percent. To enhance the contribution of irrigation to national economy, besides increasing the presence of physical water infrastructure, there is a need to: i) improve provision of agricultural inputs, ii) promote high value crops through the extension system, iii) create good market conditions, and iv) increase the efficiency of small and large schemes.

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Annex I

Table 10a: Gross margin of rain fed crops

Crop type	**Mean area (in timad)**	**Gross value of output/ mean area**	**GM rain fed**	**GM per ha rain fed**
Wheat	1.3	857	366.7	1089.6
Teff	1.8	806	437.8	956.9
Barley	1.2	507.7	429.2	1493
Maize	1.7	609.2	341	816.7
Finger millet	1.3	717	652.6	2055.4
Sorghum	2.4	754.7	644.6	1053.8
Chick pea	1.3	498.4	337.9	1031.7
Lathyrus	1.2	654.8	592.2	1970.8
Bean	1.2	725	334.3	1078.5
Lentil	0.6	309.4	250.4	1584.8
Nug	2.2	1132.3	939.6	1709.9
Grass pea	1.6	568.2	237.9	599.2
Eucalyptus	0.9	271.3	259.7	1185.6
Hops	0.6	214.1	136.5	956
Other	1.1	495.4	407.8	1553.6

Table 10b: Gross margin of irrigated crops

Crop type	Mean area (in timad)	GVOUT	GM irrigated	GM per ha
Wheat	1.4	1291.2	745.3	2077.7
Teff	1.5	904.7	514.2	1418.4
Barley	1	687.2	513.1	2052.3
Maize	1.6	864.7	610.4	1575.1
Sorghum	1.7	720.4	610.8	1480.7
Cotton	2	394.9	354.8	709.6
Chick pea	1.4	966.3	452.3	1256.5
Lathyrus	1.3	390	252	800.1
Bean	1.1	641.1	265.8	1012.6
Lentil	1	1505	1309.4	5237.6
Nug	1.4	717	538.5	1516.8
Grass pea	2.2	916.4	420.2	771.8
Pea	1.5	1467	617.7	1625.5
Linseed	2.1	445.2	252.7	493
Pepper	1	952.2	833.7	3437.9
Potato	0.9	574.6	420	1812.5
Sweet potato	2	498	397	814.3
Cabbage	0.8	821	662.3	3230.8
Onion	1.5	3112	2699.4	7415.8
Tomato	1.5	1506.1	1017.7	2765.4
Shallot	0.9	1873.5	1016.2	4471.7
Papaya	1	679.5	625.4	2399.9
Banana	1.9	534.1	475.8	995.9
Mango	1.2	711	652.2	2211
Guava	0.7	1038	933.7	5412.8
Coffee	0.7	8407.4	8341.4	45210.6
Sugar cane	0.8	1001.3	869.52	4528.77
Eucalyptus	0.8	5191.9	5113.7	26808.3
Hops	0.9	441.4	340	1456.1
Chat	0.6	1221.9	1098.5	7323.7
Enset	1	400.5	258.3	1051.2
Other	1	505.6	441.4	1736.2

Investment in irrigation as a poverty reduction strategy: Analysis of small-scale irrigation impact on poverty in Tigray, Ethiopia

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Abstract

The regional government of Tigray has invested in millions of Birr to develop irrigation schemes as a strategy of poverty reduction. The study was based on a representative sample of 613 farm households (331 irrigators and 282 non-irrigators) drawn using three stage stratified sampling with probability proportional to size. The main aim of this paper is to study the impact of irrigation on household income, therefore, to contribute to the scant literature on irrigation-poverty reduction nexus in Ethiopia, which policy makers can use it as an input to make informed policy decisions in their future endeavors. We found that farming income is more important to irrigating households than to non-irrigating households, while off-farm income is negatively related with access to irrigation. We also found that irrigating households' average income is above the regional average, while non-irrigating households' average income is 50 percent less than the average income of irrigating households. Although there can be other factors, which may contribute to the difference in income, these results are inline with our expectation and supports the decision of the Tigray government to use irrigation as a poverty reduction tool. We have used a stochastic dominance analysis and found that the results are consistent. This result differs from a previous study by Pender et al. (2002), which argues that irrigation has less impact in agricultural yields than expected, reducing returns to investment in modern irrigation.

Keyword: Tigray, Irrigation, Poverty reduction, Matching, Propensity Score

1. Introduction

Ethiopia is one of the poorest economies in the world (Hagos 2003) and Tigray is its poorest and most severely food insecure region as compared to the other regions of the country except to SNNPR (Federal Democratic Republic of Ethiopia (FDRE) 1999). Poverty reduction in Tigray is a core policy agenda of the Ethiopian government in general and the regional government of Tigray in particular. A general consensus was reached that an increase in agricultural production and poverty reduction should come mainly through agricultural intensification and adoption of technologies that improve soil moisture to use more productivity enhancing inputs. The use of productivity enhancing inputs (such as fertilizer and high yielding variety) depends much on availability of moisture in which case, investment in irrigation becomes crucial. Despite the role of irrigation in easing the effect of rainfall uncertainty on agricultural performance, Ethiopia in general having an immense irrigation potential, has remained dependent on rain-fed and less productive agriculture, which resulted in food insecurity and sever poverty. To this end, the Ethiopian government in general and the regional government of Tigray in Tigray has focused on rural investment on small-scale irrigation as a key poverty reduction strategy. Since the establishment of the Commission for Sustainable Agricultural and Environment Rehabilitation of Tigray (CoSAERT) in 1995, 54 micro-dams; 106 river diversion; and a number of spate irrigation projects were constructed with a total irrigation capacity of 3700 hectares benefiting 19,000 households (Abraha 2003). In addition to the government's effort, non-governmental organizations such as Relief Society of Tigray (REST), have invested in irrigation projects. According to Abraha (2003), a micro-dam project, to irrigate 100 hectares, is estimated to cost about 5.84 million Birr (1US$=8.65 Birr), while a river diversion project that can irrigate 45 hectares costs 1.17 million Birr, in which case investment per hectare is estimated at 58,390 and 25,896 Birr, in dam and river diversion projects, respectively.

In spite of the high optimism and the amount of resources committed to develop irrigation, Pender *et al* (2002), argued that in Tigray "irrigation has contributed to intensification of land use and to change in crop choice, but has been associated with less adoption of fertilizer and improved seeds and less improvement in yields than expected. As a result, it appears that the returns to investment in modern irrigation so far have been relatively low". On the other hand, given the experience that irrigation has been an enabling factor for the use of other productivity enhancing agricultural inputs (Dhawan 1988), and the high expectation from irrigation as anti-poverty program, the findings of Pender *et al.* (2002) seem to be paradoxical, which attract the attention of researchers, policy makers and financing agencies.

The existing literature and empirical studies dealing directly with irrigation-poverty linkage are not only dominantly of Asian origin, but they are few, recent origin and polarized. On the other hand, although there are many studies, which indirectly deal with the linkages of irrigation and household income as a proxy of household wellbeing or poverty, most of them are like a by-product of a general analysis of the phenomenon of agricultural growth and/or poverty (Saleth *et al*. 2003). Literature review pertinent to the linkages of irrigation-household income and poverty reduction is presented in the next section. In general, we note that there is a knowledge gap whether small-scale irrigation contributes to increase household income and poverty reduction. To our best knowledge, Hagos et al. (2006) is the only recent research output from Tigray which deals with the impact of small-scale water harvesting (ponds and shallow-wells) on household poverty. This study is the first of its kind anywhere in Ethiopia in addressing and comparing three irrigation systems (i.e., earth dam, river diversion and shallow wells) under different agro-ecological settings. Furthermore, it has made an effort to address the complete pathways and layers that could exist between irrigation and poverty reduction.

Accordingly, the main objectives of this paper are:

1) To study the impact of small-irrigation on household income in Tigray, so that policy makers can use the research outcome to make informed policy decision. To this end, we investigate irrigation's impact on household income. We also test whether irrigation has an effect on off-farm employment and income diversification.

2) This paper seeks to contribute to the empirical literature on irrigation-poverty reduction linkages, through a better understanding the pathways of irrigation-household income and poverty reduction from the experience of Tigray, Ethiopia.

To achieve the main objectives specified above, we develop an analytical framework that depicts the linkage between irrigation-household income and poverty reduction (see Figure 1). The framework shows how the linkage works between four inter-linked systems (which are: irrigation, socio-economic, household characteristics and agro-climatic systems).

The structure of the paper is as follows: section 2 reviews related literature, while in section 3; we describe the conceptual framework that captures the pathways. In section 4, we briefly discuss data, sampling procedure and the study area. Section 5, is dedicated to discuss the empirical method. In this section, we have discussed factors that determine participation; hence, we identify varibles that are used to match participants with non-participants. Furthermor, we have brifley discussed the advantges and limitations of PSM as an estimation method. We use section 6 to presents results and discussions followed by conclusion in section 7.

2. Literature review

Among the existing literature on irrigation and its impact on poverty reduction, some are based on empirical research, which focuses on specific locations. These types of literatures use primary or secondary data and are methodologically rigorous. On the other hand there are literatures, which are based on perceptions and logic based arguments (e.g Lipton and Litchfield, 2003;), while the third type of literature is based on project evaluation, which mostly is based on the interest of funding organization (Hussain and Hanjra, 2004). Among these, one of the studies that attempt to deal with irrigation poverty linkages is (Hussain and Wijerathna, 2004), which is a wide-ranging study that covers six major Asian countries (i.e., Pakistan, India, Bangladesh, China, Vietnam and Indonesia). Although highly aggregated and review based, Hussain and Wijerathna (2004) argued that irrigation reduces poverty both directly and indirectly, where the direct impacts are realized through labour and land augmentation effect that ultimately translates to improved productivity, employment, income and consumption, while the indirect impact is realized through enhanced local economy and improved welfare at macro level (Hussain and Wijerathna, 2004).

Regardless of the methodologies applied, most of the studies carried to investigate the impact of irrigation on poverty reduction are classified as comparative analysis, such as before and after, with and without or more or less comparisons Hussain and Hanjra (2004) is one of the descriptive/comparative type study, which attempts to study the irrigation-poverty linkage, and argued that access to irrigation reduces poverty. Furthermore, Hussain et al. (2006) has used primary data to make a comparative analysis of irrigation impact on household income in the marginal areas of Pakistan, where it concludes that small-scale irrigation is positively correlated with household income and then reduces poverty. Similarly, Bhattarai and Narayanamoorthy, (2003) has used both cross section and time series data to study the effect of investment in irrigation in poverty reduction in India, where they found that investment in irrigation as compared to investment in rural letracy was more effective poverty reduction instrument, but since they used a single equation and highly aggregated data it makes it difficult to capture the layers and linkages between irrigation, agricultural growth and poverty reduction (Saleth *et al.* 2003).

Furthermore, the success stories of China's food self sufficiency in the 1960s and 1970s, was attributed to a massive investment in irrigation (Huang et al., 2005; and Huang et al., 2006) implying that irrigation plays an important role in poverty reduction. Huang et al. (2005) has used household level cross sectional data to apply a multivariate analysis method, where it found a strong positive correlation between access to irrigation and household income, leading to poverty reduction and equitable income distribution.

As mentioned above, the literature on irrigation and its impact is polarized. For example, unlike to the above stated literature, different studies which manly used aggregated data (e.g., Rosegrant and Evenson, 1992; Jin *et al.*,2002; and Fan *et al*.,2000) have found negative and/or weak relationship between irrigation and agricultural productivity implying negative or no impact on household income and poverty reduction at large. According to Rosegrant and Evenson (1992), for example the effect of irrigation on agricultural productivity in India was found negative. Moreover, Jin et al. (2002) uses aggregated nation wide data of China's major crops but cannot find a relationship between irrigation and total factor productivity (TFP). On the other hand, Fan *et al*.(2000) has made a comparative analysis of impact of public expenditure in irrigation, research & development, road, education, electrification and rural telephone networking, where "investment in irrigation was found to have the least impact on both production and poverty alleviation" (Fan *et al*.,2000). Most of the studies that used aggregate data could not identify a positive contribution of irrigation to poverty reduction, implying that the direct effect of irrigation could be undermined by other factors which could have been observed at household and/or plot level.

In general, the lack of consensus regarding the linkages between irrigation and poverty reduction seems to mirror the general debate regarding the role of investment in agriculture. For instance, Christiaensen et al. (2006) argue that although the majority of poor people in developing countries, especially in Sub-Saharan Africa (SSA), depend directly on agriculture for their livelihood, there is no common view about the role of agriculture in economic development and poverty reduction. For example, the dual economy model inspired by Lewis in the 1950s, argue that resources have to be diverted from agriculture to the industrial sector, while a positive view that emerged in the early 1960s argue about investment in agriculture and its contribution to economic growth and poverty reduction is more than an equal amount of investment in non-agriculture (Christiaensen et al. 2006). The experience of the Green Revolution in Asia, where traditional agriculture was rapidly transformed substantiates the role of investment in agriculture in economic growth and poverty reduction (Christiaensen et al. 2006). Empirical evidences show that in areas where irrigation is widely used, agricultural yields and household income are higher, and less poverty and undernourishment are observed (FAO 2003). In the framework we made clear that the impact of irrigation comes through its multi-dimensional effect.

3. Conceptual framework

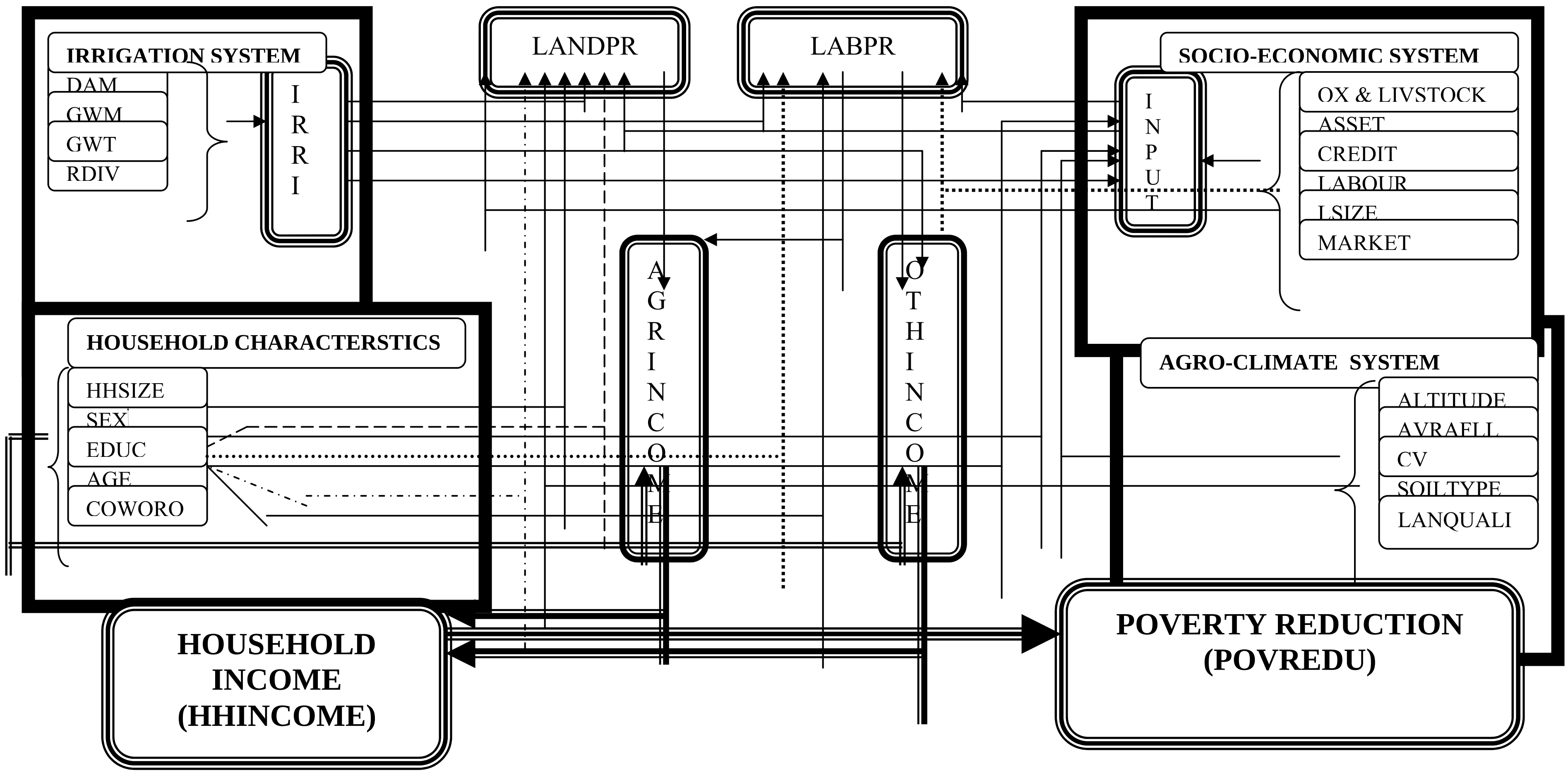
We hypothesize that irrigation had a significant impact on agricultural performance and poverty reduction in Tigray. We assume that the effect of irrigation on production is ultimately translated to household income and poverty reduction. Although it may differ from location to location and irrigation technology/system, the pathways through which irrigation can impact on poverty reduction are complex and diverse. Hence, if researchers and policy makers have to understand how irrigation affects poverty, it is essential to understand the complexity and diversity of pathways and linkages. Accordingly, we developed a conceptual framework (see Figure 1) as a guide to our research. Figure 1 illustrates the basic relationship capturing the major pathways and layers inherent in irrigation-poverty linkage, which helps to net out the impact of irrigation on poverty reduction. The framework makes clear that the impact of irrigation comes through its multi-dimensional effect, such as its effect in input use, crop intensity, land and labour productivity.

In rural areas where most of the people depend on agriculture for their food and income, water and food security are closely related (FAO 2003). In the framework, the impact of irrigation on household income and poverty reduction is captured through two major pathways (i.e., land and labour productivity). Irrigation enhances the use of agricultural inputs (such as fertilizer and HYV), which in turn improves the productivity of land and labor (especially, agricultural labor) ultimately resulting in high household income and poverty reduction. Such an agricultural performance could result either because of the input use effect or simply due to the external shock minimizing effect of irrigation.

For example, crop production in the highlands of Tigray requires more than 90 days (for vegetative and flowering), but usually the rain stays effectively for about 60 days (during July-August), where agricultural crops are grown once a year, therefore, farmers are not willing to invest in fertilizer and other agricultural inputs, because of the risk of crop failure. As a result agricultural productivity is low and poverty is high. FAO (1999) argued that higher productivity and production is associated with high input use, therefore, the main constraint to increase food production is limited uptake of new technologies by risk-averse farmers. The uncertainty caused by unreliable moisture availability is the main factor behind the risk aversion behavior of farmers. Since the exogenous component of production uncertainty is reduced with assured access to irrigation, we assume that production and income difference between irrigating and rain-fed households is observed even if there is no difference in input use.

Another dimension through which irrigation can impact on household income and poverty reduction is through its spillover effect. The economic integration (linkage) effect of irrigation on poverty reduction is important, but in most cases remains masked. As discussed above, irrigating households benefit directly through increased and stable income or because of the higher value of irrigated land. On the other hand, even landless laborers and small farmers who have no access to irrigation often benefit through higher wages, lower food prices and a more varied diet (FAO 2003). Therefore, in areas where there is irrigation project, we assume that more jobs and informal businesses (such as family based petty trade) are created. Since irrigation creates demand for small scale implements, credit, marketing and extension services, every job created due to irrigation may trigger another job in the non-agricultural sector. Figure 1 depicts the relationship between irrigation and poverty in more detail. The keys to the acronyms used in the figure are presented in table 1.

Figure 1 Impact of Irrigation on Household Income and Poverty Reduction: Irrigation-Poverty Linkages



4. Data and the study area

The data used in this paper was obtained from a survey made to study small-scale irrigation in the Tigray region, Ethiopia as part of a PhD study program. The study area covers six communities (*tabias*), each of which consists of about 4 villages. As presented in Figure 2, of the six sites, two each are in the southern and North-west zones, while the others are one each in Eastern and Central zone of Tigray; therefore, we believe that our data is representative of the region of *Tigray*.

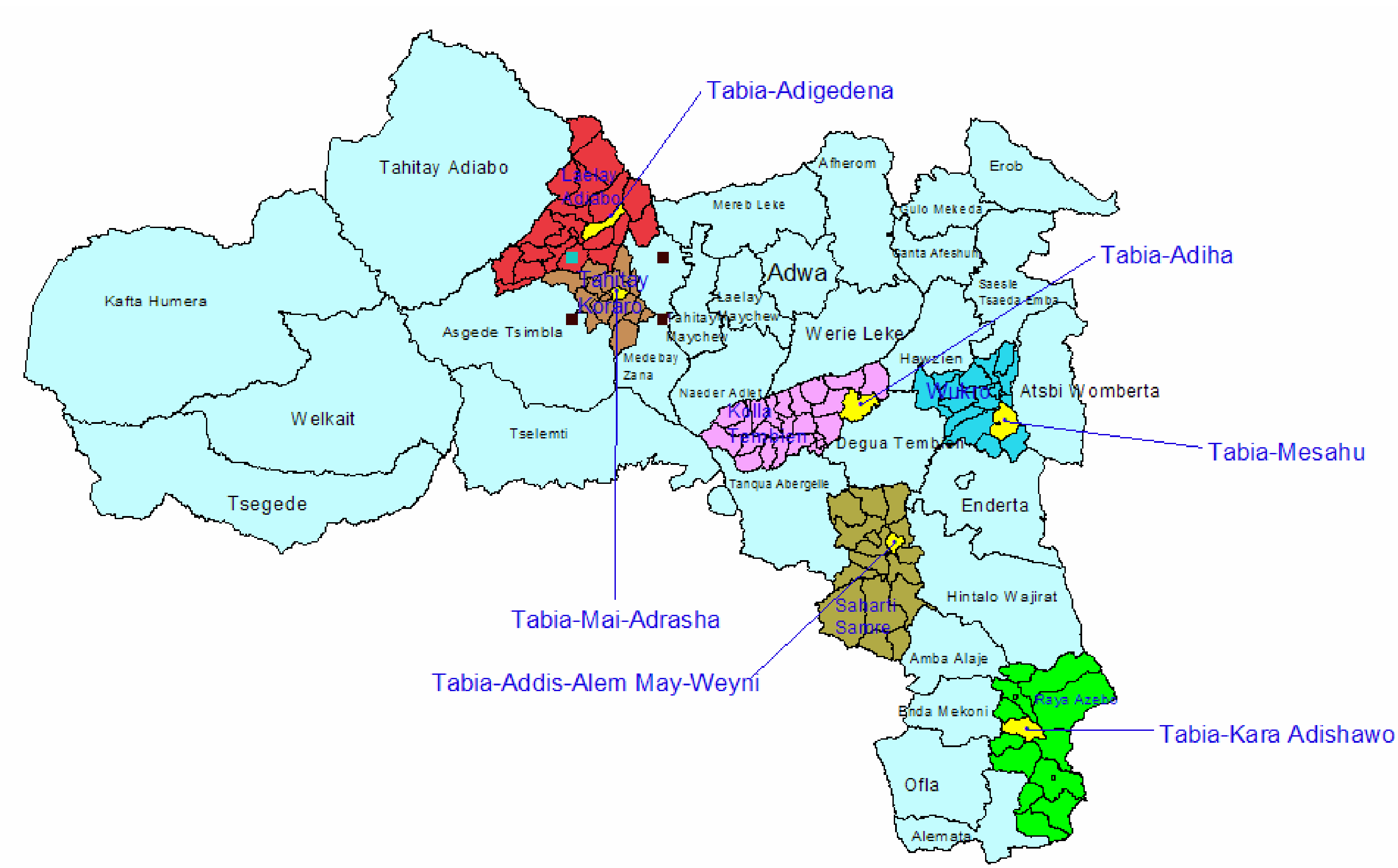


Figure 2: Map of Tigray, Ethiopia and study sites.

The sample selection process involved three stage stratified random sampling. First, all *tabias* in the region having irrigation projects were stratified based on the type of irrigation. Six sites were selected among which two of them use micro-dam, two river diversions and the rest two use ground water as a source of irrigation. Among the two ground water sites *Kara-Adi-Shawo* irrigation project located in *Golgol Raya* uses pressurized tube (drip/sprinkler) irrigation systems.

In the second stage, we stratified all farm households in each *tabia* based on their access to irrigation. Access to irrigated plot through any other means (such as formal or informal land rental contract) was not considered in the stratification process. Finally, we randomly selected 613 farm households (100 sample households from each of the five *tabias* and 113 households from *Kara-Adi-Shawo*). The proportion of sample households with and without access to irrigation mirrors the proportion of total households in the respective *tabia*. This approach enables us to collect information about non-irrigating households who are comparable in basic characteristics to the irrigators that can serve as counterfactual. From the total of 613 sample households, 331 of them had access to irrigation and 282 of them were purely rain-fed cultivators.

We asked our respondents about their household specific information. We have also collected data on farm input and output by asking each household head to recall his activities and production on a particular plot during the immediate past harvest year, that includes multiple cropping, especially in irrigated plots. Data collection was carried during October-December, 2005. Detailed plot level data was also collected. A plot is defined as a distinct management unit based on the type of crop planted during the 2004/2005 agricultural year. Plot size was not physically measured, but we ask farmers to tell us in local measurement unit (i.e., in *tsimdi)*. Four *tsimdi* is equivalent to one hectare. We have asked each respondent about the prices of input and output, but we have also randomly checked in the nearby market from which we calculated an average price for each product type in order to control the effect of price difference. The empirical method of analysis is outlined below.

5. Empirical Method

5.1. Estimation Method

The difficulty in impact evaluation is, identifying the comparison group (the counterfactual). To make an impact evaluation, we need to know what the outcome (in our case the income of households who actually have access to irrigation) would have been in the absence of irrigation (i.e., the counterfactual). Once the problem of identifying the counterfactual is resolved, the difference between the actual and the would be income is the impact of irrigation. However, since the counterfactual income is not observed, resolving such missing data problem requires feasible method of estimation that is based on economic theory. In other words, in studying the impact of irrigation, a methodological problem that is frequently observed is the tendency to assume every income and poverty difference observed between households with and without access to irrigation solely attributed to the irrigation factor (Dhawan 1988), therefore, to insure methodological rigorousness, estimating the counterfactual is at the core of impact evaluation (Baker 2000). In line with this, we used matching method to form a counterfactual against which comparison can be made. To analyze the impact of small-scale irrigation in Tigray, we consider irrigation as a treatment and rain-fed as a control. A dummy variable I is used to denote access to irrigation, where (I=1) if household i has access to irrigation, and (I=0) otherwise. Variables Y_1 and Y_0 represent household's income with and without access to irrigation, respectively. Subscripts 1 and 0 indicate income with and without access to irrigation, respectively. In line with this, the impact of irrigation on income of household i is given by:

$$\Delta_i Y = Y_{1i} - Y_{0i} \qquad [1]$$

For a household who have access to irrigation, we only observe Y_{1i}, while for those who have no access Y_{0i} is observed, implying that a household can not be in both situations at a, therefore, we only observe Y_{1i} or Y_{0i}, which can be written as:

$$Y_i = IY_{1i} + (1-I)Y_{0i} \qquad [2]$$

In Equation [2] if I = 1, (1-I) = 0, thus $Y_i = IY_{1i}$ and the reverse is also true. When we say impact, we mean the change in income due to access to irrigation, thus by rearranging equation [2], we get

$$Y_i = Y_{0i} + \Delta_i I \qquad [3]$$

If household i has no access to irrigation, I = 0, Δ_iI = 0, therefore, $Y_i = Y_{0i}$.

In summary, we draw three basic points about the whole process of examining the impact of irrigation. Firstly, the framework differentiates between outcomes (Y_{1i} and Y_{0i}) and impact (Δ_i). The former is simply about describing the outcomes (Y_{1i} and Y_{0i}), while the second is about impact (Cobb-Clark and Crossley 2003). Secondly, the analytical framework allows for heterogeneity in impact as well as in income (income without irrigation). This point is very important in an empirical impact study and differentiates the analytical framework adopted in this study from other models which assume homogeneity. The assumption of heterogeneity is important, because in practice, all households who have access to irrigation can not benefit equally due to heterogeneous characteristics. Thirdly, the framework is restrictive, because it assumes a Stable-Unit-Treatment-Value (SUTV). As explained in the second point, the impact of irrigation varies across households due to their heterogeneous characteristics, and it assumes that any impact is confined within that household which implies SUTV, thus it rules out the possible interaction effect, however, this may not be plausible assumption, because of the spillover effect of irrigation.

The assumption of heterogeneity is important to frame our analysis. According to Cobb-Clark and Crossley (2003), population average treatment effect (ATE) [E(Δ_i)] and average treatment effect on the treated (ATT) $\left[E\left(\Delta_i \middle| I=1\right)\right]$ are different, but are frequently estimated impact parameters, which can be specified as in equation (4) and (5), respectively.

$$ATE = E\left(\Delta_i\right) = E\left[Y_{1i} - Y_{0i}\right] = \left\{E\left[Y_{1i} - Y_{0i} \middle| I=1\right]\Pr\left(I=1\right)\right\} + \left\{E\left[Y_{1i} - Y_{0i} \middle| I=0\right]\Pr\left(I=0\right)\right\} \quad [4]$$

Since the objective of this paper is to estimate the average treatment effect on the treated (ATT), Equation (4) is irrelevant. Hence, the average effect of the treatment (irrigation) on the income of the treated (ATT) can be written as:

$$ATT = \left[E\left(\Delta_i \middle| I=1\right)\right] = E\left[Y_{1i} - Y_{0i} \middle| I=1\right] = E\left[Y_{1i} \middle| I=1\right] - E\left[Y_{0i} \middle| I=1\right] \quad [5]$$

The difference between equation (4) and (5) is that Equation (4) estimates the average treatment effect of irrigation on the income of the whole population irrespective of household's access to irrigation, i.e., E(Δ_i), while Equation (5) estimates the average treatment effect conditional on access to irrigation, i.e., E(Δ_i| I = 1), which is ATT. The most common evaluation context is one of ex-post evaluation, where we wish to know what change in outcomes an intervention delivered for those who were subject to the intervention (Cobb-clark and Crossley 2003).

ATT could have give a policy idea about the possible impact of irrigation if more investment is made to expand the program and more households get access to irrigation. However, the basic problem in estimating ATT is the missing data problem. For example, in Equation (5), $E\left[Y_{1i} \middle| I=1\right]$ is observed, while $E\left[Y_{0i} \middle| I=1\right]$ is missing. If we assume that the impact of irrigation is homogenous, it would imply that Equation (4) is equal to Equation (5), i.e., ATE = ATT. Thus the missed data would have been estimated by $E\left[Y_{0i} \middle| I=0\right]$ in Equation (4), because homogeneity assumes that $E\left[Y_{0i} \middle| I=1\right] = E\left[Y_{0i} \middle| I=0\right]$. However, since different households have different characteristics, they respond quite differently to the same treatment. Hence, the realistic assumption about the impact of irrigation is heterogeneity, which invalidates the possibility that the missed data $E\left[Y_{0i} \middle| I=1\right]$ in Equation (5) can be approximated by $E\left[Y_{0i} \middle| I=0\right]$ as in Equation (4). Therefore, the basic question is, how can we estimate the income of those households who actually have access to irrigation in the absence of irrigation.

One possibility to handle such a problem is to use the income of households who have no access to irrigation to estimate what the income of those households who have access to irrigation would have been in the absence of irrigation which can be written as:

$$E\left[\Delta_i \middle| I=1\right] = E\left[Y_{1i} - Y_{0i} \middle| I=1\right] = E\underbrace{\left[Y_{1i} \middle| I=1\right]} - E\underbrace{\left[Y_{0i} \middle| I=1\right]} \quad [6]$$

Observed Missing

If we use income of non-participating household to estimate the unobservable/missing data, equation (6) can be rearranged as:

$$E\left[\Delta_i \left| I=1\right.\right] = E\left[Y_{1i}\left| I=1\right.\right] - E\left[Y_{0i}\left| I=0\right.\right]$$

[7a]

By subtracting and adding $E\left[Y_{0i}\left| I=1\right.\right]$ to equation (7a) we get

$$E\left[Y_{1i}\left| I=1\right.\right] - E\left[Y_{0i}\left| I=0\right.\right] - E\left[Y_{0i}\left| I=1\right.\right] + E\left[Y_{0i}\left| I=1\right.\right]$$

[7b]

By rearranging the above specification, we obtain

$$E\left[Y_{1i}-Y_{0i}\left| I=1\right.\right] + E\left[Y_{0i}\left| I=1\right.\right] - E\left[Y_{0i}\left| I=0\right.\right] =$$

$$E\left[\Delta_i\left| I=1\right.\right] + \left\{E\left[Y_{0i}\left| I=1\right.\right] - E\left[Y_{0i}\left| I=0\right.\right]\right\} = ATT + BIAS$$

[7c]

Therefore, it is now clear that Equation (7c) suffers from bias because the income of households with and without access to irrigation would be different in the absence of irrigation, why identifying a counterfactual is the core of impact evaluation. While experimental design method is theoretically ideal for establishing a counterfactual, it is practically impossible, hence, it has been shown that non-experimental design methods, particularly the matching method is considered as the best solution in practice (Cobb-Clark and Crossely 2003). In Equation (7c), $ATT = E\left[\Delta_i \left| I\right.\right]$ and $BIAS = \left\{E\left[Y_{0i}\left| I=1\right.\right] - E\left[Y_{0i}\left| I=0\right.\right]\right\}$, therefore if a parametric regression method is applied, the assumption will be no selection bias in program placement, however, when the program is policy induced (such as placement to irrigation), it is purposive placement, then the outcome will depend on treatment status implying selection bias (Ravallion, 2005).

Specifically, matching is used to estimate the expected counterfactual $\left\{E\left[Y_{0i}\right], I=1, X_i = x\right\}$ using $Y_{0i}, I=0, X_i$ close to x drown from the households who have no access to irrigation, i.e., I =0 to serve as a comparison group for each household $\left\{E\left[Y_{1i}\right], I=1, X_i = x\right\}$ in the treated, i.e., I =1, therefore, the missing data is now estimable through the counterfactual as follows.

$$\Delta_i = Y_{1i} - E\left[Y_{0i}\right] \qquad [8]$$

But, since Equation (8) estimates homogeneous impact, while the heterogeneous impact (ATT) is estimated as:

$$ATT = \left[E\left(\Delta_i \left| I=1\right.\right)\right] = \frac{1}{I}\sum\left(Y_{1i} - E\left[Y_{0i}\right]\right)I = \frac{1}{I}\sum \Delta_i I \qquad [9]$$

5.2. Selection procedure of participants

When we embark on impact evaluation, especially when non-parametric method is employed, it is important to have clear understanding about the selection processes of project site beneficiary placement, administrative and institutional details of the program (Ravallion, 2005), both at household and plot level.

Accordingly, in Tigray, irrigation project sites were selected based on environmental and geological futures of the area, which includes: availability enough catchments area, sufficient reservoir, presence of sufficient command area, geological feasibility, short crust length. In the regional state of Tigray, it is a tradition to consult the community and make sure that the project is accepted by the community before construction is started. Moreover, priority is given to drought prone areas. Accordingly, since the site selection criteria are related to topographical issues, whether a plot is irrigated (treated) or not depends on factors, such as rainfall agro-ecology; slope of land, susceptibility to erosion, soil type and soil quality. Commonly, irrigation projects found in lowland areas with upstream catchments, therefore, we assume that plots that become irrigated are steep sloped, and those which are susceptible to erosion. Furthermore, because of continuous soil erosion and/or sediment accumulation that take place prior to project inception, potentially irrigable plots can be peroxide by their soil chrematistics.

The issue of household's access to irrigation (i.e., whether a household is treated or not) is relevant after the project is constructed. According to criteria used in the region, priority is given to farm households who get land within the command area before the project was constructed. The standard irrigated plot size is one tsimidi (i. e., 0.25 ha, that represents an area a farmer can plough with a pair of oxen within a day), hence, who had more than one tsimidi were lowered to one tsimidi considering that one tsimidi of irrigable land is equivalent to 2 or 2.5 tsimidi of rainfed land (depending on the availability of land in each community), however, in most of the communities, the withdrawal was done without compensation because of scarcity of land. Farm households who lost land because of water in the reservoir are the next beneficiaries to get the standard size of irrigable land in the command area. Finally, given that the command area allows (i.e., there is unoccupied irrigable land), additional farm households become beneficiaries among which poor households (i.e., who lacks livestock and have more family size) and female headed households get priority. Although small in number (49 households), we found that households can access irrigable land through land rental market. Accordingly, we used household head's sex, family size, female and male adult members of the household, plot size, a dummy variable for type of land rented in (1=irrigated, 0=raiinfed), number of plots owned by the household and dummy variable for ownership of land (i.e., whether the household has rented in land or not) as matching variables to estimate the propensity score. Usually, households with more family size, especially with more dependent are considered as poor in the rural areas of Tigray as elsewhere in Ethiopia. Plot number was used as matching variable, because it proxies the probability of having land in the command area and the probability of being considered as a poor. If a household owned more plots, the probability of having land in the command area is high, while the probability of being considered as poor to get access to irrigation is low. Although, livestock ownership was used as a selection variable, it is also an outcome of access to irrigation; hence, we opt not to use it as selection criteria.

5.3. Why Propensity Score Matching (PSM) Method?

In practice, participation in anti-poverty program cannot be randomly; hence, matching method is among the appropriate evaluation tools to assess the impact of such social programs. To apply the matching method, it is necessary to identify households from the non-participant group that is similar in terms of observable characteristics. However, in practice, since exact matching is rarely possible, because the observable variables based on which the counterfactual is estimated and individuals are matched can be many and different in dimensions making matching difficult, options for closeness in matching must be considered (Rosenbaum and Rubin 1985), hence, the Propensity Score Matching (PSM) method, which is based on the assumptions of conditional independence and common support, has been used as one method to solve the problem of dimensionality. The idea of estimating propensity score is used to balance households who have access to the treatment (irrigation) by choosing control households from those who have no access to the treatment (irrigation), but look like the treated households based on observable characteristics (Ho et al., 2007), therefore, are comparable to estimate the impact of irrigation. "The use of PSM relaxes the assumption of exogenous placement of anti-poverty programs, and it attempts to balance the distribution of observables, i.e., the propensity score" (Ravallion, 2005), therefore, unlike the much theoretic randomization, PSM emphasizes on the matching variables and on the quality and quantity of data

As compared to parametric models, PSM is preferred, because it relaxes randomization. Furthermore, its simplicity in relaxing the assumptions of functional forms that normally are imposed by parametric regression models, such as OLS is an advantage. "PSM allows the estimation of mean impacts without arbitrary assumptions about functional forms and error distributions. Furthermore, despite that regression models use full sample, PSM is confined to matched one (i.e., the region of common support), therefore, impact estimated with parametric models (i.e., based on full or unmatched samples) are more biased and less robust to miss-specification of regression functions than those based on matched samples."(Ravallion, 2005).

Finally, our study takes the advantage of having detailed survey data and full knowledge of the program. Our knowledge about the administrative and implementation procedure of irrigation schemes in the region helps us to identify proxy variables that determine program participation. We have collected a detailed data by administering the same questioner to both the participants and non-participants. The nearest neighbor and kernel matching methods were used to estimate the average treatment effect of irrigation on the treated (ATT). We have checked that the common support and balancing properties were satisfied in our data, hence, the remaining bias, if any, can be attributed to unobserved characteristics (Jalan and Ravallion, in press).

5.4. Limitations

There are three basic problems that confound impact evaluation in general, which includes: selection bias, spillover effect and data/measurement error (Ravallion, 2005) where our study is not exceptional. The main concern of non-parametric impact evaluation is whether the selection (placement) process to participate in the program is full captured by the control variables (Ravallion, 2005).

Since irrigation a policy induced program to reduce poverty, it is impractical to assume that participation could be random, hence, it should be emphasized that the concern about selection bias is that some of the variables that jointly influence income and access to irrigation are unobservable making it difficult to claim that the entire difference between the income of households with and without access to irrigation is attributed to irrigation (such a bias is specified in Equation 7c). This indicates that we can only minimize the level of bias. There are examples indicating that bias can be large in non-experimental impact evaluation among which (Lalonde, 1986; Glewwe et al., 2004; and Van de Walle, 2002) are few, but this does not mean that non-experimental impact evaluation methods can not be used(Ravallion, 2005).

The spillover effect is another methodological challenge of impact assessment, implying that eliminating selection bias by itself is not sufficient to identify the impact of treatment. The estimation method outlined in section 5.1 assumes that the presence of irrigation project in the community affects only those who have access to it (i.e., ATT), however, although they are not direct beneficiaries, those who get employment through the project implementation also benefits fro the project. For example, irrigation network construction and catchments treatment brought a huge employment opportunity for people inside and outside the command area. Furthermore, even after the project completion, more labour get recruited because of the labour intensive nature of irrigation. The benefits of lower food prices lead to improved nourishment of the whole community. On the other hand, irrigation brings negative externality, such as prevalence of malaria. In general, in the presence of positive spillover effect, estimated impact could be downward biased, while it could be upward biased if the negative affected is assumed in the estimation process.

6. Results and Discussion

6.1 Descriptive results

Household characteristics and resource endowments:

The descriptive results are presented in tables 2 and 3. There are no significant differences between irrigators and rain-fed farmers regarding household demographic characteristics and level of education. No significant difference is observed in farm size between the two groups. We noted that households who have access to irrigation hired more labor as compared to households who have no access to irrigation.

Both irrigating and rain-fed households have almost equal number of oxen, milk cows and labor although we observed slightly higher values in favor of irrigating households.

Comparison of level and sources of income, consumption and poverty:
Irrigators had, more diversified income sources. The irrigators had significantly higher non-crop farming income. The non-crop farming activities are mainly related to livestock rearing including dairying, poultry and bee keeping. There is no significant difference in the magnitude of income obtained from off-farm activities between the two groups, however, the contribution of off-farm income to non-irrigating households' total income is about 18 percent higher than that of irrigating households'. This might be due to the labor intensive nature of irrigation. The implication is that households who have access to irrigation are more occupied in their own farm and have less off-farm participation.

Although farming income constitutes, on average, about 72 percent of the total sample household's income, it contributes 76 percent of income of households who have access to irrigation, and only 66 percent of income of households without access to irrigation. Given the contribution of agriculture to the income of rural households, such differences in the proportion of farming income supports the argument about the role of investment in irrigation as a poverty reduction strategy. In general, the descriptive statistics makes clear that irrigators have less off-farm employment and more cropping income.

Overall, the total income of non-irrigators is only about 67% of that of irrigators. Thus the mean income for irrigators is significantly higher than that of non-irrigators. However, the difference in the total household consumption expenditure between the two groups is not that significant. The consumption expenditure is higher for irrigators only by 8.6%. The implication is that even though the observed income gap between irrigators and non-irrigators is huge, the non-irrigators where able to smooth their consumption level and bring it almost to the level of that of irrigators through various mechanisms. This confirms the usual claims made in the literature that consumption expenditure is the preferred measure of welfare to income[13]. Although the average per capita income of irrigators and rain-fed farmers are above the official poverty line that of irrigating households is almost double of that of the non-irrigating households. The difference between per capita consumption expenditure of irrigators and non-irrigators is statistically significant.

The observed income difference between the two groups is also reflected in the poverty incidence rate. The poverty incidence was calculated using a poverty line determined based on the estimated income required to access the minimum calorie required for subsistence (i.e., 2200 kcal) and other essential non-food goods and services. The official national poverty line is 1075 Birr in 1995/96 constant national average prices (Weldehanna 2004), however, the regional poverty line (for Tigray region) was estimated at Birr 1033.5 (Hagos 2003). Our study shows that poverty incidence (i.e., the proportion of poor households) among irrigators group is significantly lower than that of non-irrigators. The poverty incidence among non-irrigators is slightly higher than the regional average for Tigray and significantly higher than the national average (Table 2 and 3). In general Tigray, Amhara and SNNPR are the worst regions in terms of poverty incidence and depth.

6.2. Model results

The propensity score matching allows for the statistical comparison group to irrigation participants. Table 4 presents the logit regression used to estimate the propensity scores on the basis of which the matching was subsequently done. The logit regression suggests that the probability of access to irrigation increases as household's ownership of land (both in size and number of plots) increase.

[13] However, beware that the consumption smoothing is usually achieved through distress measures such as drawing down on the stock of assets owned such as livestock, borrowing, etc.

Table 5 gives our estimates of average income gains, off-farm labor allocation and magnitude of off-farm income difference based on Nearest Neighbor, Kernel and stratification matching methods.

The overall average income gain due to participation in irrigated agriculture ranges between 3600 to 4500 Birr based on the matching method adopted. The average income gain estimated stratified matching method is lower than that of the Kernel matching method and nearest neighbour methods. The nearest neighbour matching method is some what conservative since only 71 cases from the total of 282 rain-fed farming households were judged to be comparable to irrigators when using this method (Table 5). On the other hand, the stratification matching method is not restrictive. Although the Kernel matching method is marginally conservative as compared to stratification, but resulted in higher overall income gain. 236 rain-fed farmers where estimated to be comparable to the irrigators when using the Kernel matching method.

The mean overall income gain due to participation in irrigation calculated based on the whole irrigators and non-irrigators sample (i.e., without using PSM method) is 1413.07 (4278.445 minus 2865.377, see table 2). Thus the use of the whole rain-fed sample as a counterfactual would under estimate the impact of irrigation on income and poverty. The bias is about 2208.19 (3620.26[14] minus1413.07) Birr. Moreover, the irrigators had lower off-farm income than non-irrigators but the difference is not statistically significant.

6.3 Stochastic dominance analysis

Although randomization is considered as a powerful method of impact assessment, no single method is ideal implying that a combination of tools might be appropriate (Ravallion, 2005). Accordingly we have used a stochastic dominance analysis to check the robustness of our estimation of matching method. Such an assessment is based on set poverty lines, which ideally give the minimum income that is sufficient for an individual to fulfill a minimum level of consumption, therefore, the individual's standard of living is above the poverty line. The general principle of setting a poverty line is that the individual whose income is above the poverty line is being adequately nourished and can fulfill the basic needs. We used a poverty line equal to 1033.5 Birr (Hagos, 2003). We assessed the impact of access to irrigation on the cumulative distribution of income and then poverty reduction by simulating multiple poverty lines. We found that the stochastic dominance tests confirm the results of propensity score matching that investment in small-scale irrigation has significant impact on household income and poverty statues. Results of the stochastic dominance tests are reported in figures 3-5. Comparing the head count ratio (the first order stochastic dominance tests), we found that poverty incidence is significantly low for households with access to irrigation. Similarly, the second and third order stochastic dominance tests confirm that the depth and severity of poverty is lower for irrigating households.

7. Conclusions

Poverty reduction in Tigray regional state is a core policy agenda of both regional government and the federal government of Ethiopia. Investment in small-scale irrigation was regarded as a key poverty reduction strategy and many governmental and non-governmental organizations have constructed different irrigation systems with a total irrigation capacity of 3700 hectares benefiting about 19000 farming households. However, limited efforts have been made so far to assess whether investments in small-scale irrigation in Tigray have attained the stated objectives of poverty reduction, food security and overall socioeconomic improvement in Tigray. In fact some of the limited efforts made to assess small-scale irrigation systems are quite pessimistic (see Pender et al. 2002). The main objective of this study was to robustly assess the link between public investment in irrigated agriculture and its

[14] This number shows the minimum gain based on the estimation of stratified matching method.

impacts on income and household poverty in Tigray.

To analyze the welfare impact of small-scale irrigation, Propensity Score Matching method has been applied to a data set generated from a random sample of 613 farming households (i.e., 331 irrigators and 282 rain-fed farmers) representing different agro-ecological zones of Tigray and irrigation system typologies. The main conclusions from the study are as follows:

- There is no significant differences in household demographic characteristics between the irrigators and non-irrigators sample households
- Irrigators hired more labor indicating the relative labor absorption potential of irrigated farming as compared to rain-fed farming
- Irrigators had more diversified income sources
- Households with access to irrigation had lower participation in off-farm activities again indicating the labor absorption or on-farm employment generation capacity of irrigated agriculture
- The mean income of irrigators is significantly higher than that of rain-fed farmers. There is also a difference (although not statistically significant) in total household consumption expenditure between the two groups.
- The over all average income gain due to participation in irrigated agriculture estimated using PSM method ranges between 3600 to 4500 Birr per household per annum, which is higher than the income gain estimated based on the whole sample (i.e., using the total rain-fed farmers sample as a counterfactual or comparison group). Hence, the use of PSM avoided the under estimation of the magnitude of irrigation impact on income.
- Finally, the significant income gain has significantly reduced poverty among farmers with access to irrigation.

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Table 1. Key to the acronyms used in Figure 1 or conceptual framework.

Accronym	Description
DAM	Source of water for irrigation is micro-dam
RDIV	Source of water for irrigation is river diversion
GWM	Source of water for irrigation is groundwater :modern communal
GWT	Source of water for irrigation is groundwater: private manual
IRRIG	Access to irrigation
LABOUR	Household's labor endowment
CREDIT	Access to credit
ASSET	Asset holding
LSIZE	Land holdings size
OXEN	Number of oxen owned
LIVESTOCK	Households livestock holding (TLU)
MARKET	Distance to nearest market
INPUT	Total expenditure o inputs used (Chemicals, fertilize, seed, etc)
LANDPR	Land productivity
LABPR	Labor productivity
HHSIZE	Household size in adult equivalent
AGE	Age of household head
SEX	Sex of household head
EDUC	Number of educated household members
COWORO	Consumer worker ratio
ALTITUDE	Altitude above sea level
AVRAFLL	Average rainfall
CV	Coefficient of variance of rainfall
SOILTYPE	Soil types
LANQUALI	Land quality
AGRINCOME	Income from agriculture (cropping income)
OTHINCOME	Income from other sources
HHINCOME	Total household income
POVREDU	Poverty statues based on income level

Table 2: Summary statistics of selected variables used in estimating the treatment effect

Welfare indicators	Irrigators (N=330)		Non-irrigators (N=282)		*t*-test (Significance test of difference)
	Mean	SE	Mean	SE	
Household characteristics and resource endowments					
Family size (number)	5.066	.120	4.681	.127	-2.206**
Family size (adult equivalence)	4.495	.126	4.154	.129	1.884*
Female adult members of the household (number)	2.650	.078	2.482	.076	-1.5302
Male adult members of the household (number)	2.417	.082	2.199	.087	-1.817*
Number of plots the household cultivated in 2005/06	4.574	.109	3.351	.114	-7.736***
Number of oxen the household own	1.260	.056	1.121	.066	-1.625
Number of milk cows the household own	.656	.057	.660	.075	0.043
Farm size in hectare	5.018	.160	5.038	.203	0.082
Household members who can read and write (number)	1.426	.084	1.259	.081	-1.418
Income and consumption					
Total Household income in 2005/06 (Birr)	4278	364	2865	224	-3.178***
Total Household consumption expenditure in 2005/06 (Birr)	3058.839	111	2817.016	106.248	-1.555
Proportion of farming income (%)	.76	.011	.66	.016	-5.234***
Per capita income (Birr)	1230.097	169	799.304	63.477	-2.248**
Per capita expenditure(Birr)	803.190	34	785.259	30	0.393
Poverty incidence (%)	.44	.027	.56	.030	3.111***

Table 3. Poverty by region using poverty line based on Basket of Kcal

Region	Per capita consumption expenditure (Birr) (1999)	Poverty Index (%)		Poverty Gap (2002)
		1999	2002	
Tigray	903.60	0.58	0.56	0.17
Afar	1105.6	0.52	0.33	0.10
Amhara	917.2	0.57	0.54	0.16
Oromia	1184.0	0.35	0.34	0.08
Somali	1166.4	0.35	0.31	0.07
Benshangul-Gumuz	1026.8	0.48	0.47	0.13
SNNPR	945.5	0.57	0.56	0.18
Gambela	1223.5	0.42	0.34	0.09
Harari	1459.7	0.29	0.22	0.05
Addis-Ababa	1569.0	0.30	0.30	0.09
Dire Dawa	1397.1	0.25	0.29	0.07
National	**1087.8**	**0.46**	**0.45**	**0.13**

Source: FDRE (1999, 2002)

Table 4: Estimation of the propensity score to estimate the impact of irrigation on household's income, off-farm labor participation, and off-farm income

Variable	Variable Description	Coef.	z
accirri	Access to Irrigation (1=yes, 0=no)		
plotsize	Plot size in hectare	-2049959(.0378145)	-5.42
typland	Type of rented in land (1=irrigated, 0=rainfed)	-.4637671(.4452168)	-1.04
hheadsex	Household head sex(1=male, 0=female)	.0742088(.2271787)	0.33
familysize	Family size in number of people	.0532757(.0483211)	1.10
femwl	Adult female working labour	.0183509(.1003034)	0.18
mamwl	Adult male working labour	-.0856737(.0919116)	-0.93
plotnumber	Number of plots operated by the household in 2005/06 production year	.5404309(.0649462)	8.32
ownrship	Whether a household rented in land (1=yes, 0=no)	-.1359277(.183545)	-0.74
_cons	Constant	-1.079743(.4993401)	-2.16

Notes: () = Std. Err.; *, **, *** Significant at 10%, 5% and 1%, respectively;
Treatment is Access to Irrigation

Table 5: Impact of irrigation on household income, household labor allocation and off-farm income (Bootstrapped standard errors): Estimation results of matching method

Impact on	Matching Method	Number of Treated	Number of Control	Average Treatment effect on the Treated (ATT)	*t-statistic*
Income	Nearest neighbour (Equal version)	331	71	3940.604 (1348.995)	2.921**
	Nearest neighbour (random version)	331	71	3940.604(1677.466)	2.349**
	Kernel Matching Metod	331	236	4405.777 (1382.702)	3.186**
	Stratification	331	259	3620.260 (1516.378)	2.387**
Off-farm labour allocation	Nearest neighbour (Equal version)	331	71	14.171 (20.037)	0.707
	Nearest neighbour (random version)	331	71	14.171 (23.227)	0.610
	Kernel Matching Metod	331	236	8.808 (14.145)	0.623
	Stratification	331	259	9.605 (9.958)	0.965
Off-farm Income	Nearest neighbour (Equal version)	331	71	77.023(233.666)	0.330
	Nearest neighbour (random version)	331	71	77.023(446.155)	0.173
	Kernel Matching Metod	331	236	-256.966(288.294)	-0.891
	Stratification	331	259	-103.900(97.895)	-1.061

Note: numbers in parenthesis are bootstrapped standard errors, ** significant at 5% level of significance, *df = 8*

Figure 3: First order stochastic dominance test to compare the incidence of poverty among households with and without access to irrigation

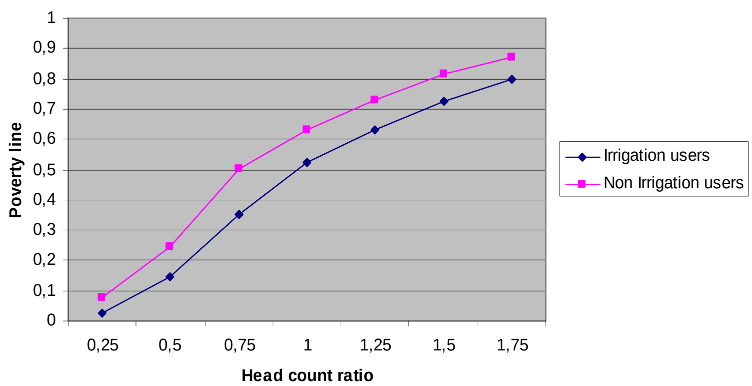


Figure 4: Second order stochastic dominance test to compare the depth of poverty among households with and without access to irrigation

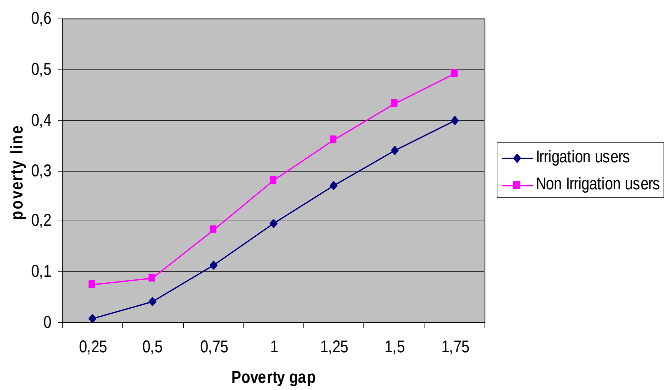
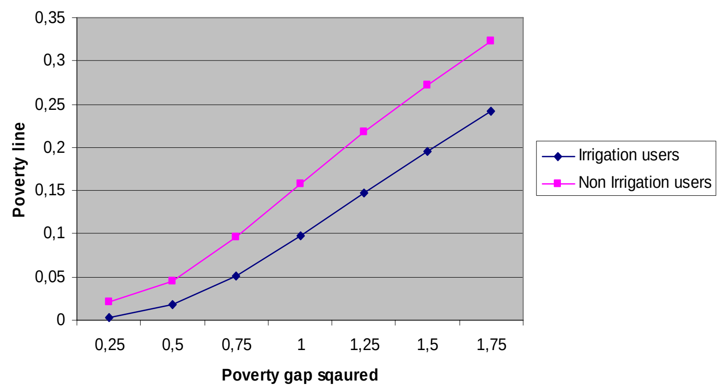


Figure 5: Third order stochastic dominance test to compare the severity of poverty among households with and without access to irrigation



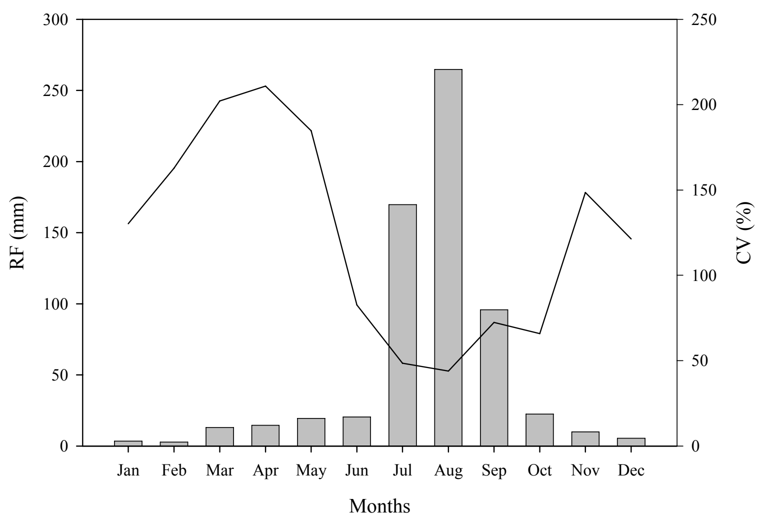


Figure 6: Average monthly rainfall distribution (RF) and Coefficient of Variance of rainfall CV) of Tigray (1956-2006)
Source: Ethiopian Metrology Agency, Tigray branch office

Appendix 1: Logit model Estimates of Propensity Score Matching

****
Algorithm to estimate the propensity score
****
The treatment is access to irrigation (accirri)

access to irrigation 1=yes, 0=no	Freq.	Percent	Cum.
0	282	46.00	46.00
1	331	54.00	100.00
Total	613	100.00	

Estimation of the propensity score

Iteration 0: log likelihood = -422.93873
Iteration 1: log likelihood = -377.59997
Iteration 2: log likelihood = -376.19771
Iteration 3: log likelihood = -376.18939
Iteration 4: log likelihood = -376.18939

Logistic regression Number of obs = 613
LR chi2(8) = 93.50
Prob > chi2 = 0.0000
Log likelihood = -376.18939 Pseudo R2 = 0.1105

accirri	Coef.	Std. Err.	z	P>z	[95% Conf.	Interval]
plotsize	-.2049959	.0378145	-5.42	0.000	-.279111	-.1308809
typland	-.4637671	.4452168	-1.04	0.298	-1.336376	.4088418
hheadsex	.0742088	.2271787	0.33	0.744	-.3710532	.5194707
familysize	.0532757	.0483211	1.10	0.270	-.0414319	.1479834
femwl	.0183509	.1003034	0.18	0.855	-.1782401	.2149419
mamwl	-.0856737	.0919116	-0.93	0.351	-.2658171	.0944697
plotnumber	.5404309	.0649462	8.32	0.000	.4131387	.6677231
ownrship	-.1359277	.183545	-0.74	0.459	-.4956693	.2238138
_cons	-1.079743	.4993401	-2.16	0.031	-2.058432	-.1010546

Note: the common support option has been selected
The region of common support is [.24230422, .98838866]

Description of the estimated propensity score in region of common support

Estimated propensity score

	Percentiles	Smallest		
1%	.2458666	.2423042		
5%	.2771301	.2439084		
10%	.3179111	.2447952	Obs	590
25%	.4128555	.2452673	Sum of Wgt.	590
50%	.5375359		Mean	.5527539
		Largest	Std. Dev.	.1792381
75%	.6757212	.9483694		
90%	.8177568	.9499213	Variance	.0321263
95%	.8822696	.952905	Skewness	.3062784
99%	.9415825	.9883887	Kurtosis	2.282861

****

Step 1: Identification of the optimal number of blocks

Use option detail if you want more detailed output

****

The final number of blocks is 8.This number of blocks ensures that the mean propensity score is not different for treated and controls in each blocks

****

Step 2: Test of balancing property of the propensity score

Use option detail if you want more detailed output

****

The balancing property is satisfied

This table shows the inferior bound, the number of treated and the number of controls for each block

Inferior of block of pscore	access to irrigation 1=yes, 0=no 0	1	Total
.1428571	36	2	38
.2857143	46	6	52
.3571429	38	39	77
.4285714	60	107	167
.5714286	49	93	142
.7142857	21	54	75
.8571429	9	30	39
Total	259	331	590

Note: the common support option has been selected

****

End of the algorithm to estimate the pscore

****

end of do-file

The Impact of Small Scale Irrigation on Household Food Security: The Case of Filtino and Godino Irrigation Schemes in Ada Liben District,

East Shoa, Ethiopia

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Abstract

Irrigated production is far from satisfactory in the country. The country's irrigation potential is estimated at 3.7 million hectare, of which only about 190,000 hectare (4.3 percent of the potential) is actually irrigated. The aim of this paper is to identify the impact of small-scale irrigation on household food security based on data obtained from 200 farmers in Ada Liben district of Ethiopia. Different studies revealed that access to reliable irrigation water can enable farmers to adopt new technologies and intensify cultivation, leading to increased productivity, overall higher production, and greater returns from farming. In the study area also about 70 percent of the irrigation users are food secure while only 20 percent of the non-users are found to be food secure. Access to irrigation enabled the sample households to grow crops more than once a year; to insure increased and stable production, income and consumption; and improve their food security status. The study concludes that small-scale irrigation is one of the viable solutions to secure household food needs in the study area but it did not eliminate the food insecurity problem.

1. Introduction

1.1 Background

Ethiopia is faced with complex poverty, which is broad, deep and structural (MoFED, 2002). Despite the importance of agriculture in its economy, the country has been a food deficit country for several decades, with cereal food aid averaging 14 percent of total cereal production

(FAO, 2001). Irrigation is one means by which agricultural production can be increased to meet the growing food demand in Ethiopia (Awulachew *et al*., 2005). However, in Ethiopia irrigated production is far from satisfactory (Woldeab, 2003). While the country's irrigation potential is about 3.7 million hectares (WSDP, 2002), the total irrigated area is 190,000 ha in 2004, that is only 4.3 percent of the potential (FAO, 2005).

It was claimed that Ethiopia can not assure food security for its population with rain fed agriculture alone without a substantive contribution of irrigation. Thus, the government of Ethiopia has prepared a water sector development program to be implemented in 15 years between 2002 and 2016. this program assigned a prominent role to the development of irrigation in the country for food production (mowr, 2001). this paper reports the results of a study conducted to assess the efficacy of irrigation led food insecurity eradication and poverty reduction policy objectives of ethiopia based on data collected from godino and filtino small scale irrigation schemes found in ada liben district of the oromia regional state of ethiopia.

1.2 Irrigation and Household Food Security: some empirical evidences

Chamber (1994) based on some empirical studies confirms that reliable and adequate irrigation increases employment, i.e., Landless laborers as well as small and marginal farmers have more work on more days
of the year, which ultimately contributes to food security. A study conducted in 10 Indian villages in different agro-climatic regions shows that increasing irrigation by 40 percent was equally effective in reducing poverty (reducing food insecurity) as providing a pair of bullocks, increasing educational level and increasing wage rates (Singh *et al*., 1996). Kumar (2003) also stated that irrigation has significantly contributed to boosting India's food production and creating grain surpluses used as drought buffer. A study by Hussain *et al*. (2004) confirms that access to reliable irrigation water can enable farmers to adopt new technologies and intensify cultivation, leading to increased productivity, overall higher production, and greater returns from farming. This in turn opens up new employment opportunities; both on farm and off-farm, and can improve incomes, livelihood, and the quality of life in rural areas. The same study identified five key dimensions of how access to good irrigation water contributes to socioeconomic uplift of rural communities. These are production, income and consumption, employment, food security, and other social impacts contributing to overall improved welfare.

According to a study carried out on five irrigation schemes in Zimbabwe, the schemes were found to act as sources of food security for the participants and the surrounding community through increased productivity, stable production and incomes (Mudima, 1998). The same study reported that farmers participating in irrigation schemes never run out of food unlike their counterparts that depend on rain-fed agriculture.

Ngigi (2002) disclosed that in Kenya for the two decades agricultural production has not been able to keep pace with the increasing population. To address this challenge the biggest potential for increasing agricultural production lies in the development of irrigation. According to the same study, irrigation can assist in agricultural diversification, enhance food self sufficiency, increase rural incomes, generate foreign exchange and provide employment opportunity when and where water is a constraint. Nigigi concluded that the major contributions of irrigation to the national economy are food security, employment creation, and improved foreign exchange earning.

A study by IFAD (2005) states that in Ethiopia, the construction of small-scale irrigation schemes has resulted in increased production, income and diet diversification in the Oromia and Southern Nation and Nationalities People (SNNP) regions. According to this study, the cash generated from selling vegetables and other produce is commonly used to buy food to cover the household food demand during the food deficit months. The same study further added that during an interview conducted with some farmers, it was disclosed that the hungry months reduced from 6 to 2 months (July and August) because of the use of small scale irrigation. Moreover, the increase in diversity of crops across the schemes and the shift from cereal-livestock system to cereal-vegetable-livestock system is starting to improve the diversity of household nutrition through making vegetables part of the daily diet. A study conducted by Woldeab (2003) also identified that in Tigray region irrigated agriculture has benefited some households by providing an opportunity to increase agricultural production through double cropping and by taking advantage of modern technologies and high yielding crops that called for intensive farming.

However, these studies were descriptive than analytical in that they did not formally account for/ isolate the possible contribution of other confounding variables such has household/village characteristics, and other policies and interventions that might have as well contributed to the food security status differences between irrigators and non-irrigators. Moreover, the empirical works in this area are very scant in Ethiopia in particular and in Africa in general. Thus, the study aims to contribute to the small scale irrigation-food security literature and to provide policy conclusions and implications for future planning of irrigation systems.

2. Research methodology

2.1. Study area, sample size and sampling techniques

godino and filtino small scale irrigation schemes are found in ada liben district and were constructed by oromiya irrigation development authority (oida) in 1996 and 1998, respectively (oida, 2000). the water source for godino irrigation scheme is wedecha dam, which has the capacity to irrigate about 310 ha. while the water source for filtino irrigation scheme is belbela dam, which has a capacity of irrigating 100 ha. the irrigable land in the respective command areas is distributed to farmers by the government. except few farmers who lease-in additional irrigable land almost all farmers in the area own quarter of a hectare. the major types of crops grown by irrigation are onion, tomato, potato and chick pea among others.

Out of the 45 Peasant Associations (PA) that are found in the Ada Liben district, two PAs namely *Godino* and *Quftu* were purposely selected mainly because of availability of irrigation schemes. To select sample respondents from the two PAs, first the household heads in the two PAs were identified and stratified in to two strata: irrigation users and non-users. Then the sample respondents from each stratum were selected randomly using simple random sampling technique. Since the number of household heads in the two groups was proportional, equal number of sample is drawn from each group, i.e., 100 household heads were selected from each group. In total 200 household heads were interviewed.

2.2. Data collection

The data required for this study was collected from sample respondents using a semi-structured questionnaire. The enumerators for the data collection were selected on the basis of their educational background and their ability of the local language. One week training was given to the enumerators about method of data collection and the contents of the questionnaire. Data collection proper was started after pretest was conducted and modifications were made based on the feedback from the pretest. Secondary information that could supplement the primary data was collected from published and unpublished documents obtained from different governmental and non-governmental organizations.

2.3. Method of data analysis

The study employed both descriptive and econometric techniques. The descriptive analysis was performed using frequencies, means, and maximum and minimum values. The econometric analysis employed the Heckman two-step procedure to identify the impact of small scale irrigation on household food security from among possible other household food security influencing factors.

Heckman two-step procedure: Evaluating the impact of a project/program on an outcome variable using regression analysis can lead to biased estimate if the underlying process which governs selection into a project/ program is not incorporated in the empirical framework. The reason for this is that, the effect of the program may be over (under) estimated if program participants are more (less) able due to certain unobservable characteristics, to derive these benefits compared to eligible non-participants (Zaman, 2001).
To evaluate the impact of a program, a model commonly employed can be expressed as:

$$Y = X\beta + \alpha I + u \quad (1)$$

Where Y is the outcome/impact, X is a vector of personal exogenous characteristics and I is a dummy variable (I=1, if the individual participates in the program and 0 otherwise). From this model, the effect of the program is measured by the estimate of α. However, the dummy variable 'I' can not be treated as exogenous if the likelihood of an individual to participate or not to participate in the program is based on an unobserved selection process (Maddala, 1983). Some studies have shown the limitations of applying the classical linear regression methodology to the analysis of samples with selectivity bias (Heckman, 1979, Dardis *et al*. 1994, Sigelman and Zeng, 1999, Maddala, 1992). Application of the classical linear regression model does not guarantee consistent and unbiased estimates of the parameter. One solution to this problem in econometrics is the application of Heckman two-step procedures. It is considered as an appropriate tool to test and control for sample selection biases (Wooldrige, 2002).

The Heckman two step procedures involves two equations. The first equation (i.e., the selection or participation equation) attempts to capture the factors governing membership in a program. This equation is used to construct a selectivity term known as the 'Mills ratio' which is included as independent variable to the second equation known as response or outcome equation. If the coefficient of the 'selectivity' term is significant then the hypothesis that the participation equation is governed by an unobserved selection process or selectivity bias is confirmed. Moreover, with the inclusion of extra term, the coefficient in the second stage 'selectivity corrected' equation is unbiased (Zaman, 2001). Therefore, to evaluate the impact of small scale irrigation on household food security, we use the Heckman two-step procedure.

Specification of the Heckman two-step procedure:

Let Z_{ik} be a group of K variables which represent the characteristics of a household i which influences the probability of participation in irrigation agriculture measured by a latent variable D_i^* and γ_k are the coefficients which reflect the effect of these variables on the probability of being an irrigation farmer, and X_{is} is a group of variables which represent the characteristics of household i which determine household's food security (C_i) and β_s are the coefficients which reflect the effect of these variables on household food security. Thus, the Heckman two-step procedure takes the following form:

$$D_i^* = \sum_{K=1}^{K} \gamma_k Z_{ik} + u_i \qquad (2)$$

$$C_i = \sum_{S=1}^{S} \beta_s X_{is} + \varepsilon_i \text{ Observed only if}$$

$$D_i^* > 0... \qquad (3)$$

Where the disturbances u_i and ε_i follow a bivariate normal distribution with a zero mean, variance σ_u and σ_ε respectively, and covariance $\sigma_{\varepsilon u}$. Therefore, we define a dichotomous variable D_i which takes a value 1 when a household is an irrigator and 0 otherwise. The estimator is based on the conditional expectation of the observed variable, household food security (C_i):

$$E\left(C_i / D_i^* > 0\right) = x\beta + \sigma_{\varepsilon u}\sigma_\varepsilon \lambda(-\gamma z) \qquad (4)$$

Where λ is the inverse Mills ratio defined as $\lambda(-\gamma Z) = \phi(-\gamma Z)/(1-\varphi(-\gamma Z))$; β and γ are the vectors of parameters which measure the effect of variables X and Z, ϕ and φ are the functions of density and distribution of a normal, respectively. The expression of conditional expectation shows that C_i equals $x\beta$ only when the errors ε_i and u_i are non correlated, i.e., $\sigma_{\varepsilon u} = 0$; otherwise, the expectation of C_i is affected by the variable of equation 2. Thus, from expression 4 we find that:

$$C_i / D_i > 0 = E\left(C_i / D_i^* > 0\right) + V_i = x\beta + \sigma_{\varepsilon u}\sigma_\varepsilon \lambda(-\gamma Z) + V_i \qquad (5)$$

Where V_i is the distributed error term, $N\left(0, \sigma_\varepsilon\left(1 - \sigma_{\varepsilon u}\left(\lambda(\lambda - \gamma Z)\right)\right)\right)$

3. Results and discussion

3.1. Descriptive Results

The variables included in the model are defined in table 1. The dependent variable for the first stage of the Heckman two-step procedure is participation in irrigation. This variable is a dummy variable (given a value of 1 if the household participates in the irrigation scheme and 0 otherwise) for the second stage of the model household food security status is a continuous variable measured by the annual food expenditure in Birr of the household per adult equivalent. Before discussing the econometric results, however, we present some interesting descriptive results.

One of the pervasive features of food insecurity in Ethiopia is that it is usually seasonal. It mainly coincides with the active agricultural season or wet season. To this effect we have tried to see if there is discernable difference in the timing of food inadequacy between irrigators and non-irrigators. Surprisingly, there is no difference regarding the timing of food shortages between irrigators and non-irrigators (See Figure 1). The food shortage months start as early as June (which is the beginning rainy season and therefore agricultural activities in the study areas) and extends up to November (which is the beginning of harvest season). No household from the irrigators group has reported food shortage in June. September is the most serious food shortage month among non-irrigators, while October is the peak food shortage month for irrigators. About half of the non-irrigators reported food shortage in the month of September. However, there is a stark difference regarding the incidence rate of reported food shortage between the two groups. The proportion of farmers reporting food shortage in every month is significantly lower for irrigators group. It is interesting to note that irrigation has not eradicated the food insecurity problem even in this seemingly better off part of the country indicating the depth of the problem.

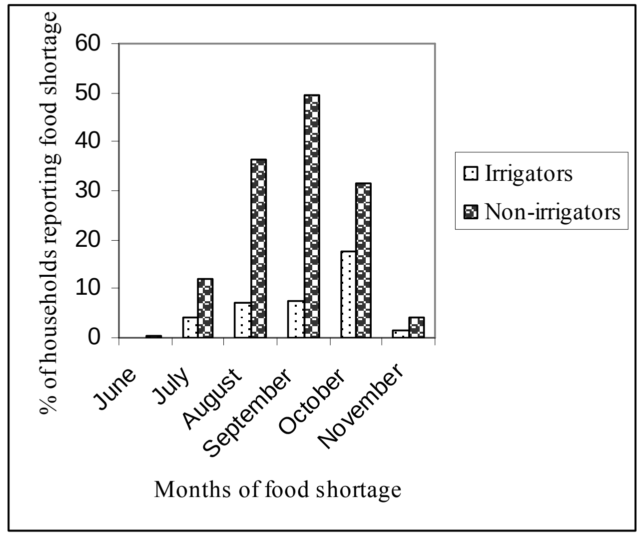

Figure 1. Incidence of reported food shortage by months

The irrigators and non-irrigators have slightly different copping mechanisms in the advent of food deficit problem (See figure 2). None of the irrigators have reported off-farm employment as a coping strategy and also relatively fewer irrigators reported to have used credit as a means of copping with food shortage. It must be noted that using wage employment and consumption credit as a strategy to avert food insecurity is considered as a distress measure or strategy in Ethiopia. Small animals (such as sheep, goats and chicken) is the most important copping strategy among both irrigators and non-irrigators.

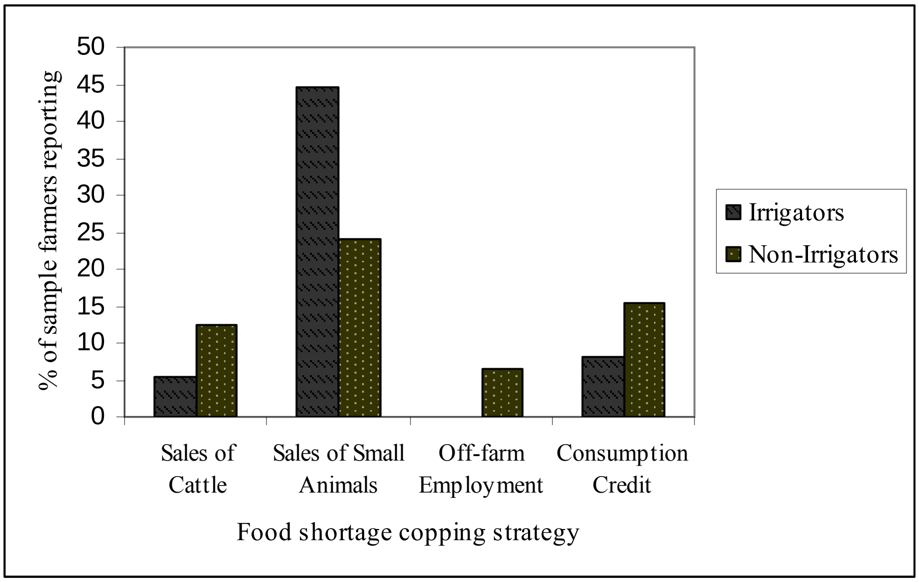

Figure 2. Food shortage coping mechanisms

Based on how households adapt to the presence or threat of food shortages, the overall Coping Strategy Index (CSI) has been calculated for each of the sample households and the resulting values were averaged for irrigators and non-irrigators. It was found that the average CSI for irrigator households is 11.4, while for non-irrigators the corresponding value is 31.4. The mean difference is statistically significant (Table 2). The higher the CSI, the more food-insecure is a household (reference). Therefore, based on CSI the non-irrigator households are more food insecure as compared to irrigator households.

The calculated food consumption expenditure per adult equivalent values also confirms the food security status difference between irrigators and non-irrigators (table 2). The average food consumption expenditure per adult equivalent per annum for irrigation user households is 1322.4 Birr, while the corresponding figure for non-users is 774.4 Birr. The mean difference is statistically significant. Moreover, the total consumption expenditure (both food and non-food) for irrigators is almost double that of non-irrigators.

The minimum food consumption expenditure per adult equivalent above which a household is considered to be food secure (alternatively below which a household is considered as food insecure) was calculated based on the estimated cost of acquiring the recommended daily calorie allowance, which was taken as 2200 kcal per adult equivalent per day[15]. This cut-off value is estimated to be Birr 900.0 per adult equivalent per annum. Thus, households having food consumption expenditure per adult equivalent of less than Birr 900 are considered as food insecure, while those earning more than Birr 900 are considered to be food secure. Based on this indicator, again there is substantial difference in food insecurity incidence rate between irrigator and non-irrigators households (see figure 3). Generally out of the 200 sample households 45 percent of them are food secure and 55 percent of them are food insecure.

15 This cut-off value was calculated following Greer and Thorbecke (1986) food energy intake method of measuring household food security

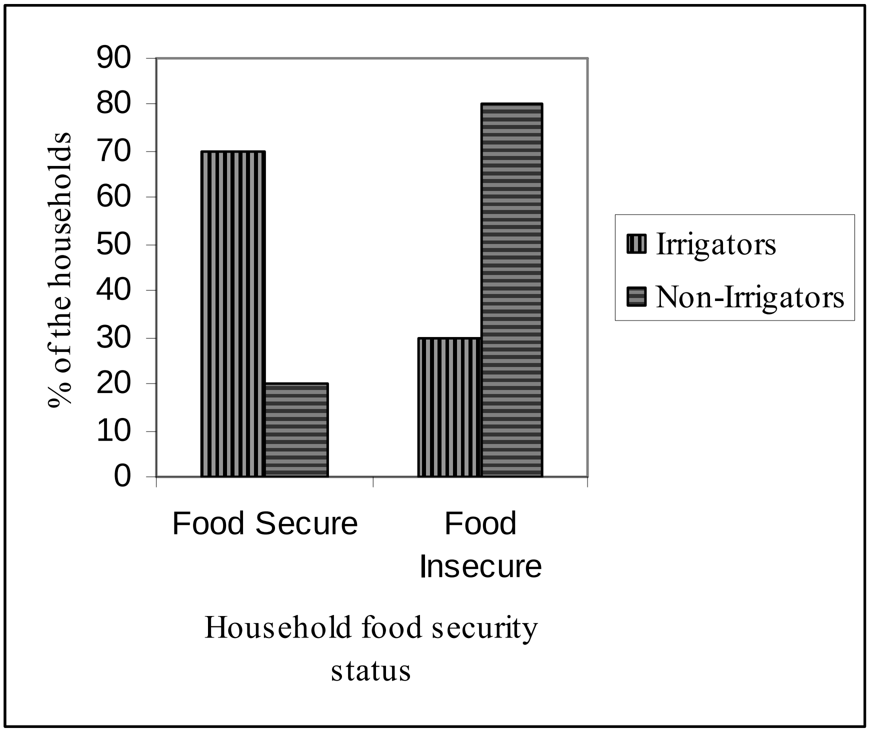

Figure 3. Household food security status differentiated by access to irrigation

When comparing other indicators of welfare between irrigation and non-irrigators, statistically significant differences were detected (Table 3). For example, irrigators have small household size, higher level of education, large livestock holding size, and better quality (fertility) cultivable land. The irrigators had also better access to extension and credit services (Table 4). In conclusion, the descriptive analyses indicate that irrigators are better off in terms of food security status and other welfare indicators. But is this due solely to access to irrigation? Other observable and unobservable variables might have contributed to the observed food security status difference between irrigators and non-irrigators. Therefore, we know turn to the presentation of Heckman's two stage regression model to show the impact of access to irrigation on food security while controlling for the effects of other observable and unobservable confounding factors.

3.2. Econometric Analysis Results

Determinants of likelihood of access to irrigation: The first stage of the Heckman model predicts the probability of access to the irrigation scheme of a household. Among the observable hypothesized variables, those that significantly influenced the probability of participating in irrigation farming include nearness to the water source, household siz size of cultivated land, livestock holding, the quality of land owned by a farmer and access to credit (Table 5). The relationship between household size and participation in irrigation project is non-linear. As the size of a household increases by one adult equivalent, the probability of access to irrigation decreases by 30.4% but only up certain point beyond which a unit increase in household size starts increasing the likelihood of participation in irrigation. As the size of cultivated area increases the probability of being an irrigator decreases. This may imply that irrigators tend intensify their cultivated land, while rain-fed farmers try to put more land under cultivation.

Irrigators have significantly more livestock than their rain-fed only farmers. They also possess more fertile land.

Determinants of household food security: The significance of the lambda term in the second stage of the Heckman procedure, confirms the presence of selectivity bias (Table 6). As expected, access to irrigation had significant impact on household food security. In the study area irrigation enable households to grow crops more than once a year, to insure increased and stable production, income and consumption thereby improving food security status of the household. This result is consistent with the finding of Abebaw (2003). The other variables that significantly enhance household food security are experience (as indicate by farmers age in years), access to extension service, and size of cultivated land. .
The relationship between household size and food security is non-linear (see the coefficients for household size and its square variable). The negative and significant coefficient of household size reveals that larger household size leads to food insecurity, but only up to a certain point. The coefficient of the variable indicates that as the household size increases by one adult equivalent the food consumption expenditure of the household decreases by 391.9 Birr. This result is consistent with the finding of Mulugeta (2002) and Yilma (2005). Contrary to other similar studies (Belayneh, 2005), in this study female headed households had better food security status than the male headed households. The coefficient of the variable shows that when the head of the household is male, food consumption expenditure of the household decreases by 331.1 Birr. The possible justification for this inverse relationship could be that though male headed households are in a better position to pool resource to increase production, they might spent more money on nonfood expenses rather than spending on food items to meet the household's food needs.

The regression result also shows that as the cultivated land size increases, a household is able to increase and diversify the quantity and type of crop produced, which may in turn lead to increased consumption and household food security. The coefficient of the land size variable shows that as the household gets one more hectare of land food consumption expenditure of the household increases by 85 Birr. This result is consistent with the findings of Mulugeta (2002), Ayalew (2003), Abebaw (2003) and Yilma (2005).

Access to extension service and nearness to the water source are also found to have a positive relationship with household food security. The positive effect of access to extension service may indicate that in the study area, those households who get technical advice and training or those who participated in field demonstrations are well aware of the advantage of agricultural technologies and adopt new technologies and produce more, thereby improving the household food security status. The nearness to the water source may be a surrogate variable for access to irrigation. It has already been shown that to the irrigation scheme, significantly improves household's food security status. The possible other justification could be that the nearness to water source may proxy the location of the farms in relation to the irrigation water source . Therefore, households who are closer to the irrigation scheme do not incur much cost to access their farm so they can follow up the farm activity closely and frequently and may get a better yield.

4. Conclusion and Implications

The variables that significantly predict access to irrigation are: household size, size of cultivated land, livestock holding, farmers' perception of soil fertility status, access to credit, nearness to the water source and household size square. The variables that reduce the probability of access to irrigation are large household size, large cultivated area and access to credit. Rain-fed farmers tend to have large cultivated area. The negative relationship between access to credit and access to irrigation may be explained by the fact that: (1) in Ethiopia, the institutional credits usually give priority to rain-fed agriculture, and (2) the demand for credit among farmers with access to irrigation may be lower for they can satisfy cash needs through sales from their irrigated crops.

The variables that increase the probability of participation of farmers in irrigation farming include large livestock holding size, ownership of relatively fertile land and nearness to water source. Obviously, those households that are situated near the water source are more likely to participate in irrigation scheme. However, it does not mean that placement of an irrigation scheme in the village is solely governed by hydrological considerations. It involves political process and power relations.

In the study area the use of small-scale irrigation contributes significantly to improve household food security. In addition to access to irrigation, access to irrigation, household size, sex of the household head, size of cultivated land, and access to extension service significantly influence the food security status of a farm household.

The relationship between a household food security status and household size is non-linear (see the signs for the variables household size and the square of household size). As the size of a household increases the per capita food expenditure decreases, but up to a point, after which the per capita food expenditure starts to increase as the household size increases. Contrary to expectation, female headed households are less likely to be food insecure as compared to male headed households. This needs further investigation, however, tentatively it may be explained by differences in the expenditure behavior of male and female farmers-female members of a farm household tend to spend more on food items to guarantee the food needs of the family before anything else. Another possible explanation may be that the male members of a female-headed household may have gainful employment elsewhere thus contributing to household food security.

Size of cultivated land and household food security are positively related indicating larger farm size improves household food security. Households with large farm size are found to be food secure; however, there may not be a possibility of expanding cultivated land size any more because of increasing family size and degradation of the existing farm land. Therefore, household must be trained as to how to increase production per unit area (productivity).

Access to extension service is also positively related to household food security. Extension workers could play a key role in transferring knowledge to the rural people easily there by improving production and consumption. Capacity building of the existing ones and training more extension workers might help address the issue.

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Table 1. Definition of model variables

Variable code	Variable type	Variable definition	Mean	Std.	Expected sign
ACCIRRG	Dummy	Access to irrigation of the household			Positive
HEADAGE	Continuous	Age of household head in years	48.0	13.5	Positive
HEADAGE2	Continuous	Age of the household head square			Positive
HHSIZEAE	Continuous	Household size in adult equivalent	4.7	1.7	Negative
HHSIZEAE2	Continuous	Household size in adult equivalent square			Positive
EDUCATA	Category	Education of the household head /illiterate, read and write, grade 1-4, grade 5-8 and grade >8/			Positive
SEXHEAD	Dummy	Sex of the household head (1=male, 0=female)			Positive
CUTLAND	Continuous	Cultivated land size in hectare	1.5	1.2	Positive
LIVESTOC	Continuous	Total livestock holding in TLU	6.7	4.2	Positive
DISMARKE	Continuous	Distance from the market place in km	6.7	2.1	Negative
SOILFERT	Dummy	Farmers' perception of soil fertility status (1= fertile, 0= infertile)			Positive
SUPPEX	Dummy	Access to extension service (1= access, 0=no access)			Positive
CREDIT	Dummy	Access to credit (1=access, 0=no access)			Positive
NEARNESS	Continuous	Nearness of households to water source in km	13.0	9.7	Positive

Table 2. Comparison of consumption expenditure per adult equivalent between irrigators and non-irrigators

	User		Nonuser		MD	t - value
	Mean	Std	Mean	Std		
Food consumption expenditure	1322.3	563.4	774.4	369.7	547.8	8.0***
Total expenditure	1,780.3	946.4	955.6	434.5	824.7	7.9***
Coping strategy index	11.4	13.9	31.4	16.1	19.93	9.1***

Source: survey result (2006)

*** indicates significance level at 1 percent.

Table 3. Summary of descriptive statistics of sample households by access to irrigation /continuous variables/

	User		Nonuser		MD	t - value
	Mean	Std	Mean	Std		
HEADAGE	46.8	14.4	49.5	12.5	2.7	1.4
HHSIZEAE	4.3	1.7	5.1	1.8	0.7	3.0***
DEPRATIO	0.4	0.1	0.5	0.1	0.0	3.1***
CUTLAND	1.5	1.5	1.4	0.7	0.1	0.9
LIVESTOC	7.3	3.4	5.0	2.6	2.2	3.6***
TOTPRODUC	13,689.1	21,706.8	2,255.4	3,487.0	11,433.7	5.2***
TOTEXPEN	1,780.3	946.4	955.6	434.5	824.7	7.9***
DISMARKE	7.3	2.2	6.1	1.9	1.2	4.0***

Source: Survey result (2006)
*** indicates significance level at 1 percent.

Table 4. Summary of descriptive statistics of sample households by access to irrigation /discrete variables/

Variable	User	Nonuser	Total	$\chi 2$
EDUCATAGORY				0.007***
Illiterate	69	58	127	
Read and write	1	13	14	
Grade 1-4	3	7	10	
Grade 5-8	15	15	30	
Grade >8	12	7	19	
SEXHEAD				0.6
Female	7	9	16	
Male	93	91	184	
SUPPEX				0.002***
Access to extension	67	45	112	
No access to extension	33	55	88	
CREDIT				0.01***
Access to credit	31	48	79	
No access to credit	69	52	121	
SOILFERT				0.001***
Fertile	93	67	160	
Infertile	7	33	40	

Source: Survey result (2006)
*** indicates significance level at 1 percent.

Table 5. Estimation result of the Binary Probit model and its Marginal Effect

Variable	Coefficient	Marginal effect
CONSTANT	2.634 (0.203)	1.050 (0.203)
AGEHEAD	-0.861 (0.248)	-0.343 (0.248)
HHSIZEAE	-0.764 (0.021) **	-0.304 (0.021)
SEXHEAD	0.414 (0.438)	0.165 (0.438)
EDUCATAGORY	-0.293 (0.764)	-0.117 (0.764)
DISMARKE	-0.324 (0.673)	-0.129 (0.673)
CUTLAND	-0.604 (0.004) ***	-0.241 (0.004)
LIVESTOC	0.362 (0.000) ***	0.144 (0.000)
SOILFERT	0.838 (0.019)***	0.334 (0.019)
SUPPEX	-0.427 (0.169)	-0.170 (0.169)
CREDIT	-0.615 (0.024)**	-0.245 (0.024)
NEARNESS	0.403 (0.008)***	0.160 (0.008)
AGEHEAD2	0.722 (0.302)	0.288 (0.302)
HHSIZEAE2	0.687 (0.034)**	0.274 (0.034)

Dependent variable	Access to irrigation
Weighting variable	One
Number of Observations	193
Logliklihood function	-69.13
Restricted log likelihood	-133.65
Chi squared	129.03
Degree of freedom	13
Significance level	0.00

Source: Model out put (2006)

*** and** are level of significance at 1 percent and 5 percent respectively

Values in parenthesis are p values

Table 6. Estimation Result of the Selection Equation and its Marginal Effect

Variable	Coefficient	Marginal effect
CONSTANT	1553.936 (0.000)***	1553.936 (0.000)***
ACCIRRIG	576.882 (0.000)***	576.882 (0.000)***
AGEHEAD	14.918 (0.348)	14.918 (0.348)
HHSIZEAE	-391.676 (0.000)***	-391.676 (0.000)***
SEXHEAD	-331.133 (0.001)***	-331.133 (0.001)***
EDUCATAGORY	1.736 (0.930)	1.736 (0.930)
DISMARKE	13.567 (0.378)	13.567 (0.378)
CUTLAND	85.751 (0.058)*	85.751 (0.058)*
LIVESTOC	-5.063 (0.717)	-5.063 (0.717)
SOILFERT	-47.613 (0.534)	-47.613 (0.534)
SUPPEX	117.729 (0.069)*	117.729 (0.069)*
CREDIT	-44.539 (0.429)	-44.539 (0.429)
NEARNESS	9.602 (0.009)***	9.602 (0.009)***
AGEHEAD2	-0.112 (0.441)	-0.112 (0.441)
HHSIZEAE2	25.607 (0.001)***	25.607 (0.001)***
LAMBDA	-243.448 (0.041)**	

Dependent variable	Total food (Total food expenditure per adult equivalent per annum)
Number of Observations	193
Selection rule is:	User =1
Log-L =	-1395.69
Restricted (b=0) Log -L =	-1489.70
R-squared =	0.58
Correlation of disturbance in regression and selection criteria (Rho)	-0.67
Prob value =	0.00

Source: model out put (2006)

*** ** and * show level of significance at 1percent, 5 percent and 10 percent probability level.

Values in parenthesis are p values

A Comparative Analysis of the Technical Efficiency of Irrigated and Rainfed Agriculture:

A Case of Awash and Rift Valleys of Ethiopia

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Abstract

Ethiopia's economy is heavily dependent on the agricultural sector, which contributes 45% of the GDP, providing livelihood for 85% of the population and accounting for 60% of the foreign exchange earning. Ethiopia, one of the poorest countries in Sub-Saharan Africa, has been repeatedly hit by drought resulting in famine and the loss of life of thousands of its rural citizens. The country's agriculture mainly depends on rain fed peasant farming which accounts for 96% of the food produced in the country. On the other hand, it is estimated that the major river basins of the country can irrigate about 3.5 million-hectare of land and at present only about 161,010 ha or 4.6% is irrigated around the major river basins. Though the expansion and better utilization of this irrigation potential is unattested, the production efficiency of the existing irrigation systems also needs attention. This paper compares the technical efficiency of rainfed and irrigated agricultural production in Ethiopia. Using the stochastic production frontier approach, the study concludes that the existing irrigation systems are not that efficient and there is a need to make them operate near their production frontier. The production frontiers of both irrigated and rainfed agriculture is estimated along with the technical efficiency of each farmer in both groups and the two groups are compared in relation to their respective frontiers. The marginal and average productivities of the important factors of production is also calculated and compared.

1. Introduction

Ethiopia has a total land area of about 113,000,000 hectares (Annual Report in the Ethiopian Economy, 1999). The economy is heavily dependent on the agricultural sector, which contributes 45 percent to GDP, 60 percent of the foreign exchange earnings and provides livelihood to 85 percent of the population (EEPRI, 2005). Of the arable land, only 40 percent is currently cultivated (Awulachew et al, 2005). As a result of the importance of agriculture in Ethiopia's economy, the government has embarked on an agriculture centered rural development program which is meant to spearhead the country's economic development program (Government of the Federal Republic of Ethiopia, 2003). Irrigation development is viewed as an integral part of this economic development program as promulgated by the Ethiopian Water Sector Strategy (Federal Democratic Republic of Ethiopia, 2001).

It is estimated that the major river basins of the country can irrigate about 3.5 million-hectare of land. At present only about 161,010 ha or under five percent is irrigated (Annual Report on the Ethiopian Economy). The private sector accounts for 6,000 ha of the developed irrigated area (Amare, 2000). Unpredictable rainfall coupled with a high rate of population growth, makes Ethiopia unable to feed its people. Even under favorable growth scenarios of rain fed agriculture, the country still faces a deficit of food crops.

The policies for economic development are formulated in an environment which can be referred to as the "Ethiopian Paradox". The Ethiopian Water Resources Management Policy (1999) states that Ethiopia is endowed with relatively higher amounts of rainfall in the region and has a surface runoff of about 122 billion cubic meters of water, excluding ground water. The same document also states that "…a number of studies made in the field confirm that if the country's water resources are developed to cater for irrigation, it would be possible to attain agricultural surplus enough both for domestic consumption as well as for external markets." pp VIII. However, even given this estimated potential, Ethiopia continues to be a recipient of food aid.

Irrigation development is therefore perceived as one of the strategies for alleviating the paradox. The government of Ethiopia has an irrigation development strategy which aims to develop over 470,000 ha of irrigation by 2016. Fifty two percent of this development will be large and medium scale schemes while the remaining 48 percent will be small scale schemes[16] (Federal Democratic Republic of Ethiopia, Water Sector Development Programme 2002-2016). Small scale irrigation development is therefore envisaged to play a critical role in the government's strategy for addressing the food security situation in Ethipoia and solving the paradox. However, the estimated area under small scale irrigation is owever, only 68,210 hectares in 1996/97 (CSA, 1998), only 30 percent of what the government plans to develop by 2016, showing that this irrigation sub sector still has great potential for contributing to the Ethiopian's government development objectives.

During the former Derg[17] regime, many small scale irrigation schemes were collectivized. They were generally poorly operated, managed and maintained and currently most, if not all, need for rehabilitation (CRS, 1999). Many small-scale irrigation infrastructures, especially traditional diversion weirs, which tend to be washed away by flash floods, need annual upkeep. Siltation and damage within the canal system from flooding are also major concerns for small scale irrigation (ibid). The degradation of upper catchments and watersheds in many areas does not help the situation (ibid).

Because of the ambitious government plans to expand small scale irrigation in Ethiopia, it is important to study, among other performance parameters, the production efficiency of small scale irrigation schemes . Many believe that the existing irrigation schemes are not operating efficiently, and that much has to be done to improve their efficiency. For example, CRS (1999) has identified that the existing small scale irrigation schemes exhibited inefficient use of water, leakage from unlined canals and faulty usage of irrigation water. This study estimates the technical efficiency of small scale irrigation in Ethiopia.

2. Objectives

The objectives of the study are to:

estimate and compare the technical efficiency of dryland and small scale irrigation farmers.

compare the technical efficiency of different small scale irrigation schemes and

[16] According to Awulachew et al (1999) irrigation projects in Ethiopia are identified as large-scale irrigation if the size of command area is greater than 3,000 ha, medium scale if it falls in the range of 200 to 3,000 ha, and small scale if it is covering less than 200ha.

[17] Desalegn and Miheret, 2004 characterized the Derg regime in Ethiopia as a Marxist-Leninist unitary state with an ideologically driven state or command economy policy.

make recommendations that lead to improved technical efficiency.

3. The study sites

Batu Degaga Irrigation project is located at 8° 25′ North latitude and 39° 25′ longitude, in the upper Awash River Basin. The elevation of the project area is around 1350 meters (Yusuf, 2004). The total developed irrigable area of the project is 140 ha of which 60 ha is currently under cultivation. Batu Degaga was established by World Vision Ethiopia, a non-governmental organization in 1992. In 1993, a Farmers' Water Users Association was formed and was led by the selected administrative committee from the irrigation project. The numbers of beneficiaries in the project were varying from year to year but now there are 120 members (ibid). Extension advice at Batu Degaga is being provided by six agricultural extension agents permanently residing around the irrigation system. They are graduates of the newly established agricultural training colleges.

Doni irrigation project is located in the upper valley of Awash River Basin and 33 Km North of Sodore Recreational Center. Geographical location of the project is 8° 30′ N and 39°33′ E and the elevation varies from 1240m to 1280m above sea level. It has a different development path from Batu Degaga. Some 30 years ago, a private investor constructed a low head gravity weir in Awash River and about 3 km of main canal for the scheme. During the Derg, the land was nationalized and distributed to smallholders. A Producer Cooperative was established to administer and use the scheme. However, scheme operation and maintenance was not good enough to keep it functional and after few years it almost collapsed. Following the downfall of the Derg, a group of individual farmers who owned land within the boundary of the irrigation scheme started rehabilitating it and requested the assistance of CARE-International in Ethiopia (a non-governmental organization). The request for rehabilitation was accepted in 1994 and the construction was completed in 1997 (ibid). At the time of study, there was no development agent assigned to the irrigation project to provide extension advice, however, Yusuf (2004) wrote that there was one development agent assigned by the Woreda's Irrigation Bureau to assist, advice, organize and monitor the irrigation project activity and the farmers in the association.

The Godino irrigation project is located in East Shewa zone of the Oromia region, Ada Liben Woreda. The water source is a big reservoir. The runoff of the surrounding catchments areas supplying the Wedecha and Belbela streams are made to run to the Reservoir and the water is distributed through canals. Though a Water Users Association does exist, Oromia Irrigation Authority and Woreda authorities control water distribution.

At Batu Degaga and Doni farmers grow vegetables like onions and potatoes. At Godino a mixed farming system consisting of vegetables, namely, chickpea, pea, onions, potatoes and cereals like maize, wheat and teff are practiced.

4. Data collection

The selected small scale irrigation schemes, namely, Doni, Batu Degaga, and Godino, which are located in the Rift Valley of Ethiopia, were chosen due to their relative proximity to the capital, Addis Ababa. Primary data were collected using the household as the unit of analysis. From each irrigation scheme, 50 randomly selected households were beneficiaries of irrigation and another 50 randomly selected households belonged to a control group who did not have access to irrigation. The control group is not far from the irrigation schemes. They are just bordering the irrigable area. Socio economic and production data were collected for the sample households for a year, between March 2004 and February 2005. Production data was used to compute the gross value of production per household.

The area planted was summed across irrigation seasons where applicable. Data on labor, family and hired, was collected for each cropping season by operation and also summed across seasons. The number of corrugated iron sheets of on the roof of the house of the farmer was used as a proxy for capital. Worku G. (1999) used the same methodology. Data were also collected on fertilizer applied, the number of oxen days used for plowing, money spent on seed and pesticides, and the total number of irrigations. Household size and off farm income were collected to give an idea of the household's dependence on irrigation.

The data were collected with funding from the International Water Management Institute (IWMI).

5. Methodology

The study utilizes the stochastic frontier production function, as developed by Aigner, Lovell and Schmidt (1977) and Meeusen and Van den Broeck (1977), to estimate technical efficiency.

For a cross section of firms, the stochastic frontier production function is given as:

$$Yi = f (Xi, b) + ei \quad , i= 1,\ldots,N \ldots\ldots\ldots.1$$

where Yi is the output of the ith firm, Xi is vector of inputs, and b is a vector of production function parameters. ei is an error term made up of two components such that:

$$ei = vi - ui \quad \ldots\ldots\ldots..2$$

In equation 2 the error term vi is assumed to be a symmetric disturbance that is independently distributed as N(0, s2v). This error term is thought to exist due to favorable and unfavorable external shocks out of the firms control and also to errors of measurement. It is this part of the error term that makes the frontier stochastic as firms can temporarily be above the frontier if the value of vi is large enough (Aigner et al., 1977).

The error tern ui is assumed to be independent of vi and meets the condition that $ui > 0$, or is truncated above zero. This error term provides deviations from the frontier. The negative sign in equation 2 along with positive values of ui cause negative deviations from the frontier for each observation. In their original paper Aigner at al.(1977) modeled this error term as a half–Normal and also as an exponential distribution.

In this study the frontier production function is used for cross-sectional data as described by Jandrow et al (1982) to estimate farm level technical inefficiency. The computer software FRONTIER Version 4.1 which gives the opportunity to specify the error term as half-Normal and truncated half-Normal was used to estimate the production function. The production function was specified as:

Value of output = (A, L, F, S, R, O, I, P)

where

A = Total area planted (ha).

L = labor used in person-days

F = Fertilizer applied in kg

S = Amount of money spent on seed (Ethiopian Birr, 1 USD = 8.65 Birr)

R = number of sheets of corrugated iron of the roof of the house (what is the need of including this variable if we are going to take it out of the estimation model.

O = number of oxen days for plowing.

I = total number of irrigations during the year.

P = amount of money spent on pesticides (Birr)

In all the three irrigation centers, average land holding family labor days used in production are higher in the dry land setting than that of the irrigation. However, irrigating farmers use much more hired labor. Output and off farm income are also very high in the irrigation setting as compared to the control group. Table 1 shows the mean values for the collected data.

Table1: Mean values of collected data by irrigation system

	Batu Degaga		Doni		Godino	
	Irrigation	Dry land	Irrigation	Dry land	Irrigation	Dry land
Off farm income (Birr)	187.8	96.2	1,790	1520	422	192.8
Household size	5.3	5.4	3.3	4.6	5.2	4.9
Irrigated land in h (ha)	0.55	1.53	0.44	1.78	0.36	0.67
Family labor days	49.6	83.1	9.2	83.6	80.1	89.8
Hired labor days	276.6	52.8	235	43.2	23.2	26.1
Fertilizer (kg)	255.8	100.8	1,161	37.3	136	253.8
Seed (Birr)	858.2	173	2,988	177	293	305
Iron sheets	**11.4**	4.3	27.4	13.5	30	23
Number of irrigations	27.2	----	61.7	----	15	----
Plowing oxen days	16.6	18.6	14.4	17.4	11.7	18.4
Pesticides (Birr)	459.3	80.1	2008	9.5	50	33.7
Value of output	16,374	4535.7	24,448	3,253	2,662	3294

6. Model Specification

An important issue in this study is the choice of functional form and the distribution of the error term. It is not assumed that the irrigation systems all have the same functional form which makes the comparison of technical inefficiencies somewhat complex. We started with a

general translog functional form and then test whether the equations can reduce to either a partial translog or a Cobb Douglas using a one-sided generalized likelihood ratio test. The chow test is used to determine

whether some of the schemes could be pooled together and thus estimate on equation. The same is done for the dryland data.

The different Chow test showed that the data from Doni and Godino could be pooled together. The likelihood ratio test also showed that the equation for the combined Doni and Godino data could be reduced to a Cobb Douglas. The same test (LR test = 36.4) showed that the half normal distribution of the error term was a better fit. The same result was arrived for the dry land data for Doni and Godino.

The irrigation and dryland data for Batu Degaga is therefore treated separately. Model specification tests for the irrigation data showed that the equation for Batu Degaga was a full translog with a truncated half normal error term.

7. Results

Estimation is done using FRONTTIER Version 4.1, a computer program for stochastic frontier production and cost function estimation, which was developed by Tim Coelli

7.I Production function analysis

7.1.1 Irrigation Settings

7.1.1.1 Doni and Godino together

The combined data for Doni and Godino has a sample size of 93. The variables included in the production function are the natural logarithms of output, land, number of irrigations, seed, fertilizers, pesticides, labor and the number of sheets of corrugated iron (as a proxy for capital) and the interactions of these variables. In the translog model the main variables with their interaction terms are 23 variables while there are 15 variables that are believed to explain inefficiency of farmers.

After some iterations, the likelihood ratio test showed that the Cobb-Douglas production function is the right specification for this data with 7 explanatory variables of the production function and 14 variables that are believed to affect efficiency of farmers. The same test also showed that the half normal distribution of the error term is the better distribution.

The final Maximum Likelihood Ratio estimates of Doni and Godino irrigation schemes combined:

	coefficient	standard-error	t-ratio
constant	3.37	0.64	5.24
land	0.08	0.13	0.58
water	0.06	0.09	0.69
seed	0.34	0.11	3.20
fertilizer	0.28	0.08	3.39
pesticide	0.02	0.05	0.46
labor	0.36	0.10	3.50
roofing	-0.005	0.04	-0.11

The dependent variable of this equation is the natural logarithm of output and all the explanatory variables are in natural logarithm form i.e the model is a double-log model.

FRONTTIER Version 4.1 gives the level of inefficiency of each farmer and the mean efficiency of the system along with the production function estimates. Inefficiency effects (variables that are believed to explain farmers' inefficiency) vary in number from scheme to scheme because variables that don't have any variability were avoided from the model.

7.1.1.2 Batu Degaga

The data for Batu Degaga has a sample size of 51. The variables included in the production function are the natural logarithms of output, land, number of irrigations, seed, fertilizers, pesticides, labor and the number of sheets of corrugated iron (as a proxy for capital) and the interactions of these variables. In the translog model the main variables with their interaction terms are 23 while there are 13 variables that are believed to explain inefficiency of farmers.

The different likelihood ratio tests showed that the production function for Batu Degaga can be represented by a full translog function while the error term has a truncated normal distribution.

The Maximum Likelihood Estimation results of the production function for Batu Degaga irrigation scheme is:

	coefficient	standard-error	t-ratio
constant	0.66	1.42	0.46
land	0.48	1.20	0.40
water	0.49	0.18	2.67
seed	0.19	0.07	2.76
fertilizer	0.03	0.72	0.04
pesticide	-0.40	0.41	-0.96
labor	1.79	0.85	2.09
roofing	0.33	0.51	0.64
landsq	-0.07	0.27	-0.27
fertsq	0.07	0.04	1.81
pestsq	-0.04	0.03	-1.13
laborsq	-0.18	0.17	-1.05
roofsq	-0.04	0.15	0.29
landfert	0.09	0.30	0.30
landpest	-0.04	0.07	-0.58
landlabor	-0.11	0.35	-0.32
fertpest	-0.03	0.09	0.33
fertlabor	-0.04	0.17	-0.22
pestlabor	0.15	0.10	1.50

As was the case for Doni and Godino, elasticity of labor in Batu Degaga irrigation scheme possesses the highest magnitude from among the main factors of production. A unit percentage change in the amount of labor days used will bring about a 1.8 percentage change in the amount of output produced. This change is also statistically different from zero. This implies that labor is not an abundant resource in the irrigation scheme. We can increase output in this irrigation scheme by increasing the supply of labor. Since this labor variable is defined as a labor day, if the farmer increases the number of labor days he or she spent on their farms by one percent, they can increase their agricultural output by 1.8 percent.

On the other hand, if we can somehow increase the water supply of the irrigations and hence increase the number of times farmers irrigate their land by one percent, we can bring about a 0.5 percentage increase in their agricultural production. This coefficient of water is also statistically significantly different from zero.

A percentage increase in the size of land will also bring about a 0.48 percent increase in output. This is in line with many other studies whereby they confirm the very small size of land in Ethiopia being detrimental to agricultural production.

The capital proxy (the number of sheets of corrugated iron of the roof of the house of the farmer) also showed that a percentage change in the capital of the farmer brings about a 0.33 percent change in agricultural output.

Fertilizer and seed are the other factors of production with a positive influence on output. A percentage change in the amount of fertilizer used will bring about a 0.29 percent change in output. A percentage change in seed also brings about a 0.18 percent change on output, though the coefficients of both fertilizer and seed are not statistically significant. Pesticide has an unexpected negative sign.

7.1.2 Dry land Settings

As per the results of the Chow test, the dry land data surrounding Doni and Godino irrigation schemes were estimated together while those around Batu Degaga were treated separately.

7.1.2.1 Doni and Godino dry land together

The combined dry land data for Doni and Godino has a sample size of 100 and the better representation of the data according to the likelihood ratio tests is a Cobb-Douglas production function with a half-normal error distribution. The model has 6 explanatory variables of the production function and 11 efficiency effect variables.

The final Maximum Likelihood Ratio estimates of the model for the dry land agriculture for Doni and Godino combind

	coefficient	standard-error	t-ratio
constant	3.82	0.51	7.54
land	0.23	0.13	1.70
seed	0.60	0.11	5.57
pesticide	-0.02	0.03	-0.77
labor	0.35	0.13	2.71
roofing	0.02	0.02	0.79
oxen	-0.18	0.11	-1.62

In this dry land setting, increases in the usage of factors like labor, seed, land, and capital increases output, though at different percentage increases. A percentage increase in the value of seed increases agricultural output by 0.6 percent. Since close to all farmers reported to use local varieties of seed, this coefficient showed that farmers are not using even local varieties of seed up to their full potential.

As was the case for the irrigated agriculture, labor is not a very abundant resource even for the dry land agriculture. A unit percentage increase in labor still increases output by about 0.35 percent and this elasticity coefficient is statistically different from zero. This may also be because of the small family size of these areas from the national average or it could also be due to the nearby high demand of hired labor by the irrigation farms.

The tiny holding size of land, as was the case for irrigated agriculture, is restricting agricultural output. A unit increase in the size of land increases agricultural production by 0.23 percent and this coefficient is statistically significant. This could be due to the very small size of farmers in the areas, though it is a bit higher when compared with that of irrigating farmers.

Though statistically insignificant, a percentage change in the capital of farmers, as can be seen from the coefficient of the proxy variable, increases output by 0.18 per cent. The statistical insignificance may come from the fact that dry land farming is not capital intensive in Ethiopia.

Farmers seem to use more oxen days on their farm as can be seen from the negative sign of the 'oxen' coefficient. A unit increase in oxen (defined as the number of pairs of oxen used for plowing the land times the number of days they plow) will decrease output by 0.17 per cent. The use of pesticide also has an unexpected negative sign in the production function. However, both the oxen and pesticide coefficients are statistically insignificant.

Batu Degaga Dry land

The dry land data around Batu Degaga irrigation scheme has a sample size of 47. The estimation result showed that the better representation of this data is a translog model with a half-normal distribution of the error term. The five main variables in the production function with their squared and interaction terms make the total variables in the production function to be 16. There are also 11 inefficiency-explaining variables in the model.

The final Maximum Likelihood Ratio estimates for dry land agriculture in Batu Degaga:

	coefficient	standard-error	t-ratio
Constant	13.0	1.57	8.23
Land	2.12	1.12	1.89
Pesticide	0.44	0.23	1.93
Labor	-3.15	0.79	-4.0
Roofing	0.35	0.16	2.17
Oxen	1.45	0.90	1.61
Landsq	0.81	0.21	3.80
Pestsq	0.006	0.15	0.39
Laborsq	0.28	0.14	1.96
Roofsq	-0.09	0.04	-2.38
Oxensq	-0.43	0.34	-1.26
Landpest	-0.09	0.06	-1.49
Landlabor	-0.30	0.30	-1.00
Landoxen	-0.08	0.336	-0.23
Pestlabor	-0.03	0.05	-0.52

Pestoxen	-0.06	0.05	-1.41
Laboroxen	0.23	0.33	0.69

Dry land farmers around Batu Degaga are highly constrained by their size of land. A unit percentage increase in the size of land will bring about a 2.1 % increase in agricultural output, showing the relative scarcity of land in the area.

Labor seems to be deployed excessively on this agriculture. A percentage increase in labor days will bring about a 3.1 percent decrease of output. The redundant use of labor may not be surprising in the face of scarce land resource.

A percentage increase in the number of oxen days brings about a 1.5 per cent increase in output. The coefficient is also statistically significantly different from zero. Increase in the level of pesticide use by one per cent also brings about a 0.4 per cent increase in agricultural output while that of capital brings 0.34 per cent increase.

7.2 Inefficiency Effects

7.2.1 Efficiency of Dry land settings

7..2.1.1 Doni-Godino Irrigation Scheme

There were 14 inefficiency effects that are believed to explain the inefficiency of farmers in Doni and Godino irrigation schemes. The maximum likelihood estimation of FRONTTIER Version 4.1 gives the estimates of these variables with that of the production function. In this computer program, the dependent variable is level of inefficiency (not efficiency). As a result, we expect the variable to have the opposite sign of its effect on the efficiency.

Technical inefficiency effects for Doni and Godino irrigation schemes are:

	Coefficients	standard errors	t-ratios
credit	-0.09	0.19	-0.46
advice	-0.26	0.16	-1.61
offfarm	-0.00004	0.00003	-1.39
hhsize	0.07	0.04	1.89
gender	0.31	0.16	1.91
eduhh	0.03	0.02	1.75
age	-0.01	0.01	-0.87
agesq	0.00006	0.0002	0.38
edumem	-0.05	0.18	-0.28
extension	0.05	0.13	0.35
medslope	0.08	0.13	0.65
steeply	0.06	0.19	0.30
mdummy	0.49	0.21	2.36
tdummy	0.44	0.23	1.88
sigma-squared	0.20	0.03	5.91
gamma	0.0005	0.01	0.04

As can be seen from the negative sign of the coefficients, farmers who get credit within the last three years and who are beneficiaries of agricultural advisory services, perform better in terms of efficiency than those who don't. Since the coefficient on advice is statistically significant, we can say that advice makes a tangible improvement in efficiency of farmers.

Farmers who have higher off-farm income are also more efficient than those who don't. This may be due to the fact that the extra income may enable them to invest on improved technologies. It might also be the case that farmers with high off-farm income, especially those in small local trades, are more exposed to different ideas than those who don't have.

Males are found to be more efficient than females in Doni and Godino irrigation schemes. The coefficient of gender is also statistically different from zero.

Farmers located at the middle and tail locations of the watercourse are less efficient than those at the head reaches. As can be seen from the dummy variable for medium location of farms (mdummy) and tail locations of farms (tdummy), farms at the head reach are more efficient. The coefficients of both of these variables are statistically significantly different from zero. The other inefficiency variables were found to be not statistically different from zero.

The mean efficiency of farmers of Doni and Godino irrigation schemes is 55.6 %. That is we can increase output of these farmers by 44.4% by just re-allocating their input use.

Percentages of Technical Efficiency Estimates for Doni and Godino Irrigation Schemes Together

Range of efficiency levels	Frequency
< 0.3	0
0.3 to 0.39	17
0.4 to 0.49	28
0.5 to 0.59	17
0.6 to 0.69	10
0.7 to 0.79	9
0.8 to 0.89	5
0.9 to 0.99	3
1	4

7..2.1.2 Batu Degaga

The model for this irrigation scheme has 12 inefficieny-explaining variables.

Mean efficiency of the irrigated scheme is 76 %. That is without extra input, re-allocations of the farmers' resources can increase output by 24%.

Percentages of Technical Efficiency Estimates for Batu Degaga Irrigation Scheme

Efficiency Range	Frequency
< 0.3	1
0.3 to 0.39	1
0.4 to 0.49	6
0.5 to 0.59	4
0.6 to 0.69	3

0.7 to 0.79	5
0.8 to 0.89	16
0.9 to 0.99	15
1	0

7.2.2 Efficiency of Dry land Farmers

7.2.2.1 Doni and Godino dry land farmers:

There are 11 inefficiency variables in this model. The highest level of efficiency of farmers is exhibited in these areas. The mean efficiency of these farmers is 79.8%. However, we can increase the output of the farmers by 20.1% with the same level of inputs that farmers are using.

Percentages of Technical Efficiency Estimates for Dry Land Farmers Around Doni and Godino

Efficiency Range	Frequency
< 0.3	2
0.3 to 0.39	0
0.4 to 0.49	6
0.5 to 0.59	4
0.6 to 0.69	8
0.7 to 0.79	8
0.8 to 0.89	50
0.9 to 0.99	22
1	0

7.2.2.2 Batu Degaga dry land Areas

The final model for these farmers includes 11 inefficiency-explaining variables. The mean efficiency of the farmers is 65.6%, implying that we can increase agricultural output of the farmers by 34.4% by reallocating their resources.

Percentages of Technical Efficiency Estimates of Dry Land Farmers in Batu Degaga

Efficiency Range	Frequency
< 0.3	0
0.3 to 0.39	7
0.4 to 0.49	2
0.5 to 0.59	13
0.6 to 0.69	7
0.7 to 0.79	3
0.8 to 0.89	5
0.9 to 0.99	8
1	2

7.2.3 Comparison of Efficiency between the irrigation schemes and rainfed agriculture

In two irrigation schemes dry land farmers happened to be more efficient than irrigation farmers with respect to their own frontiers.

In Doni and Godino areas, the efficiency of irrigation farmers is 55.6 %. However, the mean efficiency of farmers with no access to irrigation around these irrigation areas is 79.8 %. This may be due to the fact that low level of output of the dry land farming system is forcing the farmers to allocate the small resources they have more efficiently than the irrigation farmers. The difference between the dry land and irrigation farmers in these areas is more than 24 percentage points.

The mean efficiency of farmers in Batu Degaga irrigation scheme is 76% while dry land farmers around this scheme are 65.6 % efficient. The difference in efficiency of these two groups of farmers is more than 10 percentage points.

But we should take note of the fact that the two types of farmers are facing two different frontiers. The irrigators are facing a higher frontier than the dry land farmers and are on average more far from their frontier while dry land farmers are closer to their low frontier. That is to say the availability of water for irrigators has pushed their frontier outwards and made them productive. And yet, the high inefficiency of these farmers indicates that there is even more potential to be exploited and the potential presented by water isn't yet exploited.

To compare the frontiers of irrigators and dry land farmers, points on the frontier in each system are selected, specifically the average of the logarithmic transformations that were used to estimate the frontiers. These averages are then converted back to original, non-logged, levels to give comparable input combinations on the frontiers of each system. Makombe et al, 2001, used this methodology. The results of this evaluation show that Doni and Godino irrigation schemes require 0.77 ha of land, 26.6 days of irrigation, Br 706.3 worth of seed, 320 kg of fertilizer, Br 202 worth of pesticide, and 114.4 labor days to produce Br 5, 271 worth of output. On the other hand the dry land farmers surrounding these two irrigation schemes require 1.22 ha of land, Br 194.4 worth of seed, Br 4.9 worth of pesticide, 97.5 labor days, and 15.2 pairs of oxen plowing days to produce Br 2,591 worth of output. This implies that irrigators and dry land farmers don't face the same frontier and the frontier for irrigators is much higher than that of dry land farmers.

In Batu Degaga, irrigation requires 0.92 ha of land, 22.2 days of irrigation, Br 299 worth of seed, 148.4 kg of fertilizer, Br 181.3 worth of pesticide and 244.7 labordays to produce Br 8,103 worth of output; while dry land farmers in this area are required 1.3 ha of land, Br 22.2 worth of pesticide, 121.5 labor days and 14 pairs of oxen plowing days to produce Br 4,024 worth of output. These show that irrigators face a higher frontier than dry land farmers.

7.2.4 Marginal Productivities

To compute for marginal Productivity of inputs we first non-linearize the estimated production function and take the first derivative of output with respect to the specific input for which its marginal productivity is to be determined.

For Doni and Godino irrigation schemes together, the estimated production function is:

$$\text{Lny} = 0.34 + 0.78\ln(\text{land}) + 0.6\ \text{lnwater} + 0.34\text{lnseed} + 0.28\text{lnfert} + 0.21\text{lnpest} + 0.36\text{lnlabor} - 0.48\text{lnroof}$$

$$Y = 0.34(\text{land})^{0.78}(\text{water})^{0.6}(\text{seed})^{0.34}(\text{fert})^{0.8}(\text{pest})^{0.21}(\text{labor})^{0.36}(\text{roof})^{-0.48}$$

Taking the first derivative of Y with respect to each input and evaluating the resulting equation at the mean of regression variables gives the marginal productivity of each input.

For the dry land farming around Doni and Godino

Y = 0.38(land)0.23(seed)0.6(oxen)-0.18(pest)-0.2(labor)0.35(roof)0.18

Marginal productivity of inputs in Doni and Godino areas, based on frontier regression estimates:

	Doni Godino Irrigated		Doni Godino dry land	
Attribute	Level	marginal productivity	Level	marginal productivity
Value of output	5,271		2,591	
Land	0.77	32,529	0.2	18.6
Irrigations	27	687	---	
Seed	705	15.8	194	0.05
Fertilizer	320	78	---	
Pesticide	202	32.1	5	-0.66
Labor	114	97.6	98	0.05
Oxen	---		14	-0.2

All inputs have higher marginal productivity in the irrigated agriculture compared with dry land agriculture. The result showed that any additional money spent on increasing land holdings, or to increase the number of times farmers can irrigate their land, to supply fertilizer and pesticide have high return in the irrigation schemes of Doni and Godino. The irrigation schemes can also accommodate more farmers or the existing farmers should spend more time on agriculture since an additional laborday spent on the farm will bring about a high return.

8. Conclusion and recommendation

8.1 Conclusion

The paper tried to analyze the level of efficiency of farmers between irrigated and dry land farmers based on three irrigation schemes in Ethiopia. These schemes are Doni, Godino and Batu Degaga irrigation schemes.

The empirical findings showed that inefficiency of farmers prevail in Ethiopia very significantly, a result which is in conformity with other efficiency studies of Ethiopian farming by Abay and Assefa (1996), Abrar (1998), Croppenstedt and Abbi (1996) and many others. The contribution of this paper in efficiency studies of Ethiopian Agriculture is that it compares the efficiency levels of irrigation and dry land farming. Though, there are very few irrigation schemes in Ethiopia, much inefficiency is exhibited in the existing schemes. In fact in two of the irrigation schemes, among three studied, their surrounding dry land farmers are more efficient than the irrigating farmers, compared of course, with respect to their own frontiers.

Both for the combined data for Doni and Godino as well as Batu Degaga irrigation scheme, among all the explanatory variables, labor has the highest elasticity of output. In Doni and Godino, a one-percentage change in the amount of labor days will bring about a more than 0.36 percent change in output. We can also increase agricultural production in these two irrigation schemes by more than 0.28 percent if we increase fertilizer use by one percent. A percentage change in the value of seed also brings about a more than 0.34 percent change in output. In Batu Degaga, a unit percentage change in the amount of labor days used will bring about a 1.8% percentage change in the amount of output produced. On the other hand, if we can somehow increase the water supply of the irrigations and hence increase the number of times farmers irrigate their land by one percent, we can bring about a 0.5 percentage increase in their agricultural production. A percentage change in seed also brings about a 0.18 percent change on output. These coefficients are also statistically significantly different from zero.

In terms of explaining the inefficiency of farmers, agricultural advices, existence of off-farm income and the location of farms on the watercourse appeared to have significant influence on the efficiency of farmers. Farmers at head reach are more efficient than farmers at the middle and tail locations of the watercourse. Males also happened to be more efficient than females. The coefficients of these variables are statistically significantly different from zero. Moreover, availability of credit, number of years of education of the head of the household (in Batu Degaga only), existence of a member of the household who completed primary school, age of the head of the household and the slopes of farmlands have their expected signs, though statistically insignificant.

The empirical findings also showed that there is significant inefficiency in the sampled irrigation schemes. The mean efficiency of farmers of Doni and Godino irrigation schemes is 55.6 %. That is we can increase output of these farmers by 44.4% by just re-allocating their input use. Mean efficiency of the Batu Degaga irrigation scheme is 76 % implying that without extra input, re-allocations of farmers' resources can increase output by 24%. In Doni and Godino irrigation schemes dry land farmers happened to be more efficient than irrigation farmers with respect to their own frontiers. The dry land farmers nearby these schemes have a mean efficiency of 79.8 %. However, irrigators are more efficient than dry land farmers in Batu Degaga area.

8.2 Recommendations

In the face of resource constraint of many farmers and their high inefficiency levels, much attention should be given in affirming that farmers are using to the best of the little resource they have. Many farmers especially in the irrigated agriculture are performing way far from their frontier. In the irrigated agriculture, government and other relevant bodies should facilitate credit facilities since those farmers who were beneficiaries of credit are much closer to the frontier. Agricultural advices should also be given to farmers in a concerted manner since this variable was found to significantly affect the level of efficiency of farmers. Education has also a positive impact in terms of farmers' efficiency. Therefore government should intensify its efforts to expand education to the rural sector. The fact that families where there is at least one member who finished primary school are more efficient further justifies the need for expanding education. Activities that create more off-farm income to the rural sector are also things to be encouraged since off-farm income happens to increase the efficiency of farmers.

Since the marginal productivities of inputs in the irrigation schemes are very high, attention should also be given to increase the availability of these inputs. Government and other relevant bodies should try hard to bring more land to irrigations since the marginal productivity of land of the irrigated agriculture is tremendous. The irrigation schemes of the lowland that follows the Awash River should find ways to attract more labor from the highlands where labor is expected to be abundant. The weather condition of this area along with the high demand for hired labor by the neighboring large commercial and state farms has made it difficult for the smallholders to obtain as much labor as they want. The marginal productivity of labor in these schemes is very high. Fertilizer, pesticides and seeds should also be better supplied to the irrigation schemes since the marginal productivity of these inputs happened to be very high.

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Impact of irrigation on livelihood and food security in the modern Hare river irrigation scheme in Southern Ethiopia

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Abstract

The purpose of the undertaken study was to evaluate the impact that the modern Hare river irrigation scheme had on household food security as well as on lifestyle changes of the population in the study site Chano Chalba. This was done on the basis of the FAO food security pillars access to food, availability of food, utilization of food and the overall factor of food stability. RRA tools were used to conduct a before-after comparison, considering a ten years period. The quantitative data was analysed using SPSS and/or Excel and simple statistical measures such as cross tabulations, frequencies, percentages and means gave a visible overview of the outcomes.
The modern irrigation scheme did not affect the livelihood and food situation directly but indirectly through other modernizations that came with and after the construction of the modern main canal, e.g. road, merchants, agricultural office, health centre, drinking water points, school, electricity etc.
The major trigger was the introduction of a new banana type so that farmers changed from food crops to cash crops to earn a higher income. Following, the wealth situation of the population ameliorated but less food crops are produced and people become more dependent on the local market. The infrastructure of the study site developed in a positive way but still education, especially on food issues, are needed to have a sustainable repercussion and to secure people's health and food situation. Further positive changes on the food situation could be able if the higher income was utilized more efficiently and if the construction of the modern irrigation scheme had been more appropriate and by incorporating the farmer's requests.

Key-words: poverty, irrigation, livelihood, food security

1. Introduction

1.1. Background on food security and irrigation

In the 1996 Rome Declaration on World Food Security, food security is defined as "Food that is available at all times, to which all persons have means of access, that is nutritionally adequate in terms of quantity, quality and variety, and is acceptable within the given culture."
Further, the FAO speaks of food security on household basis when all members of a household can be supplied with sufficient and adequate food, whether through their own production or through buying of food.

According to the Aggregate Household Food Security Index (AHFSI)[18], established by the FAO (1995), Ethiopia had an index below 65, i.e. critical food security status, between 1991 and 1993.

[18].The AHFSI calculates the "food gap" between the undernourished and average national requirements, the instability of the annual food supply and the proportion of undernourished in the total population. The index ranges from 0 to 100, with 100 representing complete, risk-free food security and zero, total famine (FAO, 1995).

In Ethiopia, irrigation has a long tradition (Kloos, 1990). One of the main targets of irrigation systems is to fortunate agricultural production in qualitative as well as in quantitative meaning (Mengistu, 2003). Harvests shall be enlarged so that people either produce enough food for the non-harvest time or to sell their overproduction and earn some money to buy food. Another opportunity to produce more food crops is irrigated gardening, an activity mainly done by women.

In Ethiopia, there has been a revival of irrigation during the last decades in order to enhance rural development and food security (FAO/WFP, 2006). Given that 85 percent of the people are employed in agriculture (Mengistu, 2003), developing this sector could help to reduce poverty and enhance food security of the majority of the Ethiopian people.
As Lankford (2003) argues there must be a positive balance of benefits against risks and costs of irrigation. A more secure and increased crop productivity, improved planning and timing of start of the cropping season and extended harvest season, raised number of jobs and income are some knock-on effects that show how irrigation facilitates economic transactions and improves livelihoods and the wealth and infrastructure of whole villages (Lankford, 2003).

1.2. Irrigation and food security in Ethiopia

Case studies undertaken by Thompson (1991), Lall and Broadway (1994) and Adem (2001) already highlighted the positive impacts of enhanced accessibility to water for irrigation. Besides an extended growing period, a higher variety in food and cash crops and, as a result, an increase of cash income, food shortages could be reduced. Nearby, the target communities improved the infrastructure of their village and standard of living in general.
Negative impacts of the projects were over watering of some fields, overproduction of certain crops and competition for water from nearby communities.

Kennedy et al. (1992) compared the effects of cash crop schemes on health and nutrition in six countries. They concluded that "increases in income have to be accompanied by improvements in the health environment in order to have a significant effect in reducing preschooler morbidity and improving child nutritional status."
Among the reasons for negative impacts were reduction in the household's production of food crops, increased food prices, loss of household access to land due to changing tenure relations and household expenditure patterns favouring durable consumer goods.

1.3. Statement of the problem

High reliance of the people on their own food production has a direct impact on local food availability and on accessibility. Some coping strategies, which are eroding the household asset base, are used by the most vulnerable population to survive (FAO/WFP 2006).

As IFAD stated in 2005, irrigation has the potential to reduce food insecurity by several factors. "For the farmer, the soils, crops, livestock, weather, water, nutrients, pests, markets, income, outgoings, shelter, transport, fuel, property, family and social networks, and much more, all form part of the integrated environment in which he or she makes a livelihood. Improving food security through irrigation affects or is affected by each of these aspects. A major challenge is to design meaningful integrated solutions to the real problems faced by farmers" (IFAD, 2005).

Therefore the consequences of irrigation systems both positive and negative have to be assessed so that policy makers, government and other NGOs can react and, finally, burst the vicious circle of poverty and enhance food security.

1.4. Objectives of the study

As irrigation development is often associated with cash crops, irrigation investments' contribution to food security is often questioned. This study gives, among other things, an answer to this question, in case of Chano Chalba and the modern Hare river irrigation scheme.
It is figured out how the modern irrigation canal changed the agricultural production and livestock holdings/population, income sources and expenditures, health situation, hygienic standards, market situation, lifestyle of the households and the infrastructure of the study site.

For the purpose of investigating the perceptions of household food security, the research focused on the four dimensions of food security: availability of food, access to food, utilization of food and the overall factor of food stability.

Following, the established hypothesis concerning the four dimensions of food security, were:

1.	Availability:	Since the modern irrigation scheme was introduced, households have a better and more sustainable availability to food than before (whether through their own production and/or buying).
2.	Access:	The access to food and other assets are better developed today compared to ten years ago. (markets are better available; enough money to buy food)
3.	Utilization:	Since the construction of the modern canal, people have a more varying and balanced diet. Since the construction of the modern canal, people have more time for cooking and education thus people have a better knowledge of a balanced diet and related effects. Since the construction of the modern canal, people have more meals a day, are not restricted in the choice of their food, and are healthier and physically stronger.
4.	Stability:	The food security situation is more solid and offers more stability throughout the year and periods of stresses, shocks and in terms of seasonality.

In concrete, the results of this case study provide an insight of the impacts that the modern Hare irrigation scheme has primarily on household food-security but also on the environment, economy and society. It contributes to the project "Impact of Irrigation Development on Rural Poverty and Environment", coordinated by the International Water Management Institute (IWMI), the University of Natural Resources and Applied Life Sciences Vienna (BOKU) and ARC Seibersdorf Research in association with the BOKU Research for Development Forum (DEV-FORUM).

The externalities shall also be valuable for other researchers and stakeholders and influence the thinking on approaches to irrigation development. The concerned population gets a better view of their present situation, impact of outside interventions on their livelihoods and consequently are enabled to make better-informed decisions about their future livelihood strategies.

Thus the study focused only on the named study site, the gained results are just valid at local level and cannot be generalized to a larger population.

2. Description of the study area

2.1. General description of the country

Ethiopia is a landlocked country in the horn of Africa. It comprehends 1 120 000 square kilometres total land area, whereof 8 percent are farmed by smallholder peasants and about 3 100 000 hectares are fallow. The total area of grazing and browse is estimated to be up to 65 000 000 hectares, of which 12 percent is in mixed faming, the rest in pastoral areas (MoA, 2000 as cited by Mengistu, 2003).

Agriculture plays a central role in economic and social life. It is the leading sector in national economy, composing 40 – 50 percent of GDP and around 90 percent of export earnings. About 6 million people are chronically food insecure and depend on food aid throughout the year, another 10 million are considered as vulnerable (FAO/WFP, 2006).

Subsistence agriculture is almost entirely rain fed and yields are generally low. The existing irrigation potential is far from being reached (Mengistu, 2003).

The population is estimated to 76.5 million (World Bank, 2007) and is growing rapidly, with about 2.9 percent annually (Kebede, 2003).

38 percent of the population are underweight, another 47 percent stunted. Infant mortality rate is 107 per 1000, 47 percent of children

aged under five are malnourished and 10.5 percent affected by wasting (FAO/WFP, 2006).

2.2. Description of the study site[19]

2.2.1. Location of the study site and the modern irrigation scheme

Chano Chalba is a Peasants Association that lies in the SNNPR, Gamo Gofa Zone, in the South of Ethiopia. Hare River is one of the four main rivers draining to the nearby located Lake Abaya.

The Hare irrigation scheme comprises a total irrigable area of 2224 ha and there exist three different irrigation schemes. In Chano Chalba, the modern Hare right side irrigation scheme is used (Bantero, 2006). The community has a common diversion weir with the neighboring Kebele Chano Mile. This weir is located next to the asphalt road, leading both to Addis Abeba and Arba Minch.

2.2.2. Climate

Chano Chalba, lying in the lowlands at 1169 m a.s.l. near to Arba Minch, has a tropical climate with maximum and minimum temperatures between 30.3°C and 17.4°C, respectively.
February and March are the hottest months with rare rainfall, while June to August and November to January are more moderate with higher precipitation. The monthly average rainfall recorded from 1970 to 2006 at the Arba Minch Farm and Arba Minch University station is in total 829.3 mm, respectively (Bantero, 2006).

2.2.3. Soil fertility

Along the modern irrigation canal in Chano Chalba, soil is sandy at the head of the modern main canal where soil fertility is poor. In the middle parts, there is loam and soil fertility is very good. At the tail of the canal, people brought soil from another place to increase soil fertility. Beside this soil, there exists silty loam and soil fertility is also good (Agricultural Office, 2007).

2.2.4. Farming system and cropping season

From February to May, food crops (e.g. maize, sweet potato) are planted while cash crops are both planted and harvested. During the summer months, from June to September, food crops are harvested and, as it is rainy season, cash crops are also planted and harvested. From November to January, when it is dry season and the most critical time during the year, there are no agricultural activities undertaken (Agricultural Office, 2007).

The more recently introduced cash crops banana, mango, avocado and papaya have the advantage that they have to be planted only once (trees!). From then on, they are less time consuming because weeding is not that important compared to sweet potato or maize.
Moreover, these cash crops, especially the banana, can be harvested nearly every two months depending on the effort the farmer has taken.

2.2.5. Land holdings and distribution

Chano Chalba comprises a total area of 799 ha of which 649 ha are cultivated, in average landholdings from 0.5 to 3.50 ha. 199 ha are cropped annual, 450 ha perennial, and all of the agricultural land is irrigated. Forests cover 40 ha, grassland 20 ha and 90 ha are occupied by others (Bantero, 2006).
Because of the high population growth, the resettlement and return of soldiers, land holdings became smaller compared to former times and it is not possible to increase the land size. The only possibility is to rent land from poor people, their way to increase cash income (Group discussion, 2007).

2.2.6. Population and family constitution

As already mentioned, Ethiopia's population is growing rapidly. In Chano Chalba, a total population of 2980 people was recorded in 1988 and increased to 6200 inhabitants in 2005 (Catholic Church Mission, 1988; Agricultural Office, 2007). Households increased from 445 in 1998 up to 732 households in 2005 (Agricultural Office, 2007).

[19] During the realisation of this study, rare data on the study site were available. Therefore, the information given in the chapter "Description of the study area" is based on the statements from key informant interviews and group discussions.

The interviewed households consisted in average of 8.5 members.

2.2.7. Problems and advantages of the modern irrigation scheme

The modern irrigation system was built up and paid by the Chinese Government in cooperation with the Ethiopian Government. Main purpose of its construction was to increase the amount of irrigation water, enhance cash crop (cotton) and food crop (beetroot) production and to decrease water losses (Agricultural Office, 2007; Belete, 2006).

During the construction, there was a disagreement between the Ethiopian and Chinese Government because the Chinese did not build the main canal the way the Ethiopians wanted so the Ethiopian Government redrew every responsibility for the project. However, the Ministry of Agriculture brought the material to construct also modern field canals but unfortunately the Chinese had already stopped before the main canal was finished.

Although the modern canal led to a lot of advantages, one of the main objectives of the construction has failed because water loss is still a problem. Moreover, increased water usage by farmers and salinity are constraints for adequate irrigation practices.
At the head of the modern canal, the field canals break when there is too much water, especially during rainy season. In the middle, the canal is lower than the fields and if there is not enough water in the canal, people cannot irrigate their fields. The construction of a dam is seen as solution to this problem. Further problems in this part of the canal are siltation and damage by farmers.

One of the main advantages of the concrete canal is its robustness. Digging the destroyed and blocked canals (e.g. after heavy rains) again and again to make the water flow was a time consuming activity. Besides, if the water was standing too long, people as well as livestock that drank from that water became ill easily. Unfortunately, the field canals are still traditional.

3. Methodology

3.1. Sampling procedure

Purposive sampling was used to examine the impacts the modern irrigation canal had all over its longitude. Indicators for the sampling were the household's wealth situation, average size of land holdings, and the use of both the modern scheme today and the traditional before, so that the changes of a ten years period could be deducted. The sampling included 9 households each from the head and tail of the main canal while 11 are from the middle (Table 1). The difference of two more in the middle is a result of the unreliable sampling procedure of the Kebele officer that the researcher faced in the beginning.

Table 1: Sampling scheme of households for household interviews

Location of main farmland	Head			Middle			Tail		
Wealth Category of HH	3 R	3 A	3 P	4 R	3 A	4 P	3 R	3 A	3 P
Total HH interviewed	29								

3.2. Data collection methods

Due to time and finance limitations but to get reliable in-depth information, rapid rural appraisal tools were used.
Primary data was collected from key informants, local people, focus groups, experts, observation, transect walks and questionnaires from the selected households.
Maps and timelines were established in cooperation with the participants and gave a visible overview about the construction of the modern irrigation canal, availability of irrigation water throughout the year and agricultural practices.

Rankings accompanied the household interviews and were used to evaluate preferences or importance of main crops planted, income sources and expenditures.
Secondary data was obtained by comprehensive literature review and from offices operating in the area, to get the necessary data on agricultural production data and market prices.

3.3. Data management and analysis

The collected data was recorded in a laptop to avoid data loss. Descriptive data was coded and analysed in the light of the literature reviews. Quantitative data was introduced into SPSS and/or Excel and simple statistical measures such as cross tabulations, frequencies, percentages and means were used to reduce the volume of data, making it easier to understand.

4. Results and discussion

4.1. Availability of food

4.1.1. Agricultural practices: From food crops to cash crops

Cropping patterns changed definitively since the modern irrigation system was built and since the Kebele got its own Agricultural Office in 1996 that introduced a new banana type (Asmara banana) in order to increase farmer's income and to improve their livelihoods.
This banana tree is smaller, easier to plant and harvest and harvest-outputs are higher; it needs less treatment thus is less labour- and time-consuming. The linear form of the fruit makes it better transportable than the "older" banana type (Hawesh banana). The only disadvantage of the Asmara banana compared to the Hawesha banana is its higher water demand.

In former times, farmers were mainly planting food crops (maize, teff, sweet potato, beetroot) for their own consumption as well as cotton as cash crop. In the meantime, nearly all of the farmers changed totally to cash crop production (banana, mango, avocado), defined as crops that are mainly planted for selling. Some of the farmers still have a little piece of land where they plant at least some food crops for the household's own consumption while others divide their plot into different parts to plant on one half cash crops and on the other half food crops.

Data from the Agricultural Office in Chano Chalba showed the increase in production both of cash crops and food crops during the last ten years. The increase in food crops is explained with the growing population size, the higher cash crop production by the shift to monoculture of banana and mango.
According to the statement above, the situation of food produced by the households for their own consumption was better in the past. At the time this study was carried out, cash crops supplied the households with the necessary money to buy food from the markets.

The magnitude of the shift to cash crop banana is also shown in Table 2 below. For 27 of the 29 interviewed farmers (93.1%), banana is the most important crop today. On second rank comes maize (13 people, 44.8%), followed by the recently introduced cash crop mango (8 people, 27.6%).

Table 2: Importance ranking of crops (CC = cash crops; FC = food crops); first three ranks

Rank	Today			Before		
1	Banana (CC) 93.1%	Maize (FC) 44.8%	Mango (CC) 27.6%	Cotton (CC) 37.9%	Maize (FC) 27.6%	Sweet potato (FC) 10.3%
2	Maize (FC) 44.8%	Mango (CC) 27.6%	Sweet potato (FC) 17.2%	Sweet potato (FC) 37.9%	Cotton (CC) 20.7%	Maize (FC) 17.2%
3	Cotton (CC), Sweet potato (FC), Maize (FC) Each 20.7%			Maize (FC) 34.5%	Sweet potato (FC) 27.6%	Cotton (CC) 24.1%

Source: Household interviews/rankings, 2007.

Concerning the diversity of crops being grown, there is less different kind of food crops but more different kind of cash crops grown on the main field today.
In average, farmers are planting 2.14 different kinds of food crops and 2.21 cash crops today, compared to 2.52 food crops and 1.72 cash crops before.

Reason number one for the change to mono cropping is the higher income farmers get from the recently introduced cash crops banana and mango. Although the new banana type needs more water, it seems to be more resistant against drought, compared to maize. Moreover, food crops do not grow properly next to the big banana trees that consume all of the water and give a big shadow.
Other recently introduced fruit trees, especially mango but also papaya, already show to be a big success, not like the attempt of a local cereal called "Taleba" where soil-fertility did not fit and the crop was abolished soon.

Since the farm size of the households has decreased, people have to make a more precise choice on what to grow thus food crops have declined for the benefit of cash crops and the related higher income.
More detailed, 14 farmers (48.3%) use more, 9 (31%) less and 6 (20.7%) the same space on their plot to grow cash crops today.

4.1.2. Practices to keep soil fertility

People had another cropping pattern before the modern canal was constructed. They changed the crops on the field or even left a part fallow so that it could regenerate; livestock was hold close to the fields and its dung was used as a natural fertilizer.
Since changing to mono cropping banana, soil is loosing steadily its fertility (Agricultural Office, 2007). Furthermore, the farmers are not familiar with the use of industrial fertilizer and have little knowledge and practice. The attempt of the Agricultural Office (1994) to keep soil fertility by applying chemical fertilizer was abolished soon because of the high costs and the bad introduction and performance (Agricultural Office, 2007).
Instead, the Agricultural Office started recently to give lessons on generating compost. While it was only 9 farmers out of 29 (31%) who were using organic fertilizer before, the number increased to 24 (82.8%) who started to use compost recently to keep and increase soil fertility.

4.1.3. Use and practices of irrigation water

Farmers in Chano Chalba were irrigating with a traditional system since long time ago. Today, all farmers in Chano Chalba are irrigating both their main field and garden.
Regarding the irrigation time, the Head of Water User Association who is in charge with coordinating the irrigation scheme, allows the farmers to irrigate two or three times a year but irrigation time also depends on soil type, crop type and on the weather conditions.

From the 29 interviewed people, 25 (92.6%) are irrigating temporary, i.e. two to maximum four times during the year, and 2 persons (7.4%) use the irrigation water for their crops all over the year. No further explanations were given to explain this case.

By contrast, ten years ago it was 15 farmers (57.7%) who irrigated temporary while 11 (42.3%) irrigated all over the year.

One of the main purposes of irrigation is to increase the agricultural production. But in case of Chano Chalba it is difficult to compare the different crop types and, comparing the information with the data given by the Agricultural Office it is hard to believe that half of the people stated that their harvest has decreased compared to ten years ago.
It is more reasonable and believable that 25 of the interviewees (86.2%) claimed that their agricultural production is still influenced by lack of rain.

4.1.4. Storage of food crops and cash crops

In the past, when people were mainly growing maize as food crop, they stored the harvest in a barn next to the house. Today, the cash crops banana and mango are usually sold directly to the merchants and the small amount of maize farmers still plant is often not necessary to store. While all of the 29 interviewed farmers had stocks ten years ago, it is only 16 (55.2%) today. From the ones who still have maize stocks today, 7 (24.1%) said that their reserves last longer, 8 (27.6%) shorter and for 1 farmer (3.4%) it remained the same.

4.1.5 Home gardens

The importance of the home gardens lies on the bigger variety of food for the household's consumption and for women to get their own income by selling the surplus of these crops.

In the study site, only 15 (51.7%) of the 29 interviewed households had a home garden ten years ago while everyone (100%) is in possession of one today. One of the reasons is that their fields were nearer to their houses, so they did not need a garden but planted their food crops directly on the field.
Concerning the above mentioned diversity of food, farmers are planting 4.43 different crop types, mainly food crops, in their gardens today. Ten years ago, the 15 households who had a garden had only 1.46 different food crops.

According to this result, the people have a bigger choice in food, especially in fruits like mango, avocado, papaya, and can enrich their diet above all with micro-nutrients like vitamins and minerals. The left-over is sold by the women and girls on the local market or on the street to earn some money that they can manage themselves.

4.1.6. Livestock

In Chano Chalba, oxen, cows, goats, chicken, donkeys and sheep are and were kept as cattle. Livestock is generally a household asset and needed to overcome periods of food shortages. Therefore, it is usually used for the households own consumption and only in certain cases, mainly from wealthier farmers, sold.
Meat, eggs, milk and butter are incorporated in the daily diary but not consumed often. Milk is known to be healthy and therefore saved for young children and pregnant or lactating women.

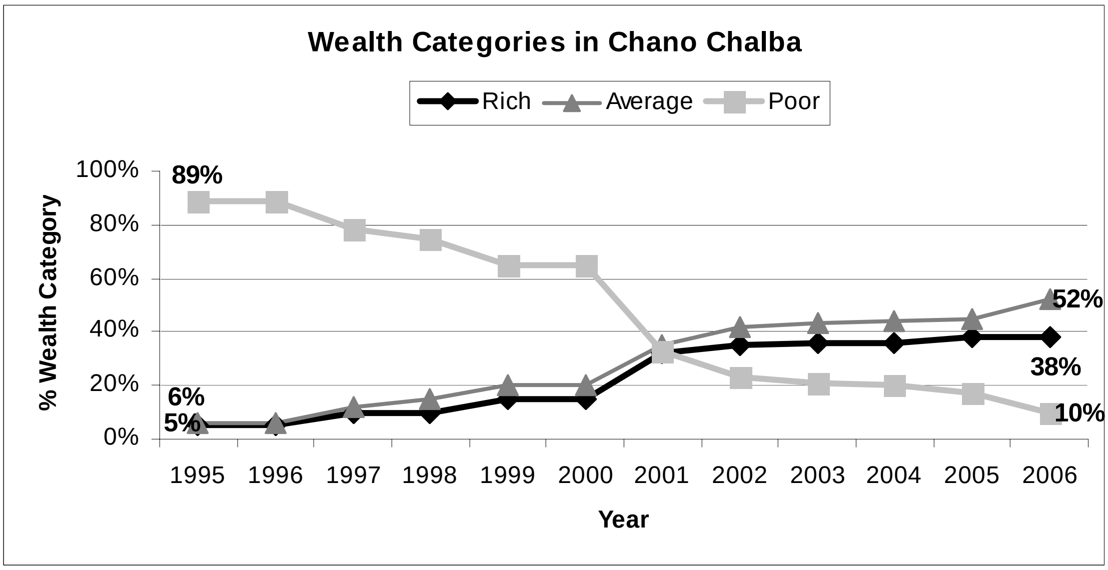
The given data on livestock changes are controversial. According to the information of the Agricultural Office of the Kebele, livestock population on household basis doubled since 1997. But 24 (82.8%) of the 29 interviewed people claimed that they have less livestock today compared to ten years ago.
The reason for the decrease of livestock has nothing to do with the construction of the modern canal but is a problem of the small landholdings and the high population density. Thus, the cattle have to be brought to the highlands or near to the lake while ten years ago there was enough space near to the fields and the cattle's dung was used as natural fertilizer.
Moreover, most of the animals died because of the sleeping-sickness that is transfused by the tse-tse-fly. That problem was removed five years ago when they got nylon nets that caught and killed the flies. Furthermore, the Agricultural Office started with livestock vaccinations in Chano Chalba once a week.

Thus people have less livestock, the availability of livestock products like butter, milk, cheese and meat has declined. Prices at the market are considered as too expensive so there is less diversity of animal products, especially in proteins, in their diet.

4.1.7. Income and expenditures

As can be seen from Figure 1, the wealth situation of the Kebele developed in a positive way. There are more "richer" and "average" households today while the category "poor" decreased.

Figure 1: Development of wealth categories in Chano Chalba, 1995-2006



Source: Agricultural Office, February 2007.

- **Income**

Since ever, cash crops were seen as main source of income in Chano Chalba. Due to the shift to cash crops, people have a higher and more constant income today, although the number of different income sources decreased significantly from 3.17 to 2.24.

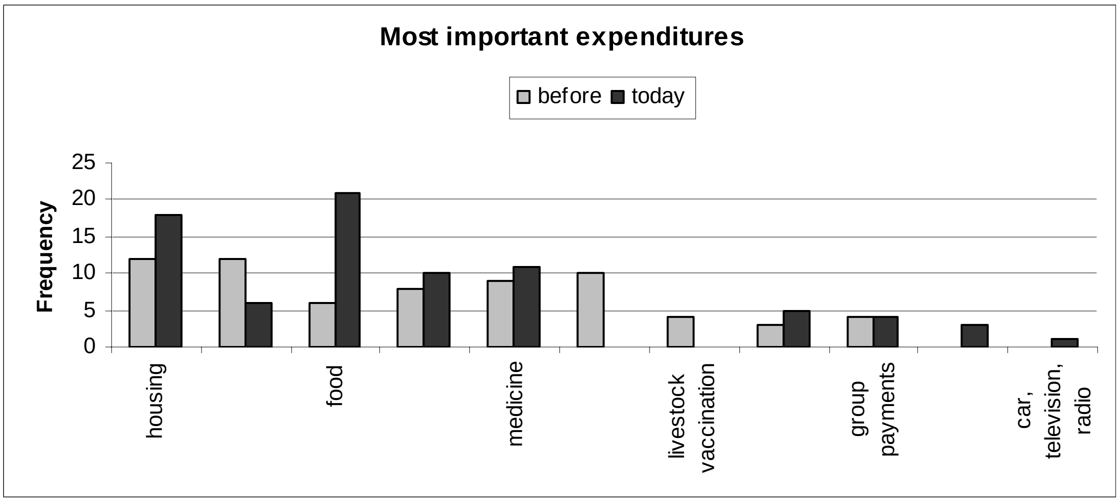
Selling of home made talla, arake or honey, income sources ten years ago, is considered as less important today. The production has decreased for both selling and own consumption. Reasons for the abandonment of beehives, was spraying of DDT several years ago to kill the mosquitoes that transmit malaria but also displaced the bees.

- **Expenditures**

Income from cash crops is generally managed by the male household head, mostly in accordance with his wife. In female headed households it is the women who decided how to spend the income.

Generally, people spend more money on food purchase, housing, education and medical expenses today than ten years ago while expenditures on clothes as well as governmental taxes play a minor role. Since electricity came recently, it was not of importance in the ranking ten years ago, neither expenses on mobiles, television and else.

Figure 2: Importance ranking of expenditures; (mentioned most often on rank 1 to 3)



Source: Household interviews/ranking, 2007.

The result that most of the people placed housing on first rank is connected with the fact that people were often moved to another place of the Kebele during the resettlement and that they could afford iron sheet roofs instead of grass roofs because of their higher income from the cash crops. Housing is seen as a big and important investment that is only made once. Some also put it on first place because it was an expenditure of a high amount of money that they had saved for a long time for exactly that purpose.

When asking whether the households spend more, less or the same amount of their income to purchase food today, the answers were as shown in Table 3: Money spent on food purchase, today compared to ten years ago

Table 3: Money spent on food purchase, today compared to ten years ago

Answer	Frequency	%
More	**24**	**82.8**
Less	4	13.8
Same	1	3.4

Source: Household interviews, 2007.

The reason for the bigger amount spent on food purchase is first because people have less food crops and livestock, thus they produce less themselves to eat, and second that food prices are higher today. That stands in relation with each other because if there are more people who need to buy food from the market but less who sell their food crops there, the competition is higher and following prices on the markets increase.

When people spent money on food purchase ten years ago, it was because they wanted a bigger variety. They bought food they did not produce themselves but that were considered as healthy, like peas and beans. Others, on the contrary, just bought salt and oil. Today people do not have enough food crops so they need to buy even part of their staple food.

4.2. Access to food

4.2.6. General changes in the Kebele's infrastructure

The infrastructure developed to a great extent since the modern irrigation system was constructed and brought a lot of benefits to the Kebele: the Agricultural Office, the Health Centre, a road, electricity, the school, a telephone station, potable water points, flour mills, etc. The money for these improvements was provided both by the Government and the inhabitants of Chano Chalba.

Farmers consider the road as most important innovation because it made the access to the markets easier, merchants came from Addis Ababa and people could sell their crops. That is underlined by the 15 people (53.6%) who abnegated that they would have got the same income from cash crops ten years ago while 5 people (17.2%) answered in the affirmative and 8 (28.6%) could not give an answer. Explanations when abnegating never included the irrigation scheme but the lack of knowledge about the value of the bananas and the absence of the road, thus the missing merchants.

4.2.7. Markets and market prices

Chano Market takes place every Monday and is the most important market for the people of Chano Chalba. People are coming from the surrounding Kebeles (Chano Mile, Chano Dorga, Kola Shara), the highlands (Dorze, Chencha), Arba Minch and from Lante, to participate in this social event.

The next bigger market people tend to go is in Arba Minch, a 2 hours walk, while the preferred Chano Market is reached within half an hour by all the inhabitants.
The better transportation system to surrounding villages is connected to the new road because people could catch one of the minibuses that cruised between Lante and Arba Minch if they had the necessary money.

Although there is more food available on the markets today, both in quantity and quality, it is also a fact that people get less food for the same amount of money.
Data on retail prices at Arba Minch from 1996 until 2005 were looked up on the most important foodstuffs and show the steady increase.

4.3. Utilization of food

4.3.6. Local food

Ethiopia is famous for "enjera", a flat, pancake like bread made from teff. Enjera is eaten with different kind of sauces, that consist, depending if fasting day or not, in meat or vegetables.
The situation is different in Chano Chalba. There, maize is staple food and they usually make the local bread, or other dishes like porridge, from it. Because of the higher price, enjera made from teff is mostly eaten for holidays, when people afford "better" food.

"Halakko", moringa stenopetala, grows in nearly every garden and contributes a lot to the daily diet. Although it is not among the most preferred dishes of the people it is eaten up to 2 or 3 times a day. Moringa stenopetala is related to the moringa oleifera which has its origin in the North of the Himalaya and was already used as a nutritious supplement by old traditional healers in Asia and Africa to help sickly people. The fruits contain important minerals, vitamins, amino acids and enzymes. It has sufficient amounts of iron, zinc and copper as well as 17 to 18 amino acids that are the most important components for the construction of proteins and the immune system (Schulz, 2006).
Studies in Senegal, Malawi and Tanzania confirmed its positive effect on child growth when consumed regularly and it was diagnosed that it decreased the proneness to cold-infections, worms and certain skin allergies up to 70%.
Moreover, it is of special interest because it stimulates lactation and it was proved that it removes hazardous materials from water (Schulz, 2006).

Usually, people eat the same the whole day or two different kinds of meals, depending whether they are on the field or not. The typical daily meal consists of roasted maize or beans, tea made from the coffee leave, "halakko", served with the local bread or sweet potatoes. All around the day, people eat bananas, mangos and avocados, some fresh made bread and drink water with lemon.

People are used to eat maize, in best case differently prepared, three to four times a day. 12 of the interviewed farmers (41.4%) stated that they can afford to prepare their meals from different kind of ingredients and 3 households (10.3%) eat the same dish all over the day.

4.3.7. Number of meals

The number of meals depends whether people spend the whole day on the field and how far away the field is located. As mentioned before, the banana trees do not need so much treatment as the time-and work consuming cash crops.
That is why 7 (24.1%) of the 29 farmers eat more meals today, 4 (13.8%) less and for 18 interviewees (62.1%) there was no change in number of meals.
When it comes to the choice of food and according to the FAO definition of food security that "...food is acceptable within the

given culture", only 7 people (25%) said that they can eat whatever they want today while it was 21 (75%) ten years ago. The reasons are again connected with the decreased food crop production and the increase of market prices.

4.3.8. Healthiness of food and "food education"

Concerning the healthiness of food, it is difficult to make a clear statement. As already mentioned, people have a bigger variety both from fruits in their garden as well as on the market. Although some products became more expensive, they could be substituted by cheaper ones, and as it turned out during the interviews, people have quite a good knowledge about food preparation, also due to the lessons they got from the Health Centre. It depends on the people how important they consider a healthy diet and how they spend their income.

Although 9 (31%) of the 29 farmers stated to have more times of food shortages today compared to ten years ago, the author thinks differently because all the people seen in the study site did not show any observable signs of under nutrition and, furthermore, if people have enough money to renew their houses, they should have enough money to eat, too. Information of the Health Centre also showed that there are no noteworthy problems with malnutrition and data gathered from the Arba Minch Catholic Church Medical Section showed that the low incidence of malnourished children that existed in former times also decreased. If there are still cases of malnourished children, the UNICEF distributes food and supplements (Alimi) to the Health Centre of the Kebele where women can get it for free.

4.3.9. Health situation, sanitation and nutrition

Reasons that the health situation improved in Chano Chalba was induced by the construction of the potable water pumps as well as by the lessons from the Health Centre on food preparation and water storage, the distribution of mosquito-nets, a family planning model, antenatal examination, free vaccinations and education on topics like hygiene in kitchens, FAO breastfeeding recommendations, toilets, hand washing and cleaning practices.

5. Conclusion and recommendations

- **For the irrigation scheme and its stakeholders**

As can be seen from the results of Chano Chalba, irrigation requires not only governmental support. Management and rehabilitation should be done from a bottom-up viewpoint and pro-poor, so that farmers "own" the irrigation schemes and make it more efficient.
Although it is difficult for a non-irrigation-expert to say whether the dam, that is wished from the farmers of the study site, made sense and provided the necessary water that is needed during dry season or not, it is clear that people would make a bigger effort to sustain the irrigation system. Water losses might also be smaller if the field canals were made the modern way, from concrete.

- **For Chano Chalba and its inhabitants**

Chano Chalba developed step by step and is still moving on since they got the modern irrigation scheme. The road, the Agricultural Office, the Health Centre, electricity etc., all interventions improved the situation of the inhabitants to some extent. Only regarding their food situation, it seems that the positive change has not taken place yet. In contrary, people are somehow restricted in their choice of food. The explanation of this problem from the author's point of view is both the missing education of most of the people as well as the focus on other targeted values of the population.
Although the author would say that the food situation of the study site is not in a bad state, yet no one is starving or suffering from under nutrition and people look quite healthy, there is no doubt that it could be much better.
Regarding the people's values, they have to decide themselves what is most important to them.
Questions pop up when thinking about what would happen if the market for the cash crop banana changed and people lost their (only) source of income. Then there would be a lack of food crops grown, people would not have the necessary money to buy food from the market where prices might rise even more.
A shift to producing again more and maybe different kind of food crops could be helpful, although farmers would have to accept a

smaller income. But as the experiences of some of the interviewees showed, people who plant food crops and cash crops to the same extent are not worse off at all.
Moreover, as already recognized by the farmers and experts, mono cropping has negative impacts on the agricultural area by reducing soil fertility. But first, farmers have to be aware of the problem so that they give more effort and place bigger emphasis on strategies on keeping soil fertility.

The ongoing strategy of family planning to slow down the rapid population growth of the past years might show its success in the coming years and hopefully it will change the situation of landholdings in a positive way.
Also the lessons people got in sanitation and health care practices should show a positive impact in the livelihood of people.

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Impact Assessment of Rainwater Harvesting Ponds: The Case of Alaba Woreda, Ethiopia

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Abstract

Rainfall in the arid and semi-arid areas is generally insufficient to meet the basic needs of crop production. Thus, there is now increasing interest to the low cost alternative generally referred to as 'water harvesting' especially for small scale farming systems. In Alaba, even if government efforts of household level water harvesting schemes are wide spread, the performance obtained was not assessed. Due to this reason, there was a need to asses the impact of the existing rainwater harvesting systems in Alaba Woreda.

The study assesses the determinants of households' adoption of rainwater harvesting ponds, and its impact on agricultural intensification and yield in Alaba Woreda, southern Ethiopia. Results are based on data collected from a survey of 152 households and 1036 plots operated by the households. Households were stratified into those with rain water harvesting ponds and those without from which equal number of sample households ware drawn. Analysis of descriptive information (mainly focusing on cropping pattern) and econometric methods are used. Analysis of qualitative information supplemented the econometric results.

The finding in the cropping pattern shows that, farm households have started to grow new crops (vegetables and perennial crops) as a result of water availability from the water harvesting ponds. Results of Probit analysis on the determinants of adoption of rainwater harvesting ponds shows that household size, education status of household head, ownership of livestock (cattle, oxen and pack animals), homestead plots and type of pond explained adoption statistically significantly. Results of analysis of qualitative information, consistent, with the Probit model results, also showed that labor requirement, economic problem to use simpler water lifting and watering equipments, inability to easily understand the benefit of the technology and problems related with the structure of the RWH technology adopted were some of the major problems faced by households, and have a negative impact on the technology adoption rate.

The Ordinary Least Square estimation of the determinants of the value of crop production shows that adoption of RWH has a positive and statistically significant effect on value of crop production, after controlling for input use and other factors. This shows that RWH ponds have direct and significant impact on value of crop production. We also find that households with RWH technology use more labor and seed but less oxen power compared with those households who have not adopted the technology. Moreover, labor and seed inputs have positively significant impact on yield while the effect of oxen power is insignificant. These results show that in addition to its direct impact, RWH has significant indirect impact on value of crop production through its effect on intensity of input use.

Labor requirements and cost considerations appear to be important factors that influence household's adoption of RWH technology. This implies that research and development interventions need to take account of the labor and cost demands of the technology. The effectiveness of the technology adoption is mainly constrained by problems related to water lifting and watering equipments, and accidents occurring due to

absence of roof cover and fence to the ponds. This implies that support will be needed to provide affordable but improved water lifting and watering equipments, and give training to farm households on construction and use of roof covers and fences to the ponds. As households shift to high value but perishable commodities due to the RWH, emphasis needs to be given to marketing extension, especially in facilitating markets and market linkages to farmers.

Future intervention to promote RWH technologies need to provide due attention to quality, rather than focusing on the number of adopters. Households appear to neglect the community ponds since they focus on using cleaner water obtained from household ponds and other sources of clean water. In this process the community ponds are becoming a cause of health problems. Thus, it is important that appropriate attention be given to the community ponds as well.

Finally, it was found out that women are getting benefit from the technology adoption as any member of the family. Their participation in the technology adoption is mainly in watching the ponds. They also have contribution in planning and decision making stage, and in giving support during construction, maintenance and clearance of the pond. Female headed households are being constrained to be beneficiaries due to economic and manpower shortage.

1. Background

Ethiopia, like other Sub-Saharan African (SSA) countries, is an agrarian economy, with a very small industrial sector. The agricultural sector, on average, accounts for about 45% of the GDP, 90% of merchandise export earnings, 80% of employment, more than 90% of the total foreign exchange earnings, 70% of the raw material supplies for agro-industries, and is also a major supplier of food stuff for consumers in the country. Smallholders who produce more than 90% of the total agricultural output and cultivate close to 95% of the total cropped land dominate the sector. Agricultural production is highly dependent on the vagaries of nature with significant variability in production and actual production patterns (Demeke et al, 2005).

Due to population increase in the highland areas, more and more marginal areas are being used for agriculture which led to the degradation of the natural resources .One of the major challenges to rural development in the country is how to promote food production to meet the ever-increasing demand of the growing population. Rainfall in the arid and semi-arid areas is generally insufficient to meet the basic needs of crop production. In degraded areas with poor vegetation cover and infertile soil, rainfall is lost almost completely through direct evaporation or uncontrolled runoff. Thus, overcoming the limitations of these arid and semi-arid areas and making good use of the vast agricultural potential under the Ethiopian context, is a necessity rather than a choice. Thus, there is need for appropriate interventions to address the prevailing constraints using suitable technologies for improved and sustainable agricultural production.

With regard to agricultural water development, small scale irrigation seems to be preferred to large scale schemes. The reason for the preference of small-scale irrigation to large scale irrigation includes the high capital requirement and cost of constructing large scale scheme which can only benefit a fortunate few but easy adaptability of small scale irrigation (Turner, 1994).

There is now increasing interest to the low cost alternative generally referred to as ‘water harvesting’ especially for small scale farming systems. Runoff, instead of being considered as a problem, can be harvested and used for different purposes, which otherwise is lost and causes soil erosion. Various methods of rainwater harvesting are available, through which rainwater is captured, stored and used at times of water scarcity. Rainwater harvesting can be broadly defined as a collection and concentration of runoff for productive purposes like crop, fodder, pasture or trees production, livestock and domestic water supply (Ngigi, 2003).

Collection and storage of rainwater for different purposes has been a common practice since ancient times. The system was used thousand years ago in many parts of the world. There are also evidences indicating ancient churches, monasteries and castles in Ethiopia used to collect rainwater from rooftops and ground catchments. Birkas in Somalia region and different runoff basins in Konso are good examples of the traditional rainwater harvesting practices in Ethiopia. Moreover embankment and excavated ponds[20] for agriculture use and water supply, runoff farming and various types of soil moisture conservation techniques for crop production could be mentioned as examples (Nega, 2004).

In Ethiopia, promotion and application of rainwater harvesting techniques as alternative interventions to address water scarcity were started through government initiated soil and water conservation programmes. It was started as a response to the 1971-1974 drought in Tigray, Wollo and Hararge regions with the introduction of food-for-work (FFW) programme which were intended to generate employment opportunities to the people affected by the drought. Since then, however, the interventions have been extended to the other parts of the country with very limited coverage. The low level of community participation and declining attention were some of the major reasons for the limited coverage (Ngigi, 2003).

After the fall of the military government, both the Transitional Government of Ethiopia (TGE), established in 1991, and the Federal Democratic Republic of Ethiopia (FDRE), established in 1995, have adopted an economic development policy to achieve food self sufficiency and sustainable development, based on a strategy called Agricultural Development-led Industrialization (ADLI) , which gives more emphasis to improvement in agricultural productivity. Besides, recognizing the problem of variability in the rainfall distribution in the country, the 1995 strategy advocates for water centered sustainable rural development (Desta, 2004). Based on this, several rain water harvesting technologies have been constructed by regional states, NGOs, communities, and individual farmers through out the country.

To mitigate the erratic nature of rain fall in the arid and semi-arid parts of the country, which threatens the lives of millions of people, a national food security strategy based on the development and implementation of rainwater harvesting technologies either at a village or household level was adopted after 1991. The Federal Government had allocated a budget for food security programs in the regions, an amount equal to ETB 100 million and ETB one billion during the 2002 and 2003 fiscal years, respectively. Of the total budget, most of it was used by regional states for the construction of rainwater harvesting technologies including household ponds, in collaboration with the Federal Ministry of Agriculture and Rural Development (Rami, 2003).

Even if government efforts of household level water harvesting schemes are wide spread in Alaba, the performance obtained was not assessed. Due to this reason, there was a need to asses the impact of the existing rainwater harvesting systems in Alaba Woreda to determine their effectiveness and sustainability. In addition, there was a need to assess the condition of indigenous rainwater harvesting

[20] According to (Nega, 2005) they are defined as follows.
Pond: is small tank or reservoir and is constructed for the purpose of storing the surface runoff
Excavated pond: is a pond type constructed by digging the soil from the ground
Embankment pond: type of pond constructed across stream or water course consisting of an earthen dam.

technologies and practices in Alaba. Hence, this study is aimed to fill this gap of knowledge in the region.

The purpose of impact assessment is to determine the welfare changes from a given intervention on individual, households and institutions and whether those changes are attributable to the project, programme, or policy intervention. Impact assessments are often undertaken ex ante, evaluating the impact of current and future interventions, or ex post, evaluating the impact of past intervention. It can also be made concurrently within the project cycle (Shiferaw et.al, 2005). Our focus in this study is the ex post impact assessment. Ex post assessment attempts to understand the pathway through which observed impacts have occurred and why interventions fail or succeed in attaining stated objectives. Hence, ex post assessments can inform policy choices as to whether related planned programme interventions should be discontinued, modified, improved or sustained in the future (Ibde).

Hence, this study is aimed at assessing the impact of rainwater harvesting ponds on crop yield using a quantitative approach supplemented by a qualitative approach in Alaba. In particular the study focuses on:

- Identifying the determinants of household decision to adopt rainwater harvesting ponds.
- Examining the impact of rainwater harvesting ponds on crop yield, input use and cropping pattern.
- Assess the constraints and options to improve rainwater harvesting ponds
- Assess the differential impact of the technology by gender
- Derive policy implications to improve the performance of the rainwater harvesting ponds.

The study is expected to identify problems encountered, so that possible measures are taken when these interventions are replicated in other parts of the Woreda or the country. Besides, being an empirical study it will help to add to the empirical literature that uses the combination of both quantitative and qualitative approach in assessing the impact of RWH technology interventions on agricultural production. Finally, understanding the impact of the RWH technologies on agricultural productivity and the determinant factors of rainwater harvesting ponds, which affect productivity or level of yield, is a vital issue for designing appropriate agricultural development policies and strategies, as well as technology interventions. Therefore, the outcome of this study may serve as a source of additional information which may be of significant use to policy makers and planners during the designing and implementation of RWH technology strategies.

The study was conducted amid some limitations. One of the limitations is the unavailability of base line data. Such data would reflect the condition of the farm household’s agricultural production process pre-technology intervention, and would have been helpful to compare more comprehensively and evaluate the relative effect of the technology intervention on agricultural productivity overtime. The other limitation of this study is related to the lack of accurate measures and valuation techniques to include the environmental benefits and costs that accrue from the RWH technology intervention.

2. Literature Review

Agriculture is the most water-demanding sector, in addition to being a major source of employment and a major contributor of the national gross domestic product (GDP) of many developing countries in Africa. Agriculture in Ethiopia provides 86 percent of the country’s employment and 57 percent of its GDP. Rain fed crop cultivation is the principal activity and is practiced over an area of 27.9 million hectares (ha) of land (Gebeyehu, 2006).

Some empirical studies suggest that irrigation has shown some positive impacts in increasing agricultural productivity and thereby increase the income of farm households, who participate in the irrigation schemes (FAO, 1993). In the context of farm households living in the Sub-Saharan African countries, irrigation has, however, proved costly and can only benefit farm households with large plots in addition to concerns related with the environmental and health side effects of the schemes.

Large-scale dam and irrigation projects have not been widely implemented in Ethiopia as they have often proved to be too expensive and demanding in construction and maintenance. Therefore, water harvesting tanks and ponds at the village or household level are proposed as a practical and effective alternative to improve the lives of rural people at little cost and with minimal outside inputs. In theory, household water harvesting can be done mainly through the effort of the individual farmer. Use of stored rainwater could supplement natural rainfall and make farming families less vulnerable to drought and therefore less dependent on outside help in harder times (Takele, 2002)

The experience in China on the development of rainwater harvesting shows that since the 1980's , Gansu, Sichuan, Guangxi, Guizhou and Yunnan provinces adopted rainwater harvesting techniques. To date, rainwater harvesting projects have been carried out in about 700 counties of 15 provinces in semi-arid and humid areas covering two million km 2 and with a total population of 0.36 billion. By the end of 2001, about 12 million water cellars, tanks and small ponds were built with a total storage capacity of 16 billion m3, supplying water for domestic use for 36 million people and supplemental irrigation for 2.6 million m2 of dry farming land. This has helped the people access water and engages in agricultural production hence improving food security and alleviating poverty. Rainwater harvesting has also been known to benefit ecological and environmental conservation (UNEP, 2005).

Impact of rainwater harvesting as shown in a case study of Mwala division, Kenya indicates that harvesting runoff water for supplemental irrigation is a risk-averting strategy, pre-empting situations where crops have to depend on rainfall that is highly variable both in distribution and amounts. By using underground spherical tanks having a combined capacity of 60 m3, seasonal water for supplemental irrigation for an area about 400 m2 was guaranteed. With rainwater harvesting, farmers have diversified to include horticultural cash crops and the keeping of dairy animals. For instance households with supplemental irrigation earn US$735(per ha) from cash crop compared with US$146 normally earned from rain fed maize. This has contributed to food security; better nutrition and higher family income (RELMA-in-ICRAF, 2004).

India has a long tradition of rainwater harvesting so much so that it is regarded as one of the dying tradition of the country[21]. However, it has been reviving apace in many parts of the country, particularly in rain scarce areas. Derwadi village, a village in the central state of Maharashtra, is one of such dry villages of India. A remote village with no assurance to drinking water, with farming being mainly rain fed based and agricultural production can't meet more than three-month food of the village, Derwadi used to be a desperate village with no employment opportunity for the community and where schooling is a distant dream for the kids of the community. The villagers established a link with an Indo-German watershed Development NGO called Watershed Organization Trust (WOTR), which later assisted them to construct contour trenches, farm and contour bunds, and check dams. A degraded land then stared to provide adequate water both for drinking and for irrigation, thus paving the way for transformation of the lives of the villagers. They not only managed to diversify from traditional pearl millet to other host of crops ranging from various vegetables to cotton, but also managed to produce the crops in surplus and be able to

[21] This document on India's experience is obtained from website www.rainwaterharvesting.org/rural, where an interesting account of experience with rainwater harvesting in more than 20 Indian villages is presented.

sell, perhaps for the first time, to big towns. They managed to send their kids to school. With the help of the NGO they also managed to form self help association that enabled them to organize and carry out such activities as construction of toilet, kitchen garden and improved cocking devices.

The other experience with rainwater harvesting from India is Gandhigram village of Gujarati state. This village is also one of the water scarce areas of the country, constantly suffering from acute water scarcity both for consumption and production. Assisted by a local NGO called Shri Vivekanand Research and Training Institute, the community started to build communal dams- small and big- in 1995 so as to store rainwater and use it during dry season. A committee was formed from among the beneficiaries to oversee the distribution of the water and maintenance of the dams. They evolved an interesting management mechanism where each household is asked to pay Rs 3 (equivalent of $0.067) per month for water supply for consumption purpose, and Rs 250(equivalent to $5.56) per ha for irrigation purpose. The community managed not only to secure sustained supplies of water for domestic consumption, but also was able to embark upon producing high value crops like ground nuts, wheat, onion and cumin. They managed to increase their agricultural yield and work availability has also increased for land less laborers. As it has become beneficial, the momentum for rainwater harvesting continued in the village as is evident from community's interest to increase the number of dams by constructing new ones. Interestingly enough, they are now on the stage of forming a cooperative for processing and marketing their agricultural products.

By the 1990's, Zambia's southern province was recording unprecedented levels of food insecurity, hunger and general poverty. Government food, seed and fertilizer relief support become the norm rather than the exception for many households. During the 2002/2003 season, over 12% of the farm households were estimated to have adopted conservation agriculture technologies which included the use of rainwater harvesting. This was estimated to involve at least 50,000 hectares. The experience of Zambia shows that crop yields have on the minimum doubled. Maize yield rose from under 0.5t/ha to above 2t/ha and cotton from 1.5t/ha to 3t/ha under conventional as compared to conservation agriculture respectively. This has been attributed to improved rainwater harvesting made possible by the planting stations and surface cover. Most farmers have diversified their cropping system to include crops such as maize, beans and sunflower. Increased production at the household level in the last five years has introduced the rapid re-birth of a cash economy among the communities. This has propelled private entrepreneurship in agricultural related trading. Large and small private entrepreneurs have emerged and are selling agricultural inputs and other household commodities as well as buying off the crop. Most households are able to put up for sale 20-30% of their produce. The ultimate effect is enhanced livelihoods (UNEP, 2005).

Hatibu et al (2004) tried to quantify the effect on farmers' income and living standards of different rainwater harvesting methods, taking two districts, Maswa from north and Same districts from Eastern parts, of Tanzania. All types, viz. in-situ, micro and macro catchments and rainwater harvesting with storage are all practiced in the two regions in descending order of prevalence; in-situ is more prevalent in both regions followed by micro and macro catchments, with rainwater harvesting with storage being the least. The harvested rainwater is used mainly to grow maize in Same area while it is used for rice in Maswa region. Good rainwater harvesting increases yield of maize (in Same area) by four fold of rain fed yield level, and two fold for rice (in Maswa area)(Ibid).

It is only recently that rainwater harvesting has started to receive significant attention from Ethiopian government though it has a long history. It has been regarded as one of the crucial tools to achieve food self-sufficiency, and is being implemented on a large scale particularly in water scarce areas of the country. As the phenomenon is quite recent, detailed study hasn't been made. However, some preliminary studies have been made on some parts of the country. Rami (2003) is one of such studies, and is basically an account of two weeks field visit in Amhara and Tigray regions. The emphasis is mainly on rainwater harvesting implementation related problems in the regions and the prospects of using it for the stated objective of attaining food self-sufficiency. It has been found that RWH is top of the agenda in the two regions, as is the case at national level, with some times over ambitious plans of constructing wells and ponds.

The success in attaining the planed amounts of tanks and ponds to be constructed and the perceptions of the beneficiaries are found mixed. Shortages of required construction raw materials, lack of timely dispersal of finance and shortage of skilled labor have been among the factors inhibiting the attainments of the stated goals. This is evident from Amhara region where it once was planned to construct 29005 tanks made of cement and plastic and 27955 wells were excavated for the purpose but only 12614 tanks were constructed. Furthermore, the tanks constructed so far are found to be substandard, many collapsed and majority leak and seep water, the main factor being lack of experienced masons and supervisors and mismatch between the type of soil in the area and the tank construction method. The tanks were first tested in Adama area and implemented in the two regions, with basically different soil structures from Adama area, without-taking into account the specificities of the two regions (Rami, 2003). In addition, most of the construction was assigned to each Woreda as a quota resulting in less attention being paid to quality as compared to number. Further, the implementation tended to be top-down approach, particularly in Amhara region, and this has also contributed its share to the problems (Ibid).

Besides, rainwater harvesting is found to have undesirable, but not unexpected, health side effects. For instance many people and livestock have been drowned into the tanks and ponds, with often no fences and live saving mechanisms like ladder and ropes (Ibid). It is also cited by people living near the ponds as a source of malaria out break. However, it doesn't mean that rainwater harvesting didn't have any positive effects on the community. It has enabled them to grow crops of short growing periods like vegetables. And some have had good experience, as is the case in Tigray region where, for instance, "a farmer and his wife were able within a single season to pay their old extension credit of more than 1000 Birr through the planting and sale of vegetables (cabbages, tomatoes, beans and peppers) (Ibid). The upshot is that rainwater harvesting is beset with challenges and can be an utter failure and end up in undesirable negative consequences if not cautiously approached. However, it can play immense role in helping attain food security if implemented with thorough consultations with the beneficiaries and is accompanied with other activities like afforestation and soil conservation and fertility enhancing practices.

The econometric approach has some limitations in accurately and fully measuring the changes resulting from NRM interventions, especially those changes which are non-quantifiable. Hence, as a remedy to the shortcomings of the econometric approach, at present ,researchers like Kerr et.al (2005) are advocating that better results could be obtained using an integrated quantitative and qualitative approach in assessing the impact of NRM interventions.

Kerr et.al (2005) employed quantitative analysis (as with and without design mainly employing instrumental variable approach) and also qualitative information to better understand interest in relation to relevant research questions, and to identify the projects' unintended consequences in evaluating the performance of watershed projects in India. Specifically, the study tries to identify: the successful projects, the approaches adopted which lead to the success and additional characteristics of particular villages' contribution to achieve improved natural resource management, higher agricultural productivity, and reduced poverty. The results of the study show that in both of the states, participatory projects combined with sound technical inputs performed better as compared to technocratic, top-down counterpart. Evidence also found on the existence of potential poverty alleviation trade-off during an effort to increase agricultural productivity and conserve natural resources through watershed development. Particularly, the empirical result indicates the existence of strong evidence on the skewed distribution of benefits towards largest land holders in projects, which are more successful in both conservation and productivity .The short-term costs imposed on 'losers' (i.e. the poor) may be substantial and projects would gain from a greater focus on mechanisms to share projects benefits (Shiferaw et.al, 2003).

Apart from the qualitative analysis approach used in the early periods, the literature on quantitative analysis approaches for assessing the impact of natural resource management policy or technology interventions can include the econometric approach (Shiferaw et.al, 2003).The commonly applied method in natural resource management intervention impact assessment, i.e., the econometric approach, is developed by linking the measures of current output, cost or profits directly to past research investments. In this approach, either a primal function, based on estimated production function, or a dual function, using a profit or cost function and their related system of supply and factor demand functions are employed. In general, once the econometric approach is adopted, the impact of the natural resource management technology or policy intervention is obtained by translating the parameter estimates of the function used, into economic benefit value (Shiferaw et.al, 2003).

For instance, Pender et al. (200l) employed a structural econometric approach, to explore the impact of land management and investment on the value of crop production in Uganda .The data for the analysis obtained from a survey of 451 households. Selected regressors include several variables at the village, household and plot levels. The study has shown that improvement in land management can lead to higher productivity and lower land degradation. Participation in technical assistance programs, pursuit of certain livelihood strategies, investment in irrigation, and promotion of more specialized production of cereals or export crops are found to achieve "Win-Win" outcomes, increasing agricultural productivity while reducing land degradation. The results of the study don't support the optimistic 'more people-less erosion' hypothesis, though the results are consistent with population induced agricultural intensification', as hypothesized by Boserup. In addition it indicates the need to make further research to identify profitable as well as sustainable land management options, as no land management practices except irrigation were found to be very profitable in the short-run (Shiferaw et.al, 2003).

Gebremedhin et al.(2002, 2000), have applied an econometric analysis to examine the nature and impact of community woodlot and grazing land management's respectively; and identify the determinant factors of collective action and its effectiveness, in Tigray, Ethiopia. Empirical results of the analysis indicated that, more collective action exists manage community woodlots in areas with intermediate population density. In relation to community grazing land management, results from the regression analysis depict that, while population pressure has resulted in reduction of violations of use restrictions of grazing land in areas with low and intermediate level of population density, intermediate population pressure has the tendency to reduce the development of use restrictions and the enforcement of penalties (Gebremedhin et.al, 2000). Besides, while negative relationship has been observed between communities access to market and household's contribution to collective action, tree planting, and the survival rate of trees (Gebremedhin et.al, 2002). However, the result from both studies reveal that, the presence of external organizations is negatively associated with the probability of community payment to guard, survival rate of trees, and collective action for grazing land management Gebremedhin et. al (2002, 2000).

3. Methods of the study

Sampling and data

The data for the analysis is obtained from a household and plot level survey in Alaba Woreda. The Woreda is located 310 km south of Addis Ababa and about 85km southwest of the Southern Nations Nationalities and Peoples Regional (SNNPR) state capital of Awasa. A semi-structured questionnaire has been employed to interview household heads.

A total of 152 households which are selected using a stratified sampling technique have been surveyed. Based on farming system practiced, the 73 peasant associations in the Woreda are stratified in to two, namely 43 peasant associations with Teff/ Haricot Bean Livestock and 30 peasant associations with Pepper/ Livestock farming system. From each stratum 2 peasant associations were selected randomly and the households within each of the four peasant associations were further stratified by adoption of RWH technology. In the end, from each of the four randomly selected peasant associations, a total of 38 households were randomly selected, where 19 of the farm households adopting the technology and 19 farm households without the technology stratum.

Moreover, interview has been done with experts working in the OoARD (office of Agricultural and Rural Development). Secondary data was also used from publications, books, articles etc. to supplement the data.

DATA ANALYSIS

Qualitative approaches are increasingly used in conjunction with quantitative approaches and such combinations can enhance the validity and reliability of impact evaluations. While quantitative approaches allow statistical tests for causality and isolation of programme effects from other confounding influences, quantitative methods excel at answering impact assessment questions about ‘what’ and ‘how much’, whereas qualitative methods are preferred for exploring questions of ‘how’ and ‘why’. A mix of quantitative and qualitative approaches is ideal because it provides the quantifiable impacts of the intervention as well as an explanation of the processes and relationships that yielded such outcomes (Shiferaw et.al, 2005).

Descriptive Analysis

This part mainly focuses on describing the impact of rainwater harvesting ponds on the cropping pattern. Cropping pattern of the farm household’s has been assessed based on the farming system.

Econometrics approach

Empirical model and econometric estimation

Since there is no predetermined model that can be used in the quantitative estimation, following Pender and Gebremedhin (2004), models for the use of inputs on each plot (from equation 2 up to equation 6); adoption of RWH ponds (equation 1); and the value of crop production on each plot in 2005/06 (from equation 7 to equation 9) are adopted in this study.

To identify the determinant factors that influence the farm households’ decision to adopt RWH pond or to invest on various types of RWH ponds, a probit model is estimated. Hence, a ***RWHp*** dummy variable (where 1=household with RWH technology and 0=household without RWH technology) is modeled as a function of village-level factors (X_V), plot-level factors (X_p), household-level factors (X_h) and pond type which can be plastic covered or concert basement (**P**).These can be written as follows:

$$RWHp = f(X_V, X_P, X_h, P) \ldots\ldots. (1)$$

Where, *Household- level factor* (X_h) *includes:*

- *Human capital (demographic features) - age, household size, educational status.*
- *Physical capital - land holding, value of all assets owned, value of livestock which includes oxen, packed animals, poultry, cattle etc.*
- *Social capital- membership in local organization and associations.*
- *Financial capital-households saving and credit access.*

Village-level factors (X_v) *includes:*

- *Indicators of agricultural potential: rainfall condition(here due to lack of adequate information at PA level, during estimation, location dummies has been used in order to capture the difference in rainfall, altitude, population density and other environmental factors for the four PAs included in the study).*
- *Household access to services and infrastructure: walking time from the farm household's residence to the nearest input/ output town market, village market, Cooperative shops and all-weather and seasonal road.*

Plot-level factors (X_p) *- Natural capital*

- *Indicators of quality of the plot (size of plot, slope of the plot, soil depth, soil type and soil fertility of the plot), how the household acquired the plot, the purpose for which the plot is used and walking time from farm household's residence to the plot in hours.*

In the crop production regression and input use regressions, a logarithmic Cobb-Douglas specification is used. This leads to a theoretically consistent specification for output and input demands, and reduces problems due to outliers and non-normality of the error term found when using a linear specification (Pender and Gebremedhin, 2004).

Thus, the use of inputs – Labor days/ha (**lnL**), Oxen power days/ha (**lnO**), Seeds kg/ha (**lnS**), use of Fertilizer (**F**), and use of Manure/Compost (**M/C**), are modeled as a function of explanatory variables including village-level factors (X_V), plot-level factors (X_p), household-level factors (X_h) and the predicted value of adoption of rainwater harvesting ponds (**RWHp**).The models for the variable inputs can be written as follows:

$$\ln L = f(X_V, X_P, X_h, RWHp) \ldots\ldots\ldots\ldots (2)$$
$$\ln X_K = f(X_V, X_P, X_h, RWHp) \ldots\ldots\ldots (3)$$
$$\ln S = f(X_V, X_P, X_h, RWHp) \ldots\ldots\ldots (4)$$
$$F = f(X_V, X_P, X_h, RWHp) \ldots\ldots\ldots\ldots (5)$$
$$M/C = f(X_V, X_P, X_h, RWHp) \ldots\ldots\ldots (6)$$

Where, ***ln*** *stands for logarithm*

The econometric model used depends on the nature of the dependent variable. For use of labor, oxen power and seeds on cultivated plots, the least squares regression is used while the regression equations for the variable inputs, fertilizer and manure/compost, Probit model is used since the dependent variable is dummy variable.

Finally, in assessing the impact of RWH ponds on agricultural output, the value of the agricultural output harvested from a plot is modeled in three different alternatives. First, a full model of the value of crop production from a plot is modeled as a function of village-level factors (X_V), plot-level factors (X_p) and household-level factors (X_h). Besides, the use of variable inputs Labor (**ln*L***), Oxen power (**lnO**), Seeds (**ln*S***), Fertilizer (***F***), Manure or Compost (***M/C***) and the predicted value for adoption of RWH ponds (***RWHp***) are included.A full model of the value of crop production from a plot can be written as follows:

$$\ln Y = f(\ln L, \ln O, \ln S, F, M/C, X_V, X_P, X_h, RWHp) \ldots\ldots. (7)$$

However, in the second regression, household-level characteristics (***X_h***) and adoption of RWH pond (***RWHp***) are omitted. This is because the effect of these variables on production may be indirectly through the use of inputs. Thus, the second - structural model of the value of crop yield is modeled as a function of all factor inputs by excluding household-level factors (***X_h***) and adoption of RWH pond (***RWHp***) from the regression. Thus the second model of the value of crop yield from a plot is given as follows:

$LnY = f\ (lnL, lnO, lnS, F, M/C, X_V, X_P)$ ………………………………………… (8)

The third model developed in this study for the value of crop production is a reduced-form equation, which includes all village-level, plot-level, household-level characteristics as explanatory variables and the predicted value for adoption of RWH ponds. However, it excludes the use of inputs like Labor (**ln*L***), Oxen power (**lnO**), Seeds (**ln*S***), Fertilizer (***F***) and Manure or Compost (***M/C)*** from the model. This specification can avoid the potential for endogenity bias. And also to examine the total effect of all factors on crop production, and whether it is a direct effect on production or indirectly through its effect on the use of inputs and adoption of RWH ponds.

The models for reduced- form specification of the value of crop production from a plot can be written as follows:

$LnY = f\ (X_v, X_p, X_h,$ RWHp) ……….. (9)

In all cases, the least square regression was used to estimate the value of crop production.Generally, one important point that should be noted is that, for equation 2,3,4,7 and 8 robust regression is undertaken to avoid the hetroskedasticity problem that was observed during estimation. And also problem of multicolinearity and omission of variables has been checked.

Qualitative Analysis

These approach analysis the perception of experts and farmers regarding the constraints and opportunities of RWH technologies. The qualitative information was gathered using an open-ended question that was included in the questionnaire in order to augment the results of the econometrics analysis.

4. Results and Discussions

Impact on Cropping Pattern

As part of the assessment for the impact of RWH technology intervention on the farm household's crop choice decision, the study has employed a descriptive analysis of the crop mix for those with RWH technology in the different farming systems. Here, the crop types are classified into categories such as annual crops, perennial crops, vegetables, spices, others and no new crops. As can be seen from the table below, of the total number of the crop types sawn by all the sample households (382 plots), 188 observations are in the teff/haricot bean/livestock farming system category and 194 observations are under the pepper/livestock farming system category.

In the teff /haricot bean/livestock farming system, of the total *188* observations, 60.1% grow vegetables where as 4.3%, 6.9%, 4.3% represent annuals crops, perennial crops and spices, respectively. In the vegetable crop category cabbage, onions and carrot account 16.5%, 14.9% and 12.2%, respectively. On the other hand, in the pepper/ livestock farming system, of the total 194 observations 67% is vegetables category where as 6.2%, 4.1%, 2.1% represent annual crops, perennial crops and spices. In the vegetable category which have great share from the different classifications cabbage, beet root, tomato, carrot and onion, account for 16.5, 12.9, 10.3, 9.8 and 8.8 percent, respectively.

The result of the crop mix analysis imply that, the shift in farm household's crop choice decision towards highly priced and marketable agricultural products like vegetables and perennial crops or increment in the number of harvesting per year(intensification), could have a positive impact on the farm households income as well as level of living. However, the level and magnitude of benefit accrue to the farm household will significantly depend on market and infrastructure accessibility. This is because most of the crop categories sawn in farm households with rainwater harvesting technology are perishable; for example, vegetable represent the highest percentage of (60.1%) in Teff/Haricot bean/ livestock farming system and (67%) in pepper/ livestock farming system. Hence, unless these products are able to reach to consumers immediately after harvested, either their market value will decrease with time or it might be a loss to the farm household. Besides, an examination of the type of crops grown under the vegetable category witnessed that most farm households have concentrated on specific crops (tomato, cabbage, onions, and carrot) and the production and supply of these crops in large quantities might reduce the price of the commodities and there by affect the economic feasibility of the technology. Thus, effort should be made to supply variety seeds to farmers so as to diversify the type of crops grown.

Table 1: Types of crop grown after start to use the technology based on farming system

		Category of crop types grown						Total
Farming system	Type of crops grown	Nothing new	Annuals crops	Perennial crops	Vegetables	Spices	Others	
Teff/ Haric	No new crop grown	40 (21.3)						40
	Chat		1 (.5)					1
	Coffee			12 (6.4)				12
	Banana		1(.5)					1
	Sugarcane			1 (.5)				1
	Avocado		2 (1.1)					2
	Papaya		4 (2.1)					4
	Onions				28 (14.9)			28
	Ginger(Jinjible)				1 (.5)			1
	Pepper					6 (3.2)		6
	Carrot				23 (12.2)			23
	Tomato				7 (3.7)			7
	Cabbage				31 (16.5)			31
	Chilli Pepper					2 (1.1)		2
	Kale				4 (2.1)			4
	Sweet				1 (.5)			1

	potatoes							
	Garlic				3 (1.6)			3
	Beet root				15 (8)			15
	If other specify						6 (3.2)	6
	Total	**40 (21.3)**	**8 (4.3)**	**13 (6.9)**	**113 (60.1)**	**8 (4.3)**	**6 (3.2)**	**188**
Pe pp er/ liv	No new crop grown	38 (19.6)						38
	Chat		2 (1)					2
	Coffee			8 (4.1)				8
	Orange		1 (.5)					1
	Banana		2 (1)					2
	Pineapple		1 (.5)					1
	Avocado		2 (1)					2
	Mango		1 (.5)					1
	Papaya		2 (1)					2
	Onions				17 (8.8)			17
	Pepper					4 (2.1)		4
	Carrot				19 (9.8)			19
	Tomato				20 (10.3)			20
	Cabbage				32 (16.5)			32
	Lettuce/'Selata'/				5 (2.6)			5
	Kale				6 (3.1)			6
	'Kosta'				4 (2.1)			4
	Sweet potatoes				1 (.5)			1
	Garlic				1 (.5)			1
	Mandarin		1 (.5)					1
	Beet root				25 (12.9)			25
	If other specify						2 (1)	2
	Total	**38 (19.6)**	**12 (6.2)**	**8 (4.1)**	**130 (67)**	**4 (2.1)**	**2 (1)**	**194**

*The number in the bracket shows percentage value *The number out of the bracket shows frequency

Determinants of adoption of RWH pond, input use and crop yield

Determinants of Households Decision to Adopt RWH Pond

The estimation results of the Probit model for the determinants of household's decision to adopt RWH technology is presented in

Table 2. As can be shown in the table, from the locational dummies, Ulegeba Kukke shows stastical significance at 10% level. No association has been found between village level factors and technology adoption decision.

Household human capital

Household size is positively correlated with the adoption decision of rainwater harvesting ponds at 5% level of significance. This means households with large family size are more likely to adopt the technology since they can compensate costs involved in hiring labor for any activity that the technology demands. This implies that research and development interventions need to take account of the labor and cost demand of the technology. Households who can read and write, and those who are educated up to grade seven are more likely to adopt RWH. The positive association with the technology adoption can occur with the expectation that they can understand the benefit more easily and are more open to access information than illiterate households. This implies that expansion of education in the woreda will have a positive impact in increasing the adoption decision rate.

Household physical capital endowment

From the household physical resource endowment indicators included in the model, oxen, cattle and pack animals have depicted positive correlation with adoption decision of the technology. This indicates that adoption of the technology requires large resources, thus households with a better physical resource are more likely to invest on technology interventions than those with few physical resource. The positive correlation with oxen power may be due to households focus on agricultural production. However, it should be noted that the significant explanatory variables have insignificant effect in magnitude implying its less importance to make policy implication.

Plot level factors

Among the plot level factors, household decision to adopt RWH pond is more likely in homestead plot. The result indicates farm household's effort to fully utilize family labor so as to meet the human resource requirement during construction and utilization of water, thereby reduce the finance that could otherwise be needed for hiring labor. It can also show the capital constraint faced by households to buy modern water lifting equipment. The most interesting implication of this result is that, the accumulated water is used to produce crops with high market value rater than used as supplementary source of water during dry spells, as initially intended by government when the technology was introduced as country level. Ponds with concrete basement have shown stastically significant negative correlation with adoption of rainwater harvesting pond at 1% level. This implies that the higher cost involved in pond construction will result in less technology adoption decision.

Determinants of Agricultural Input Use

The estimation result for the agricultural inputs of: labor person days per hectare, oxen power days per hectare, seed - kg/ha, fertilizer and manure or compost is presented in Table 3.

Impact on use of Oxen Power

The estimation regression analysis also indicates that, adoption of rainwater harvesting technology has a negative stastically significant association with use of oxen power, more likely due to lower use of oxen power and more human labor on homestead plots where the technology is mostly adopted.

The locational dummies of Ulegeba Kukke, Andegna Hansha and Hamata are positively associated with value of oxen power used relative to Mudda Dinokosa. From the household access to services and infrastructure indicator, only nearness to village market is significantly correlated with more use of oxen power. Probably the correlation could be because of the possibility to get more seed and fertilizer enabling them to use more oxen power in order to increase their agricultural productivity. Moreover, it is shown that medium rainfall condition is positively correlated with the use of oxen power than low rainfall condition.

In the household level factors, household size, heads who can read and write, and those who are educated up to fourth grade are positively associated with the use of oxen power at 1% level of significance. This implies those households having large family size and educated members are more likely to use oxen power to utilize labor available in the family to produce more output. From the household physical resource endowment indicators, owned land has shown positive correlation with the use of oxen power at 5% level of significance, which implies that more oxen power will be used by heads who own more land. In addition, ownership of goats and sheep, and beehive are stastically significant at 10% level. The significance might imply household's involvement in sheep, goat or honey trading to get extra income and use more oxen power in order to increase agricultural production especially in cases when the household has large land size.

In relation to household head's membership in various associations, the study showed that relative to households with heads a member in association, households with heads not a member in associations are negatively correlated with oxen power use. This might imply, non-members may depend on activities that don't use oxen power as their source of livelihood. Farm households with saving have depicted significant negative association with oxen power use, more likely households with saving are engaged in livestock production, trading or use the money for health expenditure and for some other purposes.

The amount of oxen power used has shown significant positive association with flat and moderately sloped plots in comparison to steep plots. The result might indicate farmers risk aversion behavior due to crop failure which could be caused by high runoff problem. Plots with medium soil depth are less likely to use oxen power compared to plots with deep soil depth. Homestead plots have stastically significant negative correlation at 1% level. This means, it is less likely that households will use oxen power on homestead plots. However, the likely use of oxen power is shown to be significantly higher in crop land plots. An interesting result is found in the relationship between plot size and oxen power use, where larger plot size is significantly associated with lower oxen power use.

Impact on use of Seed

As expected the estimation of the regression analysis indicates that, adoption of RWH pond has stastically significant association with more likely use of seed. This could probably imply the impact of the RWH technology on crop production is indirectly through its effect on intensity of agricultural inputs.

The regression result depicts that no evidence has been found between locational dummies and amount of seed used. From the village level indicators, closeness to town and village market is significantly associated with more use of seed, probably the household heads are less likely to be engaged in non-farm labor employment and hence, more emphasis be given to crop production.

With respect to household size, large family size is significantly associated with more use of seed, probably indicating that the members in the household utilize labor by working in agricultural activity which demands more seed. From the education status, households with heads who can read and write, and those with formal education up to fourth grade have shown positive association with use of seed relative to illiterate headed households. Households endowed with large sized land are significantly associated with more use of seed. No significant correlation has been observed between social and financial factors, and amount of seed used. The result in the correlation between plot level factors and intensity in use of seed, more likely use of seed is shown on cropland and homestead plots.

Impact on labour use

As anticipated the estimation of the regression analysis indicate that, adoption of RWH technology has a positive stastically significant association with use of higher labor, most likely due to the higher level of labor requirement during watering , construction an other activities involved.

As can be seen from the result of the regression analysis, location dummy of Hamata PA is associated with more likely use of labor input at 5% level of significance. From the correlation between household access to infrastructure and service indicators and use of labor input, closeness to village market, town market and seasonal roads are associated with higher intensity in use of labor input. Probably household heads are engaged in farming activity by utilizing more seed, oxen and fertilizer use. Areas with high rainfall depict statistically negative association with labor input use, suggesting the need for more labor input in areas where there is low rainfall.

The result of the regression analysis shows that, a farm household with large family size has stastically significant association with use of more labor. Probably the positive correlation with labor input could be because of either inability of the economy to absorb the excess labor force in extended families or constrained by transaction cost in the labor market and there by the family members are compelled to engage in crop production at the existing plot. Stastically significant negative correlation exists between the age of the household head and use of labor input. That means older-headed households are less likely to supply labor.

Furthermore, in relation to the household physical resource endowment, ownership of more oxen power is likely to utilize more labor input than in cattle and pack animal ownership. This is probably due to complementarity. An important point that should be noted is the insignificant impact of this variables when consider the magnitude. In relation to household head’s membership in local organization, the study witnessed that, members in Edir and other related local organization are more likely to use labor input than those who are members in Edir only. In addition, households with saving are less likely to use labor input, probably suggesting household’s involvement in activities other than agriculture.

The result also shows a mixed correlation between plot level factors and labor input use. For instance, labor input use is significantly greater on plots with flat and medium slope than plots with steep slope, perhaps indicating farmers risk aversion behavior and their emphasis on short term benefit. Since steep sloped plots are more exposed to soil erosion problem. More over, less of labor input is used on inherited and plots with medium soil depth. Homestead plots have stastically significant negative association at 1% level. However, more use of labor input is observed on cropland plots. An interesting result is found in the relationship between plot size and labor input use, where larger plot size is significantly associated with lower labor input use.

Impact on use of Fertilizer

As can be seen on table 3, the adoption of RWH technology is shown to have insignificant impact on use of fertilizer suggesting that its impact on crop production isn't seen indirectly through its effect on fertilizer input.

From the village level factors, walking time to the nearest village market has a negative correlation with fertilizer use at 10% level of significance. That means households closer to the village market are more likely to use fertilizer. No evidence has been found on the existence of correlation between the likely use of fertilizer and factors like human, social and financial capital part of the household level indicators. Further more, strong positive correlation has been found between value of beehives and the likely use of fertilizer, which is perhaps due to households focus on beekeeping activity enabling them to buy more fertilizer using the incremental income.

In relation to the association between plot level factors and the likely use of fertilizer, crop land plots are shown to have positive association with the use of fertilizer at 1% level of significance. Less fertilizer use is observed on homestead plots due to more possibility to use manure or compost than buy fertilizer. In small plot size it is more likely to use higher amount of fertilizer which is mainly due to an increase in efficiency when household's own small sized plots. Moreover, plots closer to the residence of the farm household have depicted significant correlation with more likely use of fertilizer.

Impact on use of Manure or Compost

As can be depicted from table 3, adoption of RWH technology is found to have insignificant impact on manure or compost. No evidence has been found on the existence of correlation between the use of manure or compost and the locational dummies. From the locational dummies, household's nearness to village market, town market and seasonal road is more likely to use manure or compost inputs. Probably this is due to the use of more labor seed input when the household is closer to this services. In areas where there is high rainfall, more use of manure or compost is observed.

Further more, from the household level factors, households with large family are more likely to use manure or compost, probably due to the availability of labor to carry manure or compost to the farm land. With respect to educational status, household heads with formal education up to fourth grade are less likely to use manure or compost relative to illiterate heads. Most likely this could be affected either by educated headed households positive correlation with more likely use of fertilizer there by reducing the likely use of manure or compost , or these households are constrained by labor required to carry manure or compost to the farm.

In relation to household's physical resource endowment, ownership of large sized land is correlated with less likely use of manure or compost, probably due to its high demand for labor input to carry manure or compost to wider farm lands. Ownership of large number of oxen is correlated with more likely use of manure or compost. Those engaged in livestock production as shown by ownership of large number of cattle and beehives are less likely to use manure or compost.

With respect to the financial capital part, households who have access to credit are more likely to use manure or compost input. Probably due to the possibility of using the credit to buy seed, oxen etc. which might lead to demand more manure or compost .In addition, those with saving are also more likely to use manure or compost. Probably due to their preference to spent it on other things than on fertilizer by replacing it with manure or compost.

Finally, in relation to the association between plot level factors and the likely use of manure or compost, the result witnessed that, state owned and inherited plots are positively correlated with more use of manure or compost. On the other hand, on flat and moderately steep plots, households are more likely to use manure or compost than on those steep sloped plots, probably to avoid risk of crop failure. Medium soil depth is more likely to use manure or compost. Plots that are highly fertile are more likely to use manure or compost than those infertile once because it will be risky for the household to use the input on infertile plot than fertile once. Households are less likely to use manure or compost on cropland plots but more likely to use it on homestead plots, probably due to its closeness to the residence of the farm household.

Impact on Crop Yield

Table - 4 presents the full model of the value of crop yield (column-2). Here, variables such as household level factors; household – human, social, physical, and financial capital endowment; and adoption decision of RWH technology that were included in the unrestricted OLS regression have been found to be jointly statistically insignificant. In column – 3 and column– 4 results of the structural and reduced models are shown respectively.

The impact of adoption of RWH technology on crop production can be explained in two ways, directly or indirectly. The direct impact is, if the accumulated water is used to supplement the shortage of water during dry spell periods in rain fed crop production, where as the indirect impact is through its effect on intensity in use of agricultural inputs. The estimation result of the study indicate that, adoption of RWH technology is shown to be positively correlated with value of yield at 1% level of significance. This might imply that the direct impact of the technology adoption on crop production is significant. An examination of the indirect impact shows that, households with RWH technology are significantly correlated with higher use of labor and seed but lower use of oxen power than those without the technology. Intensity in use of labor and seed input has a positively significant impact on yield while oxen power has insignificant impact on yield.

As can be seen from the structural model for the value of crop yield, in the village level factors, seasonal road have negative stastical significance at 10%. With respect to the impact of plot fertility on value of crop yield, households are more likely to produce more output in moderately fertile plots than infertile once. As can be observed from the table, cropland and homestead plots are more likely to produce more yield. Besides, the result indicates the positive impact of use of labor, fertilizer and seed on value of crop yield. In the reduced model of crop yield, depicted in column 4 of table 4, village level factors, plot level factors, household level factors and household rainwater harvesting technology adoption decision were included in the regression and assessed with respect to their impact on the value of crop yield.

The village level factors don’t explain variation in the value of crop production. Moreover, from the household level factors, household size has shown positive association with value of crop yield at 10% level of significance. This implies that households having large family size are more likely to produce more output. With respect to the impact of household physical capital endowment, greater ownership of cattle has shown association with higher value of crop yield (and stastically significant at 10% level).From the plot level factors included, state owned plot are more likely to produce more output than rented plots. Possibly indicating household’s high future discount rate and become less likely to invest on productivity enhancing activities on rented plot. Plots with shallow and medium soil depth are less likely to produce more output than plots with deep soil depth. It is also shown that, cropland and homestead plots are more likely to produce more output compared with grazing, woodlots and spice plots. In addition, a negative significant association is observed between plot size and value of crop yield.

As can be depicted from the result of the reduced model, household family size is positively correlated with value of yield at 10% level of significance implying that large family will produce more output. From the determinant factors of input use table, households with large family size have shown significant association with use of higher labor, seed, oxen and more likely use of manure or compost. Intensity in use of labor has a positive impact on yield at 1% level of significance. This suggests that yield averages 11% higher per additional labor a household uses. Moreover, average yield increases by around 9% per additional seed amount used by the household. Even though fertilizer isn't significantly affected by household size, fertilizer is positively correlated with value of yield at 1% level of significance. That means yield is more likely to increase with more use of fertilizer input. Household age and education have insignificant impact on value of yield. However, household age has a significant impact on labor. Old age is negatively associated with labor input use. Educational status has a positive impact on seed and oxen input use.

Variations in resource endowment among households will obviously have an impact on the level of crop yield either directly or indirectly through their effect on the household's demand for agricultural inputs. Of the factors, which are used to measure household physical capital endowment, ownership of cattle has a positive impact on the value of crop yield. However, it has insignificant impact when consider the magnitude to make policy implication. Households with saving are negatively associated with labor and oxen inputs use. Probably they might prefer to be involved in non-farm activities. Credit access and saving have a positive impact on manure or compost input use. Household access to services and infrastructure facilitates the movement of inputs to and outputs from rural parts to towns, where large market is available. The regression result shows an increase in yield when the household is located closer to seasonal road and is stastically significant. Households closer to village market are able to use higher amount of seed, labor, oxen and more likely to use fertilizer and manure or compost input. In addition, households closer to cooperative shops and seasonal roads are more likely to use labor input and those nearer to town market are able to increase seed amount.

The result of the value of crop yield also shows that, state owned plots witnessed stastically significant association with higher value of crop yield. Probably, suggesting that farmers are more likely to invest on productivity enhancing activities on state owned plots. It is also shown that shallow and medium soil depth has stastically significant association with lower yield than on deep soil depth. Finally, crop land and homestead plots are shown to have positive association with value of yield.

Perceptions of the constraints and opportunities in adoption and use of RWH technologies

Farmers were asked to rank the purpose for which the accumulated water was used based on the amount of water utilized in each activity. As can be seen in table 5 below, households use the pond water for different purposes including as source of drinking water for animals and households. In addition to using the water for washing cloths and cooking, households use the water for nursering some plants, for vegetable and fruit production. About 40.8% of households responded that they use the water for vegetable production as a supplementary during dry spell periods to be their first choice. In the second rank, 27.6% of the households use the water for nursering. About 23.7% and 18.4% of the households use it for drinking and for livestock respectively.

Table 5. The purpose of the pond water

	Rank1	Rank 2	Rank 3	***Rank 4***
	Freq(%)	Freq(%)	Freq(%)	Freq(%)
For HHH drinking water	7(9. 2)	15 (19. 74)	**18(23.7)**	2 (2.6)
Drinking water for livestock	4(5. 3)	13 (17.11)	9(11.8)	**14(18.4)**
Nursering	26(34.2)	**21 (27.6)**	12 (15.8)	1(1. 32)
Vegetable production	**31(40.8)**	14 (18.4)	1 (1. 32)	3(3. 95)
Spices production	2(2.6)	1 (1. 32)		
Fruit production		2 (2.6)		
Washing cloths and food cooking	6(7.9)	10(13.16)	19 (25)	4(5. 3)
Total	76(100)	76(100)	59(77.6)	24(31.6)

Table 6 depicts cross tabulation of the type of RWH technologies adopted at plot level with their corresponding equipments used for water lifting and application. As shown in the table, 65.3% of the households represent those who adopted plastic-lined RWH pond and those waiting for plastic sheet. Concrete structures made of clay and/or cement accounts 34.7%. Of the total 47 households with plastic cover and none basement, 38.3% use metal Bucket for lifting and watering plants while 29.8% of the households use big plastic container '*Jerikan*'. Besides, households with concrete based ponds mainly use mental bucket followed by big plastic container, pulley and 'commendary' each accounting 20% of the households.

Table 6. Cross tabulation between type of RWH technology and type of water lifting equipments used

	Type of water lifting equipments used								Total
	Pulley	'Commendary'	Pot	Tridle pump	Jog	'Jerikan'	'Tanika'	Bucket	
Ponds covered with plastic and none covered basement	2(4.3)[b]	7(14.9)	2(4.3)		1(2.13)	14(29.8)	3(6.4)	18(38.3)	47(65.3)
% of Total	2.8	9.7	2.8		1.4	19.4	4.2	25	
Ponds with concrete basement	5(20)	5(20)		1(4)		5(20)	1(4)	8(32)	25(34.7)
% of Total	6.9	6. 9		1. 4		6. 9	1. 4	11.1	
Total	7(9.7)	12(16.7)	2(2.8)	1(1. 4)	1(1.4)	19(26.4)	4(5.6)	26(36.1)	72(100)

[b] Values in brackets are percentages.

In addition, the last raw of table 6 shows the distribution of each type of water lifting and application equipments used in the total 72 plots with RWH technology. Thus, from the total households with RWH technology majority of them (36.1%) use metal Bucket for lifting and watering plants followed by use of big plastic container (26.4%) and 'commendary' (16.7%).The highest percentage in the use of metal Bucket for water lifting and watering plants indicates the difficulty for a farm household in terms of time as well as labor days required to irrigate the entire plantation in the plot. This difficulty is due to lack of capital for buying or renting simpler equipments which is a major detrimental factor affecting the rater of rainwater harvesting technology adoption.

As can be seen on table 7 below, only 19.7% of the households that adopt the technology have a cover for their pond while 80.3% of them respond that they didn't put a cover for their ponds. This might result in lots of problems like accident on animals or kids, bad smell when the volume of water lowers which could be source of malaria, high evaporation rate. Of the households with a cover for their ponds 33.3% and 26.7% of them use wood (trees) and Satera respectively. Besides, 13.3% of them use Cob, wood with kenchibe and wood with Sinkita each. On the other hand, with regard to those who use fence to avoid risks, 68.4% of them use it while the rest 24 households don't use fence for their ponds. Most of the households use wood as a material to do the fence followed by using wood with kenchibe accounting 25% and 23.1% of them kenchibe alone.

Table 7. If the pond has a cover and fence

Does your RWH pond have cover?		If yes, what are the materials used?		Does the pond have fence to avoid risk?		If yes, what are the materials used ?	
	Freq(%)		Freq(%)		Freq(%)		Freq(%)
Yes	15(19.7)	Wood	5(33.3)	Yes	52 (68.4)	Wood(acacia tree)	20 (38.5)
no	61(80.3)	Cob	2 (13. 3)	no	24 (31.6)	Cob	2(3.85)
Total	76(100)	'Satera'	4(26.7)	**Total**	76(100)	'Kenchibe'	12 (23.1)
		Wood and 'kenchibe'	2(13. 3)			Cob and 'kenchibe'	3(5.77)
		Wood and 'Sinkita'	2(13. 3)			Wood and 'kenchibe'	13 (25)
		Total	15(100)			'Kenchibe' and thorn	2 (3.85)
						Total	52(100)

* Sinkita and kenchibe are kinds of bush trees. Satera is a grass material

Households with RWH technology were asked to list problems they encountered during implementation and utilization of the technology. These include problems related to RWH pond (33.7%), 37.9% of the total frequency of responses represents problems related with lack of equipments, 5.76% of responses mentioned problems related with agricultural inputs and 9.47% cited problems related with health. Thus, problem of equipment for water lifting and application is shown to be the dominant one with 37.9%.

Of the pond related problems, accident on animals and kids, absence of roof cover followed by quick dry up of the accumulated water problems take the highest share of 39.4, 36.8 and 14.4 percent respectively. The highest percentage observed in the accident could be due to absence of cover for the pond, absence of fence to the pond, and wrong location of the pond which might increase accident on kids due to closeness to the house. The high proportion of uncovered ponds could be due to lack of finance or may be due to less awareness given by the experts or probably due to weakness of the households. Quick dry up of the pond water could be related to the RWH technology or structural design of the technology which emanates from lack of extension workers with the necessary skill about the technology during construction or even lack of roof cover for the pond.

Furthermore, of the problems related to equipments used during pond utilization, the respondents mainly focused on the problem of water lifting equipment and lifting of water from the pond representing (around 78%). This is followed by problem of water application by using heavy materials reducing interest to produce vegetables in a wider place accounting around 42%.In summary, majority of the problems cited by respondent households revolves around two issues: those related to RWH ponds and equipment problems.

Possible solutions were suggested by households with RWH technology to overcome the aforementioned problems. Most of the solutions suggested focuses mainly on the need for government support in terms of finance, arranging training or experience sharing tour to household heads. Lack of equipments needed and problems related to RWH pond being the dominant problems observed, 81.5% of the households responded that they need government support or other organization to supply them with more simple modern materials either by sharing 50% of the cost or via long term credit so that they can produce more. About 40.8% of the households suggest support from government to avoid waste of labor power and time in the process of water application; we need more simple modern materials either in the market at lower cost or via long term credit since the price of water lifting and watering equipments are unaffordable at household level.

In addition, for problems related to RWH ponds, governments or other organizations help or credit to make them buy iron roof since other raw material don't stay long and the need for professional help on the need of having cover and fence to minimize risk accounts 38.1% each. On the other hand, 18.3% indicates the need to have continuous assessment to have positive impact on how to use and produce in each season and will help to give solution for problems that household face.

Households with RWH technology were asked to list benefits they get after they start to use the technology, and in general the total frequency of responses (251) reported the benefits sited by farmers are classified in to four major categories. As can be seen from Table 8, these includes new things found after they start to utilize pond (48.21%), 39.4% of the total frequency of responses represents benefits related to water supply or availability, 11.6% of the responses mentioned benefits related with production side and 0.8% are those related to individual opinions.

Table 8. List of Benefits

Se.No		CATEGORY OF THE BENEFITS REPORTED				Total
		Water supply for	New things	Production side	Individual opinions	
1	domestic use	33 (43.4)				33 (13.15)
2	new food varieties in our diet		47(61.7)			47(18.73)
3	Reduce consumption expenditure by producing what we used to buy from the market		28(36.8)			28(11.16)
4	For animals especially for those who can't go long distance to drink water.	37(48.7)				37(14.7)
5	It was able to get water for households easily and timely	29(38. 2)				29(11.55)
6	Produce vegetable beyond home consumption and get money to be used for different purposes by selling the remaining amount.		26(34.1)			26(10.36)
7	Helps to use water for permanent plants during the dry season e.g. Chat, Coffee, Papaya etc			6(7.8)		6(2.39)
8	Enable us to produce more than once in a year by using the pond water during dry spell period			9(11.8)		9(3.59)
9	create new job opportunity by developing the habit of working in dry season and use their time better than before		20(26. 3)			20(7.97)
10	Can avoid dry up of pepper nursering by using water in the pond			14(18.4)		14(5.58)
11	The negative side out weights positive one because the pond construction isn't dome well and it has no plastic cover				1(1. 3)	1(0.4)
12	I'm glad that the pond isn't covered by plastic or cement basement because it will help not to create bad smell when small animals died				1(1. 3)	1(0.4)
	Total	99(39.4)	121(48.21)	29(11.6)	2(0.8)	251(100)

Of the new benefits observed, 61.7% of the households respond the existence of new food varieties in their diet while 36.8, 34.1 and 26.3 percent are reduction in consumption expenditure by producing what we used to buy from the market, produce vegetable beyond home consumption and sell the remaining to use the money for different purposes and creation of new job opportunity by developing the habit of working in dry season and use their time which isn't known before respectively. In addition, the existence of water in their compound was seen as beneficial for animals especially for those who can't travel long distance to drink water and help the household to get water easily and timely instead of holding heavy material for a long distance to fetch water with 48.7% and 38.2% respectively. Finally, from the production side, 18.4% of the households responded that it is used to avoid nursering of pepper from being dried while 11.8% of them responded that it helps to produce more than once in a year using the water during dry season and 7.8% use the water for permanent plants during the dry season.

Finally, half of the sampled households were asked about the factors hindering them from adopting the technology. Of the total responses reported, reasons mentioned related to lack of financial capital problems represent 41.8% particularly related to poor economic situation to cover cost involved in pond implementation. Besides, 17.2% of them are related with lack of knowledge and follow up on the technology and most people don't think that it will give that much benefit. Where as, problem of raw materials mainly due to unfair distribution of raw materials needed to take out the water inside, plot/farm land due to small size land around the homestead and other reasons which mainly includes less work initiation mentioned account for 10.7% each from the total responses reported.

Gender and RWH Technologies

At present, there is a growing tendency towards the adoption of low cost and simple alternative water management technologies like rainwater harvesting technologies. RWH technologies have the potential to contribute towards the Millennium Development Goals (MDGs) with a view of eradicating poverty and hunger, provision of safe drinking water and sanitation, ensuring environmental sustainability, promoting gender equity and women empowerment. It is one way of improving the living conditions of millions of people, particularly those living in the dry areas. Water scarcity especially for domestic and agricultural purposes compromises the role of women in food production. Hence, provision of water by promoting rainwater harvesting and management technologies reduces the burden on rural women and thus increasing their productivity.

This part tries to see the participation of women in male headed households in planning and decision making stage, construction, maintenance, clearance and watching stages. In addition, it will try to address the question if women are benefited and in what terms, and the reasons if they aren't benefited from adoption of the technology. Besides, female headed households were asked if they are selected as beneficiaries and how they are selected, and if not, why not. The constraints that they face to use RWH technology are also considered.

Most households replied that there is equal responsibility among women and men to participate in planning and decision making accounting for 85.5% of the total rainwater harvesting technology adopters. This is followed by 17.1% of households who have mentioned that during planning, the women suggest the time for the work to provide a better food service. With regard to construction, 57.9% of the households said that, women participated directly (by supplying water) and indirectly (by preparing food and coffee) for workers. And about 33% of the households suggested that, women assisted by providing the needed raw material (like stone, sand, cement from home to where they work etc) and removing the soil from around the pond to a bit far area.

In the case of women participation in maintenance, clearance and watching, 72.4% of the households responded that they mainly participate in watching kids and animals from getting into the pond accidentally since they spent most of their time at home. This is followed by their participation in cleaning the area of the pond accounting 55.3%. Women participation during the dry season to carry out soil or sand that enters into the ponds in rainy season has taken 50% of the household's response. And about 30% of the households participated in maintenance by bringing water, raw material, food service and protecting the pond from being destroyed.

In relation to female headed households, 67.1% of the households who adopt RWH technology responded that they aren't selected as beneficiaries whereas the remaining 32.9% replied that they are selected to be beneficiaries. Out of those households who responded that female-headed households are not selected to be beneficiaries, 68.6% of them mentioned that the main reason is economic and manpower problem. Less interest and initiation due to less participation in agricultural work account for 17.6% of the household's response. About 16% of the households responded that bias exists towards male headed households on the ground that the ladies can't go through the hard work, and the same percentage for the reason that they don't have anyone to teach them about its use and purpose indicating less knowledge about the work. On the other hand, out of those households who responded that female-headed households are selected to be beneficiaries, 52% said that government or agricultural extension is voluntary to give chance for anybody depending on their working ability in agriculture. About 44% replied that it depends on their capacity to cover cost involved in pond construction. Moreover, 36% of them responded that it is their own initiation that matters.

With regard to the benefits achieved by women from the adoption of the technology, about 78% of the households responded that they are beneficiaries in terms of reduction in expenditure by using vegetable produced for home consumption and selling the remaining. More over, 61.8% of the households consider the time saved that would have been wasted in fetching water and 22.4% on ability to eat different and new food varieties.
Generally, the result implies that women are getting benefit from the technology adoption as any member of the family. Their participation in the technology adoption is mainly in watching the ponds. They also have contribution in planning and decision making stage, and in giving support during construction, maintenance and clearance of the pond. Female headed households are being constrained to be beneficiaries due to economic and manpower shortage.

5. Conclusions and Recommendations

Conclusions

Due to population increase in the highland areas, more and more marginal areas are being used for agriculture which led to the degradation of the natural resources .One of the major challenges to rural development in the country is how to promote food production to meet the ever-increasing demand of the growing population. Rainfall in the arid and semi-arid areas is generally insufficient to meet the basic needs of crop production. In degraded areas with poor vegetation cover and infertile soil, most of the rainfall is lost through direct evaporation or uncontrolled runoff. Thus, overcoming the limitations of these arid and semi-arid areas and making good use of the vast agricultural potential under the Ethiopian context, is a necessity rather than a choice. Hence, to alleviate these development constraints, the Federal government and Regional states, and NGOs working in research and development, have invested huge resource on rainwater harvesting technology.

In this study, methodologies including descriptive(cropping pattern), econometrics and qualitative analysis are used to assess the determinants of households' adoption of rainwater harvesting ponds, and its impact on agricultural intensification and yield in Alaba Woreda, southern Ethiopia. Interview has also been done with experts on rainwater harvesting ponds.

The finding in the cropping pattern shows that, farm households have started to grow new crops (vegetables and perennial crops) as a result of water availability from the water harvesting ponds. The crops are those which are highly priced and marketable ones implying the potential of RWH technologies to enhance a farm household's income. However, the benefit depends on market and infrastructure accessibility, and diversification in the types of the crops. Results of Probit analysis on the determinants of adoption of rainwater harvesting ponds shows that household size, education status of household head, ownership of livestock (cattle, oxen and pack animals), homestead plots and type of pond explained adoption statistically significantly.

In accordance with government's target, the Ordinary Least Square estimation of the determinants of the value of crop production shows that adoption of RWH has a positive and statistically significant effect on value of crop production, after controlling for input use and other factors. This shows that RWH ponds have direct and significant impact on value of crop production. We also find that households with RWH technology use more labor and seed but less oxen power compared with those households who have not adopted the technology. Moreover, labor and seed inputs have positively significant impact on yield while the effect of oxen power is insignificant. These results show that in addition to its direct impact, RWH has significant indirect impact on value of crop production through its effect on intensity of input use.
Results of the qualitative information, consistent, with the crop mix and econometric results, also showed that households started to grow crops that weren't grown previously. In addition, it indicates that effectiveness of the technology adoption is mainly constrained by problems related to water lifting and watering equipments, and accidents occurring due to absence of roof cover and fence to the ponds. Generally, directly or indirectly, labor requirements and cost considerations appear to be important factors that influence household's adoption of RWH technology.

Recommendations

The benefit found from the high valued and perishable commodities due to RWH, depends on market and infrastructure accessibility, and diversification in the types of the crops. Thus, efforts should be made to assess various agricultural commodities as well as giving emphasis to marketing extension, especially in facilitating markets and market linkages to farmers.
The impact of household RWH technology adoption on the value of crop yield has been found to be stastically significant. Therefore, to mitigate the erratic nature of rain fall in the arid and semi-arid parts of the country, development and implementation of rain water harvesting technologies will be helpful to promote productivity and sustainable intensification of the rain fed agriculture.
However, the success of the technology adoption is mainly constrained by problems related to water lifting and watering equipments, and accidents occurring due to absence of roof cover and fence to the ponds. This implies that support will be needed to provide affordable but improved water lifting and watering equipments, and give training to farm households on construction and use of roof covers and fences to the ponds.
Labor requirements and cost considerations appear to be important factors that influence household's adoption of RWH technology. This implies that research and development interventions need to take account of the labor and cost demands of the technology.

RESULTS OF ECONOMETRIC ESTIMATION

Table-2 Determinants of adoption of RWH pond (Probit)

Explanatory Variables	Probit use of RWH technology		
	Coefficient (dF/dx) ‡	Z	P>z
Peasant association dummy,cf., Mudda Dinokosa			
Ulegebba Kukke	-0.0007837*	-1.85	0.065
Andegna Hansha	-0.0004302	-1.01	0.312
Hamata	-0.0003513	-0.72	0.472
Household access to services and infrastructure			
Walking time to the nearest town market (in hrs)	-0.0001269	-0.61	0.545
Walking time to the nearest village market (in hrs)	0.0001965	1	0.316
Walking time to the nearest cooperative shops (in hrs)	0.0001392	0.52	0.603
Walking time to the nearest all weather road (in hrs)	0.0002143	1.02	0.308
Walking time to the nearest seasonal road (in hrs)	-0.0000296	-0.06	0.954
Rain fall condition, cf., low			
Medium	-0.0004712	-0.84	0.401
High	-0.000446	-1.46	0.145
Household size	0.000111**	1.96	0.05
Age of household head (in Ln)	0.0002167	0.29	0.772
Education level of household head, cf., illiterate			
Read and write	0.0079635***	3.25	0.001
Up to 4th grade	0.0018686	1.44	0.149
Up to 7th grade	0.00026301*	1.86	0.063
Up to 10th grade	7.41E-06	0.01	0.991
Household resource endowment			
Land owned (in ha)	-0.000184	-0.85	0.395
Value of cattle (both local & cross bred cows, calves, heifers, yearling, bulls)	3.59E-07**	1.98	0.048
Value of oxen (local and breed)	5.24E-07**	2.2	0.027
Value of sheep and goat	-4.44E-07	-0.72	0.472
Value of pack animals (donkey, horse, mule)	6.69E-07*	1.88	0.06
Value of poultry (both local & improved)	2.19E-07	0.64	0.519
Value of beehives (improved, modified, traditional)	3.85E-08	0.27	0.79
Value of all assets owned (plow set, farm equip, motor pump, radio,..	-3.23E-08	-0.33	0.74
Household membership in local organization, cf., members in Edir and other local organizations			
Membership in Edir only	0.0002847	0.7	0.487
Household membership in associations, cf., association members			
No membership in association	-9.37E-06	-0.02	0.985
Household financial capital , 1= yes			
Household with credit Access,1= yes	-0.0000753	-0.17	0.865
Household savings, yes=1	-0.0002764	-0.71	0.478
How household acquired the plot, cf., rented and share cropping			
Allocated by the state	0.5627719	0.00	0.997
Inherited	0.5999944	0.00	0.998
Slope of the plot, cf., steep slope			
Flat	0.0044407	0.00	0.999
Moderate	0.0686505	0.00	0.999
Soil depth of the plot, cf., deep			
Shallow	-0.0002766	-0.32	0.751
Medium	-0.0001365	-0.11	0.912
Soil fertility level of the plot, cf., low fertility			
High fertility	0.0141321	1.25	0.21
Moderate fertility	0.0010029	1.11	0.267
Purpose for which the land is used, cf., grazing ,woodlots and spice land			
Cropland	-0.0002559	-0.33	0.74
Homestead	0.0695164***	4.8	0.000
Plot size in ha (in Ln)	0.0005554	0.94	0.345
Walking distance from household's residence to the plot (in hrs)	-0.00168	-0.72	0.472
Type of pond, cf., ponds with plastic cover and those without a cover			
Ponds with concrete basement	-0.377571***	-4.54	0.000
Number of observations	1036		
LR chi2 (41)	350.92		
Prob > chi2	0.0000		
Pseudo R2	0.6399		

*** is significant at 1%; ** is significant at 5%; * is significant at 10%

‡Reported coefficients represent effect of a unit change in explanatory variable on probability of adopting RWH technology.

Table – 3 Determinant factors of input use during 2005/06 agricultural fiscal year

Explanatory Variables	Ln (Seed/ha)	Ln (Oxen-days/ha)	Ln (Labor-day/ha)	Whether fertilizer were used	Whether manure/compost were used
Peasant association dummy,cf., Mudda Dinokosa					
Ulegebba Kukke	-0.245172	0.15099*	0.058052	0.0655231	-0.0197904
Andegna Hansha	0.214534	0.203828***	0.039733	-0.1935646***	0.079232
Hamata	0.001953	0.168604**	0.172659**	-0.1475076**	-0.0190538
Household access to services and infrastructure					
Walking time to the nearest town market (in hrs)	-0.104291**	-0.016135	0.020109	0.206203	-0.0265866*
Walking time to the nearest village market (in hrs)	-0.125701**	-0.072537***	-0.117138***	-0.0425217*	-0.0363848**
Walking time to the nearest cooperative shops (in hrs)	0.034241	-0.02963	-0.057824*	-0.0280787	-0.0054926
Walking time to the nearest all weather road (in hrs)	0.040986	-0.011034	0.022569	-0.0090631	0.0078478
Walking time to the nearest seasonal road (in hrs)	0.184175	0.097555	-0.110871*	0.0753763	-0.129366***
Rain fall condition, cf., low					
Medium	-0.084553	0.112657**	-0.054333	0.0087776	0.0026803
High	-0.091135	0.008501	-0.212387***	0.0527761	0.2818222***
Household size	0.026266*	0.021049***	0.043193***	-0.0024128	0.0094189*
Age of household head (in Ln)	0.125784	0.108762	-0.181818*	-0.0654953	0.0254648
Education level of household head, cf., illiterate					
Read and write	0.230052*	0.231572***	-0.087174	-0.0931605	0.0654167
Up to 4th grade	0.257753*	0.192213***	-0.078671	0.0288443	-0.0862418**
Up to 7th grade	0.083556	-0.024551	0.002305	-0.0171464	0.0307067
Up to 10th grade	0.071938	0.080617	-0.053017	-0.0293807	-0.0785635
Household resource endowment					
Land owned (in ha)	0.007845*	0.006203**	0.00167	0.0027194	-0.0037889**
Value of cattle (both local & cross bred cows, calves, heifers, yearling, bulls)	-1.73E-05	-5.90E-05	-6.98E-05***	4.99E-06	-0.0000345**
Value of oxen (local and breed)	4.28E-05	2.83E-05	4.82E-05*	0.0000103	0.0000485***
Value of sheep and goat	0.000167	0.000129*	-9.97E-07	-5.99E-06	-5.83E-06
Value of pack animals (donkey, horse, mule)	-0.000118	-0.000051	-8.93E-05**	7.97E-06	-5.84E-06
Value of poultry (both local & improved)	-0.000809	0.000172	0.000323	-0.00039	0.0003529
Value of beehives (improved, modified, traditional)	-0.00041	0.000376*	0.000197	0.0003235*	-0.0004251***
Value of all assets owned (plow set, farm equip, motor pump, radio, ...)	3.62E-06	-1.66E-05	-2.19E-05	7.05E-06	-3.57E-06
Household membership in local organization, cf., members in Edir and other local organizations					
Membership in Edir only	-0.215644	-0.115894	-0.210552***	-0.089469	0.0591204
Household membership in associations, cf., association members					
No membership in association	-0.094869	-0.191782***	0.042779	-0.0621948	-0.0014808
Household financial capital , 1= yes					
Household with credit Access,1= yes	-0.137139	0.070683	-0.06814	0.0624094	0.056192*
Household savings, yes=1	-0.072473	-0.327655***	-0.114424**	0.0126967	0.1128724***

Table – 3 continued

Explanatory Variables	Ln (Seed/ha)	Ln (Oxen-day/ha)	Ln (Labor-day/ha)	Whether fertilizer were used	Whether manure/compost were used
How household acquired the plot, cf., rented and share cropping					
Allocated by the state	-0.506682***	-0.141824*	0.084312	-0.1988535***	0.158752***
Inherited	-0.382232***	-0.169708**	-0.111456*	-0.1364283**	0.1498123**
Slope of the plot, cf., steep slope					
Flat	-0.119189	0.530278*	0.446515*	0.1701381	0.3856669*
Moderate	-0.10287	0.51544*	0.547266**	0.1265144	0.2790531**
Soil depth of the plot, cf., deep					
Shallow	-0.021532	0.129045	-0.117212	-0.0475644	0.2127672
Medium	-0.000324	-0.300583***	-0.315847***	0.0428845	0.1378711*
Soil fertility level of the plot, cf., low fertility					
High fertility	0.048873	0.101733	0.035063	-0.0829447	0.1586607**
Moderate fertility	0.144556	0.089368	0.062933	-0.0517906	0.479061
Purpose for which the land is used, cf., grazing ,woodlots and spice land					
Crop land	0.419156***	0.37224***	0.614584***	0.4647761***	-0.0924947**
Homestead	3.09079***	-0.340097***	-0.472505***	-0.5890224***	0.4247779***
Plot size in ha (in Ln)	-0.180882	-0.912926***	-0.779754***	-0.2589599***	0.539933
Walking distance from household's residence to the plot (in hrs)	3.312421	0.011153	-0.12605	0.2058507**	-0.1616669
Adoption of Rain Water Harvesting technology (predicted value), 1=yes	3.312421***	-0.291091*	0.265723*	0.1043238	0.0748814
Constant	4.448353***	4.83144***	6.78531***		
Number of observations	1036	1036	1036	1036	1036
F (41,994)	8.80	14.08	14.46		
Prob > F	0.0000	0.0000	0.0000		
R squared					
LR chi2 (41)				281.62	353.37
Prob > chi2				0.0000	0.0000
Pseudo R2				0.1964	0.3137

*** is significant at 1%; ** is significant at 5%; * is significant at 10%
Reported coefficients represent effect of a unit change in explanatory variable on probability of use of the mean of the data
Ln represents natural logarithm

Table – 4 Determinants factors of value of crop yield

Explanatory Variables	Ln (Value of yield/ha) Full Model ‡	Structural Model ¶	Reduced Model
Peasant association dummy,cf., Mudda Dinokosa			
Ulegebba Kukke	-0.240465**	-0.16942**	-0.272749***
Andegna Hansha	-0.091321	-0.05626	-0.101886
Hamata	-0.332615***	-0.29741***	-0.387513***
Household access to services and infrastructure			
Walking time to the nearest town market (in hrs)	-0.037325	-0.02798	-0.037513
Walking time to the nearest village market (in hrs)	0.039986	0.041098	0.01502
Walking time to the nearest cooperative shops (in hrs)	-0.017744	-0.03863	-0.016557
Walking time to the nearest all weather road (in hrs)	-0.020955	-0.01405	-0.020943
Walking time to the nearest seasonal road (in hrs)	-0.13985*	-0.16159**	-0.083644
Rain fall condition, cf., low			
Medium	0.016212	0.01092	0.003531
High	0.10563	0.095822	0.08433
Household size	0.008924		0.015446*
Age of household head (in Ln)	-0.1558997		-0.13447
Education level of household head, cf., illiterate			
Read and write	0.007438		-0.059152
Up to 4^{th} grade	0.064804		0.110153
Up to 7^{th} grade	0.058197		0.079857
Up to 10th grade	0.123428		0.107066
Household resource endowment			
Land owned (in ha)	0.00154		0.0031
Value of cattle (both local & cross bred cows, calves, heifers, yearling, bulls)	4.44E-05*		4.55E-05*
Value of oxen (local and breed)	-3.44E-05		-1.22E-05
Value of sheep and goat	9.65E-05		8.20E-05
Value of pack animals (donkey, horse, mule)	8.94E-06		-3.14E-05
Value of poultry (both local & improved)	0.000275		0.00021
Value of beehives (improved, modified, traditional)	4.64E-06		-3.61E-05
Value of all assets owned (plow set, farm equip, motor pump, radio, ..)	-8.60E-06		-7.41E-07
Household membership in local organization, cf., members in Edir and other local organizations			
Membership in Edir only	-0.12421		-0.14033
Household membership in associations, cf., association members			
No membership in association	0.133489*		0.077884
Household financial capital , 1= yes			
Household with credit Access,1= yes	0.084706		0.045664
Household savings, yes=1	0.01175		-0.000479
How household acquired the plot, cf., rented and share cropping			
Allocated by the state	0.285989***	0.220717***	0.175439**
Inherited	0.14397*	0.09171	0.047545

Table – 4 continued

Explanatory Variables	Ln (Value of yield/ha)		
	Full Model	Structural Model	Reduced Model
Slope of the plot, cf., steep slope			
Flat	0.107935	-0.05085	0.157219
Moderate	0.213	0.052619	0.253161
Soil depth of the plot, cf., deep			
Shallow	-0.342699**	-0.2061	-0.276843*
Medium	-0.320594**	-0.2085	-0.269564*
Soil fertility level of the plot, cf.,low fertility			
High fertility	0.083002	0.12039	0.042061
Moderate fertility	0.10888	0.136898*	0.099062
Purpose for which the land is used, cf.,grazing ,woodlots and spice land			
Cropland	0.545698***	0.53749***	0.692927***
Homestead	0.22273*	0.273696***	0.376867***
Plot size in ha (in Ln)	-0.056483	-0.02842	-0.123963*
Walking distance from household's residence to the plot (in hrs)	0.085783	0.101174	0.077678
Labor-day/ha (in Ln)	0.101176***	0.110689***	
Oxen-day/ha (in Ln)	0.018104	0.006066	
Seed/ha (in Ln)	0.086711***	0.086715***	
Use of fertilizer,1= yes	0.164603***	0.171696***	
Use of manure/compost, 1= yes	-0.115259*	-0.11909*	
Adoption of Rain Water Harvesting technology (predicted value),1=yes	0.055424		0.510136***
Constant	6.686813*	6.272492***	7.859654***
Number of observations	1036	1036	1036
F (46,989)	8.11		
F(27,1008)		12.18	
F (41,994)			6.14
Prob > F	0.0000	0.0000	0.0000
R squared	0.125	0.0967	0.0953

*** is significant at 1%; ** is significant at 5%; and * is significant at 10%.
Ln= natural logarithm.
‡ Reported coefficients represent effect of a unit change in explanatory variable on probability of use of the mean of the data.
¶ Variables that were jointly statistically insignificant in the unrestricted OLS regression were excluded from the structural model

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Discussion on Theme 2: Irrigation Impact Poverty and Economy

Chair: Dr. Birhanu G/Medhin
Rapporture: Micheal Menkir

The chairman for this session introduced the theme and the floor was opened for questions, comments and suggestions.

Questions and Discussions

2.1 What are the inefficiencies variables, that the government policy makers can take up and go for improvement

2.2 What is the level of inefficiency/efficiency within irrigated agriculture itself? Since it is obvious that the production level of farmers cannot fell on the frontier line. How much is the efficiency or inefficiency difference between irrigated and rainfed agriculture?

2.3 The year 2005/2006 was a high rainfall year; so percentage contribution of irrigation on GDP would be less than in a draught year.

Ans-yes analyses may have underestimated percentage contribution slightly. clearly the percentage contribution of irrigation varies b/n good and poor rainfall year

2.4 How sustainable is use of irrigation from experiences of salinity?

2.5 Development especially in high evaporation areas in large scale irrigation schemes. It is suggested that future studies should consider this aspect.

2.6 What should be the size of the sample area of irrigated agriculture to be representative to talk about its contribution the national economy (GDP)

2.7 Using chow´s test you were able to pool the data of Doni and Godino but not Batu Degaga. Does this mean features were behaving in the same manner? Given that their location is different.

2.8 Area expansion increases agricultural production which has some contribution to poverty reduction. However extensive agriculture has its negative impact on the natural resource i.e degradation. Your analysis is based on extensive agriculture rather it is better to consider intensive agriculture for land and water productivity development. Therefore how do you see the natural resource degradation and environmental deterioration in your poverty analysis

2.9 Efficiency issue should be seen with respect to rainfall availability. In Godino water is abundant, rainfall rich. Therefore irrigators are less efficient. However in Batu Degaga water is pumped and it has a cost. So this is incentive for higher efficiency. The area is also dry land with highly variable rainfall. Therefore while considering efficiency water availability and rainfall should be an important parameters.

2.10 Increase of water supply by 1 percent leads to 0.5 percent output what should be the limit o f applying more water, since over application will lead to miss management and inefficient water use. In the future farmers may be able to pay for the water they use for irrigation (from experience of other water scarce countries like Morocco, Jordan and Israel. Is there a possibility of using this in terms of cost recovery and operational and management cost of irrigation projects?

2.11 While talking about the need for irrigation need for the countries GDP growth. Are we considering other sectors using the same source like hydropower, water supply

2.12 Quality of water definitely decreases as consumptive use (irrigation) increases. so is not important to consider the decrease in the value of same volume of water in the future in calculating or equating monetary value of water?

2.13 How do you say that irrigation time increases production? Irrigation time usually depends on the stream size a farmer is receiving.

2.14 How is it possible that farmers located at the tail end of the system are less efficient and at the same time dry land farmers are more efficient. Answer- Found the comment valid but could not consider during the study due to the complexity of determining the volume of water received by a farmer. Answer , Tail end users are less efficient due to water limitation because of over abstraction of water by upstream users

2.15 In your recommendation you stated that households with access to irrigation will remain poor what does this indicate?

2.16 The reason for livestock absence is not only because of less grazing land but mainly due to sleeping sickness (Trzpanosomiassis), lowland livestock disease.

2.17 In your conclusion less choice is put as a negative aspect but we found those who specialised (follow one cropping pattern) are the richest of the beneficiaries as they can buy their food crops.

Ans- the livestock disease happened some 10 years ago, but now lack of grazing land is the main reason. And less choice of food is related to the education status

2.18 There is a confounding effect between irrigation and rain fed agriculture. Farmers with access to irrigation could be making more money or income from their rain fed production. How can we deal with this problem?

2.19 What are the differences between depth of poverty and severity of poverty? What are the parameters that are required to address these two terms?

2.20 What is the optimal investment cost per hectare of irrigation projects specially small scale projects

2.21 What are the inefficiency variables which can be taken by the government

2.22 Definition of technical efficiency. Due to inherent nature of inefficiency every farmers cannot fall towards the frontier line

2.23 There are different kinds of small scale irrigation which irrigation systems are viable from the 25 SSI

2.24 Did you see the effect of supplementary irrigation in your analysis

2.25 Have you considered the cost of the dam? Is the water free?

2.26 No one mentioned about sustainability of the irrigation projects. Salinity in middle awash valley....?

2.27 Why did you leave commercial farmer like the one in Maki Ziway area in your analysis

2.28 Change in quality of water what is the economic impact of low quality water

2.29 Input-output pricing are they incorporated in your analysis

2.30 How do you identify poverty in the beneficiaries of irrigation schemes

2.31 Female Household are they included? what is the finding with respect to Female households

2.32 What is the difference between depth and severity of poverty

2.33 Interaction between rain fed and irrigation systems. How do you deal with confounding effect

2.34 Do you see the size of irrigable land which should be allocated example in Tigray it is 0.2 ha if tit is more it is not manageable? So did you come across of such kind of analysis.

2.35 What is the limit for investment? what kind of marketing is essential to impact the GDP? The other problem is the discrepancy between land and water availability

2.36 Share cropping is widely practiced. farmers lease their land. Do you consider this when you talk of impact of irrigation

2.37 What is the reason behind for female household to be more food secured than male headed household?

2.38 In the Alaba presentation the positive impact of water harvesting structures is shown what about its impact on health? Is the adoption continued even after its introduction by the government?

Theme three:

Irrigation Institutions and Support Services

Papers

1. Status of irrigation institutions and support services in Ethiopia
2. Does access to small scale irrigation promote market oriented production in Ethiopia?
3. Multiple Effects of Small Scale Irrigation in Ethiopia

Status of Irrigation Institutions and Support Services in Ethiopia

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Abstract

Ethiopia is investing good amount of scarce resources on irrigation development. But the performance of many of the irrigation schemes is often far from satisfactory with disappointing results of public investments. In this study, the type and performance of irrigation institutions and availability of support services were investigated taking three large and nine small scale irrigation schemes from different parts of the country.

It was noted that at the macro-scale, the mandates the Ministry of Agriculture and Rural Development and the Ministry of Water Resources in irrigation development were not clearly articulated and scrupulously tended. The set up of irrigation institutions from Federal to Woreda level is frequently changing ensuing institutional memory lapse, duplication of efforts, and lack of accountability. The roles of Water Bureaus and the Agriculture and Rural Development Bureaus with respect to irrigation development are not clearly defined to date. Irrigation extension service was observed as an unsatisfactory and the training of farmers in irrigated crop production was wanting.

Only the agro-industrial state schemes - sugarcane and cotton farms - are relatively well managed with little or no institutional and support service problems. Many of modern small scale irrigation schemes (86%) are nominally managed by Water User Association (WUA) with well crafted bylaws. However, many of them lack the authority to enforce them. The use of local courts to fine offenders was noted to be ineffective. Compared to formal institutions like water user association, traditional institutions were found to be better efficient for their penalty sanction mechanisms are stronger.

Beneficiaries lack skills and institutions to manage common property resources; consequently, irrigation infrastructure quickly falls into a state of disrepair. Substantial numbers of the beneficiaries don't feel that they own/control the water. In the perception of the many irrigators, maintenance of the headwork and main canal are the responsibility of the 'government'. But government organizations are more focused on the development of new schemes. Maintenance was observed to be the most serious problem (74%) that caused underperformance of many schemes. The main cause was attributed to lack of fund (37%) and poor organization and planning.

Water shortage ensued water theft and unauthorized canal breaching are said to be the major (78.1%) sources of conflict and water shortage in the irrigation schemes under investigation.

Marketing problem caused by absence of communal planning, contractual farming, transport access and staggered production system targeted for market was cited as the disincentive to expand irrigated crop production. Supply of seed, pesticide and insecticide is also identified to be the major challenges in diversifying production. The availability of support service in terms of inputs (seeds, fertilizer, herbicides, fuel, farms implements) was noted to be below satisfactory. The Bureaus of Agriculture are said to be the major provider of support services (35%). The service from research institution was reported as minimal. Service Cooperatives organized by the Cooperatives Promotion Agency have stared to deliver fertilizer in their cooperative shops recently.

In conclusion, irrigation water management institution is to be established and empowered with appropriate statutes. It is to be provided with extension and support services. The beneficiaries should be consulted in the

planning and they should be accountable for the public investment.

Does Access To Small Scale Irrigation Promote Market Oriented Production In Ethiopia?

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Abstract

The study examined the extent and nature of market oriented production in irrigated compared to rainfed systems in Ethiopia. By doing so the paper identifies the role of irrigation in market-oriented production, while at the same time highlighting the main constraints to market oriented development. Our results indicate that irrigation contributes significantly to increases in market participation, volume of marketed produce and, hence, income, by inducing shifts in farmers' cropping mix. The impact of commercialization of production on household food security is not direct and immediate mainly because of failures in the food market.

While irrigation enhances market production, there are series of factors that pose serious constraints to market production. Land size, oxen holding, access to market and means of transport were found to be important determinants of market oriented production calling for policy interventions in land markets, access to productive assets and infrastructure development and policy measures to improve the performance of agricultural markets. The study also found education has market promoting effect in terms of increasing the probability of participation and volume of sale. Increased support to education can, thus, help in the long-term to transform traditional subsistence agriculture into more market-oriented agriculture. Finally there are unobserved site specific effects, related to location and other covariates, which influence market participation and volume decisions.

Key terms: irrigation, change in cropping mix, market participation, volume of sale, Probit and Truncated regression; Ethiopia, Africa.

1. Introduction

Irrigation development is expected to increase market participation of producers (Rosegrant et al., 1995; MoFED, 2006). Higher yields, higher cropping intensity and all year round farm production leads to increased market-oriented production, implying a shift in supply (marketable surplus production) and perhaps food security. Irrigation is also expected to lead to changes in crop mix (cash crop orientation) which is expected to have far reaching consequences on household welfare (Joshi et al., 2003). Crop-switching as Hussain and Hanjra (2004) noted involves substituting low yielding and low profitable crops with new high-yielding and more profitable crops. Implicitly this implies switching from subsistence production to market-oriented production (ibid.). There are reports, however, that indicate that increased market orientation may not necessarily ensure food security especially if the macroeconomic environment is not conducive or there are distorted trade policies or there is poor infrastructure development (Van Braun, 1995) or social protection for food security is not provided through markets and government interventions (de Janvry et al.1991).

In risky environments such as Ethiopia, smallholder farmers, who constitute the bulk of the population, are often caught in production of low-risk/low-return food grains. With insufficient cash funds, and unpredictable outcomes, they cannot afford to take the risk of diversifying from subsistence food production into potentially higher-return ventures (such as growing cash crops for market), or of spending their limited cash on purchased agricultural inputs, because if they fail – either because of crop failure, price collapse, or lack of demand – they will not have either the basic food they would otherwise have produced, nor the cash to purchase it, and their families will go hungry (MOFED, 2006 p.6). Irrigation removes some of the risks associated with rainfall variability and thereby increases the likelihood of using purchased quality inputs due to the reduced risk of crop failure. Irrigation is, hence, expected to remove or ease risk so that farmers can venture into an inherently high risk-high return production pathway, which may have a significant effect on poverty reduction (MoFED, 2006).

While irrigation development is expected to induce such changes, the realization of these effects cannot be taken for granted. This could be especially true in countries like Ethiopia, where many of the preconditions for market production seem to be missing. The households' orientation towards market production is often hampered by various factors at the household and village levels, by market access conditions and other institutional and policy factors. The World Bank (2006) indicated that current limited access to transportation and markets undermines incentives for surplus agricultural production and reinforces the highly vulnerable subsistence-oriented structure of the economy. It further indicated that smallholder farmers, generally with less than 1 hectare of land, account for about 95 percent of the agricultural output. In times of good weather, roughly 75-80 percent of the output is consumed at the household level (World Bank, 2006). Bhattarai and Pandy (1997) in their study in Nepal indicated that wheat production was economically more profitable in locations with better access to irrigation and rural infrastructure. They also found that farmers with access to irrigation and markets are found to be much more responsive to changes in wheat prices than farmers without access to such infrastructure, indicating the complementarity between infrastructure development and access to market and crop productivity. Lapar et al. (2003) pointed out that smallholders generally have inadequate capital resources—including, physical and financial resources, but also intellectual capital resources such as experience, education and extension— which limits their ability to diversify production portfolios. Lapar et al. (2003) further indicated that the inability of smallholder producers to take advantage of economies of scale in production and marketing is a significant impediment to market participation. Smallholders are often disadvantaged due to poor access to information and market-precipitating services such as extension visitation and credit assistance and these impediments often give rise to low rates of adoption of improved technologies that could potentially increase productivity, diversification and, hence, market participation. In addition, poor infrastructure often increases the transaction costs of smallholder market participation.

However, there is little empirical evidence on market participation in developing countries, particularly in Africa. The limited studies there are focus on smallholder producers' decision to participate in coarse grain markets (Goetz, 1992) or in livestock markets (Lapar et al. 2003; Bellemare and Barrett, 2006). To our knowledge there is no

study, which has systematically investigated the role of irrigation in inducing market-oriented production in Sub-Saharan Africa.
A sound understanding of the patterns of market oriented production and the constraints it faces could contribute to the development of more appropriate policies regarding institutional arrangements and the creation of adequate infrastructure, which could benefit a large mass of smallholder producers. This study is an attempt in this direction. Specifically it aimed to: (i) examine the extent and nature of market oriented production in irrigated sites in contrast to rainfed areas in Ethiopia; (ii) identify the determinants of market-oriented production, including the role of irrigation in the process, and (iii) draw implications of market oriented production on food security and poverty reduction.

We used a unique dataset covering various small and medium scale irrigation schemes, both traditional and modern. Corresponding data from rainfed systems were used as a control. We explored the differential impact of irrigation development on market production as contrasted to rainfed systems. In explaining a household's decision to participate in the market we introduced the distinction between participation per se and volume decisions (i.e. level of participation). Where participation investigated whether the household produces and sells products to the market regardless of the amount (value) of sale and the level of participation investigated the factors that influence the quantity of sale. It is difficult to assume *a priori* that the factors that influence the household's decision to participate in the market are different from the factors that influence volume decisions. Hence, we also tested whether the decision to participate and the volume of sale are made simultaneously using appropriate econometric techniques.

The paper is presented as follows. Part two presents a theoretical model for modeling participation and volume decisions followed by the presentation of testable hypotheses and econometric approaches in parts three and four. In section five the study site and data description and some descriptive statistical summary results are presented. Part six discusses the econometric results and part seven concludes and draws policy conclusions.

2. Modeling participation and supply decisions

We developed a simple conceptual framework that captures interactions, processes and outcomes that result from irrigation development. Unlike rainfed agriculture, irrigation development enhances cropping intensity as households are able to produce more than once in a year. Irrigation also opens new horizons for growing new crops which are not usually possible under rainfed conditions (Joshi et al., 2003; Hussain and Hanjra 2004; Hussain, 2005; Huang et al., 2006). Furthermore, irrigation development enhances increased use of purchased inputs by reducing the risk of crop failure and increasing returns to agriculture and, hence, increasing household's willingness to use purchased farm inputs such as fertilizer, herbicides and pesticides and also hired labor (Hussain and Hanjra, 2004). These changes in cropping intensity and shift in cropping choice (diversification) are expected to have far reaching consequences on food security and poverty, not least through the market behavior of smallholder farmers (Pandey and Sharma, 1996; Hussain and Hanjira, 2003; Hussain and Hanjra 2004; Huang et al., 2006).

Irrigation development is expected to trigger this host of processes. However, while irrigation is the necessary condition to induce these changes, it is not as such a sufficient condition as there are various factors that influence these processes. First we present the theoretical model that focuses on the household's decision to produce for the market before we present the possible factors that influence market participation and volume decisions.

We consider market participation and supply decisions in the context of traditional Probit and Tobit models applied to household production data (see Lapar et al. 2003). For each household, i, i = 1, 2,…N, assume that the observed data, namely y_i = 1 if participation is observed and y_i = 0 otherwise, is conditioned by a K-vector of household-specific covariates, x_i. The decision rule is to participate when the utility of doing so, say, $U_i(x_i)$ exceeds utility $V_i(x_i)$, which is the utility reaped from some alternative enterprise (e.g. to produce food crops). Taking Taylor-series expansions of these two utility functions around the point x_i = 0, yields the linear model, y_i = 1 if $x_i \gamma \geq x_i \mu$, y_i = 0 if $x_i \gamma < x_i \mu$, where γ and μ are K-vectors of first-order effects depicting the impacts on the two utilities of changes in the levels of the covariates. Subtracting the left-hand-side from both sides of the inequalities, equating the result to a latent variable, Z_i, and permitting the equality to hold with error, μ_i, we are left with

$Z_{pi} = x_i \beta_p + \mu_{ip}$, $Z_i \geq 0$ if $y_i = 1, Z_i \leq 0$, otherwise. (1)

Here $\beta_p \equiv \gamma - \mu$ measures the difference in allocating resources to either enterprise, i.e. food or cash crop production.

Supply decisions are modeled in a similar way. We assume that the quantity supplied on the market is a linear function of another set of household characteristics, which may be the same as the set represented by the covariates xi, above. Specifically, the supply relationship is:

$$Z_{si} = x_i \beta_s + \mu_{si}, \qquad (2)$$

where Z_{si} denotes household i's the volume supplied; x_i denotes covariates relevant to the supply decision; β_s denotes a vector of unknown parameters depicting the relationship between supply and the household covariates; and $\mu_{si} \sim N(0, \sigma_{si})$ denotes random error.

Unlike the latent specification in the Probit model, the dependent variable in (2) takes on positive and zero values. When a zero value is observed, we assume this to imply that the household in question, rather than possessing an excess of the marketable product, actually has a demand for the commodity (that is, a negative supply). Hence, sales quantities are left-censored at zero.

3. Hypotheses

In this section we present, in the form of testable hypothesis, various factors that influence the irrigation-market production nexus.

In most rural economies, farm households are dominant decision-makers when it comes to the management of land and water resources. Farm households appear to represent an extremely robust and dominant decision-making unit in relation to production, consumption and market exchange in the types of economies we studied. Farm households, therefore, become the natural core units in our models and analysis. Various development interventions, including irrigation development, may have changed their decision-making environment, however, in terms of their capacity to produce, access markets and the prices and price variability they face in these markets.

In a world with well developed markets, households will participate in all factor and commodity markets when these factors are used in production and commodities are produced and/or consumed by the households, as long as factors and commodities are imperfect substitutes and distribution of factors and commodities vary across households. There will always be gains from trade when trade is costless (zero transaction costs). Such a world favors specialization. Under such scenario, irrigation development is expected to promote market oriented production

regardless of the households' consumption demand.
In the real world there are transaction costs causing there to be price bands where purchase prices are higher than selling prices. Significant positive transaction costs and information asymmetries can lead to market imperfections (de Janvry et al., 1991). For an economy where there are both sellers and buyers of a factor or commodity, in the so called two-sided markets, positive transaction costs and information asymmetries lead to non-participation and a "self-sufficiency orientation" for factors that are owned and used in production and commodities that are produced and consumed by households. In general, we expect that the higher the transaction costs, the wider the price band and the larger share (%) of households that will be non-participating. An implication of this is that market non-participation can be an indicator of the size of the transaction costs in a specific two-sided market. However, the distribution among households and substitutability of factors in production and commodities in consumption within households may also influence the degree of non-participation. The higher the elasticity of substitution in production and consumption the higher we expect the probability of non-participation to be. Overall, significant market non-participation is a sign of significant market imperfections in an economy. On the basis of these broader perspectives, we developed some testable hypothesis.

H1. Smallholder producers with access to irrigation are more likely to participate in markets than farmers under rainfed systems.

H2. Smallholder farmers with better access to markets (i.e., close to larger markets) are expected to be much more likely to participate in the market than farmers without access to such infrastructure.

H3. Households with better endowments such as labor, capital (including livestock), land and other resources such as information and education are more likely to participate in markets than households with fewer endowments.

H4. Smallholder farmers are often disadvantaged due to poor access to information and market-supporting services such as extension services and credit assistance and these impediments often give rise to low rates of adoption of improved technologies that could potentially increase productivity, diversification and, hence, market participation.

Hypothesis three implies that poverty may limit households' participation in markets. Besides, food insecure households may allocate most of their resources to meet their food demands, even if growing for the market is economically more rewarding. Hypothesis four implies that availability of inputs and new technologies also facilitate market oriented production. In this case, the functioning of input markets and extension services play an important role in facilitating increased adoption of new technologies (improved seeds, agronomic practices, etc) by farmers. Adoption of new technologies plays a critical role in farmers' increased market oriented production as technological change without increased commercialization seems unlikely because of the increased use of purchased inputs and diversification/specialization are inherent elements of most technological innovations in agricultural production. Hence, policies to speed up commercialization and technological change move jointly in a reinforcing way (von Braun, 1995). Hence, we propose that households with good access to services (input and capital markets) are more likely to participate.
These hypotheses were tested systematically. The results are reported in the subsequent sections.

4. Econometric estimation

Let the amount of crops supplied by a household i be given by:

$$y_{si} = x_1\beta_1 + \mu_1 \quad \textbf{\textit{(3)}}$$

where y_{si} is the volume of sales supplied by the household that is expected to depend on the vector x_1 regressors outlined in equation (2). As y_{si} is censored this can be estimated using variants of censored regression models. The most often used model is the Tobit model (Wooldridge, 2002).

The participation equation, whether the household decides to participate or not, is given by:

$$y_{pi} = 1[x\delta_2 + v_2 > 0] \quad (4)$$

where (x, y_{pi}) are always observed whereas y_{si} is observed only when $y_{pi} = 1$. Eq. (4) can be estimated using variants of the binary choice model, in our case we used the Probit model. We assumed that (u_1, v_2) is independent of x with mean of zero implying that x is exogenous, and $v_2 \sim N(0,1)$.

One of the assumptions in, and important limitation of, the Tobit model is a single mechanism determines the choice between $y_{pi} = 0$ versus $y_{pi} > 0$ and the amount of y_{si} given $y_i > 0$. However, in reality participation decisions and volume decision could be separate, and are influenced by different factors. Estimating these decisions simultaneously while the decisions are separate may lead to inconsistent estimates and wrong conclusions. Alternatives to censored Tobit have been suggested to allow the initial decision of $y_{pi} = 0$ versus $y_{pi} > 0$ to be separate from the decision of how much y_{si} given $y_{pi} > 0$. These include Cragg's double hurdle model (Probit plus Truncated regression model) (Cragg, 1971) or Wooldridge's model using Probit plus lognormal regression models (Wooldridge, 2002). Hence, nested (log-likelihood ratio test) and non-nested Voung test (Voung, 1989) model test statistics were derived to determine whether to use the Tobit model formulation or either the Cragg or Wooldridge model. If these test results showed that these were separate decisions, then we used the double hurdle model (Cragg, 1971) or Probit plus lognormal regression models (also known as Wooldridge model) along with other explanatory variables to explain volume decisions of households.

The Cragg model has the advantage that it nests the Tobit model and a likelihood ratio test can be performed easily to determine if the household market supply decision is best modeled by a one-step or a two-step procedure. The difficulty in comparing the Wooldridge model against the Cragg model is that they are not nested to each other. The same is true for Tobit model and Wooldridge model. We used the Voung (1989) non-nested model selection test. Following, Greene (2000) and Fin and Schmidt (1984) the restriction imposed by the Tobit model is tested against the Cragg model by performing a likelihood ratio test of the following.

$$L = 2(\ln L_{probit} + \ln L_{truncatedregression} - \ln L_{Tobit})$$

…………………………………………(5)

where L is distributed as chi-square with k degree of freedom (K is the number of independent variables including a constant). The Tobit model was rejected in favor of the Cragg model if L exceeded the chi-square critical value. The likelihood ratio test statistics of chi2 (37) = 4574.21, p=0.0000, indicated that the restrictions imposed by the Tobit model is rejected in favor of the Cragg model. Thus, the same household and farm characteristics did not have equal influence on both the participation decision and the decision for how much to sell. It also implies that the participation decision and volume decision are not made simultaneously. However, hypothesizing that a given variable is interrelated with the participation decision and not with volume decision or vice versa is difficult. Consequently, the three models are estimated with the same variables.

Once the Tobit model was rejected, the Cragg model could be compared with Wooldridge model using Voung's non-nested model specification test. Voung's non-nested model specification test is given by

$$V = n^{-1/2} LR_n(\hat{\theta}_n, \hat{\upsilon}_n) / \hat{\omega}_n \rightarrow N(0,1) \quad (6)$$

where $LR_n(\hat{\theta}_n, \hat{\upsilon}_n)$ is the difference between the log-likelihood values for the two models, $\hat{\theta}_n$ and $\hat{\upsilon}_n$ is the maximum likelihood estimators from the two models, respectively and V is distributed as a standard normal variable. The Voung test statistic of (V= -27.858, p= 0.000), strongly indicated that the Cragg model dominates the Wooldridge model. The critical values (c) for the 1 and 5 percent significance level are 2.58 and 1.96, respectively. Consequently the results presented below are derived from the Cragg model.

Finally, we also corrected the standard errors for clustering effects by assuming that observations are not independent within the cluster although they are independent between clusters, in this case the household (Rogers, 1993). This is fair assumption as management could vary across households but not within plots run by the same household.

5. Study site description and data description

This study is part of a comprehensive nationwide study on the multiple impacts of irrigation on poverty and environment run between 2004 and 2007 in Ethiopia. It was a component of the Impact of Irrigation on Poverty and Environment (IIPE) research project run by the International Water Management Institute (IWMI) with support from the Austrian government. The socio-economic survey, which investigated the impact of irrigation on poverty and irrigation contribution to national economy, addressed a total sample size of 1024 households from eight irrigation sites from 4 regional states involving traditional, modern and rainfed systems (see Fig. 1 and Table 1A). The total sample constitutes 397 households practicing purely rainfed agriculture and 627 households (382 modern and 245 traditional) practice irrigated agriculture. These households operate a total of 4,953 plots (a household operating five plots on average). Of the total 4,953 plots covered by the survey, 25 percent (1,250 plots) are under traditional irrigation, 43 percent (2,137 plots) are under modern while the remaining 32 percent (1,566 plots) are under rainfed agriculture. The data collected include demographics, asset holdings, access to services, plot level production and sale and input use data (distinguished between irrigated and rainfed), constraints to agricultural production and household perceptions about the impact of irrigation on poverty, environment and health and other household and site specific data. The data was collected for the 2005/2006 cropping season.

6. Results and discussion

Summary statistics

We present a summary of some of the most important variables here (for details see Table 1 below). Of the total households surveyed, about 54 percent of the households participated in the market by selling a product and earning an average of Birr 591 (SD 2169) [††††††]. The gross value of sales realized by households varies greatly

[††††††] 1 US Dollar (USD) = 8.39625 Ethiopian Birr (ETB) in May 2006.

as can be seen from the high variance. This variation is also stronger between farmers working in different irrigation types. Households in traditional irrigation and in modern schemes earn an average income of Birr 699 (SD 2679) and Birr 779 (SD 4090) respectively from crop sales in contrast to rainfed Birr 476.10 (1076.1). It seems that average gross value of sales from modern irrigation schemes is higher than those from traditional schemes. However, testing for equality of the mean, in sales between the three irrigation types, indicated that there is a statistically significant difference (p-value 0.0001). However, a separate test for traditional and modern scheme indicated that the mean difference is not statistically different (p-value 0.5354). This indicates that there was no difference in mean value of sales between traditional and modern schemes, although average sales from both sources are higher than those obtained from the rainfed system.

When asked about whether the households faced any output market and marketing problems about 59 percent responded that they did not face any problems while the remaining 41 percent said that they did. There is a difference in the perception of the presence of a market and marketing problems between farmers working in rainfed systems and under irrigation systems. More farmers under irrigation systems seem on average to face market and marketing related problems than those working under rainfed systems. The major problems include: market problem (low demand and low selling price) (30.7%), distance to market, road and transport problems (23%), same product & peak time supply (20 %), unstable prices (11%), lack of services (information, service cooperatives, high tax) (5.3%), high purchase prices of agriculture goods when they want to buy them (4.4%), low supply and poor quality (3.3%), exploitation by local traders (1%), and others (additional costs) (0.7%).

The functioning of input markets is expected to influence the functioning of output markets through its influence on production. Hence, we wanted to understand whether farmers faced any input access problem during the 2005/06 cropping season. Reporting on their experience of input access, about 53 percent of the households responded that they had no input access problem, compared with 47 percent who indicated that they did. The problems included: high input prices (45.8%), shortage of capital (high down payment, not member of service cooperatives and lack of access to credit) (18 %), lack/shortage of supply of inputs (mainly pesticides and herbicides but also fertilizer) (16 %), lack of timely supply (10 %), shortage of equipment and materials and skilled labor to apply these inputs (2.4), and distance to input markets and lack of supply locally (1.9%). The most important problems are, hence, high input prices, lack of credit access and lack of availability of inputs in space and time. There is a significant difference in the perception of the presence of input related problems between farmers working in rainfed systems and under irrigation systems. On average more farmers under rainfed systems seem to face input access problems than those working under irrigation.

Moisture stress and water shortages could pose serious constraints to agricultural production and, hence, to market supply of agricultural outputs. Asked if households faced any shortfall in rain during the production season about 61 percent of the respondents indicated they did not, while the remaining 39 percent indicated that they did. Similarly, irrigation farmers asked if they faced water shortage during the irrigation season, 73 percent responded that they did not, while 27 percent of the respondents did.

We present the composition of crops under different irrigation systems. The percentage values indicated the percentage of the plots covered by these crops (Figure 3). The dominant crops under traditional irrigation system, in order of importance are: maize, wheat, teff, followed by horticultural crops such as mango, potato, banana and tomato (Figure 3a). In the modern irrigation schemes, in the order of importance, the dominant crops are teff, maize, onion, wheat, tomato, barley and potato (Figure 3b).

In the rainfed agricultural system cereals are the dominant crops: teff, wheat, maize, sorghum, barley and pulses and oil crops. Horticultural crops such as onion, potato and perennial crops such as mango and *gesho* (local hops) each cover less than 1 percent of the total plots (Figure 3c).

Finally we looked into the nature of market production, i.e. whether households are really exercising shifts in their cropping choice? Or is it just the produced surplus which is supplied to the market? How are the quantity of sales and value of sales correlated? We estimated a simple correlation coefficient between quantity and value of sales. A calculated correlation coefficient of 0.18 indicates that there is low linear association between quantity and value of outputs. Therefore, it could be that farmers are shifting to more valuable products as the crop composition also attest.

Explaining market participation

The results from the Probit regression model on factors that determine households' market participation, are reported in Table 2 below. The fitted binary choice model is found to explain the observed variation with the observed probability of 0.60 and predicated probability 0.62. We also estimated the marginal effects for the Probit model and these are reported here.

Farmers working under different irrigation management schemes may have different probabilities to participate in the market. Households working in modern irrigation schemes were found, albeit at 10 percent level of significance, less likely to participate in the market compared to rainfed farmers. Similarly, farmers working under the traditional irrigation scheme are found to have not significant difference in participating in output markets. These results show that participation *per se* is not influenced by whether the household works under irrigation system or not. However, when we disaggregate by crop types, farmers growing irrigated annuals and irrigated perennials are more likely to participate in the market in contrast to farmers that grew rainfed annual crops, with marginal effects 0.21 and 0.29 respectively. It is believed that this is because the rainfed annual crops tend to be mainly food crops. The participation of the farmers growing rainfed perennials is found not to be significantly different from those growing rainfed annuals perhaps indicating the inherently low scale of cash crop production in the former. Hence, the result strongly indicates that irrigation significantly contributes to market participation by enabling farmers to grow crops that are marketable although rainfed growers also sell crops for various reasons.

Various household characteristics and resource level endowment variables were found to have a significant effect on any households' decision to participate in the market. From among the household characteristics education attainment of the head of the household and family size were found to be significant in explaining market participation. The number of years of education of the head was found to be positively and significantly associated with the households' decision to participate in the market implying that educated households are more likely to participate in the market. As education increases by a unit, the probability of participation increases by about 2 percents. On the other hand family size was found to have a negative effect on market participation indicating that households with more family members are more likely to focus on food production to meet family food requirements. This is typical of economies where food markets are not well developed and, hence, households choose to first be food-self sufficient, before they produce for the market. From among the household resource endowments, the size of the operated land area has a positive and highly significant effect on the decision to participate in markets. A unit increase in area of operated holding leads to a 23% increase in the likelihood of participation. This result indicates that land holding size could be an important constraint to market participation even if irrigation access is ensured. Other resources such as labor (both female and male), oxen holding were found to be insignificant in explaining market participation perhaps indicating that these resources may not pose as significant constrains to participation *per se* in rural Ethiopia.

Distance to the market where produce is sold and type of means of transport had also significant effect on market participation. Market participation *per se* increased with distance to market where the products are sold. Although this sounds counter intuitive, this may be related to the fact that households who manage to transport to distant but larger markets are likely to benefit from the high price differentials manifest in fragmented markets. As agricultural markets in Ethiopia, as in most rural economies of the developing world, are not well developed, price effects are not easily transferred across locations. This implies that farmers need to select markets where their products can fetch good prices and the incentive to take a product further afield requires market knowledge as a precondition. Below we test this theory by determining if the value of output increases with distance to the market where the output is sold. Conversely, this may also suggest that irrigation schemes are not positioned close to markets. Participation also seems to increase with the use of donkeys as a means of transport in reference to use of human power. Those who used donkeys are 6 % more likely to participate in the market compared to those who used human power.

Access to input markets were also found to have significant effect on market participation of households. The households who reported to have faced input access problems were found to be the most likely ones to participate. This may reflect a reverse causality in that those who participated in the market ones most likely to face input access problems. Households producing for the market were about 6 percent more likely to face input access problems such as untimely availability of seeds, seedlings, and chemicals. This result was reflected during the rapid appraisal study which indicated that farmers had a hard time getting vegetable seeds and pesticides. This may call for reorientation of the input supply system to meet the requirements of the irrigation system.

Community (site) level effects were also found to be significant in explaining variations in the probability of participation. These effects could be related to village level covariates (such as location of the site, agro-ecology and crop suitability factors, irrigation experience, weather conditions and other external effects) which may influence market conditions. So taking Debre Zeit (Wedecha Belbela systems) as a reference, we found that households in Endris (marginal effect -0.20), Golgol Raya, Haiba (marginal effect -0.17) and Hare (marginal effect -0.11) are less likely to participate in the market while households in Golgotha are more likely to participate (marginal effect 0.28). Both the Wedecha and Golgotha irrigation schemes are located close to the major markets, Addis Ababa and Nazareth, on a well established marketing route for vegetables (see Fig. 1). However, from the results we have here it is difficult to attribute to one factor, e.g. distance to market, as being the principal factor influencing market participation. It is likely that the dummy variables confound various factors. Hence, we can only say that there are site level covariates influencing market participation.

Finally, although less expected plot level characteristics such as slope of the land and soil quality were found to be significant in explaining market participation. Accordingly, households operating land with medium (marginal effect 0.07) and steep slope (marginal effect 0.08) were found to be more likely to participate than those operating flat lands. One possible explanation could be that the slope of land may influence crop choice, so irrigated annuals and/or perennials are grown on such lands. Households operating medium (marginal effect 0.06) and good quality lands (marginal effect 0.08), i.e. with more productive soils, were found to be more likely to participate. The effect of these plot characteristics on market participation could be through their influence on crop choice and productivity. Below we will explore further if the same set of factors also affect the level of participation, the volume of sale made by households.

Explaining volume decisions

The most important determinants of volume decisions (measured by the value of sale) are reported below. But for the truncated model we did not report the calculated marginal effects as the purpose of our analysis is not confined to the sub population. Hence we report the coefficients as indicated in Table 3.

Households operating both modern and irrigation schemes supply more to the market than farmers working in the rainfed system. In line with the results from the binary choice model, farmers growing irrigated annuals and irrigated perennials supply more to the market in comparison to farmers that grow rainfed annuals because, as indicated above, the rainfed annual crops tend to be mainly food crops. The results here, hence, strongly indicate that irrigation significantly contributes not only to market participation but also to increased supply of produce to the market. This could be the result of increased cropping intensity and diversification into more cash crops, mainly horticultural crops. Households that reported to have faced shortages in rainfall supplied significantly lower volumes of produce, and hence, earned less from the market. This indicates that shortfalls in rain, may pose a serious constraint to market development.

In line with the results in the probability model, education and family size were also found to be significant in explaining the amount of sale. The education level of the head of household was found to be positively and significantly associated with high value of sale, implying that educated households are more likely to be market oriented. This may be because they are well positioned to choose high return crops and introduce innovative technologies. In contrast to the negative influence of family size on explaining market participation, here family size was found to have a significant and positive effect on volume of sale. This suggests that once households have decided to grow for the market, the family size does not negatively influence volume of sale.

Furthermore, households' resource endowments, specifically the size of the operated land area and oxen holding, have positive and highly significant effects on the volume of sale. Farmers usually allocate part of their land to grow high value crops after they have allocated sufficient land to grow food crops. Oxen holding increases the chance of increasing operating land holding through informal land transaction such as sharecropping and fixed renting. Therefore, households endowed with more land and oxen holding are more likely to sell more to the market than households with smaller land holding and no oxen.

Distance to market where the output was sold has significant effect on the volume of sale strengthening our conjecture that households who are able to participate transport their produce further but to more attractive markets. In line with this, the volume of sale was found to be significantly influenced by the choice of transport. In this case, households who rent vehicles have higher volumes of sale compared to those using human power. Moreover, unlike the result in the Probit model, use of donkeys as a means of transport has a negative effect on the volume of sale indicating perhaps that higher volume of sale requires other means of transport than pack animals or human power (e.g. *ISUZUs,* the famous small trucks which can operate deep in rural areas.)

In contrast to the participation decision, reported market related problems were found to have no significant effect on the amount of goods sold. This implies that market and marketing related problems may deter households from participation but once they have made the decision to participate they supply what they can. However, those who reported input access problem were also found to be supplying more produce to the market. This may reflect, as argued earlier, a reverse causality in that those who participated in the market are more likely to face inputs access problems. It could also be related to the location of the irrigation schemes in relation to input supply centers and the orientation of the input supply system of the country. Access to off-farm income was found to have a negative effect on the value of sale perhaps indicating that those who have access to off-farm income do not consider it worth the effort of growing for markets.

The same community (site) level effects were also found to be significant in explaining variations in the volume of sale. So taking Debre Zeit (Wedecha Belbela systems) as a reference, we found that households in Haiba, Hare and Tikurit supply low volumes of output while households in Golgotha and Zengeny supply more output (i.e., more valuable), Disentangling which specific site level variables are important in explaining market participation is something that needs further inquiry.

Finally, the same plot level characteristics such as slope of the land and soil quality were also found to be significant variables in explaining volume decisions. Accordingly, households operating lands with steep slopes were found to supply more than those operating flat lands. One possible explanation is that the slope of land influences crop choice, so irrigated seasonal or perennials are grown on such lands. Households operating medium and good quality lands, i.e. with more productive soils, were found to be supplying higher volumes of output, underlining that production enhancing factors have also market participation enhancing effects.

7. Conclusions and recommendations

The objective of this study was to examine the extent and nature of market oriented production under irrigated systems in contrast to rainfed systems in Ethiopia. The study t identified determinants of market-oriented production, including the role of irrigation in the process, in order to understand the main constraints and opportunities for market oriented development. Based on the study findings we have drawn policy implications relating to institutional arrangements and the creation of adequate infrastructure, which could benefit a large mass of smallholder producers.

One of the most important findings of this study is that irrigation contributes to a significant increase in market participation, volume of marketed produce and, hence, income. Farmers working under irrigation, traditional or modern, supply more marketed produce and earn more income than farmers operating under the rainfed system. The bulk of the contribution comes from irrigated annual and perennial crops, which indicates that farmers are shifting their cropping mix as a result of access to irrigation.

While irrigation enhances marketed oriented production, there are a series of factors that pose serious constraints to the process. Households having on average relatively larger plots are found to be more market oriented. This implies that those who have smaller plots on average have access problems and tend to focus on food production. This is especially true with households that have bigger family sizes. This calls for policy intervention in the area of easing land transactions and assisting household's to access important productivity increasing assets such as oxen.

The study also shows while the impact of market oriented production on income poverty is direct and immediate; households are faced with a possible trade-off between growing for the market and growing for home consumption. Growing for the market may not ensure household food security in a situation where food markets function poorly. Under this situation of market failure households prefer first to be food self-sufficient and only then become involved in market production. Another entry point for policy could, therefore, be to create the necessary infrastructure and policy environment to improve the performance of food markets. Such measures could induce farmers to be more market oriented.

Market problems and input access problems seem to be pervasive in Ethiopia, and more so in areas where irrigation-induced market oriented production is high. The study indicated that farmers face diverse market problem such as low demand and low selling price, distance to market, road and transport problem, same product and peak time supply, unstable prices, lack of services (information, service cooperatives, etc) and high tax. Similarly farmers reported that they faced diverse input access problems the most important of which were high input prices, lack of credit access and lack of availability of inputs in all seasons and sites. Transport problems seem to pose a serious problem as well. Households who are able to rent vehicles supply more to the market. Those unable to transport their produce are unable to reap the benefits of better markets. The implication of this evidence is that irrigation development and market infrastructure development are poorly linked. Hence, there is a need to link irrigation development with road infrastructure development and improvements in other marketing services. There is also a need for reorientation of the input supply system to fit the requirements of the irrigation system.

The study also found that education has market promoting effects in terms of increasing the probability of participation and volume of sale. Adequate support to education can, thus, help in the long-term transform traditional subsistence agriculture into more market oriented and modern agriculture. Finally there are unobservable site specific effects that influence market participation and volume decisions. Identification of the most important village level effects requires further inquiry.

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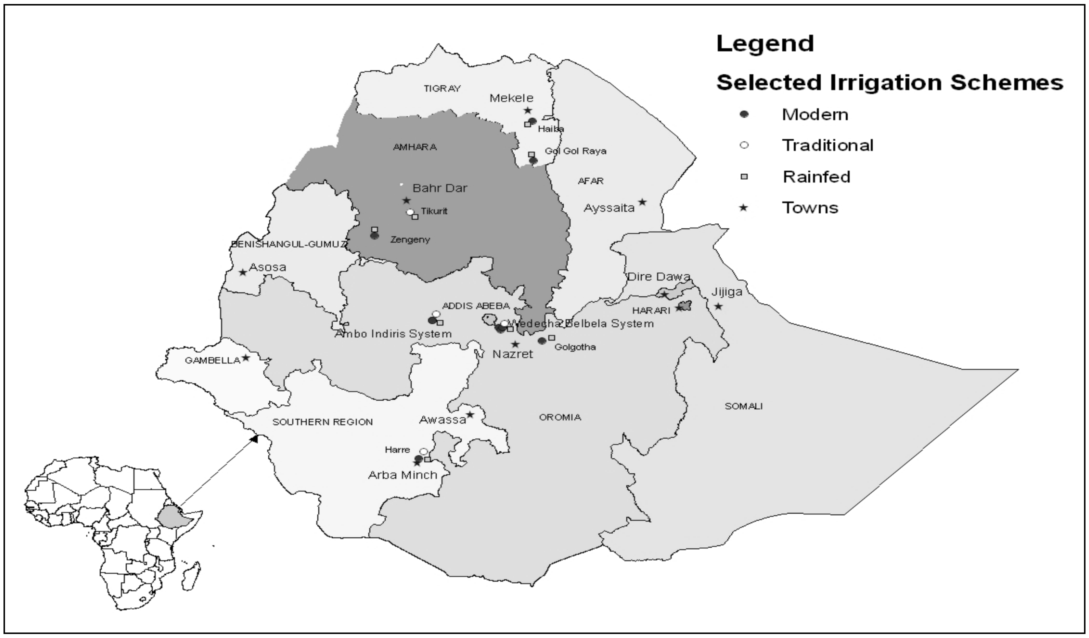


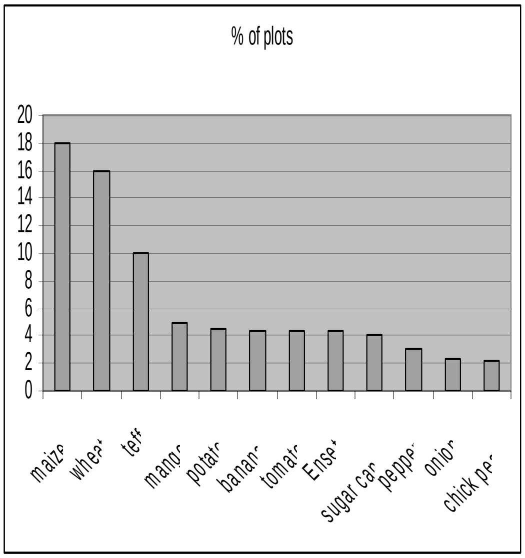
Fig. 1: Sample sites

Table 1A: Study sites

Region	Scheme name	Typology	Closer town	Irrigation type	Sample size
Oromiya	Endris System	Small	Ambo	Modern	55
				Traditional	55
				Dryland	55
Oromiya	Wedecha-Belbella System	Medium	Debre Zeit	Modern	55
				Traditional	53
				Dryland	57
Oromiya	Golgotha	Medium	Nazareth	Modern	55
				Dryland	55
Amhara	Zengeny	Medium	Gimjabet	Modern	55
				Dryland	53
Amhara	Tikurit	Small	Bahir Dar	Traditional	83
				Dryland	47
Tigray	Haiba	Medium	Samre/ Mekelle	Modern	54
				Dryland	54
Tigray	Golgol Raya	Micro-irrigation	Alamata	Modern	53
				Dryland	46
SNNPR	Hare	Medium	Arba Minch	Modern	55
				Traditional	54
				Dryland	55

Table 1: Summary statistics

Variable name	Mean (Standard deviation in parenthesis)		
	Overall	**Rainfed**	**Irrigated**
Age of household head, years (n= 4915)	46 (15)	45.0 (15.09)	46.29 (15.05)
Years of education of household head (n= 4900)	2.0 (3.1)	2.05 (3.06)	1.98 (3.07)
Family size, (n= 4948)	5.7 (2.4)	5.54 (2.35)	5.87 (2.48)
No. of Female adults (n= 4948)	1.4 (0.85)	1.34 (0.74)	1.39 (0.89)
No. of male adults (n= 4948)	1.5 (1.0)	1.45 (0.94)	1.58 (1.07)
Amount of income from non-farm, Birr (n= 4948)	537 (3067)	705.54 (4125.69)	459.60 (2422.15)
Remittances, Birr (n= 4948)	243 (1973)	27.38 (646.05)	342.89 (2339.14)
Number of oxen (n= 4923)	1.4 (1.2)	1.56 (1.07)	1.32 (1.21)
Number of donkeys (n= 4923)	0.5 (0.9)	0.65 (0.94)	0.50 (0.86)
Number of contacts of household with extension agent (n= 4948)	1.6 (3.2)	2.36 (3.97)	1.25 (2.73)
Number of contacts of extension agent with households (n= 4948)	2.5 (5.3)	3.79 (6.38)	1.89 (4.59)
Land area, ha (n= 4786)	1.4 (1.2)	1.34 (1.39)	1.42 (1.19)
Distance to market where output was sold, km (n= 4947)	7.6 (6.9)	8.36 (7.49)	7.18 (6.67)
Gross value of Sales, birr (n= 4948)	591 (2169)	476.10 (1076.1)	645.14 (518.65)
Market problem Dummy (yes =1) (n= 4953)	40.7	37.7	42.1
Input access problem Dummy (yes =1) (n= 4953)	46.6	53.3	43.4
Rain/water shortage Dummy (yes =1) (n= 4953)		39.1	26.8



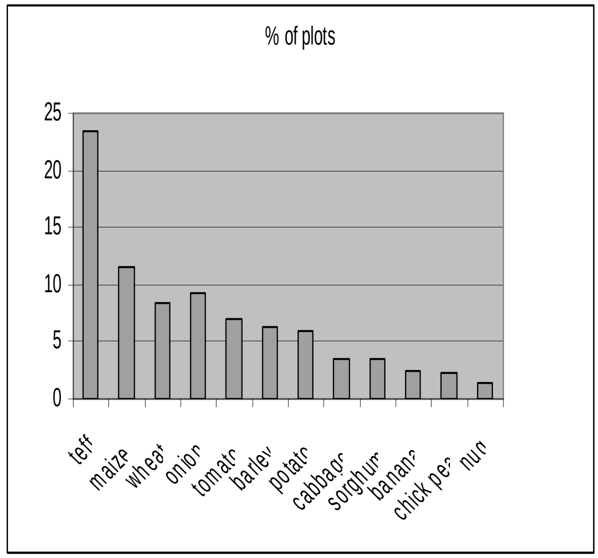


Fig. 3a: Dominant crops under traditional irrigation system (n= 1240) Fig. 3b: Dominant crops under modern irrigation system (n= 2092)

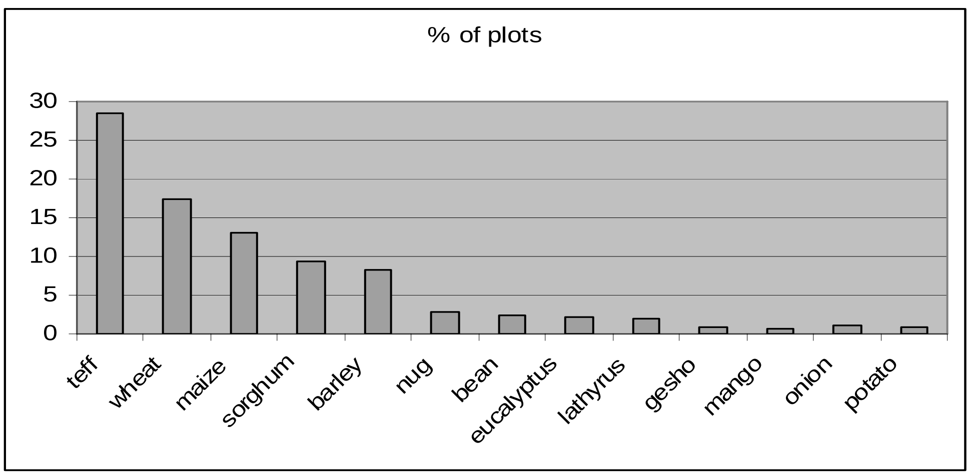


Fig. 3c: Dominant crops under modern rainfed system (n= 1533)

Table 2: Determinants of the probability of participation (standard errors adjusted for cluster effects)

Dependent variable : Whether the household sells a product to the market or not (0/1)

Variable description	Coefficient	Standard errors
Female headed household (dummy variable male =0)	0.022	0.078
Age of the household head	0.001	0.002
Education level of head	0.017	.010*
family size	-0.026	0.016*
Female adult	-0.050	0.037
Male adult	0.038	0.032
Off-farm income	1.02e-06	7.69e-06
Remittance income	0.0001	0.00003
Oxen holding	-0.013	0.025
Distance to the market where output is sold (in km)	0.016	0.005***
Means of transport (donkey) (reference= human)	0.151	0.090*
Means of transport (horse) (reference= human)	0.228	0.171
Means of transport (mule) (reference= human)	0.115	0.199
Means of transport (vehicle) (reference= human)	0.059	0.118
Household's contact with extension agent	0.003	0.011
Land area (in ha)	0.062	0.023***
Rain shortage (dummy 1= yes)	0.026	0.074
Irrigation water shortage (dummy 1= yes)	-0.021	0.085
traditional scheme (dummy reference =rainfed)	-0.050	0.084
Modern scheme (dummy reference =rainfed)	-0.278	0.075***
Input access problem (dummy 1= yes)	0.171	0.065***
Marketing problem (dummy 1= yes)	0.042	0.059
Dry land perennial (reference dry land seasonal)	0.109	0.120
Irrigated seasonal (reference dry land seasonal)	0.582	0.070***
Irrigated perennial (reference dry land seasonal)	0.996	0.158***
Endris irrigation scheme (reference= Debere Zeit)	-0.506	0.095***
Golgol Raya irrigation scheme (reference= Debere Zeit)	-0.448	0.136***
Golgota irrigation scheme (reference= Debere Zeit)	0.921	0.192***
Haiba irrigation scheme (reference= Debere Zeit)	-0.441	0.112***
Hare irrigation scheme (reference= Debere Zeit)	-0.281	0.152*
Tikurit irrigation scheme (reference= Debere Zeit)	-0.020	0.128 *
Zenegeny irrigation scheme (reference= Debere Zeit)	-0.038	0.184
Medium Slope (dummy reference= flat) |	0.190	0.0622***
Steep slope (dummy reference= flat)	0.215	0.102**
Medium fertility (dummy reference= poor)	0.165	0.077**
good fertility (dummy reference= poor) |	0.228	0.078***
_cons |	-0.194	0.176
	Number of obs = 3754	
	Wald chi2(36) = 300.17	
	Prob > chi2 = 0.0000	
	Log pseudo-likelihood = -2276.33	
	Pseudo R2 = 0.0969	

*, **, *** significant at 10, 5 and 1 percent level of significance.

Table 3: Level of participation (Value of sale)
Dependent variable: Value of sale (in Birr)

Variable description	**Coefficient**	**Standard errors**
Female headed household (dummy variable male =0)	-3679.5	(473.846)
Age of the household head	37.04	(79.00)
Education level of head	2001.188	(486.2001)***
family size	2831.62	(689.7989)***
Female adult	-4731.888	(1960.598)**
Male adult	-2636.161	(1702.532)
Off-farm income	-1.124729	(.3445668)***
Remittance income	-.5153223	(.7632368)
Oxen holding	-2780.298	(1304.623)**
Distance to market	160.1715	(107.3297)
Means of transport (donkey) (reference= human)	-23025.99	6164.656***
Means of transport (horse) (reference= human)	-2342.406	6569.129
Means of transport (mule) (reference= human)	7528.12	8567.152
Means of transport (vehicle) (reference= human)	19583.99	5675.037***
Household's contact with extension agent	-1264.534	(688.0457)*
Land area	6722.116	(728.9046)***
Rain shortage (dummy 1= yes)	-7626.328	(4227.934)*
Irrigation water shortage (dummy 1= yes)	-3272.534	(4214.353)
traditional scheme (dummy reference =rainfed)	20030.93	(5983.328)***
Modern scheme (dummy reference =rain fed)	17768.58	(5768.995)***
Input access problem (dummy 1= yes)	13467.66	(3457.655)***
Marketing problem	-4479.403	(3194.229)
Dry land perennial (reference dry land seasonal)	-11678.92	(10525.31)
irrigated seasonal (reference dry land seasonal)	17526.23	(4057.36)***
irrigated perennial (reference dry land seasonal)	24931.89	(7034.23)***
Endris irrigation scheme (reference= deberezeit)	-5600.18	(5543.335)
Golgol Raya irrigation scheme (reference= deberezeit)	-9191.548	(6577.918)
Golgota irrigation (reference= deberezeit)	11853.08	(6385.049) *
Haiba irrigation scheme (reference= deberezeit)	-197758	(24293.52)***
Hare irrigation scheme (reference= deberezeit)	-47682.18	(11743.92)***
Tikurit irrigation scheme (reference= deberezeit)	-28460.84	(7124.578)***
Zenegeny irrigation scheme (reference= deberezeit)	39782.97	(9889.322)***
Medium Slope (dummy reference= flat) |	2169.702)	(3414.557
Steep slope (dummy reference= flat)	26719.8	(6862.004)***
Medium fertility (dummy reference= poor)	11340.24	(6171.729)*
good fertility (dummy reference= poor) |	12887.67	(6265.083)**
_cons	-106551.5	(13938.39)***
sigma _cons |	8990.92	(327.1781)***

Number of obs = 4610
(2086 left-censored observations at gvout<=0 2524 uncensored observations)
LR chi2(31) = 294.28
Prob > chi2 = 0.0000
Log likelihood = -32017.082
Pseudo R2 = 0.0046

*, **, *** significant at 10, 5 and 1 percent level of significance.

Small Scale Irrigation Interventions for System Productivity and Natural Resource Management in Ethiopian Highlands: Benefits and Best-bets

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Abstract

Water scarcity became a common phenomenon in Ethiopia with drought frequency of at least once in three years while the country owns a large irrigation potential that should be exploited sustainably. Various national and international institutions are currently engaged in developing small scale irrigation (SSI) schemes for poverty alleviation. A monitoring and evaluation exercise was conducted in 2004 and in 2006 in four administrative regions of Ethiopia, namely Tigray, Southern regions, Oromia and Amhara, to assess the benefits and associated environmental effects of SSI investments of the International Fund for Agricultural Development (IFAD). A combination of participatory M&E tools namely, individual interviews, group discussions, key informants, review of relevant documents and field observations were used. The mission was supported by an in depth pre-mission socio-economic survey in three representative irrigation schemes. Data from the sites indicated that 50 % of the respondents had improved food security and higher income, while 26% of the respondents did not see any change on their livelihoods. Crop yield under irrigation was by 35% to 200% higher than under rain fed conditions, with much higher benefit obtained from high potential areas and in farms where external inputs (fertilizer, improved seeds and pesticides) are accessible. The positive effect was more visible with horticultural crops. There has been also a shift towards improved varieties with access to irrigation. Farmers replaced early maturing but low yielding varieties with high yielding varieties. Crop diversification increased significantly, in some sites from three to about 15 species, although this decision making process did not favour legumes. The apparent effect was on crop rotation, intercropping and land management with in the order of 79, 42 and 35%, respectively. On the other hand, there is a decline in number of livestock per household, but an increased number of draught oxen. The decline is associated with reduced grazing area due to conversion of dry season fallow to vegetable fields and an increase in area enclosure in the sloppy landscapes. The shift from cereal to vegetable-dominated cropping increased the competition for water between downstream and upstream users and between resource-rich and poor farmers. The impact of irrigation schemes should be evaluated better on long term benefits than short term fixes, as farmers initiated long term investments like planting perennial fruits, bought calves and other retail trade investments. The communities would benefit most from further integration of livestock into the schemes by adopting feed sourcing strategies for dairy and fattening. The paper also presented best-bets for improved irrigation management in Ethiopia.

Introduction

Water, land and finance are becoming the scarcest resources in the agricultural system of Ethiopia, scarcity being severe in regions where population pressure is high, access to market infrastructure is low and environmental calamities are frequent. Inefficient water management in the rainfed agriculture coupled with accelerated land degradation plays an important role in aggravating the recurrent food insecurity in the country. In the recent years, drought became a common phenomenon, happening in any part of the country at any time of the year, with a frequency of at least once in three years. Four different drought scenarios were identified in the mixed crop-livestock systems of Ethiopia namely, terminal drought, intermittent drought, foreseeable drought and definite drought (Amede, et al., 2004a). In situations where agricultural production is operating under these various drought scenarios, with annual rain fall variability of 40 to 50%, supplementary irrigation became a necessity for food production, particularly for intensifying systems through high yielding and input responsive varieties and breeds. Currently, the growth in food production in Ethiopia is primarily due to expansion of agricultural land while production pre unit of investment remained stagnant.

On the other hand, Ethiopia owns a wide range of irrigation opportunities with about 9.85 million ha of potentially irrigable arable land, while only 3 to 5% of the potential is currently under irrigation (WCD, 2000) accounting for approximately 3 per cent of total food crop production. Current yield from rain-fed land is only about 50% of the irrigated land, given all other inputs remain the same, thanks to the recurrent drought and limited adoption of water management practices. If the country is to achieve its stated aims of food self-sufficiency and food security, the current production shortfalls call for drastic measures to improve production efficiency of both irrigated and rain-fed agriculture. In response, the government of Ethiopia as stated in its Poverty Reduction Strategy Paper (PRSP) emphasized the importance of improved water resource development and its utilization to achieve food security through enhanced use of small scale irrigation. Since the early 1990s' the federal and regional governments of Ethiopia, with financial assistance from donors, have been attempting to upgrade traditional small scale schemes, built small scale dams, diversions and water harvesting ponds to respond to these environmental calamities. However, the performance of the irrigation systems has been poor. There exists a substantial yield gap in irrigated farms between achievable and actual yield both in terms of yield per unit of land but also yield per unit of water depleted.

Moreover, there exists conflicting reports regarding the agricultural benefits of small scale irrigation and its impact on natural resource management (Tafesse, 2003; IFAD, 2003; Kijne, FAO; Ersado, 2005). In some sites, small scale irrigation has significantly increased crop yield, and households using irrigation have higher agricultural production than non-intervention communities (Ersado, 2005). In others, small scale irrigation didn't bring significant increase in crop yield and livestock productivity directly but increased yield by about 26& by promoting increased use of improved seeds and fertilizer (Pender and Gebremedhin, 2004). These differences on impact of irrigation on agricultural productivity may have appeared because of the fact that small scale irrigation for food security is more than just technologies; but comprises production, marketing, credit, social, policy and institutional issues (Tafesse, 2003). It could be also because of differences in methodologies. In general, irrigation farming is expected to reduce farmers' exposure to variability in crop and livestock yields and therefore improve food insecurity, especially in the more remote, disadvantaged and poorer areas; to raise agricultural production and rural incomes where crop diversification and market-oriented agriculture can be promoted; and to enhance the capacity of communities to demand for better services but also to test, modify and adopt improved technologies.

The objectives of this paper are i) to quantify the negative and positive effects of small scale irrigation on small holder farmers and their systems and ; ii) to identify the biophysical and socio-economic factors affecting the performance of small scale irrigation schemes .

Materials and Methods

Sites and regions

Four major administrative regions of Ethiopia, namely Amhara, Oromia, Southern Regions and Tigray were considered for the study. These areas are characterized by food insecurity, drought prone and very high human and animal population. Based on altitude, annual rain fall and average temperature, these sites fall into two of the major traditional agroecological zones namely; i) Weinadega: mid highlands between 1 500 and 2 300 mts above sea level with wheat, teff, barley, maize, sorghum, faba beans and chickpeas as predominant crops while cattle, donekeys and small ruminants are the predominant animals and; ii) Dega: highlands between 2 300 and 3 200 meters with barely, wheat, oilseeds, and lentils as predominant crops and sheep and cattle being dominant livestock enterprises.

During the field work a total of 16 of the IFAD SCP II irrigation schemes, those established in 1988?? in Tigray, 5 in Oromia, and 2 in SNNPR were considered. In addition discussions were held in all four project regions, and with a total of 14 project woredas. Most of these woredas are considered by the Disaster Prevention and Protection Commission (DPPC) as food insecure (Fig 1). Since time did not permit visits to all 58 schemes of the project, a sampling approach was taken. A variety of scheme characteristics was identified (including distance from roads/markets; age; perceived performance), but nevertheless some compromises had to be made due to accessibility. In Oromia and SNNPR the opportunity was taken to visit older and new schemes while in Tigray schemes were selected covering a range of remoteness from Mekelle.

The studied schemes have been selected through a two-stage procedure. First a list was compiled of schemes constructed under SCP II and operated for at least three years (i.e. the more “mature” sites for impact assessment). Next one scheme in each of SNNPR, Oromia and Tigray has been extracted by simple random sampling.

Data Collection

The quantitative and qualitative date about the impact of small scale irrigation on system productivity and food security was collected in two rounds; between 13th September and 14th October 2004 and from 12 November to 2 December 2006, as part of an IFAD field evaluation mission. The study team started the mission by interviewing and discussing with IFAD stakeholders at different hierarchies starting from the federal ministry of water resources in Addis Ababa down to the scheme site team members. The data collection considers interviews of farmers, community leaders, extension agents, key informants, district subject matter specialists, bureau heads and federal authorities. We used PRA tools including transect walks, community group discussions, sample measurements and secondary data from actors at all levels. The mission was supported by a pre-mission socio-economic survey, which was carried out to obtain in-depth understanding of three small scale irrigation schemes (Hizaeti Afras in Tigrai, Nadhi Gelansedi in Oromia and Dobena in Southern regions) in the period June-September (IE Preliminary survey, 2004). Prior to the field trips a checklist was prepared considering relevant agronomic, natural resource management and livelihood indicators and considered during data collection from the respective sites, communities and stakeholders. The pre-mission survey also considered three information sources namely literature review, focus group discussion for communities and questionnaire for interviewing selected households. A PRA tool has been administered for focus group discussions with WUAs consisting of men and women. The focus group participants were 15-20, with 5-6 women per meeting. A prepared checklist was used as a guide for the exercise. A questionnaire was prepared for a household survey and 84 farmers in Dobena and 155 farmers in Nadhi Gelan Sadi and 136 farmers in Hizaeti Afras were interviewed. The interview was carried out by random walk from homestead to homestead: adult heads of household with irrigated land were interviewed. In the case of Dobena, all households were interviewed, as the scheme users were fewer than the planned sample (100 to 150 respondents per scheme).

During the main mission, a combination of five participatory M&E tools were used to assemble information and data namely, individual interviews, group discussions, key informant interviews, review of relevant documents and field observations. On site, the information gathering techniques included quantitative (through structured questionnaires) and qualitative (through semi-structured interviews) methods with both individual informants and groups, and observations combined with discussions. Secondary data and information from woreda, regional and federal institutions that have had a stake in respective projects were also carefully studied.

Results and Discussion

Scheme development

The project sites were identified for SSI development either because the respective communities contacted the woreda officials through their local representatives (e.g. Nazre in Tigrai) demanding the development of irrigation schemes. In other sites, the schemes were identified by irrigation engineers through a pilot survey in assessing various water resources, including perennials rivers. The need for upgrading the traditional irrigation schemes arose from the fact that traditional schemes were underperforming despite years of experience of communities in irrigation management. The results of the interviews indicated that the reasons why communities demanded for upgrading traditional schemes were 1) continual distraction of canals by erosion, siltation, animals and human activities; 2) extremely high labor demand to maintain and clean traditional irrigation canals; 3) considerable loss of irrigation water from the traditional canals due to seepage and easy destruction of canals by heavy rains; 4) the difficulties faced by the respective communities to build permanent crossovers over gullies to reach communities on the other sides of gullies and river sides, as it was observed in Mumicha in Oromia; 5) most of the traditional command areas were those on flat lands and valley bottoms, but it excluded fields even with very slight slopes and; 6) there was very limited institutional support in accessing marketable enterprises, technological innovations, and integrated extension services to crop, livestock, land and water management.

1. Impact on system productivity

The impact of irrigation schemes on system productivity could be seen from the perspective of its effect on crop, livestock and labour productivity in the respective sites. Though the time period was very short to evaluate the impact of irrigation on the productivity of some of the systems, as the schemes were 2 to 10 years old, there are variable results emerging from different sites and regions.

1.1 Crop yield

In average, crop yield under irrigation was at least by 35% higher compared to non-irrigated farms (Table 1), with benefits being much higher in high potential areas and in farms where external inputs (fertilizer, improved seeds and pesticides) were accessible. Maize was one of the most preferred crops farmers have been producing under irrigation across sites, accompanied by vegetables. Farmers have indicated a significant yield increase, particularly in drought sensitive crops like maize (Tables 1 and 2), which otherwise could completely fail if the terminal or intermittent drought coincides with the drought sensitive stage of the crop i.e. flowering period. Most farmers with market access produced green maize (about 20% of the area across Tigray) (COSART, 2001) with high stover quality for fodder. A case study in Tigray showed that in good years a farmer obtained about 6 and 3.5 tonnes ha-1 of maize under irrigated and rain-fed conditions, respectively, with about 60% yield advantage. A comparable amount of yield advantage was displayed by a farmer in Burka Woldiya, Oromia. Across sites, crop yield under irrigation was by 35% to 200% higher than under rain fed conditions (Tables 1 and 2), with much higher benefit in high potential areas and in farms where external inputs (fertilizer, improved seeds and pesticides) are accessible.

In drought prone sites, farmers replaced the early maturing but low yielding variety (e.g. Katumani) by a high yielding maize cultivar (e.g. Awassa 511) thanks to access to irrigation and obtained a 200% grain yield increase (BOA, Wukro Woreda, 09/2004). A similar trend was obtained with wheat and faba beans (Table 2). Farmers in Nazre (Tigray) indicated that they got up to 4x more onion yield today because of the combination of access to irrigation, good varieties, access to pesticides and better extension support. Crop yield increase was substantial particularly for horticultural crops not only because of improved access

to irrigation but also associated trainings and improved flow of information in pest management, organic manure application and improved water management skills. Moreover, the survey conducted in the three representative schemes indicated differences in crop yield among sites. For instance, in Dobena, the yield of tomato, potato cabbages and onions were 102, 94, 82 and 44 qt/ha while in Nadhi Gelan Sadi, it was 35, 37, 24 and 38 qt/ha, respectively (data not presented), which could be explained by difference in agricultural potential of the sites, particularly due to soil fertility and rain fall amount and distribution. In general, an increase in crop yield was accounted not only to improved access to irrigation but also to associated services in extension and input delivery. Moreover, the current distribution of water by water masters followed the principle of rotational irrigation for priority crops known to the majority and exceptionalities are established only after strong negotiation. For instance in Nazre, the order of priority for getting access to water was faba beans, tomato, pepper, onions, and spices. This form of bylaws may limit farmer innovation and responsiveness of individuals to market demands.

They consumed 71% of the cereals, pulses and oil seeds, 26% of the vegetables and about 2% of the fruits while they sold the rest to generate cash income. An economic analysis done with 10 representative heads of households indicated that their total gross earnings from the sales of these products was EB 22,602. Their net cash income per household after deducting costs was EB 1,141. In addition each household retained produce to a value of EB 1,181 which they used for home consumption (IFAD, 2004).

In few schemes (e.g. Belessa), irrigation had no significant effect on crop yield for various reasons. In some it was because of shortage of water at the critical crop stages, while in others it was because of poor agronomic practices related to very low population density, late weeding, lack of fertilizer application and absence of pest control.

1.2 Crop diversification

Traditionally, most of the sites were cereal growers, except for Chat in Harer and Onions and Pepper in few sites near to major roads. The primary cereal crops grown under supplementary irrigation were maize, wheat, and barley. With the development of irrigation schemes farmers have shifted towards growing diverse crop, in some sites up to 10 new marketable crops, predominantly vegetables. The bureau of agriculture played a key role in the introduction of new crops through establishing multiple demonstration plots in farmers' fields. Access to irrigation and opening up of new market opportunities encouraged farmers to systematically allocate their land to various enterprises, both in rain fed and irrigable fields. For instance in Lalay agula, Tigray, farmers allocate 30, 31, 25, 10 and 3% of their land to wheat, maize, pepper, barley, and teff, respectively under rainfed conditions, while under irrigation the land allocation was 35, 10, 50, 2 and 1.5% for pepper, onions, maize, tomato and cabbage, respectively (COSART, 2001). Besides, almost all varieties of crops grown in the sites at the time of the mission were improved varieties came along with the diversion schemes via the Woreda bureaus. For instance in Lalay agula, there has been a shift from the local maize variety Birhu to improved varieties, Katumani and Awassa 511 due to better access to irrigation water. Moreover, the diversion of the canals helped the extension to easily establish seed multiplication sites for non-traditional vegetables and spices, mainly onions, potato and tomato and hence it facilitated the growing of non-traditional crops in the area (data not presented).

Cropping Sequence and Management

Access to irrigation in most sites created an opportunity for double and in few cases for triple cropping. However, due to the decreasing water availability and an overwhelmingly increasing demand for water by downstream users, the possibility to expand irrigable land became unattainable, as it was the case in Dobena, Southern region. In the current rain-fed cropping systems cereals and legumes are grown in rotation, while in the irrigable fields with vegetables and fruit trees are grown primarily in rotation with cereals. This cropping practice limited the possibility of integrating nitrogen fixing, soil improving legumes like faba bean in the irrigation systems. It is partly because of the small land size of irrigable plots (about 0.20 ha per household) and partly due to market preference for selected crops. In situation where crop rotation was not practiced the risk to deplete the soil in a very short time and the possibility of pest incidence is obvious. For example, growing potato and tomato rotatively on the same land, without a break crop, may create a favorable ground for pests like potato late blight that would make it difficult to grow both crops next time. Hence, crop rotation as a component of integrated pest and soil fertility management should be sought as it was also a concern shared by practicing farmers across sites.

Despite the above mentioned concerns, interviewees indicated that irrigation brought in considerable changes on the farming system through improved crop rotation (cereals in the main rainy season and vegetable in the off season using irrigation), intercropping and improved land management (particularly terracing and use of organic manure) within the order of 79, 42 and 35%, respectively. In the three sample sites the farmers who practiced improved agronomic management of crops across the various practices after irrigation scheme was developed were 22.2, 41 and 36% in Dobena, Geland Sedi and Hizaeti Afras, respectively (Table 6).

Livestock systems

Feed shortage was apparent short before the main rains, between the months of April and June across sites. The decline in forage availability was associated partly to conversion of dry season fallow to vegetable fields and an increase in area enclosure of the traditional grazing areas in the sloppy landscapes, accompanied by frequent drought. Contrary to earlier reports, there is a decline in the number of livestock per household as a consequence of introduction of schemes across the regions regardless of agro ecology, but again there are also an increased number of draught oxen (data not presented). Other research findings also reported that increased irrigation was associated with a reduction in ownership of livestock but with increased adoption of technologies that enhanced productivity (Benin etal. 2003).With access to irrigation semi-pastoralist communities (e.g. Gedemmso, Oromia) have been converted to a crop-livestock system with significant reduction in stock.

In theory, the expansion of the irrigable area should have allowed farmers to produce more biomass all year round, partly as crop residues and grasses on strips, borders and hilly patches. However, the biomass produced from the vegetable fields was rarely used as feed source as the livestock rejected to it unless there were no other feed options in the system. Moreover, some farmers complained to the mission that the local authorities did not allow them to grow forages using irrigation as the current bylaws established by the water user associations gave priority mainly to food, fruit and vegetable crops. These bylaws may limit innovations in promoting livestock enterprises (e.g. Dairy and fattening). With increased vegetable production from irrigated plots and subsequent income some farmers, e.g. Amhara region, afforded to upgrade part of their stock with fewer but more productive breeds and in the process released part of their crop land for pasture development (Benin, et al., 2003).

Seed and fertilizer use

According to farmers view across the sites, decline in land productivity was strongly associated with soil fertility decline, prevalence of new pests and diseases in the system, excessive soil erosion and in some cases soil salinity.

The majority of farmers across the regions have been introduced to use of inorganic fertilizers only very recently, mainly through the extension systems. The potential effect of fertilizers on crop yield and farm income is much better understood than 10 years a go, though this capacity building process may not have been explicitly associated with the irrigation projects. However, only about 55% of the farmers across the sites 55% use fertilizers (mainly DAP), particularly for maize (data not presented). The government was their major input source for chemical fertilizer, mainly through credit arrangements. For instance, in Gereb koky, Tigray, the typical use of inorganic fertilizers in the irrigated fields was about 50 kg/ha, applied mainly to high value vegetables and green maize. On the other hand, perennial crops like coffee and chat did not receive any inorganic fertilizer across the visited sites, partly because they are commonly grown in fertile homesteads. The increased use of irrigation and fertilizer, however, did not attract much use of improved seeds because either they were unavailable or unaffordable to farmers. The local extension agents were multiplying seeds of only selected crops, mainly maize, potato and onions. Hence most farmers in the sites still use their own seed (Table 3). The source of seeds in three schemes was 55, 23 and 22% for own seeds, government sources and purchased, respectively (IE Preliminary survey, 2004). While seeds for cereal crops, vegetable and coffee are secured from multiple sources, seedlings for fruit trees are commonly purchased from the local market.

Similarly, recent reports from the region (G. Medhin etal. 2003) indicated that there is decreased use of chemical fertilizer with irrigation after the credit service for fertilizers was abandoned. Credit and financial services are not yet sufficiently addressing the needs of irrigation users to move into sizable market oriented enterprises. As an effect, there is a shift towards use and management of organic fertilizers namely manure, compost and crop byproducts in most sites, with an increasing number of practitioners adopting these practices (IE Preliminary survey, 2004) For instance in Burka Woldiyaa six out of seven randomly interviewed farmers practiced composting for the last two years. A farmer in Nazre, who conducted an informal experimentation described that on a 200 m^2 farm land he got a maize grain yield of 5, 4 and 1 qt from organic fertilizer, inorganic fertilizer and no fertilizer, respectively (personal communication).

Impact on household food security

The major effect of the irrigation projects on the communities was through the attitudinal change that they could produce for the market and could buy their food from the income they generate on farm. This is not yet a common knowledge in the rain-fed agricultural systems of Ethiopian Highlands.

Farmer interviews across the regions in the high potential areas (with at least 5 or more months long growing season) and low potential areas (with four or less months long growing season) (Engida, 2001), revealed that crop yield of cereals (e.g. maize) increased by about 70 and 20%, respectively, not only due to access to supplementary irrigation but also due to increased support of government institutions in extension and input delivery. In general, crop diversification has significantly increased, in some cases from only three crops before the construction of the scheme up to 15 crop species, encompassing various vegetable and high value crops (e.g. Gedemmso in Oromia). With access to irrigation, intercropping and relay cropping are also becoming common practices even in monocropping-dominated systems (Table 5). About 40% of the farmers produced more food than before the scheme was constructed, particularly apparent in the drought-prone environments (e.g. Amhara) and in areas where there was no access to irrigation earlier (Benin etal. 2003). Data from three sites also indicated that 34, 26 and 16% of the respondents had access to more food, no change or obtained increased income, respectively (IE Preliminary survey, 2004). In some cases, vegetables became part of the daily dish of farmers (e.g. Chelekot in Tigray). This should have a positive effect on household health, particularly through the integration of calorie, vitamin and micronutrient rich vegetables and fruit crops (Amede et al., 2004b). However, food security has not yet been fully achieved in almost all sites due to the small land holdings, low soil fertility status and other calamities. However, 83% of the interviewed farmers still consider lack of enough irrigation water responsible for low crop yield in irrigated crops (Table 4).

Impact on natural resource management

There were both negative and positive impacts of the irrigation projects on the environment. The major negative impact was done during the construction phase whereby new farm gullies were created and debris from the construction plots were placed on farmlands.

Soil Conservation and land rehabilitation

There are differences among regions, the longest physical structure being made in Tigray and the lowest in Oromia. In the selected sites between 21 and 54% of the households indicated that small scale irrigation attracted soil and water conservation practices (Table 5). The difference in performance was dictated by the historical view and understanding the status of land degradation in the regions and the subsequent regional policies. In situation where extensive soil conservation was made in the 1980s (e.g. Burke Woldiyaa and Mumicha in Oromia), erosion and runoff was considerably reduced with very limited active siltation seen on the valley bottoms and diversion canals (Personal communication, 2004). In some regions (e.g.

Tigray), a considerable amount of work in managing the upper slope of the schemes was done through the construction of soil conservation terraces and tree bund stabilizers, which was a necessity to sustain the future performance of the schemes. This was done by introducing regional policies since 1992, whereby an obligatory 20 days per year labour contribution by every resident in the region was adopted. This labour was mostly used to construct and rehabilitate terraces and landscapes. This type of policy could reverse land degradation especially if it is done in a participatory way. It could lead to community action with apparent economic and social benefits in terms of fodder, fuel wood, water and other resources.

However, although terraces are in place in most of the sites the effectiveness of these structures in reducing erosion, in improving water infiltration and in performing other environmental services was not assessed. Participatory impact assessment of the structures to display the positive and negative effects on the system could attract investors and the interest of communities to manage them sustainably. Moreover, integrating niche compatible trees on the soil bunds may reduce the pressure on cow dung, which is currently used as a cooking fuel, to be used for soil fertility restoration. Burning dung is one of the practices aggravating land degradation, particularly in the Amhara and Tigray regions, as it breaks the nutrient recycling in crop-livestock systems.

There is a huge land area which became under area enclosure in all regions though the size and management modalities differ from region to region. It was done particularly to protect schemes and upper slopes from producing silts but also to rehabilitate exhausted upper slopes. In most cases it was done in consultation and agreement with the local communities. In sites where area enclosure is practiced for at least two or more years, like in Gereb koky, with an area enclosure of 30ha, the vegetative cover of the system increased considerably. It was valued by the communities as a means to recharge the springs, as sources of bee forage, and also as a strategy to restore indigenous trees like *Dodonaea viscose* and *Olea africana*. In some cases farmers were allowed to graze their oxen in the protected areas during ploughing times. However, the sustainability of the enclosure would heavily depend on the immediate benefits communities and household will obtain and the strength of the local institutions.

Labor availability

In situation where the cropping season is doubled because of increasing access to irrigation during the dry seasons, the pressure on household labor was apparent. The shift in systems from less labor intensive cereals to labor intensive vegetables (Table 6) caused an increasing labor demand. When a vegetable farmer was compared to a cereal farmer the demand for labor was 1638 and 406 man days per ha, respectively, which was about 400 % higher, indicating that there could be a need for an additional labor through hiring, debo (local labour sharing arrangement among age groups) or any other arrangements. Farmers' interviews in Lalay agula revealed that lined canales and cemented diversions reduced the pressure on farm labor, about 5 to 8 man days per family per season, which otherwise used to be invested in cleaning and repairing furrows after the main rainy seasons. This has created a job opportunity for the land less youth across the regions.

Upstream and Downstream Relationships

The presence of very few perennial rivers aggravated by recurrent drought, and extensive awareness creation campaigns towards a shift to vegetable farming in almost all schemes incurred a considerable competition for water in the command areas and beyond across regions, and caused shortage of water for down stream users

(Table 4). Competition for irrigation water between upstream and downstream users, between vegetable growers and chat growers, between farmers with big irrigable plots and small plots, and between water users and water managers have been surfaced during the various formal and informal discussions. Farmers in two sites in Harer, Oromia indicated that there is less water for down stream communities than ever due to the need for frequent watering of the vegetables in the upstream fields. The traditional system, which has a considerable Chat farming, demanded watering only once in a month and used to release a considerable amount of water to downstream users. On the other hand, recently introduced vegetable crops like tomato require water once in a week, particularly in areas where the evapo-transpiration is very high. The consequence was that there was an emerging conflict between upstream and down steam users, and in some sites (e.g. in Burka Woldiyaa) the case is presented to the local court. Additionally, some farmers started to divert the water to non-traditional farms using motor pumps and gravity, commonly without asking for consent with the traditional water users. In some cases, these were people highly protected by local and regional authorities with very limited chance for the small farmers to maintain the statuesque.

In situations where there is an absolute water scarcity, it is only households residing on the source who could benefit from the limited water flows. Communities residing down stream tend to send their water master to negotiate with upstream communities in times of critical demand.

Lessons Learned

In areas where institutions and market incentives are in place (e.g. Ziwai in the Rift Valley of Ethiopia), farmers have doubled or tripled their incomes in a very short period of time. In other isolated, less accessible areas (e.g. Belessa in the Amhara region), there is no visible change on the income and livelihood of the people, even four years after the irrigation infrastructure is in place and being operational (personal observation).

In general, there are very few operational SSI schemes in the country that could be labeled as optimum because of the various difficulties facing them at different times and scales, ranging from shortage of technologies to imperfect markets. An innovation systems approach is required to enable the schemes bring the expected impact on the livelihoods of the people, including the identification of various challenges small scale irrigators are facing at farm, community, district and higher scales. There is also a need to look for success stories where combination of technological, policy, institutional and market interventions made some irrigation investment worth investing to make the respective rural communities food secured and keen to protect the environment. Table 7 displays interventions that made few irrigation schemes success story.

a. Access to irrigation and the associated institutional services given by governmental and non governmental institutions helped farmers to improve their income and enhanced their capacity to shift towards market-oriented agriculture. Unfortunately, priority was given only to the crop sector while livestock, particularly dairy and fattening, could have increased the benefits by much higher orders.

b. Although crop diversity is one key way of minimizing risk and exploiting opportunities, too much diversity in the farmers' fields may prevent them from more efficiently developing their production skills and creating functional market links with specialized traders and consumers. Too little diversity may again lead to deteriorated market prices during the peak season. Hence farmers' should be assisted to optimize the number and type of enterprises that are managing and minimize market trade-offs for better decision making.

c. Although there is a better use of land based resource under irrigation, farmers are still dependent on low input management, which may not bring the expected quantity and quality reflecting market demands. Hence there is a need for diversifying the inputs supply systems including credit opportunities.

d. Water is a very scarce resource, and the demand for irrigation water is on the rise. Hence irrigation investments should be supported by water saving agronomic and technical measures, including mulching, tie-ridging, minimum tillage, lining of canals and drip irrigation.

e. The current extension support on irrigation agronomy is far from responding to farmers' expectations. Participatory on-farm research on irrigation frequency, crop water demand, crop rotation, organic resource management, micro dose application of chemical fertilizers, management of perishable seeds and related issues should be promoted. The process should give farmers the chance to innovate.

f. It could be necessary to distribute demonstration fields to various farm niches and landscape positions to reflect field variability. Promoting the capacity of elite farmers 'like the Hirsha Cadre's in Tigray' will enhance the scaling-up process to reach more farmers and communities sustainably.

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Table 1. Comparison of yield of various food and vegetable crops of irrigated and non-irrigated farms in Lalay agula, Tigrai (SCPII scheme). N= 6

Crop type	Yield (qt/ha)		
	Non –irrigated farms	Irrigated farmers	% increase
Maize	25.75	43.75	69
Onions	102	172	68
Pepper	11	17.75	61
Tomato	200	300	50
Carrot	226	305.25	35
Potato	174.8	250	43
Cumin	4.25	7.50	76

Source: Woreda Bureau of Agriculture, Wukro, 09/2004.

Table 2. Crop yield before and after the irrigation project in Shoba, Oromia (SCPI scheme). n= 10, nd= not determined.

		Yield (Qt/ha)		
Crop type	Land area (ha)	Before the project	After the project	rease
Barley	Nd	10	12	20
Wheat	Nd	8	16	100
Maize	Nd	15	25	66
Faba bean	Nd	4	12	200

Source: Dessie, 2004

Table 3. Seed source for major crops in IFAD sites (Mean of 3 sites) SD

Seed source	No of sample	rce
Own seed	708	.
Government	294	)
Purchase	284	.
Total	1286	.0

Source: IE Preliminary Survey, 2004

Table 4. Experiences in access to irrigation water in three schemes of IFAD sites in Ethiopia.

Management practices	Irrigation site						Total	
	Dobena		N.GalanSadi		Hizaeti Afras			
	sample	% Users	ample	% users	ample	% users	ample	% users
Practice crop rotation	51	61.4	109	70.3	135	99.3	295	78.9
Mulching			68	43.9	7	5.1	75	20.1
Intercropping	52	62.7	106	68.4			158	42.2
Contour farming			46	29.7	12	8.8	58	15.5
Physical soil conservation	16	19.3	84	54.2	29	21.3	129	34.5
Biological soil conservation			9	5.8	5	3.7	14	3.7
Other change in farm	2	2.4	5	3.2	1	0.7	8	2.1

Table 5. Change in farming practice as an effect of the SSI schemes, n=374.

Experience in water supply	Irrigation site				*Total*			
	Dobena		N.GalanSadi		Hizaeti Afras			
	Count	Col %	Count	Col %	Count	Col %	Count	*Col %*
Sufficient water not available	73	90.1	125	82.2	106	80.3	304	*83.3*
Sufficient water available	5	6.2	27	17.8	25	18.9	57	*15.6*
Poor management of water	3	3.7	-	-	1	.8	4	*1.1*
Total	81	100.0	152	100.0	132	100.0	365	100.0

Table 6. Labor requirement of various vegetable and field crops (man days/ha) in irrigated farms of Northern Ethiopia.

Crop	Pre-planting operation	Cropping operation	Post harvest operation	Total
Onions	110	255	10	375
Potato	24	253	16	293
Carrot	50	235	15	300
Cabbage	110	235	10	355
Shallot	50	255	10	315
Maize	14	40	10	64
Wheat	22	60	10	92
Barley	22	60	10	92
Teff	18	68	12	98
Beans	18	34	8	60

Source: COSART, 2001

Table 7. Best bet interventions for small scale irrigation schemes; lessons identified from selected schemes and communities that work best.

Technology for SSI	Where does it fit best?
Irrigation water	Water-saving lines canals
	Multiple cross-over alignments
	Water reservoirs with closing lockers
	Furrow irrigation practiced
	More perennials than vegetables or cereals
	Market access is reliable
	Local institutions function
Vegetable farming	Close to town markets
	Reasonably good road network
	Rotational cropping practiced
	Water supply is adequate
	Managed by literate and young farmers
High yielding varieties	Water supply is adequate
	Better access to inorganic fertilizers
	Rotation with legumes possible
	Land shortage is not apparent
	Managed by resource-rich farmers
Inorganic fertilizer	Best used for maize
	Water supply adequate
	Is accompanied by compost and manure
	Higher Urea and less DAP
Organic fertilizer	Biomass is abundant
	Cow dung is not used for cooking
	Composting is practiced
	Preferably for fruit trees and vegetables
Pest management	Avoid growing potato and tomato together
	Uproot diseased plants
	Crop rotation practiced
	Field health sanitary practiced

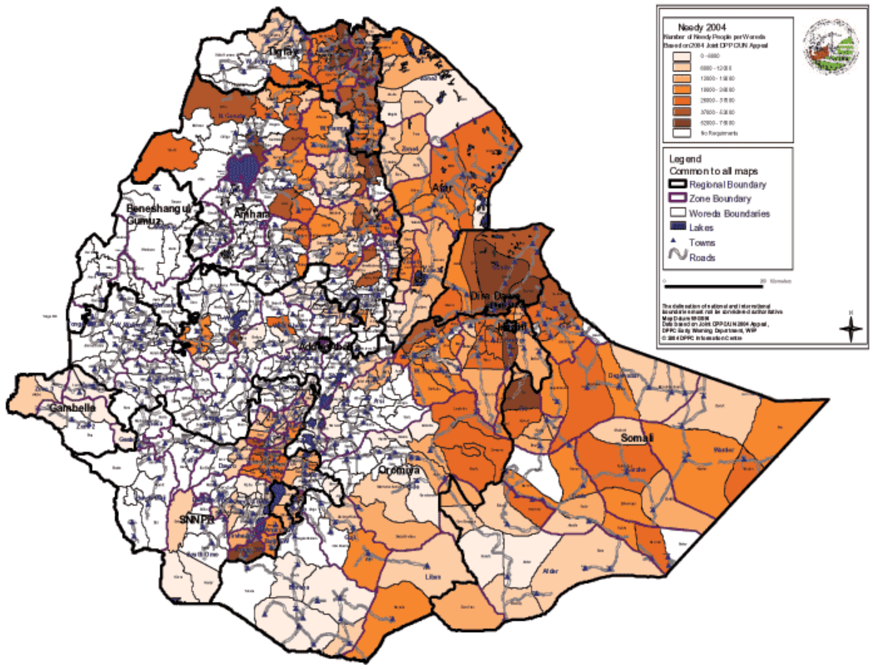

Fig. 1. Food insecure and secured Woredas in Ethiopia (DPPC, 2004)

Institutions, Management Practices and Challenges of Small-Scale Irrigation Systems in Ethiopia: A Case Study of Two Modern Smallholders Irrigation Systems in Western Oromia, Ethiopia

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Abstract

This paper examines the institutional arrangements that facilitate irrigation management and the present state of irrigation management and establishes where problems have occurred in the operation of Gibe-Lemu and Gambela-Terre Small-scale irrigation systems. The study employed the case study approach to tackle the research. Key informant and expert interview, desk review of different documents produced about the projects, group discussion, direct observation and structured interview schedule were used to collect data. The study proved the proposition that the government has uncritically supported the irrigation systems. Enabling legal system of land and water rights, strong woreda level state irrigation agency, support services (irrigation extension) and well-established water users associations through which purposes of irrigation are achieved were not adequately planned and put in place. These shortcomings undermined irrigation management, ultimately risked feasibility and sustainability of irrigated agriculture. Findings revealed poor record of accomplishment, in spite of the difference between the two systems, in managing water distribution in terms of the three most important performance indicators: adequacy, reliability and equity in water distribution. Water related conflicts are rampant but not settled yet. In addition, results indicated that irrigation had positively impacted irrigators' livelihoods in terms of diversification and intensification of crop production, household income, housing and employment generation and this social effect of irrigation was significantly different between irrigation systems (due to difference in the institutional and socioeconomic context of the two irrigation systems) and locations within irrigation systems. Nonetheless, many irrigators did not maintain these positive changes for long. The constraints were scarcity and unreliability of water and management and socioeconomic problems. These, in turn, were mediated by lack of: a) clearly defined and well enforced institutions of land and water rights; b) technical problems in design and construction; c) inadequate institutional capacity of the local state irrigation agency to coordinate and support decentralized management of irrigation; d) policy related problems; e) inadequate organization of users for self management; and f) problematic social relation of power among water users. Finally, the paper draws a number of conclusions, using the theoretical notions like context, social requirement for use, social effects and social construction, about policy options and requirements in the readjustment of the surveyed irrigation systems and in the design of irrigation projects of these types.

Key words: Institutions, irrigation, management practice and challenges

Institutions, Management Practices and Challenges of Small-Scale Irrigation Systems in Ethiopia: A Case Study of Two Modern Smallholders Irrigation Systems in Western Oromia, Ethiopia

Introduction

Gibe Lemu and Gambela Terre small-scale irrigation systems were constructed to promote household food security through effective and equitable use of the available land and water resources. However, these projects were poorly performing and the area under irrigation is below expectation. Nevertheless, more grounded and detailed scheme-specific information on the reason why it is so is and which help guide future policy for smallholders irrigation promotion not available. It is increasingly being recognized that poor performance is not only a consequence of technical performance in design and construction, but institutional and management problems tended to be more common constraints to the success and exploitation of small-scale irrigation schemes in sub-Sahara Africa. In addition, in-depth understanding of technical and agronomic problems of irrigated agriculture is impossible without understanding the social organizations (institutions, the policy environment and social relations) in which it is embedded. The general objective of this study is, therefore, to examine and describe the reasons for the disappointing performance of the target irrigation systems with a focus on the institutional arrangements that facilitate irrigation management, the present state of irrigation management at the local and grassroots levels and establish where problems (gaps) have occurred.

Specific objectives:

- To analyze the institutional arrangements and relationships that affect management and 'performance' of the irrigation systems;
- To understand how users are organized for self management of irrigation;
- To understand how the irrigation systems are managed and;
- To identify and clarify the major challenges of the irrigation systems; and
- To suggest possible options/strategies for rehabilitation of the surveyed irrigation systems and in the design of similar irrigation projects

Methodology

The research work included both appraisals of theoretical assumptions on conditions of possibility for successful irrigation as well as the analysis of empirical data obtained during field research. The socio-technical approach to irrigation (the social shaping perspective of irrigation technologies) by Mollinga (2003) and elements of the social organization of innovation theory by Engel (1997) were used in developing the instruments for data collection; formulation of the hypothesis and in the interpretation and explanation of the data collected and the facts in the irrigation systems.

The study employed the case study approach to tackle the research. There are ample reasons for using the case study approach. The first reason is the nature and objective of the research itself; irrigation management practices and analysis of institutional contexts and causes of the problem are complex processes and therefore require detailed investigation and comprehensive understanding. Secondly, the conventional questionnaire survey (structured interview schedule) alone does not allow comprehensive understanding and adequate description of how the schemes are actually managed and what institutional and socio-economic variables and processes explain poor performance of the schemes.

Methods of Data Collection

Secondary Data Collection

Secondary data was collected through desk review of the regional and national irrigation policy statements, legal frameworks regarding irrigation land and water rights institutions, proclamations and regulations, project write-ups, project appraisal documents, different reports produced about the projects and past case study papers on irrigation.

Primary Data Collection

Relevant primary data were collected using various instruments such as

- Key informant interview; conducted to generate general understanding of the irrigation systems. In addition, the information obtained through this tool was also used for developing more focused questionnaire for the household interview
- Interview (semi-structured) with

executive committee of water users and officials and experts with relevant government agencies at regional, zone and wereda levels of accountability

- Group discussion: 60 purposively selected irrigators, divided into six groups (three in each irrigation system), and each with group size of 10 members were involved. Irrigators from the head-end to the tail-end areas were included in the groups so the data generated reflects the actual situations and facts at all water levels.
- Direct observation of events during many visits paid to the schemes
- Household interview using structured questionnaire

For the questionnaire survey, 65 sample households were selected using the following procedure:

a) First, the sample frame was obtained from the executive committee of WUAs;
b) Then, the beneficiary households were stratified into head-end, middle and tail-end irrigators based on their location in the farm layout of the irrigation systems and proportion was assigned to each group for inclusion in the sample; and
c) The households were stratified on the basis of their location with the basic assumption that there could be inequity in the distribution of irrigation water and the benefits derived from irrigation as a result of weakness in water control, technical problems and lack of management structures that suit layout of the irrigation infrastructures (see also Vermillion/IIMI, 1997:30-31);
d) 30 % (from each scheme) of the sample frame were selected using stratified random sampling technique and participated as respondents in the household interview.

2.2. Data Analysis

Both qualitative assessment and descriptive analysis techniques were used for data analysis. The data generated through household interview was analyzed by employing SPSS. The study employed descriptive statistical methods such as frequency, percentage, mean, and[23] standard deviation, X^2-statistic, T-test and ANOVA/F-test for analyzing the data generated through household interview.

Rsult and Dscussion

Description of the Irrigation Systems

Gibe Lemu Lemu and Gambella-Terre irrigation systems are found Gobu Seyo District, East Wellega Zone of Oromia Region. Gibe-Lemu is located at 80km towards Addis Ababa from Nekemte, capital of East Wellega zone and 3Kms from Bako town. Gambela –Terre SSIS is located at 12kms from Ano-town, the district capital and 30km from Bako, the biggest town providing access to markets for farmers. The rainfall in both irrigation systems is unimodal. The unimodal rainfall pattern dictates the single cropping season. However, in recent years, the pattern of the rainfall becomes uneven and unpredictable with negative implication on food production.

The total irrigable command area of the Gibe-Lemu irrigation scheme is 113 ha. A main canal having a length of 7kms conveys water into the command area. The method of distribution to the main, secondary canals and TUs is continuous, while it is rotational in the farm units as per the initial design of the project. However, currently, the method of supply to the TUs is rotational due to the decline in the volume of water conveyed into the diversion weir. The method of application to the farm units is rotational, while the method of application of water is furrow. Seven days are one irrigation interval for each farm unit at the time of design (Korea Design Team, 1990). However, there is severe water scarcity in the scheme to day to supply water in accordance with this interval.

Gambella-Terre SSI project was initiated (during the Derg Regime) in line with the political interest of the Derg, i.e., to be used as instrument for promoting collectivism through cooperative farming. Initially, it was designed to develop an irrigable area of 80ha. In 1995, additional 34 turnouts, division box and other structures were constructed along the main conveyance canal to bring additional 70 ha of land, which was not considered in the initial design, under its command area so as to benefit up stream farmers whose land holdings fall on the left and right sides of the main conveyance canal. This increased the command area from 80ha to 150 ha. Nevertheless, there is a wide gap between the supply of water to day and during the time of designing the project (1988).

Table3.1 Average distance from the market

Round trip distance (minute):	Gibe Lemu Mean	N	St.De	Gambela Terre Mean	N	SD
From the main road:	55.20	25	40.56	116.75	40	64.22
From the market:	93.24	25	51.32	144	40	77.49

Source: - Field survey, *=household, **= Male headed households, ***=Female headed households

The average round trip distance from the main asphalt road and the market place is different between the two irrigation systems. Irrigators in Gambela Terre have to walk longer hours than Gibe Lemu to access the nearest local market to sale their agricultural produces (Tables 3.2). In addition, there is no all-weather road connecting the irrigation system to the main asphalt road despite the fact that it is one of the material contexts for successful irrigation (Engel, 1997; Mollinga, 2003; Dillon, 1992: FAO, 2003). Further, farmers in Gibe Lemu have long standing (more than half a century) tradition in practicing traditional irrigation while farmers in Gambella-Terre had no irrigation experience before arrival of the new irrigation project.

The Institutional Setting of Irrigation Management at Local and Grassroots Levels

3.2.1. Local Level Institutional Arrangements

Structure and Management Capacity of the District Irrigation Desk (DID)

Oromia Irrigation Authority was responsible for SSI development in Oromia between 1999 and 2004. Following the 2004 restructuring, the independent district irrigation extension office and the specialized development centers were merged with the District Agriculture and Rural Development Department (DARDD) with no clear line of communication with the Branch and

Regional Offices of the Irrigation Agency responsible for irrigation development in Oromia. The District Irrigation Desk (DID) has been created in the DARDD as a team in 2004 and the full time irrigation extension workers become multipurpose.

Now the Gobu Seyo District Irrigation Desk (GSDID) and the extension centers are accountable for supporting user-based/decentralized management of irrigation and coordination of efforts of partners in the administration of irrigation in the district. Nonetheless, it has inadequate capacity to shoulder these responsibilities in terms of human resource development, technical units, structure and logistics in spite of the government policy for capacity building and institutional development. The GSDID has been consisted of only one team leader who is in charge of the Desk. It operates only with 20% of the required technical staff (table 3.2). Regarding transportation means, the Desk is equipped with only one motor bicycle, one room (office), one table and one chair which are exclusively used by the Team Leader by the survey date (March, 2005). In terms of structure, the GSDID lacks organizational unit (development centers) with DAs fully responsible for irrigation at the scheme levels. But, CTA (1999: 91-92) argue that a necessary condition for more efficient and lasting management of smallholders' irrigation is existence of management capabilities, which are built through organizational and institutional development at various levels; from the apex through the middle level to the grassroots levels.

Table3.2 Manpower status of GSDID; as of March 2005

Discipline (positions)	Required and Approved	Available	Gap
Team leader	1	1	-
Irrigation Engineer	1	-	1
Irrigation Agronomist	1	-	1
Community participation Expert	1	-	1
Water Harvesting Expert	1	-	1
Total	5	1 (20%)	4 (80%)

Institutional instability had adversely affected the human resource capacity and structure of the local irrigation agency. For example, the irrigation sector institution in Ethiopia experienced reorganization in 1983, 1994, 1995, 1999 and 2004. This in turn has challenged human resource development and affected structure and existing human resource capacity of the irrigation sector institution. It could not maintain its trained manpower at both district and grassroots levels. The number of trained professionals who were working on irrigation at the District Irrigation Office was reduced following the restructuring in 2004. This weakened irrigation expertise at the District level. Until the 2004 reorganization, there had been one trained DA (Diploma graduates, who received in-service training in irrigation) in each irrigation system. These trained DAs were taken to district to work in other offices. However, no full-time and trained DAs assigned after that. In addition, the newly assigned DAs have multiple mandates and over stretched with many activities. Therefore, they are unable to undertake strict follow up of user-management of irrigation and could not deliver adequate irrigation extension services to farmers.

Stakeholders and Partnership in Irrigation Management

The policy framework for small-scale irrigation development in Ethiopia states that management of SSIS is a joint responsibility. In view of this, the regional state irrigation agency identifies cooperative promotion and input supply desks, district and grassroots level administrative and legal entities and farmers and their organizations as main stakeholders in the administration of irrigation in the study area. In addition, in 2004, the regional government merged five concerned district level government agencies in one institution; Agriculture and Rural Development Department (ARDD), with the assumption that organizational proximity can provide a fertile ground for collaboration. Although merging is a good opportunity, the five institutions did not work together in irrigation management as expected; the achievement has mainly been physical proximity of the agencies although the social shaping perspective of irrigation technologies assumes that irrigation systems are socially constructed.

The responsibility for coordinating partners fell on the District Irrigation Desk (DID). Nevertheless, it could not manage to do it owing to lack of well-established institutional and functional framework for cooperation and harnessing their efforts. Lack of adequate involvement of the partners in turn adversely affected irrigation management in many ways, including:

- Necessary inputs for irrigation could not be availed to farmers regularly; his responsibility fell on the input Supply Desk.

- Irrigation has no research input; adaptive crop varieties that work under the situation of irrigation and watering frequency (irrigation agronomy) recommended for irrigation are non-existent. Although there exists one big research center of the Oromia Agricultural Research Institute in the nearby area, it has not been supporting irrigation development through supplying relevant technologies. This is due to the fact that agricultural research policies and strategies are not adjusted to meet requirements of irrigation and none-existence of enabling institutional framework for harnessing efforts of the research system with irrigation;

- The district and village level administrative and legal entities do not play any meaningful role in water control and conflict resolution though the task has become more complex to be addressed by 'Kore Aba Laga' and the simple informal rules alone (bylaws); and

- Water users not organized into legally recognized entities in accordance with the principles of organization of cooperative societies. This responsibility rests with the cooperative promotion desk. Nevertheless, it did not discharge this responsibility.

Support Services

The support services, in Molliga's and Engel's words 'the material conditions of possibility' for successful irrigation include, among others, improved seeds that work under irrigation and strong extension services (Engel 1997:147, Mollinga 2003: 24 and Dillon, 1992: FAO 2003). However, survey results revealed only 48% and 35% of the sample households ever used seeds of improved vegetable and cereal crop varieties in Gibe Lemu and Gambela Terre respectively. Out of the sample households, 36% in Gibe Lemu and 27.5% in GTSSIS procured improved seeds of maize and potato from the extension service. Nonetheless, the maize and potato seeds they obtained from the extension service are not recommended specifically for irrigation. In addition, seeds of carrot, onion, tomato, chile and other vegetable crops that irrigators regarded as 'improved' seeds have mostly been procured from the market or shops; they are not specifically recommended for production under irrigation. Therefore, they did not suit the irrigation systems, for they are affected by disease.

Overall, irrigators have not regularly been supplied with these support services mainly because the government policy on agricultural input supply, agricultural research and rural extension, gives more priority to those farmers registered in package program for rain fed agriculture. It tended to favor, in terms of both supply and timing of supply, rain fed agriculture during the main rainy season.

Institutional and Organizational Conditions within the Irrigation Systems

Land Distribution and Its Problems

Gibe Lemu and Gambela Terre Small-scale irrigation schemes were constructed to resolve the problem of farmland shortage, increase production and productivity and to improve farmers' livelihoods through effective and equitable use of the developed land and water resources. In view of this, ORLUA Proclamation No. 56/2002) states a maximum of 0.5 ha is retained for each former landholder in the command area and each member is equally allocated 0.25 ha per household. Nonetheless, this has not been finished in practice in both irrigation systems. Results indicated the whole command area has been owned only by 22.4%

(in Gibe Lemu) and 57% (in Gambela Terre) of the intended beneficiary households. Former plot holders continued to control and manage land areas that fall in the range of 0.5ha to 12ha in Gibe Lemu and 2ha to 5ha in Gambela Terre irrespective of their resource capacity to fully use it for irrigation. This has been in spite of the fact that the rest farmers are landless; tenants and/or sharecroppers (specially in Gibe-Lemu SSIS).

The problem of landlessness and skewed distribution of irrigable land was more severe 2. in Gibe Lemu. Out of the irrigators, 2o% did not possess own irrigable plots, while some rich farmers were managing 9-12ha of potentially irrigable land. T-test also showed there was significant difference among households in Gibe Lemu; which is significant at the 5% level. Landless farmers and those who own small plots access irrigation land mainly through sharecropping system, labor exchange and exchange of ox for land **(see appendix table**). Similar study by JICA and OIDA (2003: 3-6) in East Shoa and Woldeab (2003) in Tigray also documented that sharecropping system (leasing-in and leasing-out) is one of the common option available to land owners with low resource capacity and landless farmers and farmers with smallholding.

Fair distribution of irrigable land has not been achieved in both irrigation systems by the survey date. The government failed to achieve fair distribution of irrigable land because: a) land redistribution issue was not dealt with during design and construction, b) GTSSIS was initiated in line with the political interest (collectivism) of the Derg regime in which case land redistribution was not an issue and; c) lack of policy and enabling legal system for redistribution for a long period and a time lag between the issuing of the Oromia Rural Land Proclamation and operational regulation.

1.

Inadequate land tenure in turn has created management difficulties in the schemes. Both 'Kore Aba Lega', DAs and the local state irrigation agency do not clearly know the actual size of irrigable plot managed by individual households. Hence, they could not adjust water allocation and resource mobilization to amount of water used and irrigable area controlled by individual households. Equal contributions are requested from all members who cultivated 0.5ha-12ha of irrigable plots. Ali Seid (2002), Lema (2004) and JICA and OIDA (2003) found similar problem in their study in North Wello and East Shoa zone respectively. In addition, some farmers are over supplied with water, while some others obtained water, which is far short to meet their needs due to the guesswork in water allocation. Over supply has led to misuse in the context of severe water scarcity.

3. Organization of Users for Self-Management of Irrigation

Organizational Set-up

In accordance with the federal and regional policy framework for small-scale irrigation development in Ethiopia, "Kore Aba Lagas" are in charge of water allocation, distribution, observing the water rights of members, conflict management and coordination of maintenance activities.

Although there are many deficiencies in their organization, the water users in both irrigation systems have created their own management structures and crafted internal bylaws as one of the social requirements for better management. Executive committees, sub-committees and water user teams (WUTs) were formed at irrigation system and distribution levels [territory units (TUs)] to facilitate water control and coordination of maintenance activities

All water users are organized into 6 WUTs (Water users teams) in Gibe-Lemu (group size ranging 10-20 members and in Gambela Terre into four WUTs "goxi" with the number of members per WUT ranging from 17 to 44. Nonetheless, the group size of two WUTs in Gambela Terre is above the optimum range (20-30) for good management (See Woulter, 2002: Blank, 2002). In these WUTs it has been observed, because of large group size, greater socioeconomic differentiation and lack of mutual understanding among users, which led to severe problem of water distribution and conflict over water. Similar study in Kenya showed that, the whole schemes or part of it was not operational, in all schemes consisting of groups of over 30 members (Woulter, 2002). With a membership below 30, he observed no water distribution problem in Kenya. To the contrary, the situation in Gibe Lemu contradicts with Woulter's findings. The number of members of WUTs is 10-20, which is below 30 but still there is water distribution problem and users could not settle water dispute themselves. This shows group size is not the only factor for social cohesion and effective group performance in water distribution.

Viability of the Water Committees for Self-Management of Irrigation

The responsibility for running management of the irrigation systems was delegated to "Kore Aba Laga" in the hope of enhancing effectiveness, equity and responsiveness in irrigation management and to ensure sustainability. Nonetheless, they were not organized in such a way they can ensure these objectives of decentralized management, although good organization is one of the social requirements for good irrigation governance. They have deficiencies in their management structures. They have no recognized legal power and the roles, responsibilities and authorities of the different positions along the management structure are not clearly defined and even it is totally missing from the by-laws of the 'Kore Aba Lagaa' in Gambela Terre.

The committee lacks transparent accountability to users although it is one of the essential factors for good irrigation governance. Constituencies (water users) accuse committee members for power abuse, selfishness, lack of commitment, and for not observing the internal bylaws. Nevertheless, informants reported that they were not held accountable through legal processes. One informant in Gibe Lemu, Name-Mohammad Shumiye, expressed the intensity of the accountability problem using the following proverb:

"Y**egebere balesiltan yasyilign gebeya new'**, meaning, the committee members abuse the power and authority we vested on them and prioritize their interest and irrigation fields in water allocation and distribution"

Irrigation Management Practices within the Irrigation Systems

Water Management

Water Allocation

Water committees are in charge of water allocation with little support from irrigation agronomists and development agents. They allocate water and prepare rotational schedules every year in September. However, water users expressed that Water allocation made by the 'Kore Aba Lagas has limitations in terms of both design and implementation. In terms of design, it does not clearly define water rights of individual farmers and TUs due to the guess work in water allocation. Equal water supply period per turn is allocated for all TUs and individual water users in spite of the variation in water requirements of the different crops grown, area of irrigable plots managed by individual irrigators and water demands in different TUs. The major impediments for proper allocation and scheduling of water distribution (as reported by committee members), include:

- Guess work in water allocation; the water committee undertakes water allocation and defines water rights of members not based on study on water requirements of different crops, irrigable plot area possessed by individual irrigators and measurement of the yearly water supply due to capacity problem. This is because the local state irrigation agency failed to provide satisfactory technical assistance in undertaking these water management tasks and in building their capacity; and.

- Water users are not willing to register types of crops they grow (vegetables or perennials) and area of their irrigable plots with the committee for clear definition of water rights in spite of the law (bylaws).

Water Distribution

The most important performance indicators in the distribution of irrigation water include adequacy, timeliness and equity in the supply of water (World Bank, 2000). Table 3.3 shows users' evaluation of performance of "Kore Aba Legas" in water distribution. The water committees in both irrigation systems were found to be in efficient in managing water distribution in terms of the three indicators. In Gibe Lemu and Gambela Terre, 80% and 90% of the sample households witnessed that they could not obtain the quantity of water that can support irrigation over the plot area they manage. The vast majority, 76% (in Gibe-Lemu) and 80% (in Gambela Terre) of irrigators were not able to obtain water in a reliable manner. Further, results of chi-square analysis indicated

Table 3.4.Water users' opinion about water distribution in Gibe Lemu and Gambela Terre irrigation systems

Item	Opinion by irrigation system and location			
	Gibe Lemu (N=25)		Gambela Terre (N=40)	
	Count	%	Count	%
Enough water is not obtained	20	80	36	90
Water is not reliable	19	76	32	80
Water distribution is unfair	21	84	33	82.5

Source: Field Survey

Access to adequate irrigation water and the problem of unreliability of water has strong association with location of farmers' irrigable plots relative to the headwork. The difference between locations was highly significant in Gambela Terre (X2=10.6, X2-Prob. =0.005 (for adequacy) and P<0.005 for reliability). This implies there is a greater probability that access to adequate and reliable supply of water is highly unlikely if the farmer's irrigable plot is in the tail-end area in Gambela Terre (appendix Table1). Water is scarce and the problem of unreliability is more severe in tail end areas in both irrigation systems.

Table3.4 Order of reasons why farmers do not obtain adequate water for irrigation, Gibe-Lemu and Gambela Terre SSIS

Irrigation system	Statistics	Water scarcity	Seepage loss	Poor water control	Turn abuses
Gibe Lemu	N	6	3	5	9
	% Of farmers	24	12	20	36
	Rank	2nd	4th	3rd	1st
Gambela Terre	N	20	2	8	9
	% of farmers	50	5	20	22.5
	Rank	1st	4th	3rd	2nd

Source: Field survey, March 2005

Tables3.4 shows farmers ranking of problems that constrained the supply of adequate water in a timely fashion. Water scarcity due to decline in the quantity of water conveyed into the scheme and uncontrolled distribution were the prime factors responsible for scarcity and unreliability of water. In Gibe_lemu, hydraulic and technical problems (water scarcity and seepage water loss) tended to be the least important constraints for not meeting water needs in the scheme, indicating institutional and management

Problems are more relevant. Water users in Gibe Lemu believe that the current volume of water conveyed into the scheme can meet water requirement in the command area with some adjustment and adaptation of water allocation to the change in water supply and if there had been strong system management. Water scarcity is the most important reason for not obtaining the needed amount of water for irrigated agriculture in command areas of Gambella Terre SSIS

Table 3.5 Social groups that get more water by illegal means

Groups	*Percentage of farmers giving the response*		
	All HHs (N=65)	Gibe Lemu (N=25)	Gambela Terre (N=40)
		4.	
Farmers with large family size	89.5	60	42.5
Head-end farmers	89.5	76	82.5
Rich farmers who irrigate perennials	39.7	36	35

Source: Field survey

Alongside the above, results revealed that Water Committees were not able to ensure equity in water distribution (Table3.5). Informants reported that powerful and rich socioeconomic groups, in their words, 'gulbetegnas'/'bully farmers' have been benefited more. Head-end farmers had better access to irrigation water owing to their proximity to the headwork (location advantage). They release water for the down stream farmers once their fields saturated with water. Households with large family size are more powerful (because of size) and often, they exercise power to obtain water by illegal means. They also take advantage of the relatively large family size and/or labor in defending their water rights. Rich farmers in the middle areas, especially in Gambela Terre, irrigate large areas of tree crops which are not in the priority list and do not releases water for the tail-end farmers. Nonetheless, the WUA committee could not regulate this distribution inequity owing among others to resistance by the powerful groups.

Water Scarcity: Causes and Coping Measures

Causes of Water Scarcity

Water is scarce in the irrigation systems; especially in Gambella Terre. Table3.6 shows perceptions of irrigators about causes of water scarcity. Gibe and Dokonu rivers, which are water sources for Gibe Lemu and Gambela Terre, were diverted at 2 and12 locations respectively. This decreased the quantity of water conveyed into the schemes. Nevertheless, the problem has not been addressed due mainly to first, there was no enabling legal system, which clearly defines the water rights of the upstream traditional irrigators and irrigators in the new irrigation projects. In spite of the general constitutional rule, there are no formal operational rules and regulations for managing the relation between the upstream and downstream irrigators in sharing the water from the same river. In the second place, the responsibility for addressing such problem (the role who should do what) of the different stakeholders has not been defined by the survey date.

TABLE3.6 Perceptions of irrigators about causes of water scarcity by irrigation system

Causes of water scarcity	% of farmers giving the opinion		
	All HHs (N=65)	Gibe Lemu (N=25)	Gambela Terre (N=40)
Diversion of water by traditional irrigators	89.32	88	97.5

Seepage loss	47.74	52	52.5
Increasing number of users	63.14	80	62.5
Lack of strict water control	70.84	80	80

Source: Field Survey, March2005

Alongside water diversion by traditional irrigators, the problem of water scarcity has been mediated by abuses (uncontrolled distribution), social incompatibility (in Gambela Terre) and increase in the number of water users in Gibe Lemu, against the declining quantity of water conveyed into the scheme(table3.6). Farmers in the middle areas, especially in Gambela Terre, irrigate large areas of perennial tree crops, which are not in the priority list of crops to be grown; leading to scarcity the in tail end area. Further, the designed irrigation season for the scheme (Gambella Terre) is October to March every year. However, the indigenous growing season for rain fed agriculture in the area is May to December. Farmers start irrigated agriculture by the end of December. Nevertheless, by this time, the volume of water flowing to the diversion weir has declined substantially to the extent that it cannot support irrigation over the command area of the scheme or dries totally (problem of social incompatibility). Similar studies have also documented that increasing number of users on the limited irrigation water has led to scarcity, and even limiting the types of crops grown by farmers (Alula, 2001 and Freeman and S.Silim, 2002).

Coping Measures

The following coping measures were taken to over come water scarcity

- Changing the duration of water delivery for TUs in response to the change in quantity of water conveyed into the scheme;
- Prioritizing crops to be grown; vegetable crops, which require frequent watering, were given priority. Nonetheless, irrigators did not observe this cropping pattern for not strictly implemented to supply water in a reliable manner to grow vegetables. Hence, irrigators shifted from vegetables to perennial tree crops as an adaptive measure to the problem of unreliability of water;
- Night storage was constructed (in Gambela Terre SSIS) to over come water scarcity through rotational distribution day and night. Still the volume of water flow is far short of water needs in the scheme; and
- Water users in Gambela Terre employed a paid guard; to control water distribution and to address the coordination problems of 'Kore Aba Laga' . However, the guard could not adequately manage the distribution because of the size of the irrigation system that needs control, which is beyond the capacity of one person to control.

Overall, the problem has not been fully addressed by all these means due to in built defects in the design and implementation of the adaptive measures.

Conflict Management

Water disputes persistently occur between irrigators in the new schemes and upstream traditional irrigators and among irrigators within the irrigation systems. Further, results of household interview that the majority (56% in Gibe Lemu and 57.5% in Gambela Terre) of the sample households have faced conflicts arising from water allocation and distribution (table3.8). Informants reported increasing number of water users in Gibe-Lemu (against the declinigng quantity of water conveyed), water scarcity (from the source) and poor water control as major causes.

The number of claimants of irrigation has increased over time, without being accompanied by institutional adaptation, led to competition and conflict over water. Similar findings are demonstrated in studies conducted by Freeman and S.Silim (2002) and Alula (2001). With increasing number of users, conflicts arising from water allocation became more common; water management became more problematic and the interval between watering of plots increased almost to "breaking point" (Alula, 2001).

Powerful households and rich farmers who grow crops which are not in the priority list, such as coffee, chat, and sugarcane, in the middle areas capture more water by illegal means (more serious problem in Gambela Terre); leading to scarcity in the tail-end area and tough conflict between the two groups. Nevertheless, it was beyond the capacity of 'Kore Aba Laga' to be contained. Diversion of the Source Rivers by traditional irrigators had also gave rise to external water disputes. The local irrigation agency mentioned lack of legal frameworks as the main reason for not addressing the problems.

In summary, 'Kore Aba Lagas' are ineffective, reluctant and less committed in taking care of the water rights of members and in resolving conflicts. Table4.8 shows farmers' ranking of problems that discouraged commitment of the water committees. The prominent gaps include:

1. Lack of satisfactory support from the local administrative and legal entities and the multipurpose DAs. The committees transfer cases of irrigators who were found guilty of illegal water abstraction to these entities. But they do not give satisfactory response though the task of conflict management has been beyond the legal power and capacity of 'Kore Aba Lagas' the WUA committees;
2. Lack of incentive for the managing entities; i. e.; board members of the WUA have no incentive for the time they spent in irrigation management. Coupled with resistance it frustrated and discouraged their commitment to undertake strict control of water distribution..
3. Problematic social relation of power among water users. Some members, especially the powerful households do not observe the group-based rules and do not usually give consent to be governed by the WUA committee members. Mollinga (2003) has also proved in his study in India that socioeconomic differentiation (social inconsistency) among water users had impeded emergence of viable water users organizations who can undertake effective water control.

Table3.7 Farmers' ranking of causes of poor water control and poor conflict management by water committees by irrigation system

Reasons	% of farmers and rank					
	Gibe Lemu			Gambela Terre		
	N	%	Rank	N	%	Rank
WUA-committees are reluctant	7	28	3rd	12	30	3rd
Resistance by water users	8	32	2nd	15	37.5	1st
Lack of adequate external support**	10	40	1st	13	32.5	2nd

Source: Field survey, March 2005

Maintenance of the Irrigation Systems

Farmers undertake canal cleaning and system maintenance activities under the leadership of the water committee with the assistance of multipurpose DAs. Most of the time members contribute labor for maintenance. Maintenance is carried out twice a year and very irregularly in Gambella Terre albeit the O and M manual prepared for the schemes recommends that it should be undertaken thrice a year.

In Gibe Lemu the majority (56%) of the interviewees stated that maintenance of the structures was very good; 36 percent said it was good and only 4 percent said very poor (table4.9). Evidences obtained from the DA office and the GSDID also showed that more than 75 percent of the water distribution canals were functional by the survey date although there was no clear evidence whether it had been functioning fully or partially. This is because irrigators in Gibe Lemu are more committed to maintain and sustain the irrigation system in spite of the severe coordination problem. The most important reason they suggested for farmer commitment was the role of irrigation in the life of farmers in the area and the high market value of horticultural crops produced using irrigation due to accessibility to the good commercial opportunity in Bako Town. A review of impacts of irrigation management transfer by Vermillion (1997:19) came up with similar results.

Table 3.8. Users' opinion about maintenance of the schemes

Description	Number and percent of irrigators					
	All HHS		GIBE-LEMU		Gambela Terre	
	Count	%		5.	Count	%
Very good	16	24.6	14	56	2	5
Good	22	33.8	9	36	13	32.5
Acceptable	4	6.2	1	4	3	8
Poor	12	18.5	-	-	12	30
Very poor	11	16.9	1	4	10	25
Total	65	100	25	100	40	100

Source: Field Survey, March 2005

In Gambela Terre, conveyance and distribution canal networks deteriorated due to a number of reasons. The distribution and conveyance canals became flat in many areas and pockets of water ponds created at many points along the conveyance and distribution canals (see the photo below). Results of survey on farmers' opinions indicated poor coordination of maintenance (92%), breaching of canals (87.2%) to extract water by illegal means and damage from animals (98.5%) as the major causes of damage and threats to safety of the irrigation system. Culturally, livestock freely graze over the command area for not all farmers cultivate their irrigable plots uniformly. In addition, turnouts are far a part and not evenly distributed in some areas. Hence, irrigators break canals and extract water where there is no turnout; implying technical problems in design and construction have contributed to the deterioration of the scheme, in addition to the institutional and management weaknesses.

Photo: Water pond created on the main water conveyance canal due to damage by livestock and lack of maintenance, Gambela Terre SSIS

Irrigated Agriculture: Livelihood Impacts and Threats to Feasibility and Sustainability

Impact on Farmers' Livelihoods

Irrigation had contributed towards improvement of irrigators' livelihoods through its effect on

crop production. Irrigation brought about change in cropping pattern and increased production and farm income, improved housing and wage labor employment.

One method to show the social effect of the intervention on diversification is through comparison of types of crops cultivated by farmers before and after irrigation. The types of crops and the number of farmers who grew a wide range of horticultural crops has substantially increased after irrigation (table3.8). Chi-square analysis also revealed that the production of potato ($P<0.05$), onion ($P<0.05$) and tomato ($P<0.05$) was significantly different before and after the introduction of irrigation in Gambela Terre area (table 3.8)

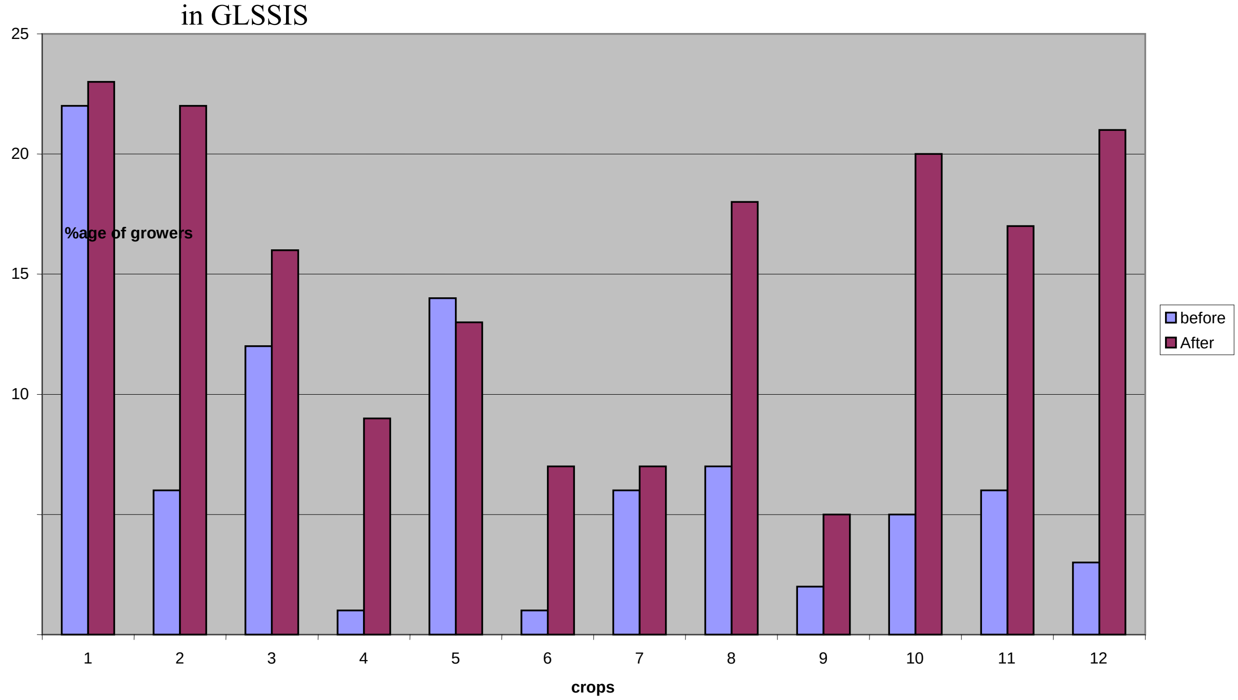
Table3.9 Comparison of agricultural diversification before and after

Crops grown	Gibe Lemu (N=25)				Gambela Terre (N=40)				
	HHs growing the crop				HHs growing the crop				
	Before		After		Before		After		X^2-tatist.
	N	%	N	%	N	%	N	%	
Maize	22	88	23	92%	15	50	23	23.59	0.835NS
Potato	6	12.5	22	875	9	29.0	29	93.5	5.226**
Onion	12	36	16	64	6	19.4	25	80.6	4.476**
Cabbage	1	-	9	37.5	7	23.3	17	56.7	0.709 NS
Pepper	14	58.3	13	54.2	11	36.7	19	63.3	0.660 NS
Carrot	1	4.3	7	30.4	2	6.9	14	48.3	2.005 NS
Chat	6	26.1	7	30.4	1	3.4	14	48.3	.967 NS
Coffee	7	28.0	18	72	5	17.2	23	79.3	1.616 NS
Sugarcane	5	20	20	80	1	3.4	10	34.5	.545 NS
Mango	6	24	17	68	8	26.7	24	80	.384NS
Tomato	3	12	21	84	6	20	21	70	4.802 *

Source: Field survey, NS=Non-significant, **=Significant at $P<0.05$

The second most visible impact of irrigation was temporal diversification of production. In Gibe Lemu, the number of households who used to grow twice increased from 8% before irrigation to 88% after irrigation and in Gambela Terre, from 2.5% before to 70% after irrigation. Results also revealed that it is significantly different between locations in Gambela Terre (X2-Prob. = 0.000) and farmers in the tail-end area benefited least. This is owing to inequity in the spatial and temporal distribution of irrigation water in the tail-end area. Furthermore, the proportion of irrigators who grow twice a year was higher in Gibe Lemu (88%) compared to Gambela Terre (70%). The difference is attributed to more severe problem of scarcity and unreliability of water and farmers biased ness towards rain-fed agriculture in Gambela Terre (see also fig3.3).

Figure3.1 Comparison of agricultural diversification before and after irrigation in GLSSIS

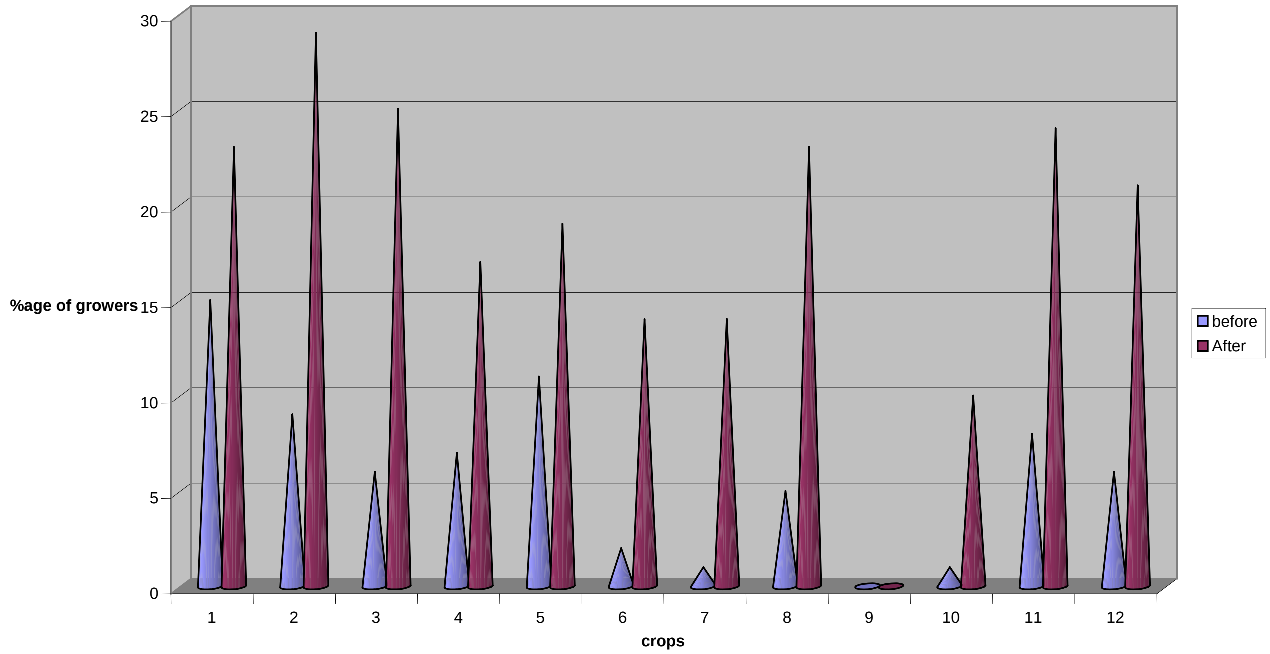


N.B:1=maize,2-potato, 3=onion,4=cabbage,5pepper,6carrot,7=chat,8=coffee,forage,10=sugacane,11=mango and 12-mango

Alongside diversification and intensification of crop production, SSI had a positive impact on the income of farm households in 2004/05. However, ANOVA showed that there was a significant difference (F=13.47, P<0.0001) in the net income of households between irrigation system and between locations. The average household net income from all sources in 2004/05 was relatively higher in Gibe Lemu (Table3.8). This could possibly be due to the relatively better supply of water, better water management and more commitment of farmers to irrigated agriculture in Gibe Lemu.

Findings of the study also revealed that the increased income from the sale of crops produced using irrigation has enabled irrigators to invest in household assets. Table3.11 shows that 17 corrugated iron roofed and 9 grass roofed houses were built through income from irrigation. The number of corrugated iron roofed dwellings built in Gibe-Lemu is 3 times as large as Gambella-Terre. In addition, the number of dwellings built by irrigators in the tail-end areas of both irrigation systems was low as compared to the other two water levels.

Figure3.2 comparison of production diversification before and after irrigation in GTSSIS



NB:1=maize,2-potato,
3=onion,4=cabbage,5pepper,6carrot,7=chat,8=coffee,forage,10=sugacane,11=mango and 12-mango

Figure3.3 Comparison of cropping intensity before and after irrigation in Gibe Lemu and Gambella-Terre

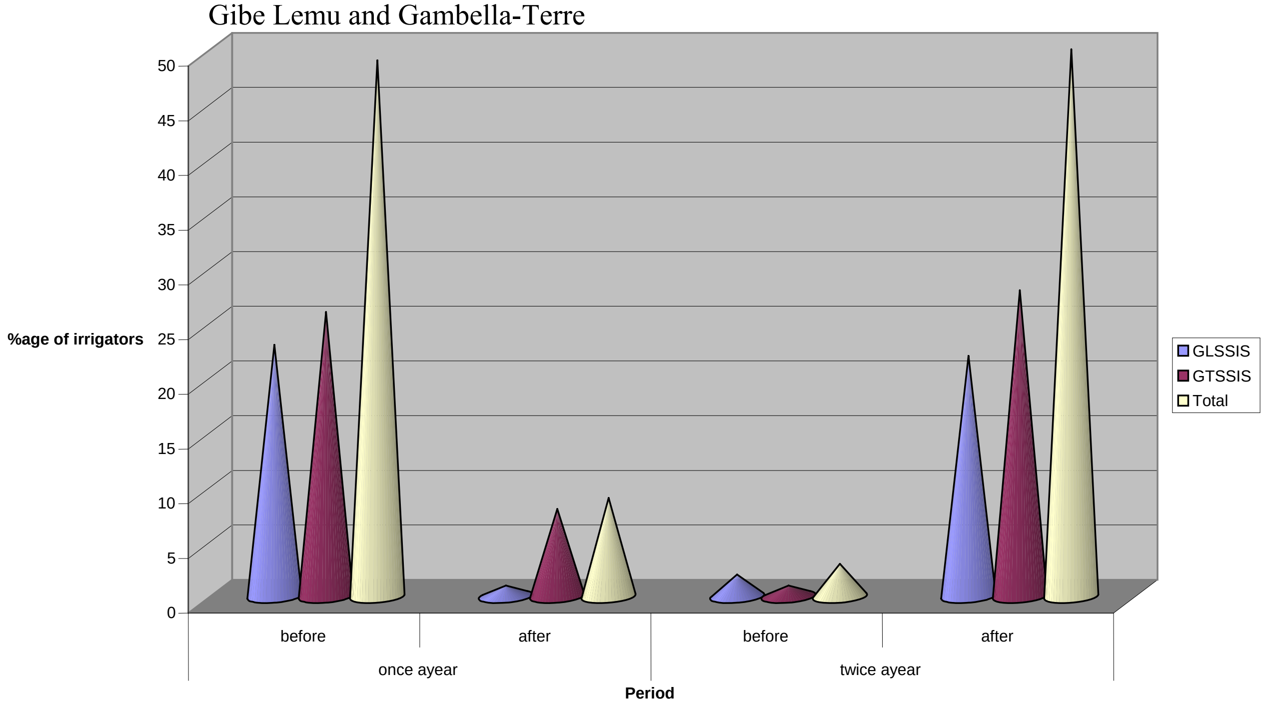


Table3.10 Household net income (Birr) from irrigated agriculture in 2004/05 by irrigation system, location and sex

Name of the irrigation system	Statistic	Location of farm plots				Sex of HHH	
		Head-end	Middle	Tail	Total	Male	Female
Gibe Lemu	Mean	946.23	797	1180	949.1	1011	534
	N	8	9	8	25	22	3
	St. Dev.	1145.9	1141	1727	1327	1396	586.02
Gambela Terre	Mean	394.61	624	276	351	372.16	177.5
	N	13	13	14	40	33	6
	St. Dev.	579.3	509.6	370	484.3	504.62	199.2

F=13.47, P<0.000

Source: Field Survey, Gibe Lemu and Gambela Terre, March-April, 2005

The use of hired causal (seasonal) and permanent labor was low in both irrigation systems as labor is not a major constraint. Irrigation created a limited number, 7 and 218, of employment opportunities (in 2004/05) for causal and permanent laborers respectively (Table3.14). A sum of birr 6705 was paid for seasonal and permanent hired labor (in 2004/05).

Table3.11 Roof materials of dwellings built through income from irrigation

Irrigation system	Roof materials of respondents house	Number and value of houses built			
		Number built (performance)	Value of the houses built		
			Mean	N	SD
Gibe Lemu	Corrugated iron	13	3801	10	2534.512
	Grass roof house	4	346.25	4	57.63
	Total	17	3704.57	14	3462.31
Gambella-Terre	Corrugated iron	4	4975.4	4	3386.62
	Grass roof house	5	380	5	164.32
	Total	9	2422.22	9	3190.52

Source:

Table 3.14 Employment impact of irrigation and cash paid for laborers in 2004/05

Description	Statistic	**Over all**		**GLSSIS**		**GTSSIS**	
		N	Cash paid (average)	No of laborers	Total cash paid	No of laborers	Total cash paid
Permanent labor	Sum	7	2805	3	1205	4	1600
	Mean	1	467.5	1	401	1	533.33
	N	7	6	3	3	4	3
	SD	-	382	0.00	288.67	0.00	166.04
Causal labor	Sum	218	3900	38	3330	180	570
	Mean	19.8	433.33	6.33	832.5	36	114
	N	11	9	6	4	5	5
	SD	38.2	970	11.62	1445.5	53.55	166.34

Risks to Feasibility and Sustainability of Irrigated Agriculture

The average plot size farmers allocated for irrigation occupies only a small portion while the land allocated for rain-fed agriculture represents the lion's share in Gambela Terre (appendix table4); implying farmers in Gambela Terre are committed less to irrigated agriculture. In addition, the actual irrigated area was small compared to the potential (150ha) and it has continuously been declining during 2001-2004/2005 (table3.15). Irrigation has totally collapsed in tail-end area that constitutes more than 53% of the total command area.

Table3.15 Estimates of actual irrigated area (ha) and its trend, 2001-2004/05)

Irrigation system	Irrigable land (ha)	Irrigated area (ha)							
		(1994) 2001/02		(1995) 2002/03		(1996) 2003/04		2004/05	
		Area (ha)	% of total	Irrigated area	% of total	Irrigated area	% of total	Irrigated area	% of total
Gibe Lemu	113	76.05	67.30	80	70.80	78	60.02	80.0	70.80
Gambela Terre	150	58.5	39	56.75	37.83	69.5	52.4	48.27	32.18
Total	263	134.55	51.16	136.75	52	130.4	49.58	1324	48.77

Source: Gobu Seyo District Irrigation Desk (GSDID)

The impact of irrigation projects on diversified and intensive irrigated horticulture and increased production not maintained for long for investment in these crops has become a risky business due to frequent crop failures. In Gibe Lemu and Gambela Terre, 92% and 84% of the sample households have faced crop failure. Hence, the majority of irrigators do not plant their irrigable plots to these fast growing vegetable crops regularly. They shifted to perennial tree crops such as: a) Sugarcane, chat, coffee and banana, in Gibe Lemu, b) Coffee, chat, 'Gesho', mango in Gambela Terre and to cereal production (mono-cropping) under rain-fed. Results of trend estimate revealed the actual irrigated area of the major vegetable crops (potato, tomato and chile) and maize has increasingly become shrunk during 2001/02-2004/05, while the area planted to perennial crops such as sugarcane and coffee had been increasing in Gibe Lemu (Figure3.4). In Gambela Terre, irrigated area of maize and chile had been declining; while irrigated area of sugarcane and coffee was increasing during 2001/02-2004/05 (figure3.5).

Farmers' perception and ranking of cause shows that water shortage, unreliable access to water and prevalence of vegetable diseases (Due to lack of adaptive seeds of crop varieties and knowledge of irrigation agronomy) were the prime constraints that threatened irrigated agriculture and dictated the change in cropping pattern (Tables3.16). Water is unpredictable and scarce due to

Figure3.4 Estimates of the trend in irrigated area of major crops in GIBE LEMU, 2001/02-2004/05

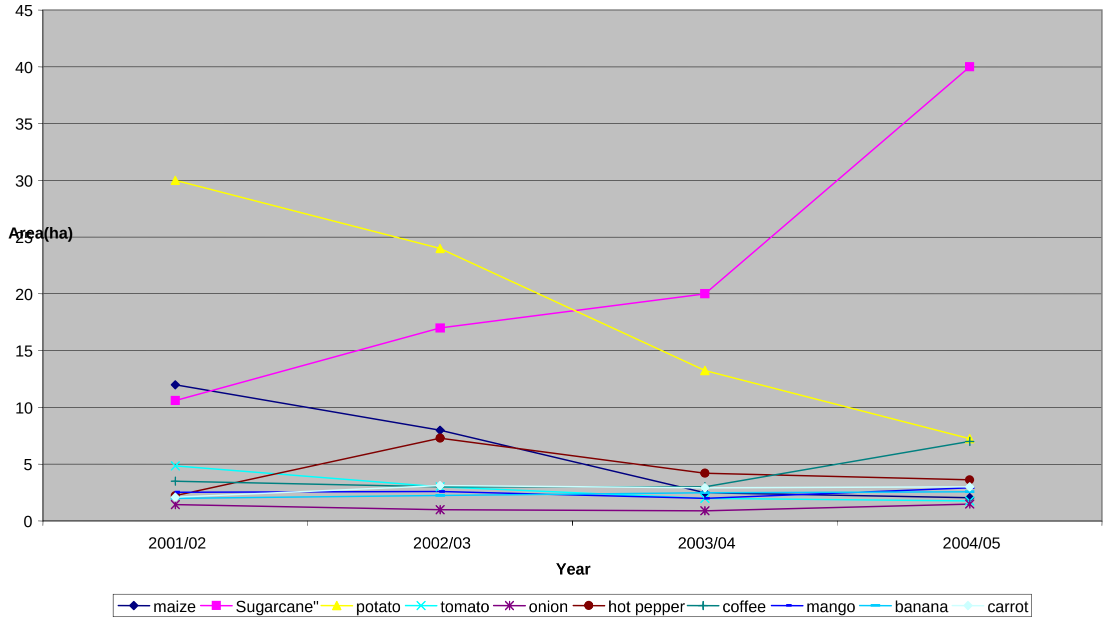
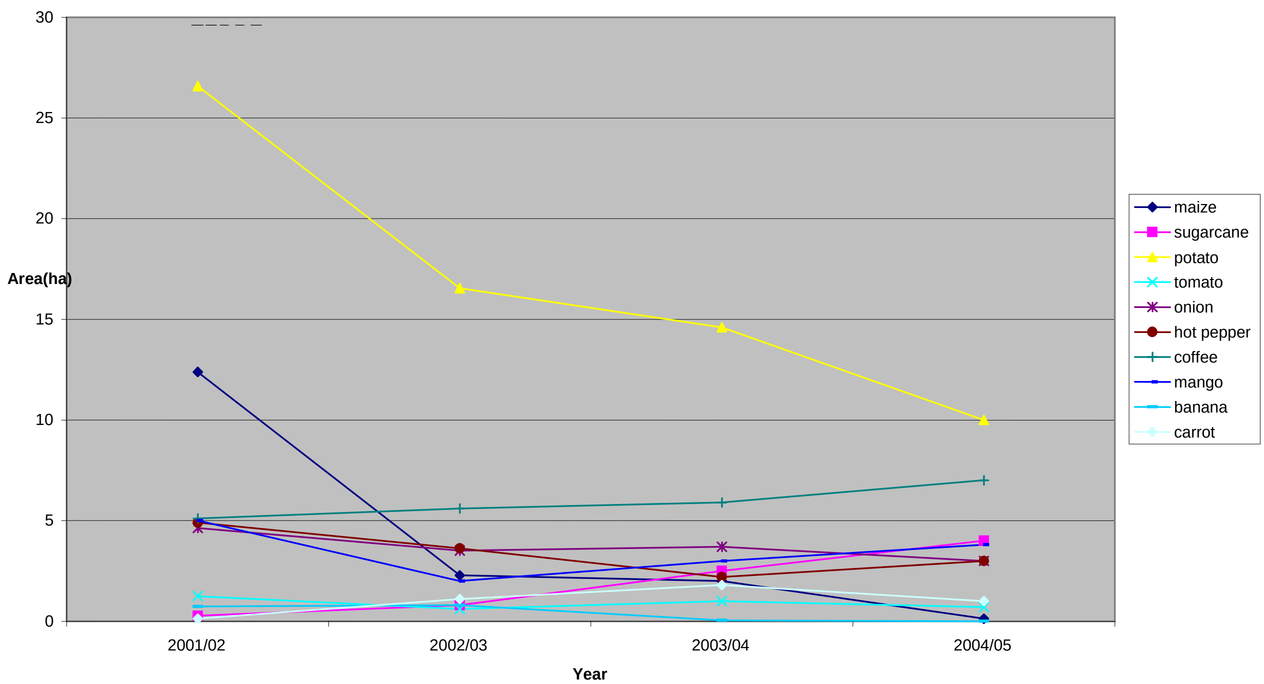


Figure3.5 Estimates the trend in irrigated area of major crops in GAMBELA



due to problems embedded in water management, definition of water rights, enforcing group-based rules and social relations among water users and decline in the amount of water from the source (hydraulic problem). Results of similar work by Alula (2001) also showed that unreliability of water supply and increased interval between watering of plots due to scarcity and poor ware management, affected the type of crop that could be grown, even apparently limiting the practice of vegetable production.

Table3.16 Farmers' ranking of the reasons for under use of their irrigable land

Statistics	Water scarcity	Unreliable access to water	Shortage of labor	Vegetable diseases
GLSSIS N	7	9	4	6
% of farmers	28	36	12	
Rank	2nd	1st	4th	3rd
GTSSIS N	18	12	5	10
% of farmers	45	30	12.5	
Rank	1st	2nd	4th	3rd

Source: Field survey

Double cropping has been less feasible and unsustainable more in Gambela Terre. In addition to the gap in institutional development and support system and management and water scarcity problems, the various groups of informants reported that double cropping is less feasible owing to the following socio-cultural problems in the area:

- Farmers have limited or no experience in irrigation before arrival of the new project. Almost all (97.5%) of them own large area of rain-fed land as an option. It was initiated primarily to promote the collectivist interest of the Derg;
- The second problem was incompatibility between the new cropping pattern and the indigenous cropping pattern and the projects growing season and farmers' growing season despite the fact that compatibility is one of the social requirements for successful irrigation. Maize planted shortly after harvesting vegetable crops is affected by disease owing to the short time frame between harvesting of vegetable crops and planting maize, and lack of cropping sequence studied and specifically recommended for the irrigation system. Horst (1998: Woldeab, 2003) and FAO (1986) also write, 'incompatibility between the project cropping pattern and farmers' cropping pattern could lead to underutilization of irrigation water'
  - A culture of open grazing during the dry season in Gambela Terre; Crop damage from livestock discouraged interested farmers to engage them selves in irrigated farming.

Conclusion and Suggested Policy Options

The study used the socio-technical approach to irrigation technologies as conceptual frame in examining institutions, management practices and challenges. The following conclusions are drown from findings of the study using the theoretical notions like context, social requirement for use and social effects:

4.1. Although it is relatively better in Gibe Lemu, there was poor record of accomplishments in water management in terms of adequacy, timeliness and equity in the supply of water, conflict management and system maintenance. Access to adequate and reliable irrigation water is more unlikely if the farmer's irrigable plot is in the tail-end area (more serious problem in Gambela Terre). It was mainly because of the lack of the social conditions (Social requirements) of possibility for successful irrigation. The main irrigation agency has weak management capacity to support WUA management of irrigation although it is a necessary condition for efficient and lasting irrigation management. The WUAs are not properly organized to run irrigation management. Users have problematic social relation. Enabling legal systems of land water rights institutions are non-existent at the operational level. Efforts of stakeholders were not harnessed in irrigation administration. These problems in turn have drastically affected management and utilization of the developed resources. Therefore, policies for future investment in smallholder irrigation development and for rehabilitation of the irrigation systems considered by this study should give due consideration to averting these problems.

4.2 Sustainable water rights of users not ensured in the irrigation systems. Water dispute (internal and external) is a major and undressed problem in both irrigation systems. It could no be addressed only through the general constitutional choice rule and the informal bylaws of water users. The problem is found to be very complex and beyond the capacity of users' organizations and local and village level administrative and legal entities. The major constraints are 1) there has been no enabling legal system (operational regulations) both at District and grassroots levels which clearly define the water rights of downstream and upstream users and rules which govern construction of new diversions; and 2) lack of clear definition of responsibilities (who should do what) for dealing with the problem. To ensure sustainable water rights of irrigators, facilitate shared use of water by downstream and upstream users and improve water management there is an urgent need for creating formal operational regulation.

4.3. Such technical resources as improved seed (technology) that is adaptive to the situation of irrigation and knowledge of irrigation (extension service and capacity building for irrigators) have not been met. This problem has been a major impediment to feasibility of irrigation. Therefore, policies for input supply, technology development (agricultural research) and rural extension have to be adjusted to meet these requirements of irrigated agriculture in the irrigation systems.

4.4. In spite of the lack of strong system management, water scarcity and unreliability and organizational and institutional problems, acceptable commitment of farmers was observed and the impact of the implemented SSI on farmers' livelihood was also relatively higher in Gibe Lemu. This could possibly be due to market stimulus (access and the good commercial opportunity at Bako Town), shortage of adequate rain-fed land and the problem of landlessness, experience and interest of farmers in irrigation and the role of irrigation in the life of farmers. This shows that irrigation should find its appropriate socioeconomic and institutional location to work effectively. The policy implication is that:

- Small-scale irrigation should be promoted where it is most demanded; and;
- Farmers' priorities and interest, compatibility of irrigation to the socio-cultural environment and farming system of the area and the opportunities (cultural, institutional, economic) for irrigation should be understood before intervention.

4.5. Irrigation has been a success in the first few years of project implementation. It has positively contributed towards increased diversification and intensification of production and livelihood improvement. Nonetheless, many farmers, what Engel (1997) and Mollinga (2003) call `the human agents` did not maintain these practices for long. They, do not practice irrigated vegetable production regularly, discontinued it, shifted to perennial tree crops or returned to the former cereal/mono-crop production under-rain-fed. The constraints that discouraged farmers participation were among others institutional and organizational weaknesses that led to poor irrigation management or the lack of what Engel (997) calls `the social organization` to coordinate and manage the irrigation systems. Therefore, adequate institutional and organizational development is crucial to enhance effectiveness of irrigation promotion and to ensure sustainability of the benefits of irrigation and the irrigation systems.

4.6. Expansion of traditional irrigation in the upstream areas of the rivers that are water sources for the schemes is a major threat to sustainability of the irrigation systems. There has been continuous decline in the quantity of water conveyed into the schemes. This led to progressive degeneration and collapse of irrigation in the tail-end area of Gambela Terre, covering more than 53% of the command area. Therefore, there is an urgent need for addressing the problem through establishing and enforcing the necessary institutional/legal framework.

4.7. One of the major factors for underperformance of the Gambela Terre SSIS is water scarcity. Therefore, future fate (sustainability) of the scheme should be determined through detailed hydrological study on the water source before embarking upon any investment aiming at rehabilitation of the irrigation system.

4.8. In nut shell, change to sustainable diversified irrigated agriculture and to double cropping not met in both irrigation systems. The challenges and sustainability constraints that need urgent intervention through developing and enforcing appropriate institutional support systems at all level, from the apex and grassroots levels, include:

1. Institutional and management limitations that led to scarcity and unreliability of water
2. Prevalence of vegetable diseases because farmers have not regularly been supplied with improved and adaptive seeds of vegetable crops that work under irrigation; because extension service and in put supply policy is biased both in terms of supply and timing of supply to rain-fed agriculture. It is not adjusted to meet the requirements of SSI at the grassroots level (the role of policy)
3. Expansion of traditional irrigation in the upstream areas of the rivers that are water sources for the schemes leading to water scarcity in the schemes. Nevertheless, there has been no enabling legal framework that facilitate the shared use of water by the two groups
4. Weak institutional capacity of the local state irrigation agency to support decentralized management of SSI
5. Weak linkage among stakeholders of SSI management both at the District and scheme levels;
6. Problem of social incompatibility between the new cropping pattern and the indigenous cropping pattern and between the projects growing season and the indigenous growing season (in Gambella Terre)
7. A culture of open grazing during the dry season in Gambela Terre

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APPENDIX

Tables

Appendix table1 Water users' opinion about water distribution by irrigation system and location of farm plots

Item	Response (yes/No)	%age of water users giving the opinion by irrigation system and location							
		Gibe Lemu (N=25)				Gambela Terre (N=40)			
		Head	Middle	Tail	X2-Stati.	Head	Middle	Tail	X2-Stat.
Enough water is obtained	Yes No	12 20	8 28	- 32	1.32NS	7.5 25	2.5 30	- 35	10.6**
Water is received when needed	Yes No	16 16	8 28	- 32	4.5NS	15 17.5	5 27.5	- 35	9.8**
Water distribution is equitable	Yes No	16 16	- 36	- 32	5.5*	12.5 20	5 27.5	- 35	9.6**

Source: Field Survey, NS= Non-significant, *= significant at P<0.1, **=Significant at p<0.005

Appendix table2 Major crops cultivated, estimates of irrigated area and trends (2001/02-2004/05), Gibe Lemu and Gambela Terre SSIS

DESCRIPTION OF CROPS GROWN	Irrigated area in ha (2001/02-2004/05)							
	GLSSIS				GTSSIS			
	2001.02 (1994)	2002/03 (1995)	2003/04 (1990)	2004/05 (1997)	2001/02 (1994)	2002/03 (1995)	2003/04 (1996)	2004/05 (1997)
MAIZE	12	8	2.5	2.06	12.38	2.28	2	0.125
SUGARC	10.60	17	20	40	0.27	0.8	2.25	4
POTATO	30.00	24	13.25	7.24	26.58	16.55	14.60	10
TOMATO	4.85	3.5	2	1.76	1.25	0.61	1.00	0.7
ONION	1.44	1	0.90	1.50	4.64	3.51	2.00	3.00
PEPPER	2.22	7.3	4.21	2.05	7.33	3.63	4.21	1
COFFEE	3.50	3.00	3	7.01	5.11	5.60	5.92	7.00
PAWPA	4.00	-	0.5	0.12	0.08	0.05	0.03	-
MANGO	2.52	2.6	2.92	2.92	5.00	2.00	3.3	6.50
BANANA	4.00	3.12	2.93	3	0.74	1.8	1.20	1

Source: Gobu Seyo Wereda Irrigation Desk

Appendix Table3 ANOVA of household net income from irrigation in 204/05

		Sum of squares	df	Mean square	F	Sig.
Amount (Br.)*irrigation sys*location	Between groups (combined)	13570199	1	13570198.64	13.47	0.000
	Within groups	1.51E+08	150	1007749.71		
	Total	1.65E+08	151			
Amount (Br.)*irrigation sys*Sex	Between groups (combined)	13570199	1	13570198.64	13.47	0.000
	Within groups	1.51E+08	150	1007749.71		
	Total	1.65E+08	151			

Appendix table 4 Average land holding by type of use

Type of use	Average plot size per household					
	Gibe Lemu			Gambela Terre		
	Mean	N	SD	Mean	N	SD
Total land size (ha)	2.54	25	3.05	3.16	40	1.77
Irrigable area	1.08	20**	0.72	0.72	39**	0.99
Area under rain-fed	1.57	25	1.73	2.5	40	1.27

Source: Field survey, the sign `**` implies the rest sample irrigators (five in Gibe Lemu and one in Gambela Terre) do not have own irrigable land

Appendix Table5 Vegetable growers who faced crop failure, by irrigation system and location of plots

Irrigation system	Do you grow vegetables every year using irrigation? (%)		Ever faced problem of crop failure (Yes/No)			
			All HHs	By location of farm plots (%)		
				Head-end	Middle	Tail-end
Gibe Lemu (N=25)	Yes	8	92	24	36	32
	No	92	8	-	4	4
Gambela Terre(N=40)	Yes	77.5	84.2	26.3	26.3	31.6
	No	20	15.6	10.5	5.3	-

Source: Field survey

Water Rights and the Processes of Negotiations among Irrigators in West Shewa Zone: The Case of Indris Scheme in Toke Kutaye District

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Abstract

Though water rights are at the core of exploiting water resources for irrigation purposes, trivial concerns were offered to the case of Indris irrigation scheme in Toke Kutaye district in West Shewa. The historical background and development of the scheme has been presented in a contentious manner. The augmenting number of competitors too paved the way for conflicts that recurrently erupt out and inevitably lead to a succession of negotiation processes. With the inception of such missing gaps, this research aimed to scrutinize water rights and the processes of negotiations among irrigators along Indris modern scheme, in Toke Kutaye district. To maintain this objective, qualitative research methods were predominantly utilized as the main data generating tools in the field.

The findings of the research depicted that Indris scheme marked three significant phases in its historical development. In these phases, explorations pertaining to water rights and processes of negotiations were found to be at their immature ground. While the elements of the riparian doctrine of water rights preponderated during its initial phase, the components of appropriative doctrine pronounced more at its middle age. A mix of ingredients from both doctrines interwoven with certain extra requirements determined the water right access of users since the conversion of the scheme into a modern style. Multiple water right rules emanating both from the customary and formal water acts have co-existed to direct the actions of users. In this regard, the theoretical orientations of legal pluralism in water right paradigms proved to coincide with the pragmatic contexts of water users from the scheme.

Conflicts in connection to irrigation water use and rights that have escalated over

Years have been attributed to the decline in the volume of water resources, institutional failures to address the causes adequately, week observance on governing water right rules and increasing demand of users. As a result, negotiation processes aiming to settle disputes were repeatedly initiated either by users, committee members (elders) or courts. The procedures pursed to narrow competing interests around the scheme confirmed the pragmatic applicability of the central arguments of both cyclical and developmental models of negotiation processes discussed comprehensively by Gulliver.

Thus, in the face of increasing demands on a declining water resource, the findings of this research revealed out that concerned individuals or relevant institutions need to exert further endeavor on the formulation of water policies that clearly stipulate specific irrigation water entitlements of users. Enforcements on the frame of references set on the water manual need to be rigorously checked on practical implementations. Awareness buildings on irrigation water right claims, promotion of negotiated approaches in disputes and accentuation on customary rules of resource use constituted the dimensions seeking meticulous considerations in prospect.

Introduction.

Ethiopia being predominantly an agricultural country, half of the GDP, close to 90% of export earnings and about 85% of people's livelihood sources has come from agriculture (CRDA, 1994:20). Irrigated agriculture, complementary to the conventional rain-fed agriculture, has a history of more than one century in some parts of the country

(Dessalegn, 1999: 10; Woldeab, 2003:25). Some indigenous schemes are said to have existed since the reign of Menelik II (National Irrigation Policy Discussion Paper, 1990:2).

The impulse to promote irrigation schemes has been triggered by the recurrently occurring droughts and worsened food insecurity situations (FAO, 2005). Tsegaye (1991:2) elicited though irrigation developments were taken to be among optional mechanisms to cope up with the prevailing poverty conditions, productivity through such systems has failed to meet the anticipated targets being constrained by multiple factors. Studies by Mokonnen (1992; FAO,1978; Lemma,1994) for instance indicated, mismanagement of irrigation practices could result in the problem of disputes, soil salinity, water logging, canal seepage and expose people to various diseases.

In West Shewa Zone of Oromiya regional state where this research endeavored to scrutinize water rights and the processes of negotiations, several irrigation schemes operate both in indigenous manner and application of modern irrigation technologies. Indris modern irrigation scheme is among the scaled up ones and located at a distance of 2 Km south of Guder town. Initially, the scheme had been operating in an indigenous manner. It was promoted into modern system completely in 1986 E.C by the financial assistance of European Economic Commission.

Despite access to water rights and processes of negotiations over irrigation water constrain the development of the practice in several regards; these concepts have been overlooked greatly by scholars or any other relevant institutions. In the case of this particular paper, problems stemming from three dimensions are apparent and do override in connection to Indris modern irrigation scheme. On the first place, insignificant searches have been made on the historical development of the scheme. Even the prevailing data regarding its historical background were not only scanty but also presented in a contentious way among the water users themselves. Secondly, what rests at the core of each resource exploitation constitutes issues of the right to hold it permanently use or transfer to the other party. The third dimension hold a concern with the competing nature of users over irrigation water, associated conflicts and the successive chains of negotiation processes held to evade disputes. All the aforementioned dimensions have not been investigated around Indris modern irrigation scheme located in Toke Kutaye district of West Shewa Zone.

Therefore, the main objective of the paper is to examine water rights and the processes of negotiations among irrigators diverting water from Indris scheme located in Toke Kutaye district of West Shewa Zone. It also specifically looks at:

- The stages in the historical background and development of Indris modern scheme.
- The nature of water rights and processes of negotiations prior to and post of 1986 E.C.
- The rules and by-laws that govern water use rights, distribution and management aspects.
- How decisions and negotiations have been made for water access and rights in light with interactive factors like gender, economic status and power.
- The significances of water right negotiations for users (in relation to livelihood improvement).
- Highlight conflict settlement mechanisms adopted by water users.

To address the above stated objectives and keep narrow the missing gaps in the three thematic dimensions noticed around the scheme, a qualitative research method was employed to gather first hand data. Hence, interviews, observations, and focus group discussions constituted principal methods in the field work. The application of all these methods makes it easier to triangulate and cross verify the generated data. To visualize certain themes with deeper insights at their naturalistic settings in the field, photography has also been used. As a whole, 53 (fifty three) persons were contacted fro interviews and 21(twenty-one) individuals took part in the focus group discussions.

Secondary sources including books, journals, research papers and official records were reviewed to substantiate the data obtained through primary means.

Thus, the primary data interpreted in this research was generated through a field work that covered a period of time ranging between March 06-07-1999 E.C and April 03-08-1999 E.C over 30 days. Preceding the main field work, preliminary field visits were made twice during the months of December and January 1999 E.C. At that state, legality to field entry and creation of rapports with district agricultural workers and few committee members were assured. On the first preliminary field visit, the surroundings of Indris modern scheme was observed. In the second round, the potential research settings were marked out and visited.

Description of the Study Settings.

Toke Kutaye district constituted one of the 21 Weredas in west Shewa Zone. It is a newly established district for administrative purposes being as a sub division of Ambo district. Guder, some 12 kilometers west of Ambo town, serves as the chief socio-economic, administrative, political and cultural capital of the district. It is situated at a distance of about 137 kilometers away from Addis Ababa on the Addis Ababa-Nekemte main road.

The district has a total area of 78,886.77 hectares (which is nearly about 788.88 in Sq Kilometers). Out of the total land only 1,384.8 hectare has been under irrigated agriculture (Strategic Planning and Management document of Toke Kutaye district, 1999:10).

The climatic situation of the district is categorized into three major divisions: the cool, the warm-temperate and the hot. These climatic divisions cover 20.99 %, 51.31 % and 27.7o %, respectively. The selected peasant associations and specific research sites chosen for this research fit in to the warm climatic division (Ibid, 1999: 14).

The rainfall distribution is bimodal. While the dry season normally lasts from the months of October to February; the main rains are received from May to September. The highest concentration of the rain falls during the months of June to August. At this season, irrigation activities have declined and the rain fed agricultural productions preponderate instead of it. As a result, the water flowing through the ditches blocked back to the main river.

As computed against its years of foundations (legendary sources trace back as far as to the last decade of 19th century), the over all social and physical infrastructures of the district in general and Guder in particular require an enthusiastic need of integrated efforts. It was reported that sectors like education, health, water supply and sanitation, and communication are components that demonstrated encouraging progresses.

Figures pertaining to the population number of the district should be looked suspiciously. This is because no consistent census has been conducted since the separation of this district from Ambo. Any how, following the separation, the Economic Planning and Development bureau of Toke Kutaye district has initiated a sort of pilot assessment to estimate the total population. Based on the estimated result, the total population residing in both rural and urban Kebeles of the district is about 122,857 out of which males account for 58,828 (47.88 %) and females constitute 64,029(52.11 %) (Economic Planning and Development document of Toke Kutaye district, 1999: 11).

Several ethnic minorities with the dominant Oromo ethnic group co-exist in the district. Official guesses state that the Oromos cover more than 95 % of the ethnic composition. The Amhara, Gurages and few Tigrians do dwell in the district (Economic Planning and Development document of Toke Kutaye district, 1999: 13).

Three chief religions have been apparent in the district: namely Christianity, Islamic and Indigenous (i.e. people's adherence to Waqefaana-believe in one supreme God) Christianity, especially the Orthodox sect has showed a substantial dominance in the area (Ibid: 17).

The economic source of the district depends on agriculture and its produces. Agriculture accounted for more than 90% of the economy of the district. Also, irrigated agriculture covers almost 18 peasant associations out of the 33 PAs in the district. The chief crops produced in the district include Teff, Wheat, Barely, Maize, Sorghum, Beans, and Oil seeds like Nug. Irrigated agriculture generates a significant amount of income from the vegetables and fruits produced at least twice per year (Economic Planning and Development document of Toke Kutaye district, 1999: 23).

To have the bird's eye-view of irrigation practices in the district, indigenous irrigation systems have said to operate since time immemorial in various sites in the district. Information extracted from the district agricultural desk revealed out that a sum of over 25 major and minor rivers have been diverted for irrigation purposes. While there are 6 indigenously operating irrigation sites in the district, comparably the modern ones make up 8 in figures. All the schemes irrigated via indigenous or modern techniques fall below or equals to 200 hectares, except the case of Indris which covers more than 200 hectares. According to Dessalegn's (1999:10) classification of irrigation schemes depending on their size, operation and management; the irrigation schemes pragmatically functioning in the district can be categorized as small scale category while exceptionally Indris modern irrigation scheme falls into the medium scale.

To depict the specific irrigation settings, peasants from 5 PAs (namely Imela Dawo, Dale Dawe, Ajo Bedo, Dhaga File and Kilinto) do divert water for irrigation usages from Indris scheme. Additionally, institutes like Agricultural Training Center, Schools and Hormat Engineering Factory claimed water for irrigation and other usages. Having extensively discussed with committee members, Development workers and experienced elders, the researcher have selected three irrigation practicing villages out of three (3) PAs identified as Selam Sefer, Dhaga File and Kilinto. The Agricultural Training Center was also included in the study as there have been frequent reactions and interactions between the peasants and the training institute. These sites were selected mainly because;

- ✓ The sites constituted upper, middle and lower categories of beneficiaries of Indris scheme. Selam Sefer and the Agricultural Training Centers represent upper users. While Dhaga File forms middle users, Kilinto constitutes the lower beneficiaries of the scheme.
- ✓ These sites have also been potential areas where both Holeta and Bako Agricultural Research Centers conducted pilot demonstrations repetitively.
- ✓ The accessibility of larger concentrations of experienced irrigators in the villages was another justification.
- ✓ Moreover, the selected villages are comparably accessible for transportations. Besides, the villages are well suited for fieldwork to explore deep information as each of them followed a nucleated settlement pattern in their respective localities.
- ✓ Lastly, as a social anthropologist, the social dramas reflected over water use rights and process of negotiations observed among upper and lower sites or between the villages and the Agricultural Training Center created a passionate feeling in the researcher's understanding to offer priorities for these villages.

Review of Literatures and Theoretical Frameworks.

A brief review of the literature on water rights and the processes of negotiations portraying the experiences of certain developing nations would be made in the first part pursued by certain cases in Ethiopia at the last part.

To begin with, socio-anthropological issues are embedded in the operation of all irrigation systems, small or large: people organize socially in order to secure water, transport it, divide into usable shares, enforce rules for its distribution, pay for it and dispose of unused portions (Cernea, 1991: 43).
Vermillion (2000:57) quoting (Arriens et. al 1996; Secker, 1996) asserted that with rising populations and diversified economies, competition for water is rapidly intensified in many developing countries, especially in Asia. Such conflicts over water resources are further aggravated by the social inequality, economic marginalization and poverty (Blank et. al, 2002:113; FAO, 2005:5).

Blank et al (2002:123) explained the multiple sources of conflict over water use in the Upper Ewaso Ng'iro North Basin of Kenya, attributing to causal factors linked with water scarcity, inequitable water allocation and distribution, election of representative water users, failure to observe water by-laws. Water conflicts associated with scarcity are attributed to over abstraction of water in the upper reaches and latent conflicts are attributed to inequalities inherent in social, cultural, economic and political disparities among the stakeholders.

There is a repetitive claim that underlines laws and traditions controlling water use in developing countries are often inadequate, unsuitable introductions, ignored or unenforceable. Fair, rigorous and swift enforcement is important in maintaining or improving adherence to water use laws and rules (Barrrow, 1987: 70).

Many developing countries have non-western legal systems. Reflecting this argument, Blank et al (2002:278) indicated the Kenyan experience presenting that in pre-colonial times, management of water was an integral part of the overall customary laws and behavioral norms of each tribal society. Access to water was guaranteed for each individual by virtue of affiliation with a specific community (e.g. a tribe or clan) and water use was regulated by the political leaders of each community (chiefs, elders, clan leaders).

Bruns and Meinzen- Dick (2000) denoted water rights are not just an analytical abstraction. The term water right is broad including diverse kinds of and levels of rights. Clearing it, Boelens and Davila (1998:87) have discussed water rights as social relationships among humans and not only between the user and the water; thus, they are rooted in the other components of the peasant community's normative system.

Water rights comprise formal rights embedded in official tittles, permits and seasonal irrigation schedules, less formal rights based on customary patterns and rights implicit in social norms and local practices (Bruns and Meinzen- Dick, 2000:28; Cotula 2006: 10). Thus, water rights are considered as legal entitlements for the abstraction and/ or use of water resources. Water rights may also be constructed as contractual rights or may be based on bodies of norms other than domestic legislations-namely customary law (Ibid).

Bruns and Meinzen-Dick (2000: 203) have offered clues on diverse levels of rights in a specific source, such as ownership rights, rights to participate in decision making process (including decisions concerning allocation of water), rights to use without rights to participate in decision making process, rights which may or may not be transferred, rights to use only for a specific season or purpose, individual rights and community rights.

Boelens and Davila (1998:88) presented that in a given region, it is not unusual for several mechanisms to operate simultaneously and it is also common to find mixtures of peasant and governmental mechanisms:

- ➢ Concession of water use rights, granted by the state administration to individuals or groups of applicants;
- ➢ Granting of formal or informal titles over socio-territorial waters by their inhabitants;
- ➢ Agreements for permanent transfer of water rights from one right-holder to another such as in the case of purchase and sale, rental inheritance, barter or gifting;
- ➢ Acquisition of rights and access to water by force; in many regions of the world, power groups have expropriated water by coercive force from peasants and indigenous peoples.

According to Boelens and Davila (1998: 29) there may be multiple bases for water claims. The two most widely recognized doctrines for water rights are based on ownership or possession of land along rivers, streams or over aquifers (riparian rights) and claims based on historic water usage (prior appropriation). The chief features of riparian rights embrace:

- ❖ Gives equal rights of use to owners of land which borders on or touches a stream or across which a stream flows.
- ❖ A riparian right is attached to land ownership - a user can take up the right to use water at any time even if

he/ she had not done so before and to do so affects existing users.

- ❖ The right is usufructuary i.e. the owner does not own the water (the resource it self can belong to the state or some other authority) only the right to use it.

One who enjoys riparian rights, therefore, should receive flows from upstream land owners with out material change in amount or quality and should ensure that down stream owners enjoy the same. On the contrary, according to the appropriative doctrine the first settler or user of water from a stream acquires a right to continue the use of that portion of water needed for the irrigation of his/her land. Prior appropriation rights may be summed up as "first in time first in right"; the earlier appropriator has a right superior to later appropriator.

Meinzen-Dick and Nkonya (2005:5) added that water rights can be broadly classified as public, common, or private property. Public water rights are rights held by the state and in which the government allocates rights to users (the case of Zimbabwe in 1990s and Mozambique 1991 serve as best examples). Common water rights refer to communal water rights where water can be used by people in ways that are specified by some community. In most African customary water law, water is considered as a community property and private ownership of water is not recognized. Private rights are rights held by an individual or corporations. It is generally only use rights that are recognized for individuals to use water in certain ways.

Rights to water may be negotiated in many contexts, not just within communities but also between communities and others sharing water resources. Various strategies may be open to communities including direct action to acquire more water and restrict others' access; litigating in court; participating in planning and other formal administrative procedures; lobbying to advocate their case to the public and politicians; and trying to reach agreements with other water users and with water management agencies are all part of negotiating rules about who gets water (Bruns: 2005: 1).

Negotiated approaches are a subset of the larger set of processes through which disputes are waged. Disputants choose where to pursue their claims, shopping among available forums to deal with water conflicts. Negotiation among disputants can often generate more creative and appropriate solutions than those imposed by a court or agency decisions. Mediations, facilitations and convening forums are among ways in which third parties can contribute more productive negotiation (Ibid).

Generally speaking, Gulliver (1979) wrote negotiations are vital to reconcile conflicts among diverse interest groups over resource use. As he puts it,

> *'Negotiation involves interaction between different claimants, not unilateral decisions made in isolation. It includes sitting around a table to craft an agreement, formal trading arrangements as well as less visible struggle over access to water, as local people comply with or contest the ways in which state agencies or other users acquire and distribute water. Thus, negotiations are processes of interactions between disputing parties whereby, without compulsion by a third-party adjudicator, they endeavor to come to an independent, joint decision concerning the terms of agreement on the issues between them. It proceeds through the exchange of information between the parties. Information is verbal and non-verbal including evidence, argument, appeals to rules and ideology, expressions of strength and proposals of terms for agreement. Negotiation is a continuing process, influenced-but not fully determined-by changes in rules and laws. Thus, agreements may mark major milestones, but usually lead to further negotiation about how the agreement is to be worked out in detail, how to monitor compliances and respond to violations, and whether to revise agreements (Gulliver 1979: 79).'*

Water rights are dynamic, flexible and

subject to frequent negotiations because of uncertain water supply, damages to intake structures, and social, political and economic changes (Meinzen-Dick and Pradhan, 2006). Reflecting this argument, Bruns and Meinzen-Dick (2000: 202), put that farmers in Nepal for example, shop for and use what they believe is the best strategy available to them in a specific situation. The strategies they use depend on the social relations between the stakeholders (such as power, kinship, economic, political) as well as the legal resources they have at their disposal.

In the Ethiopian context, studies conducted on water rights or processes of negotiations over irrigation water have appeared scanty. Furthermore, policies, legislations and rules issued in connection to water rights have also been far from satisfaction.

Yacob (2002) contended that in Ethiopia there does not yet exist a single body of rules pertaining to the use rights of and management of water resources; which holds grains of truth for water competitors in the Waiyto valley of Southern Ethiopia where his study offered a greater focus.

Zewde (1994:88) has also elucidated that there is no extensive legislation covering the use of water in Ethiopia. But, there are decrees that water is a national asset and that it can be controlled only by the central government. Additionally, Studies conducted by (FAO, 2005) reaffirmed that written information on water use is not available.

Ewnetu (1987:1) put that in Ethiopia enacted water rules appeared recently, but prior to this the people were using customarily and even today it is observed in many parts of the country.

Lemma (2004:50) in his part found out that there is no policy in the region as whole that entails about water right and entitlement.

Currently, the Ministry of Water Resources has formulated a water policy embodying the irrigation component both at Federal and Regional level, basing on the Agricultural Development Led Industrialization Policy (ADLI) of the country (MoWR: 1999). While the overall objective of the policy is to develop irrigated agriculture for the production of food and raw materials to agro industries, amongst specific issues the policy emphasized:

1. Ensure the full integration of irrigation with the overall framework of the country's socio-economic development plans, and more particularly with the Agricultural Development (ADLI) Strategy.
2. Promote users based management of irrigation systems taking account of the special needs of rural women in particular.
3. Enhance indigenous irrigation schemes by improving water abstraction, transport systems and water use efficiency.
4. Establish water allocation and priority setting criteria based on harmonization of social equity, economic efficiency and environmental sustainability requirements.
5. Recognize that irrigation is an integral part of the water sector and consequently develop irrigation within the domain and framework of overall water resources management (Ibid).

At Oromiya regional state level, a proclamation (No.30/1999) is enacted in order to reinforce the tasks of the Oromiya Irrigation Development Authority. In the proclamation, the duties and responsibilities to be assumed by the authority with regard to how best to confiscate water by users are some how indicated. Accordingly, under article 6 (powers and duties of the authority) number 1 of the proclamation reads as: initiate and submit policies, strategies, laws and regulations of the authority.

Offering a comprehensive analysis, McCornick and Seleshi (2004) have remarked on *'Water use rights in Ethiopia'* correlating with the policy environment as follows:

> *"The relevant policy and legislative framework must continue to be strengthened and allowed to evolve to accommodate the indigenous arrangements and established water-rights, and meet the new demands. The recent improvements in the national*

water policy framework has established the necessary foundation, and there is some evidence that communities are playing a more active role in the decision making with regards to allocation and management of water at the local levels, allowing for better integration of indigenous water rights and management systems (McCornick and Seleshi, 2004:8).

To wind up Ethiopia's experience regarding irrigation water rights, studies that elicited irrigation water entitlements and negotiations over it like Indris modern irrigation scheme were missing.

Theoretical Frameworks.

The central arguments of legal pluralism and processual models of negotiations were utilized as the theoretical tools to analyze water rights and the processes of negotiations at Indris modern scheme, respectively.

Legal Pluralism.

Legal pluralism begins from the recognition that multiple legal and normative frameworks coexist. The paradigm of legal pluralism has important consequences for the conceptualization of the relationship between norms and behavior. It depicted the perspective of people's experience with water access and control in which individuals draw up on a range of strategies for obtaining irrigation water. Thus, government, religious, and customary laws, development project rules, and unwritten local norms may all address who should receive water, from which sources, for what purposes (Burns and Meinzen-Dick, 2000; Meinzen-Dick and Bakker, 2001).

Therefore, the conceptual frame work of legal pluralism became indispensable in view of contemporary water rights paradigms. It aimed to explore the different conceptualization of water and water rights and the variety of legal statuses attached to water (Ibid).

Processual Models of Negotiation.

Negotiations involved two distinct though interconnected processes going on simultaneously: a repetitive, cyclical one and a developmental one. The cyclical process comprises the repetitive exchange of information between the competing parties, its assessment, and the resulting adjustments of expectations and preferences while the developmental process involved the movement from the initiation of dispute/ conflict to its conclusion leading to some outcome with its final implementation (Gulliver, 1979: 82)
Hence, the elements of the processual models were chosen to be instrumental to analyze the processes of negotiations that water users apply to settle conflicting interests while diverting irrigation water in the study localities.

Ethnographic Accounts: Findings and Results of the Research.

Historical Background of Indris Scheme: Phases of Irrigation Development.

The investigation on the historical background of Indris scheme demonstrated its development in three distinctive stages; pre-conditions in the initial phases (prior to 1972 E.C), operations in an indigenous manner (extending from 1972-1986 E.C), and complete conversion into modern style (post 1986 E.C).

In the first phase of irrigation development around Indris river, as confirmed by the participants of the focus group discussion held at Selam Sefer, the practice was introduced alongside with the introduction of the Grinding Mill technology and essentially characterized as;

- Production was only to complement household consumptions. That connoted market orientation was quite negligible.
- The practice was carried out on small pieces of land (confined only in their gardens) by few households alone.
- The vegetables and fruits planted were limited in variety.
- The involvement and advisory support of external institutions like the agricultural desk had

been missing.

In the second phase, the completion of digging the web of canals and building up the indigenous dam that in fact lasts only during the dry season marked a momentous shift in the historical development of the scheme in numerous respects. To portray the highlight of some;

- Remarkable increase in the number of water users (250 HHs).
- Incorporation of larger hectares of land under irrigation practice (about 180 hectares at its upper limit).
- Use of irrigated produces both for domestic consumption and market supply.
- Formulation of agreed up on by-laws with the technical assistance of agricultural workers and other officials from the desk. In the first phase of irrigation development, certain tacitly perceived normative rules emanating from the broader customs of the society had guided the actions of water users. Thus, such sorts of implicit normative rules were transformed into more or less written rules being interwoven with certain fragmented elements of the prevailing irrigation guidelines.
- Developed the custom of irrigating twice per a year which was not formerly patterned in the first phase.
- Institutions like the Agricultural Training Centre began to divert water as its second best alternatives. Previously, the institute used to divert a substantial amount of water from Chole River.

Along with the significant progress that accompanied the scheme's development, water users have also internalized the wide-ranging worth of irrigated farming. The compounded effects of these great changes and the increasing recognition by practitioners, created the motive for the transformation of the scheme into its third phase i.e. from indigenous scheme to modern system.

Principally, the increasing demand from the framers side and the discharging capacity of the indigenous scheme on the other hand happened to be inconsistent to meet the interests of the drastically growing population. The gap grows wider pertaining to the gradual decline in the volume of water. As a result the water users, the district and zonal irrigation bureaus as well as the Agricultural Training Center initiated a proposal to scale up the working capacity of the scheme. Amongst organizations requested, it was the European Economic Commission (EEC) that showed practical interest to donate(3.5 Million Birr) for the construction of the modern dam that took over 2(two) years. Prior to the involvement of EEC, countless efforts were in place to build up the dam in relatively strong way to function for longer durations than the indigenous manner.

The transformation of the scheme into modern operation has induced further developments besides those noteworthy moves formerly attained. Through the discussions held with the agricultural development agents, the following points were obtained:

- ✓ The command area has grown to cover 7-8Kms. In its indigenous operation, it was managed to reach users within limited radius from the source, perhaps not more than 4-5kms away from the main source. Only sites closer to the main canal got irrigation water sufficiently. Thus, the conversion of the scheme augmented the command area by at least 2-3kms.
- ✓ The scale of the scheme grew from small to medium range. It was about 180 hectares (categorized as small scheme) of land covered through indigenous irrigation techniques that stretched to incorporate about 381 hectares (categorized as medium scale) of land in its current state. The numbers of water users have also increased from 250HHs to 1020HHs as a result of opportunities secured in connection to the promotion of Indris scheme.
- ✓ The need to apply environmentally sound and scientifically proved varieties escalate based on the calculations to gain satisfactory benefits.
- ✓ The institutional capacities and management systems of irrigation water became to be handled by Indris Water Users Association (WUA). The association was formed with the mandate to operate since the aftermath of the transformation of the scheme. Problems

interlinked with water scheduling, water misappropriations (in the form of theft, seepages or salinity) received more concern in an integrated approaches since the promotion of the scheme.

- ✓ Irrigation production (fruits and vegetables) inclined to focus on market orientations. In this third phase, production for market supply outweighed household consumption.
- ✓ Water users' dependence on irrigation practice augments across the three villages. The majority of them were reluctant to engage in the practice in former phases of irrigation development.
  - ➢ A slight modification to the naming of the scheme was also another development with the promotion of the scheme. The indigenous diversion was named after the name of the river itself i.e. Indris. The intent behind the new naming has stemmed from irrigators' exclusive dependence on the water diverted from the river. On a meeting of the general assembly, which is of course the highest decisive body; it was reached a consensus to name the scheme as 'Indris Fayiissa' literally mean Indris our savior.

Indris Modern Scheme: constructed with 3.5 million Birr donated by EEC.

Basing on discussions held with the agricultural development workers and irrigation experts pertaining to factors that impeded the development of Indris scheme, state of affairs described below were extracted;

- o The policy environment regarding irrigation schemes lacked strong basis. Dearth of specific directives and guidelines on pragmatic implementations represents one instance.
- o Lack of support on financial and technical skills had also their contributions.
- o Institutional weaknesses prevailing at the three stages of the scheme's development was another constraining factor. Nearly in all circumstances institutional matters were either taken for granted or deliberately overlooked as if it could pose only miniature effects.
- o Conflicts of diverse nature (among water users themselves in their vicinity, water users of upper groups against lower reaches, or between water users and other claimant institutes) somehow lingered the developments relating with Indris scheme.

Therefore, interplay of factors both from within and outside the irrigation system has interacted to induce these encouraging changes. Above all, the internal motives of water users striving for betterment on water resource extractions interwoven with the financial donation of European Economic Commission played pivotal role to attain its current state.

Intricacy in the chains of structures and institutions involved in the management, allocation and distribution of water have moved from a state of simple operations to the level of sophisticated webs of networks directed by the frameworks of Indris Water Users Association. The general assembly of users took its ultimate power to provide decisions for the pragmatic allocations and distributions of water via the committee functioning at three levels: Executive, Gooxii (territorial level) and Garee (team level).

Water Rights among Irrigators in the Study Area: Basics for Decision and Access.

The basics for water right access and decision have enjoyed a broader spectrum of considering land rights, historical precedence/settlement in the area, financial as well as labor requirements to be maintained by users. At a time the irrigation practice commenced in the area, land rights or possessions had been considered as a factor to enable users' access to irrigation water. This signified and coincides with the elements of the riparian water right doctrine. In the second phase of the scheme's operation in an indigenous manner, historical precedence and settlement in the villages had predominantly served as a parameter to decide and secure users access to irrigation diversion on top-of land rights. With the conversion of the scheme into modern style, the decisions to admit or deny users for irrigation water rights rest on and determined through their labor contributions and fulfillment of obligations imposed by the general assembly. Water users were also noted to employ a mix of techniques for creating access to water rights in the form of sharecropping, purchase or contractual arrangements through negotiated approaches.

Informants in the three research villages have denoted the most essential factors that should be considered basics for access and decision since the conversion of the scheme into modern style:

i. The applicant should be above 18 years old and establish his/her own family.
ii. The applicant should have a well defined residence in the PA and be registered as a member of the WUA of Indris scheme.
iii. The water users need to own not only a land but also make sure that a portion of the land has to be suitable for irrigation.
iv. To reinforce their water rights access, users have to meet their obligations which are clearly incorporated on the water use manual. The obligations to be maintained by water users at the fore front encompass.
   a. Respect and materialize the by-laws of the WUA:
   b. Entire utilization of potentially available irrigation plots.
   c. The members of WUA are obliged to conduct canal cleaning and maintenance once or twice a year.
   d. Timely completion of financial fees: the obligation to timely pay their financial fees constitute among compulsions imposed on water users. The financial payments expected from water users basically comprises of;
      - ✓ Taxes collected by administrative structures depending on the total hectares of land holdings.
      - ✓ Payments aiming to compensate services rendered by distinct institutions like credit and saving services.
      - ✓ Payments imposed on water users as a punishment in recognition to their disobedient acts against the WUA by-laws.
      - ✓ Annual fees collected from water users for maintenance and operations.
   e. Safeguarding the scheme and any other assets of Indris WUA.
   f. Attendance and participation on meetings.

Certain interlocking factors do shadow the water rights of users. To outline few:

- When the scheme functioned in an indigenous manner, water right issues were not as such perceptive. As a result, the inclinations of the agricultural desk as well as water users were far from addressing themes on water rights. It has been with growing conflicts, dialogue and violation of rules that water rights got an increasing concern.
- Diminished endeavor on the enforcement of by-laws of the WUA. The poor application of directives stated on the manual made their implications to carry insignificant effects.
- The dynamic nature of water rights; the basic dimensions considered to access irrigators' water right have not been fixed. Access to land rights fundamentally determined users' water right during the initial phase of the scheme's development. This was accompanied sooner with the questions of settlement closer to the water canals i.e. historical precedence in the area. Recently, the reconstruction of the scheme also necessitates the reformation of irrigators' water right in several regards. The dynamic natures of water rights become more intricate as its rules originate from multiple origins. For instance, since the promotion of Indris modern scheme, irrigators could get accesses of water rights plausibly via:
   i. Inheritance from parents or

relatives who had formally established their irrigation water rights.

ii. Purchase of the water rights of a given user through contractual agreements.
iii. Water rights maintained through share-cropping.
iv. Water rights acquired in association with land re-distributions by the government.

The water right rules are multiple in origin and integrative in function. The predominately governing water use rules are the combination of customary normative dictations and formal-legal irrigation water management guidelines. These water right rules are inheritable, dynamic in the sense that they would be subject to revisions either for omissions or additions pertaining to the turmoil environment.

Webs of multiple factors have been investigated to hold linkages with water rights either to promote or curtail users' accesses and participations for decisions. Economic status, power, gender, ethnicity and religion comprised amongst the pertinent factors that have in one way or another contributed either to facilitate or deter users' access to irrigation water. Economic status, for instance, affected the water right of users at least as the economically better of,

- Completes a range of tuitions imposed on them earlier in relation to the economically weak.
- Can purchase access to water rights through contractual agreements or entering share-cropping. In contrast, water users in an economically weak position lack to utilize such opportunities.
- Develop a relatively strong channel of communication with the committee members, extension workers and other institutes.

In a similar talk, whatever the fashions of its manifestations, power relations have prevailed among diverse entities where in an institution or individual user either legitimately or illegitimately tries to impose their power weakening the water right of those in comparably underprivileged positions. In consistence with this view, Boelens and Davila (1998:445- 447) confirmed the conception that 'water flows in the direction of power'. Within unequal power structures, different societal bodies define their strategies in order to defend and materialize their own interests in controlling the water. Thus, ill-treated distribution of irrigation water is not only through consideration of economic status but also mystification of the power via which the user households or institute define its access. The same holds true for investigations on gender matters where in women are losers and men defined their dominance.

Alike to economic status, power interactions and gender dimensions, religious out looks and ethnicity have also carried similar effects though not as affective as dimensions discussed above. In terms of religious out looks, for instance, there were occasions when water users in the same church deliberately cover water right offenses committed against users who do not belong to the category. The tendency to sympathize or disregard one another based on ethnic considerations only rarely noticed compared to other dimensions. Rather, strong interrelationships maintained through social ties and webs of networks (like associations of Iquib/Idir, marriage, extended families, work labor parties in the form of Debaree or Debo) worked either to enhance or deter the access of users in or out of the network differently.

The pragmatic application of irrigation water right occupied a prominent place in the struggle to enhance irrigators' livelihood or income expropriated from the practice. Failures to observe the water use rules in general and ones own water right in particular deteriorated users' livelihoods. As an instance, users with longer experiences of implementing the water user rules have been reported to progressively improve their livelihoods year after year while conversely those failing to apply the rules suffer from crisis imposed on them in the form of punishments.

There existed few non-irrigators who failed to acquire the opportunity to divert water from Indris scheme due to varied reasons. None of the contacted non- irrigators claimed that constraints interlinked with water rights have never deterred them both from the access or decisions. Rather distance from the scheme/ source, decline in the amount of water for the lower stream users (Kilinto) and geographical barriers for the upper stream users (Selam Sefer) became major hampering factors on top of other personal matters.

Negotiations and Dispute Settlement over Irrigation Water in the Study Area.

Conflicts of competing interests among diverse categories of users are another dimension to be looked at with co-relation to the water right of users. The results and discussions of primary data generated during the field work proved increase both in the intensity and severity of conflicts over irrigation water matching the three phases of the scheme's development. Conflicts occur among users in a village, along the streams of the scheme or between farmers and the Agricultural Training Center of Ambo College.

The principal causes for conflicts to erupt out has been embedded in the transgression of negotiated water use rules like theft, turn abuses, failing to timely pay financial fees or deliberate ignorance of labor contributions for canal operations and maintenance and gradual decline in the volume of water resource itself. Power abuse became to be considered as the second chief factor for conflicts.

These conflicts have been handled at distinct levels within the village through elders and committee decisions, at Kebele courts or at district court. In case these conflicts emerge into disputes that stayed over a prolonged duration of time, a succession of negotiation processes and procedures would be employed to manage the case. The processes involved could range from identification of the central predicaments to the final remarks of disputants that assured their consents not to replicate a similar disagreement once again. The protracted conflict between the Agricultural Training Center and the farmers, or users in the upper and lower streams basically exhibited typical instances of the case in point.

Of course, negotiations have been carried out in dual senses: negotiations under normal circumstances and negotiations conducted to smooth disputes. In its former meaning, water users do frequently negotiate over a range of issues to be implemented with the supposition to promote the effectiveness of the entire system. These include negotiations executed in relation to a range of fees, categories of items to be irrigated, maintenance schedules and labor contributions, total hectares of land to be irrigated or possibly water scheduling days and hours. On the other hand, a series of processes of negotiations would be undertaken successively at times of serious conflicts. Generally, the steps pursued to initiate and finalize the processes of negotiations moves through state of procedures described below;

i. **Recognition of the grounds of the dispute/ Causes:** at this point the negotiators themselves or the mediators (elders, committee, Kebele or district court) examine the basis of the conflict.
ii. **Conduct assessments on the prospective points to be negotiated:** having deeply examined what have instigated the conflict; either the negotiators or mediators move to sort out the promising arenas where in negotiation would be set in motion to bring out remarkable agreements.
iii. **Persistent presentation of negotiators' respective cases and points of departure:** the segregation of points over which negotiation produce relatively stable interactions, ultimately invite negotiators to present their cases to each other and the mediators in the attempts to persuade the audiences elaborating that their argument contained more reality than their opponents. There also appeared the presumption that negotiators who aspired to gain much from the debate need to condemn the arguments of their opponents. The presentation of their respective cases usually takes much of the time in the entire processes of negotiation.
iv. **Narrowing the gap perceptible between the interests of negotiators:** the succession of appointments to heed the respective cases of water users in dialogue enable to easily distinguish the gap

in the interests perceptible between either the teams or individuals in debate. At this instance, the negotiators themselves or mediators would engaged in the facilitation of negotiation processes or suggest the strategies pertinent to successfully narrow the competing interests of claimants.

v. **Provide the final decisions to confirm and attain consensus:** with the minimization of the gap, comes the concrete decisions to be accepted commonly by the former opponent sides.

These steps largely represent the standards at least to be pursued, details of procedures incorporated in each steps vary from village to village or depending on the general setting where the negotiation have been conducted. The implications and essential arguments of the processual models of negotiation (cyclical and developmental) hold coincidences with the issues at hand. In each step of negotiation, as participants of the focus group discussions revealed out, there exist recurrent exchange of views and information that enabled the opposing categories to learn more about the expectations and responses to the particular quests embraced in the process. This notion specifically parallels with the elements of cyclical model of negotiation. The cumulative effects of each negotiation steps finally culminate in generation of the consensus sought by water users as their primary target. So, the ultimate achievement (i.e. bargaining over their irrigation water rights) elicited the central attributes of the developmental model of negotiation. The end results of negotiations over water rights assured through repetitive and cyclical processes of both information sharing and learning depicted in each stage enabled users to transform from a state of competing interests to collaborating entities.

Though the ultimate aim to conduct negotiation processes have been triggered with the motives to induce a real truce, sometimes the outcomes may not end in the way expected to attain encouraging targets. Instead, it leads to additional rearrangements for having chains of negotiations. Anyhow, at the end of negotiation processes, the competing parties or users may gain certain parts of their quests submitted for negotiations though commonly unfeasible to acquire the entire range of their initial pursuits.

Conclusion and Recommendations.

Conclusion.

Debates over access to water rights for irrigation usage and negotiations have been central among water users and institutions claiming water from Indris scheme. These debates over water right claims have been mainly attributed to rising competitions over irrigation water, drastic population growth and shrink in the volume of water due to augmented diversions points on Indris River as well as failures to strictly observe rules of conduct for resource use. Disputes associated with use rights, like farmers against Ambo Agricultural Training Center, or among the farmers themselves have predominantly prevailed in the research sites.

Though the elements of both the riparian and appropriative doctrines of water rights mirrors among the irrigators in the study sites, their know-how regarding water right entitlements appeared to be found at its infancy. Themes that center on irrigation water rights tended to be overlooked under normal circumstances. Such topics become sensitive and an area of controversy only when the rules are frequently violated affecting the use rights of members. As a whole, water right themes for irrigation diversion gradually began to receive substantial concerns corresponding to the phases of the development of Indris scheme.

The theoretical frameworks employed as a conceptual tool to examine the water rights and processes of negotiations over irrigation water among irrigators diverting water from Indris scheme proved to be in consistence with the experiences of other developing nations reviewed in the literature. Hence, both the arguments of legal pluralism advocated principally by Burns and Meinzen-Dick (2000) in water rights paradigms and the processual models of negotiations discussed by Gulliever (1979) were pragmatically apparent in the daily actions and practices of water users in Toke Kutaye district of West Shewa Zone.

In essence, the applicability of legal pluralism was verified via the multifarious sources of water rights and their integral functionality. This fitted with the conclusions of former studies carried out in various developing countries. In that regard, a study by Cleaver, et al (2005) demonstrated the conception that claims to resources in general and water in particular are made and enforced through both 'formal' (local government, Water Users Associations, tenure arrangements) and 'informal' (customary practices, social relationships, norms of use and access) frame of references.

Correspondingly, at Indris scheme, a combination of rules for water rights stemming out of the broader normative rules as well as guidelines formally enacted for irrigation water management were essentially available. In the efforts to reinforce water rights besides rules framed out indigenously, significant reforms embodying the legal environment have been accomplished with the help of Toke Kutaye district agricultural desk. While the indigenous rules exhibit the pragmatic contexts of irrigators in their respective vicinities, the formal-legal approach tends to emphasize the components of irrigation directives adopted by the government to be implemented for inducing change. The arguments extracted from these dual approaches have evidenced to effectuate the water use right claims and the processes of negotiations among irrigators in the study areas.

In this research, it was realized that customary rules were particularly effective in curbing conflicts while the formal guidelines become strong to reinforce punishments at moments either the rules are poorly interpreted or deliberately transgressed. As a result, combinations of these rules enable to have wider frameworks for the actions and behaviors admitting users to divert water. Therefore, the paradigm of legal pluralism contains much relevance with the existing realities of water users in the three selected research settings for this study (Selam Sefer, Dhaga Fillee and Kilinto).

In a similar manner, the arguments of processual models (both cyclical and developmental) of negotiations expounded by Gulliever (1979) tested to bear reliability with the way conflicts over irrigation water have been settled or the processes gone through to negotiate and renegotiate for securing access to water. Though these models are thought to work at the same instance, the cyclical model applies more to grip minor conflicts erupting out among users or teams in a village. Conversely, the developmental model of negotiation has been utilized to justify the protracted disputes continued over a number of days or a couple of months. The arguments of this same model appeared instrumental to reconcile the antagonistic interests of the Agricultural Training Center and farmers as well as frequently occurring disputes among water users at Selam Sefer (as upper stream beneficiaries) and Kilinto (as lower stream beneficiaries).

Recommendations

The views contended herein below demand the concerted efforts of interested stakeholders, users themselves, researchers or institutes to contribute their resources (in the form of time, know-how/ technical skills, donations or material supplies) to narrow missing gaps and thereby endeavor for better transformation. Hence, the clues embrace:

i. The policy pertaining to irrigation water management in general and water right entitlements in particular have been in progress time over time. This investigation indicated the need to further coin out specific water right guidelines by the relevant organs in an instructive way and equally applicable for all users.

ii. The chief stakeholders like the district agricultural desk need to provide special focus on enhancing the awareness level of users about the overall nature of water rights. Formerly, it was confirmed that inadequate attention was paid to programs that create awareness among users about water rights. As it promotes the empowerment of users in that regard, there is an acute need to incorporate water right themes in the plans for actions to be implemented.

iii. There prevailed the tendency to

increasingly undermine the role of customary rules and instead forcefully impose legally recognized rules by various government organizations. Yet, the customary rules were by no means less in effective than the formally laid directives in numerous respects (for instance, saving resources). Hence, emphasis has to be given on advocating the merits of customary rules that shines the wisdom and cumulative experiences/skills of practitioners.

iv. The causes of conflict were essentially embedded in failures either to adhere or loose implementation of the negotiated rules of water use. In this regard, the findings of the study have indicated the existence of a serious affair that must be addressed thoroughly. Therefore, water users, technical experts, the institutes claiming water from the scheme or other stakeholders need to work hand-in-glove manner to reinforce the practical interpretation of rules on the ground.

v. In the face of growing population and declining water volume, competitions over irrigation diversion would inevitably augment. Initiatives to supplement water from other perennial and potential rivers (like Heddee) have been proposed by users, the district agricultural desk and the Agricultural Training Center. As the materialization of this proposition would only be realistic with the financial assistances of interested organizations (like EEC), the study suggests conducting further assessments or searches on the likelihood to assure irrigation water sources in addition to Indris Scheme.

vi. Negotiated approaches over water rights and other themes in the irrigation system, as a best option, have facilitated desirable achievements in inducing common understandings between disputants. Despite its remarkable role to settle conflicts of interests, negotiated approaches have been declining over time tending to carry little credits among users. The study recommends offering particular considerations on collective actions that uphold the enhancement of negotiated approaches over resource use (water). The institutions like WUA mediating the access of users need also undergo periodic restructurings in a way to accommodate ever growing demands of the users.

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Technical and Institutional Evaluation of Geray Irrigation Scheme in West Gojjam Zone, Amhara Region

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Abstract

The technical and institutional performance evaluation of Geray Irrigation Scheme was made in order to identify management practices for implementation to improve the system operation and the general health of the irrigation system. The evaluation was made by looking into the selected performance indicators such as conveyance efficiency, application efficiency, water delivery performance, and maintenance indicators. The availability of institutional and support services were also investigated through a questionnaire administered to beneficiary farmers and other stakeholders. The results obtained showed that the main and tertiary canal conveyance efficiencies were 92 and 82 percents respectively. Many of the secondary and tertiary canals are poorly maintained and many of the structures are dysfunctional. Application efficiency monitored on three farmers' plot located at different ends of a given secondary canal ranges from 44 to 57 percent. Water delivery performance was only 71 percent showing a very substantial reduction from the design of the canal capacity. Maintenance indicator evaluated in terms of water level change (31.9%) and effectiveness of the infrastructures showed that the scheme management was in a very poor shape. Dependability of the scheme evaluated in terms of duration and irrigation interval showed that the scheme is performing below the intended level. The 47 percent of the land initially planned for development is currently under irrigation while there is no change in the water supply indicating that the sustainability of the scheme is in doubt. The cooperative support

services that had been rendered to the beneficiaries in the past four years were found to be minimal. Moreover, there were few indicators that show the production was market oriented. The evaluation clearly revealed the fact that conflict resolution remains to be the duty of the Kebele authorities and WUA has no legal right to enforce its bylaws. In conclusion, the overall technical adequacy of the scheme is rated

very poor requiring tremendous mobilization of the community to sustainably manage it. Proper institutional setup needs to be in place, and WUA needs to be empowered more in order to enforce its by-laws.

1. Introduction

Ethiopia is labeled as the 'water tower of Africa'. Its geographical location and endowment with favorable climate provide a relatively higher amount of rainfall in the continent. Preliminary studies and professional estimates put the nation's annual surface runoff to 122 billion m^3, groundwater potential to 2.6 billion m^3 and the average rainfall of 1090 mm (Daniel, 2007). However, the annual amount of water resources in Ethiopia gives the wrong impression that 'rainfall is adequate for crop production'. Rainfall distribution is extremely uneven both spatially and temporally.

As the capacity of the country to store the excess water is in excess is very poor, most of the water flows out carried by transboundary rivers to neighboring countries. Consequently, the country suffers from water scarcity triggered hazards, such as repeated crop failure, food insecurity, drought and famine with increased frequency. About 52 percent of the population or 214 districts of the country are known to be food insecure. The population requiring food assistance is increasing in absolute terms. In 2006, for instance, about 15 million people were food insecure mainly because of rainfall variation (Daniel, 2007).

To address the challenges of food insecurity and associated poverty, improving agricultural productivity occupies a central place in the 'Agricultural Development Lead Industrialization (ADLI) strategy of the present Ethiopian government. Fighting poverty and reducing food deficiency are at the heart of ADLI. The government has committed itself to the reduction of poverty by half, through the endorsement of the Millennium Development Goals (MDG). Irrigation development is one of the pursued strategic interventions in this regard. The government now recognizes that it is implausible to expect any great degree of agricultural production intensification under rainfed dryland farming system. Hence, tremendous efforts are underway to promote large, medium and small scale irrigations through huge financial and labor investments.

Despite the endowment of Ethiopia with huge (3.5 million ha) irrigable land, the area under irrigation development is only five percent (195 thousand ha). This shows that water resources have made little contribution towards the development of agricultural sector in particular and the community in general to date.

In the last few years, heavy investments have been made to harness the water resources of the country towards irrigation development. The ongoing Tendaho, Kessem, Gode, Koga irrigation projects over and above huge work on rainwater harvesting pond construction that has been aggressively pursued all over the country are evidences for the government's part and commitment to irrigation development. However, given the dismal and undesirable experience on the performance of the irrigation schemes developed earlier, there is no guarantee that the new schemes will deliver the anticipated benefits.

Given the anticipated importance of irrigation in food security and poverty reduction and the huge investments committed on irrigation infrastructure, it is imperative that the irrigation sector is efficient and effective in yielding desired socioeconomic returns. However, the performances of many of the existing irrigation schemes have been far from satisfactory. Several of the previously constructed irrigation projects are totally or partially abandoned. Most have not reached their planned levels of productivities and many are not financially or technically sustainable in their present forms.

For irrigation schemes to be sustainable, mutual supportiveness of irrigation hardware (irrigation infrastructure) and software (institutions) are vital. Mutual supportiveness is ensured when the hardware is cost and labor efficient, easy to operate and robust, and yielding predictable results. The software is characterized by individual/collective interest and management skill embodied in a lean organization of water users besides adequate support services.

The paradox of big expectation from irrigation development to alleviate food insecurity and rural poverty versus inability to sustainably utilize developed schemes calls for detail scrutiny of the relative contribution of prevailing technical and institutional problems of failed schemes. One such failed scheme selected for this study is Geray Irrigation Scheme. This scheme, with its source of irrigation is of excellent quality spring water with virtually zero silt, was expected to operate with minimum technical problem. However the scheme has not been able to live up to the expectations. Hence, this study was made to evaluate the contribution of the institution related problems for its technical underperformance.

2. Data and Methodology

2.1. Location of the Study Site

Geray irrigation scheme is located 10' 60'' latitude and 37'26'' longitude in Arbaetuensisa Keble located 5 km from Finoteselam in West Gojam zone. Finoteselam is located 380 km from Addis Ababa on the main road to Bahir Dar. Construction of the solid masonry diversion started in 1971 and was completed in 1972. Construction of canals and other structures continued slowly and reports indicate that the scheme was commissioned in 1984.

2.2. Technical Performance Evaluation

Technical performance indicators monitored in this study included the measurement of conveyance efficiency of the main canal and tertiary canals, application efficiency and water delivery performance.

Conveyance efficiency – This was estimated by measuring inflowing and out flowing water along the selected canal lengths (Boss, 1997)

$$\text{Conveyance efficiency} = \frac{\text{water flowing in the canal}}{\text{water flowing out of the canal}} \quad 2.1$$

Application efficiency: The ratio of the depth of water added to the root zone to the depth of water applied to the field was measured from three farmer fields that were growing potato. The criteria for selecting farms were their location associated with the reach of the canal, i.e. top, middle and lower end of the canal. The three plots of farms were chosen among those that served on the same secondary canal at the head, middle and tail reaches with the presumption that there will be differences in the availability of water among these categories of irrigators.

$$\text{Application efficiency (Ea)} = \frac{\text{Depth of water added to the root zone}}{\text{Depth of water applied to the field}} \quad 2.2$$

The water delivery performance indicator: This was calculated by measuring the actually delivered volume of water to the intended (design) volume water to be delivered.

$$\text{Water Delivery Performance} = \frac{\text{Actually delivered volume of water}}{\text{Intended volume of water to be delivered}} \quad 2.3$$

2.3. Maintenance Indicators

Proper maintenance enables the keeping of water control infrastructure in good working condition so that the design water level is maintained. The change in head (level) over structures in irrigation canals is the single most important factor disrupting the intended delivery of irrigation water. The maintenance indicators are evaluated by the following hydraulic performance indicators (Boss, 1997).

a. **The relative change of water level (RCWL) -** this was computed by taking the actual water level depth from the canal and comparing it with design value at the same position in the main canal, i.e. changes of level to the intended level.

$$\text{Relative Change of Water level} = \frac{\text{Change of Level}}{\text{Intended Level}}$$

2.4

b. **Effectiveness of infrastructure** – this measures the ratio of the number of functioning structures to the total number of structures initially installed.

$$\begin{aligned}&Effectivity\ of\ Infrastructure\\&=\frac{Number\ of\ functioning\ structures}{Total\ number\ of\ structures}\end{aligned}$$

2.5

c. **Dependability of duration** – this is estimated as the ratio of the duration and the irrigation interval of water delivery compared to the plan.

$$\begin{aligned}&Dependability\ of\ duration\\&=\frac{Actual\ duration\ of\ water\ delivery}{Intended\ duration\ of\ water\ delivery}\end{aligned}$$

2.6

d. **Sustainability** – is measured as the ratio of current area under irrigation to the initial total irrigable area.

$$\begin{aligned}&Sustainability\ of\ Irrigable\ Area\\&=\frac{Current\ irrigable\ area}{Initial\ total\ irrigable\ Area}\end{aligned}$$

2.7

2.4. The Irrigation Institution Performance Assessment

By institution here refers to social arrangements that shape and regulate human behavior and have some degree of permanency and transcending individual human lives and intentions. In this survey, the status of irrigation institution and availability of support services were assessed through questionnaires administered to the different stakeholders of the scheme. Focus group discussions were made with beneficiary farmers, elders, water user cooperative (WUC) management, the Kebele Council, and Cooperative Promotion Staff of Agriculture and Rural Development Office. Samples chosen include 13 WUC members, seven WUC executives, five Kebele Council representative, 10 irrigable land owners who are not members of the WUC, three farmers owning irrigable land but not rainfed, three farmers that don't possess but are renting irrigable land, four elderly farmers who participated during the weir.

3. Major Findings and Discussion

3.1 Characterization of the scheme

Reports indicate that Geray Irrigation scheme was officially commissioned in 1984 upon finalizing the construction of tertiary canals for the four of the seven secondary canals by the then Irrigation Development Department, while the head work was finished in 1974 by the Ministry of Agriculture. The project was government initiated in an effort to build the capacity of the then Arbaetuenissia Producers Cooperative.

The net irrigable area of the scheme was 618 ha. However, the actual area developed for irrigation was 454 ha. The main canal was 9.8 km long. The number of secondary canals was nine with a total length of 12.5 km while that of the tertiary canals was over 52 km long in total. The weir had 105 m crest length and 4 m height.

The numbers of beneficiary households that own irrigable land were 790 out of which 400 were members of the WUA and the remaining 390 were non-members. However, during the study period (2006), the area under irrigation was 215 ha only. The number of potential beneficiaries of the scheme is estimated to be 3950 people. The lowest average river discharge was reported to be 1.9 m^3/s. The maximum main canal design discharge with the gate fully opened was 1.54 m^3/s. During this study, the actual flow measured when the gate was fully opened was 1.1 m^3/s.

During this survey, the majority of the drop and other structures were dysfunctional. There are a number of illegal water abstraction and canal breaching. Majority of installed tertiary canals were not operational.

Farmers practice furrow irrigation. The furrow lengths range from as long as 54 m to as short as 8 m. There is no restriction for the type of crop one grows, but 75% of the farmers grow potato.

3.2 Technical Efficiencies

Conveyance and application efficiencies

The average main and tertiary canal conveyance efficiencies were measured as 92 and 81%. It was observed during the field work that water was leaking on places where the canal was breached, flow in canal network was not uniform, canals were heavily vegetated, water flows over the banks of the canal.

The application efficiencies measured on the three farms selected for this study is presented in Table 1. The values obtained were close to each other and low, but not very far from that expected in surface irrigation system.

Table 1. Application Efficiency

Farm	Applied Depth (mm)	Stored Depth (mm)	Application Efficiency (Ea %)
Head end of the canal	215.5	123.7	57.39
Middle of the canal	188.4	83.7	44.41
Lower end of canal	123.5	60.9	49.33

Water Delivery Performance

The water delivery performance calculated as the ratio of actually delivered (1.1 m^3/s) water to the intended volume of water (1.54 m^3/s) was 71 %. A 29% reduction in the capacity of the system was large. The effect of this reduction in the carrying capacity of the main canal was reflected in reduced area actually irrigated.

The Relative Change of Water Level

As per the design document, the main canal carries 1.54 m^3/s discharge when the height of water table is 0.47 m; whereas the height of water table measured was 0.32 m when the actual discharge was 1.1 m^3/s, resulting in a 32% water level change. This showed that the intended water level in the main canal was achieved; consequently less discharge was delivered to the farms forcing farmers either to increase the irrigation time or decrease the irrigated area.

Effectiveness of Infrastructure

As per the design document, the total number of different structures constructed was 111, but only 74 of them were functional. As a result the value of effectiveness of infrastructure was reckoned to be 67%. Nearly one-third of the structures had been destroyed. Severe mutilation of water control structures for their iron bars was in evidence.

Dependability of Duration

The intended duration of water delivery as per the design document was 10 hours irrigation time per day. However, farmers were irrigating up to 18 hours a day. The calculated dependability duration was 180% showing that it required more time than anticipated to irrigate the fields.

From all the indicators monitored in this survey, the scheme's technical performance was sub-optimal in all standards, and requires urgent maintenance.

3.2 Institutional and Support Services

3.2.1 Scheme Management

The scheme management since it was commissioned 27 years ago has been changing. Earlier in the previous government, it was managed by producer cooperatives. But when the cooperatives disbanded, the local government through the Agriculture and Rural Development Office with all its inefficiencies tried to manage the scheme. Later on, however, knowing that it can no longer effectively manage it, it crafted farmers' cooperative and passed the management without proper consultation with all stakeholders.

For the past four years, Geray Irrigation Scheme has been administered by this water user cooperatives (WUC) registered under Amhara Regional Cooperatives Promotion Agency. The cooperative adopted a generic bylaw drafted by the Agency. The bylaw indicated that the association is responsible for water distribution, system maintenance, collection of water fees, soliciting for input supplies, credit facilitation, planning and monitoring, etc. But none of these responsibilities have been executed as desired for various reasons.

3.2.2. Performance of the Water User Cooperative

Institutional arrangement on irrigation is required to overcome problems relating to irrigation water as a common property resource, to provide incentive to members disincentive for free riding and shirking. As mentioned earlier, the WUA was provided with a generic bylaws binding on all cooperative members. The first challenge in the functioning of the cooperative was the principle clash in which cooperatives were organized – i.e., membership ought to be fully on voluntary basis. When farmers share the same irrigation water resource, organizing some of them under the cooperative umbrella while leaving others as non-members seriously challenge to the effectiveness of the cooperative in water management. This is against one of the principles of enduring self governing institutions (Ostrom, 1992 as cited in Sarker and Itoh, 2001). Moreover, the cooperative manual lacks detailed operational rules (such as entry, allocation, penalty, input rules) and organizational structure specific to the irrigation scheme.

3.2.3. Operation and Maintenance Problems

As per the response of the farmers interviewed in the study area, some of the major problems that the farmers face include weir and canal leakage, and siltation of canals. These were also in clear evidence during the survey. Although the maintenance of leaking weir may be beyond the capacity of framers in which case they may solicit the support of the local government, the canal maintenance should be the duty of the cooperative. However, the status of the secondary canals and their water control structures showed that no proper maintenance has been carried out for a long time and the cooperative was not effectively shouldering the scheme management. The beneficiary farmers also acknowledged that the scheme was poorly maintained, and they attributed the problem to lack of fund for maintenance. It was, however, noted that farmers are neither contributing money for operation and maintenance nor do they pay for the irrigation water they use.

3.2.4. Conflict and Conflict Resolution Mechanisms

Conflict in the scheme both between and among the beneficiaries and the downstream farmers who are not served by the canal water was said to be rampant. Among the 45 interviewed beneficiary farmers, 44 acknowledged the presence of conflict. They attributed water shortage to be often times the cause of conflict. The survey also showed that there was no water sharing agreement between upstream and downstream users, and there was no equity in water distribution (Table 2)

Table 2. Beneficiary farmers' responses to conflict related questions

	Frequency	Percent
1. Have you ever come across a conflict between those living around the canal tertiary units and the downstream users?		
i. Yes	44	97.8
ii. No	1	2.2
2. What are the probable causes of the conflict?		
i. Unequal water distribution	4	8.9
ii. Irrigation schedule disturbed	25	55.6
iii. Scarcity of water	11	24.4
iv. Both i and ii	5	11.1
3. Is there a water sharing agreement among each of the branches?		
i. Yes	3	6.7
ii. No	38	84.4
iii. Have no information	4	8.9
4. Is water equally available to all users in the scheme?		
i. Yes	2	4.4
ii. No	42	93.3
iii. No response	1	2.2
5. Who are the actors in conflict resolution?		
i. WUA	4	8.9
ii. Kebele council/social courts	11	24.4
iii. Both i and ii	30	66.7

The survey also showed that the majority of the interviewed farmers (73%) had no confidence in the capacity of WUC management to resolve conflicts. In fact, it was learned that the major actor in conflict resolution was the Kebele Council and social courts. The problem with Kebele leadership and social courts in handling disputes was that the majority of them were not among irrigation beneficiaries. Hence, when WUC lodge complaints to the social courts, verdicts took a long time and the penalty was never proportionate to the offence.

In conclusion, the WUA is not empowered to take punitive action and enforce its by-laws. The majority of the water management problems revolve around the inability of the association to sanction offenders. The tortuous legal processes in the judicial system and the lack of recognition of the cooperatives by-laws were the most serious challenges that the cooperatives were facing currently.

3.3. Support Service

3.3.1. Extension and Training

Given the potential benefit that the scheme could provide to the beneficiary farmers and the local community, a qualified extension agent would have been imperative. It was, however, learned that farmers were not getting advice from an irrigation agronomist or from a qualified development agent. There were no organizations committed towards providing farmers with the needful training and extension services.

Table 3. Response of farmers to the kind of support they get from the government

	What kind of support the scheme gets from the government now?	Frequency	Percent
i	Input supply	3	6.7
ii	Advice	13	28.9
iii	I to ii	6	13.3
iv	No support	10	22.2
v	Have no information	12	26.7
	Total	45	

3.3.2. Access to Market and Input Supplies

The main Addis Ababa – Bahir Dar highway is only some 5 kms from the scheme. The status of dry weather road to the farms during the study period was fair. The zonal town, Finoteselam, is only some 7 km from the scheme. Market factor does not play a role in what and when to produce. When farmers were asked whether they have problem to sell their produce, their responses were that they don't have market problem. However, when farmer was asked to explain why many beneficiary farmers grow only potatoes, the response he gave was:

'We grow potatoes because if we can't sell them in Finoteselam market, we can dry them, store and use them for home consumption'.

Drying potato to extend its shelf life was a useful technology farmers practice to keep produce when it is in excess. Therefore, it is evident that farmers are not producing for a serious market. No effort of farmers were observed in the study area to take advantage of soaring demand for vegetables either in nearby Bahir Dar nor Addis Ababa markets. The problem was identified to be the fact that a truck is required to transport to the markets at Bahir Dar and Addis Ababa. However, such facility is not available to the farmers. Trucks do not come to collect one farmers pick as it would be too small to fill a truck. In principle, the solution for this problem would be to organize farmers to jointly plan and produce for the market on a pre-negotiated price. If this happens, the produce would be large enough to hire a truck, and transport the produce where market is available.

From the survey results (Table 4) shortage and/or unavailability of seeds was also cited as another problem for diversification of crops under irrigation. This again showed that the cooperative was not discharging the fundamental cause for its formation, that is providing inputs and facilitating markets.

Table 4. Causes for inability to diversify crop production

What are the problems relating to diversifying irrigated Agriculture?	Frequency	Percent
i. Scarcity of seeds	37	82.2
ii. Plant diseases	0	0
iii. Market availability	0	0
iv. Lack of sufficient irrigable land	0	0
v. Low market price for output	1	2.2
vi. Items i, ii and iii above	2	4.4
vii. Items i and ii above	2	4.4
viii. No response	3	6.7
Total	45	

3.4. Other Key Findings of the Survey

From the focus group discussion held with beneficiary farmers and the community, the following important issues were captured:

a. The WUC was not empowered to take administrative actions and enforce its by-laws. The social courts do not use the cooperative by-laws as valid instrument to sanction penalties. Farmers use local adage saying that the WUC management is a 'Lion without teeth'.

b. The penalties that the offenders pay fail to be commensurate with the infraction to deter him or her from committing similar offence in the future. Moreover, the penalties that the offenders pay were deposited into Kebele's account. Therefore, the WUC would benefit by taking an offender into a lengthy legal battle.

c. At the time of this survey, there was no development agent (DA) assigned to the scheme. Farmers reported that there was a DA with natural resource management background but he stayed only for less than one season. Hence, all the indications were that farmers were not benefiting from any technical backstopping.

d. The scheme had been under management of the government authorities until some four years ago. Hence farmers did not feel that they own the water and the irrigation infrastructure. Farmers were uncertain of the land tenure arrangements. They reflected that the land they own today may be taken away by the government at any time for lease to investors. They tried to justify this worry by citing the 20 ha land leased to an investor in the middle of the scheme.

e. There was no mutual understanding to forge equitable distribution of irrigation water among all beneficiaries. Those located in the upstream end of the secondary canal could take as much water as they wish; consequently, not enough water reaches the downstream users. Hence, to avoid crop failure due to water supply interruption at critical growth stages, the farmers located in lower end of secondary canal prefer to rely on rainfed farming.

f. Most tertiary and field canals constructed as raised canals have become dysfunctional to convey water as intended in the design. As per the design document, siphon was used to divert water from the canals to the furrows. But none of the irrigators was practicing the same. Farmers were creating their own conveyance system bypassing developed canal and water control structures. Consequently, there was tremendous water loss when water was made to flow on temporary conveyance system.

g. The responses to the question of 'who owns the scheme?' – the government or the community – were illusive and it was difficult to obtain a mutually agreed response. Although farmers felt that the head work, primary and secondary canals were the responsibilities of government, they could not pin point any them. From the local governments end, those implicated in one way or the other are the Agriculture and Rural Development Office, Cooperatives Promotion Agency and Water Resource Office.

h. There was no enough consultation with all the stakeholders before transferring the scheme management to the farmers. Hence farmers were uncertain of the government's motive.

3.5. Key Reflections Captured during the Discussions with the Staff Members of Woreda Agriculture and Rural Development Division.

1. The absence of specific roles that the offices of agriculture, water, cooperative promotion agency should play has made none of them accountable for the poor performance of the scheme.
2. Many beneficiary farmers own excess irrigable land than they can manage. Some farmers have even rainfed land outside the command area. Consequently, they do not have the capacity and the commitment to manage both irrigated and rainfed farms. Simultaneously, one alternative idea suggestion to solve this problem was to limit maximum irrigable land holding of a family. Thus providing access to as many farmers as possible.
3. Level of awareness of farmers towards marketable and high value crop production was low. Farmers tend to be complacent with what they have and produce. They do not seem to be motivated towards market oriented production.
4. The irrigation skill of farmers was below satisfactory. Farmers do not appreciate, protect and attempt to use water conveyance and control structures established during the irrigation development.
5. Farmers were not paying for the provision of irrigation water. Moreover, no cost recovery attempt has been initiated.

4. Conclusion

The irrigation potential for Geray irrigation scheme to change the life of the community is tremendous. It is endowed with excellent quality and quantity of irrigation water. The soil is highly suitable for irrigated agriculture. However, all the technical performance indicators showed that the scheme's performance was far from satisfactory. Many of the water control structures have become dysfunctional. The underperformance of the scheme was attributed to extreme neglect and lack of supervision. These it is concluded that the overall performance of the scheme was unsatisfactory.

The neglect was mainly attributed to lack of ownership. Further, many years of inefficient state management in the absence of committed development agent took the major blame for the infrastructure damage. Moreover, the recent transfer of management to service cooperatives did not confirm to the principle of long-enduring irrigation institutions. The fact that not all irrigation beneficiary farmers are members of the cooperative which again shows that institute does have clearly defined boundary condition – another requirement for good irrigation institution.

Successful traditional schemes not very far from Geray Irrigation Scheme have been perfectly functioning over 70 years using rudimentary irrigation structures and extensive annual maintenance requirements. Hence, there should not be any reason why this scheme should not have been successful provided that proper institution had been crafted right from the very beginning. The major problem identified during this study was the absence of functional institution to properly manage the scheme. The cooperatives association recently crafted has no power either to sanction penalties or enforce them. Under this scenario, efforts made by the government to rehabilitate the structure may not bring the desired changes in the life of the beneficiaries. Rather, the WUC needs to be reorganized and made effective. Uncertainties relating to land tenure need to be addressed at the earliest. Most importantly qualified development agent with irrigation agronomy background should be assigned to the scheme. Moreover, the DA should be given the responsibility to mobilize the community, following the major network rehabilitation skills.

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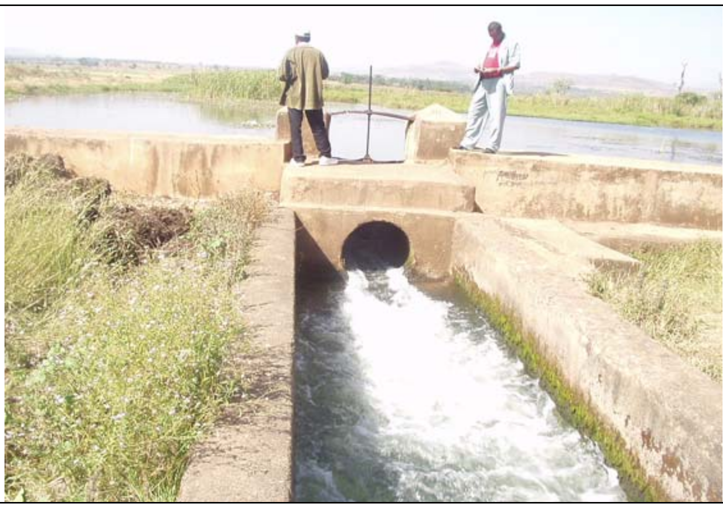

Plate 4.2 Water flowing through the gate (Intake)

Plate 4.3 Main Canal partly lined

Discussion on Theme 3: Irrigation Institutions and Support Services

Chair: Dr Kim Geheb
Rapporture: Dr. G. Makombe

The chairman for this session introduced the theme and the floor was opened for questions, comments and suggestions.

Questions and Discussions

3.1 Institutions are linked with performance and farmer participation is a big issue to improve performance of all schemes. WUA farmers need to organize themselves. Need to take into account traditional practice vs culture. Need to build on the existing traditional and cultural practices

3.2 Cost recovery is an important issue. There is indication of interest by farmers for cost recovery. From experience few schemes not functioning because of wrong design usually fail because of management issues.

Ans: Agree that WUAs are the only way out. For larger schemes can be cooperate or the government but for small scale schemes WUAs need to be empowered. Traditional schemes are successfully managed by social exclusion. For modern schemes need to go to court but courts are inefficient. There is need to empower the WUAs.

Sometimes there is a water master or a WUA but the challenge is when one asks what the role of each is when they are all there on a scheme. There is mention that responsibilities should be transferred but only one of them should be empowered. WUAs are not supported by government. Institutional conflict and confusion exists.

3.3 There is no legal status for WUAs. This is why irrigation coops were established for marketing and inputs supply. Did you notice conflict between formally established coops and community based/informal organizations? Koga is planned to have a coop. There is a hot debate in Amhara about institutional set up.

Ans: In some schemes some members of WUA are not members of coop and vice versa. There is conflict but it is managed because coops have upper hand over WUA. E.g. members of WUA are not allowed to sell produce through coop.

There is conflict and there is bad attitude regarding/towards coops. Many people were not interested to be coop members.

Koga: If coops could be managed like cooperates this is the best option. Water should have an owner. Koga will be large and there will be segments. Water needs an owner and there should be cost recovery mechanisms

3.4 Should there be a market first then farmers produce for it?

3.5 Who owns the traditional systems and who empowers the farmers to mange them. Some are function well and some not so well. What do we now about the management and are there lessons to be learned. Farmer to farmer learning was used well in Asia from schemes working well to those not working se well. To improve the performance of traditional schemes is it physical infrastructure or ids it institutional issues that need to be addressed? Traditional systems came about because farmers did something and when we build a scheme for farmers we take away this option that farmers do something for themselves.

Ans: There is incentive is getting access to water. Some farmers in remote areas were not interested in canal clearance because they do not see the benefit of irrigation. Those who have access to information and markets have incentive to produce. In Tigray there are people called production cadres who went to primary school and become farmers . They are trained by extension to help information flow. Demonstration fields are usually showing optimum conditions that are not accessible to farmers. Farmers always need to adjust to their situation.

We should not generalize that the traditional irrigation is the best, but upgrading traditional schemes is a good idea. Institutional set up should always consider local knowledge and institutions.

One irrigation scheme was fascinating. Why did it lasted for 50 years. There was a penalty practiced for offenders. An offender irrigating at night was fined 50 birr and an offender irrigating during the day was fined 30 birr. This is whey they are working well because if immediate penalty. Water father said you teach us to conserve the soil, but annually we exporting soil to neighboring countries. Why are we not constructing permanent structures if farmers are doing so year after year? Why do we tend to construct new schemes but give them low support?

3.6 How do local courts handle water rights conflicts? What percentage of conflict goes to local courts?

Ans: A substantial amount is reported to courts. The committee operates at three levels…..When it moves beyond capacity of local courts then it is reported to kebele court, then to district. When there is a serious case of theft and when there is serous case of water and or abuse of power reported to court. Two cases per day were handled by the curt.

3.7 At Indris water scarcity is the issue. At Giray, there is excess water and excess command area which is not managed by the farmers. What determines the interest of the farmer to mange certain land. We have to recognize that the government does not accept the WUA but accepts the coop. Coop should deal with water and water management issues

3.8 Geray: In this area there was a land redistribution in west Gojam zone. There is a land certification program. Is the process impacting the development of the irrigation scheme.

Ans: One of the reasons farmers are not developing irrigation scheme is because of uncertainty abut land ownership. 28 ha were given to an investor. Land certification had not reached there. Farmers are willing to invest in land if they are clear about ownership..

3.9 These are good research works exploring the local situations. Would like to see in-depth why despite positive effects and nice looking crops, what is wrong? Why do people despite the incentives, not make proper arrangements to manage schemes.

Ans: Farmers could not maintain the water intensive horticultural production for long because water became unreliable and farmers were obliged to shift from water intensive horticultural crops to perennial crops. The income has declining because of the effect of management problems.

Theme four:

Environmental and Health Impact of Irrigation

Papers

1. Case study review of investigated irrigation projects in Ethiopia
2. Environmental impact analysis of large-scale irrigation in Ethiopia
3. Brief manual “Keys for successful irrigation in Ethiopia”
4. Minimizing the negative environmental and health impacts of agricultural water resources development in Sub-Saharan Africa
5. Health and Environmental Analysis Results (10 minutes each)
6. GIS and remote sensing integrated environmental impact assessment of irrigation project in Finchaa Valley area
7. Entomological studies on the impact of a small-scale irrigation scheme on malaria transmission around Ziway
8. Irrigation and socio-economic factors related to malaria transmission in ziway, Ethiopia

Case study review of investigated irrigation projects in Ethiopia

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Abstract

Within the project "*Impact of Irrigation Development on Rural Poverty and the Environment*" emphasis was given to the rural development of communities performing irrigation. Main goal was to analyze the potential of irrigation development, which should be performed in an environmentally sound way to ensure good living conditions for future generations. Environmentally sound means to maintain soil fertility, water quality, to be concerned about health impacts and maintaining biodiversity.

The starting point for this review is an irrigation database, a classification of irrigation schemes in Ethiopia and the resulting selection of case studies of irrigation schemes. The study aims to support the clarification of environmental factors and processes related to irrigation development. The socioeconomic implications of environmental impacts of irrigation investments such as links to poverty, health and policies and institutions will also be treated. The methods used include field measurements and observations, laboratory analyses, structured questionnaire surveys and PRA.

The investigated field studies performed under the project's specific task "*Assessment of generic environmental and health issues as related to irrigated agricultural development*" are presented. The collected material is compiled and made accessible through a data base. The case studies results are critically reviewed and conclusions for future field investigation are drawn.

Key words: Irrigation development, impact assessment, environmental factors, Ethiopia

Introduction

It is commonly agreed that irrigation intensification contributes to poverty alleviation. Access to water, poverty and people's livelihoods are interlinked (Figure 1). These linkages are both direct and indirect. Direct linkages operate via localized and household-level effects, and indirect linkages operate via aggregate or national level impacts (Hussain and Hanjra, 2004). At the same time, water is becoming a scarce resource in many countries, particularly in Sub-Saharan Africa. This is also reflected in the Millennium goals of the UNITED NATIONS (2005) especially in Goal 7: ensure environmental sustainability. In the project "*Impact of Irrigation Development on Rural Poverty and the Environment*" this was one of the working hypotheses, but set in a wider environmental and socio-economic context.

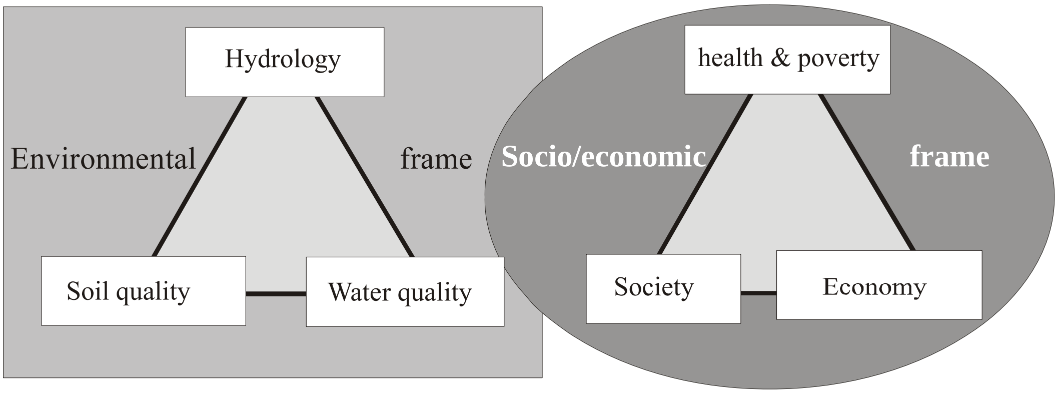

Figure 1: Interdisciplinary frames for case study investigations.

The overall goal is the understanding of impacts of past interventions and investments in irrigation. This will significantly contribute to the planning of new investments and the design of interventions for enhancing agricultural production. Emphasis is given to biophysical aspects such as ground and surface water use, soil quality parameters, land use patterns, nutrient recycling, agrochemical use and its associated risks, and wildlife and agro-biodiversity. The findings of the investigated case studies are of relevance for an improved planning and managing of irrigation and water resources in Ethiopia and other countries with similar climatic conditions, especially in Sub-Saharan Africa.

To quantify the significant positive and negative impacts of irrigation development in Ethiopia the following five specific objectives were defined (Awulachew, 2004):

1) to generate information that can be used to improve the performance of irrigated agriculture and enhance its positive benefits while minimizing its negative externalities,
2) to guide future irrigation investments and fill the gap in knowledge about the total impact of irrigation development on economy, society and environment,
3) to address specific health and poverty alleviation issues,
4) to develop methodological guidelines for assessing the impact of irrigation investment,
5) to strengthen Ethiopian capacity for interdisciplinary research and political implementation.

The assessment of irrigation practices (AIP) has to trigger actions. A prerequisite is the collaborative work with partners, based on their individual roles and mandates. This is supported by an EU sponsored co-project "Dissemination of research results in semi-arid and arid ecosystems with a focus on sustainable water resource management in Ethiopia" (short name WATERMAN). This Specific Support Action (SSA) focuses on analysis and dissemination of research results in sustainable, integrated water resource management at river-basin scale in Ethiopia. The SSA takes advantage from the existing collaborations linking together partners from different regions in Ethiopia and the creation of an inter-Ethiopian-network is supported.

Case study review of irrigation development in Ethiopia

Irrigated agriculture is a priority of the agricultural transformation and food security strategy of the Ethiopian Government. Increased availability of irrigation and less dependency on rainfed agriculture is taken as a means to increase food production and self-sufficiency of the rapidly increasing population of the country. In line with the development policy regional states and NGOs are promoting irrigation development so as to increase and stabilize food production in the country.

Under the 15- year Water Sector Development Program (WSDP), irrigation development subprogram, a total of 1606 small-scale irrigation schemes planned to be implemented mainly for the provision of food requirements (Ministry of Water Resources, 2001). Foreign governments and multi-lateral agencies are expected to co-operate with the government of Ethiopia and Non-government organizations (NGOs) to foster this program. Other non-governmental organizations and communities are also undertaking water resource development activities with the same objective. For example a large number of earthen micro-dams and river diversions have been built in the Awash Basin. Besides the development of new schemes, some traditional systems are also being rehabilitated.

The irrigation scheme classification used in this paper follows the work of Philippe Lempérière who divided irrigation projects in Ethiopia in four groups, (cited by Werfring, 2004):

- Traditional irrigation schemes that have been practiced for centuries by using perennial or seasonal streams. These schemes usually were developed by the farmers themselves without any government involvement.
- Modern communal irrigation implemented by regional governments. Rivers and run-off water, lakes, springs and groundwater are used. Generally modern communal irrigation schemes are more sophisticated than traditional ones.
- Modern private irrigation schemes started in the 1950s initiated by Dutch companies that implemented sugar estates. With the adoption of a market based economy the private schemes re-emerged in the 1990s. Water is mainly from rivers or lakes by pumps or diversions, although some small farms use water harvesting techniques.
- State farms operated by state owned enterprises, such as the Upper Awash Agro Industry Enterprise. Water is abstracted from rivers or lakes by pumps or diversions. Most of the public irrigation schemes can be found in the Awash River Valley.

For detailed studies irrigation schemes were selected and investigations were performed according to the various assignments of the project. The following aims to synthesize the case studies, highlights the main findings and reflects them in terms of the assigned deliverables of the project. Out of 26 project case study sites eight were selected for the environmental impact assessment (Table 1, Figure 2). Included in Table 1 is also a case study outside the project from Dominik Ruffeis (2006c): the Lomi Wuha irrigation scheme, for which the same approach was used. The investigation of Wagnew Ayalneh (2004) was performed at a selected case study site, but not as part of the project. In total 12 case studies, performed by ten investigators from Ethiopia and Austria, are analyzed in this report. Additional information is provided when accessible and relevant. The fieldwork took place at 13 irrigation schemes in three mayor river basins of Ethiopia, with Awash River basin, where most irrigation activities happen, being most prominently represented. The presented case studies are a good sample in terms of different irrigation scheme sizes and management practices.

Table 1. General case study site specification, numbers are given for each individual report, e.g. thesis works or unpublished documents.

Nr	Investigator	Scheme	Basin	Type of irrigation
1	Wallner/Ruffeis	Wonji/Shoa Sugar Plantation	Upper Awash	State Farm/Gravity
2	Wagnew Ayalneh	Doni, Batu Degaga, Markos, Godino	Upper Awash	Modern/Traditional Communal/Gravity
3	Ruffeis	Godino	Upper Awash	Modern Communal/Gravity
4	Damtew	Goha Woriko	Upper Awash	Modern Communal/Gravity
5	Zewdie	Amibara II	Middle Awash	State Farm
6	Ebissa	Ziway Holota	Middle Awash Upper Awash	Modern Communal/Gravity
7	Wallner/Ruffeis	Indris/Guder	Blue Nile	Modern Communal/Gravity
8	Ruffeis	Lomi Wuha (MfM)	Blue Nile	Traditional/Gravity
9	Ruffeis	Finchaa Valley Sugar Estate	Blue Nile	State Farm/Sprinkler
10	Ahmed A.	Finchaa Valley Sugar Estate	Blue Nile	State Farm/Sprinkler
11	Judt	Hare	Rift Valley Lakes	Modern Communal Traditional/Gravity
12	Ruffeis	Hare	Rift Valley Lakes	Modern Communal Traditional/Gravity

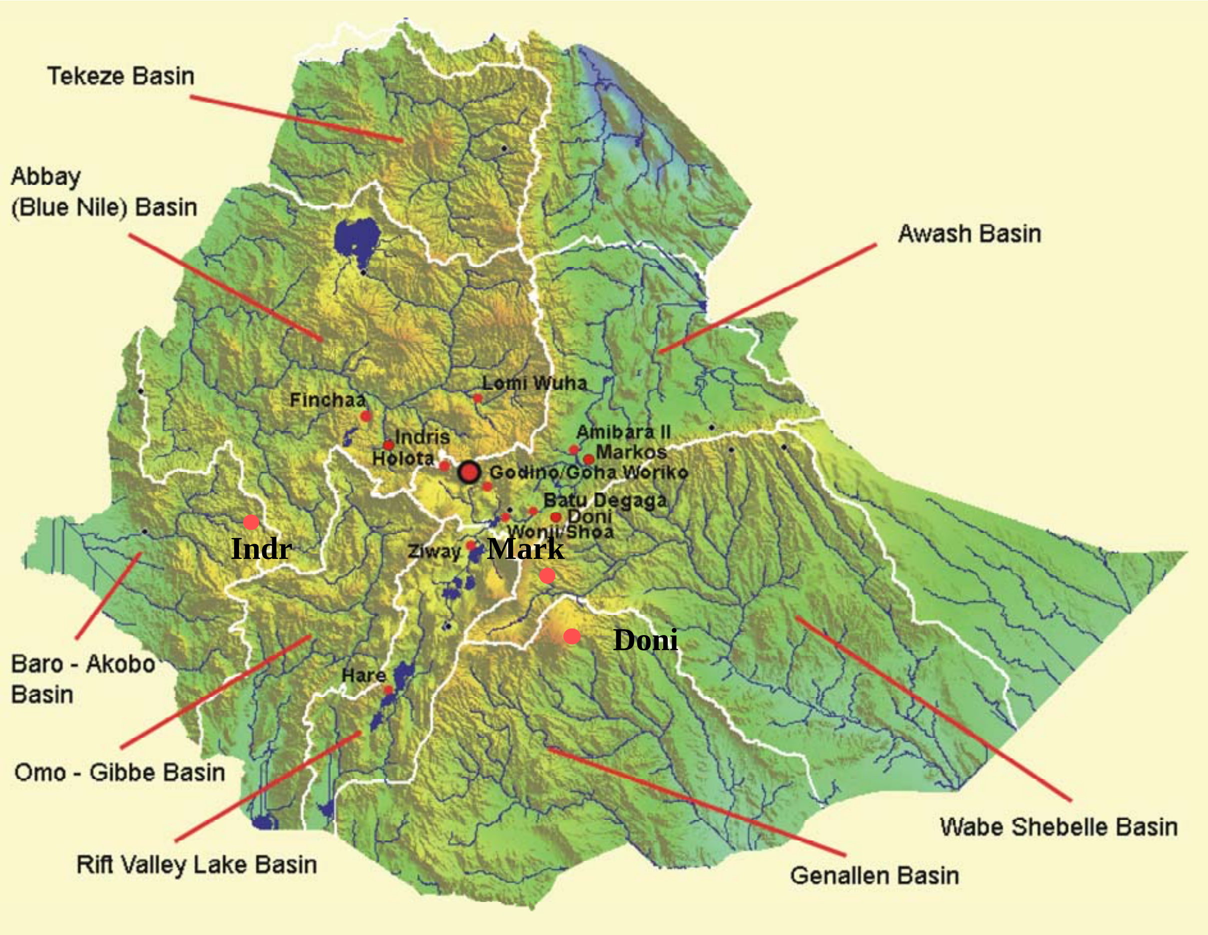

Figure 2: Investigation field site locations

Presentation of field sites and discussion of results

The investigated field sites should be considered in the broader context of irrigation in Ethiopia. The river basin development master plan studies of the Ministry of Water Resources (2001) provide an excellent overview of intervention potential in Ethiopia. Experiences and opportunities for promoting small-scale/micro irrigation and rainwater harvesting for food security in Ethiopia are presented by Seleshi B. Awulachew et al. (2005). Another broad overview of irrigation development in Ethiopia covering all river basins is provided by Seleshi B. Awulachew et al. (2007).

For better comparison of the results obtained at different locations the most important analyzed parameters and the main focus of the respective studies are presented in an investigation matrix (Table 2). The summary of performed work shows a concentration on water and soil analyses in a strong relation to environmental issues. For most of the investigated sites the other aspects of poverty alleviation, health and socio/economic considerations were treated as well or were available from other sources. Further detailed information may be obtained through the cited reports, thesis works and other literature sources.

Table 2. Investigation matrix

Nr	Environment/ natural resources	Water quality	Soil quality	Poverty alleviation/ health	Socio-economic	
1	XX	XXX	XXX		X	Awash
2	XX	X	X	XX	XXX	
3	X	XXX	XXX		X	
4	X	XXX	XXX		X	
5	XXX	X	XX	X	XXX	
6	X	XXX	XXX	XXX[1)]	X	
7	X	XXX	XXX		X	Blue Nile
8	X	XXX	XXX		X	
9	X	XXX	XXX	XXX[2)]	X	
10	XXX	XX	XX	XX	X	
11	X			XXX	XXX	Rift Valley Lakes
12	XX	XXX	XXX	XXX[3)]		

Investigation XXX high, XX medium, X low
[1)] Alemu (2007) & Kibret (2008), both for Ziway only; [2)] Chala (2007); [3)] Mabedo (2003)

As a general characterization of the investigated field sites various climatic data and the elevation, which are also important in relation to health aspects, are presented in Figures 3 and 4. For each irrigation scheme a short description and main results are provided in the subsections below.

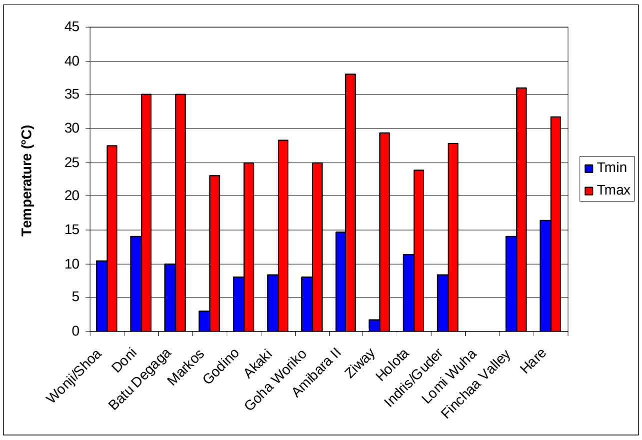

Figure 3: Temperature values of case study sites (NMA, 2006)

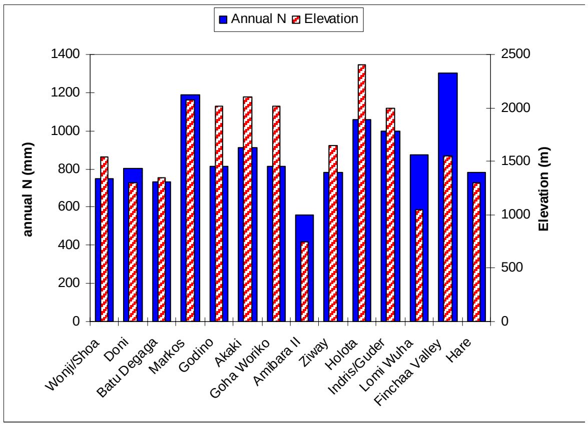

Figure 4: Elevation and annual precipitation of case study sites (NMA, 2006)

Wonji/Shoa Sugar Plantation

The first large public irrigation scheme Wonji/Shoa Sugar Plantation was constructed in 1956 as a private farm by HVA (Handels Vereniging Amsterdam). The sugar production is now subordinated under the authority of a government agency (Ethiopian Sugar Company). The scheme is located about 80 km south east of Addis Ababa, 15km south of the town of Nazareth in the Upper Awash Valley. The irrigation schema has good structures and is visibly well managed. Awash River is the irrigation source of the scheme which is located down stream of Koka dam. Koka dam was originally constructed for hydropower production in 1960. Irrigation water is diverted from the Awash River with electrical pumps and the plantation is managed as a gravity system. Excess water is stored in night storage reservoirs which cover a total surface area of 60 ha. Wastewater from the sugar factory and domestic supply is blended with freshwater and used for irrigation on some of the fields.

The whole irrigated area (6000 ha for the state farm, additionally 1000ha for the out-growers) is drained by a constructed, open surface drainage system.

Girma A. (2005) states that in most sugarcane fields of Wonji/Shoa slight to moderate soil infiltration problems are expected if groundwater occurs at shallow depths. Field observations confirmed that the groundwater depth was at all the times too shallow (in the root zone) for nearly all sugarcane fields considered in this study. Hence in Wonji/Shoa, sugarcane fields are prone to water logging and physical degradation of topsoil (Wallner, 2006; Ruffeis et al., 2007).

Doni, Batu Degaga, Godino, Marko, Goha Woriko - Oromyia Region

The Godino and Goha Woriko irrigation schemes are on both sides of the Wedecha River, located in East Shewa zone, in Oromia region near the town of Debre Zeit about 70 km from Addis Ababa. The schemes are part of a cascade system which includes two earthen dams and reservoirs. The upper dam which is located north of the two schemes Godino and Goha Worko is called Wedecha dam and is the main water source of both schemes. The dam was constructed in 1980 by Kuba Construction Brigade having the Agricultural Development Minster of Ethiopia as a client. Wedecha dam lies at an altitude of 2437 m.a.s.l. and the two schemes on an average altitude of 2010 m.a.s.l (Damtew, 2006).

Wagnew Ayalneh (2004) gathered information at household level on crop production, market and irrigation management. Investigated are four small-scale irrigation schemes, namely Doni scheme from Boset woreda, Batu Degaga scheme from Adama woreda, Godino scheme from Ada Liben woreda and Markos scheme from Wolemera woreda. The selection was based on accessibility, experience and type of scheme. 240 farmers were selected from the respective peasant association (30 irrigators and 30 non-irrigators for each woreda). The total population of irrigators and non-irrigator farmers of the four peasant associations are 627 and 3207 respectively.

The study of these small-scale irrigation schemes in the Awash Basin revealed some factors that are important for the successful implementation of small-scale irrigation schemes. The system of furrow irrigation, which is practiced in most of the schemes, has high labor demands and hence some farmers practice a flooding system. This will aggravate erosion especially in sloping plots. High electricity, repair and maintenance cost of pumps in Batu Degaga showed that electric powered pumps might be too costly for smallholder farmers (Ruffeis, 2006a). Systems that require less cost like gravity diversion systems should be looked at seriously. In the analysis of the schemes it has come out clearly that small-scale irrigation projects built or upgraded by NGO’s and government are often handed over to the farmers without proper completion of construction or technical training and without proper management establishment. This creates problems at such schemes as farmers are left with the understanding that the government or the NGO are still responsible.

Amibara II

Amibara Irrigation Project II is located in the south-eastern flood plain of the Awash River 250 km away from Addis Ababa, in a typical semi-arid agro ecological zone with an extensive pastoral production system based on with camels, cattle, goats and sheep. In 1980 the Amibara Irrigation Project II (AIP II) was established and production is mainly focused on cotton for foreign markets. Socioeconomic and environmental data were collected through informal discussions with the local community elders who were relocated from their original living area due to the irrigation development (Zewdie, 2005). Changes in the living conditions (social and cultural settings) of the rural Afar people were recorded. In addition to the survey data, secondary data on surface and ground water hydrology, production and land productivity, and primary data on soil physical and chemical properties were collected.

In this system the irrigation development considerably contributes to the local economy through establishing profitable enterprises and improving the livelihoods of thousands of people (mainly migrants who newly settled in this area) through providing job opportunities and good income. On the other hand diminishing livestock holding forced the rural pastoral community to lead under subsistence lives and some of them to migrate to towns in search of work. So the total contribution of the irrigation development in improving the livelihoods (income) of the native community of the area is none, even negative.

Ziway and Holota

Ziway is located 170 km from Addis Ababa on the way to Awassa. At Ziway, the study was carried out in the peasant association (PA) called Edo-Gojola, which was established in 1992 by SEDA (Selam Environmental Development Association). The total command area of the scheme is 2440 ha whereby only 32 ha of the farm are currently operational. Water for irrigation is diverted from Lake Ziway using motor pumps and distributed to the fields by gravity (Ebissa, 2005). Rainfall is not satisfactory and as a result low yields have been recorded that need to be supplemented with irrigation.

Holota is situated approximately 45 km west of Addis Ababa. At Holota the study was carried out in the Misrak-Shola-Ber peasant association (PA), which was established before 1971. The total irrigated area is 90 ha (Ebissa, 2005). The water source of the scheme is Holota River. The irrigation water is diverted from the river and distributed to the fields using gravity. The total area of the site is 680 hectare of which irrigation occupied 90 hectare. Clinical data from the health center data and a questionnaire were used to generate additional information.

Technical skills and innovative irrigation technology are absent in these two schemes. Both irrigators and non-irrigators use similar types of land management techniques (traditional technology). Some irrigators were found to increase their production by expanding land size and changing to other land uses while they might have better improved their poor land's condition through intensified management. Provision of training to empower farmers with new land management techniques is crucial. There is a need to have alternative water sources to alleviate the water shortage problem at Ziway and Holota. Land ownership and land use policies are very important as these determine the productive lifespan of the land through the type of investment farmer make in land management.

The overall study indicates that community-based irrigation schemes are more feasible at highlands (Holota) than at lowlands due to health impacts and water and soil deterioration, probably linked to the original water quality of the source. Improving the local supporting infrastructure such as health centers, transport, input supply institutes and credit organizations would greatly help to contribute to the sustainability of the systems. An EIA with the active participation of the whole community on the onset of the project could have removed or at least minimized the negative impacts of the irrigation scheme observed on health, environment and social conditions.

Indris

The Indris irrigation scheme is located in the western Shewa administrative region of Ambo Awraja, about 110 km west of Addis Ababa and about 10 km west of Ambo near the town of Guder. The scheme was established in 1985/86 to produce vegetables on approximately 400ha of land using irrigation (Halcrow & partners, 1989). In 1991 further plans had been made to modernize the irrigation scheme as the old structures like the weir, flumes and the channels were in poor condition and partly damaged (OIDA, 1991). Since about 1995 the command area of the system is approximately 1000ha. The whole irrigation system is divided into several smaller irrigation schemes situated along Indris River, which is its water source. The water of the investigated schemes is diverted by two different dams situated about 10km and 2km south (upstream) from Guder, respectively.

Severe downstream impacts of irrigation have been noted under low flow regimes (Ruffeis, 2006b; Wallner, 2006). In the dry periods practically the whole discharge is diverted from the river into the irrigation system. Directly after the diversions only water seeping through the diversion dam supplies the riverbed. Tributary rivers of Indris are providing the discharge for the second river diversion.

Lomi Wuha

This case study site is located in Merhabete district in Northern Shoa zone of the Amhara Regional State about 180 km north of the Addis Ababa. The topography of Merhabete is predominated by two valleys formed by the Jema and Wenchit Rivers. The infrastructure of Lomi's irrigation scheme is very basic. Three springs or spring areas are used as water source for irrigating the farmland. The water is collected in natural basins and is diverted with two earth canals supplying different parts of the scheme. The size of the command area of the system is approximately 24 ha and on-field water distribution is done with furrows.

Main hydrological impacts result from reduced run-off water, but there are no downstream users (Ruffeis, 2006c). A conflict appears between the destruction of natural vegetation in the adjacent spring area versus food security in the region. Soil conservation and protection against erosion and land degradation is provided through irrigation because of a permanent vegetation cover. Soil physical analysis results compared with parent material may explain the different soil types within the area.

Finchaa Valley Sugar Estate

Finchaa Valley is located about 330 km west of Addis Ababa in the western part of Ethiopia, eastern Wollega zone in Oromiya region. In 1975 the state farm was established that mainly produced food and commercial crops until 1991. Starting from 1991 up to now more than 8064 ha of land has been cleared and irrigated for sugar production (Ahmed Amdihun, 2006). The water source is the reservoir of Finchaa Dam (Lake Chomen) initially built for hydropower production. 25 pumps at 5 pump stations divert the water serving 34 % of the command area. 66 % of the area is irrigated using gravity off-takes at 3 locations. The Finchaa Valley Irrigation System is equipped with sprinkler irrigation devices.

Observations made during the field visit indicate that the obvious malfunction of the waste water treatment plant of the sugar factory poses a threat to downstream water bodies, especially to Finchaa River and its ecosystem. The project opened up large scale job opportunities for many thousands of people. It has also many socio-economic benefits for the valley and surrounding people. In addition Finchaa Sugar factory plays a key role in addressing the current sugar demand on the local market. There are many efforts to exploit the by-products of the factory for additional purposes like using ethanol for fuel. The estate has also an important role in the growth of national GDP and GNP (Ahmed Amdihun, 2006).

The analysis of measured water parameters at different dates shows no significant differences (Ruffeis et al., 2007). The soil degradation is in its early to moderate stage and not difficult to be addressed by alleviation measures. No further adverse impacts are to be expected caused by the water source, though malaria transmission seems to have increased because of the irrigation (Chala, 2007).

Hare

Hare River irrigation schemes are located in the Gamo Gofa Zone, in the Southern Nations and Nationalities Peoples Regional State of Ethiopia (SNNPR), about 495 km south of Addis Ababa. The irrigation systems are located between the shore of Lake Abaya and the escarpments of the highlands. Hare Irrigation System comprises three different irrigation schemes with a total irrigable area of 2224 ha belonging to four kebele administrations, Kola Shara, Chano Mille, Chano Chalba and Chano Dorga. The three irrigation schemes use Hare River as water source but have to be classified differently due to differences in abstraction and delivery structures (Ruffeis, 2006d). Chano Dorga can be classified as traditional. In the case of Kola Shara a traditional delivery system is used to allocate the irrigation water that is diverted from Hare River by a modern diversion structure. Chano Chalba and Chano Mille can be classified as modern.

Farmers complain about insufficient amounts of water for irrigation. The cause is decreasing rainfall over the last decade in the highlands, which minimized the discharge of Hare River and therefore the availability of irrigation water. The mentioned problems related to the high variability and low availability of water disproportionally affects farmers having their farmland located at the tail end of the scheme. In order to solve these allocation and availability problems one possible solution could be the construction of a reservoir to store the run-off water of Hare River (Judt, 2007). On the other hand this might have severe impacts on the hydrology of Lake Abaya, due to a reduction of annual inflow rates. The options for design and water management to control malaria in this region were investigated by Ashenafi Madebo (2003).

Summary of irrigation development impacts on the environment

From the results a standardized sampling procedure such as checklists and guidelines for field work could be developed for future investigations. Standardized does not mean that the investigations are exactly the same in each site, but that the results are presented in an easily comparative way. An example of a checklist applied at the fields sites of Wonji and Indris was provided by Wallner (2006) in her work.

Most important general findings for locations with similar conditions are summarized in Table 3. In this table a picture of the project investigations is provided and hence we do not claim it is complete. Still it may serve as a starting point for sharing knowledge and experiences. The impacts shown are the challenges for the future and need to be considered in irrigation planning and management activities. The more we know the more we can optimize our interventions for the benefit of poor people.

Table 3: Impact matrix of irrigation development on the environment and health

Nr	Scheme	Basin	Hydrology/ natural resources	Water quality	Soil quality	Poverty alleviation	Others
1	Wonji	AWASH	Rising water table, Seepage of reservoirs	Slight EC increase	Water logging Infiltration		Heavy machines
2,3 4	Oromyia		Inefficient water use (except Marcos)	Stagnant water	Salinity	Marketing, poor access to health facilities	Need for education, management Water conflicts
5	Amibara II		Flood hazard, degradation	Linkage with Lake Beseka (very high sodium cont.)	Salinity	questioned	livestock, Negative Social effects
6	Ziway Holota			Toxicity	Salinity Permeability increase	Malaria, Market access	New plant diseases, training
7	Indris	BLUE NILE	Water diversion		Risk of water logging Low fertility		detailed soil sampling needed
8	Lomi Wuha		Erosion risk		Nutrients deficit, alkaline		
9, 10	Fincha		Destruction of Ecosystem	Low EC	Low organic matter, Infiltration	Employment possibility vs. destruction of ecosystem, Malaria	Impact of sugar factory on downstream water body
11, 12	Hare	Rift Valley Lakes	Degradation, erosion, deforestation	Water logging	Low organic matter	Malaria, questioned	

Conclusion

The assessment of irrigation practices (AIP) claims not to be a new method, but tries to take advantage and adapt existing practices for irrigation projects. A step forward to quantify the significant positive and negative impacts of irrigation development in Ethiopia was achieved and the risk assessment of future irrigation investments is supported. The development of methodological guidelines for assessing the impact of irrigation investment has started. The knowledge of the total impact of irrigation development on economy, society and environment could be substantially improved. Health and poverty alleviation issues have been addressed to some extent. Data sheets and concepts for field investigations are developed and applied at field sites. Standardization of the assessment of irrigation practices and field investigations is especially useful for designing fieldworks and the comparison of results. The development of guidelines for decision makers, planners and farmers depends on standardized methodologies and procedures.

Integrated multi-purpose water utilization for irrigation has to be considered. This increases the demand for good management and the awareness of possible conflicts that may arise due to competing interests. Efficient use of irrigation water is required to avoid water loss and to control vector breeding and water-related diseases. Well planned and maintained small-scale irrigation schemes are a contribution to economic development through increased incomes, employment creation and food security. Negative environmental effects could be minimized. Salinity and its mitigation measures are a mayor concern. Large scale irrigation schemes show mostly a better management and maintenance, but are at risk of more negative environmental impacts.

A major challenge concerns the application of hydrological research for surface and groundwater resources development and management, surface water harvesting and its effect on groundwater recharge with implication to the conjunctive use of water resources. Infrastructure and market access of is a key feature of the success of an intervention. Other issues like improves health care, improved communication or a rural credit system could also support the development of rural areas.

The role of universities is to connect research and education, to share and support partners in the southern hemisphere, which is clearly visible by the “work force” named in this report. The importance of education to improve livelihood and food security is not questioned. Education in this context must reach out to all stakeholders involved in irrigation practice. Especially education and training in water management, marketing and general crop production is of high important. Finally it is believed that this project provides a contribution to strengthen Ethiopia’s capacity for interdisciplinary research and political implementation.

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Environmental Impact Analysis of Two Large Scale Irrigation Schemes in Ethiopia

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Abstract

This article presents the finding of a study undertaken to assess the status-quo and significant environmental impacts of two selected large-scale irrigation on natural resources in Ethiopia. Main focus is on the environmental impacts of irrigation on natural resources with special emphasis on soil quality, water quality and downstream impacts, hydrology and potential interference with ecosystems. For this purpose two schemes were selected. Wonji/Shoa Sugar Plantation is located in the Upper Awash Basin and Finchaa Valley Sugar Estate located in the Blue Nile Basin.

It is well known that irrigation projects can have several adverse environmental impacts that may threaten the sustainable production of agricultural goods, which is of major importance and interest in Ethiopia since it contributes 44 percent to Ethiopia's GDP, employs 80 percent of the labor force, and provides a livelihood to 85 percent of the nearly 80 million population (Awulachew, 2006, Government of Ethiopia, 2006, UNDP, 2006).

Irrigation projects inter alia can have potential impacts on the hydrological characteristics of aquifers, quality of downstream water bodies, quality of soils and ecosystems.

The most prominent results and environmental impacts of the selected case study sites could be summarized as follows. In general the irrigation water is of good quality, but the electric conductivity is unfavorable to the adjusted sodium ratio, which leads in some instances to soil crusting and has a negative impact on infiltration rate. In Wonji/Shoa the groundwater table has risen due to improper irrigation management and seepage of reservoirs. In Fincha a valuable ecosystem has been destroyed due to the establishment of the scheme and increased migration.

Key words:
Large-scale Irrigation / Environmental Impact / Water / Soil / Ecosystem / Ethiopia / Finchaa / Wonji/Shoa

Introduction

Under the title "Irrigation Infrastructures Development for Food Security and National Economic growth" the Ethiopian government started an irrigation development program in order to meet the ambitious efforts of the 15 years Water Sector Development Program, which is scheduled from 2002 until 2016. The investment in large-scale irrigation projects should guarantee to meet the demands for industrial raw materials for Agro-industries, cash crops and food crops. 26 medium and large-scale irrigation projects are planned to be implemented. Irrigation infrastructures in the country will more than double at the end of the program period, which is the year 2016 (currently only 200,000ha, this will grow by 275,000 ha). More recently, the irrigation sector development program is revised and the country has stepped up its efforts to bring additional irrigated area of 430,000 in five years, see MOFED PASDEP (2006)

In Ethiopia, irrigation projects with command areas larger than 3000 ha are classified as large scale schemes according to MoWR (2002). Werfring et al (2005) distinguish between four different types of irrigation schemes in Ethiopia: traditional, modern communal, modern private and public. Most of the medium and large scale irrigation schemes are located in Oromia and Afar region respectively. According to Tilahun and Paulos (2004) 31.981 ha and 21.000 ha of irrigated land are classified as large or medium scale schemes in these regions. In total 61.057 ha are identified as large or medium scale irrigation schemes in Ethiopia.

Since the Ethiopian Government has started to focus its development strategies on the extension of irrigated agriculture especially of large scale projects during the last decade it has become more important to explore the nexus between irrigation investments, sustainable agricultural development and potential environmental impacts in the Ethiopian context. In Ethiopia very little information and baseline date are available regarding irrigation and its environmental implications. Hence research has to be undertaken to fill this knowledge gap.

This article presents the finding of a study undertaken to assess the status-quo and significant environmental impacts of large-scale irrigation in Ethiopia. The main focus of this report is put on the environmental impacts of irrigation on natural resources with special emphasis on soil quality, water quality and downstream impacts, hydrology and potential interference with ecosystems.

In several studies a number of different environmental impacts have been identified which are directly caused by irrigation projects. Sectoral guidelines to conduct environmental impact assessments of irrigation projects (e.g. FAO, MoWR) use checklists which include the pertinent environmental impacts. These potential impacts are grouped into impact categories such as economic, socio-economic, natural resource and ecological impacts. This article puts its focus on impacts on natural resources and ecosystems which are closely related to in-field impacts on soil, water quality, hydrological issues and destruction of ecosystems due to irrigation development. In Tab.1 some of the potentially significant adverse impacts are listed.

Table 1: Typical environmental impacts of irrigation on natural resources

Impact category	Potential adverse impact	Cause
Hydrology	Rise of local water table, Water logging, Changes to the low flow regime	Improper irrigation management, Poor water distribution system Low irrigation efficiency, Seepage losses
Quality of irrigation source	Pollution of soil, Toxicity of products	Inadequate assessment of the quality of supplied water
Downstream water quality	Pollution of downstream water bodies	Improper use of fertilizer and pesticides
Soil degradation & damage of soil structure & change of soil properties	Alkalization	Quality of irrigation source
	Soil acidification	Long term leaching, Improper use of fertilizer
	Salinisation	Saline groundwater,Saline irrigation water, Saline soils, Improper irrigation management, Insufficient drainage
	Reduction of fertility	Intensive cultivation without additional amendments
	Water logging	Improper irrigation management, Soil degradation, Raise of water table, Improper drainage
	Erosion	Operation, Construction of the scheme
Ecosystem, Water bodies,	Creation of aquatic habitats	Construction of reservoirs and canals
	Destruction of ecosystem within the	Scheme construction

Wetlands	project area	
	Eutrophication and pollution of water bodies, Change of return flows	Reduced quality and amount of return flows
	Destruction of ecosystem in the adjacent area of the project	Migration tendencies, Improper land use strategy

Methodology

Study area

The study areas have been chosen for their diversity in terms of climatic conditions as well as soil types. Two large scale irrigation projects in Ethiopia were selected as case studies where primary and secondary were collected, Wonji/Shoa sugarcane plantation and Finchaa Valley Sugar Estate.
The major predominant soil types in the area of Wonji/Shoa sugarcane plantation are described as Fluvisols, Andosols and Laptosols according to FAO soil classification. Soils of Wonji/Shoa are of alluvial-colluvial origin developed under hot, tropical conditions (Fig. 1). In the region diverse soil types are observed which also vary in their production potential. (Ambachew et al, 2000). In general, soils of Wonji/Shoa can be described as a complex of grey cracking clays in the topographic depressions and semiarid brown soils. On the basis of texture they are categorized into light (coarse textured) soils and heavy soils (clayey black types) which are more common in Wonji/Shoa Sugarcane Plantation (Ambachew et al, 2000).

The soils in Finchaa valley are made of alluvial and colluvial materials from the surrounding escarpments. Five major soil types can be found in the area of Finchaa Sugar Estate of which Luvisols and Vertisols are predominant. These soils account for more than 95 percent of the cultivated and irrigated land. The irrigation scheme is divided by Finchaa River into East and West Bank (fig. 2). Currently only the West Bank is under cultivation, but the extension of the irrigated area to the East bank is planned.

Table 2: General description of the selected case study sites

	Finchaa Valley	Wonji/Shoa
Size	8064 ha	7000 ha
Location	9°30’-9°60’N; 37°10’-37°30’E	8.40°N; 39.25°E
Altitude	1550 m	1540 m
Date of Establishment	1995	1956
Type	Public, large scale irrigation	Public, large scale irrigation
Management	Government Agency	Government Agency
Basin	Blue Nile Basin	Awash Basin
Water source	Lake Chomen, Finchaa River	Awash River, Reservoir (reused water from factory)
Diversion	Pump	Pump
Irrigation	Pump, Gravity, Sprinkler	Gravity, Furrow,
N/ETo (mm/y)	1300/1500	747/2519
Agro-ecology	Weyna Dega (1500-2300m)	Weyna Dega (1500-2300m)
Main crop	Sugarcane (monoculture)	Sugarcane (monoculture)
Major Soil Type	Luvisol	Fluvisol

Figure 1: Scheme layout of Wonji/Shoa Sugar Plantation

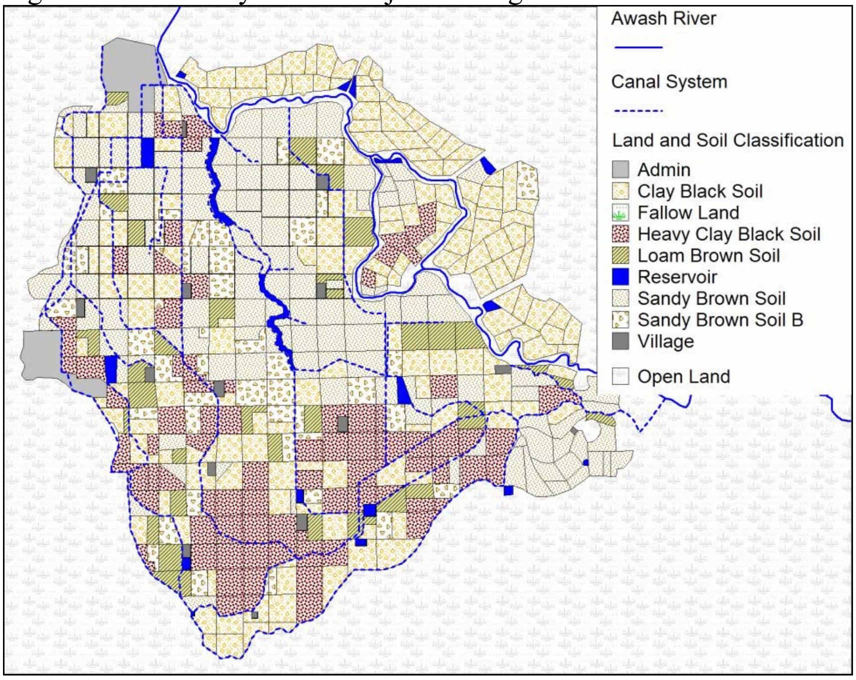
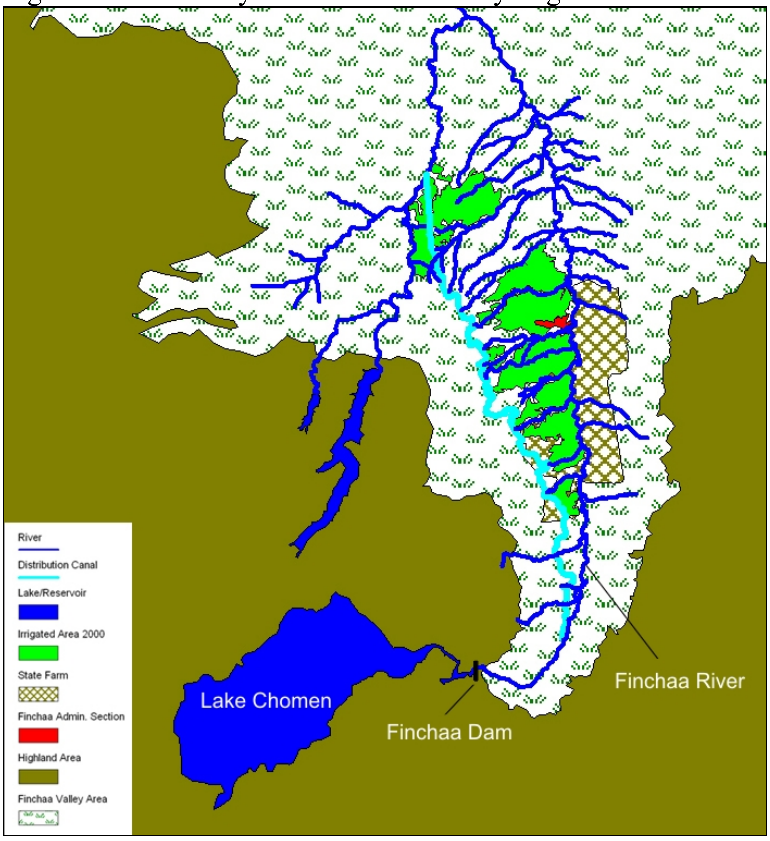


Figure 2: Scheme layout of Finchaa Valley Sugar Estate



Data Collection and Analysis

Both secondary and primary field level data were collected. Secondary data included general description of the scheme, hydrological and meteorological relevant data, information about the topology and geological characteristics of the area and about irrigation infrastructure. Research and data collection have been conducted using the "with or without" and when ever possible the "before and after" approach comparing secondary and primary data sets. The availability of

secondary soil and water quality data in the two case studies allows, to some extent, impact analysis using the “before – after” approach. Whenever possible, baseline and secondary data of research documents have been collected.
For data collection activities, specific data sheets have been designed for field level research as well as for secondary data collection.

Because only few data or baseline data were available to compare time series data and carry out before and after type of analysis, soil

samples were taken from non irrigated and irrigated fields but also from cultivated and uncultivated plots to assess potential impacts of irrigation on chemical and physical soil parameters. Disturbed soil samples were taken from the predominant soil types at different spots, depending on the accessibility and influence of irrigation on the spots, using the comparative soil sampling method. From each plot samples of different depth were taken, depending on the structure of the soil and the depth of soil horizons. Every soil horizon over 10cm was sampled, at least from 0-30, 30-60 and 60-90 cm depths (FAO 1986).
Water samples were collected from the irrigation source and potentially influenced water bodies using 1 litre plastic bottles and immediately stored in a cooling box. As some parameters may change rapidly after sampling (e.g. Nitrate) the pH was brought down to 2 by adding acid (HNO_3) to the samples to stop chemical reactions. The samples were analyzed either using in-field measurements and tests or laboratory analysis. Water sampling locations were chosen based on the spatial variations in the water stream and irrigation system (irrigation sources, the distribution canals, reservoirs, the main drain and from downstream water bodies) in order to obtain a representative sample. In table 3 chemical and physical parameters are listed which had been analysed either in the field or using laboratory facilities.
The standards and threshold values for water quality analysis were chose with respect to irrigation (FAO 1989). The widely accepted threshold values for classifying the suitability of water for irrigation are presented in table 4 (FAO, 1998). The standards and threshold values for soil chemical and physical were taken from the Ethiopian Ministry of Water Resources (2002).

Table 3: Measured chemical and physical soil and water parameters

Samples	In-field measurement	Laboratory Analysis - chemical & physical parameters
Water	Electric Conductivity	pH, Electric Conductivity
	Temperature	Cations: Na, Ca, Mg, K
	Nitrate	Anions: SO_4, PO_4
	pH	Toxic substances B, Cl
		Nitrogen: NH_4-N, NO_3
		Alkalinity (CO_3+HCO_3)
		Trace elements Fe, Mn
		SAR, adj. RNa
Soil	Profile Pit investigation	Particle size distribution of silt, clay, sand, soil texture
		pH, Electric Conductivity
		Nutrients: Na, K, Ca, Mg, P, tot N, Fe, Mn
		CEC, ESP, BSP
		Organic Matter, Nitrate

Results and Discussion

Wonji/Shoa Sugar Plantation - Water Quality Anylsis

In general the irrigation water used in Wonji/Shoa Sugar Plantation is of high quality.

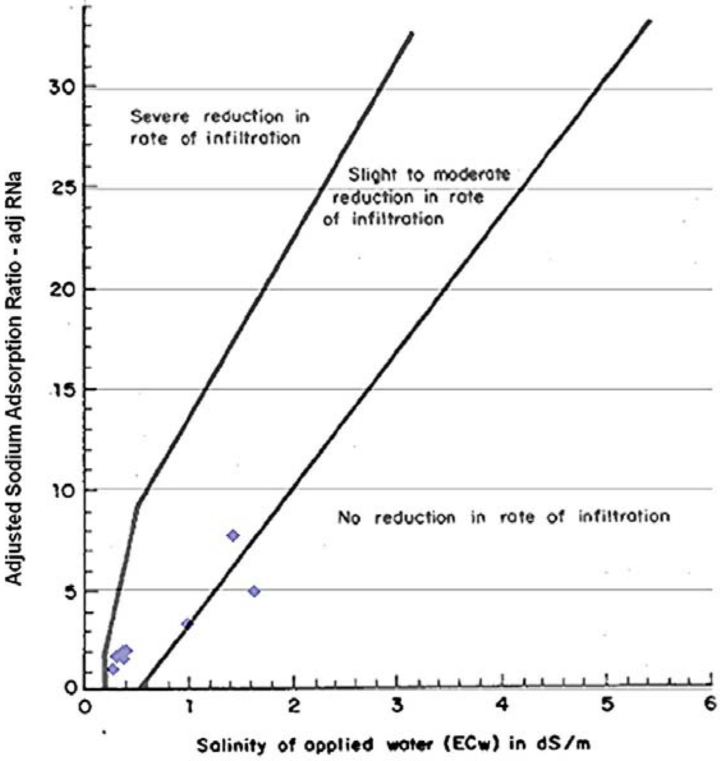
Hardly any adverse impacts on the soil quality resulting from irrigation activities are to be expected on this scheme. However **SAR/adj R_{Na}** to **EC** ratio (fig. 3) indicates that a slight to moderate reduction in the infiltration rate might occur. Low salinity water (< 500 µS/cm) is corrosive and tends to leach surface soils free of soluble minerals and salts (FAO 29, 1989). The EC value of Awash River, the irrigation water source of Wonji/Shoa, is 293 µS/cm. The tested soils show an EC from 151 to 475 µS/cm and can be rated as salt free according to the Eth. Ministry of Water Resources (2002). The absence of salt in the soil indicates an ongoing dispersion process which leads to sealing of the soil and thus reduces the soils infiltration rate (FAO, 1989). During the field study and the analysis in a soil pit destruction of the natural structure of the soil in some places could be observed. To a certain extent this destruction of the soil structure might be due to unfavourable SAR values and SAR/adj R_{Na} to EC ratio in the irrigation water of some of the water samples. Moreover soil tillage with heavy machines might also have destructive effects on the soil structure, particularly where waterlogging and high water tables occur.

Girma A. (2005) states that in most sugarcane fields of Wonji/Shoa slight to moderate soil infiltration problems are expected if groundwater occurs at shallow depths. In this regard, the groundwater depth was at all the times too shallow (in the root zone) for nearly all sugarcane fields considered in this study. This indicates that in Wonji/Shoa, sugarcane fields are prone to waterlogging and physical degradation of topsoil. Drainage water and factory used water are stored in reservoirs and reused for irrigation, therefore it is of major importance to monitor the quality of this irrigation source. The drainage water and the reservoir water shows EC values increased values compared to the irrigation water, 357 and 388 µS/cm respectively. With regard to salinity the water is still of very good quality and should not pose any problems on soils in case it is reused for irrigation. These findings are confirmed by the study conducted on irrigation water quality by Girma A. (2005). Irrigation water (i.e. Awash River water) and factory used water were free of potential hazards of salinity, sodicity and specific ion toxicities. Moreover, drainage water was nearly of similar quality. As pointed out in the previous section this could cause from slight to moderate problems regarding infiltration. The total salt content of groundwater for some sugarcane fields was relatively high (i.e., EC values exceeded 700 µS/cm); a critical limit above which osmotic effects are known to occur. SAR values (fig. 3) were low in all groundwater samples. The potentially toxic ions Na^+, Cl^- and Boron were also found at low concentrations.

The values for the **pH** of Wonji/Shoa irrigation system are in the normal/neutral range (pH = 6.5 to 8.5) for all water samples. Only the drainage water shows a lower pH of 6.3 which indicates slightly acidic water. Generally the pH in all the water samples taken does not seem to be influenced by irrigation. Similar results are given by Girma A. (2005). The measured pH values of both irrigation water and Factory used water samples varied from 7.4 to 8.1 (from near neutrality to medium basic in reaction). pH values of drainage water samples varied from 7.0 to 7.8 (normal range). All groundwater samples varied in pH values from 7.1 to 8.3.

The highest values for **chloride** and **boron** are 3.6 meq/l and 0.45 meq/l respectively. Therefore the threshold values from no restriction on use to slight to moderate restriction on use (4 meq/l for chloride, 7 mg/l for boron) were not obtained by any of the water samples.

Figure 3: Effect on Infiltration rate due to Sodicity of sampled water sources (Wonji/Shoa Sugar Plantation)



Wonji/Shoa Sugar Plantation - Soil Quality Analysis

As mentioned the tested soils show an EC from 151 to 475 µS/cm and can be rated as salt free according to the Eth. Ministry of Water Resources (2002).
The **pH** of all soil samples ranges from 7.4 to 8.4 indicating moderately alkaline soils which is typical for soils of these climates (dry, arid climate most of the year). This indicates low availability of phosphorus and other micro-nutrients (MoWR, 2002).
With a **CEC** from 46.2 to 58.4 meq/100g the soil samples are all in the range of very high CEC, according to the ratings of the Ethiopian Ministry of Water Resources (2002). This indicates good agricultural soil. The **BSP**, ranging from 62.6 to 96.65% can be rated as high for almost all soil samples which indicates a high fertility of the soil. The **ESP** of the soils lies below 6% (0.99 to 5.88%) which is definitely below the threshold of 15% and therefore the soils can be rated as non sodic. Decreases in yield would only be expected for extremely sensitive crops (ESP = 2–10) but not for sugar cane.
The content of **total Nitrogen** can be rated as high for all soils (ranging from 0.071 to 0.114%). The rating for **Potassium** is high and very high for all soil samples ranging from 1.08 to 2.63 for irrigated land and from 3.68 to 4.05 for the virgin soil. The comparison of irrigated soils and non-irrigated virgin soil shows that the content of Potassium is much higher in the virgin soil (4.05 meq/100g). The distribution of some parameters over the soil depth does not seem to be natural anymore for the cultivated soil. In general there are hardly any obvious differences between irrigated soils and the virgin reference soil as far as the chemical properties are concerned. The reason might be that the irrigation water has a very good quality and therefore no severe impacts on the soil are to be expected. A possible decline or even lack in nutrients is compensated through fertilizer application or other soil fertility management practices. The virgin soil might also be influenced by irrigation through capillary rise of the groundwater or surface runoff of the irrigated

fields and therefore not be perfectly virgin anymore.

The content of **Calcium** is high and very high in all soil samples, ranging from 18.32 to 40.72 meq/100g soil. The same applies for **Magnesium** ranging from 4.94 to 12.36 meq/100g soil.

The content of **organic carbon** of all soil ranges from 0.76 to 1.88 % and can be rated as very low in all the soil samples. This indicates that without application of fertilizers no adequate yields would be achieved.

Wonji/Shoa Sugar Plantation - Groundwater Hydrology

In Wonji problems due to irrigation are reported with regard to **waterlogging**. The ground water level within the sugar estate shows a rising tendency (observation 1999-2001, fig. 4). However, not only within the sugar cane plantation but in the whole region a rise of the water table has been reported (Teshome, 1999). This might be due to irrigation (seepage losses out of reservoirs and channels, over watering, etc) but also due to seepage losses in a great extent from the Lake Koka reservoir. The water of the Awash River is retained by Koka dam. The dam was built to assure a constant discharge in the Awash River for two hydropower stations, but it also guarantees sufficient irrigation water supply.

What has been reported before and confirmed in the field work are problems with a high water table and waterlogged fields. Especially on fields with heavy clayey soils problems with waterlogging have been discovered during the field study and the analysis in a soil pit (Wallner, 2006). However, the lighter soils – light in relation to the heavy soils of the sugar estate - seem to be of very good quality and not prone to negative impacts of irrigation under the given conditions.

In 2002 a study on groundwater level fluctuation at Wonji/Shoa sugarcane plantation was conducted by Habib D. Investigations showed that on some fields the groundwater table is less than one meter deep (ARS Annual Report, 1994). The same report indicated that in some fields downward percolation of irrigation water below the root zone, especially in soils classified as heavy black soils is so slow that it caused temporary storage within the root zone (in some places up to 10 days after irrigation). These drainage problems have even become one of the major factors in determining the composition of cane variety (Tariku, 2001). In fields located near reservoirs, irrigation canals and drains suppressed cane growth due to seepage and ground water table rise could be observed. Kediru (1997) stated that cane loss due to this problem is economically significant.

In 1998/99 a study was started in Wonji/Shoa Sugar Plantation to measure the groundwater level (GWL) fluctuation with piezometers installed in different plantation fields. Piezometers were installed at different locations near reservoirs, distribution canals and drains. One piezometer was installed in a non-irrigated area as reference (WRS).

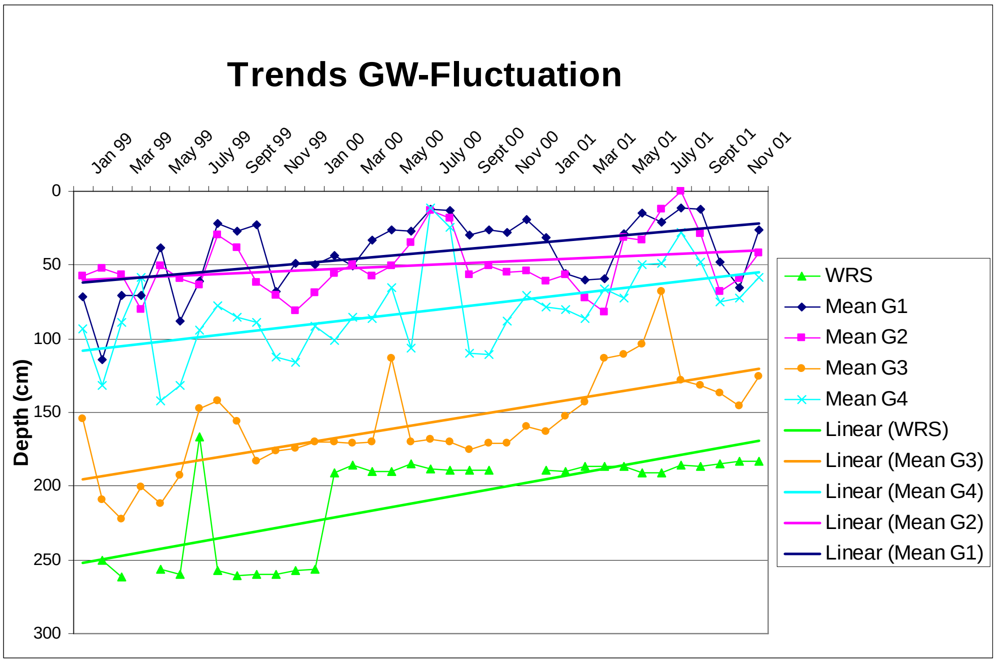
In figure 4 groundwater tables of 4 different fields (G_1, G_2, G_3 and G_4) and the reference field (WRS) are displayed for 3 years (1999-2001). Measurements are given in depth in cm from soil surface. The measurement of groundwater table of the reference area (WRS) shows the maximum water table depth values in all years and months.

The results indicate that fields which are located near reservoirs are affected by rising ground water level more than fields nearby distribution canals and fields nearby drains.

Even this short measurement time series of 1999 to 2001 shows significant increasing trends of rising groundwater table. Fields near reservoirs (G1) are most affected. Habib (2002) concludes that seepage from reservoirs and unlined irrigation canals is the reason for rising groundwater level. Near drains (G3) groundwater levels are significantly lower compared to the measurements near the reservoirs. This result shows that drains if effectively utilized can lower the ground water table. In the reference area GWL was rising the first year but decreasing the second year. Furthermore the GWL is generally at least 50cm deeper compared to the GWL of the irrigated fields.

Three years of GWL measurement reveal that fields near reservoirs are highly affected by waterlogging followed by fields near unlined distribution canals, fields away from water bodies and fields near by drains. The water level is increasing from year to year. Moreover, with the exception of fields near drains the GWL of other fields is less than 60 cm for more than 6 months per year which has a negative effect on sugar production.

Figure 4: Trends in the ground water level at Wonji/Shoa sugar plantation over three years (Habib, 2002)



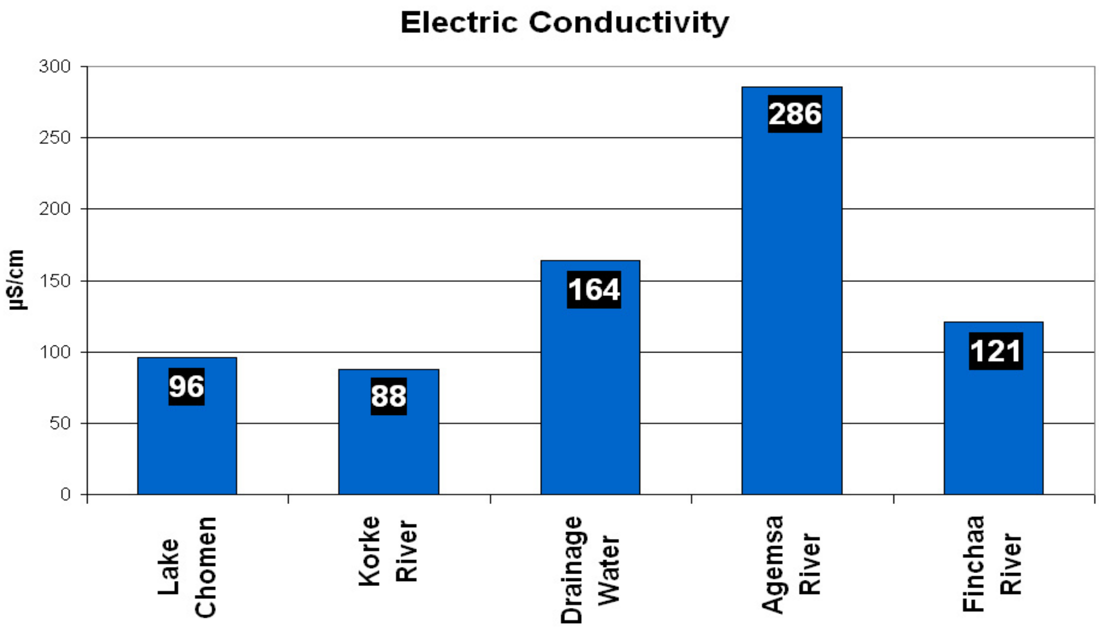
Finchaa Valley Sugar Estate - Water Quality Analysis

Water quality, regarding the physical as well as chemical parameters, of Finchaa Valley Sugar Estate can be rated as very good for irrigation purposes. However, the increase of the **EC** value of Finchaa River from 96 µS/cm measured in the upstream area of the scheme to 121 µS/cm in the downstream area shows the impact of irrigation on the downstream water bodies. This value does not include the indirect impact of irrigation by releasing pollutants by the sugar factory because the outlet of the factory was closed while EC measurements were taken. The observation made during the field visit indicates that the obvious malfunction of the waste water treatment plant of the factory poses a threat to downstream water bodies especially to Finchaa River and its ecosystem. Further investigations are necessary to investigate into the potential impact of the factory and the scheme on downstream users. Additionally an improvement or at least maintenance of the waste water treatment plant is required.

The values of the EC measurement in the field are all below the threshold value of non saline to slightly and moderate saline of 700µS/cm given by FAO (1989). This indicates no problems with salinity caused by the available water source. A detailed analysis of the EC Values of different water bodies in the adjacent area of the estate provides a deeper insight in the hydrological system of the irrigation scheme (fig. 5). The EC value of Lake Chomen (Finchaa Dam) is 96 µS/cm. The groundwater samples show slightly increased EC values of 352 and 477 µS/cm due to accumulation of salts in the aquifer. Fig. 5 shows the EC values of different water bodies within the irrigation scheme from upstream to downstream area of Finchaa Sugar Estate. As mentioned before the EC value of the reservoir is 96µS/cm and 88µS/cm for Korke River one of the tributaries of Finchaa River in the far upstream area of the scheme. Finchaa River drains Lake Chomen to the Blue Nile Basin and therefore has the same EC values. The assumption can be made that the natural EC value of surface water bodies in Finchaa Valley Area is below 100 µS/cm. The EC values of the drainage water (164µS/cm) and of tributaries of Finchaa River, e.g.

Agemsa River (286µS/cm) which are located further downstream of the estate are much higher compared to the values in the upstream area. This fact together with the increased EC value of Finchaa River (121µS/cm) measured at a location downstream of the irrigated fields indicates that the tributaries of Finchaa River crossing the irrigated area serve as the natural drainage system of the sugar farm. The increasing EC value of Finchaa River makes the impact of irrigation on downstream water bodies clearly visible. Drainage waters as well as surface run-off water possibly mixed with agrochemicals affect the water quality of the natural water resources in the adjacent area of the scheme.

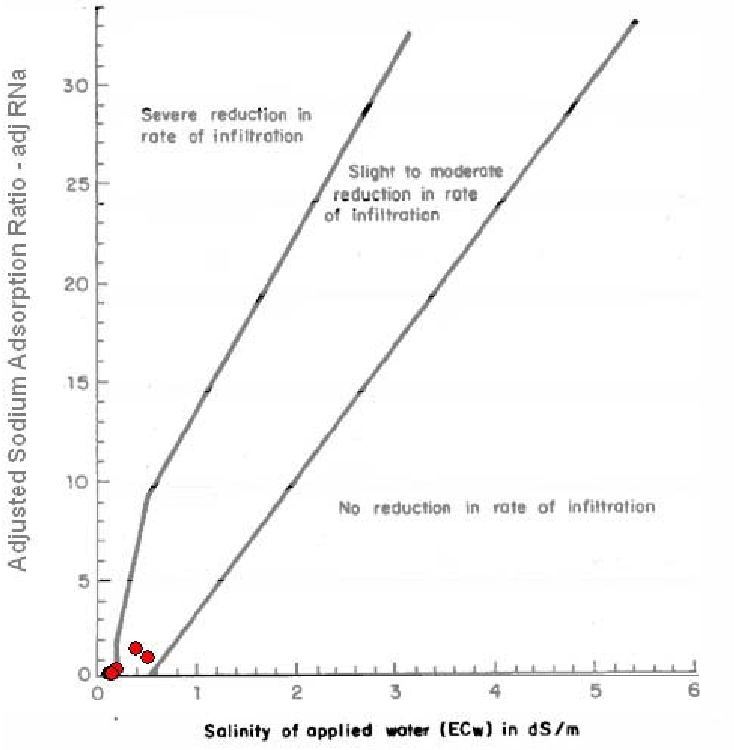
Figure 5: EC values of different water bodies from upstream to downstream areas at Finchaa Valley Sugar Estate



The ratio of adj R_{Na} to EC (fig. 6) of the irrigation water source indicates a risk of severe reduction of the infiltration rate over time. This imposed sodicity has the potential to destroy the soil structure and lead to soil crusting of the affected soil especially when EC value is low (96 µS/cm). The dispersive effects adversely influence the physical properties, e.g. infiltration rate, aggregate stability of the soil (FAO, 1989). The extent of the impact highly depends on the texture and clay-sized particles of the soil.

Since the filling of smaller pore space, sealing the soil surface and therefore reduces infiltration rates, by dispersion of finer soil particles is more likely to happen in soils with high clay content impact on Luvisols which can be classified as sandy loam to sandy clay loam with sand content over 60 % might prove to be less severe compared to the impact on Vertisols with clay content up to 60 %.

Figure 6: Effect on Infiltration rate due to Sodicity of sampled water sources (Finchaa Valley Sugar Estate)



As salinity of both applied water and the soil solution is relatively low no further swelling and dispersion of clay minerals are to be expected caused by the water source.

The threshold values for **chloride** from no restriction on use to slight to moderate restriction on use of 4meq/l are not obtained by any of the water samples. The **SAR** rating for slight to moderate restriction on use ranging from 3 to 9 neither is obtained using the SAR values nor the values for **adj** $\mathbf{R_{Na}}$. Therefore no toxic effects on plants due to irrigation are to be expected.

Finchaa Valley Sugar Estate - Soil Quality Analysis

The comparison of the collected primary and secondary **soil texture** data for Luvisols show differences related to the proportion of sand, silt and clay content. The primary data show a lower sand content for the upper soil and a higher sand content for the lower soil part and vice versa for the clay content which indicates a shifting and relocation of soil particles especially of the sand fraction. A possible reason could be found in mechanized soil tillage. The silt content of the primary data sample is twice as low as it is for the secondary data sample. This ongoing process might lead to accumulation of clay particles in the topsoil layers and therefore aggravate the gradual degradation of the soil structure by induced sodicity.

The **EC** values of all analysed soils range from 10 to 60 µS/cm which is far below the threshold value of 4 dS/m (= 4000 µS/cm). Therefore they are not affected by salinisation. According to the Eth. Ministry of Water Resources (2002) the samples can be rated as non saline. The EC value of the reference soil of the upper 30 cm is double of the value of the irrigated plots. This could be an indication for an ongoing leaching process caused by the application of water.

Secondary EC values of all analysed soil types are far below the threshold value of 4 dS/m (= 4000 µS/cm). The EC value of during the state farm cultivated Vertisols in the East Bank area is significantly higher than the uncultivated Vertisols of the West Bank. This might indicate an accumulation of salts in the rain fed cultivated soil with insufficient leaching by precipitation.

In general **pH** values of sampled irrigated Luvisols are very acidic to moderately acidic with values ranging from 4.89 to 5.62 from deeper to shallower soil depths respectively. The pH value of non-irrigated reference soils ranges from 4.56 to 4.86. Significant changes in soil pH values comparing secondary and primary data for Luvisols could not be observed. All measured values show slightly acidic tendencies, which is common for soils developed under these climatic conditions. Secondary data show that the pH of Vertisols in Finchaa Valley is higher compared to Luvisols. The measurements however show lower values for the uncultivated Vertisols (pH 6.13 - 6.5) than for the during the state farm period cultivated Vertisols (pH 6.9 - 7.37) with increasing trend for increasing soil depths. This difference between secondary and primary data might be an indicator for ongoing decline of soil pH due to irrigation and agrochemical use within the sugar estate. Washed-out-soils tend to acidification. Water dominated soils (soils of humid regions) have low values of pH, because their content of organic and carbonic acids is often subject to replenishing and recharge by rainfall. Under these conditions, the acids attack minerals, producing more acidity (Mirsal, 2004). Therefore washed-out-soils tend to acidification. According to the rating of pH values given by the Ethiopian Ministry of Water Resources Al and Mn will be toxic if present in very acidic soils. Ca, Mg and Mb may be deficient and the availability of phosphorus is low in the presence of free Al and Fe. Nitrification of organic matter is taking place. In moderately acidic soils P, Ca, Mg and Mb may be deficient. Fertilizers (ammonium sulphate and triple super phosphate) which may increase the acidity should be avoided (MoWR, 2002).

The **CEC** values of the tested Luvisols (14.02 to 14.56 meq/100g) indicate low to medium response to fertilizer application which is typical for soils with low clay content. Low CEC values can be caused by losses resulting from leaching-out, especially sodium (Na) is highly exposed to this process (MoWR, 2002). The CEC of Vertisols (23.95 and 26.54 meq/100g) however shows a different picture. The CEC shows an increasing trend with increasing soil depths. As the clay content of this soil type is significantly higher, the response to fertilizer application is more effective. This makes it even more important to plan agrochemical management for each soil type differently. The reference soil however shows a contrariwise tendency with a CEC value of 24.87 meq/100g in the upper 30 cm of soil depth and 15.52 meq/100g below 60 cm. The primary data of the year 2006 confirm the findings of the feasibility study conducted in the pre-design phase of the irrigation scheme. Proper management of agrochemicals is indispensable to avoid contamination of Finchaa valley aquifers.

The **BSP** of the two sampling spots ranging from 55.0 to 74.0 % and from 51.0 to 67.0 % respectively can be rated as medium to high. This fact indicates a medium to high fertility of the soil. The reference soils BSP values are between 37.0 to 56.0 %. Therefore the soil can be rated as medium fertile with lower values compared to the other tested soils and increasing values with depth.

None of the measured **ESP** values of the tested soils exceeds the threshold value of 15 % and can therefore be rated as none sodic soil (FAO, 1988).

With regard to **CEC** and **ESP** only **secondary data** of Finchaa West Bank area were available. From the CEC values the difference in soil fertility of Luvisols and Vertisols can be clearly seen (fig. 7). With a CEC value higher than 52 meq/100g the Vertisols are in the range of very high CEC according to the ratings of the Ethiopian Ministry of Water Resources (2002). The data for Luvisols however show medium to high CEC values ranging between 21.55 and 28.99 meq/100g. The areas where the field work in 2006 was conducted show CEC values ranging from approximately 25.0 meq/100g for the Luvisols cultivated and irrigated since the establishment of the Finchaa Sugar Estate, which is comparable to values of the uncultivated Luvisols, and below 15.0 meq/100g for the Luvisols which have been cultivated since 1975 and irrigated since 1998. This makes the long-term process of soil degradation visible induced by agriculture and especially by irrigation. Minor to major amendments might be required for the Luvisols, however the soil might show only moderate to poor response to fertilizer application (MoWR, 2002).

None of the measured **ESP** values of the tested soils neither for Luvisols nor for Vertisols exceeds the threshold value of 15 % and can therefore be rated as none-sodic soil (FAO 1988).

The **BSP** ranging from 36.36 to 50.16 % (Lc West Bank), 40.67 to 57.38 % (Lc East Bank) and from 42.98 to 52.55 % (Ve West Bank) can be rated as medium. Only the BSP from the Vertisols which can be found on the East Bank can be classified as high with values ranging from 59.47 to 67.02 %. This fact indicates a medium fertility of the Luvisols in general and the Vertisols of the West Bank. The Vertisols of the East Bank are however characterised by high soil fertility related to the measured **BSP** values.

The content of **total Nitrogen** of the tested soils can be rated as high for all tested soils (ranging from 0.05 to 0.14%). The total nitrogen content of the uncultivated reference soil is significantly lower compared to the irrigated plots.

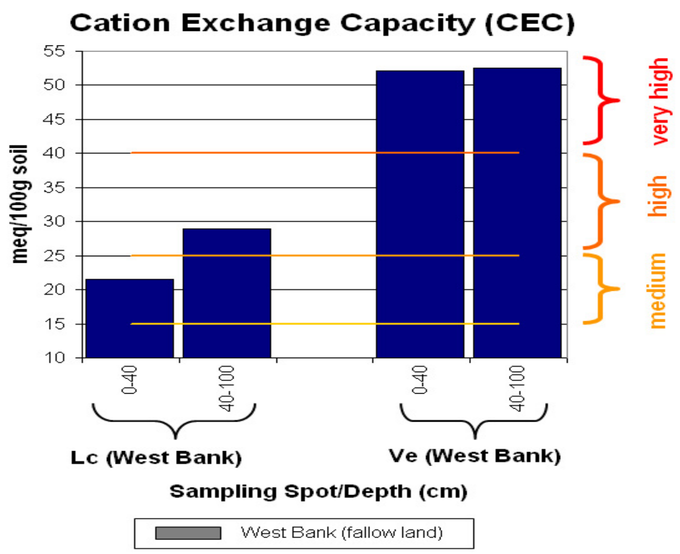
The rating for **Potassium** is low for all samples ranging from 0.2 to 0.27 meq/100g soil except the value of the topsoil of the non-irrigated plot which shows a medium content of Potassium (0.48 meq/100g soil).

The content of **Calcium** is medium (5.18 to 9.5 meq/100g soil) for the irrigated soil and low (3.36 to 4.99 meq/100g soil) for the non irrigated plot.

The tested soils show a high content of **Magnesium**.

The results show very clearly the naturally low content of **available phosphorus** in the reference soil (fig. 8) which makes the application of agrochemicals necessary in order to achieve high crop yields. It is stated that in moderately acidic soils P may be deficient which is true in this case, nevertheless fertilizers (ammonium sulphate and triple super phosphate) which may increase the acidity should be avoided (MoWR, 2002). The content of available P (29.2 mg/kg) is only high within the first 30 cm of soil depth for sampling point F 1. According to the statement of a staff member of the Sugar Estate DAP had been applied to plot F 1 shortly before the field work was conducted. Obviously phosphorus is not leached to lower soil depth as its content in 30-90 cm is significantly lower.

Figure 7: Cation Exchange Capacity of soil samples of Finchaa Valley Sugar Estate – Secondary Data

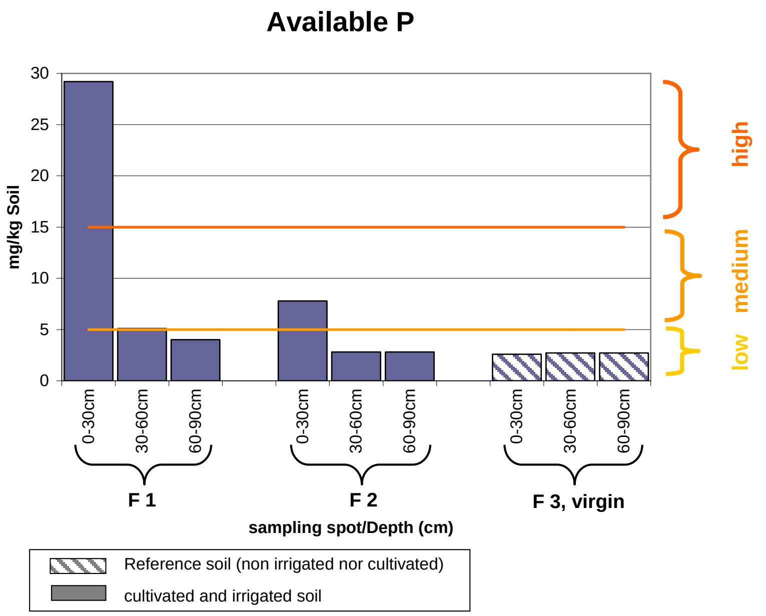


The secondary data show that the content of **total Nitrogen** of the Luvisols and Vertisols of West and East Bank can be rated as high for all soils (ranging from 0.05 to 0.27%). The content of total nitrogen in the cultivated Vertisols is significantly higher (0.27%) compared to the other tested soils. The content of total nitrogen in the uncultivated Luvisols (West and East Bank) is similar compared to the content of the irrigated soils.

The rating for **Potassium** of the Luvisols is medium (West Bank and East Bank; lower soil parts) to high (East Bank; upper soil parts) whereas the rating for K of irrigated Luvisols is low. The tested Vertisols in both areas show higher contents of K and can be rated as high. The formerly cultivated Vertisols of the East Bank have a significantly higher K content

compared to the uncultivated Vertisols of the West Bank.
The content of **Calcium** is medium for the tested Luvisols and high to very high for the Vertisols in both areas. The Ca values of the formerly cultivated Luvisols of the East bank are higher compared to the Luvisols of the West Bank which were uncultivated at that point of time. The Ca content of the tested Vertisols of the West and the East Bank are more or less similar ranging from 18.3 to 21.8 meq/100g but are higher compared to the highest Ca content of tested Luvisols (10.15 meq/100g; Luvisols, East Bank; topsoil).
The **Magnesium** content ranges from 2.32 to 4.36 meq/100g for Luvisols of East and West Bank and East Bank Vertisols. The Mg value for Vertisols of the East Bank is slightly higher with a content of 6.12 meq/100g in the topsoil. The content of Mg in all soils can be rated as high, except the content in the topsoil of the West Bank Vertisols which can be rated as medium. The analysis results of the primary and secondary data show similar Mg contents for irrigated and non-irrigated Luvisols.
The analysis of **organic content** and comparison of primary and secondary data reveals an ongoing soil degradation process caused by intensive sugar cane monoculture. The comparison of the organic carbon content of uncultivated, cultivated and irrigated areas shows a decreasing trend of naturally low organic carbon content of the tested soil types. Two reasons can be spotted as potential causes for this trend. Soil degradation which is caused by intensive agricultural production of sugar cane monoculture might be one reason. The low content of organic carbon can also be explained by the low natural pH value of the soil. The nitrification process of organic carbon which is typical for these soils and climatic conditions could be the direct cause for the very low organic carbon content of the tested soils. However, this makes fertilizers application necessary to achieve adequate yields which additionally spells the risk of groundwater pollution by agrochemicals.

Figure 8: Content of available Phosphorus of soil samples of Finchaa Valley Sugar Estate



Finchaa Valley Sugar Estate – Erosion

Two major types of soil erosion could be identified for the Finchaa Valley cases study. The effect of hinterland erosion and infield erosion jeopardizes the fertility status of the whole region and the Sugar Estate in particular. Deforestation of the highland regions caused by cutting trees for fire wood exposes the highland soils to erosive processes and contributes to high surface runoff. Population pressure aggravates this problem even more. The eroded material from the steep escarpments which is deposited on the irrigated areas of the valley bottom can lead to soil degradation. Run off estimation of the valley bottom indicates loss of eroded fertile soils due to sheet erosion estimated in the range of 5 to 10 mm/y or equivalent to approximately 100ton/ha^{-y} (Girma T., 1995). The eroded soil is deposited to the tributaries of Finchaa River which finally drain to Abay (Blue Nile) River. Considering the high content of available phosphorous which tends to be fixed to soil particles in the topsoil layer, erosion of these soil particles causes an additional threat to downstream water courses. Assuming that these present trends continue the problem of soil and land degradation induced by soil erosion may threaten the sustainability of the irrigation project.

Finchaa Valley Sugar Estate - Impact on Ecosystem

In 1975 the state farm was established which mainly produced food and commercial crops until 1991. About 3500 ha of valuable ecosystems have been cleared and destroyed for agricultural activities. Before that the valley was under natural vegetation cover and very few agricultural plots could be observed. The valley area was a sanctuary for wild animals. Tall savanna grass mixed with trees which occupied most of the valley floor created favorable conditions for a large numbers of wild animals like carnivores, browsers, grazers and other small animals. The natural vegetation in the area was dense and with full canopy during the wet season.

Starting from 1991 up to now more than 8064 ha of land has been cleared and irrigated for sugar production (Ahmed Amdihun, 2006). From 1975 to 1991 these parts of Finchaa Valley area have changed from primary to tertiary economic production; from traditional agricultural to industrial and commercial production respectively. The dominant land use classes are irrigation agriculture and agro-pastoral within the valley area and rain fed agriculture mainly in the high land area. In addition to the land clearing tree and grass species are exposed to extensive and severe bush fires (Ahmed, 2006). Two major reasons could be identified. In addition to natural factors inhabitants of the region earn their subsistence by collecting wild honey and crop cultivation. To clear their land farmers burn the forest. Since the establishment of the irrigation scheme and the beginning of sugar cane production also sugar cane burning for harvesting can be identified as a major cause for forest fires. Furthermore migration tendencies triggered by the attraction and employment options of the sugar estate increase the pressure on the ecosystem.

In developing countries like Ethiopia the GDP of a country highly depends on agricultural production. Priorities have to be outweighed between conservation of valuable ecosystems and important contribution to a country’s economy. In order to justify clearance of large natural forest areas agricultural production needs to be sustainable to avoid large scale land degradation and further adverse environmental impacts.

Conclusions

The main goal of this report was to assess the pertinent environmental implications of two selected large scale irrigation schemes in Ethiopia. For this purpose two large scale schemes in different regions were selected Wonji/Shoa and Finchaa Valley. The main focus was put on impact on natural resources like water, soil and ecosystems. Based on the pertinent environmental checklists of FAOs, World Banks and MoWRs EIA procedures, data sheets and guidelines for primary and secondary data collection were designed (Wallner, 2006) and used during the assessment. The water sources of the schemes were sampled and analyzed against FAOs standards and threshold for water used in agriculture. Additionally water samples of downstream water bodies were tested to assess potential adverse impacts. Physical and chemical soil parameters of primary and secondary data were analyzed for possible changes.

In general, the study conducted shows that the irrigation water used in the investigated case studies is of good quality with regard to FAOs standards for water used in agriculture and does not spell any risk for irrigation purposes. The irrigation water sources used in the three case study sites have low EC values ranging from 96 µS/cm (Finchaa Valley) to 293 µS/cm (Wonji/Shoa) and therefore no primary salinisation is to be expected.

With regard to impact of the used water source on the soil quality EC to SAR ratio however indicates potential negative long-term effects on infiltration rates due to damage of the soil structure and soil crusting through induced sodicity especially in case of Wonji/Shoa and Finchaa Sugar Plantation.

The most crucial environmental impacts of large scale irrigation in Ethiopia which could be identified are related to improper irrigation management and development of irrigation project on saline and saline-sodic soils. Inefficient application of water and seepage of water from reservoirs and unlined distribution canals lead to rising of groundwater table at Wonji/Shoa. Investigations showed that on some fields of the Wonji/Shoa Plantation the groundwater table is less than one meter below soil surface (Habib D., 2002). This tendency has mainly two adverse effects. The rise of the groundwater table up to the root zone interferes with the proper development of the planted crop, leads to damage of the soil structure and insufficient soil ventilation. Secondly it induces secondary salinisation due to capillary rising. Improper irrigation management and attempts to leach the accumulated salt by additional application of water, which leads to rising groundwater table, has even aggravated this effect (Tena, 2002). Besides installation of drainage systems to intercept deep percolation of the excess water, other in the long run more cost-effective measures need to be considered. Installation of drip systems could avoid excessively use of irrigation water and make the application of water more efficient and therefore increase the overall water productivity of the schemes.

According to the Ethiopian Irrigation Development Program 26 medium and large-scale irrigation projects are planned to be implemented. Due to topographic reasons most of these already established or proposed large-scale irrigation schemes can be found in the lowlands of Ethiopians major river basins such as Awash, Blue Nile and Wabe Shebelle river basin. Over 11 million ha of land in the arid, semi-arid and desert parts of Ethiopia are known to be salt affected. Large areas of the Awash River Basin especially the middle and lower parts of the basin are saline or sodic or in saline or sodic phase and thus potentially exposed to salinisation and sodicity (EIAR 2006).

Development of large scale irrigation, political decision making and investment strategies are often oriented on short-term profit maximisation whereby environmental sustainability is neglected. Due to the fact that environmental sustainability of irrigation projects is rather on the low end of the policy priority list, adverse and irreversible environmental impacts are bound to happen in the contrary nexus of profit maximisation, short-term benefits and environmental sustainability.

In order to avoid possible negative impacts of the expansion of irrigated agriculture in causing deterioration of land and soil quality, proper understanding of the quality of soil and irrigation water and implementation of appropriate measures have paramount importance for sustainable development. There is no doubt that irrigation can increase intensification and productivity, can help to limit the size of cultivated areas, can provide ample labour and agro-industrialization opportunities and other potentially positive benefits. On the other hand it can also cause negative impacts such as deterioration of soil and water quality, impact on eco-system, health and other negative externalities. It is important to support such endeavours through proper study and continuous research, so that the positive roles could be enhanced with timely mitigation measures for the negative impacts.

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Planning and management of irrigation in sub-Saharan Africa: reducing the environmental and health costs

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Abstract

Development of irrigation can result in negative environmental and human health impacts. Irrigation undertaken without full consideration of these impacts can have serious adverse repercussions, not only undermining the investment but also worsening poverty and contributing considerably to peoples' suffering. The impacts are strongly inter-linked because it is changes in the environment that cause changes in health. Furthermore, mitigation measures that reduce environmental damage often improve health outcomes. In the past, research into impacts, and the development of impact assessment methodologies, has focused primarily on large scale, capital intensive, schemes. However, small scale and less formal water management interventions, which are increasingly prevalent in sub-Saharan Africa, can also have significant environmental and health impacts. This paper summarizes the findings of a study of environmental and health issues associated with all scales of irrigation in sub-Saharan Africa. It is not a compendium of data, but rather provides an overview and framework for understanding policy and programming issues. It is recommended that a pragmatic approach to address current environmental and health planning includes three levels of implementation: i) strategic planning at the national and regional level; ii) full environmental and health assessment for government and donor funded projects; and iii) development of simplified tools for impact assessment relevant to community led, NGO and small private projects.

1. Introduction

It is widely acknowledged that irrigation can play a major role in improving food productivity, reducing poverty and sustaining rural livelihoods (Hussain and Hanjra, 2004; Smith, 2004). However, over the past two decades, investments in irrigation in sub-Saharan Africa have declined significantly (Kikuchi *et al*. 2005). There are a number of reasons for the decline, but the poor performance of irrigation, especially with respect to capital-intensive schemes, has undoubtedly contributed. Although not the sole reason, environmental factors and adverse health impacts have been a prominent cause for the disappointing performance of many schemes (Oomen *et al.,* 1990). Inadequate consideration of environmental and health issues in the planning and implementation of projects is widely perceived as a key cause of project failure (Moradet *et al*., 2005).

The environmental and human health aspects of irrigation schemes need to be considered in tandem, because they are strongly inter-linked. It is changes in the environment, in conjunction with associated socio-economic change, which results in changes in the health of local populations (Figure 1). Environmental and health impacts of irrigation are generally site specific and are multiple, varied and complex. They depend on a range of factors, including the scale of development, bio-physical conditions, management and operation, as well as the extent to which safeguards are implemented.

The potential negative environmental impacts of large capital-intensive irrigation schemes are extensively documented (e.g., Adams 1992; Dougherty and Hall 1995; Kay, 1999). Modification of river flow regimes, depletion of groundwater, sedimentation effects, soil salinization, waterlogging, water contamination and biological effects[24], have all been responsible for undermining the sustainability of schemes. Often farmers on irrigation schemes are fully aware of many environmental problems. However, because small incremental changes can take a long time to have a significant impact on productivity, often nothing is done until it is too late. It is estimated that in the southern region of Ethiopia, approximately 50% of irrigation scheme failures and below capacity performance are due in part to technical (as opposed to institutional and social) reasons, many of which are environmental in nature (e.g., soil salinization, sedimentation in headworks and channels, and drying up of rivers) (Robel, 2005).

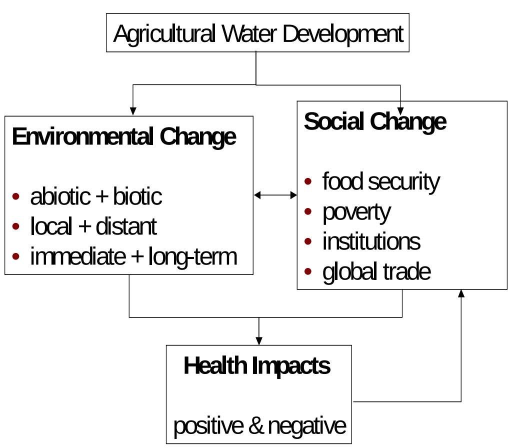

Figure 1: *Influence of agricultural water*

[24] Examples include agricultural pests and weeds and the establishment of aquatic vegetation in the water storage, distribution and drainage systems.

Although investment in irrigation is supposed to bring health benefits, through improved nutrition and income, it can have adverse impacts through the extension of water-related vector-borne diseases (e.g., malaria, schistosomiasis, liver flukes, filariasis, onchocerciasis, dengue fever, yellow fever, Rift Valley fever and encephalitis (Oomen *et al*. 1990). For example, malaria has been closely associated with the Gezira Irrigation System, in Sudan since it began in 1924. Severe outbreaks in the mid-1970s were linked to changes in irrigation management practices and the onset of pesticide resistance in malaria mosquitoes (Hunter *et al*. 1993).

Contrary to widespread belief, community-based and small-scale agricultural interventions also have environmental and health impacts (Konradsen *et al*. 2000; Mutero *et al*. 2004). These impacts are often disregarded and in many instances, there is almost no knowledge of the cumulative environmental and health impacts arising as a consequence of up-scaling. For example, small earth dams are being widely promoted throughout much of sub-Saharan Africa for multiple uses of water including irrigation and livestock watering. In many places, these dams have resulted in increased household income through improved agriculture. However, the potential environmental impacts and health consequences are rarely considered and the impacts of many thousands of dams are unclear. In Cameroon, the development of hundreds of small agro-pastoral dams led to a rapid spread of schistosomiasis (Ripert and Raccurt 1987) Similarly in Ethiopia, the construction of small dams in Tigray has led to outbreaks malaria, where previously there were none (Ghebreyesus *et al*. 1999).

2.Environmental and Health Planning in Irrigation Projects

The need to take environmental and health considerations into account as part of ensuring sustainable development is now widely recognized. Many countries in sub-

Saharan Africa have national policies, strategies (e.g., National Environment Action Plans) and legislation that stipulate the need for appropriate environmental planning and management of projects. Most international financing institutions (e.g., The World Bank, ADB and IFAD) as well as many bilateral donors (e.g., CIDA, Danida, DFID, GTZ and USAID) and international development agencies (e.g., FAO), have environmental policies that mainstream environmental issues at operational levels (Bos, 1999). Commercial organizations (e.g. banks) are also increasingly environmentally aware and many have signed up to the Equator Principles, which provide a common framework to manage environmental and social issues (http://www.equator-principles.com/principles.shtml).

To support these policies a large number of Environmental Assessment (EA) tools have been developed. These include project-level Environmental Impact Assessment (EIA), Strategic and Sectoral Environmental Assessments (SEA), Social Impact Assessments (SIA), Health Impact Assessments (HIA) and Environmental Audits and Appraisals (EAA) (Table 1). However, currently there remains considerable diversity among donors and other institutions in their mandates and approaches to dealing with social issues (including health). Most institutions routinely consider social impacts that are mediated by the environment, such as the health impacts of water pollution and many also consider a range of physical/biological impacts on directly affected groups (e.g., displacement or adverse impacts on local communities). Nevertheless, current coverage of human health aspects within environmental and social assessments is widely regarded as inadequate (Birley *et al.* 1997). Public health agencies are often excluded or only marginally involved and Environmental Health Impact Assessments (EHIA) are generally underutilized as tools for health protection (Fehr, 1999).

Practical approaches to EHIA have been advocated by the World Health Organization and the Asian Development Bank. The WHO/FAO/UNEP/UNCHS Panel of Experts on Environmental Management for Vector Control (PEEM), jointly with the Danish Bilharziasis Laboratory, developed a training course on rapid health impact assessments, later further refined and disseminated by the Liverpool School of Tropical Medicine (Birley 1995; Furu *et al.* 1999; Bos *et al.* 2003). In addition, some good text books are now available (e.g., Kemm *et al.* 2004). However, for the most part EHIA development has occurred in parallel, but is not integrated, with EIA methodologies. There is need for much better integration. A policy shift is required so that institutions promote EHIA rather than EIA (Amerasinghe and Boelee 2004).

Table 1: *Environmental, Health and Social Assessment Tools*

Environmental Impact Assessment (EIA)
A process for examining the environmental and human consequences, both beneficial and adverse, of a proposed development activity, and for incorporating appropriate measures to address them into project design and implementation. In many instances EIA is defined broadly to include social dimensions such as health.
Health Impact Assessment (HIA)
Similar to EIAs, these are intended to focus specifically on the health implications of a project, in situations where greater emphasis is required.
Social Assessment (SA)
Similar to EIAs, these are intended to analyze, manage and monitor both the intended and unintended social consequences of a development. They may be used to promote social goals such as social inclusion or poverty reduction.
Strategic Environmental Assessment (SEA)
A process to assess the environmental and social implications of strategic decision-making. SEA differs from EIA in that it is applied to policies, plans and programs rather than to projects. It addresses a number of shortcomings of EIA in that it is capable of addressing the cumulative impacts of projects (i.e., where one project stimulates other development), it can address synergistic impacts (i.e., where the impact of several projects exceeds the sum of the individual project impacts) and it can address global impacts such as biodiversity loss.
Environmental Management Plans (EMP)
Strategies developed for ongoing activities to avoid, mitigate or compensate for adverse impacts. They should include specific quantifiable aims and objectives and assign responsibilities and budgets for the environmental and social (including health) impact management measures.
Environmental Audits and Appraisals (EAAs)
Determine the effectiveness of mitigation measures conducted and, where appropriate, propose remedial measures.

3. Constraints to successful planning and management

In common with other regions in the World, in sub-Saharan Africa, approaches to reduce the negative impacts of irrigation schemes are successful in some circumstances but are not effective in others. Constraints to environmental and health management, and the successful implementation of measures to ameliorate negative impacts, arise for a range of technical reasons as well as limitations in human, financial and institutional capacity.

Many countries lack the resources to properly enforce policies and to ensure that recommended practices are followed. Consequently, despite current national policies, EIAs are most often restricted to large construction projects and are largely donor-driven. For example, the effectiveness of the Environmental Council of Zambia (ECZ), the lead institution for overseeing EIAs in Zambia, is severely curtailed by the inadequate budget and limited human resources (McCartney et al., 2004).

Failure of measures to mitigate negative impacts often stem from a lack of sufficient information at the design stage in planning (Morardet et al. 2005). More often than not, baseline information is unavailable for irrigation projects. Furthermore, adverse environmental and health consequences often occur because schemes are planned and managed in isolation from other things occurring within the catchment. In many instances too little thought is given to the dynamics of catchment change and there is inadequate evaluation of the specific biophysical and socio-economic context in which the scheme is located. Available descriptions of effective mitigation measures generally do not include the underlying assumptions or specifications that were used to design them. Without appropriate criteria and specifications for the design of measures, it is unusual for the measures to achieve the desired goals. To develop the necessary criteria and specifications, sufficient information must be obtained. Very often the environmental, ecological and socio-economic monitoring required, both for design prior to the implementation of a scheme and afterwards to assess the effectiveness of protection measures, is inadequate. For example, in Ghana a data checklist sent to 22 irrigation schemes, provided limited information for just three schemes. This lack of data was attributed to poor data keeping and the fact that, for the majority of schemes, assessment of environmental and/or health impacts had never been undertaken (Kranjac-Berisavljevic and Cofie, 2004). In relation to health, baseline information on the health and socio-economic status of communities, and hence their susceptibility to change, is often lacking (Fehr, 1999).

To a large extent the effectiveness of environmental and health management depends on the abilities of those people who plan and manage mitigation measures. In many parts of sub-Saharan Africa, the requisite professionals are unavailable or not proficient in the interdisciplinary working habits necessary for successful environmental and health planning and management. Furthermore, there is often a lack of coordination between relevant government departments. In a review of World Bank projects in Africa, the most frequently cited recommendation for corrective action for environmentally sensitive projects was improvement of capacity in responsible institutions (Green and Raphael 2000). This lack of capacity is being be exacerbated by the HIV/AIDS epidemic (Cohen, 2002).

Another major limitation to formal environmental and health procedures is that often there are no mechanisms to ensure adaptation in the design of the project. Usually the people who demand the assessment are not the same as those who decide on changes in the project design or even whether or not the project will be carried out. Most sub-Saharan African countries have neither the necessary framework to ensure legal compliance nor organized civil society to ensure that recommended environmental and health safeguards are implemented. In such situations the contractual arrangement with the donor may be the major means for ensuring compliance. However, in the absence of a transparent accountable system this arrangement is rarely successful. Very little is known about the proportion of assessments that lead to actual adaptations or implementation of mitigating measures.

However, a study of the follow-up to the EIA conducted for the Koga irrigation scheme in Ethiopia found that only two of the twenty major recommendations made in the EIA were being implemented satisfactorily. The lack of follow-up was largely attributed to institutional failure, with no single authority being responsible for ensuring that the EIA recommendations were implemented (Abebe *et al.* 2007).

In a global review of the effectiveness of its EA procedures the World Bank found that key constraints to successful implentation in projects for which EA was not deemed to have been performed effectively were: i) the lack of a definitive Environmental Management Plan (EMP) with time-bound actions and responsibilities; ii) the absence of environmental monitoring indicators; iii) a lack of reporting requirements for project performance (including environmental and health indicators) and iv) the absence of legal commitments by borrowers to undertake environmental actions (World Bank 1997).

4. Recommendations

Clearly, if irrigation is to make a significant contribution to realizing the potential of agriculture in sub-Saharan Africa, there is need for much improved and integrated planning. Measures that promote sustainability by, among other things, capitalizing on the opportunities for enhancing human health, should be at the core of agricultural water development. The EA process, recommended by most donors and governments, is widely recognized as a useful for identifying issues and developing plans to address them. However, within sub-Saharan Africa there are, as outlined above, many constraints to the process and subsequent follow-up is often weak. Furthermore, the process is inappropriate for many small-scale developments. Subjecting smallholder and community-led projects to full environmental and health assessment, and monitoring, although justifiable, is often neither economically feasible nor practical.

Against this background, the following recommendations are a pragmatic attempt to address current limitations in environmental and health planning and management pertaining to irrigation development. Focused on what governments and donors can do to improve planning and management, the recommendations are divided into three categories:

- strategic planning at national and regional level
- agricultural water projects for which full environmental and health assessment should be mandatory (i.e., all government and donor funded projects, whatever their size, plus all other projects involved in commercial agricultural production and greater than 20 ha in extent[25])
- agricultural water projects that by-pass current procedures and for which it is unrealistic to expect full environmental and health assessment to be conducted (i.e., private, community and NGO organized projects smaller than 20 ha in extent[2]).

4.1 Strategic planning at national and regional level

4.1 Implement Strategic Environmental Assessment at regional and national level

Strategic environmental assessments (SEAs) can be used to plan irrigation development at national level and for major international river basins (e.g., Zambezi, Limpopo, Volta). SEAs are most valuable if they integrate environmental, health and social concerns and attempt to reconcile development, environmental protection, community rights and human health. Regional and national development goals, as well as issues such as climate change and loss of biodiversity, and commitments to international conventions (e.g., the Convention on Biological Diversity) should be considered.

4.2 Improve and promote EHIA

Currently health impact assessments are often conducted in isolation from environmental assessments. Since much of the information to be collected on environmental receptivity and community

[25] The suggested value of 20 ha is arbitrary but intended to make recommendations operationalizable. Governments could decide on a more appropriate figure, based on the specific agro-ecological conditions and development needs of their country.

vulnerability is the same it is mutually beneficial if they are integrated. Where necessary, EHIA should specifically include the issues of migrants and livestock that hitherto have tended to receive very little attention.

4.3 Improve regional capacity for Environmental and Health Assessment

All countries without compulsory environmental and health assessment processes should consider enacting laws that make these mandatory for large infrastructure projects, including large irrigation projects. In many countries strengthened institutional arrangements would assist in the implementation of environmental and health assessment processes. For example, establishing environmental units within Government ministries responsible for irrigation could be contemplated. The effectiveness of such units would be enhanced if they work closely with national environment agencies and appropriate health authorities.

4.4 Adopt harmonized environmental and health procedures

The ability of governments to implement sound environmental and health practices would be improved if donor agencies harmonized procedures and developed a consistent framework for the evaluation, planning and management of environmental and health aspects of irrigation. Procedural requirements should conform to current international best practice and be clearly laid down in regulations and operational manuals.

4.5 Conduct regionally specific research

More research is needed on the benefits of incorporating environmental and health safeguards in irrigation planning and operation versus the cost of not taking potential negative impacts into account. Another researchable issue stems from the lack of monitoring, both for water resources development projects and in the health sector. With baseline data not available, proxies need to be developed to provide alternative ways to the same information. Specific tools need to be developed to facilitate assessment of long-term health and environmental impacts. For example, long term cohort studies are required that are not feasible within the context of individual EHIA.

Agricultural water projects for which full environmental and health assessment should be mandatory

4.6 Implement comprehensive options assessment

Comprehensive options assessments, undertaken during the scoping of irrigation projects, provide a means, early in the planning process, to eliminate unacceptable projects or project components. Comprehensive environmental and social audits can help determine the causality of environmental and human impacts and the relative magnitude of impacts at a basin or regional level, which can then be compared to alternative development scenarios. It is essential that environmental, health and social criteria, as well as technical, economic and financial factors, are considered when comparing alternatives.

4.7 Identify and quantify intended livelihood and health benefits

The environmental and health impacts of irrigation are diverse. As with any development process, trade-offs between social, environmental and economic goals are inevitable. As far as possible these trade-offs need to be identified and made explicit. Often it is assumed that, by improving food security and/or peoples' socio-economic status, water development will inevitably result in health benefits and improved livelihoods. However, the intended livelihood and health benefits are rarely made explicit, and in reality, neither costs nor benefits are evenly distributed amongst stakeholders. Environmental and health assessments, as well as management plans, need to take into account the socio-economic diversity of communities and ensure that the weakest and most vulnerable are not adversely affected. Intended health and livelihood benefits as well as means of verification need to be identified and stated at the outset of any irrigation scheme.

4.8 Plan and manage using a catchment-wide perspective

Given the inter-linkages between impacts and what occurs elsewhere in the catchment it is essential that projects are planned and managed within the specific socio-economic and biophysical context in which they are located. Consideration must be given to potential environmental impacts on, as well as impacts caused by, the development. Assessments of impacts on the catchment water balance and sediment fluxes, including evaluation of possible future development (particularly relating to land-use change), are essential. The potential cumulative affect of small-scale interventions should be specifically included in assessments.

4.9 Improve data generation and analysis related to environmental and health impacts

A major constraint to the sustainability of agricultural water development is the lack of site-specific data and long-term monitoring; pre-requisites for informed decision-making. For this reason measures to significantly improve data generation and analysis related to environmental and health impacts should be encouraged (e.g., coordination of existing data collection efforts between sectors and/or establishment of meta-databases). Ideally monitoring strategies would be mandatory in all projects and governments and donors must provide adequate funding to enable this.

4.10 Develop innovative ways for financing environmental and health measures

The cost of effective environmental and health measures is often very high and must usually be borne by the organization responsible for the irrigation development. The most common mechanism for financing these measures is to incorporate the costs into the capital financial package of the project. The costs that are most readily incorporated into the capital costs are those that occur once (e.g., construction of fish ladders in dams). Financing on-going obligations, such as environmental and health monitoring, is more difficult. Whilst it is sometimes appropriate for beneficiaries to cover these, in many cases it is not. For this reason donors and governments ought to investigate innovative ways of financing recurring costs, such as trust funds[26].

4.11 Develop innovative approaches to ensure compliance with environmental and health requirements

Incorporating environmental protection and health measures into irrigation projects is made difficult by the failure of many project operators to fulfill voluntary and mandatory obligations. Innovative approaches to encourage compliance ought to be investigated. Options could include: a) the use of performance bonds, supported by financial guarantees and expressed in wellbeing-related outcomes and not just agricultural yields and water use efficiency; b) implementation of a sector-specific environmental management system, perhaps constructed around that developed by the International Standards Organization (ISO); c) development of an ethical code for large-scale irrigation projects to ensure that environmental and health concerns are adequately addressed.

Agricultural water projects for which it is impractical to conduct full environmental and health assessment

4.12 Increase local-level awareness of environmental and health issues

Governments and donors should support campaigns of health awareness carried out by community health teams and training programs that, in collaboration with community groups (e.g., farmers associations, agricultural water user associations, water committees and women groups), increase

[26] Trust funds have been suggested as a possible mechanism for financing the mitigation of the environmental impacts caused by large dams (Bizer 2000). A project-specific trust could be established at the outset of a project (by the project financier) with the condition that funds are used specifically for environmental and health management, including monitoring. The approach could incorporate annual contributions from the scheme owners/beneficiaries as well as other organizations (e.g., governments or donors), with the environment and health program funded from the proceeds of the trust.

awareness of potential environmental hazards and approaches to mitigation. Information on practical ways to maximize health benefits should be provided, as well as outlining potential hazards and approaches to mitigate negative impacts.

4.13 Develop "user-friendly" methods of rapid appraisal for evaluating small-scale projects

Donor and government funded programs that promote small-scale development (e.g., the community driven development program of the World Bank), should conduct program-specific environmental and health assessments. These should assess the potential impacts of the micro-projects to be financed under the program and the possible cumulative impacts of scaling-up. They should set the context for lower-level assessments and, based on the priorities for attention, simple checklists, intended for use by small local organizations and communities, should be developed to evaluate the impacts for individual micro-projects.

4.14 Ensure programs that promote small-scale agricultural water development are embedded within rural development programs

Governments and donors should ensure that programs promoting small-scale irrigation are undertaken in conjunction with broader rural development programs that include water and sanitation, as well as health components. Care must be taken that these projects are designed so that the main beneficiaries are clearly identified and the objective of improving livelihoods through irrigation remains the primary focus.

Concluding remarks

Addressing environmental and health impacts are crucial for the sustainability of future irrigation development in sub-Saharan Africa. The recommendations presented above focus on ways to improve the policies and practices pertaining to impact assessment and planning for both large and small developments. To be effective the recommendations require a coordinated effort and long-term commitment from both governments and donors. If implemented they will contribute to better awareness of the linkages between environmental and health impacts and improve the sustainability of irrigation development in sub-Saharan Africa.

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GIS And Remote Sensing Integrated Environmental Impact Assessment of Irrigation Project In Finchaa Valley Area

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Abstract

This research was conducted in order to assess the environmental impacts of Finchaa irrigation project using GIS and remote sensing techniques. Because of the limited resources only some environmental parameters were selected. These parameters are natural vegetation, soil/land, water quality, climate and health conditions.

The normalized vegetation index (NDVI) analysis was used to detect the spatial and temporal change of vegetation biomass in the study area. The result indicated that the natural vegetation biomass is declining. This is mainly due to the expansion of agricultural land and escalating human made structures in the area.

The water physico-chemical analysis demonstrated that the down stream water has more chemical substances and degraded physical properties than the up stream counterparts. The direct leakage of industrial liquid waste and the agro-chemicals from irrigation fields are supposed to contribute for this result. The GIS analysis of a 100 meter buffer around Major rivers and tributary streams is found to be a necessary action to mitigate the problem of pollution.

The soil chemical and physical property analysis in the irrigated and non irrigated fields reveals that the soil samples taken from irrigated fields contain higher phosphorous, Nitrogen and organic carbon compared to its counter parts. The use of agro-chemicals in the irrigation fields contribute for the result.

From the twenty two years rain fall, temperature and humidity data no abrupt inclining or declining trend is observed that could tell the possible impacts of the project. The post irrigation development years witness that some water born diseases and malaria case records have increased. It is also found out that expansion of irrigation fields and the respective Malaria case records are positively correlated.

Generally, despite the significance of the Finchaa irrigation project, it has negative environmental repercussions. This is evident from vegetation cover distraction, water quality deterioration in the down stream area, alteration of soil physical and chemical components and increasing health threats. If the current condition continues the problems may out weight the benefits of the irrigation project. Thus in the project site and adjoining areas urgent environmental conservation is necessary. This helps to sustain the existing and revitalize the fading resources.

1. Introduction

1.1 Background Information

The expansion of irrigation scheme in Ethiopia lend a hand to achieve food self sufficiency and poverty reduction. Irrigation agriculture makes production more unwavering than the rain fed agriculture. Proper planning and management aided irrigation projects contribute for the growth of national GDP and GNP. It also creates job opportunities for several thousands of people directly or indirectly.

Despite their significances, however, irrigation practices have sometimes adverse impact on environmental conditions. It is known that Human activities have a profound effect up on the natural environment and are becoming the main agent of environmental degradation.

Finchaa valley was one of the few areas in Ethiopia to preserve its natural conditions for years. The topographic set up made the area to be inaccessible. In 1975 the valley was selected as a suitable site by the state farm to produce food and commercial crops. After few years the area was again chosen to establish a sugar factory. Following these there were many activities carried out in the area. Some of these activities have an enormous positive contribution while some others have negative effect on the environment.

In Finchaa valley, following the establishment of the sugar factory more pronounced land degradation is observed. There is large scale land clearance (deforestation) by the factory for new irrigation field.

In addition there are many people in and outside the valley that earn their livelihood from forest and forest products.

The factory uses agrochemicals like fertilizers, pesticides and herbicides in irrigation fields and the wash away collected in ditches and then join the nearby tributary stream. On the other hand some Part of the liquid waste from the factory spillover the treatment plant and joins Finchaa River. The problems emanate from the little attention given for environmental conservation as the main objective is to maximize production and productivity. The cumulative effects of these all problems can result in environmental degradation.In Finchaa valley there exists a continuous disturbance on vegetation cover, soil, and water. If the trend goes on, there will be an extreme effect on the environment. Thus, it is indispensable to carry out environmental impact assessment (EIA) of the irrigation project in the area.

Environmental Impact Assessment has been recognized as an integral part of the early planning studies of irrigation projects in order to identify any expected negative impacts and to suggest the necessary actions to curb the problem. In addition, EIA can consider different designed alternatives for the project as an essential step for better decision making. The application of Geographic information system (GIS) and remote sensing can facilitate the study of environmental impact assessment of irrigation projects for a better outcome.

1.2. Objectives of the study

1.2.1. General Objectives

- To Asses the impact of the irrigation project on the natural environment of Finchaa valley Area.

1.2.2. Specific Objectives

- To see the impacts of Finchaa irrigation scheme on vegetation cover using satellite images of different years.
- To explore the extent of soil quality degradation as a result of the irrigation scheme.
- To asses the impact of the irrigation on water quality in the upstream and down steam water of Finchaa River.
- To see the climatic change (temperature and rain fall) over the past 22 years and interpret the results on sustainability of the irrigation project.
- To investigate some health threats following the irrigation project spatially and temporally.
- To propose some valuable measures to be taken to mitigate the negative impacts of the irrigation project on the environment in such away that assures sustainable development.

1.3 Research Methodology

In order to make out the positive and negative impacts of the irrigation project on the environment of Finchaa valley area more of primary and some secondary data are collected. Some of these data are integrated with GIS and remote sensing techniques in a way that manifests the impacts of the irrigation project on the environment.

To best investigate the positive as well as negative impacts some components of the environment are preferred for investigation. These are vegetation cover, soil/land, water, climate and health cases records.

The first line consideration is given to the direct environmental impacts of the irrigation scheme. In light of this the indirect impacts are also inspected to the best of the researchers' knowledge and available resources.

Different years of satellite images are used for the vegetation cover change with the expansion of the irrigation in Finchaa valley. Under this the scope and extent of variation in land cover, land use, reflectance properties, Image differencing, erosion estimation and the NDVI analysis are explored and quantified.

To investigate the impacts of the irrigation on the soil the physical and chemical soil analysis has been made. The soil samples in different sites were collected. These sites are the irrigated fields, ploughed but not yet planted and non irrigated (vegetated) areas. The samples were taken in three layers and totally nine samples were analyzed. The result is believed to show the soil component anomalies in the irrigated and non irrigated areas and the possible causes. Visual presentation of the land with and without irrigation also gives some idea about the level of land degradation. Some GIS integrated slope analysis also provides slope differences and the intensity of erosion.

In order to investigate water quality problems water samples from upstream and down stream areas were taken and these samples are supposed to show the spatial water quality changes. This intern helps to examine the impacts of the project on water quality. Quantity wise the irrigation water use will be incorporated to asses the problems emanating from under and/or over utilization of water.

Long year's meteorological data are used in order to evaluate the micro climate of Finchaa valley area for temporal anomalies. In light of this panorama other environmental components are examined and possible solutions recommended. This again helps to foretell the sustainability of the irrigation scheme in relation to climatic favorability.

The unstructured interview to the concerned bodies and past research works furnish with valuable information with respect to the past-present natural and socio-economic setup of the area. These data are integrated with impact assessment and GIS/RS techniques in such a way that shows the kind and extent of changes that have been taking place.

2. Impacts of the Irrigation project on Vegetation and Soil

2.1. Impacts of the Irrigation project on vegetation cover

2.1.1. General Conditions of Natural Vegetation Cover

In developing countries the attention given for vegetation conservation is less compared to the need for development. In realizing their policies for food self sufficiency and agricultural productivity preeminent value is given for irrigation developments even some times at the expense of environmental considerations.

Depending on the management system irrigation projects can have both positive as well as negative impacts on vegetation cover. Undoubtedly the expansions of irrigation projects have many advantages. However, in most cases there happens change in the natural ecosystem following large scale irrigation developments. Obviously in order to under take large scale irrigation projects the vegetation cover in the area needs to be cleared and different construction activities should be carried out. Natural Vegetation as one of the eminent part of the ecosystem is negatively affected with such development activities. Large scale forest resource degradation can change the natural environment. This in turn puts the sustainability of irrigation projects in question. Conversely if appropriate consideration is given for vegetation conservation the forest area can be delineated and effective afforestation and reforestation can be carried out. For that matter vegetation resource can be keep hold around the hills, on vacant and marginally suitable lands. The conservation of natural vegetation can fix the problem of soil erosion, micro climatic disturbances, biodiversity and it balances many of the environmental systems.

Well planned irrigation schemes have good natural vegetation conservation and management plans. Effective management and proper balancing of these seemingly conflicting issues should be treated wisely.

Finchaa valley in the pre 1975 years was virtually under natural vegetation cover. The tall savanna grasses mixed with short and medium trees predominate the elevation below 1600m.The steep escarpments and the far down stream areas experience dense vegetation growth. The gallery forests occupy the networks of major rivers and their tributaries. As it is evident from the MSS satellite image of 1972 there was no apparent human intrusion to the valley. From unstructured interview made with local elders there were some individuals who went to the area to collect wild honey from trees and hunters for valor.

The first intrusion to the valley was successfully made by the state farm in 1975. Since this time it is estimated that the state farm cleared about 3,500 hectors of land (vegetation) .The 1986 TM image reveals that some parts of the eastern and western banks of Finchaa River are occupied with some food and commercial crops. Even at this moment most part of the valley was under the natural vegetation cover.

The construction of the road dawn the escarpment made the forest resources accessible and vulnerable for human interference. This opened up a new episode for the forest resource exploitation. Still to the present Finchaa valley is considered as an ideal site for hard wood and bamboo forests used for fire wood and construction activities.The beginning of 1990s can be seen as the second turning point in the forest history of the area. In these years Finchaa valley was selected as the most suitable site for sugar cane plantation and industrial development. In the mean time the state farm abandoned the farm and handed over the area to Finchaa sugar Factory. In 1991 the Finchaa sugar project started extensive mechanized vegetation clearance. From the three major Companies that carried out the feasibility study any of them did not recommend for any single area buffering for natural vegetation conservation. Almost all attention was on sugar cane production and strategies for expansion. Accordingly the west bank of Finchaa River was considered more suitable and fertile and at present about 8,064.88 hector is under sugar cane plantation. (See fig 4.3)The factory neglected the east bank until the recent years. This year Vegetation clearance and land preparation has been taking place on the eastern bank. The total area of 7,108 hector is expected to be irrigated. Despite the fact that the expansion escalates the industrial productivity, it further aggravates the problem of deforestation in the valley.

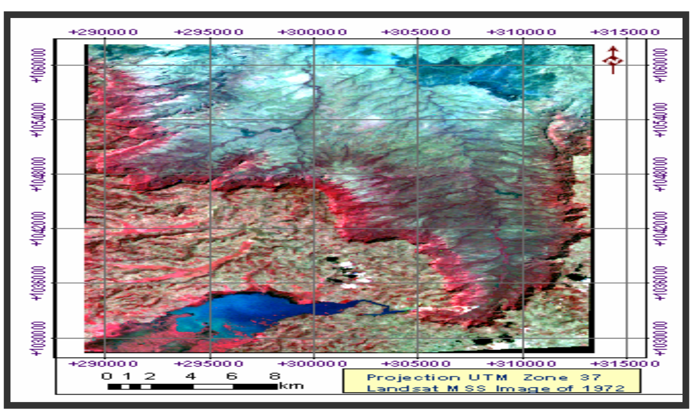


Figure 2.1. RGB/321 MSS satellite images of Valley Area 1972 with 30 meter resolution.

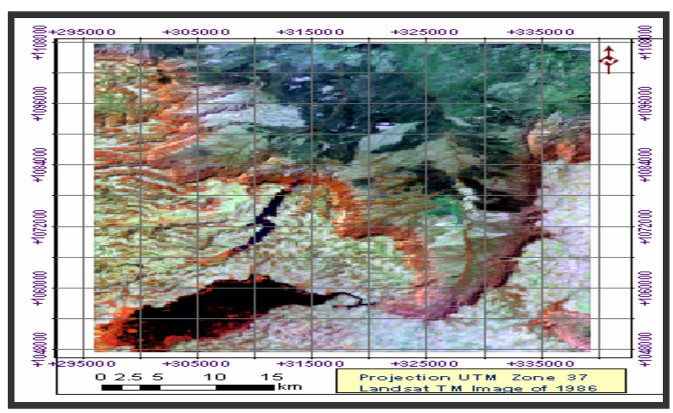


Figure 2.2. RGB/321 TM satellite Valley Area 1986 with 30 meter resolution.

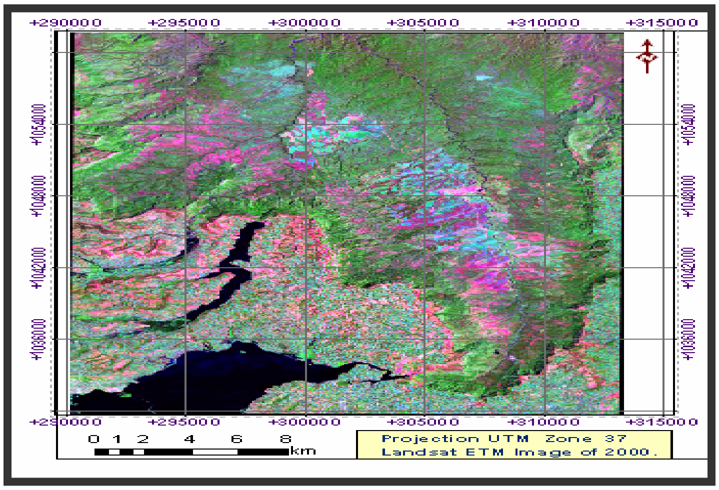


Figure 4.1. RGB/321 ETM satellite images of Finchaa Valley Area 2000

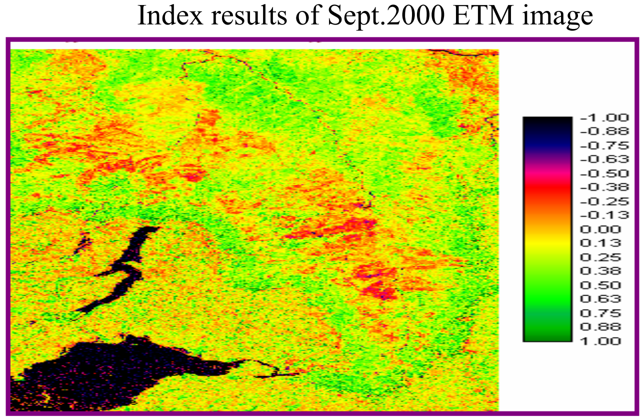
From the visual image interpretation it is evident that there is land cover change. Some features like the vegetation biomass are diminishing while some others like Finchaa Lake are increased in size. Even though there is large scale vegetation clearance there are efforts made by the factory to plant trees on unused areas. To the present Finchaa sugar factory under forestry department planted 600 hectors of land in the afforestation program.
One of the tree species preferred is eucalyptus tree .This was so for the accessibility of the tree.

Currently the department has the plan to cover 2,200 hectors of land under the reforestation and afforestation programs.However, this amount is very less with respect to the vegetation clearance which has been taking place for long years in the area. In comparison to the vegetation that has been cleared the present afforestation program reclaim for not more than 7.5 percent of the land under irrigation. Even if the future goal of the department is attained it reclaims only for about 27.3 percent of the present land under irrigation. At the time 13,000 hectors of land is irrigated if only 2,200 hectors of land is under forest cover it means that less than 17 percent of the cleared land is revitalized.
The irrigated field has increased a lot. In 1997/98 about 932.27 hectors of land was harvested and after eight years that is in 2005/06 it increased by more than seven folds. By implication the vegetation cover is retreating with the same or even more rate.
Deforestation is the major problem in Finchaa valley area. The large scale vegetation clearances by the factory together with individuals earning a livelihood from forest products are devastating the vegetation resource. Forest fire is one of the critical causes for the vegetation degradation. In addition to the naturally instigated fire the factory and some individuals play a significant role in triggering the problem. The fire escaping from the frequent cane burning by the factory and irresponsible action by individuals who are looking for timber, charcoal, fire wood, Wild honey collection, construction wood and others exacerbate the obliteration.

2.1.2. The Normalized Difference Vegetation Index

Normalized difference vegetation index (NDVI) is a method used to analyze the vegetation cover of an area. NDVI is calculated from reflectance measured inthe visible and near infrared channels from satellite-based remote sensing. NDVI shows the temporal and spatial change of Vegetation cover. The difference between two images is calculated by finding the difference between each pixel in each image and

Figure4.6. The Normalized vegetation Index results of Sept.2000 ETM image



generating an image based on the result. The NDVI Analysis

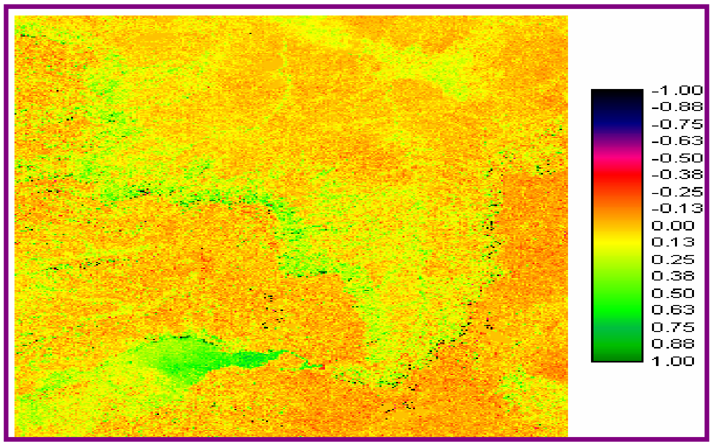


Figure4.6. The Normalized vegetation Index results of Dec.1972 TM image

of the 1972 Multi spectral scanner (MSS) image of Finchaa valley area reveals that there is more vegetation biomass in the study area (NDVI>0) compared to the later years.

The Normalized vegetation index of 2000 image shows lesser vegetation biomass compared to the 1972 image. The expansion of cultivated areas, bare lands and built up areas are apparent in the NDVI analysis. These areas appeared as deep red and NDVI < 0.0. This means that many areas that were formerly under vegetation cover are turned up into Human made features.

Table 4.1: The Normalized Vegetation index result of the 1972, 1986 and 2000 satellite images.

Year	Landsat MSS		Landsat TM		Landsat ETM	
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
1972	87.3427	66.2614	-	-		
1986	-	-	80.4064	63.1612		
2000					68.2834	58.5612

Table 4.1 Reveals that the mean and standard deviation of the 1972, 1986 and 2000 images has been decreasing. This could indicate the rate of vegetation cover destruction.

Generally the Visual image interpretation and the Normalized vegetation index results confirm that the vegetation biomass of Finchaa valley area has been diminishing. There are three major factors that can explain this circumstance. These are the expansion of agricultural lands, growing settlement areas and large scale deforestation that has been taking place for many years. Still the present trend indicates that the deforestation will continue to the virgin lands. By taking the aspiration of the factory for expansion in to consideration large effort should be made in afforestation and reforestation projects. Strict measures should be taken to stop illegal forest resource exploitation and the frequent fire. Afforestation and reforestation activities should not be considered as a superfluous activity. Beyond harmonizing many of the natural systems they can serve as a means to solve many problems like soil erosion, hot weather conditions, degradation of biodiversity, fire wood and wood product requirements and many others.

4.2. Impacts of the Irrigation project on Soil

Soil is one of the most decisive natural resources. It has been supporting the increasing number of life in our planet earth. Now a days the large number of population increased the demand for food, this in turn put forth full-size pressure on land /soil resource. Areas formerly considered as marginal are currently being cultivated. The demand for big yield created enthusiasm to look for alternative means. One of these is getting bigger yield through customary agricultural practices like irrigation systems, use of fertilizers, pesticides, herbicides and many other agricultural inputs.

Irrigation schemes beside their positive contributions have many shortcomings on the physical and chemical properties of soil in particular and the environment in general. The FAO repository document mentioned some of the adverse impacts of irrigation schemes on soils which include Salinization, Alkalization, Water logging, soil pollution and Soil acidification.There are two dominant soil types in the project area; these are

the Luvisols and vertisols. Luvisols covers 75 percent of the irrigated land. These soils are partly made of alluvial and colluvial materials from the surrounding escarpments. Luvisols has limited fertility and agricultural suitability. Water logging is not a vital problem in the area as the factory is using over head sprinkler irrigation system. This consecutively evades the problem of salinization. In order to maximize production the Agro-chemicals have been used in the irrigation fields .The most common ones are fertilizers, pesticides and herbicides. The two commonly applied fertilizers are Urea and Dap. The brief summery of the total amount of agro-chemicals is presented in table 4.1. (See Appendix 4 for the details)

Table 4.2. Shows that the use of fertilizers, pesticides and herbicides has been increased in an alarming rate with the expansion of irrigation. The Use of large scale agro-chemicals alter the physical and chemical properties of the soil which can damage the soil quality and use full living organisms.

Year	Fertilizers (Qunt.)	Pesticides(Lts.)	Herbicides(Lts.)
1994/95	219.4	480	5
1995/96	5,224	20,074.5	8
1996/97	5,806	10,403	267
1997/98	4,003	311.8	20
1998/99	15,952.68	5,278	716
1999/00	17,264.9	10,914.56	216.51
2000/01	23,097.01	25,794.31	2,943
2001/02	19,444.25	17,585.9	2,330
2002/03	23,274.7	15,899.51	1,019
2003/04	25,760.3	14,370.63	2,368
2004/05	36,538.69	17,837	2,712
Total	**176,584.93**	**138,949.21**	12604.51

In order to see whether there is change in the soil physico-chemical properties of the dominant Luvisols in the irrigated fields samples are collected and analyzed. Luvisols are preferred for analysis because 75 percent of the irrigation is carried out in this soil. The samples are taken from three sites in three layers. The first site is the non irrigated field where there is no human interference. The second site is ploughed but not yet planted field. In this site none of the agricultural inputs are applied. The third site is the irrigated field where the agricultural inputs have been used. In each of the three sites soil samples from three spots are collected and mixed to form only one composite soil sample. The three layers are the top layer (0-30 cm), the middle layer (30-60) and the bottom layer (60-90cm).Totally nine samples were investigated and the result will be presented under 4.2.1 and 4.2.2. The three spots are believed to show the possible positive and/or negative impacts of irrigation scheme on the physical and chemical properties of the soil. In addition the comparative results of samples from cultivated but not planted and non irrigated spots can reveal weather the change is due to human intervention or natural causes. The soil sample from vegetation cover area is supposed to reveals the natural properties of the Luvisols in the area. Thus, the site selection for soil samples is intentional and made in such away that shows the impacts of irrigation on the physical and chemical properties of the soil.

2.2.1. Irrigation and Physical properties of the soil

The Luvisols and vertisols occupy more than 95 percent of the Finchaa valley area. Luvisols have reddish brown color and weakly developed structure. They have also shallow profile and limited fertility. Luvisols are composed of sand which decreases with increasing depth. This soil is the most exploited soil in the valley. About 75 percent of the irrigation is carried out on Luvisols. The vertisols on the other hand have black color and shallow profile. Vertisols contains more clay materials with increasing depth.

Table 4.3.The physical properties of the Luvisols from irrigated, Ploughed but not planted, and vegetated area in three layers. (0-30, 30-60, 60-90)

LUVISOLS	**FROM IRRIGATED FIELD**			**FROM PLOUGHED BUT NOT PLANTED**			**FROM VEGETATED AREA**		
Depth(cm)	0-30	30-60	60-90	0-30	30-60	60-90	0-30	30-60	60-90
Total sand (percent)	63.55	57.33	53.34	51.16	41.87	41.78	51.56	35.78	41.35
Silt (percent)	4.17	2.08	7.26	7.60	4.39	4.39	12.37	25.27	11.52
Clay (percent)	32.28	40.59	39.40	41.25	53.74	53.83	36.07	38.95	47.13
Texture class	SCL	SC	SC	SC	C	C	SC	CL	C
Ph-H2o(1:2.5)	5.62	5.20	4.89	5.62	5.04	5.04	4.86	4.48	4.56
Ph-kcl(1:2.5)	5.16	4.79	4.76	5.08	4.57	4.58	4.42	4.00	3.87
Ec(ms/cm)(1:2.5)	0.03	0.04	0.02	0.03	0.01	0.01	0.06	0.02	0.01

Table 4.3 illustrates that the total sand content of Luvisols decreases with increasing soil depth in all sampled layers. The silt content of the soil from vegetated area is higher. This can be due to the lesser amount of erosion in vegetated areas compared to the cultivated areas. The clay content of the soil in ploughed and vegetated areas increases with the increasing depth. Unlike the non irrigated fields the clay content of the soil from irrigated site is higher in the 30-60 cm depth. This can be due to the excess water that dissolves soluble minerals and percolates down. On its way it accumulates the insoluble clay in this horizon. Generally the texture class of the Luvisols in all locations ranges from sand clay loam (SCL) to clay (C). Such soils are known to be suitable for irrigated cane plantation with cautious soil management. The soils in all the three spots of the three layers are found to be acidic. The PH is less than 5.6. It is investigated that there is perceptible PH difference between irrigated and non irrigated soil. The average PH value of the soil in the irrigated area is 5.3 where as in the vegetation area the value is 4.6. This shows that the soil in the vegetation cover site is more acidic than the soil in the irrigated field. Theoretically the fertilizers, pesticides and herbicides that have been applied to the cane fields seem to increase the PH of the soil. But the result shows that the soil in the irrigation field is less acidic than in the vegetation area. Three main reasons can explain this result. In the first place the surplus water use in the irrigated areas can wash the chemicals vertically and laterally. Secondly cultivation by itself can alter the inherent Ph of the soil by exposing the soil. Finally the respective composition of the soil forming parent material can be different in the sample sites.

2.2.2 Irrigation and Chemical properties of the soil

The Normal Soil chemical properties can be altered by natural and human made factors. Industrial toxic wastes, hazardous chemicals, Agricultural malpractices and inputs, and many others constitute the human factors. Alternatively due to some natural processes in the system there may be alteration of soil chemical properties. In this respect the physico-climatic conditions play a key role to change the chemical properties of the soil.As it is illustrated in table 4.4 the average amount of chemical elements in the three sample areas are different. The amount of exchangeable bases (Exch. Na, K, Ca and Mg) varies with increasing depth. Generally speaking the amount of Potassium, Calcium and Magnesium decreases with increasing depth while sodium increases with depth.Exchangeable calcium and sodium is higher in the irrigation and cultivated but not planted fields than the vegetated areas. The total percentage of Nitrogen is higher in the irrigation field. The Available phosphorous is extremely high in the top layer of the irrigation fields. These higher amounts in the irrigation field are due to the fertilizers (Urea and DAP) that have been used in the irrigated areas. The organic carbon is found in higher quantity in the vegetated area. The soil sample from the vegetation area are found to be more acidic than the irrigation Fields. This is mainly due to high organic content in the vegetated areas. On the other hand the less acidic nature of the soil in the irrigated area is related to the exposure and excess water use in the irrigation fields.

Luvisols	**Irrigated field**			**Cultivated but not planted**			**Vegetated area**		
Depth in cm	0-30	30-60	60-90	0-30	30-60	60-90	0-30	30-60	60-90
Exch. Na(meq/100gm of soil	0.13	0.16	0.13	0.15	0.13	0.17	0.13	0.11	0.13
Exch. K(meq/100gm of soil)	0.20	0.15	0.16	0.27	0.20	0.21	0.48	0.18	0.16
Exch.Ca(meq/100gm of soil)	5.82	5.82	5.18	9.50	8.72	8.72	4.99	3.36	3.36
Exch. Mg (meq/100gm of soil	4.16	4.20	2.59	6.05	2.62	4.36	4.99	4.20	5.04
Sum of cations (meq/100gm of soil)	10.48	10.54	8.19	16.13	11.90	13.69	11.39	9.66	11.34
CEC(meq/100gm of soil)	14.02	14.48	14.56	23.95	25.12	26.54	24.87	21.46	15.52
Organic carbon (percent)	1.17	0.58	1.69	0.90	0.65	0.65	1.40	1.14	0.78
Nitrogen (percent)	0.14	0.10	0.14	0.13	0.09	0.09	0.09	0.07	0.05
Available P(mg p_2o5/kg soil)	29.20	5.10	4.00	7.80	2.80	2.80	2.60	2.70	2.70
Exchangeable Acidity	0.17	0.21	0.13	0.13	0.22	0.22	0.38	1.79	2.65

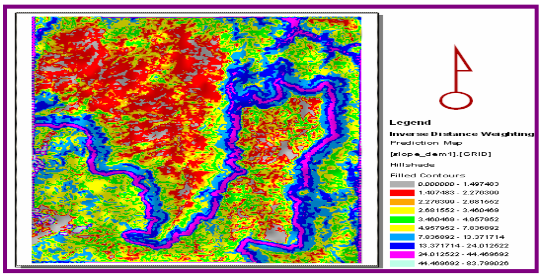
In addition the acidic nature of the soils in the vegetation areas shows that the soil in the area is naturally acidic and the human intervention minimizes the soil acidity.

Generally the analysis of the three soil samples indicates that there is alteration of some of the soil physical and chemical properties as a result of the irrigation scheme. The level of alteration hardly results in full-sized soil pollution at this level. However the cumulative impact could grow in to soil quality degradation. Thus there are signs of soil pollution in the Irrigated areas. There are several reasons that can explain this condition of which application of the agro-chemicals is one.

2.2.3. Soil Degradation

It is found out that one of the preeminent problems of soil in Finchaa valley area is erosion. There is active soil erosion in the surrounding areas and irrigated fields. The surrounding steep escarpments with average slope ranging from 5 to 65 percent create favorable condition for erosion. There is also high rain fall intensity (90-120mm/hr) which is highly erosive. Rain fall intensity greater than 50mm/hr is believed to be erosive. In Finchaa valley area human intervention exacerbates the problem of erosion, especially deforestation and road construction. The large scale deforestation exposed the soil for agents of erosion and contributes for high runoff. Due to terrain inconvenience the roads have been constructed by dissecting hills and uplands which facilitate the birth and intensification of sheet, rill and gully erosions. Road construction and the frequent maintenance also play a vital role in aggravating the problem.

The energetically operating sheet, rill and gully



erosions around the escarpment donate the fertile top soil to the valley floor. This partly fed fertile soil to the irrigation fields. On the other hand however, the high runoff from elevated ridges accelerates the formation and intensification of gully and considerable deposition on the roads and cane fields. The active erosion and expansion of gully in the road side made road construction a year round activity. In addition beyond taking the fertile top soil erosion has been expanding active gullies and turns the potentially irrigable lands in to bad land.

Figure 4.9. Slope based Interpolation Map showing General Conditions of erosion

There is a general elevation decline from south to north and from the eastern and western edges to Finchaa River. This indicates that the general trend of erosion is to Finchaa River first and finally to the Abay gorge. The tributaries fed fertile soil to Finchaa River and the soil finally transported to Abay River.

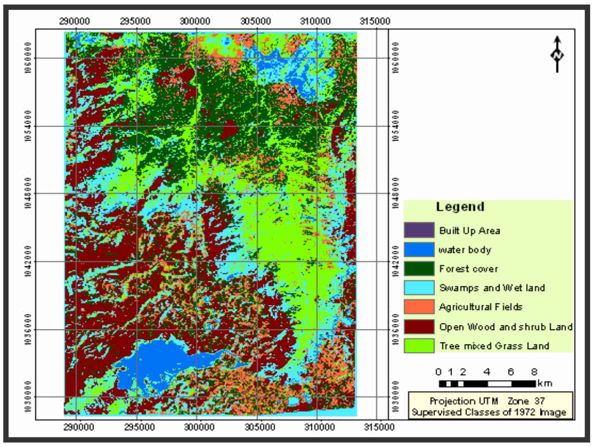
The digital elevation model based run off estimate indicates that there is high runoff pattern in the areas that lies from the eastern and western escarpments to the banks of Finchaa River. This is due to the steep slope down the escarpment to the valley floor. Obviously the high runoff in these areas contributes for high rate of erosion. Thus the topographic set up and human activities make soil erosion to be a critical problem in the study area.

In a nutshell one of the critical problems of soil resource in the project area is erosion. The use of agro-chemicals in the irrigation fields has also its own share to degrade the soil quality. Soil pollution emanating from chemical pollutants is found to be moderate in the study area. This can be due to soluble nature of chemicals that have been applied and the quantity in proportion to the total sampled soils. But there is greater possibility of the agro-chemical use in the irrigation fields to alter the soil quality in the long run.

The Soil erosion mainly takes the fertile top soil and contributes for expansion of gullies and there by reduce the potentially irrigable lands. These two major soil problems needs proper follow up and management. If the present trend continues, in the long run the problem of soil/land degradation can put the sustainability of the project in question. Persistent and considerable efforts should be made to mitigate the impacts of erosion on the soil and potentially irrigable lands.

2.2.4. Land use and Land cover

Finchaa valley area have transformed from primary to secondary and tertiary economic activities; from traditional agriculture to industrial and commercial activities. There is land use land cover change in the area since 1975.



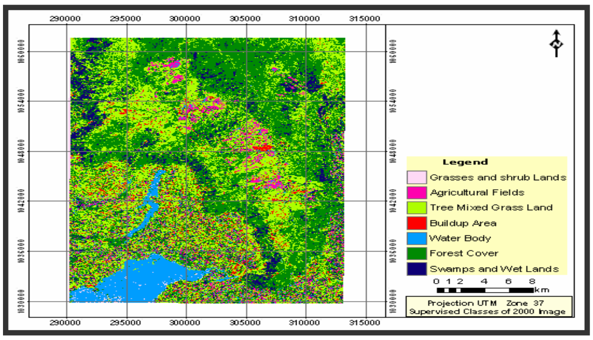
In the pre 1975 years there were no considerable land use classes in Finchaa valley area. Most of the areas were under the natural vegetation cover. From 1975-1991 the state farm used to produce some food and commercial crops on about 3,500 hectors of land in the valley floor. This incident attracted few people to the area to get jobs in the farm but still the number was not that much substantial. During this period there were no significant land use classes except for the state farm and few fragmented private holdings out side the valley. With the beginning of the sugar project in 1991 extensive land has been cleared and irrigated. Currently the irrigated land is about 8,064.88 hectors and the built up areas occupy approximately 200 hectors of land in the valley. The dominant land use classes are irrigation agriculture; Rain fed agriculture, built up areas, roads, artificial reservoir, lakes, and others.

The land cover of the study area can be categorized in to two classes. These are the natural and artificial land covers. The human made features in the area composed of towns, roads, drainage canals, ponds, agricultural and irrigated fields, and artificial lakes. Only a few artificial structures are observed near Finchaa dam in the MSS image of 1972 following the construction of the dam. (See figure 4.1) In these years approximately more than 95percent of the area was under natural environment.

In the TM image of 1986 some artificial developments have been observed (See Figure 4.2).This is mainly because of the introduction of the state farm to the valley and slight population growth in the surrounding high lands. From this time on wards agricultural lands have been expanding in the valley and the surrounding areas.

it is evident that many of the area were under Savanna grasses, open wood land and dense forest. There were no significant land use classes in this year. The present Amerti Lake was in its swamp stage. In the upper right corner the area that appeared as lake is incorrect .Rather it is spike involved during Satellite image acquisition. In the land use classification of 1972 the built up area category is very small and insignificant and therefore not represented in the unsupervised classification. In this year very few agricultural plots are observed.

In the ETM image of 2000, which is after 22 years, significant human made features are evident in and around Finchaa valley. The vast



irrigation fields and built up areas have increased. By implication the vegetation biomass in these areas has diminished. (See fig 4.3)

In the surrounding areas the rain fed agricultural plots have intensified. Some smaller towns and villages are observed including Finchaa town, Achane, Homi and Kombolcha villages. The size of Finchaa Lake is also increased compared to the pre 2000 years. However from the field observation it is perceptible that in recent years the size of the lake is diminishing. In the

Figure 4.12. Supervised Land use/ land cover Map Of 2000 image.

unsupervised classification map agricultural land, built up areas, bare lands and the size of the lake have increased in size. The Amerti swamps grow in to a perennial lake. Conversely the total share of dense forest, open wood land, savanna grass lands have diminished.

Generally there have been land use and land cover changes in the study area. This is mainly due to favorable climate and environmental conditions which instigate agricultural and industrial development activities in the area. This phenomenon was in turn followed by population growth and intensification of agriculture and industrial developments. The development of the irrigation scheme in the project area facilitates the alteration of the natural ecosystem and brought changes in the land use land cover of the study area.

2.2 Irrigation project and water Quality and Health Conditions

2.2.1. Impacts of Irrigation project on Water Quality

2.2.2 General Conditions of water in Finchaa Valley Area

In the study area the Finchaa and Amerti-Nashe rivers form the main drainage system. They both join the Abay River in the far down stream area. The irrigation field and the Finchaa sugar factory lie with in the networks of Finchaa river system. They both relay on this river to meet their water requirement. Finchaa River is diverted to cane fields near the power house in the upstream area through concrete canals. At present the west bank canals run for about 44 kilometers. Water from the canal is pumped to irrigation fields and finally sprinklers shower the water to the growing cane. The extra water from cane fields flow to the near by ditches and join one of the nearest tributary streams.

On the other hand the industrial waste water is taken to the treatment plant which is situated to the east of the factory. The factory uses a rock filtration treatment method. However some of the instruments of the treatment are nonfunctional. The waste water coming from the factory over flows due to these broken parts and two stream-sized crude waste water flows to Finchaa River. These direct leakages together with the agro-chemicals from irrigation fields indisputably alter the physico-chemical properties of the water.

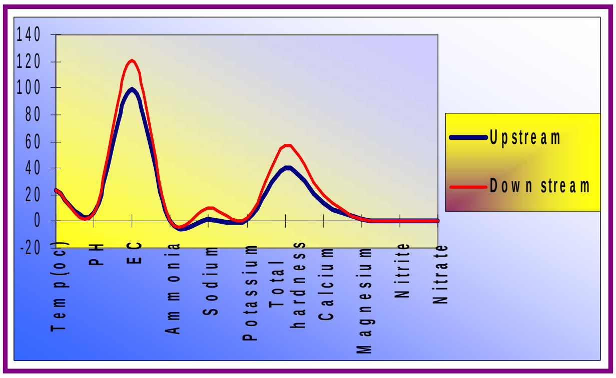
This phenomenon affects the living organisms in water in particular and the environment in general. Again Finchaa River as one of the tributaries of Abay River crosses the boundaries of Sudan and Egypt. Any water quality problem in this place arise dispute with these countries. Thus strict water quality control works should be carried out in and around the industrial and agricultural sites.

2.2.3. The Physico-Chemical Properties of the Up Stream and Down Stream Water

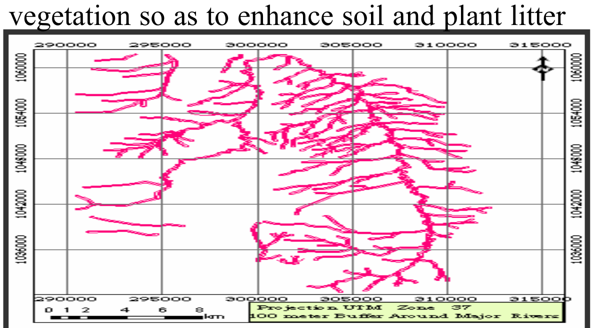
The physical and chemical properties of water characterize the water quality. These properties of water are susceptible for change. The addition of toxic wastes to the surface or sub surface water alters the normal composition. The PH for instance is sensitive and decisive factor for the survival of living organisms in water.On experimental lakes in North West Ontario Schindler (1988) find out that due to change of PH from 5.4 to 5.1 over all, the number of species in the lake at PH 5.1 was 30 percent lower than in the pre acidification years. In order to asses the impacts of the agro-chemicals and industrial wastes, water Samples from the up stream and down stream areas are taken and analyzed. (See Appendix 5)

The up stream area refers to the water near the power house where the water does not get in contact with water from irrigation and industrial wastes sites. The down stream comprises the water after it mixes up with water from streams in the irrigated and industrial waste sites. (See Figure 5.2 for sample sites)

In order to increase the accuracy of the results water sample was not taken from the irrigation ditches and direct industrial waste water. Rather the Mixed down stream water was preferred so as to avoid inaccuracies and exaggerated results.The physical properties of water like pH, EC, Odor and color are found to be different in the upstream and down stream areas. The PH and EC are lower in the upstream water compared to the down stream water. This could be due to difference in the chemical constituents in these two sites. The color differences are also discernable.



The results of the water chemical analysis also indicate that some elements are found in a higher quantity in the down stream than the upstream water. (See appendix 5)
As it is evident from Figure 5.3 almost all of the inspected elements are found to be higher in the down stream water. This could be due to two major reasons. In the first place the extra water washed the agro-chemicals from irrigated
Figure 5.3. The physical and chemical properties of upstream
and down Stream Water from Finchaa
River. fields and joins the river.
The Second main reason is the liquid waste from the industry and the urban areas that directly or indirectly drains to surface or subsurface water. These two cases comprise the point and non point source for the pollution. The industrial waste water escaping from the treatment plant forms the point source pollution while the agro-chemicals from irrigation field cover the non point source for the pollution.
In an effort to alleviate the problem of water pollution the point and non point sources should be given priority. As a point source the contribution of waste Water from the industry can be addressed by continuous follow up and maintenance of the treatment plant. It is again advisable to replace the treatment plant with modern and effective instruments and methods. And the problem of non point source can be mitigated by avoiding the direct contact of the excess water from irrigation ditches and metropolitan wastes with the river and tributary streams. This can be possible by creating a buffer around Finchaa and Amerti-Nashe Rivers and major tributaries. (See figure 5.4)
The buffered zone needs to be covered with vegetation so as to enhance soil and plant litter

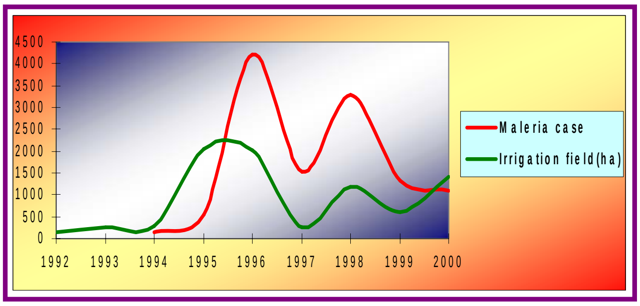


filtration and purification. As an alternative approach the extra water from the irrigation field can be collected in an artificial reservoir and treated before it discharges to the main rivers.
Generally, the water samples from Finchaa River indicate that there is water quality difference between the upstream and down stream area. This shows that, to a greater or lesser extent, there is water pollution in the River. The discrepancy in the physico-chemical properties of water is supposed to be from the industrial wastes, agro-chemicals from irrigation fields and to a lesser extent metropolitan wastes forming the point and non point sources.
Figure 5.4. 100m Buffer around the Finchaa and Nashe rivers and their major tributaries.

2.2.4. Health Conditions in the Post Development Years Of the Irrigation project

There is no recorded health status data before the establishment of Finchaa sugar factory as there was no settlement in the valley. However, from unstructured interview made with local inhabitants some people asserted that the area had been affected by epidemics even before the arrival of the state farm. The interviewee sited the problem as one of the impeding factor for permanent settlement not to take place inside the valley in the former years.
Booker international agriculture Ltd (1977) in the feasibility study for Finchaa sugar project affirmed that there exists Malaria and Tsetse fly in the valley. The company added that this could be a challenge for the project workers and residents of the valley. Currently there is one health center in the valley and some recorded case information is available. Accordingly the intestinal and malaria cases have been increased from 1992 on wards. From the informal interview made with the staff of the health center three possible rationales can explain this scenario. In the first place the water used for drinking is pumped from the canal with diminutive treatment. Secondly the expansion of irrigation can facilitate the spread of malaria and access to unclean water. Finally the population explosion in a short period of time may inflate

the proportion of patients compared to the early years.
Malaria is the top health problem in the last 12 years. The fluctuating Weather conditions together with the expansion of irrigated fields and ditches can be the factors behind the problem. The fluctuation in malaria case records arises from the inconsistent use of anti-malaria chemical sprays and expansion of irrigated lands. The Second and third top health threats are Guardia and Ascaries. These intestinal problems in most cases are water born disease which can be related with unhygienic water use for drinking. The haphazard increment of intestinal parasite and malaria case records can be due to natural or human made reasons. On one hand the natural set up of the valley and the climatic conditions can facilitate the birth and growth of pathogenic organisms in the area. On the other way round human interference have changed some of the existing natural systems. In other word the expansion of human made environments results in alteration and degradation of the natural ecosystem.
These environmental modifications create a fertile ground for some insects and pathogenic organisms which give birth to the spread of diseases. The classical example here is the



expansion of irrigation and increasing malaria case records.
Figure 5.9.Expansion of Irrigation fields Vs Malaria case records.
As it is evident from figure 5.10 Malaria cases are increasing with the expansion of irrigation fields. In the beginning few malaria cases were seen in the valley. For the 1992 and 1993 there were no recorded malaria cases data available in the health center. But for the consecutive two years fewer malaria cases were recorded. From 1995-1997 large number of malaria cases were observed. (See appendix 3) In these years extensive sugar cane plantation was carried out in the valley. The lag time between highest malaria case and the expansion of irrigation could be due to the time taken for reproduction and stages of development in human body.
In general there is no health data available on the pre irrigation development years of the valley. Since 1992 malaria and intestinal parasite case records have increased. Conversely the health facility given in the valley has improved a lot since 1992.It is found out that there is a positive relation ship between malaria cases and expansion of irrigation fields. The intestinal health threats are also interlinked with unclean drinking water. Well organized preventive and controlling measures should be implemented as the health cases are interrelated with workers productivity.

3. Conclusions

In order to see the possible environmental impacts of irrigation projects some parameters were selected. Some of the Geographic information system and remote sensing techniques were also used. Accordingly, it is observed that the natural environment in Finchaa valley has been modified due to agricultural and industrial developments since 1975. Following this modification the irrigation project have both positive as well as negative impacts on the environment.
From the positive contributions the project opened up large scale job opportunities for many thousands of people. It has also many socio-economic benefits for the valley and surrounding people. In addition Finchaa Sugar factory play a key role to address the current sugar demand in a local market. There are also many efforts to exploit the byproducts of the factory for other extra purposes like using ethanol for fuel. The project has also an important role for the growth of national GDP and GNP.
On the other hand the attention given for natural resource conservation is less and this has been devastating some of the environmental components. There has been large scale vegetation clearance taking place in the study area. The NDVI image analysis of the 1972 MSS and the 2000 ETM images shows that the vegetation biomass is diminishing. The intensification of agricultural and industrial developments together with population explosion has the coin share for the decrement. The large scale deforestation has

been devastating the vegetation and wild life resources in particular and the biodiversity in general. There are efforts made by Finchaa sugar factory to rehabilitate the forest resource. But the amount and rate of deforestation in one side and the reforestation and afforestation projects on the other side are incomparable in any measure.

In addition deforestation is facilitating the progress of runoff and accelerates erosion. Accordingly soil erosion is a critical problem in the project area. The active erosion, beyond taking the fertile top soil, is changing some of the potentially irrigable lands in to Bad Lands. In some areas there are gullies that extend for about 30 m. The topographic set up and Human induced factors are responsible for the active erosion in the area. The steep slope in the escarpments surrounding the valley promotes greater runoff. The Road construction and the frequent maintenance down the valley made the soil ready for erosion.

The physical and chemical analysis of the soil samples taken from irrigated field, cultivated but not yet planted and Vegetation cover area are found to be different. The total sand content of Luvisols decreases with increasing soil depth in all sampled layers. While the clay content increases with depth. The exchangeable bases are higher in the irrigated and cultivated area than the vegetation cover area. Relatively Organic carbon, Nitrogen and phosphorous are found in large quantities in the irrigation fields especially in the upper layer (0-30cm). The use of agro-chemicals in the irrigation fields are supposed to contributes for this result. In general some of the physical and chemical properties of the soil in the irrigated and non irrigated sites are found to be different. This shows that, to a lesser or greater extent, there is soil contamination that could lead to full-size soil pollution. The result of water samples from up stream and down stream areas indicates that the physico-chemical properties are different in these two areas. The down stream water contains more chemical substances than the up stream water. The point and non point sources contribute for the pollution. The point source comprises the industrial waste water that escapes from the treatment plant and join the river. The non point sources involve the use of agro-chemicals (fertilizers, pesticides and herbicides) and the metropolitan wastes that join the tributary streams. Thus, based on the water samples inspected there is water pollution emanating from poor industrial waste water treatment and the leftovers of the agro-chemicals used in the irrigation fields.In most cases climate is the reflection of the natural environment. Any system disturbance on the environment can affect the climatic conditions. The analysis of the 22 years rain fall, temperature and humidity data can not meaningfully imply any climatic change as a result of the irrigation project. This is due to the sluggish and unpredictable nature of climatic anomalies. It is reasonable however to say that there is imperceptible changes following the environmental degradation. Still it is open for further specific and detailed works to see the impacts of irrigation on the local climate. Case records of Malaria and some water born disease have been increasing following the opening of Finchaa irrigation scheme. There is a positive correlation between malaria case records and expansion of irrigation fields. Although the health care facility given has improved a lot, the number of patients boost up by a large number. This shows that big attention is given on disease control than prevention. The environmental modifications and the diminutive prevention measures contribute for the large number of malaria and water born diseases case records.Generally despite of its positive consequences, the irrigation project in Finchaa valley area has a negative impact on the environmental components. Especially on the vegetation cover, soil quality, water quality and partly on some health conditions. But this does not, in any way, mean that the problems out weight the benefit of the factory and that the problems are out of control. The degradation is in its early to moderate stage and even not difficult to address and alleviate them all. The possible solutions are much easier and cheaper in this moderate stage of the environmental degradation. But undoubtedly if the current trend keeps on the problem would get more complex and difficult to reclaim. Thus, urgent attention should be given for the environmental rehabilitation and conservation.

4. Recommendations

In line with the findings of this selective parameter based environmental impact assessment the following recommendations are presented:

1. The environmental considerations should not be disregarded in any way and with any justification seeing that well organized environmental management positively contribute for better productivity and sustainability.

2. The rehabilitation of devastated vegetation biomass should be given first line attention as it helps to maintain the soil, water, climate and biodiversity of the area. Finchaa sugar factory should tackle the problem of frequent Forest fire and large scale deforestation that are observed inside the valley.

3. There should be well organized and effective afforestation and reforestation programs to reestablish the ecosystem. Some areas like the surrounding escarpments, river sides, agriculturally non suitable and marginal lands can be delineated and protected as the forest area.

4. There should be continuous follow ups and assessment of the physico-chemical properties of the soil in the irrigation fields. This helps to see the impacts of fertilizers, herbicides and pesticides on the soil quality and to take timely measures.

5. Strict physical and biological measures should be taken to impede the actively operating erosion and growing gully problem in the irrigation fields and the surrounding areas.

6. Finchaa sugar factory should establish a modern and efficient waste water treatment plant in order to stop the two stream-sized industrial waste water and irrigation field wash away leakages to the river. Further inspections should be carried out for the water quality problem in the down stream area and appropriate measures should be taken.

7. In addition to disease controlling strategies, research based preventive approaches should be adopted so as to mitigate the escalating malaria and water born disease case records and their far reaching impact on production and productivity.

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Entomological studies on the impact of a small-scale irrigation scheme on malaria transmission around Zeway, Ethiopia.

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Abstract

To evaluate the impact of a small-scale irrigation scheme on the level of malaria transmission in a semi-arid area, entomological studies were conducted in Zeway area, Central Ethiopia. Larval and adult anophelines were sampled during the dry and short-rainy seasons from irrigated and non-irrigated villages. Overall, significantly higher density of *Anopheles* larvae were found during the dry season in the irrigated village (Mean = 38.3 larvae/100 dips) than the non-irrigated village (7.4 larvae/100 dips). Canal leakage pools, irrigated fields and irrigation canals were the major sources of *Anopheles* mosquitoes. Larval and adult *Anopheles pharoensis* and *An. arabiensis,* principal malaria vectors in Ethiopia, were more abundant in the irrigated village than the non-irrigated village throughout the study period. Hourly light trap catches revealed that peak indoor and outdoor biting activities of *An. arabiensis* and *An. pharoensis* occurred during the early period of the night before the local inhabitants retire to bed. The majority of blood-engorged *An. arabiensis* (0.78) and *An. pharoensis* (0.69) had fed on humans, suggesting that their highly anthropophilic nature in Zeway area. *Plasmodium falciparum* infection rates of 1.02% and 0.54% were determined for *An. arabiensis* and *An. pharoensis*, respectively, in the irrigated village. This study demonstrated that due to poorly maintained irrigation structures, the irrigation scheme created conducive breeding grounds for malaria vector species, particularly during the dry season. Consequently, the period of malaria transmission might possibly extend from seasonal to year-round, involving the dry season. Proper water management coupled with environmental management such as source reduction could reduce vector abundance and hence malaria transmission in the irrigation schemes.

6.

7. **Key words:** *Anopheles*, malaria transmission, small-scale irrigation scheme, *Plasmodium falciparum* sporozoite rate, Zeway, Ethiopia.

1. Introduction

Development of irrigation schemes is widely recognized as a key for promoting economic growth, ensuring food security and alleviating poverty in most developing countries (Lipton et al., 2003). However, past experience shows that inadequate consideration of both environmental and public health impacts can seriously undermine the sustainability of such schemes (Gratz, 1988; McCartney et al., 2007). Key among the potential negative impacts is the link between irrigation and malaria – a disease that affects between 300 and 500 million people each year globally and claims the lives of 1.5 to 2.5 million people annually (WHO, 2006).

By increasing the availability of surface water for breeding, irrigation favors the development of large populations of disease vectors such as anopheline mosquitoes responsible of transmission of malaria. Hence, there is great concern that irrigation can lead to increased malaria transmission especially in sub-Saharan Africa where 90%

of the global malaria burden exists and the prevailing climatic factors support proliferation of malaria vector mosquitoes and development of the parasite in the vector. However, the relationship between irrigation and malaria is not straightforward and varies according to endemicity and seasonality. In stable malaria endemic areas of sub-Saharan Africa, studies have shown that malaria transmission is equal or less in irrigated-rice growing areas compared with neighboring areas without irrigated rice cultivation (Josse et al., 1987; Lindsay et al., 1991; Boudin et al., 1992; Faye et al., 1993; Henry et al., 2003). The explanation for this finding is yet unresolved, but in some cases at least, could be attributed to displacement of the most anthropophilic (human blood seeking) malaria vector *Anopheles funestus* by *An. arabiensis* with lower vectorial capacity, as the later thrives more than the former in irrigated fields (Ijumba and Lindsay, 2001). It has also been suggested that many communities near irrigation schemes benefit from the greater wealth created by the schemes, often leading to better access to improved health care and hence receive fewer infective bites compared to those outside such schemes. On the other hand, in areas where malaria is absent or unstable, introduction of irrigation was found to place the non-immune population at a high risk of acquiring the disease, increasing malaria morbidity and mortality (El Gaddal et al., 1985; Ijumba et al., 1990). In such areas, irrigation, especially during the dry season, might alter the malaria transmission pattern from seasonal to annual, as observed in the Sahelian region of Mali (Sissoko et al., 2004) and in sub-arid irrigated areas of Madagascar (Marrama et al., 2004).

In Ethiopia, where three quarters of its land mass are potentially malarious, introduction or expansion of irrigation schemes can increase the burden of malaria in the country. A detailed epidemiological study in the highlands of Tigray, northern Ethiopia, has reported that malaria incidence in young children was sevenfold higher in communities near irrigation microdams than those further away (Ghebreyesus et al., 1999). A recent entomological study in the same area has reported 5.9-7.2 times more adult *An. arabiensis* (the main malaria vector in Ethiopia) in the dam villages than the controls, non-irrigated villages (Yohannes et al., 2005). The study also indicated that seepage water at the base of the dam, leaking irrigation canals and waterlogged fields were the main sources of *An. arabiensis* throughout most of the year. However, despite extensive development of irrigation schemes in semiarid fertile areas of the country with unstable disease transmission (MoWR, 2005), in-depth information on the link between irrigation and malaria in such environmental settings is lacking. The main objective of this study was to assess the possible impact of irrigation-based agricultural activities on malaria transmission in a semi-arid area with seasonal disease transmission.

2. Materials and Methods

The study area

The study was undertaken between February and May 2006, in two rural farming villages, Abene-Girmamo and Woshgulla, located in Zeway area (8^{o}00`N, 38$^{o}$40`E), Central Ethiopia, 165 Km south of Addis Ababa, in the middle course of the Ethiopian Rift Valley (Figure 1). Both study villages are at a distance of 5-6 Km from Zeway town, which is situated alongside Lake Zeway. The area receives between 700-800 mm of annual rainfall, with the heavy rains during the months of June to September and short rains in April and May (National Meteorological Agency). The mean annual temperature is 20 ^{0}C, and February is the hottest month of the year.

Malaria transmission in Zeway area is generally unstable (seasonal), with peak transmission occurring between the months of September and November, immediately after the main rainy season, while the second less pronounced transmission period falls between April and May in the short-rainy season. *Plasmodium falciparum* is the most prevalent malaria parasite in Zeway area, responsible for 60-70% of malaria cases. Vivax malaria is also common in the area, particularly in the dry season, but generally less prevalent. (Abose *et al*., 1998b; Zeway Malaria Control Unit, unpublished report). *Anopheles arabiensis* is the primary malaria vector in Zeway area, and elsewhere in Ethiopia, while *An*. *pharoensis* plays secondary role (Rishikesh, 1966; Abose *et al*., 1998a; Abose *et al*., 1998b; Ye-Ebiyo et al., 2000).

Abene-Girmamo is an irrigated rural village, situated at an altitude of 1647 m. The village is inhabited by 934 people, mainly dependent on subsistence farming. The community is mainly comprised of the Oromo and Silte ethnic groups. Most families own livestock (mainly bovine, ovine and equine), with a human to cattle ratio of 1: 0.4. Woshgulla is a non-irrigated agricultural village, situated at an altitude of 1654 m, with a population size of 741. The village is located 8 Km away from the irrigation schemes in Abene-Girmamo. The inhabitants are dependent on subsistent rain-fed agriculture during the months of the wet seasons. They also keep livestock (mainly cattle, equine and ovine), with the mean human to cattle ratio of 1: 0.6. The domestic animals in both villages spend the night either indoors in the same homesteads with the owners or outdoors in open cattle enclosures. The main type of housing in these villages was circular huts, made of mud-brick walls and thatched roof. Mud-brick-making pits, partly covered with water, were commonly found at the backyards of households that commonly practice brick-making either for domestic use or for sale. These pits were mostly functional during the dry season but became non-functional in the wet seasons, because the rains could damage newly formed moist mud-bricks before they dry. Each village had a water-harvesting pool, i.e., collection of rainwater in a wide and deep well (volume ~ 2m width x 2m length x 6m depth) with corrugated iron-roofing.

The source of water for irrigation in Abene-Girmamo is Lake Zeway, located 5-6 Km away from the scheme. Water is pumped from the lake by three long plastic pipes (0.4 m diameter and 4-5 km long) that run underneath the ground to reach the unlined surface canals at uplifted soil mass. The surface irrigation canals feed smaller field canals to cover the entire agricultural field. However, due to poor construction and lack of maintenance, there were many leaking canals, causing leakage pools at unwanted places. These pools never dry because of continuous water leakage from the irrigation canals. Water logging also occurred in the agricultural field as a result of over-irrigation and water retaining characteristics of the soil. Sometimes, poor drainage led to water logging in the field. The uplifted soil walls of the surface canals were also frequently perforated and formed leakages, mainly due to the action of domestic animals while drinking water in the canals. Onion, cabbage and maize (*Zea m. mays*) were commonly grown under irrigation throughout most of the year.

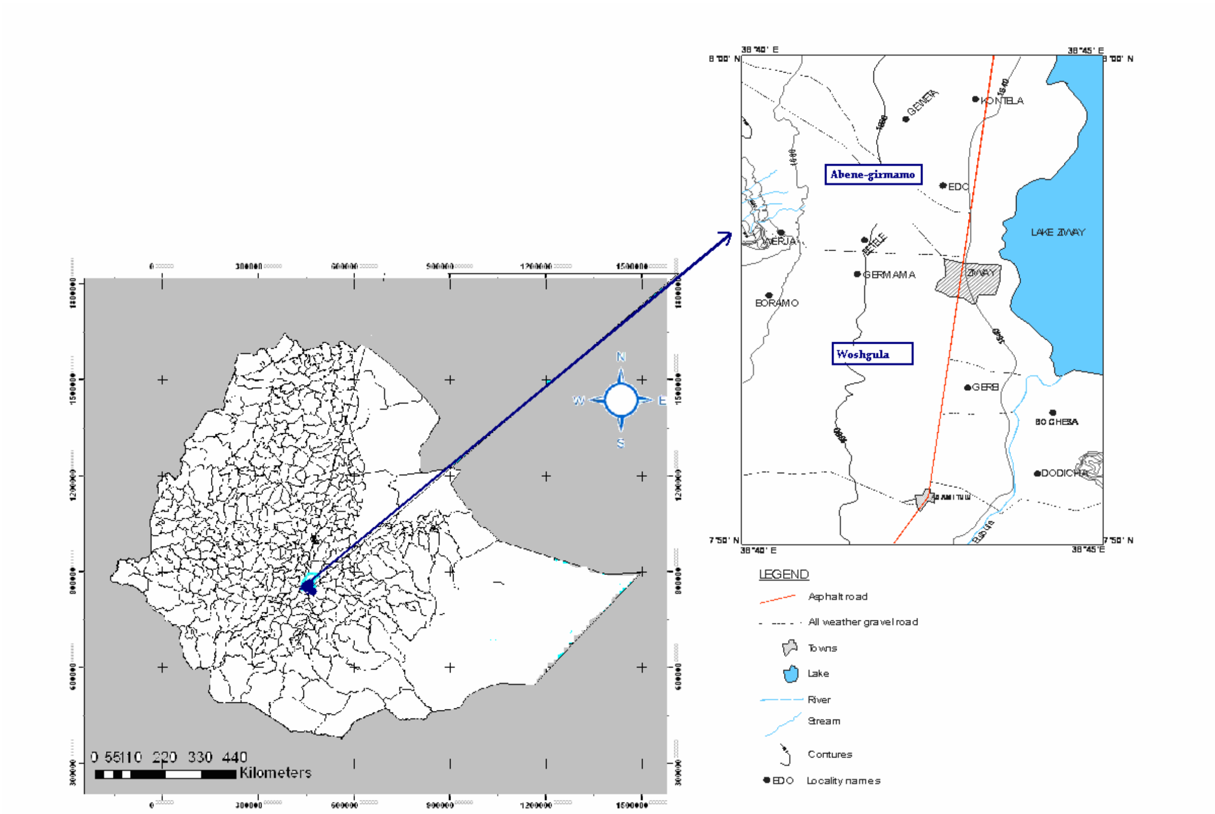

Figure 1. Location of the study area in Ethiopia and map of Zeway area (the two study villages are shown in bold rectangles).

Entomological surveys

Entomological surveys comprised larval and adult mosquito collections in the irrigated and non-irrigated study villages during the dry (February/March) and short-rainy (April/May) seasons of 2006.

Anopheline larvae were sampled for eight days between February and March in the dry season and also between April and May in the short-rainy season of 2006. At each survey, all available potential mosquito breeding habitats such as irrigation canals (unlined surface canals with still water due to back-flow), canal leakage pools (pools formed from leaking main canals), irrigated field paddies (water logging in the field due to over-irrigation and poor drainage canals), water-harvesting pools, mud-brick-making pits and rain pools within one kilometer radius from each study village were surveyed using standard dippers (350ml). The surface area of each potential mosquito breeding site was estimated in square meter (m^2) and sampling was made at a rate of 6 dips/m^2. One 'sample' was defined as 30 dips (or less, in smaller sites) taken over a surface area of 5 m^2. For sites in the range of 5-10 m^2, one sample was taken, whereas two samples were taken from sites in the range of 11-20 m^2 and so forth. An upper limit of six samples was set for all sites with water surface area exceeding 50 m^2 (Amerasinghe and Munasingha, 1988). Larval anophelines sampled from each type of breeding habitat were transferred to separate vials and killed by gently heating and preserved in 70% alcohol for later species identification.

Adult anophelines were sampled from indoors and outdoors for ten consecutive nights between February and March in the dry season and between April and May in the short-rainy season of 2006. Three techniques: i.e., CDC light traps, mouthpiece aspirators and space-spray, were used for adult sampling. In order to obtain a representative sample of the mosquito population for the irrigated village, a total of 6 houses were randomly selected (2 from the edge of the village at close proximity to the irrigated field [~300 m], 2 from the middle [~600 m] and 2 from the far side of the village [~800m]). Similarly, the non-irrigated village was roughly divided into three sampling zones based on proximity to the non-irrigated agricultural field and two houses were randomly selected from each zone. Untreated bed nets were distributed for the households and the same houses were used throughout the study period. A total of six outdoor sites (~100 m away from occupied houses) was also selected in each village for outdoor light trap collection.

A total of twelve (six indoors and six outdoors) CDC light traps (Model 512; J. W. Hock Co., Atlanta, USA) was operated in each village from 1800 to 0700 hours throughout each sampling night. Each indoor light trap was hung on a wall; with the bulb about 45 cm above the head of a person sleeping under an untreated bed net (Lines *et al*., 1991). Outdoor light traps were hung on trees at close proximity (~50 to 100 m) to open cattle enclosures where some individuals spend the evening keeping their livestock from theft. To determine peak activity of anophelines during the period of the night, hourly mosquito collections were also conducted indoors and outdoors by light traps. Using mouthpiece aspirators and space-spray, female *Anopheles* mosquitoes were collected from their daytime resting sites both indoors and outdoors (Service, 1993). While collecting light traps the following morning, a team of three collectors holding aspirators and torchlight searched for resting mosquitoes from the six light trap houses and from possible outdoor-resting sites (burrow pits, ground holes, tree holes, open cattle sheds and among vegetations) in each village. For the purpose of comparison, the team of collectors spent the same period of time (20 minutes) indoors and outdoors (Abose *et al*., 1998b). Using white sheets of cloth and an aerosol of pyrethroids (Mobil flit; Mobil Africa Sales Inc., Belgium; Composition [% weight]: Tetramethrin 0.12; Phenothrin 0.12; Allethrin 0.25; Solvents, Propellants and essential oils 99.43), indoor-resting anophelines were also collected from six selected houses in each village. Before spraying the houses, all openings that could allow mosquito escaping (such as doors, windows, and holes on the walls) were closed, and the entire floor was covered with the white cloth. The houses were then sprayed with Mobil flit for about 5 minutes and left closed for 10 minutes. Thereafter, the sheets were brought outside the rooms to inspect and collect the knock-down mosquitoes. Mosquitoes collected by the different techniques were counted and kept in separate paper cups for latter identification and mosquito processing.

Species identification and dissection

At Zeway Malaria Control Laboratory, preserved anopheline larval samples were counted and individually mounted on microscope slides for species identification based on morphological characteristics (Verrone, 1962b). Only third and fourth larval instars were used for species identification of anopheline larvae. Adult anophelines collected by the different sampling methods were also sorted out into species based on morphological characteristics (Verron, 1962a). One-third of unfed female *Anopheles* mosquito collections obtained from light trap catches and all unfed female anophelines caught resting indoors and outdoors were dissected to determine parity rates for each species during the dry and short-rainy seasons. Ovaries with coiled tracheal skeins were considered as nulliparous (did not lay eggs), while those with stretched out tracheoles were taken as parous (laid eggs) as described by Lewis (1958). All the remaining female anopheline samples and the head-thorax region of dissected mosquitoes were stored in the silica-gel dessicator and transported to Addis Ababa University, Biomedical Science Laboratory, and kept at room temperature (19-22 ^{o}C) for later mosquito processing.

Mosquito processing

The head-thorax region of each dried female anopheline was tested for the presence of *P. falciparum* and *P. vivax* sporozoite antigens using Enzyme-Linked Immunosorbent Assay (ELISA) (Wirtz *et al.*, 1987). The direct ELISA procedure described by Beier and colleagues (Beier *et al*, 1988) was used to determine the sources of blood meals (human *vs.* bovine) of the blood-engorged female anophelines.

Data analysis

Daily larval and adult mosquito collections were entered into Microsoft Excel Database and log-transformed ($\log_{10}$ [n+1]), and tested for normality before analysis. The abundance of larval and adult anophelines was compared between villages and seasons using nonparametric Mann-Whitney *U*-test. The same test was applied to compare the indoor and outdoor density of adult anophelines. The relative abundance of *Anopheles* species in the larval and adult collections was compared using Kruskal-Wallis Test, a non-parametric test for ascertaining significance among more than two variables. Larval density was expressed as the mean number of anopheline larvae per 100 dips. Sporozoite infection rate of each *Anopheles* species was expressed as the proportion of mosquitoes containing malaria sporozoite antigen from the total samples of a species tested by ELISA. The Human Blood Index (HBI) for each *Anopheles* species was calculated as the proportion of samples positive for human blood from the total blood meals of a particular species tested. The level of significance was determined at 0.05. All analyses were done using Microsoft Excel 2003 and statistical software, SPSS version 13 (SPSS Inc, Chicago, IL, USA).

3. Results

Larval habitats and abundance

Total number of positive larval habitats, number of *Anopheles* larvae collected and larval density in the irrigated and non-irrigated study villages during the two sampling seasons are presented in Table 1. Four-times more positive *Anopheles* larval sites were encountered in the irrigated village (n = 51) compared to the non-irrigated village (n = 12) during the study period. Consequently, higher *Anopheles* larval densities were found in the irrigated village (mean no. larvae per 100 dips = 36.0; 95% CI = 25.4–48.5; z = -3.196, $P < 0.001$) than the non-irrigated village (mean no. larvae per 100 dips = 14.9; 95%CI = 9.1–20.8) throughout the study period. The difference in *Anopheles* larval abundance and positive larval sites between the dry and short-rainy seasons was significant in the non-irrigated village whereas there was insignificant seasonal difference in the irrigated village. Overall, *Anopheles* larval production in the non-irrigated village was associated with the wet seasons while high larval production in the irrigated village was evident both in the dry and wet seasons.

Anopheles larval collections were composed of five species, among which *Anopheles arabiensis*, *An. pharoensis* and *An. coustani* were the major species. The distribution of *Anopheles* species in different larval habitats in the irrigated and non-irrigated villages is shown in Table 2. Among the five types of larval habitats in the irrigated village, canal leakage pools and irrigated field puddles were the most important sources of *An. arabiensis*, accounting for nearly 60% of the larval collection during the study period. For *An. pharoensis*, canal leakage pools and irrigation canals were the major larval habitats as more than 90% of larval collection of this species were obtained from these habitats. In the non-irrigated village, brick-making pits and rain pools were the most important *Anopheles* larval habitats. Overall, around 80% of the total *Anopheles* larval production in the irrigated village was from three types larval habitats (irrigated field puddles, canal leakage pools and irrigation canals) associated with the irrigation scheme.

Adult anopheline collections

A total of 1271 adult anophelines was collected from the two study villages during the study period, of which 94% (n = 1213) and 6% (n = 58) were from the irrigated and non-irrigated villages, respectively (Table 3). *Anopheles pharoensis* was the major species predominantly sampled in the irrigated village during the dry season (56.9%; n = 340; X^2 = 52.294; df = 2; P < 0.001) while *An*. *arabiensis* predominated in short-rainy season (50.2%; n = 309; X^2 =17.751, df = 2, P < 0.001). Of the few adult anophelines collected in the non-irrigated village during the short-rainy season, the majority (65.5%, n = 38) were *An*. *arabiensis*. No mosquito was collected in the non-irrigated village during the dry season.

The density of *An*. *pharoensis* per light trap-night was higher during the dry season (mean no. mosquito/trap/night = 2.24; 95% CI = 1.21–3.17; Mann-Whitney U = 2422.0, z = -5.244, P < 0.001) than the short-rainy season (mean no. mosquito/trap/night = 1.48). The difference between indoor and outdoor densities was significant, being higher outdoors (Mann-Whitney U = 4646.0, z = -4.257, P < 0.001) than indoors. In contrast, the mean density of *An*. *arabiensis* was higher during the short-rainy season (mean no. mosquito/trap/night = 1.70; Mann-Whitney U = 1840.0, z = -2.569, P = 0.01) than the dry season (mean no. mosquito/trap/night = 1.23; 95%). There was also significant difference between the indoor and outdoor densities, being higher indoors (Mann-Whitney U = 3849.5, z = -5.849, P < 0.001) than outdoors. The density *An*. *coustani* was higher outdoors (Mann-Whitney U = 5772.5, z = -2.342, P = 0.001) than indoors during the two sampling seasons. Although the densities of *Anopheles* mosquitoes were generally very low in the non-irrigated village during the study period, similar indoor-outdoor trends were noted for the three species. Overall, *An*. *arabiensis* was more endophagic while *An*. *pharoensis* and *An*. *coustani* were more exophagic in the study area.

Peak hourly activity of Anopheles *species*

Peak indoor and outdoor activities of *An*. *arabiensis* were observed during the early period of the night, between 18:00-19:00 and 19:00-20:00 hours, respectively (Figure 2). Thereafter, its activity steadily decreased both indoors and outdoors throughout the rest of the night. Peak indoor and outdoor activities of *An*. *pharoensis* occurred between 20:00-21:00 and 19:00-20:00 hours, respectively, which gently declined thereafter, but with a remarkable increase between 22:00-23:00 hours at outdoors (figure 3). For *An*. *coustani*, its peak indoor and outdoor activities were recorded between 18:00-19:00 hours, which sharply dropped thereafter but with a remarkable peak between 22:00-23:00 and 05:00-06:00 hours, indoors and outdoors, respectively (Figure 4). Overall, about 75%, 66%, and 69% of the biting by *An. arabiensis*, *An. pharoensis* and *An. coustani* occurred during the early period of the night (before 22:00 hours), before the local people retire to bed.

Parous rate

Parous rate of *Anopheles* species in the irrigated and non-irrigated study villages during the dry and short-rainy seasons is presented in Table 5. In the irrigated village, the parous rate of *An*. *arabiensis* was higher during the dry season (58.7%, n = 46) than the short-rainy season (22.2%, n = 81). In contrast, the parous rate of *An*. *pharoensis* did not vary significantly between the two sampling seasons; 43.3% (n = 39) and 41.2% (21/51) in the dry and short-rainy season, respectively. For *An*. *coustani*, higher parous rate was recorded during the dry season (18.2%, 4/22) than the short-rainy season (3.4%, 1/29). In the control village, among few anophelines caught during the short-rainy season, only two parous *An*. *arabiensis* females (5.3%; 2/38) were found. Overall, *An*. *arabiensis* and *An*. *pharoensis* had higher parous rate during the dry season, suggesting higher longevity of these species in this season.

Host feeding preference

Table 6 shows the sources of mosquito blood meals in the irrigated village. Among 120 blood-fed *An*. *arabiensis* specimens tested, 70.8% (n = 85) and 14.2% (n = 17) were positive for only human and bovine bloods, respectively. Some (7.5%, n = 9) were mixed blood meals originated from human and bovine, and the remaining were unidentified (7.5%, n = 9) - possibly originated from other domestic hosts (e.g. equines and ovines). Overall, the Human Blood Index (HBI) for *An*. *arabiensis* was found to be 0.78. Out of 142 blood-engorged female *An*. *pharoensis* specimens tested, 61.3% (n = 87) and 20.4% (n = 29) had human and bovine blood meals, respectively. Some blood meals (7.7%, n = 11) were composed of both human and bovine bloods, and 10.6% (n = 15) of *An*. *pharoensis* blood meals were not identified. Overall, the HBI for *An*. *pharoensis* was found to be 0.69. From a total of 16 blood-engorged *An*. *coustani* specimens, only one specimen (6.2%) was positive for human blood while the majority (75%, n = 12) gave positive result for bovine blood. The overall HBI for *An*. *coustani* was 0.06. The ELISA results showed that *An*. *arabiensis* and *An*. *pharoensis* are the most important anthropophagic species in Zeway area.

Sporozoite rate

The *P*. *falciparum* sporozoite rates of *Anopheles* species in the irrigated village is presented in Table 7. None of the samples tested were positive for *P. vivax* sporozoites. Among 424 female *An. arabiensis* specimens collected from the irrigated village and tested for *P*. *falciparum* sporozoites, 5 (1.18%) were found to be positive. None of the thirty-one *An*. *arabiensis* specimens caught in the non-irrigated village were positive for *P*. *falciparum*. Among the total of 509 *An*. *pharoensis* collected from the irrigated village, three (0.59%) were tested positive for *P*. *falciparum* sporozoites. None of the four *An*. *pharoensis* and sixteen *An*. *coustani* specimens collected in the non-irrigated village was positive for malaria sporozoites. Seasonally, higher *P*. *falciparum* sporozoite rate of *An*. *arabiensis* was recorded in the short-rainy season (1.47%; 4/272) than the dry season (0.66%; 1/152). The *P*. *falciparum* sporozoite rate of *An*. *pharoensis* was 0.92% (3/325) in dry season, while none (0/184) were positive in the short-rainy season. Overall, the *P*. *falciparum* sporozoite rate of *An*. *arabiensis* and *An*. *pharoensis* suggests the potential of these species in malaria transmission in the irrigated study village during the dry and the short-rainy seasons.

Table 1. Total number of positive larval habitats, number of *Anopheles* larvae collected and larval density (mean no. larvae/100 dips) in irrigated (Abene-Girmamo) and non-irrigated (Woshgulla) villages in Zeway area, Central Ethiopia, during the dry (February/March) and short-rainy (April/May) seasons of 2006.

	Irrigated village			Non-irrigated village		
Season	Total no. positive larval habitats	No. of *Anopheles* larvae collected (%)	Larval density[δ] (95%CI)	Total no. positive larval habitats	No. of *Anopheles* larvae collected	Larval density (95%CI)
Dry	38	797 (46.0)	38.3 (26.2–50.5)*	5	69 (22.8)	7.4 (4.4 –10.5)
Short-rainy	33	936 (54.0)	34.9 (24..9–45.9)*	11	233 (77.2)	15.2 (9.3–21.1)
Overall	51[a]	1733 (100)	36.0 (25.4–48.5)*	12[a]	302 (100)	14.9 (9.1– 20.8)

[δ] Larval density refers to mean number of *Anopheles* larvae per 100 dips. 95% confidence interval is shown in brackets. * The difference in seasonal larval density between the two villages was significant ($P < 0.001$).

[a] The overall total number of larval habitats in each village is not equal to the sum of positive larval habitats in the two sampling seasons since the same larval habitat can occur in both seasons.

Table 2. Distribution of *Anopheles* species* in different types of larval habitats in irrigated (Abene-Girmamo) and non-irrigated (Woshgulla) villages in Zeway area, Central Ethiopia, between February and May 2006.
* Only third and fourth larval instars were sorted out into species

Village	Larval habitats (Total no. of positive sites)	*An. arabiensis* (%)	*An. pharoensis* (%)	*An. coustani* (%)	*An. cinere*	*An. squamosus*	Total (%)
Irrigated	Brick-making pits (5)	70 (18.5)	2 (0.4)	72 (21.5)	0	0	144 (12.3)
	Canal leakage pools (12)	108 (28.5)	242 (52.8)	57 (17.1)	0	0	407 (34.6)
	Irrigated field puddles (23)	118 (31.1)	41 (9.0)	66 (19.8)	0	0	225 (19.1)
	Irrigation canals (4)	45 (11.9)	173 (37.8)	85 (25.4)	0	1	304 (25.9)
	Rain pools (7)	38 (10.0)	0 (0.0)	54 (16.2)	3	0	95 (8.1)
	Total (51) (%)	379 (32.2)	458 (39.0)	334 (28.4)	3 (0.3)	1 (0.1)	1175 (100)
Non-irrigated	Brick-making pits (7)	57 (52.8)	8 (88.9)	14 (45.2)	-	-	79 (53.4)
	Rain pools (4)	51 (47.2)	0 (0.0)	17 (54.8)	-	-	68 (45.9)
	Water harvesting pools (1)	0 (0.0)	1 (1.1)	0 (0.0)	-	-	1 (0.7)
	Total (12) (%)	108 (73.0)	9 (6.1)	31 (20.9)	-	-	148 (100)

Table 3. Number of adult *Anopheles* mosquitoes collected from irrigated (Abene-Girmamo) and non-irrigated (Woshgulla) villages in Zeway area, using different sampling methods, during the dry (February/March) and short-rainy (May/April) seasons of 2006.

Village	Season	*An. arabiensis*	*An. pharoensis*	*An. coustani*	Total (%)
Irrigated	Dry (%)	182 (30.4)	340 (56.9)	76 (12.7)	598 (49.3)
	Short-rainy (%)	309 (50.2)	212 (34.5)	94 (15.3)	615 (50.7)
	Total (%)	491 (40.5)	552 (45.5)	170 (14.0)	1213 (100)
Non-irrigated	Dry (%)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
	Short-rainy (%)	38 (65.5)	4 (6.9)	16 (27.6)	58 (100)
	Total (%)	38 (65.5)	4 (6.9)	16 (27.6)	58 (100)
Grand Total (%)		529 (41.6)	556 (43.8)	186 (14.6	1271 (100)

Table 4. Indoor and outdoor density of *Anopheles* species (mean no. mosquitoes /light trap/ night) in irrigated (Abene-Girmamo) and non-irrigated (Woshgulla) villages in Zeway area, during the dry (February/March) and short-rainy (April/May) seasons of 2006.

Village	Species	Mean no. mosquito/ light trap/ night					
		Dry season			Short-rainy season		
		In	Out	Mean	In	Out	Mean
Irrigated	*An. arabiensis*	1.53	0.93	1.23	2.14	1.22	1.70
	An. pharoensis	1.74	2.72	2.24	1.31	1.65	1.48
	An. coustani	0.50	0.73	0.62	0.57	1.00	0.79
	Any anopheline	3.77	4.38	4.09	4.02	3.87	3.97
Non-irrigated	*An. arabiensis*	0.00	0.00	0.00	0.63	0.21	0.32
	An. pharoensis	0.00	0.00	0.00	0.07	0.00	0.03
	An. coustani	0.00	0.00	0.00	0.05	0.23	0.13
	Any anopheline	0.00	0.00	0.00	0.75	0.44	0.59

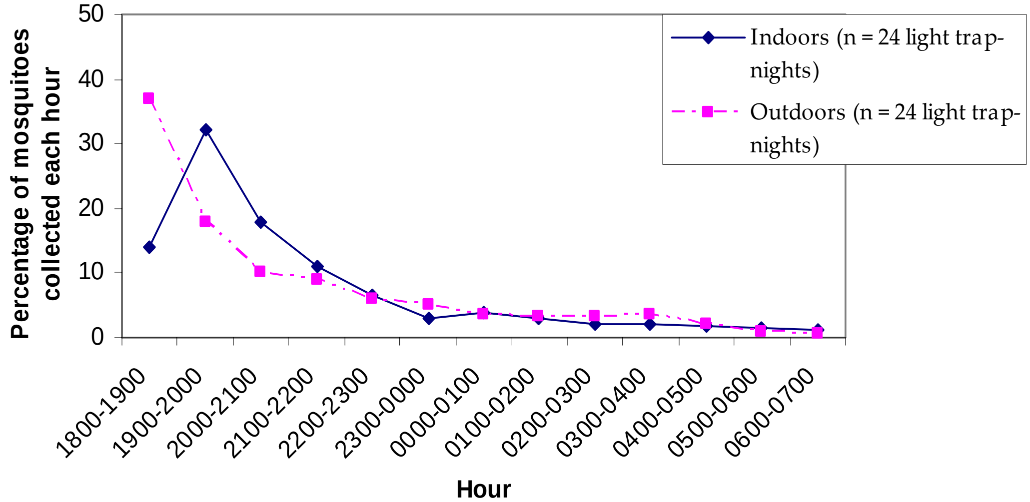

Figure 2. Hourly activity of *Anopheles arabiensis* indoors and outdoors from light trap catches (as percentage of mosquitoes collected each hour) in an irrigated village in Zeway area, during the study period (February to May 2006).

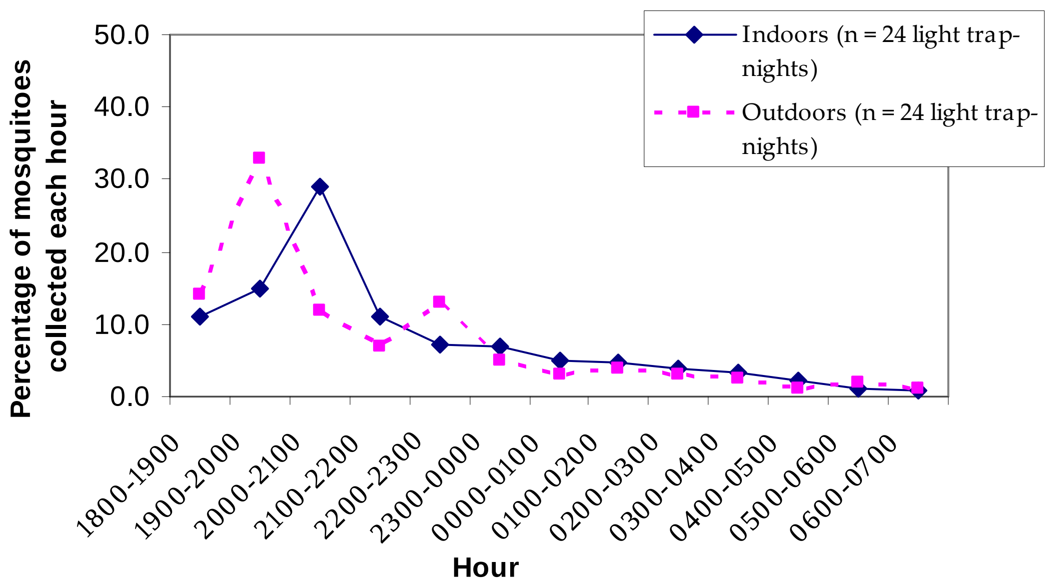

Figure 3. Hourly activity of *Anopheles pharoensis* indoors and outdoors from light trap catches (as percentage of mosquitoes collected each hour) in an irrigated village in Zeway area, during the study period (February to May 2006).

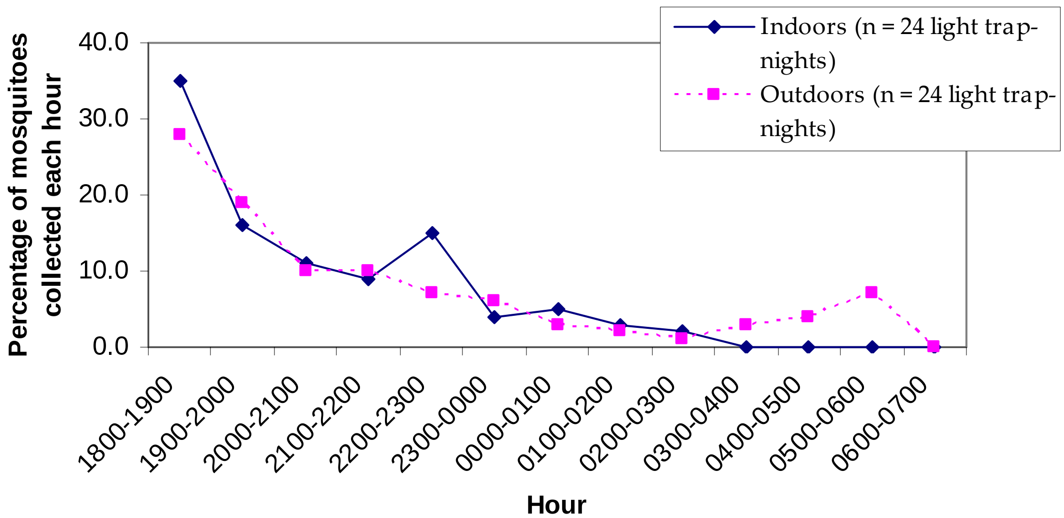

Figure 4. Hourly activity of *Anopheles coustani* indoors and outdoors from light trap catches (as percentage of mosquitoes collected each hour) in an irrigated village in Zeway area, during the study period (February to May 2006).

Table 5. Parous rate of *Anopheles* species in the irrigated (Abene-Girmamo) and non-irrigated (Woshgulla) villages in Zeway area, Central Ethiopia, in the dry (February/March) and short-rainy (April/May) seasons of 2006.

Village	Season	*An. arabiensis*		*An. pharoensis*		*An. coustani*	
		N[1]	P (%)[*]	N	P (%)	N	P (%)
Irrigated	Dry	46	27 (58.7)	90	39 (43.3)	22	4 (18.2)
	Short-rainy	81	18 (22.2)	51	21 (41.2)	29	1 (3.4)
Non-irrigated	Dry	-[#]	-	-	-	-	-
	Short-rainy	38	2 (5.3)	4	0 (0.0)	16	0 (0.0)

[1] N = number of specimens dissected

* P is the number of parous females, and the percentage of P is calculated from N.

[#] - (minus sign) indicates that no mosquito was collected during that season and thus no dissection.

Table 6. Number (and percentage) of blood-fed *Anopheles* mosquitoes tested positive for human and/or bovine bloods by direct ELISA, from collections obtained from an irrigated village in Zeway area, Central Ethiopia, during the study period (February to May 2006).

Species	No. of mosquito tested	Human only (%)	Bovine only (%)	Mixed blood* (%	Unidentified (%)
An. arabiensis	120	85 (70.8)	17 (14.2)	9 (7.5)	9 (7.5)
An. pharoensis	142	87 (61.3)	29 (20.4)	11 (7.7)	15 (10.6)
An. coustani	16	1 (6.2)	12 (75.0)	0 (0.0)	3 (18.8)

* Mixed blood meal refers to a blood meal containing both human and bovine bloods.

Table 7. *Plasmodium falciparum* sporozoite rate of *Anopheles* species collected from an irrigated village (Abene-Girmamo) in Zeway area, Central Ethiopia, during the dry (February/March) and short-rainy (April/May) seasons of 2006.

Season	*An. arabiensis*		*An. pharoensis*		*An. coustani*	
	N	SR (%)	N	SR (%)	N	SR (%)
Dry	152	1 (0.66)	325	3 (0.92)	61	0 (0.00)
Short-rainy	272	4 (1.47)	184	0 (0.00)	70	0 (0.00)
Overall	424	5 (1.18)	509	3 (0.59)	131	(0.00)

N – number of mosquitoes tested by ELISA.
SR – number of mosquitoes tested positive for *P. falciparum* sporozoites.

Note: none of the mosquitoes collected from the non-irrigated village were positive for malaria sporozoites.

4. Discussion

The present study revealed that the small-scale irrigation scheme in Zeway area has created breeding sites for the two malaria vector species, namely, *An*. *arabiensis* and *An*. *pharoensis*. The most important prolific *Anopheles* larval habitats were found to be poorly constructed irrigation canals (that allow water to stand for a period of time), canal leakage pools (formed due to perforated soil walls of the irrigation canals) and waterlogged fields (field puddles formed due to over-irrigation). The same breeding habitats have been shown to create conducive breeding grounds for *An*. *arabiensis* in the dam villages of Tigray, where microdam-based irrigation is practiced during the dry season (Yohannes *et al*., 2005). In agreement to our findings, in Mwea irrigation scheme, Kenya, it has been reported that *An*. *arabiensis*, *An*. *pharoensis* and *An*. *coustani* thrive well in irrigated fields where rice was commonly grown (Ijumba *et al*., 1990; Muturi *et al*., 2006). In irrigation schemes of Faiyum Governorate, Egypt, irrigation ditches, seepage water collections and irrigated fields with moderate crop growth were shown to be the major sources of *An*. *pharoensis* during the dry season (Soliman *et al*., 1967), in line with our finding for the same species in the present study.

We also observed that larvae of *An*. *arabiensis* were predominantly abundant in newly formed canal leakage pools and field puddles, while larval *An*. *pharoensis* preferred canal leakage pools and irrigation canals covered with vegetations. Even in the same larval habitats where the two species coexisted (such as canal leakage pools), *An*opheles *arabiensis* mostly preferred the shallow, sunlit and disturbed (muddy) margins of the habitat while *An*. *pharoensis* was frequently sampled around the shaded and deeper parts of the habitat with encroaching vegetation. This indicated that *An*. *arabiensis* and *An*. *pharoensis* have different larval habitat requirements. Previous studies have shown that *An*. *arabiensis* prefers open, shallow and temporary breeding habitats while *An*. *pharoensis* thrives in shaded, permanent water bodies with emergent vegetation (Snow, 1983; Gillies and Coetzee, 1987).

Rains are known to have dual effect on the development of mosquito larvae. When it rains, new mosquito-breeding sites are created; at the same time at other previously existing sites, some individuals will be washed away. We observed that newly formed breeding sites were sooner colonized by *An*. *arabiensis* and *An*. *coustani* (as these species prefer such habitats) while older permanent larval habitats of *An*. *pharoensis* diminished. Similar observations were reported in Mwea irrigation scheme in Kenya, where larval *An*. *arabiensis* were found abundantly in newly flooded rice fields in the wet season but a few weeks later, when the rice moderately grew, *An*. *pharoensis* was the one predominated (Mukiama and Mwangi, 1989).

This study generally confirmed that the irrigation scheme in Zeway area has created good *Anopheles* mosquito breeding conditions by restoring the lost surface water during the dry season. Thus, *Anopheles* larval production in the irrigated villages of Zeway area is no longer restricted to the wet seasons; rather continuous breeding of *Anopheles* mosquitoes throughout most of the year is possible as the crucial linkage between the rainy seasons is provided by the irrigation activities. Therefore, there is a potential for dry season malaria transmission in the irrigated villages of Zeway area, as malaria vector mosquitoes (*An*. *arabiensis* and *An*. *pharoensis*) thrive well in breeding sites created by the irrigation scheme coupled with the prevailing climatic factors that could facilitate development of the aquatic stages of the vector as well as the malaria parasites inside the female anopheline.

Consistent with the observed seasonal trend in larval abundance, variations in seasonal adult densities were also evident during the study period. The density of adult *An*. *arabiensis* was higher in the short-rainy season than the dry season while the densities of *An*. *pharoensis* and *An*. *coustani* peaked in the dry season. Similar seasonal trend was observed in villages at close proximity to Lake Zeway, where *An*. *arabiensis* outnumbered *An*. *pharoensis* during the wet season while the latter dominated the former in the dry season. These species are common in irrigated villages elsewhere in Africa where they occur sympatrically (Snow, 1983; Mukiama and Mwangi, 1989; Ijumba *et al*., 1990; Muturi *et al*., 2006).

Indoor and outdoor light trap catches revealed that *An*. *arabiensis* was more endophagic while *An*. *pharoensis* and *An*. *coustani* showed a more exophagic behavior. We observed that the local people in the study area spend the early part of the night (on average up to 10 pm) outdoors either working on their field or taking care of their cattle. Such night time behavior of the local people might increase the chance of receiving more bites by the inherently exophagic populations of *An*. *arabiensis* and *An*. *pharoensis* in the study area. Similar suggestion for *An*. *arabiensis* was previously made by Ameneshewa (1995) who worked in Gergedi (Awash valley, about 80 Km from Zeway) reported that the biting behavior of this species depends strongly on the availability of host either indoors or outdoors during the period of its biting activity in the evening. *An*. *pharoensis* and *An*. *coustani* are well known exophagic species in Ethiopia (Nigatu *et al*., 1994; Adugna and Petros, 1997; Abose *et al*., 1998b; Taye *et al*., 2006) and elsewhere in Africa, such as Kenya (Ijumba *et al*., 1990; Mukiama and Mwangi, 1989), Sudan (El Gaddal et al., 1985) and Cameroon (Antonio-Nkondjio *et al*., 2006).

We found that peak indoor and outdoor activities of *An*. *arabiensis*, *An*. *pharoensis* and *An*. *coustani* occurred during the early period of the night (before 22:00 hours), coinciding with the night time behavior of the local people in the study area. Similar early biting behavior was previously reported for *An*. *arabiensis* and *An*. *pharoensis* in Zeway (Abose *et al*., 1998b), and *An*. *arabiensis* in Tigray (Yohannes *et al*., 2005). In Sille, an irrigated village in southern Ethiopia, Taye *et al*., (2006) reported that peak biting activities of *An*. *pharoensis* and *An*. *coustani* occurred between 18:00 and 20:00 hours, which is in agreement with the present findings for the two species. In contrast to the observed early biting periodicity of *An*. *arabiensis* in the present study area, these authors reported a peak biting activity between 23:00 and 3:00 hours for the same species in Sille. Interestingly, 40 years ago, in Zeway area most *An*. *gambiae* s.l. (presumably *An*. *arabiensis*) fed readily after 23:00 hours and little early evening biting activity was recorded (Rishikesh, 1966), suggesting that the early biting behavior of this species has evolved since then. The early biting activity of *An*. *arabiensis* is likely to be a consequence of long-term application of residual insecticides, particularly DDT, selecting for early biting behavior as it has also been suggested recently in Tigray (Yohannes *et al*., 2005). Moreover, such early biting activity of the malaria vector populations in the current study area is likely to compromise the efficacy of insecticide-treated bed nets as large proportion of bites occurred before the local people, including children, go to sleep under their bed nets.

In the present study, *An*. *arabiensis* had a higher parous rate during the dry season than the short-rainy season while *An*. *pharoensis* showed insignificant variation in its parous rate during the two seasons. This report is inconsistent with a previous finding in Upper Awash that recorded a higher parous rate for *An. arabiensis* during the wet season than the dry season (Ameneshewa, 1995). The explanation for this discrepancy is that following the unusual heavy rains in April, high recruitment of young ones into the existing older population might have resulted in a higher proportion of nulliparous females and hence lower parous rate. The parity rate of *An. arabiensis* and *An. pharoensis* thus suggested higher longevity during the dry season, hence likely to maintain malaria transmission during this season of the year.

The reported Human Blood Index (HBI) for *An. arabiensis* (0.78) and *An. pharoensis* (0.69) in the present study reaffirmed the importance of these species in malaria transmission in Zeway area. Yohannes *et al* (2005) reported an HBI of 0.72 for indoor-resting *An. arabiensis* in Tigray, northern Ethiopia, which is a comparable finding for the same species in the present study. An HBI of 0.66 was reported for *An. arabiensis* in Konso, southern Ethiopia, (Tirados *et al*., 2006), which is lower than the present finding, as the species population in Konso was reported to be exclusively exophagic. Adugna and Petros (1996) reported higher HBI for *An. pharoensis* (0.84) and *An. coustani* (0.26) from samples collected in mixed dwellings. In our study, *An. coustani* had shown an exceptionally high preference of *An. coustani* (75%) for bovine blood – hence less likely to play significant role in malaria transmission. Hence, the present study confirmed that *An. arabiensis* and *An. pharoensis* are the two most important anthropophagic species in Zeway area, which is in agreement with previous reports from the same area (Rishikesh, 1966; Abose *et al*., 1998b).

The *P. falciparum* sporozoite rate of 1.18% for *An. arabiensis* in the present study is comparable to the 1.1% sporozoite rate reported from Arbaminch (Habtewold *et al*., 2001) and Sille (Taye *et al*., 2006; Tirados *et al*., 2006), but lower than a 1.52% sporozoite rate in the adjacent, Wonji area (Ameneshewa, 1995). A 0.88% *P. falciparum* sporozoite rate of *An. pharoensis* in the dry season confirms the vectorial role of this species in malaria transmission in the irrigated villages of Zeway area particularly during the dry season. On the other hand, *Anopheles arabiensis* was found infected with *P. falciparum* sporozoites both in the dry and short-rainy seasons, suggesting that this species play significant role in malaria transmission both in the dry and wet seasons of the year. These findings could be the first report for the dry season and also for *An. pharoensis*. Hence, the role of *An. pharoensis* in transmitting *P. falciparum* should not be underestimated in areas where this species is abundant.

The major short-coming of the current study was that larval and adult collections were made merely on seasonal basis, only focusing on the dry and short-rainy seasons, due to which monthly variations at different periods of the year were not shown. Hence, further longitudinal studies in the same area are required to ascertain the present findings.

In conclusion, although development of irrigation schemes is of paramount importance to increase crop yield and hence to ensure food security and economic growth in Ethiopia, its adverse health problems may pose significant public health concerns. The findings of the present study underscore the importance of irrigation schemes in semi-arid areas like Zeway in maintaining malaria transmission particularly during the dry season, when mosquito abundance is normally presumed to be limited. Proper water management and control measures such as source reduction through environmental management could help to reduce mosquito-breeding sites and thus malaria transmission.

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Malaria Transmission In Ziway, Eastern Shewa Zone, As Related to Irrgation Development

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Abstract

Malaria is the major public health problem in Ethiopia in general and in the Oromia Regional State in particular. Ziway is one of Oromia regions with frequent malaria epidemics usually occurring at the end of the main rainy season, September to mid December. In addition it is one of the regions in Ethiopia where unreliable rainfall frequently affects agricultural production. The government of Ethiopia supported the development of small-scale irrigation schemes to ensure food self-sufficiency and sustain agricultural productivity. However, without proper planning such schemes are known to worsen vector-borne disease endemicity. The objective of the study was to assess the effect of small-scale irrigation schemes on malaria transmission around Ziway. Blood smear samples were examined at the end of the main rainy season and the dry season of 2005/2006. Overall irrigated areas had significantly higher (19.2%; $p<0.05$) malaria infection prevalence rate as compared to the non-irrigated study sites (16%). In irrigated areas all age categories showed higher malaria infection prevalence in the dry season as compared to the rainy season. However, the difference was significantly ($P<0.05$) higher only in the age category greater than 15 years old. Control interventions through integrated malaria control approaches that include education about its importance, source reduction and combined efforts by agricultural and health workers during the establishment of small-scale irrigation schemes are recommended.

Key words: Agriculture, *Anopheles pharoensis*, Ethiopia, Irrigation, Malaria, *Plasmodium falciparum*, *P. vivax,* Ziway.

Introduction

In Ethiopia, approximately 4-5 million cases of malaria are reported annually (in a normal transmission year) (WHO, 2005). Malaria is found in about 75% of the total area of the country, and 40-50 million (>65%) of the total population is at risk of infection (Tulu, 1993 and WHO, 2005). Transmission usually occurs at altitudes <2000 meters above sea level. The two main seasons for transmissions of malaria in the country are September–December, after the heavy summer rains, and March–May, after the light rains. *P. falciparum* and *P. vivax* are the dominant human malaria parasites, which account for about 60% and 40% of cases, respectively (Tulu, 1993).

Irrigation projects in Ethiopia are identified as large scale irrigation (> 300 ha.), medium scale irrigation (200-300 ha.) and small scales irrigation (< 200ha.) (Awulachew *et al.,* 2005).Traditionally farmers have built small scale-schemes on their own initiatives, sometimes with government technical and material support (MoWR, 2002). The farm size varies between 0.25 ha and 0.5 ha (Awulachew *et al.*, 2005). The Federal or Regional government normally constructs small scale modern schemes. Such schemes were expanded after the catastrophic drought in 1973/74 to achieve food security and better peasants' livelihoods by producing cash crops. Such schemes involve dams and diversions of streams and rivers (Awulachew *et al.,* 2005).

Irrigation schemes in some parts of the country were found to increase malaria transmission (Ghebreyesus *et al.,* 1999). These irrigation schemes had been introduced to reduce dependence of local agriculture on irregular rainfall. However, while the schemes have had a positive impact on agriculture, the effect on health has been worrying, with an increased incidence of malaria. The findings in Ethiopia raise fears that, unless properly thought out schemes to improve the environment are in place, irrigation could do as much harm as good (Ghebreyesus *et al.,* 1999). Therefore, it is vital to gain a better understanding of the influence that irrigation and agricultural activities have on the spread of malaria especially as developing countries extend their irrigated areas to feed rapidly growing populations.

The general objective of this study was to generate information for an effective and economically viable integrated management strategy that describes health and irrigation factors, to create effective malaria prevention in irrigated area. Hence, malaria transmission has been assessed as related to irrigation development at the study sites, by determining the prevalence of the *Plasmodium* infections in irrigated and non-irrigated areas at different villages around Ziway. Secondly, options have been identified for creative malaria control if it is found increased with irrigation.

Materials and Methods

Study Area

The study was conducted in Oromia Regional state, East Showa Zone, Adamitulu Judo Kombolcha Woreda (figure: 1). It is 163 Km south of Addis Ababa alongside Lake Ziway. Similar to other Ethiopian regions the main rainy season of the area starts in June and extends up to August/September while the short rainy season begins in March and extends to April/May. The area mean annual temperature of 20^{O}C and annual maximum and minimum temperature of 27.5 ^{O}C and 13.9^{O}C respectively. The mean annual rain fall of the area varies between 700 and 800 mm (Figure: 2) .The area is characterized as lowland with sparsely distributed *Acacia* trees and thorny bushes.

At the beginning of the study, relevant socio-demographic information was sought from the agricultural and health office experts of the area through structured interviews. This was followed by selection of specific sites/villages and two cross-sectional surveys at the end of the rainy and during the dry season. The rainy season data were colleted in September/October, which is the period with the highest malaria transmission almost every year in Ziway (Abose *et al.,* 1998; Seyoum *et al.,* 2002). The dry season study was conducted in February/March before the beginning of the short rainy season and before the second round indoor insecticide spray begins.

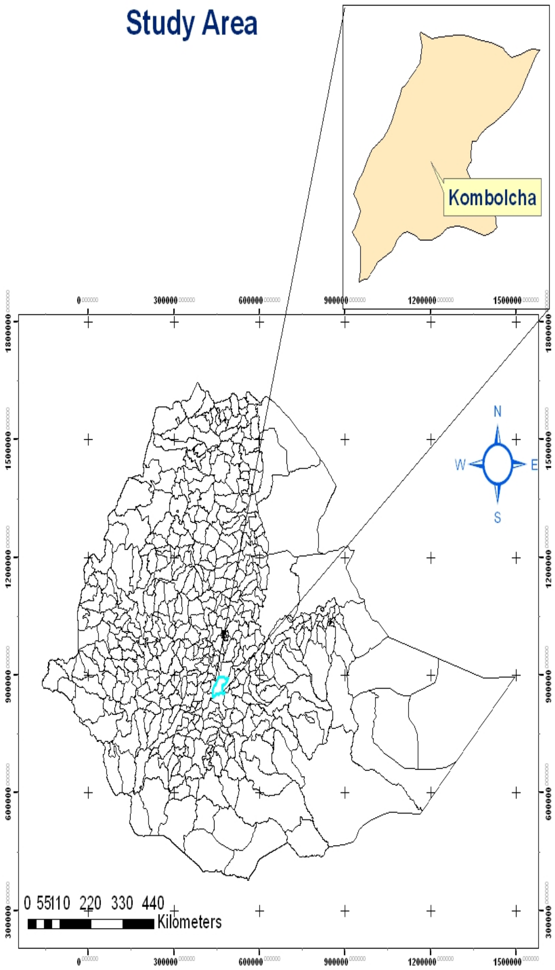

Figure 1: Map of Ethiopia showing location of the study site

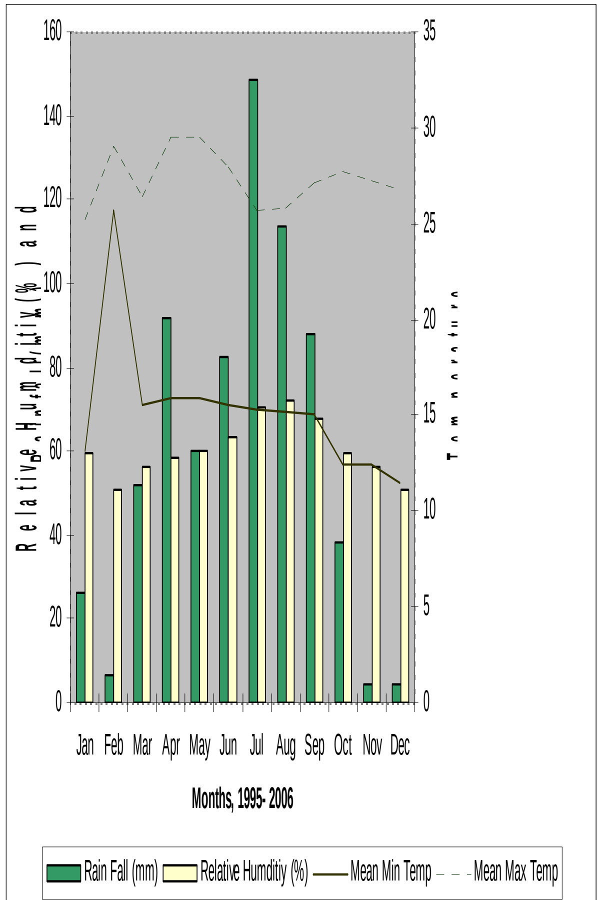

Figure 2. Monthly rainfall (mm), mean relative humidity, mean maximum and minimum monthly air temperatures (^{0}C) of Ziway area, 1995-2006.

Source: National Meteorological Agency (NMA)

Selection of the irrigated area was done based on pre-defined criteria 1) the irrigation site should be far from the lake that is the main source of irrigation water in order to avoid the effect of vectors that breed in natural habitats; 2) farmers should live in close proximity to the irrigation fields but away from the lake; 3) the site should be accessible and close to the Woreda health center for easy of sample transport and examination. Abine Germamo was found to be the area, which best fitted to the selection criteria. It is found more than 5 km away from the source of irrigation water (the lake) and non- irrigated area.

Abine Germamo is found at the northern outskirts of Ziway town by the side of the road coming from Addis Ababa. It includes previous kebeles Hizbawi Betele, Abine Gijota and Abine Germamo. It is located at 1647 meters above sea level. According to the information obtained from the agricultural office, the number of households in this kebele reaches up to 934. However, the beneficiaries of irrigation in the 2004/2005 production season were only 75 households. Lake Ziway is the source of irrigation water. Both the eastern (the field between the lake and the road) and the western side of the main road are irrigated but almost all the farmers are living on the western side of the road. Pumps are used in order to lift the water, then it is delivered over a long distance through pipes and surface canals. Finally the water is diverted down to all irrigation fields by surface irrigation with the help of the force of gravity. The houses of the farmers are found in close proximity to the irrigation fields. All the inhabitants of the area, those benefited from irrigation (irrigators) and those without access to irrigation (non-irrigators) are almost all found in close proximity to the irrigation fields.

The main criteria for selecting the non-irrigated area were: 1) it should be at a distance beyond the reach of mosquitoes from the irrigated area and the lake (Ghebreyesus et *al.,* 1999; Klinkenberg *et al.,* 2005; Yohannes *et al.,* 2005); 2) with the same topographical position, comparable agricultural production system and other important features except irrigation as the irrigated areas (Ghebreyesus et *al.,* 1999; Klinkenberg *et al.,* 2005; Yohannes *et al.,* 2005); 3) accessibility. Three areas were taken into consideration for the selection of the non-irrigated area but Weshgule was found to be the area, which fitted to the selection criteria best. Weshgule is found at the southern outskirts of Ziway town at 1654 meters above sea level.

Sample selection

We assessed malaria parasite prevalence, a direct indicator of the impact of malaria, in communities with and without irrigation (Klinkenberg *et al*., 2005). Six year of malaria case data in the study areas from the Health office at Ziway was taken for the determination of sample size. Average of positive cases 1999/2000 - 2004/2005 of the irrigation area divided by the population of 2003/04 of the area was taken as average annual prevalence in irrigated area and average of positive cases of 1999/2000 - 2004/2005 of the non-irrigated areas divided by the population of 2003/04 of the area was used to estimate the prevalence in the non-irrigated area. Using Win Episcope 2.0 (developed by facultad de veternaria Zara goza, Wagningen University and University of Edinburgh) computer soft-ware the sample size was determined. It was estimated by using the difference between proportions with 95% level of confidence interval and value of 80% for the power with the formula (for the sample size) for a two-tailed test:

$$n = \left[\frac{Z(a) + Z(b)}{p_1 - p_2}\right]^2 * \left[(p_1 * q_1) + (p_2 * q_2)\right]$$

Where Z (a) and Z (b) are the value of student's t at specified confidence level and at the specified power, respectively, and p_1 and p_2 are proportion in population one and two respectively and $p_1.q_1$ and $p_2.q_2$ are the variance of the proportion in population one and two. Hence the sample size according to this method was calculated to be 700. Meanwhile, based on prevalence rate obtained from parasitological survey conducted at Ziway Eddo-Gojola irrigation area by Abose *et al.,* (1998), the sample size was calculated to be 280. Then by taking the average of these two calculations the sample size was finally determined to be approximately 500 samples (individuals) each from the irrigated and non-irrigated areas.

The applied sampling method was probability sampling; where each member of the population has a known non-zero probability of being selected. Systematic sampling was used in the study. The list of households for the selected areas, knowing that the list does not contain any hidden order, was obtained from the kebele leaders and it was used as a sampling frame. After the required sample size had been calculated every n^{th} record, calculated by dividing the sample size by the average family size of the area, selected from a list of population members. Every head of the household found at home during sample collection was informed about the study and the consent form was read to them. When they agreed to participate in the study blood smear samples were collected from all family members. In case a household did not want to participate in the study or if the head of the household not found at home, then the next house was taken as a replacement.

Parasitological survey

Blood samples were colleted by skin pricking of the finger onto glass slides at the end of the rainy season and during the dry season of the study. Specialized laboratory technicians of the Woreda malaria control laboratory did the blood sample collection from the selected households (Figure 6 & 7). The thick and thin blood smears were prepared on the same slide side by side, properly labeled, air dried and then the thin blood smears were fixed with methanol on-site. The samples were carefully transported to the Ziway Woreda health office laboratory where specialized laboratory technicians did the staining and parasitological test by microscopic examination. The samples were put into slide boxes and transported to Addis Ababa and further examination of all the positive samples and 10% of the negative samples (Ghebreyesus *et al*.,. 1999) were also done in AAU Biomedical Science laboratory. The thick and the fixed thin blood film slides of the second season (dry season) samples were properly stained and examined at Ziway Woreda health office laboratory. Afterwards, these were also put into slide boxes and then transported to the Ethiopian Health and Nutrition Research Institute (EHNRI) Laboratory, Addis Ababa, where further conformational examination was done by technicians of the institute.

The quality of the Giemsa staining solution was checked before using directly to the samples. A fresh 10% Giemsa solution in tap water was prepared and the air-dried slides were immersed into a staining jar for 10 minutes. The stained slides were rinsed by tap water and put in upright position to dry (Schilchtherle *et al.,* 2000). The stained thick and thin films were observed under 100x oil immersion objective light microscope. First, the thick blood smear samples were observed in order to know whether the sample is positive or negative. When a sample was found positive then the thin blood smear was used to identify the species.

Ethical considerations

Ethical considerations were addressed by treating positive malaria cases according to the standard drug regimen. Informed consent was obtained from adult study subjects and from parents and guardians in case of children before sampling. The project obtained ethical approval from the Ethical Committee of the School of Graduate Studies of Addis Ababa University. The project was also discussed with concerned authorities in the study areas and their agreement was obtained. Those individuals with positive results were treated with the required treatment and dose free of charge. The treatment was given in collaboration with the Woreda health office according to the guidelines of Ethiopian Ministry of Health. In this study, no invasive procedure other than the finger pricking, which is used for routine diagnosis, was used. Experienced laboratory technicians performed finger-pricking in order to avoid unnecessary pain and bleeding. For finger pricking, a single disposable sterile lancet was used per person to avoid possible transmission of infection.

Results

Blood smear samples were examined from a total of 2435 study participants, 1060 males and 1375 females. A total of 427 parasite positive slides were found in both study sites, 232 (19.2%) in irrigated villages and

195 (16%) in non-irrigated areas. Out of 198 (18.6%) infected males 10.3 % were in irrigated areas and 8.3% were in non-irrigated areas. Out of 229 (16.6%) infected females 8.9% were in irrigated areas and 7.7% in non-irrigated areas. Overall malaria infection prevalence in irrigated areas was significantly ($P<0.05$) higher than the prevalence in non-irrigated areas. Moreover, the result revealed that there was no significant ($P>0.05$) difference in malaria infection prevalence between the two sexes (Table 1).

Table 1. Overall malaria infection prevalence in the irrigated and non-irrigated areas, Ziway (2005/06).

	No. of study participants	Malaria positive cases (%)	
		Irrigated	Non-irrigated
Male	1060	110 (10.3)	88 (8.3)
Female	1375	122 (8.9)	107 (7.7)
Total	2435	232 (19.2)*	195(16.0)

* Significant difference at (X^2, $P<0.05$)

The rainy season malaria prevalence in the irrigated area was (16.0%) and in the dry season it was (22.7%, Table 2). The finding showed that malaria transmission in irrigated areas during the dry season was significantly ($P<0.05$) higher than during the rainy season. For the non-irrigated areas, the rainy and the dry season malaria infection prevalence was (19.6%) and (11.5%), respectively. The rainy season infection prevalence of non-irrigated areas was significantly ($P<0.05$) higher than the prevalence in the dry season (Table 2). Moreover, additional analysis by season revealed that malaria infection prevalence during the dry season was significantly ($p<0.01$) higher in irrigated areas (22.7%) as compared to non-irrigated areas (11.5%). Nevertheless, during the rainy season, malaria infection prevalence in irrigated areas (16.0%) was significantly ($p<0.05$) lower than in non-irrigated areas (19.6%, Table 2).

Table 2. Overall malaria infection prevalence in irrigated and non-irrigated areas during the rainy season and the dry season, Ziway (2005/06).

Study areas	Season	Malaria positive cases (%)
Irrigated areas	Rainy (n=699)	112 (16%)
	Dry (n=528)	120 (22.7%)*
Non-irrigated areas	Rainy (n=692)	136 (19.6%)*
	Dry (n=516)	59 (11.5%)

* Significant difference at (X^2, $P<0.05$)

Comparison of infection prevalence of malaria in different age categories in irrigated and non-irrigated areas during the rainy and the dry seasons of the study is shown in table 3. In irrigated areas all age categories in the dry season showed higher malaria infection prevalence as compared to their infection prevalence in the rainy season. However, the difference was significantly (P<0.05) higher only in the age category greater than 15 years. In non-irrigated areas higher, though not significant, infection prevalence was depicted in all age categories during the rainy season as compared to the prevalence during the dry season. Overall, there was a decreasing but not significant trend in infection prevalence of malaria with increasing age categories within a season.

Table 3. Age-specific malaria infection prevalence in the irrigated and non-irrigated areas during the rainy and the dry season, Ziway (2005/06).

Area	Age	Season			
		Dry		Rainy	
		No. Examined	% Positive	No. Examined	% Positive
Irrigated	<5	156	26.9	212	21.7
	5 to 9	112	21.4	168	16.2
	10 to 14	58	20.8	70	15.7
	>15	202	20.3*	249	11.2
Non- irrigated	<5	153	17.5	189	24.7
	5 to 9	125	13.2	165	20.4
	10 to 14	46	10.1	82	17.3
	>15	192	7.1	256	14.4

* Significant at (X^2, P<0.05)

Analysis of infection prevalence of the *Plasmodium* parasite species was done in irrigated and non-irrigated areas during the rainy and the dry seasons of the study. In the irrigated areas infection prevalence of *P. falciparum* in the dry season was significantly (P<0.05) higher than its prevalence in the rainy season, whereas infection prevalence of *P. vivax* in the rainy season was significantly (P<0.05) higher than its prevalence in the dry season. For the non-irrigated areas, rainy season infection prevalence of *P. falciparum* was significantly higher (P<0.05) than the dry season infection prevalence and the same scenario was observed for *P. vivax* (P<0.05, Table 4).

Table 4. Species-specific infection prevalence of malaria parasites in the study population during the rainy and dry seasons in the irrigated and non-irrigated areas, Ziway (2005/2006).

Area	Season	No. Examined	% Species	
			% *P. falciparum*	% *P. vivax*
Irrigated	Rainy	699	9	7*
	Dry	528	21*	1.7
Non-irrigated	Rainy	692	12.6*	7.1*
	Dry	516	10.7	0.8

* Significant difference at (X^2, P<0.05)

Discussion

Irrigation structures often offer ideal habitats for the proliferation of anopheline mosquitoes, including vectors of malaria. A study conducted in Tigray (Northern Ethiopia) for instance, indicated an overall increase in incidence of malaria in the villages close to dams as compared with the control villages (Ghebreyesus *et al*., 1999). Another study in Southeastern Ethiopia had shown malaria due to *P. falciparum* and *P. vivax* to be the main health problems in irrigation schemes along the Genale River (Birrie *et al.,* 1997). A study in Arba-minch also showed irrigation activity to have created a year round breeding habitat for the anopheline mosquitoes (Ashenafi, 2003). The present study looked into the situation in Ziway where small-scale irrigation has been in practice for decades but the extent of its linkage with malaria has not been studied. The study findings are in agreement with the earlier reports that assessed the impact of construction of small irrigation dams on the incidence of malaria in Tigray (Ghebreyesus *et al*., 1999) and that of Klinkenberg *et al.* (2005) in the irrigated areas in Ghana.

The difference in malaria prevalence between irrigated and non-irrigated sites was more pronounced during the dry season. Probably, this is because the irrigation structures in the area would provide suitable breeding sites for malaria vector mosquitoes during the dry season, while those in the non-irrigated area dry out. Since mosquito-breeding sites such as pools and puddles would be equally available both in the irrigated and non-irrigated areas during the rainy season, such increase in malaria prevalence was not observed with irrigation. The humid environment during the small rains (March, April and May) which was at the same level of humidity following the big rains (October) (National Meteorological Agency, NMA) and the humid environment, which also is created through irrigation during the dry season, would enhance vector longevity. Moreover, Robert (2004) observed, the increase in the density of foliage of plants will provide more shelter for adult mosquitoes, extending their longevity. Likewise, when the residual soil moisture increases with irrigation, it will extend the range of sheltered habitats for mosquitoes. This would explain the higher adult density of *An. pharoensis* in irrigated areas during the dry season (Abose *et al*., 1998).

An. pharoensis is the second important vector, next to *An. arabiensis*, implicated in malaria transmission in Ziway (Abose *et al*., 1998; Seyoum *et al.,* 2002). This species mostly rests outdoors on vegetation. The irrigated farming in the area where vegetables such as onion, cabbage, tomato, and cucumber, as well as cereal crops, mainly maize, were grown and other trees planted for fencing irrigation fields would provide ideal sites for resting and enhancing longevity of this vector species. The relevance of enhancement of longevity of vector mosquitoes to malaria transmission has been shown by the findings of Mukiama and Mwangi (1989) where higher adult population of sporozoite-infected *An. pharoensis* was more abundant in irrigation schemes in Kenya. Moreover, the higher minimum temperature of the dry season in the irrigated areas would contribute to completion of parasite life cycle inside vectors.

Furthermore, according to Carrara *et al.* (1990), *An. pharoensis* was the main malaria vector for intensive *P. falciparum* transmission in Senegal River delta where all examined *An. gambiae* Giles *sensu lato* were *P. falciparum* sporozoite negative. Besides the report from Senegal, the role of *An. Pharoensis* in *P. falciparum*-dominated malaria transmission in Ziway study area during the dry season is supported by the entomological survey concomitantly conducted in the area (Solomon Kibret *et al*., 2008 also in this proceedings).

The higher dry season malaria transmission, related to availability of water bodies, was similar to what was reported by Carlson *et al.* (2004) that water in pits created during brick-making supported the development of malaria vectors and thus enhanced dry season malaria transmission in western Kenya. On the other hand, the higher prevalence of malaria in the non-irrigated areas during the rainy season might be due to "draw-down" phenomenon in the irrigated areas whereby rapid drying and over-flowing of the irrigation structures would disturb the vector breeding sites and lead to decreased transmission. Bziava and Kruashvili (2002) had shown that periodic "draw-down" of irrigation canals can be used as an ecological measure for malaria control.

In irrigated areas farmers in older age groups will be at work early in the evenings when the prominent vector of the dry season will be active so these people will have a higher risk of infection. Higher malaria prevalence in older age groups in Ethiopia was also reported by Yohannes and Petros (1996) by observing the absence of apparent decrease in prevalence with increasing age in Nazareth, Ethiopia. Although Abose *et al.* (1998) reported that men in the area were affected more than women, considering that adult men are more likely to spend the evening hours outdoors working in their plantations and might receive more mosquito bites than women, the present study revealed no significant difference in malaria infection prevalence between the two sexes. This suggests lack of difference in the outdoor stay behavior of the two sexes and is consistent with the findings of Himeidan *et al.* (2005) in an irrigated area in Eastern Sudan.

It is generally known that *P. falciparum* is dominant during the peak malaria transmission season in September and October, while *P. vivax* tends to dominate during the dry season in Ethiopia (Tulu, 1993). The present findings from the non-irrigated areas confirm the above generalization for *P. falciparum*. Decreases in *P. falciparum* prevalence have been shown to allow the potency of other parasite species (Smith *et al.,* 2001). The lower infection prevalence of *P. vivax* in irrigated areas during the dry season could be due to the fact that *P. vivax* is most prevalent in unstable transmission conditions (Gilles and Warrell, 1993) and hence its rate of transmission may not be influenced by irrigation.

Irrigation has created enhanced conditions for endemicity of *falciparum* malaria by changing its seasonal patterns. In irrigated areas, stable malaria transmission favors *P. falciparum,* whereas transmission of *P. vivax* was much lower as its transmission would be suppressed by *P. falciparum* (Smith *et al.,* 2001). An irrigation-associated increase of *P. falciparum* infection prevalence during the dry season was also reported from India, where extensive irrigation had triggered *P. falciparum* dominated malaria in the virgin levees of Thar Desert in India (Tyagi, 2004).

Although all factors that contribute to malaria risk are not fully understood (Robert *et al.,* 2003), seasonality features, which could be altered in time through irrigation, availability of surface water, humidity and temperature are factors which affect vector abundance, longevity and parasite development inside vectors (Woyessa *et al.,* 2004; Teklehaimanot *et al*., 2004). The study site (Ziway) has an average temperature of 20.7^{0}C with the higher temperature occurring during dry season (Figure 4) (Teklehaimanot *et al*., 2004). At 20^{0}C, 3 weeks are needed for *P. falciparum* development inside mosquitoes while *P .vivax* can develop in 16 days (Gilles and Warrell, 1993; CDC, 2004). As the temperature increases, for instance at 22^{0}C, mosquito's life cycle and *P. falciparum* development inside mosquitoes will be completed in 18 and 7.9 days, respectively (Teklehaimanot *et al*., 2004), and hence *P. falciparum* would be favored and could suppress other human *Plasmodium* species (Smith *et al.,* 2001).

Persistence in *P. falciparum* malaria may also be due to other more direct human activities (Singh *et al.,* 2004). For example, *P. falciparum* has developed resistance to sulfadoxine pyrimethamine in most parts of Ethiopia (Worku *et al.,* 2005) and hence Coartem (Artemisin-based Combination Therapy) is now recommended as substitute therapy. However, the population in Ziway, during the study time, mainly uses sulfadoxine pyrimethamine (personal communication with health worker), as this is available on the market. Such patients are likely to serve as reservoirs of the parasite and may lead to augmented *P. falciparum* transmission in the dry season.

Conclusions and Recommendations

The following conclusions can be drawn from the present study on the impact of small scale irrigation on malaria transmission in Ziway. Significantly higher prevalence of malaria was observed in irrigated areas as compared to the non-irrigated areas in Ziway. This suggests that the irrigated areas around Ziway are more favorable for breeding and activity of malaria vector mosquitoes, which enhances their longevity and facilitates completion of parasite life cycle for most months of the year. Malaria infection prevalence significantly increased at irrigated sites during the dry season when compared with the parallel scenario during the rainy season. This was exhibited in all age groups but, older age groups (greater than 15 years old) in irrigated areas had significantly higher infection prevalence during the dry season as compared to the same age group in the rainy season.

To counter the increased malaria risk near developed water resources, there is a need for special attention to health issues in the implementation of ecological and environmental development programs. Simultaneously, awareness creation educational interventions must be undertaken so that the use of ecological control measures, mainly focusing on eliminating breeding sites and personal protection through the use of ITN are effectively practiced. In depth studies including comparisons between different agro-ecological zones are needed to assess the overall importance of irrigation-related epidemiology of malaria in Ethiopia.

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KEYS FOR SUCCESSFUL IRRIGATION IN ETHIOPIA

How to enhance water efficiency?

Minimise excess water use through implementation of efficient irrigation methods, effective irrigation scheduling, and soil moisture determination and retention. The following practices are designed to minimize water losses from evaporation, deep percolation and runoff:

- Develop a crop demand-dependent irrigation schedule.
- Determine soil type characteristics to estimate effective irrigation application rates, durations and frequencies. For instance, sandy soils may require more frequent but shorter duration applications.
- Till the land along the topographic contours to reduce runoff.
- Water early in the morning or evening to reduce evaporation losses.
- Collect stormwater and irrigation runoff in a series of ditches or drains that return the excess water to a storage pond, if appropriate and necessary.
- Maintain all parts of the irrigation system, routinely inspect all water lines, tanks, valves and pumps for leaks. Keep replacement and repair parts on hand.

How to prevent soil erosion?

Soil erosion by water depends on:

- the slope: steep, sloping fields are more exposed to erosion;
- the soil structure: light soils are more sensitive to erosion;
- the volume or flow rate of surface runoff water: larger or rapid flows induce more erosion.
- the vegetation cover of the soil.

Erosion is usually heaviest during the early part of irrigation, especially when irrigating on slopes. The dry surface soil, sometimes loosened by cultivation, is easily removed by flowing water.

After the first irrigation, the soil is moist and settles down, so erosion is reduced. Newly irrigated areas are more sensitive to erosion, especially in their early stages.
There are two main types of erosion caused by water:

- Sheet erosion - even removal of a very thin layer or "sheet" of topsoil from sloping land. It occurs over large areas of land and causes most of the soil losses.
- Gully erosion - removal of soil by a concentrated water flow, large enough to form channels or gullies. These gullies carry water during heavy rain or irrigation and gradually become wider and deeper.

Therefore pay attention to use low flow velocities when applying water, especially at the beginning of the crop vegetation period and at higher terrain slopes.

How to prevent water related disease hazards?

Irrigation alters the environment by creating con... suitable for parasitic vectors, which then spread d... among producers and the wider population. Irrigatio... in general increase the risk of water related disease... malaria etc. Especially stagnant irrigation water can... as breeding site for mosquitoes.

Therefore reduce mosquito breeding sites by avoid... ga... en water surfaces of storage ponds or tanks and apply efficient drainage measures.

This leaflet was prepared in the framework of the collaborative project "Impact of Irrigation on Poverty and Environment in Ethiopia" (2004-2007).

Authors: M. Schönerklee, R. Spendlingwimmer, W. Loiskandl, D. Ruffeis

Why irrigation?

Irrigation is one of many important initiatives that can offer opportunities for change. Good access to a whole range of agricultural technical skills and inputs is needed if the benefits are to be maximised.

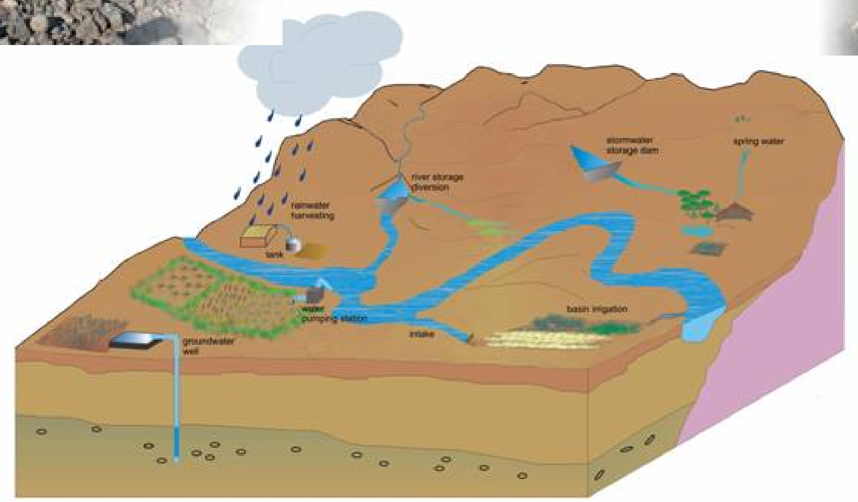
- Higher agricultural yields
- Wider variety of crops in wet and dry seasons
- Longer growing seasons, multi-harvesting
- Increase agricultural production and enhance food security
- Poverty reduction

The amount of water used by the plants depends on the crop type and will rise with evapotranspiration as a result of:

- High temperatures
- High wind speed
- Low humidity
- High intensity of sunlight

Which water resources are available and can be used?

- Rainwater harvesting (tanks or ponds)
- Streams, rivers, lakes or pools
- Shallow or deep groundwater resources, springs



AUSTRIAN RESEARCH CENTERS

Consider the following key issues and natural conditions when using irrigation for agriculture

Why is water quality important?

The suitability of water for irrigation depends on the amount and the type of s irrigation water contains. A high salt content of irrigation water leads to salini of soils.

- Salinity – amount of salt contained in the water ("salt concentrations")
    - o Electric conductivity
    - o Total dissolved solids

The salinity of water is easily measured by means of an electrical device, it is expressed in terms of electrical conductivity.
The higher the salt concentration of the irrigation water, the greater the risk of salinization.

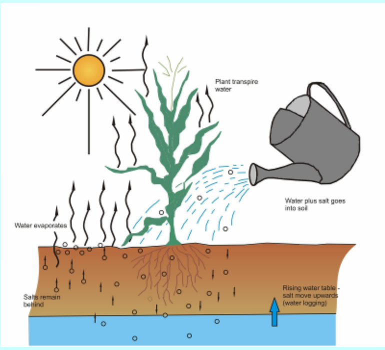
Salt concentration	Electric conductivity	Soil salinization risk	Restrictions on use
Less than 0.5 g/l	Less than 800 µS/cm	No risk	No restriction on its use
0.5 – 2 g/l	800 – 3100 µS/cm	Slight to moderate risk	Should be used with appropriate water management practices
More than 2 g/l	More than 3100 µS/cm	High risk	Not generally advised for use unless consulted with specialists

If possible, a full water analysis should be carried out by an analytical laboratory to assess potential impacts on the infiltration rate and soil:

- Major mineral compounds (Calcium, Magnesium, Sodium, Potassium, Chloride, Sulfate, Nitrate, Carbonate, Boron, Fluoride)
- Calculation of Sodium Adsorption Ratio (SAR)

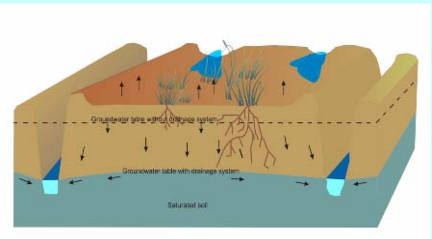
How to conserve the soil fertility and avoid salinization?

The irrigation water will move much faster through a soil with large pores (sandy soil) than through a heavy clay soil with smaller pores. Soil structure influences how easily water and air can move through the soil (permeability) and the penetration of roots.



The soil structure can be improved by good practices such as crop rotation. Cycles of wetting and drying improve soil structure whereas cultivation of very wet or very dry soils can destroy the structure. Adequate soil cultivation like tilling is also required to prevent water-logging problems.
After irrigation, the water added to the soil is used by the crop or evaporates directly from the moist soil. The salt, however, is left behind in the soil. If not removed, it accumulates in the soil; this process is called salinization. Soils that contain a high amount of salt are harmful to plants and therefore reduce soil fertility and agricultural yields.
Furthermore the presence of salts, especially in heavy clay soils, has the effect of breaking down the soil structure and therefore reducing the soil permeability to air and water.

Why is drainage needed?



During irrigation the water infiltrates into the soil and is stored in its When all the pores are filled with water, the soil is said to be saturated more water can be absorbed. The water flowing from the satura downward to deeper layers, feeds the groundwater reservoir. As a re groundwater level rises. Following heavy rainfall or continuous over-ir water-logging may occur which means that the groundwater table m reach and saturate part of the root zone. If this situation lasts too l plants may suffer.
In order to prevent these negative effects, drainage measures are necessary. Excess surface water is removed through shallow open drains. Excess groundwater is removed through deep open drains or underground pipes. Leaching of salts by sufficient percolation water can only be achieved if an efficient drainage system exists and water-logging can be avoided.

Which irrigation method is appropriate?

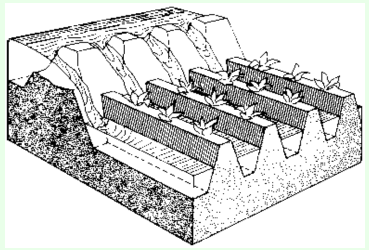
Each irrigation method has advantages and disadvantages that should be taken into consideration when choosing the most suitable irrigation method. The main factors influencing the selection of the type of irrigation are:

- Natural conditions (soil type, slope, climte, water quality, water quantity)
- Type of crops to be grown

Watering-Can/Bucket irrigation

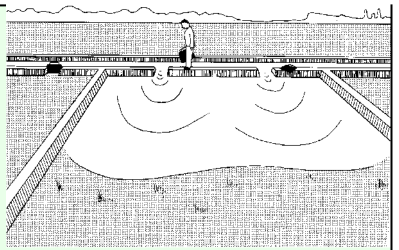
This water-efficient method is appropriate for small plots of land, such as vegetable gardens, which are close to the water source.

Furrow irrigation



Furrows are narrow ditches dug on the field between the rows of crops. The water runs along them as it moves down the slope of the field and is gradually absorbed into the bottom and the sides of the furrows wetting the soil. Furrows are generally used on farms with large uniform fields where long furrows can be formed at regular intervals between the crop rows.

Basin irrigation



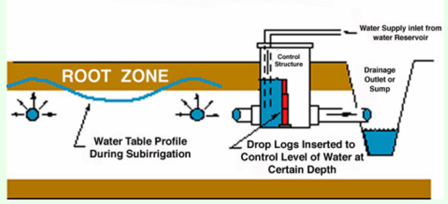
Basins are horizontal, flat plots of land, surrounded by small dykes or bunds which are totally flooded during irrigation. Flooding should be carried out rapidly so that water spreads quickly across the whole basin and an even water distribution can be achieved.
Water is normally brought to the basin in earth channels using gravity.
Where water has to be pumped from the water source it should be pumped to the highest point and then be distributed in channels by gravity.

Drip irrigation

In drip irrigation the water is led to the field through a pipe system. The distribution system within the field consists of tubes perforated at regular intervals. In this way water is slowly and directly supplied drop by drop to the plants.
Drip irrigation is most efficient for irrigating individual plants such as trees or widely spaced row crops like vegetables.

Sub-surface irrigation

Water is supplied to the plants from below the surface by controlling the level of naturally occurring shallow groundwater. The water is made to flow into open channels where the level is controlled by earth banks. However, a regular drawing down of the water level is essential to avoid water-logging of the plots and crop damage.



Discussion on Theme 4: Environmental and Health Impact of Irrigation

Chair: Dr. Akissa Bahri
Rapporture: Gayathri Jayasinghe

The chairman for this session introduced the theme and the floor was opened for questions, comments and suggestions.

Questions and Discussions

4.1 Intervention in the development of small scale irrigation development will cause some environmental impact but their impact may not be significant. Is there a limit (lower) for which EIA study may not be required in view of size?

Ans: The impact is similar, thus there is no difference between schemes in terms of size. Focus should be made on strategic approach and the assessment should be made using simple questionnaires that could be used by the communities or NGOs. The cumulative effect of a number of small scale schemes should be considered rather than isolated individual schemes.

Comment: The issue of environmental impact should be seen by balancing the positives and the negatives without affecting the resource base. Using inputs like water will be positively influencing the environment by producing more food per area!

4.2 In the two large scale irrigation schemes how come that NO_3-leakage is not monitored? Notable effect is expected on downstream users.
Is it not possible that the soil organic matter accumulation could be expected to be stable, given the vegetation cover from the perennial crop and good management (in the sugar cane schemes)?

4.3 Whether there is irrigation or non-irrigation, there is malaria in the prone areas. Instead of talking about irrigation as causing malaria spread it would be better to associate this with improper management of irrigation water. What is your comment on this?

Ans. Yes, it is bad management of water that causes leakages in the systems, but still the problem is due to the introduction of irrigation

4.4 The papers from Solomon and Kibret are of the same supervisor and the same area of investigation. The facts were known like when there was incidence, type of malaria occurance, so

i) what were the big differences between the two?
ii) What was the significance of this study?
iii) What idea are you forwarding to policy makers and the new findings drawn from these studies?

4.5 The comment about watershed management around Fincha where they spend 2 million Birr per year;

- where is the soil erosion going on? Is it in the sugar estate or outside?
- What would be the picture of Fincha if there is no intervention in the form of sugar estate?

Irrigation schemes are found in the Malaria belt of Ethiopia. It could have been better to compare the before and after irrigation development situation

Comment: Put irrigation water management as one of the preventive measures to be recommended in the research undertaking.

4.6 What are the environmental impacts (negative) or concerns related to Wonji/Shoa sugar estate given the sugar estate is working for the last 50 years or more?

4.7 What is the objective of the EIA on Fincha and Wonji since this should have been done before the project is implemented? If, what is presented is environmental monitoring and evaluation how can it be carried out in the absence of baseline data and initial EIA?
How do you assess the impact of Koga before the construction is completed? There is integrated watershed management being done. The downstream impact indicated is not based on concrete data and research.

Ans: What has been done is analysis (status quo) of existing projects to see the impact of irrigation on environment.
The watershed management project lags behind the dam. Downstream flooding of the dam is not considered.

Comment: Environment impact in Koga is an issue of sequencing. It is a first measure which integrates watershed management, irrigation, and storage. Some are delayed due to capacity, but those measures are yet to be implemented and should not be perceived as failures.

4.8 Paper on Wonji and Fincha: When we say there was no database, does it mean were/are no project appraisal documents when the estates were developed?
Paper on "key success factors….." Clarification: does this mean that such knowledge/practice(s) is not known here in Ethiopia?

The statement that health impact assessment should consider not only diseases, but also health improvement from improved food security and economic status. Is it possible to integrate the two aspects?

4.9 What is the optimum investment cost per hectare for SSI in Ethiopia?
What is the contribution of investment on flower industries to the national economy? (they also use drip irrigation)

How are the riparian and appropriative laws being practiced in the context of the project

Comment: Although environmental issue is a common concern that should be looked at for ensuring sustainability, one needs to be clear about whether or not we need to carry out EIA before and after interventions.

4.10 Irrigation and Malaria transmission in Ziway area: People living near the lake are anyway more exposed than those who are living away from the lake, so how is it possible to conclude that irrigation is responsible rather than the lake?

Ans: This condition was taken into consideration and the study covered villages away from the lake in 4-5km distance
Brief discussion was made with the presenter and satisfactory answers were given.

4.11 From the indicators of environmental resilience, in these farms, Fincha and Wonji, lots of fertilizers are used. Can expect nitrogen leakage impact on downstream users. Has this been investigated.

Ans: Observed increase in Nitrogen in the water.

One slide shows a decline in organic matter in the soil. I thought in these intensive systems, because of the year round crop cover one would expect to see increased organic matter in the soil.

Ans: Problem could be that it is a monoculture. But need to look into this.

4.12 Not clear about the objective of the EIA. My understanding is that EHIA is done prior to investment. Fincha and Wonji are very old. So is what you are doing really env monitoring and evaluation? If so, are you doing this because pre investment EIA for these schemes are not available?

4.13 Not having baseline data is common. Is there no project appraisal documents? If we don't have appraisal documents does it mean we cannot do an impact assessment?

Ans: True, but what we did was trying to assess the status quo of impact of existing irrigation schemes.

4.14 Koga, is the first project of large scale scheme for smallholder irrigation. Scheme under mid construction. SO how did you reach the conclusion that there are environmental impacts?
One aspect of Koga is watershed management. And Environmental authority is a member of the steering committee.

Ans: EIA was conducted but this didn't consider downstream impacts of change in flow regime. Possible impact on fisheries. 2. EIA made recommendations about a lot of things that should be done before the dam is constructed. Eg water shed conservation work that should have been done before the dam is constructed. Although these have commenced, not progressed as planned. The organization that is supposed to make sure the recommendations are carried out is not pushing hard enough to make sure these are implemented.

4.15 It is a known fact that in any intervention in irrigation there is env impact. Must be some relation to size of sheme and delay of impact. Is there any conditions where EIA is not necessary?

Ans: In-field impact is the same regardless of size of scheme, but other kinds of impacts may have a delayed effect, eg fertilizer use. For small scale irrigation, total amout of water abstracted from the water source can have an impact.

Ans: Small schemes do have impacts. Yes, economically not feasible to make EIA for every small scheme. For small schemens recommendations is to do strategic EIA to see what the impact would be of upscaling. Also for a small scheme rapid assessment methods through questionnaires…etc may be more appropriate rather than a full scale EIA.

Ans: has the experience that in the regions, consultants have to include EIA. They are there but content is sometimes weak.

Ans: don't ignore the cumulative effects.

4.16 Although I personally believe in EIA. I have difficulty in understanding if this EIA can be done before implementation. Need basic understanding of EIA.

Ans: EIA is a means of preventing failure rather than costly repairs. Learning from past lessons rather than re-inventing the wheel.

4.17 Assessment of the health and Env/: we tend to be biased by looking at impact in terms of diseases. How can we balance the negative of the diseases vis a vis the food security impact on health.

Ans: Absolutely true. Looking at +ve and _ve is the best. What happens now is that assumptions are made about +ve impacts but these are not quantified. Useful as far as possible if impacts are quantified in a way that they can be validated and trade-offs assessed.

Ans: Koga is the first experience in the country to integrate watershed management to reduce sedimentation in the dam. Not complete ignorance but delay in implementation of certain components due to complex problems. In Ethiopia it is not water development that has contributed to degredation but the absence of it. Important to reverse this.

Ans: the koga study shows lessons on how to follow up on EIA s that are done.

Comment: It seems there is a North South conflict of priorities. ? Advisors from WB "promote eco-agriculture" for example. Is this really appropriate for Ethiopia?

4.18 Skeptical of the results because villages near the lake are more susceptible than villages farther away. How did you attribute the high malaria to irrigation rather than the lake? One alternative is proper water management to prevent malaria. Advise inclusion of this point in the recommendations.

Ans: Both control and study villages were at the same distance from the lake and 4-5 km away which is more than the average flight range of the arabiensis vector.

4.19 Watershed management is practiced by Fincha with a spending of about 2m per year. Where does the soil erosion actually occure? Is within the sugar estate or around the area where there is deforestation? What would happen if the sugar estate was not there? Generally, unplanned interventions can have devastating effect on ecosystems. For example, in lake Tana where we thought there were large areas of wetlands and actually intensively cultivated. So, whether there is a scheme or not, degradation is going to happen anyway. So it is better that studies compare impacts of planned vs unplanned use.

Comment: Most of our irrigation schemes are in Malaria belt. Better to compare before-after situation.

4.20 Is it irrigation or type of crop that is related to increased Malaria? There is a recent discussion on maize contributing to the increase of Malaria. Can change in crop management mitigate malaria? What are the policy recommendations we can make?

Comment: With or without irrigation there is malaria. Try to find out the impact of quality of management of scheme on Malaria. It is preferable to say that bad water management causes fertile ground for malaria breeding. Effective irrigation will not produce impounding, seepage, etc so relating to management sounds better.

Ans: Proximity of the study villages to lake zeway 4-5km a little beyond a common flight range of arabiensis. Both villages are equi-distant from lake. There are also "buffer" villages between Ziway and the study villages that deflect vectors from the study villages.
Canal leakage and over-irrigation has been observed in the study sites as 'bad' management.

Group discussion and findings

After the presentation of the four themes i.e. statues quo analysis, characterization and assessment of performance of irrigation in Ethiopia; irrigation impact on poverty and economy; irrigation institutions and support services; and environmental and health impacts of irrigation development. Participants were sub divided into four groups (working group I to IV) according to the above themes. The outcome of their discussions is shown in the group work presentations as indicated in the home page.

Way Forward and Synthesis Plan

Dr. Deboorah Bossio made a summary of the symposium and discussion points pertinent for the way forward. Her presentation is included in the paper presentations shown in the home page. Intensive discussions and recommendations were provided by the participants based on the following two leading questions

- What impacts would we like to have?
- Who could make it happen?

Exhibition

Under the poster exhibition displays of posters related to the project and supplementing some of the papers presented in the symposium by the respective authors and the overall description of the project. A total of 11 posters were exhibited and demonstrated by authors as shown below.

Table: Posters presented

Name	Poster title	Institution
Abdu Beshir	Analysis of irrigation systems using comparative performance indicators: A case study of two large scale irrigation systems in the upper Awash River Basin	Oromia Water Works Design Enterprise
Abonesh Tesfaye	The Impact of Small Scale Irrigation on Household Food security: The Case of Godino and Filtino Irrigation Schemes in Ada Liben District	MoWR
Ahmed Amdeyehun	GIS and Remote sensing Integrated Environmental Impact Assessment of Irrigation Project in Finchaa Valley	
Aster Yilma	Irrigation potential of Ethiopia	IWMI-NBEA
Belete Bantero	Hare River Irrigation close to Arba Minch has become a way out for Many Households from Poverty to Prosperity	World Vision
Dr. Seleshi Bekele	Impact of Irrigation on Poverty and Environment: Research Project	IWMI-NBEA
Yihenew	Malaria Transmission In Ziway, Eastern Oromia Zone, As Related To Irrigation Development	
Wallner K. a	Field Parameter Evaluation to Support Environmental Impact Analysis of Irrigation in Ethiopia	a Department of Water, Atmosphere and Environment, Institute of Hydraulics and Rural Water Management, BOKU, Austria
Judit Christine	Impact of irrigation on livelihood and food security	University of Natural

	in the modern Hare river irrigation scheme in Southern Ethiopia	Resources and Applied Life Sciences, Vienna-Austria

Closing

The symposium was officially closed by Ato Abara Mekonnen, Chief Engineer of the Ministry of Water Resources. In his closing remark he emphasized the importance and value that this research will add to irrigation development in Ethiopia.

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