Initiatives, Opportunities and Challenges in Shallow Groundwater Utilization: a Case Study from Debrekidane Watershed, Hawzien Woreda, Tigray Region, Northern Ethiopia

Nata Tadesse[1], Asmelash Berhane[2], and K. Bheemalingeswara[3]

[1, 3:] Applied Geology Department, Mekelle University
[2:] Land Resources management and Environmental Protection Department, Mekelle University.
[1]Corresponding author: tafesse24603@yahoo.com

ABSTRACT

This paper assesses the opportunities and challenges of household irrigation practices that use groundwater as source in an area in Debrekidane watershed (45.1 km^2), Tigray region, northern Ethiopia. It was done by evaluating the recharge and discharge potential of the aquifers, different water harvesting recharge structures and the impact of the intervention on the livelihood of the households. The recharge and discharge potential of the wells were determined from the pumping tests conducted on selected wells. The potential of different recharge structures were determined by evaluating size and nature of their construction. Impact of the intervention on livelihood of the household was assessed through developed semi-structure questionnaires, and by conducting focal group, individual, formal and informal discussions. There are about 360 hand dug wells in the study area getting recharged through the water harvesting structures and directly from rainfall. The numbers of beneficiaries are 326, out of which 5 % are women headed households. Nine per cent of the owners have double hand dug wells. The major opportunities identified in the area include planting variety of new trees, plants, and cultivating of highly valued crops, improvement of the households feeding habits and generation of regular income; and introduction and adoption of water lifting technologies. At the same time spacing and sliding of walls of the hand dug wells, simultaneous production of similar type of vegetable crops by many farmers, wastage of lands due to many wells and the waste debris material, maintenance of water lifting technology, water scarcity; and proper water utilization are some of the major challenges that are faced in the area. Though intervention has changed the situation from meager to significant production, the benefits can further be enhanced by overcoming the identified challenges.

Keywords: Groundwater, water harvesting, hand dug well, irrigation opportunities, Tigray, Ethiopia.

1. INTRODUCTION

1.1 Background

Water is mankind's most vital and versatile natural resource. It is available in the form of surface waters in rivers, lakes, ponds, and oceans and as groundwater in subsurface.

Water on the surface of the earth in the form of rain, percolates through the soil, and occupies subterranean permeable layers, is known as groundwater (Driscoll, 1986: Fetter, 2001: Hamill and Bell, 1986: Stephen, 1999: Tomar, 1999: Todd, 1980). Utilization of water depends on its abundance and quality. Groundwater utilization for irrigation, livestock's, domestic, and industrial purposes is maximized from time to time. This is particularly true with increasing global food demand where extraction of groundwater for irrigation is considered as a potential strategy in the developmental programs. Many developing countries including in Africa, increasing agricultural productivity is considered a key to poverty reduction (Prastowo et. al., 2007; Mirjat et. al., 2008).

According to Rosegrant et al. (1999), during 1950 - 1980's, irrigation activities have expanded rapidly and currently it accounts for about 72% of the global water withdrawals, and about 90% of water use in the under developed countries. In mid-1990's, irrigated agriculture contributed nearly 40% of the world food production in 17% of the cultivated lands. According to El-Ashry (1993: Cited in Graham et. al., 2006), 18% of the world's agricultural land is irrigated but it produces 33% of the total harvest.

The average rate of development of irrigation in the Sub-Saharan African region (40 countries) over the past 12 years is 43,600 ha/year, with an average of 1150 ha/year. Some counties such as Tanzania, Nigeria, Niger, Zimbabwe and South Africa have higher average rate of development i.e. 2000 ha/year (FAO, 2001).

Ethiopia has abundant surface water resources, contributed by 12 major river/drainage basins in the country, out of which seven are having trans-boundary. The total annual runoff from these basins is estimated at about 111 billion cubic meters (Ministry of Water Resources, 2001). The major rivers carry water and sediments and drain mainly to the arid regions of the neighboring countries. There are also eleven major lakes comprising a total area of 750, 000 ha (Ministry of Water Resources, 2001).

Although Ethiopia's water resource is large, very little of it has been utilized for agriculture, hydropower, industry, water supply and other purposes. Due to this so far only about 160, 000 ha (about 4%) of the potential irrigable land i.e. about 3.7 million ha has been developed in the country (Ministry of Water Resources, 2001).

Among various parts of the country, Tigray region is one of the area worst affected by frequent droughts. In Tigray, about 621,000 households, constituting about 75 %, of the total population of about four million is food insecure and seriously threatened by the droughts, which hit the region every 3-4 years (Hugo, 2003). Major climatic limitations for agricultural production are erratic rainfall, unpredictable monsoons, which often combined with intermittent dry spells that regularly threaten the survival of the crops, resulting in reduced production and food insecurity. Though, the annual rainfall is unpredictable and vary in amount from 20% - 40%, like in most other regions, proper utilization of even the available amount i.e. its collection and storage is not being done. This is a matter of serious concern and demands attention.

In order to reduce dependency on large amounts of assistance, the Regional Government four years ago, has geared itself with an ambitious goal to eradicate 88% of the food deficit. It has formulated a "Rural Development Strategy Plan" based on water, agriculture and cooperatives. Water harvesting with ponds and groundwater extraction by shallow wells was one of its main objectives, intended to increase the agricultural production during relatively good times and secure crop production during dryer years.

The Regional Bureau of Water Resource Development estimated that "Tigray can potentially irrigate 50,000 ha of land using various water management schemes" which include micro and medium sized dams, river diversions, groundwater exploitation and pump irrigation (Hugo, 2003). At present, the favored choice is the water harvesting ponds and groundwater through shallow hand dug wells. One of the major objectives of the water-harvesting schemes in Tigray was also to provide supplementary irrigation to grow staple crops particularly during frequent dry spells which often make the harvests fail. In such a case, it was proposed by experts including Agriculture extension experts that the use of household ponds and shallow wells for the production of fruits, cash crops and vegetables can help the individual farmer to obtain additional income and also to meet the household consumption needs in difficult times.

With this background, present paper discusses the opportunities and challenges in terms of proper utilization of shallow groundwater for irrigation in an area in Debrekidane watershed, in eastern part of the Tigray Region. Like in other parts of Tigray Regional State, in Debrekidane watershed, the households are extracting groundwater through hand dug wells and utilizing it for irrigation and livestock purposes since 2003. Though, the interventions have helped to produce different high value crops two to three times in a year, the benefits and challenges of such irrigation practices and its short term and long-term effects have not been assessed properly. Present study tries to highlight such problems and provide some practical solutions.

1.2 Objectives

The present study tries 1) to assess the opportunities and challenges of shallow groundwater utilization for irrigation purpose; 2) to understand the significance of water harvesting and shallow groundwater utilization at the household level; 3) to know the impact of the intervention on household livelihood; 4) to recognize the pros; and 5) to identify the gaps and the scope to fill such gaps.

2. DESCRIPTION OF THE STUDY AREA AND HYDROGEOLOGY

2.1 Location

Debrekidane watershed, the area of present study, is located in Tigray Regional State, Northern Regional State of Ethiopia, about 106 km northeast of Mekelle town, capital city of the Regional State and lies between 39º 25' to 39º 30' E and 13º 52' to 13º 57' N

(Fig. 2.1). It has an aerial coverage of about 45.09 square kilometers with a mean altitude of 2200 m above sea level. The watershed comprises two Tabias (which is small administrative units), Debre Birhan and Selam, respectively.

2.2 Climate

The mean annual rainfall of the watershed is 524.08 mm (Nata, 2003). The watershed is characterized by only one rainy season, that is, the rainy months are contiguously distributed and there are two dry seasons during the year. The rainy season consists of six rainy months that range from April to September, and the little rains occur from April to June and also in September. The heavy rains occur during July and August with very high concentration in both months. In these six months rainy period about 86.6 % of the annual rainfall occurs. The little rains account for 24.9 % of the annual rainfall and 28.7 % of the rains that occurred in the rainy period. The heavy rains account for 61.7 % of the annual rainfall and 71.3 % of the rains that occurred in the rainy period. The watershed has not experienced moderate and high concentration of rainfall. Among the two dry seasons, the first dry season starts in January till March and the second from October to December. These dry seasons are characterized by low amount of rainfall, accounting for about 13.4 % of the annual rainfall. The mean annual air temperature of the watershed is 18.1ºC, and the yearly average maximum and minimum temperature is 25.1ºC and 10.8ºC, respectively. The annual range of temperature is 3.7ºC (Nata, 2003).

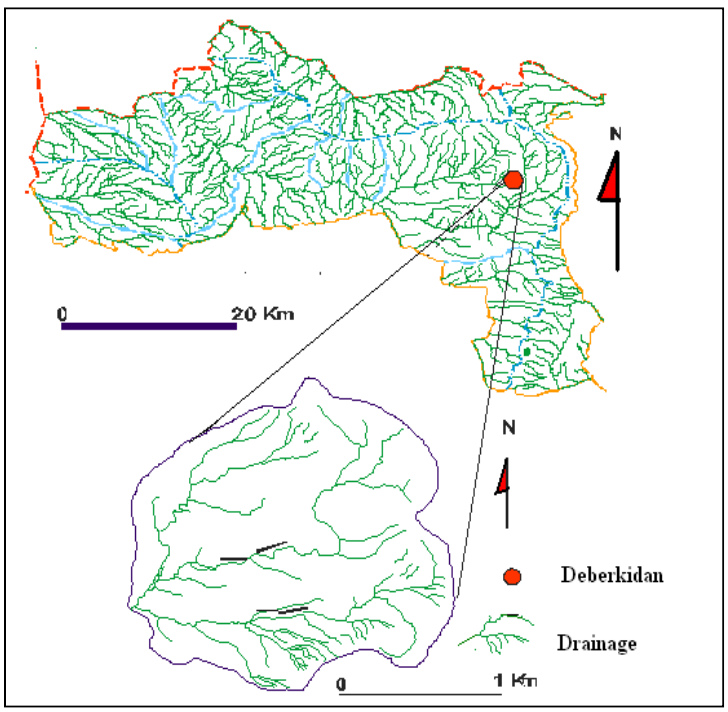

Figure 2.1. Location map of the watershed

2.3 Hydrogeology

2.3.1 Aquifer Types

Different types of rocks and unconsolidated sediments in the watershed, which behaves as aquifers, have been classified based on the type of permeability that they exhibit and the extent of the aquifer. Therefore, the watershed is classified into the following two aquifer areas.

1. Localized aquifers with intergranular porosity and permeability (unconsolidated sediments: alluvial sediments along the margins of the major rivers and their tributaries and in the plateau area); and,
2. Less extensive aquifers with intergranular and fractured porosity and permeability (consolidated sediments and basement rocks: Sandstone, tillite, basement rocks).

2.3.2 Hydrogeological Characteristics

The study area consists of four different types of lithological units. These include Precambrian low grade metamorphic basement rocks (metavolcanics, metavocaniclastic and metasedimentary) at the base and the overlying younger Paleozoic sedimentary rocks such as sandstone and tillite and followed by the recent alluvial deposits. Detailed description of the hydrogeological characteristics of these rocks is given below. The hydrogeological characteristics of the different rocks and unconsolidated sediments of the watershed have been discussed with particular reference to their water storage and transmission capacities. The hydrogeological map of the area is given in Fig. 2.2.

Metamorphic rocks

The basement rocks are generally impervious, nevertheless local pockets of groundwater reservoir occur in the weathered and fractured zones. Geological and hydrogeological logs of 9 hand dug wells in the western and central parts of the watershed indicate that the weathered and fractured zones are the main sources of groundwater supply. Average thickness of these zones together is about 4.8m. The discharge rates of hand dug wells situated in basement rocks range approximately from 0.4 to 1.5 l/s.

Sandstone

Sandstone is characterized by the presence of both primary and secondary porosity and permeabilities. Compared to primary, the secondary porosity developed due to fracturing seems to be quite significant. It is highly weathered and fractured. As it was observed in the open hand dug wells, the average thickness of the weathered and fractured zones as a whole reaches up to a maximum of 4 m depth. Fracturing has increased its void space as well as its capacity for water transmission and enhanced its usefulness to the water supply. However, in some parts, it has a high degree of clay cementation that reduces its permeability and productivity. In general, this lithounit forms a highly potential aquifer in flat areas of the study area in north and northeastern parts of the watershed. On the other hand, in south and southeastern parts of the study area, due to steep to gentle slopes it acts as a conduit for circulation of water rather than forming an aquifer.

Tillites

Presence of considerable amounts of silt and clay minerals together with silty-clayey cement and iron hydroxide matrix, makes this lithounit almost impermeable and unsuitable for groundwater storage. However, in some areas, the fractures impart an enhanced capability for groundwater flow and storage and help it to play the role of an aquifer. The maximum thickness of the weathered and fractured zones together is about 4.5 m.

Alluvial Deposits

This unit is found overlying all the other units in the central, eastern, western and northwestern parts of the study area both on the plateau, along the margins of the major rivers and their tributaries. The alluvium comprises of clay, silt, sand and gravel sized particles in different proportion. These deposits have an average thickness of 3.50 m. In the western part of the study area, these deposits are considered potential to hold water due to their primary intergranular porosity and permeability whereas in northwestern, eastern, and central parts of the study area, the alluvium acts as a conduit rather than an aquifer.

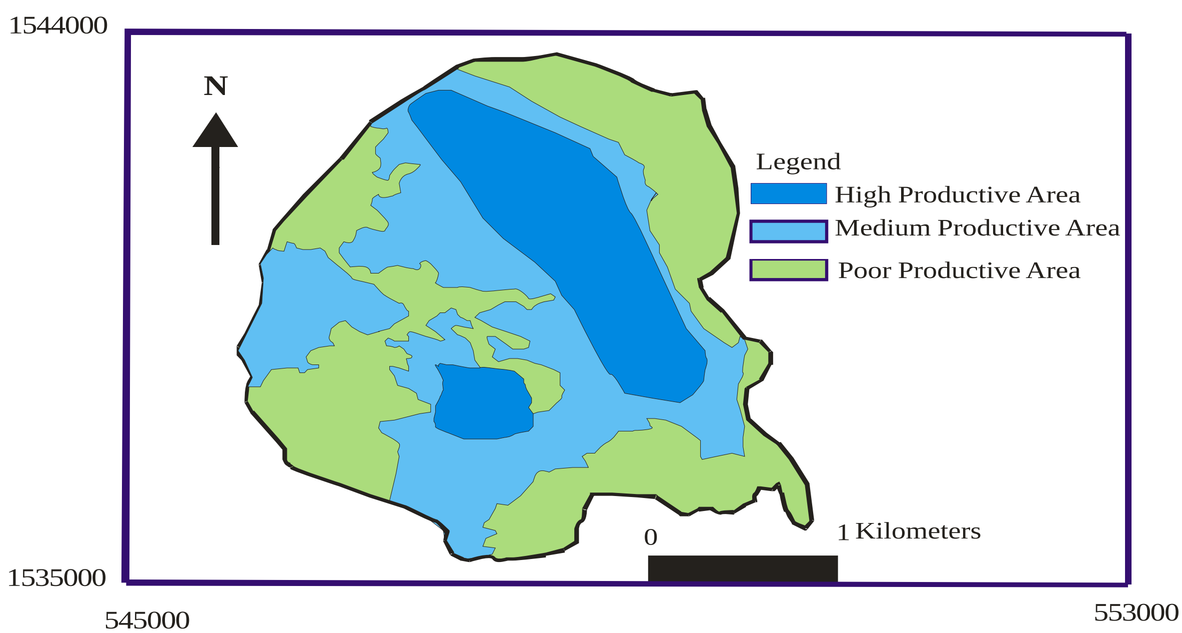

Figure 2.2. Hydrogeological map of the study area.

3. METHODS

To assess the opportunities and challenges of groundwater utilization for irrigation purpose the methods employed comprises of office work and fieldwork. . The lithological and structural data collected in the field has been transferred on to the topographic map with a scale of 1:50,000. The secondary data has been collected from different governmental and non-governmental organizations. During the fieldwork an inventory of the hand dug wells has been made and different types of data such as water table, well depth and recharge and discharge estimations have been collected in addition to the preparation of lithologs. Data related to discharge (Q) and recharge (Q_r) of the hand dug wells in the watershed were collected by recording water table fluctuations during pumping and recovery periods for 12 randomly selected hand dug wells for four consequent pumping tests. Accordingly, the time taken to pump (ΔT), the drawdown (D), and the time of recovery (Tr) for the pumped depth with the corresponding area of a hand dug well (A) after pumping has been stopped were recorded. The data has been analyzed using AquiferTest software. Various water harvesting structures such as ponds, trenches in both downstream and upstream areas were properly identified and data related to their storage capacities were collected.

The discharge and recharge conditions were evaluated on the basis of physical observation made by transect walk along prefixed traverses in the watershed and secondary data. Impact of the intervention on livelihood of the household was assessed through developed semi-structure questionnaires, and by conducting focal group, individual, formal and informal discussions. For this purpose 40 hand dug well beneficiaries or households were interviewed. Out of these, 7.5 % are female headed. SPSS version 11 (SPSS, 2002) software was used to analyze the data.

The boundary of the watershed has been delineated with the help of GPS in the field and latter was finalized with the help of ArcView GIS 3.2 software.

4. RESULTS AND DISCUSSION

The results are interpreted in terms of intervention, opportunities generated due to the intervention and the challenges emerged during the course of implementation.

4.1 Intervention

The intervention is in the form of suggesting construction of percolation ponds in the upstream at geologically and structurally suitable areas and suggesting trenches and pits in the upstream along particular contour lines for providing percolation. Utilization of the lands of the upstream areas by constructing such structures and providing scope for the growth of a variety of plants and grass is one of the innovative ideas implemented in the area since 2003 providing sites for suitable shallow wells in the downstream. Construction of 360 hand dug wells in such small area is the impact of the benefits not only in the form of agriculture production but also in the form of secondary benefits such as growth of animal husbandry and related activities. Though, the water harvesting programs have been initiated since 2003 or so in the area, it took many years to educate the beneficiaries (end users) regarding the benefits of such initiatives and the need to adopt such practices so as to improve the economic conditions of the agriculture-dependant communities. With time, the benefits though minimum, have provided enough reason for others to realize the opportunities associated with such harvesting programs and the need to implement them.

4.2 Opportunities

Though the focus initially was on irrigation using shallow groundwater in the downstream catchments areas, with time, there was a need to introduce suitable water harvesting systems so as to sustain the irrigation activity in the area. In the process, various irrigation opportunities have been increased with time with introduction of different systems like percolation ponds, trenches, pits, soil moisture. Following is the account of such opportunities.

4.2.1 Hand Dug Well Development

Many shallow hand dug wells have been developed gradually in the watershed mainly for the purpose of irrigation and out of 326 beneficiaries, 34 (9 %) of the owners have owned double hand dug wells. Some of the beneficiaries utilize the wells for other additional purposes such as rrigation, domestic and livestock purposes (12.5%) and the remaining 87.5 % only for irrigation.

Prior to the introduction of moisture harvesting measures in 2003, there were only few wells in the area (about 5% of the existing 326). These were constructed by the few innovative farmers who had exposure to groundwater utilization schemes when they were in Eritrea. Major boom in the wells construction (about 95%) was taken place between 2003 and 2005 after the introduction of moisture harvesting measures. All the wells were constructed manually. Based on the assessment made in the watershed, the adoption of intervention in the watershed is relatively very high.

Out of the observed hand dug wells, 72.5% are constructed in the unconfined aquifers and the remaining in the confined aquifers. The aquifer rocks in the area are fractured and weathered phyllite, slate, sandstone, tillite and unconsolidated alluvium. Many hand dug wells are partially penetrating these aquifers.

With the exception of a very few wells, which are closed and fitted with hand pump, most of them are open and equipped with pulley, treadle and motor pumps. Dug well geometry varies from circular, rectangular, trapezoidal and irregular in shapes. The diameter of the circular dug wells ranges from 4 to 10 m and some of the rectangular dug wells have dimensions up to 6 * 8 m. Generally, the depth of the dug wells range from 3 to 15 m. Some of the wells have masonry lining and most of them have dry brick or stone lining.

The depth of static water level varies from 0.2 - 6 m. Water table rises to the surface level during the rainy season and becomes shallow particularly in the unconfined aquifers while during the peak of dry season the majority of them will go dry.

4.2.2 Yield and Recovery of Hand Dug Wells

During well inventory, assessment of discharge/yield of the hand dug wells (Q) for the specified time and depth (Q_r) was carried out. Accordingly, the yield of the well is ranging from 1.25 to 6.94 lit/sec, with a mean of 4.88 lit/sec. In general, the yield characteristics of dug wells depend upon several factors, namely:

(a) Landform - whether located in pediment, buried pediment or valley fill areas.
(b) Regolith - its thickness and permeability.
(c) Fracture characteristics of bedrock.
(d) Local groundwater regime: whether the well is located in groundwater recharge or discharge area.
(e) Depth of water table and its fluctuation.

The discharge of the dug well in the area is found to be low because (i) dug wells are tapping only the top most or at the most the next lower water bearing stratum, and (ii) water from dug wells can be withdrawn only at velocity equal to or smaller than the critical velocity for the soil, so as to avoid the danger of well siltation.

Recovery measurement was also conducted after pumping has been stopped. In all the wells the time of recovery was more than the time of pumping. This might be due to partial penetration of the aquifers or low productivity nature of the aquifers. In addition, the increasing number of wells mainly in unconfined aquifer in the area is another reason for the low rate of recharge.

4.2.3 Percolation Ponds and Household Ponds

As the groundwater utilization practices were in operation before the introduction of water harvesting activities - the availability of water became a challenge to the beneficiaries. To overcome this limitation, machine operated percolation ponds were introduced in the area. As a result, about 46 percolation ponds with water holding capacity more than 1620 cubic meters per pond were constructed in the upper catchment area. The total estimated annual water harvest by these structures is about 74,520 cubic meters. Clay lined, plastic sheet lined and concrete lined ponds were constructed.

Household ponds were also constructed for the same purpose of recharging groundwater - supplementary irrigation purposes during the interruption of rainfall in rainy season. As expected they also have a positive effect on groundwater recharge, especially, the clay lined ponds which allows percolation particularly downward and contributes more to the groundwater compared to other types. There are about 441 household ponds present in the area having a water holding capacity of about 182 cubic meters per pond. Maximum possibility of water harvesting is estimated to be about 0.08 million cubic meters. This is one of the benefits achieved due to the groundwater recharge.

Additional merit of the construction of percolation ponds is to minimize the runoff generated from the upper part of the catchment areas. By minimizing the total amount of runoff (through big or small streams) the formation of new gullies are also minimized.

Figure 4.1. Percolation ponds constructed in the watershed.

4.2.4 Enclosure of Grazing Lands

As part of the next phase of the program, grazing land development and improvement activities were undertaken in the watershed especially, with the assistance of Irish-Aid project where trenches were constructed in grazing lands. This has improved the infiltration rate and minimized the runoff by increasing the surface roughness. Rehabilitation of the land use system had a positive contribution in terms of minimizing land degradation through free grazing. Such trenches made in the farm lands due to availability of water have helped to introduce plantation of fodder trees like *leucaenia leucocephala, sesbania sesban*. The grasslands in the area are protected from direct livestock interference particularly during summer season because cut and carry system is adopted during this season unlike open grazing practiced during dry season

4.2.5 Recharging Measures for the Enhancement of Discharges

In Debrekidane watershed, the moisture harvesting practices are exercised in the upper catchments as well as on the farmlands in the lower catchments. The practice of physical and biological soil and water conservation measures are implemented through free mobilization of the community for 20 working days per annum. Besides, to rehabilitate the environment, implantation of soil and water conservation was practiced through Food for Work program. The introduction of moisture harvesting practices have reduced the runoff and increased the contact time of water and land and thereby increasing infiltration rate. This has further helped to improve the upper catchment areas and in turn groundwater recharge. Now, about 22% of the study area is covered with physical soil and water conservation practices. The type of physical soil and water conservations practiced in the area with their corresponding amount is summarized below (Table 4.1).

According to the observations and experience of the community, increasing groundwater levels were observed after few years of physical and biological soil and water conservation measures implemented in the area. In addition to the response of the beneficiaries, the field observation of the rising water table levels in the hand dug wells and reappearance of earlier dried up springs and emergence of swampy areas are some of the indicators of the changing groundwater conditions, in response to the harvesting measures. Besides, as part of soil and water conservation practices in the watershed, the households undertook plantation of tree seedling in homestead, gully, farmlands, and community lands. This is an opportunity for the expansion of agroforestry in the watershed.

Table 4.1. Type of soil and water conservation measures implemented in the watershed.

Type of techniques	Watershed		Total (km)	Total Area (ha)
	Free	FFW		
Stone bunds	2.3	204	206.3	257.875
Hillside terraces	3.7	349.42	353.12	176.56
Trench	82	14.565	96.565	120.7063
Stone faced trench	0	337.64	337.64	422.05
Check dam	140.73	12.82	-	153.55*
Total	228.73	918.445	993.625	977.19**

Source: Debrabrhane Tabia extension office and Hawzien Woreda Bureau of Agriculture and Natural Resources, 2005.
Where FFW is Food for Work program.
*: The total volume is in m^3.
**: the summation of the first four rows excluding check dam.

4.2.6 Diversification Opportunity

Groundwater availability has provided an opportunity to introduce new tree plants that were not found before in the watershed. At present, the beneficiaries have planted a total of about 1295 different multipurpose utility tree plants in their farmlands. According to the respondents, about 114 (8.8 %) fruit trees (Guava, grafted orange and papaya), 371 (28.65 %) fodder trees (*leucaenia leucocephala, Sesbania sesban*) and 810 (62.55 %)

other trees (planted for the purposes of fuel wood, construction materials etc.) were planted by the households.

4.2.7 Adoption of Water Lifting Technologies

Adoption of water lifting technologies is another opportunity started in the area following the introduction of hand dug wells. Presently there are about 64 treadle pumps (Fig. 4.2) and 43 motorized water pumps operating in the area. Since, treadle pump is comparatively cheaper, $ 71 (approx. 650 Ethiopian Birr (EB)) and easier to handle, it has become the choice of many farmers. Of course, majority of the farmers irrigate their farmlands manually using pulley system.

The households having the advantage of water lifting technology are trying to expand their land holdings depending on the availability of water and land. Thus the average size of the land holding has increased from small piece of land (<100m) to more than quarter of a hectare. Additional lands are being obtained by negotiations and/or renting from those who don't have hand dug wells or those who have hand dug wells but unable to work due to different reasons. This has resulted in further increase of the over all food production. Those who are still irrigating their lands using old practices are restricted to small pieces of lands (<100 m^2). Increasing demand for treadle and motor pumps is further providing opportunities for small-scale treadle pump making and supplying companies and related job opportunities in the region.

Figure 4.2. Treadle pump.

4.2.8 Improved Household's Feeding Habit and Income

Before the introduction of hand dug wells in the watershed, the household's agricultural production was totally rain dependent. According to the responses of the interviewee, due to very small farmland holdings and erratic and unreliable rainfall, on an average the households were able to harvest food sufficient only for about 4 to 5 months if there is enough rainfall. The remaining food gap was supplemented by a combination of activities including purchase from the market or Food for Work or Cash for Work and Food Relief programs.

Due to the intervention, the farmers have overcome this challenge by producing crops more than one time in a year and at the same time practicing both complimentary and supplementary irrigation using the shallow groundwater. According to the respondents, the dominant crops grown under new irrigation practices are tomato (44 %), maize (13 %), onion (13 %), green paper (12 %), potato (11 %) and cabbage (7 %). The size of the irrigated farmland also varies from less than 100 m^2 to half hectare with an average of 0.27 ha.

Vegetables, fruits and others which were produced earlier in limited amount only in the rainy season are being produced abundantly for major part of the year. This is enabling the farmers to grow additional food crops. This has improved the household's feeding habits in addition to generating extra income by selling their products in the market.
Apart from tomato which is common in the area, maize crop is preferred instead of other vegetables because the maize is a preferred food in the area and at the same time the stem serves as animal feed. Consumption of maize is almost 100% compared to the vegetables like tomato, onion, green pepper, potato and cabbage which is only about 5 – 10 % of the total output and the remaining to the Market. The corresponding average income in monetary terms is about $ 173 (1575 EB). The estimated annual income ranges from less than $ 55 (500 EB) to $ 495 (4500.00 EB). These values are almost similar to those estimated in the Mai Nigus micro dam area, which is located around 150 km north of the study area (Mintesinot et al. 2004).

4.3 Challenges

Some of the problems arising due to the interventions and related developments identified in the study area are spacing of wells, wells wall sliding, wastage of lands, maintenance of water lifting technology, market and water scarcity.

4.3.1 Spacing

In the area, the sites of the wells are not dependent on the availability of groundwater but depend on the location and size of the land. The range of spacing of wells varies from less than one meter to above 70 meters. The main reason for the existence of closely spaced wells is related to the land ownership. As a result, the beneficiaries face a challenge of over exploitation of the water during the scarcity periods, especially during dry/drought period. Consequently, some of the users are forced to limit their production frequency to supplementary irrigation practices.

4.3.2 Wall Sliding

The shape of the shallow wells is dominantly trapezoidal. The lithologs of the wells in majority of the cases show that the upper layer is comprised of unconsolidated alluvium varying in thickness from 30 cm to 1 m. Due to the fragile nature of these alluvial soils, the walls of the wells very often get affected by sliding. To overcome this challenge, farmers have tried to cast the upper layers with riprap so as to avoid the sliding of black cotton soil. This method is also ineffective during high rainfall where over sliding occurs. This has an impact on water quality in terms of increasing turbidity and non-functioning of the wells, especially where the top layer is black cotton soil which is prone to sliding even by low intensity rains. Some of the wells which ceased to function due to the sliding are shown in Fig. 4.3. To overcome this limitation, some of the walls of the wells are secured by stone lining and/or masonry works where the money and material are not the limitation. The masonry work is concentrated only in the aquiclude part because the aquifer part is relatively harder, consolidated, stabilized and do not undergo sliding.

Figure 4.3. Sliding of the walls in hand dug wells in the watershed.

4.3.3 Wastage of Lands

In Debrekidane watershed almost 9% of the hand dug well beneficiaries have more than one well within their farmlands. Due to this, some of the cultivable land is lost. A household who owned a hand dug well loses about 48 to 79 square meter area due to the construction of the well. Households who have two wells, the loss become double. Besides construction, the excavated soil and rock materials, which are found dumped just near to the well, also occupy certain amount of the farmland and further minimizing the available cultivable land. Based on the response of the interviewed beneficiaries, the cultivated land that is unusable due to the accumulation of the excavated soil and rock material is about 514.5 m^2 with an average of 22.37 ± 17.67 m^2 per hand dug well. Considering the total hand dug wells in the watershed, estimated total wastage of farmland is about 3.14 – 4.24 ha.

4.3.4 Maintenance of Water Lifting Technology

Utilization of water lifting technologies has become an advantageous to boost food security in the area. The maintenance of machines and availability of spare parts for water lifting pumps has become major challenge. According to the response of the beneficiaries water pumps often become non-functional due to technical failures. Such failures together with the delays in their repair further affect the irrigation activity. For maintenance and checking, the farmers depend on the towns such as Hawzien, Mekelle, Adigrat and Wukro which are far away from their area and high cost of maintenance cause delays.

4.3.5 Market

Due to the water harvesting initiatives, the agriculture production of different vegetables has increased and in turn supply to the local markets for sale. Though minor amounts are consumed at household level, major part of the product is being sold in the market. The dominant type of vegetable crops produced for market is tomato, followed by onion and green pepper. Farmers transport their products using human or equines and sell in the local market in Hawzien town which is about 8 km. The product is sold in the town in the price range of $ 0.1 – 0.39 per kilogram. However, according to Hawzien Woreda Bureau of Agriculture and Natural Resources and the respondents, the market price varies from season to season. In the study area, one of the problems associated with production and market is the farmer's production is not market oriented. All the farmers are producing the same type of vegetables, dominantly tomato, at the same time. As a result, they face market problems. According to Mintesinot et al. (2004), creating better market access to the produced crops especially for the perishable and high value crops, might make the farmers to cultivate more crops and increase their income.

4.3.6 Water Scarcity

Water scarcity is also considered a limitation in the watershed especially during low amount of rainfall where the amount of water recharge becomes less. As a result, the potential of wells in providing water for irrigation purpose becomes limited. According to the respondents, the most critical time of water shortage is from February to mid of May. Besides this, less awareness of the communities on proper ways of water utilization and management and storage limitations also adds to the water scarcity.

Apart from these challenges, lack of seeds for high value crops and pests and diseases of vegetables and other crops are some of the other challenges which needs to be addressed.

5. CONCLUSIONS

Intervention in terms of water harvesting program and related shallow groundwater wells has increased the opportunities and at the same certain constraints in the utilization of groundwater for irrigation. Considering the benefits earned by the farmers from this intervention, the advantages outweigh the disadvantages. Presently, the households are benefited with production of different high value crops two to three times in a year, with regular additional income and improved feeding habits.

Some of the problem areas identified and addressed in this study are a) groundwater potential of the watershed needs to be investigated, b) community wells approach may be adopted to overcome the wastage of cultivated lands, c) farmers should be advised on the site selection and drilling of the wells, d) groundwater and soils suitability for irrigation should be evaluated, e) groundwater utilization and management policies should have to be formulated and implemented to overcome possible future conflicts in the utilization of groundwater resource, f) recharging measures needs to be given due attention by the community to maintain and maximize the recharge, g) training on the maintenance of water lifting technologies should have to be given to the beneficiaries, h) farmers should be advised to follow market oriented agricultural production, i) to maximize crop yield and increase the efficiency of water utilization, water saving mechanisms like family drip irrigation should be introduced, j) possible market outlets should have to be searched by the Woreda Bureau of Agriculture and Natural Resources and Cooperative of the Woreda, and, k) with the expansion of moisture harvesting structures and irrigation in the watershed, health- related issues associated with such measures should be given due attention.

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7. REFERENCES

Driscoll, Fletcher G., 1986. Groundwater and Wells, Second Edition, Johnson Screens, St. Pau., Minnesota.

FAO, 2001. Smallholder irrigation technology: prospects for Sub-Saharan Africa... http://www.fao.org/documents/show_cdr.asp?url_file=/docrep/004/y0969e/y0969e00.HTM , Accessed date 11/7/2005.

Fetter, C. W., 2001. Applied Hydrogeology 4th Edition, Prentice Hall Inc. Upper Saddle River, New Jersey.

Graham, W.B.R., I.W. Pishriria, and O.I. Ojo, 2006. Monitoring of groundwater quality for small-scale irrigation: Case studies in the Southwest Sokoto-Rima Basin, Nigeria. Agricultural Engineering International: The CIGR Ejournal. Manuscript LW 06 002. Vol. VIII.

Hamill, L. and Bell, F. G., 1986. Groundwater Resource Development, Butterworths, London.

Hugo Rämi, 2003. Ponds filled with challenges: Water harvesting – experiences in Amhara and Tigray, United Nations Office for the Coordination of Humanitarian Affairs (OCHA), Ethiopia.

Ministry of Water Resources, 2001. Initial national communication of Ethiopia to the United Nations Framework Convention on Climate Change (UNFCCC). A report submitted to the conference of parties of the UNFCCC under the GEF support Climate Change Enabling Activities Project of Ethiopia. Ethiopia, Addis Ababa.

Mirjat, M.S., A.S. Chandio, S.A. Memon and M.U. Mirjat, 2008. Nitrate movement in the soil profile under irrigated agriculture: A Case study. Agricultural Engineering International: The CIGR Ejournal. Manuscript LW 07 024. Vol. X.

Mintesinot B., Nata T., Abiot L., and Dagmawi T., 2004. Community Based Irrigation Management in the Tekeze Basin: Performance evaluation of small scale irrigation schemes: A Case Study on My Nugus Micro Dam in Tigray, Northern Ethiopia: *http://www.iwmi.cgiar.org/asessement//files/word/publicatios*, Accessed date 05/11/2006.

Nata Tadesse, 2003. Hydrogeological Investigation and Environmental Sound Plans for the Development of Groundwater in Weri River Basin, Tigray, Ethiopia: A Dissertation Submitted in Partial Fulfillment of the Requirement for Doctorial Degree of University of Natural Resources and Applied Life Sciences (BOKU), Vienna.

Prastowo, S. Hardjoamidjojo, B. Pramudya, K. Murtilaksono, 2007. Performance of shallow groundwater irrigation schemes in Nganjuk-East Java, Indonesia. Agricultural Engineering International: The CIGR Ejournal. Manuscript LW 07 013. Vol. IX.

Rosegrant, M.W. and Clauidi Ringler, 1999. Impact Food Security and Rural Development of Reallocating Water from Agriculture, Environment and Production Technology Division, International food Policy Research Institute (IFPRI); EPTD Discussion Paper No.47, USA http://www.ifpri.org/divs/eptd/dp/papers/eptdp47.pdf, Accessed date 16/10/2005.

Stephen A. Thompson, 1999. Hydrology for water management. Rotterdam: A. A. Balkema.

Todd, Davied Keith, 1980. Groundwater Hydrology Second Edition, John Wiley & Sons, Inc., New York.

Tomar, Manta, 1999. Quality Assessment of Water and Wastewater, Lewis publishers, New York.

SPSS, 2002. SPSS software, version 11.0. Chicago: Mac OSX.

Appendix

Table 1. Some of the hand dug wells and their characteristics.

Characterize Parameters/ Hand Dug Wells ID			HDW-1	HDW-2	HDW-3	HDW-4	HDW-5
1. Location	X (Easting) (UTM)		550220	550745	550686	550709	550608
	Y (Northing) (UTM)		1540161	1539986	1540004	1540071	1540031
	Altitude		2179 m	2185 m	2183 m	2186 m	2185 m
2. Well characteristics	Well shape		Trapezoidal	Rectangular	Rectangular	Rectangular	Trapezoidal
	Well diameter	Top	2.1 m				3.10 m
		Bottom	2.0 m				2.70 m
	Well depth		7.82 m	7.00 m	6.0 m	5.50 m	5.40 m
	Well width			4.30 m	3.80 m	4.20 m	
	Groundwater level	Piezometer	1.90 m	-			
		Water table		3.60 m	1.35 m	2.10 m	3.20 m
3. No. of productive layer(s)			2	2	1	1	2
4. Nature of the well	Partially penetrated		✓	✓	✓	✓	✓
	Fully penetrated						
5. Position of upper groundwater level	With in productive layer			✓	✓	✓	✓
	Out side productive layer		✓				
6. Aquifer types			Confined aquifer	Multi layer unconfined & confined aquifers	unconfined Aquifer	unconfined Aquifer	Multi layer unconfined & confined aquifers
7. Nature of aquifer			Inter.& IF.	Inter.& IF.	Inter.& IF.	Inter.& IF.	Inter.& IF.
8. Purpose of the Well			For Irrigation	For Irrigation	For Irrigation	For Irrigation	For Irrigation

(Continued)

Characterize Parameters/ Hand Dug Wells ID			HDW-6	HDW-7	HDW-8	HDW-9	HDW-10	HDW-11
1. Location	X (Easting) (UTM)		550555	550426	549802	549555	549484	550280
	Y (Northing) (UTM)		1539988	1539949	1540461	1540368	1540371	1539450
	Altitude		2183 m	2181 m	2176 m	2171 m	2177 m	2171 m
2. Well characteristics	Well shape		Rectangular	Rectangular	Rectangular	Rectangular	Irregular	Rectangular
	Well diameter	Top						
		Bottom						
	Well depth		5.05 m	5.20 m	5.50 m	2.75 m	8.00 m	3.30 m
	Well width		5.20 m	4.10 m	6.80 m	4.00 m		3.90 m
	Groundwater level	Piezometer						
		Water table	1.70 m	3.05 m	3.00 m	2.20 m	4.80 m	2.40 m
3. No. of productive layer(s)			1	1	1	1	1	2
4. Nature of the well	Partially Penetrated		✓	✓	✓	✓	✓	✓
	Fully Penetrated							
5. Position of upper groundwater level	With in Productive layer		✓	✓	✓	✓	✓	✓
	Out side Productive layer							
6. Aquifer types			unconfined Aquifer	unconfined Aquifer	unconfined Aquifer	unconfined Aquifer	unconfined Aquifer	Multi layer unconfined & confined aquifers
7. Nature of aquifer			Inter.& IF.	Inter.& IF.	Inter.& IF.	Frac.	Inter.& IF.	Inter.& IF.
8. Purpose of the Well			For Irrigation	For Irrigation	For Irrigation	For Irrigation	For Irrigation	For Irrigation

(Continued)

Characterize Parameters/ Hand Dug Wells ID			HDW-12	HDW-13	HDW -14	HDW-15	HDW-16	HDW-17
1. Location	X (Easting) (UTM)		550098	550059	550032	549943	549791	550565
	Y (Northing) (UTM)		1539353	1539567	1539383	1539372	1539380	1539902
	Altitude		2168 m	2166 m	2171 m	2166 m	2164 m	2172 m
2. Well characteristics	Well shape		Rectangular	Rectangular	Rectangular	Trapezoidal	Rectangular	Rectangular
	Well diameter	Top				3.40 m		
		Bottom				2.00 m		
	Well depth		7.95 m	4.37 m	7.33 m	5.80 m	2.68 m	3.70 m
	Well width		3.00 m	3.34 m	4.90 m		4.00 m	4.00 m
	Groundwater level	Piezometer						
		Water table	5.40 m	2.90 m	5.90 m	5.60 m	2.23 m	1.91 m
3. No. of productive layer(s)			2	2	3	2	2	2
4. Nature of the Well	Partially penetrated		✓	✓	✓	✓	✓	✓
	Fully penetrated							
5. Position of upper groundwater level	With in productive layer		✓	✓	✓	✓	✓	✓
	Out side productive layer							
6. Aquifer types			Multi layer unconfined & confined aquifers	Multi layer unconfined & confined aquifers	Multi layer unconfined & confined aquifers	Multi layer unconfined & confined aquifers	Multi layer unconfined & confined aquifers	Multi layer unconfined & confined aquifers
7. Nature of aquifer			Inter.& IF.	Inter.& IF.	Inter.& IF.	Inter.& IF.	Inter.& IF.	Inter.& IF.
8. Purpose of the Well			For Irrigation	Multiple use	For Irrigation	Multiple use	For Irrigation	Multiple use

(Continued)

Characterize Parameters/ Hand Dug Wells ID			HDW-18	HDW-19	HDW-20	HDW-21	HDW-22	HDW-23
Location	X (Easting) (UTM)		550453	550295	550343	550256	549986	549865
	Y (Northing) (UTM)		1539941	1540062	1540147	1540286	1540274	1540437
	Altitude		2175 m	2179 m	2179 m	2179 m	2173 m	2176 m
Well aracteristics	Well shape		Trapezoidal	Rectangular	Rectangular	Rectangular	Rectangular	Trapezoid
	Well diameter	Top	6.30 m					6.80 m
		Bottom	3.10 m					3.00 m
	Well depth		3.20 m	4.25 m	4.60 m	5.20 m	4.05 m	2.00 m
	Well width			4.00 m	3.90 m	3.60 m	4.10 m	
	Groundwater level	Piezometer						
		Water table	1.90 m	2.40 m	3.80 m	2.90 m	2.28 m	1.85 m

No. of productive layer(s)		2	2	2	2	2	2
Nature of Well	Partially penetrated	✓	✓	✓	✓	✓	✓
	Fully penetrated						
Position of upper oundwater level	With in productive layer	✓	✓	✓	✓	✓	✓
	Out side productive layer						
Aquifer types		Multi layer unconfined & confined aquifers	Multi layer unconfined & confined aquifers	Multi layer unconfined & confined aquifers	Multi layer unconfined & confined aquifers	Multi layer unconfined & confined aquifers	Multi laye unconfine & confine aquifers
Nature of aquifer		Inter.& IF.	Inter.& IF.	Inter.& IF.	Inter.& IF.	Inter.& IF.	Inter.& IF
Purpose of the Well		For Irrigation	For Irrigation	Multiple use	Multiple use	Multiple use	For Irrigatior

Note: Inter - Intergranular: IF-Intergranular and Fracture; Frac- Fracture; Multiple Use- for irrigation, domestic and livestock's uses.