# Towards improving smallholder agriculture: Role of *climate information* services in Ethiopia

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## Abstract

Several studies have suggested effective climate information outreach is invaluable for smallholders' decision-making on farming operations as a viable strategy to cope with extreme effects of climate change and increased productivity. Starting with the review of development and agriculture issues, this thesis seeks to investigate the knowledge and practice of improved agro-ecological techniques as well as roles of actors and access to information communication technology options among smallholders. It also aims for better understanding of what would constitute an improved role for climate information in the context of agricultural advices to sustaining agricultural production and food security in Ethiopia. With recognitions of enabling *soft*- and *hard*-infrastructure facilities in time and space dimensions, this thesis hypothesizes that appropriate climate information enhances smallholders' ability to effectively mitigate the adverse effects of climate change which hamper their farming. Percentage comparisons, based on responses from households are performed. Knowledge and practice levels of improved agro-ecological techniques, the roles of actors, access to information and communication technology are also plotted. My results suggest smallholders have low knowledge and practice levels of improved agro-ecological techniques. Moreover, family-ties play important roles for knowledge transfers, with both the household and farming managements being highly skewed in favor of men and selective technical supports from extension officers. Low or no access to information communication technology options also account for low adoption of the techniques, which in turn contributes to low agricultural productivity. Moreover, the identification (at *niche-, micro, meso-, macro- and exo-levels*) of stakeholders forms the basis for distilling concrete recommendations to improve agricultural operations and institutional efficiency. Acknowledging the efforts made so far, the government of Ethiopia should take the initiative to create a gender-balanced and ground-reaching enabling environment for institutions and stakeholders involved in climate information outreach programs. This, undoubtedly, supports development of successful and resilient adaptation strategies to smallholders and the agriculture sector in Ethiopia.

**Key words:** *Climate change impacts, Climate information, Smallholders, Agriculture, Development, Food security, Information and Communication Technology, Sub-Saharan Africa.*

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I dedicate this piece of work to my wife *melhiq* and son *'amenye* - my priceless gifts on earth.

Mulugeta MG.

## Table of Contents

## List of Figures



## List of Tables

## List of Abbreviations

Af/sGR - **Af**rican/**As**ian **G**reen **R**evolution
AFRINT - "**Afr**ica" and "**Int**ensification"
AIS - **A**gricultural **I**nnovation **S**ystems
AKIS - **A**gricultural **K**nowledge and **I**nformation **S**ystem
ARDB - **A**gricultural and **R**ural **D**evelopment **B**ureau
CBE - **C**entral **B**ank of **E**thiopia
CGIAR - **C**onsultative **G**roup on **I**nternational **A**gricultural **R**esearch
CLIPS - **Cl**imate **I**nformation **P**rediction **S**ervices
ECX - **E**thiopian **C**ommodity **E**xchange
EPA - **E**nvironmental **P**rotection **A**uthority
ETC - **E**thiopian **T**elecommunication **C**orporation
FAO - **F**ood and **A**gricultural **O**rganization
FDRE - **F**ederal **D**emocratic **R**epublic **E**thiopia
GoE - **G**overnment **o**f **E**thiopia
GTP - **G**rowth and **T**ransformation **P**lan
ICT - **I**nformation and **C**ommunication **T**echnology
IFAD - **I**nternational **F**unding for **A**gricultural **D**evelopment
IFPRI - **I**nternational **F**ood **P**olicy **R**esearch **I**nstitution
IISD - **I**nternational **I**nstitute for **S**ustainable **D**evelopment
IMF - **I**nternational **M**onetary **F**und
MDG - **M**illennium **D**evelopment **G**oal
MoA - **M**inistry **o**f **A**griculture
MoFED - **M**inistry **o**f **F**inance and **E**conomic **D**evelopment
MoWE - **M**inistry **o**f **W**ater and **E**nergy
NARS - **N**ational **A**gricultural **R**esearch **S**ystem
NGO - **N**on-**G**overnmental **O**rganization
NMA - **N**ational **M**eteorological **A**gency
PASDEP - **P**lan for **A**ccelerated and **S**ustainable **D**evelopment to **E**nd **P**overty
PRA - **P**articipator **R**ural **A**ppraisal
SAA - **S**asakawa **A**frica **A**ssociation
SADA - **S**avannah **A**ccelerated **D**evelopment **A**uthority
SPSS - **S**tatistical **P**ackage for **S**ocial **S**ciences
SSA - **S**ub-**S**aharan **A**frica
TED - **T**echnology, **E**ntertainment and **D**esign
UN/DP - **U**nited **N**ations/**D**evelopment **P**rogram
WB-IC4D - **W**orld **B**ank- **I**nformation and **C**ommunication **f**or **D**evelopment
WMO - **W**orld **M**eteorological **O**rganization

## Definitions and Explanatory Notes

"**Bega**", "**Belg**" and "**Kiremt**" refers to the *dry* (October to January), *short-rainy* (February to April) and *main-rainy* (June to September) seasons in most parts of Ethiopia (respectively);

"**Climate Information**" refers, in the context of this thesis, to three broad and interconnected aspects of *agricultural advices* on *weather and climate*; *policy reforms, technical* (extension services) and *technological* (access to ICT); and *production decision makings* (related to market information) that play crucial roles to increase agricultural production.

"**Information** and **Communication Technology (ICT)**" refers to any devices, tools, or applications that permit the collection, processing, storage or exchange of data (Delloite, 2012) and rely on internet, telecommunication networks, mobile phones, personal computers and databases (Sulaiman *et al.*, 2012). The adoptions, adaption and diffusions of these technologies suit smallholders to increase yield and generate a range of other potential benefits including poverty alleviation and environmental conservations (Djurfeldt *et al.*, 2011);

"**Participatory Rural Appraisal**" an approach used by Non-Governmental Organizations (NGOs) and other institutions involved in the development programs. The approach takes indigenous knowledge and practice of the target population (rural community, for instance) in the planning and management of development projects and programs;

"**Region**", "**Zone**" and "**Woreda**" refer to the second, third and fourth tier of government in the administrative structure of Ethiopia (respectively). Zones have not been explicitly recognized as an administrative structure in the constitution. **Kebele** refers to the lowest *urban* level governmental administrative structure. Farmers' association in rural context refers to the same term - in local terms *Ye'Geberewoch hibret sira mah-ber*;

"**Resilience**" in the context of this thesis, it refers to the ability (-ies) of smallholders to overcome shocks resulting from climate variability and change due to lack of knowledge and skills of farming operations as well as isolation from and poor technology access;

"**Smallholders**" refers to the bulk of Sub-Saharan Africa population who depend (ed) little on either state or market for daily existence; who held back by a number of economic, political and institutional factors at local, regional, national and international levels; who experience a prolonged and multidimensional crisis such as high degree of subsistence farming, low productivity, low and uncertain incomes, high risk of exposure to market failures and climatic adversaries and increase to multiple source of off-farming income (Djurfeldt *et al*., 2005). The AFRINT team defined it from the consumption viewpoint as "people who eat from the same pot and sleep under the same roof/in the same dwelling". In the context of this paper, similar meanings attached to *households*, *small-scale farmers* and *smallholder farmers*;

"**Teff**" is an annual crop and a species of love-grass (*Eragrostis tef*) widely growing in Northeastern Africa highland areas. It is the most commonly used staple-crop in Ethiopia, especially among the urban community;

# Part-I: Introduction

Smallholders in Sub-Saharan Africa (SSA) have long history of traditional farming knowledge and practices that are highly challenged by the adverse effects of climate change and were seen as hardly supporting their livelihood (Salinger *et al*., 2000). Regularly updated climate information immensely supports smallholders in their on- or off-farm activities. Research in Burkina Faso shows that access to regularly updated climate information and taking part in participatory workshops with various stakeholders improve farmers productivity and hence their livelihoods (Roncoli *et al.*, 2009). Moreover, a case study in Uganda, Senegal and Malawi on Information and Communication Technology (ICT) and climate change emphasizes that ICT helps rural farmers for climate change adaptations through knowledge sharing (IISD, 2011). The case study in Egypt, Kenya and Zambia also recognizes participation of private sectors and donors in the rural development strategies as an important agricultural policy instrument and diffusions of ICT options to sustain the agricultural operations (Deloitte, 2012).

Smallholders in Ethiopia, however, generally lack access to such climate information and allied infrastructure services to improve their agricultural productivity. These challenges include low levels of knowledge and practices of improved agro-ecological techniques, limited participation of actors at all levels and low access to ICT facilities. For the realization of sustainable agricultural operations, smallholders need to be updated with timely climate information services (Salinger *et al.*, 2000). It is also important to place emphasis on agricultural policy strategies that take the viability of climate information services to promote food production and security among smallholders in Ethiopia (WMO, 2007). These realities are the main reasons for choosing smallholders in Ethiopia as a case study to justify the viability of climate information services to improve the agricultural operations.

Using the contemporary concepts of development and agriculture related to ICT, agriculture productivity and improved agro-ecological techniques, this thesis reviews the significance of climate information based on the existing realities among smallholder farmers in Ethiopia. The thesis argues that the limited or low level of knowledge and practice of agro-ecological techniques have not effectively contributed to the agriculture productivity. The communication between actors at all levels is limited horizontally and with family-oriented knowledge transfer means of agricultural operations highly skewed in favor of men. Roles of actors for financial and technical supports as well as for the adoption, adaption and diffusion of ICT options to smallholders are also very low. If climate information with the supports of ICT infrastructures has to effectively contribute to putting new knowledge into use, the gap between knowledge and practice needs to be bridged (Sulaiman *et al.*, 2012).

This thesis has four parts. The current part presents the conceptual framework, motivation and significance, statement of purpose, research questions and design, methodology and limitations. The second part is the literature review section which details the background concepts to better cement the link between climate information outreach and agro-ecological technique practices among smallholders. This section also assesses the existing policy frameworks, actors at various levels, institutional setups and technology options that play crucial roles for advancing the knowledge and practice of agro-ecological techniques and the need for timely climate information for the farming operations. The third part depicts the result of my analysis from the AFRINT project. The last part is the discussion and conclusion section based on the results from the previous sections and positive experiences from case studies. Opportunities for further research are also included in the last part.

### 1.1. Conceptual Framework

Development in agriculture sector views has been contesting and is still the central discussion agenda (Moor, 2010) between schools of thoughts and taken to mean different things at different times, places and professions - the dominant meanings have been those attributed by economists and used in economics (Mahmoud, 2007; Chambers, 2004). This thesis discusses pendent concepts of development related to agriculture between two camps and the policy directions of the Government of Ethiopia (GoE) in relation to these camps. The World Bank (WB) reports, mainly (World Bank, 1997, World Bank, 2008; World Bank, 2012 and World Bank-IC4D, 2012), on one side and critiques to the reports on the other side will be presented vis-à-vis the two camps. Finally, reflections and stands of the author regarding the discussions of agriculture for development end the section.

The different ideologies on development in agriculture are mostly related to three issues: *farm size*, *farm scale* and *farm type* (Woodhouse, 2010). Farm size refers to the sizes of farm areas, while farm scale is associated with investment farming that substitute labor by capital or mechanization. The third issue is farm type which is related to the type of farming practices.

The WB, International Monetary Fund (IMF) and scholars such as Travis J. Lybbert, Christopher B. Barrett, John G. McPeak, Winnie K. Luseno and others advocate Agriculture for development as *accumulation* or *capitalist* or *investment* farming as the only way out for nations whose economy is highly dependent on agriculture. On the other camp (*New left*), scholars such as Mike Davis, Göran Djurfeldt, Ernest Aryeetey, Philip McMichael, Stephen Gliessman, Michael Lipton, Robert Chambers and others advocates *small-scale* and *intensification* farming or through rational farm-land *distributions* to smallholders (Yahia M.

Mahmoud) or *no-till* (Food and Agricultural Organization - FAO) or *smallholders-focused* rural development strategy (United Nation Development Program - UNDP).

Thoughts of the first group are towards economic growth through capital investment by giving less space and attentions to the social and environmental dimensions. These places industry at the heart of developmental thinking as a real engine to economic growth and consecutively social welfare could be achieved. On contrary to these groups, the second camp prioritizes social issues and environmental concerns as central for development strategies and emphasis on the so called – the *ignored* and/or *discriminated* sectors such as agriculture (McMichael, 2009). According to the *New left,* economic growth could be achieved only when social and environmental concerns are effectively addressed. It is important to note worthy of the common views between these schools of thoughts on development ideologies as good for change from different standpoints – *macro* to *micro* or *large-first* and *small-second* approaches or vice-versa. These views have differed, always should and will continue to be and what is good and what sorts of significant changes are the central ideas of development.

The World Bank (1997) report issues in refocusing attentions on the roles and effectiveness of states as a didactic device to policy makers: *what to do, how to do it, and how to improve it* in a rapidly changing world. The report underlined that development requires an effective state that plays a facilitator role in encouraging and complementing the activities of private businesses and individuals. These roles must focus on industry-led economic fundamentals, but should always be tailored to capabilities. Adding to this, the report also issues to place agriculture afresh at the center of the development agenda through large-scale and commercialized farming schemes. These ideas of development are easier for economists to incorporate people and social institutions in their economic models.

Later (World Bank, 2008), the Bank's focus was towards market-based approach as a means to poverty reduction and agricultural growth. The report acknowledges the growing concerns and roles of the social dimension as pivotal for agricultural development strategies in addition to – the so called *states* and *private sectors* as defined by the Bank. This shift of thinking by the WB and advocates considers capitalistic agriculture as not merely - *investment* oriented but as a way of opening a room for "agro-ecology" to harmonize agriculture with capital and production through nature (Moore, 2010). Moreover, the report regionalized agriculture in terms of its roles to national economy as *agriculture-based* (such as in SSA countries) to *transforming* (as in South-East Asia and North Africa countries) and as *urbanized* (as in most of Latin America and much of Europe and Central Asia countries). This categorization, according

to Woodhouse (2009), and placing agriculture as a center of agenda for regions like SSA, disconnects the rural-urban linkage.

Most of the agricultural production in developing states is, as has been, mainly by smallholders and continues to be only when smallholder's efforts are supported by actors at all levels, the Bank with its 2008 report acknowledges. The concern, according to the Bank's report, is the market-failure issue to fully support the national economy. For this reason, the Bank sways back to its former stand (World Bank, 1997) and underlined the issues of scale-production, marketing and labor-intensive commercial farming as a way out for better form of production, efficient markets system and key instrument to reduce rural poverty. Moreover, the report places high emphasis on large scale and space that need to be given for state as a responsible actor to chain all the other stakeholders in the agricultural sector, through for instance rural development strategies, and as an agent to correct the market failures, regulate public-private partnerships. In its summary, the Bank underlined that it is only when these issues are effectively addressed that agriculture can take pivotal role in the development agenda.

On contrary to this, according to scholars such as Mike Davis – from *New left* review of development, these development ideas standardize, depersonalize, miss much the interest of the rural community, advocates of *urbanization without growth* and may purport to measure what cannot meaningfully be measured (Davis, 2006). In his book - *Planet of Slums*, Mike Davis criticized development policies of the WB and IMF as being responsible for the cause and maintenance of the problem in relation to urbanization and commercialization of agriculture products (Davis, 2006:15). Moreover, these policies squeeze the roles of agriculture and are deterrents to subsistence farming and rural development. According to McMichael (2009), the *agriculture for development* vision of the WB is the new *mantra*, as long as corporate markets remains functional with the same dogma and the productivity is the task of diversified small farming - *new wine in old bottles*. One pushing-factor of the rural community from countryside, according to the *New left* scholars, is the policies and acts of deprivations to practice the subsistence economies that had sustained them in the past. These scholars claimed urban growth is exploding without significant economic growth where cities are growing with a decreasing capacity to support residents by creating a widely varying *informal economy*.

The other indication of the WB's policy directions towards smallholders is reflected with its two latest reports (World Bank, 2012) and (World Bank-IC4D, 2012). In these reports, the Bank shows its clear interest regarding the inclusiveness of smallholders in the fields of ICT to enhance the roles of agriculture for development. Specifically to the adoptions, adaptions and diffusions of ICT infrastructures to

smallholders, both the WB and the *New Left* advocates do not show distinct difference. Both camps acknowledge the contributions of ICT to the agriculture sector and share points including: ICT a key to help governments to make arrangements for stakeholders' interest in the policy reforms, especially in the agriculture sector; to access information for policy makers, all stakeholders in the agriculture sector and to improve smallholders farming operations; to improve public and private services in the agriculture sector such as facilitate the delivery of extension services; to efficiently supply chain of cooperation between actors; to smallholders agriculture growth through better aggregation of production and reduced information asymmetry; to enhance collective actions through more affordable and reliable communication means and tools; to facilitate peer- and expert-level workshops for experience and knowledge sharing aims. Moreover, both camps adhere to the roles of ICTs as viable tools for climate change and variability adaptations and effective mitigations strategies.

The GoE promotes the adoption of these two development ideologies as fundamental policy instruments with two of its prominent economic and development policy strategies: Growth and Transformation Plan (GTP)[1] and Plan for Accelerated and Sustainable Development to End Poverty (PASDEP)[2]. The GoE gives emphasis for industry-led, commercialization of agriculture and enhanced participation of private sectors. The economic vision[3] of Ethiopia states introduction of alternative and improved agricultural practices through technology (such as ICT) to sustain the economic growth and welfare of the citizens as invaluable measures to pull millions out of poverty (IMF, 2011; MoFED, 2002). These include improved agricultural infrastructures, services and land management practices; new marketing networks and partnerships; reliable credit schemes and coherent institutional frameworks (Amha, 2011).

Opportunities to take part in the formulation of policies and strategic plans, actors could play enormous roles as development partners in Ethiopia by establishing partnerships to create functioning environments in order to decentralize communication flows between actors at all levels. These actors also play important roles ranging from the provisions of facilities to direct contributors of the accompanying diffusions of ICT to make the communications effective (Deloitte, 2012). These means of communications, in all forms, undoubtedly support the channeling of climate information as a viable tool

[1] A medium term strategic framework for five years period from 2010/11 to 2014/15 (IMF, 2011).

[2] A five years action plan formulated by the GoE in 2005/06 aiming at lay outing directions for accelerated, sustained and people-centered economic development to attain the Millennium Development Goals (MDGs).

[3] "*Building an economy which has a modern and productive agricultural sector with enhanced technology and an industrial sector that plays a leading role in the economy; to sustain economic development and secures social justice; and, increase per capita income of citizens so that it reaches at the level of those in middle-income countries.*"

to reach the underserved groups of the community with updated information on a regular basis (Roncoli *et al.*, 2009; WMO, 2009). African smallholders, with no exception to the Ethiopian equivalents, have limited or no ICT options for the latest information updates on climate and improved agro-ecological techniques, and thus hardly adjust their livelihood activities accordingly (Djurfeldt *et al.*, 2011; UN, 2010). Hence, supports from actors such as donors and NGOs are vital to ensure the provisions and diffusions of ICT options to smallholders for a successful end-flow of the available information.

Throughout the thesis, the discussions of climate information, ICT, agricultural productivity and agro-ecological techniques switch between fundamental thoughts of agriculture for development. The author acknowledges the role of *financial* and *technical supports* as well as *advices on policy formulation* from international actors to strengthen the agriculture sector, rural development strategies and sustainable economic growth in Ethiopia. The main challenge to these policies is the implementation aspects of them. Most of these policies barely reach to the ground to benefit the majority of the society - smallholders. Knowing these facts, the author believes the adoption, adaption and diffusions of ICT infrastructures to effectively outreach climate information services to smallholders as pivotal for the success of rural development strategies in the country. These agricultural hubs (as emphasized by Deloitte, 2012) strengthen the relationships between all actors for better outcome. Moreover, the author takes the side of giving emphasis to the irreplaceable roles of human dimension and the environmental concerns as central for food security and rural development issues in Ethiopia. Maintaining what is on the hands of millions – *subsistence* and moving forward is the only way to *include the excluded* as long as agriculture for development is concerned.

## 1.2. Motivation and Significance

Focusing on agriculture and rural development in the context of SSA is crucial for three main reasons: to *guarantee food security*, as *source of employment* and as the only means for *key products and services* (Amha, 2011; Mahmoud, 2007). Agriculture with its accompanying benefits is the mostly affected sector in SSA due to the devastating effects of climate change (Djurfeldt *et al.*, 2011, Djurfeldt *et al.*, 2005). The changing climate affects agricultural operations and leads to reduced yield per head in areas such as SSA (Salinger *et al.*, 2000). Taking the varying effects of climate change on different types of crops into account, devising climate change adaptation mechanisms on agricultural operations is the only way forward (Mahmoud, 2007; WMO, 2001). In response to such extreme climate effects on farming operations, some of the adaptation mechanisms include: policy reviews; effective management of the

existing facilities; re-arrangement of institutional set-ups; adopting improved agro-ecological techniques; improving the climate information services for early warning purposes (WMO, 2009).

It is important to place emphasis on updated climate information services for farmers that includes advise on farming operations, such as when to sow, how to control the weeding, how to apply fertilizers, how to irrigate, when to harvest, and when to dry and so on (Salinger *et al.*, 2000). Policy as well as decision makers need to understand the viability of climate information when formulating sustainable development strategies to promote food production and security in areas such as SSA. Climate information issues should be the center of food security discussions among various actors not only as a simple communication language (Sulaiman *et al.*, 2012) but also as a national resource (WMO, 2007).

The significance of this thesis is twofold. First, it explores existing realities among smallholder farmers in Ethiopia including the knowledge and practices of agricultural operations, roles of actors and access to ICT infrastructures. Second, it points out the issues of climate information and timely advices on farming operations not only as a benefit to small-scale farmers by improving their livelihood, but also its contribution to economic growth of Ethiopia. It is worth noting the multi-scale challenges of making climate information services available in a useable form for smallholder farmers knowing the difficulties in down-scaling climate and weather information in relation to forecasts and above all the need for information that is timely enough to give farmers time to react (Christoplos, 2009). The results of this thesis could be taken as important input for decision makers and other stakeholders that focus on smallholder farmers when planning policies related to agriculture development strategies in Ethiopia.

### 1.3. Statement of purpose and Research Question

Ethiopia is one of the SSA countries known for nearly 85% of its population dependent on agriculture as the back-bone for its economy with the bulk constituting the poor. Some serious problems such food security and mass poverty affected rural community and the agriculture sector of the country for decades and continue to date. It is important to pin the issues of small-scale agriculture in Ethiopia and how it can contribute the wellbeing of the rural community and the economic growth of the country in general. Effective outreaching of climate information services to smallholders in Ethiopia is one way of enabling the rural community to engage in farming operations with timely updated knowledge and practices. These services, with coordinated supports of actors at all levels and ICT infrastructures in place, not only help smallholders maintain the subsistence farming they have for generations but also are means to advance their agricultural production.

These issues of smallholders in Ethiopia trigger dozens of questions about *what type of* and *how* climate information should support their farming operations and *its effect* on the overall success of agriculture development in Ethiopia. For this purpose, a panel data from the AFRINT is chosen. The panel data are designed in a certain way to understand the agro-ecological, market, geo-political and institutional conditions, primarily for agricultural intensification (Phase-I and -II) and for food security (Phase-III)[4] purposes in SSA (Djurfeldt *et al.*, 2011; Djurfeldt *et al.*, 2005). As remarked earlier, the main purpose of this thesis is to put emphasis on climate information and demonstrate how smallholders could benefit from it using the AFRINT 2008 survey in particular. These questions from the 2008 questionnaire are designed to assess the current knowledge and practice levels of improved agro-ecological techniques, actors' roles, as well as access to ICT options and their links to climate information services. Table 1 lists the primary research questions for this thesis, as well as the source and tools used in their analysis for the intended outcomes.

### 1.4. Research design

In this section I will demonstrate the analytical links between each research question (Table 1) and the desired communication among actors at all levels to give the over-all picture of the research process. Moreover, the roles of ICT infrastructures to guarantee climate information services to smallholders are also taken in to account. The author argues that the available AFRINT panel data is sufficient enough to understand the variables in question and show the existing realities among smallholder farmers in Ethiopia.

The analytical linkages between each research question and climate information could be explained from the understanding of the concepts and constituents of climate information. Climate information is a timely weather and climate information that support the general public to adjust livelihoods and decision making accordingly (Salinger *et al.*, 2000). Such information should be effectively communicated between the source of information and the target. Sulaiman *et al*. (2012) magnifies the value of communication beyond its traditional meaning as being only a process of information dissemination. According to the authors, it is also a tool to mediate the processes that strengthen innovations of ICT, role of actors and institutional capacities.

[4] This phase of the project is not commenced yet.

**Table 1.** The main and sub-research questions.

| | *Research Questions* | | | *Data source and Tools* | *Analysis* | *Outcome* |
|---|---|---|---|---|---|---|
| **RQ-1** | **What are** | **the knowledge levels** | **of improved agro-ecological techniques among smallholder farmers in Ethiopia?** | - AFRINT survey,<br>- SPSS Stat. 17.0,<br>- Ms-Excel, | - Assessment of agro-ecological techniques,<br>- Percentage (%) calculations of the "awareness"- and "practice"-levels, | - Have knowledge of majority of improved agro-ecological techniques,<br>- Less techniques are practiced despite knowhow |
| | | **the current practices** | | | | |
| **RQ-2** | **What are the most determining factors accounting for the knowledge and practicing gaps?** | | | - AFRINT survey,<br>- SPSS Stat. 17.0,<br>- Ms-Excel, | - List of factors from HHs' responses,<br>- Most constraining factors, | - Climate information as one possible option for practicing agro-ecological techniques, |
| **RQ-3** | **What are** | **the roles of actors'** (niche-, micro-, meso-, macro- and exo-levels) | **to channel climate information to the underserved?** | - AFRINT survey,<br>- SPSS Stat. 17.0,<br>- Ms-Excel,<br>- literature review, | - Roles of family,<br>- Extension services,<br>- Knowledge transfer and supports by other actors, | - Roles of actors at:<br>→*Niche-, Micro-, Meso- and Macro-* levels, and<br>→*Exo-levels* at the global context, |
| | | **the ICT options** | | | - Assessing assets of and access to ICT, | - Assets and access levels to ICT, |
| **RQ-4** | **How can climate information benefit smallholders to advance agro-ecological practices and deliver increased production?** | | | - literature review, | - Literature review related to climate information and agro-ecological techniques from elsewhere, | - Climate information dissemination for improved agro-ecological techniques |

(*Source*: Author)

In relation to smallholders, access to ICT options immensely support smallholders to improve their productivity (Djurfeldt *et al.,* 2011); this in other words ensure access to timely climate information services (Roncoli *et al.*, 2009). These services include meteorological events, seasonal forecasts and information about predicted long-term trends (Christoplos, 2010) and range from appropriate seed selection and application of improved agro-ecological techniques (Salinger et al., 2000) to an indirectly related market information (Johnson *et al.*, 1986). These farming and livelihood adjustments can be realized with the enabling policy frameworks that put smallholders and actors' cooperation at all levels into account (Deloitte, 2012). Moreover, provisions and diffusions of appropriate ICT options to channel climate information services between smallholders and actors are invaluable. In the context of this

thesis, climate information has three broad and interconnected parts: the *weather and climate*, *technical and technological*, and *market* information aspects (Figure 1).

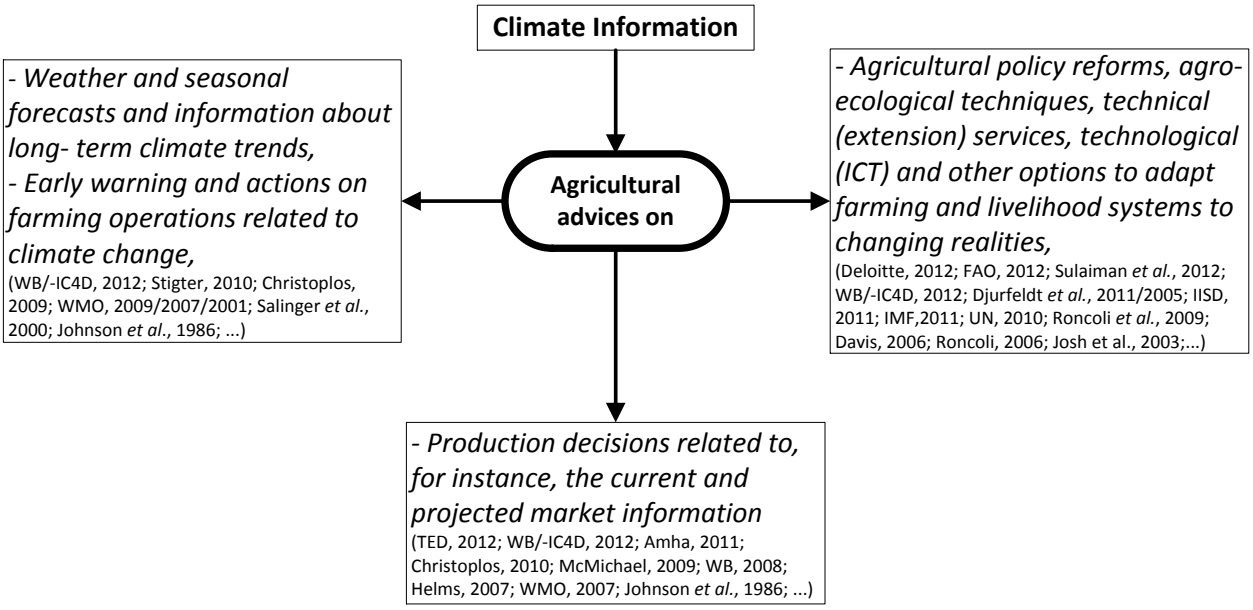


**Figure 1.** The three broad and interconnected aspects of climate information related to agriculture. (*Source*: Author)

Knowing the broad and interconnected constituents of climate information, it is clear to understand the relationship between climate information services and agricultural related operations and decision makings among smallholders in Ethiopia. That is, low adoption of improved agro-ecological techniques lead to low productivity (Djurfeldt *et al.*, 2011; UN, 2010; Djurfeldt *et al.*, 2005), which in turn indicate poor access to updated climate information (Roncoli *et al*., 2009; Roncoli, 2006). In other words, timely climate information services help smallholders increase their knowledge of the improved agro-ecological techniques and adjust their farming operations in advance, which in turn results in increased productivity. This is the focus of the first research question (RQ1).

One approach deployed in this thesis is the gap analysis of knowledge and practices of improved agro-ecological techniques among smallholders. The gap analysis identifies the most common factors hindering smallholder farmers from practicing improved agro-ecological techniques. Sulaiman *et al*. (2012) underlined the use of technical (extension services) and access to technological facilities (ICT) to effectively bridge the gap existing between knowing and practicing of agro-ecological techniques among smallholders. This is where the second research question emanates from (RQ2); it seeks to answer questions related to factors in connection to knowledge and climate variability. Based on the identified

factors, I assume that fundamental links exist between climate information services and knowledge of climate change and its variability.

The other aspect of this thesis is assessing the current roles of all actors responsible for the practice of improved agro-ecological techniques among smallholders. Some of these include actors with the source of the information, mediating institutions engaging in channeling the available information, financial institutions, extension officers, family members and fellow farmers (Roncoli *et al.*, 2009; WMO, 2007). All these actors need to establish a sustained communication platform both at the same levels and across the hierarchies (UN, 2010). The communication between actors should go further than simple dialogue to means of experience sharing medium and as resource to put sectors and actors in a sphere (Sulaiman *et al.*, 2012). These options are shown with arrows sourcing and ending at the same levels as well as linking all actors (RQ3). On the other hand, actors' roles on knowledge transfer and practices of improved agro ecological techniques as well as on the suggested solution for the gaps are indicated by arrows crossing between each research questions. The other part of the 3$^{rd}$ research question focuses on assets of or access to ICT among smallholders of Ethiopia. In this regard, active roles of actors as well as existence of *soft*- and *hard*-infrastructure facilities are important for effective outreaching of climate information to smallholder farmers in SSA and in Ethiopia in particular (Dzanku *et al.*, 2011; Salinger *et al.*, 2000).

In the end, all the results of my analysis will be explained using case studies (in response to RQ4). Conclusions will be drawn based on prospective roles of actors and ICT options to benefit smallholders with improved knowledge and practices of agro-ecological techniques. The whole idea of the research process could be visualized in Figure 2.

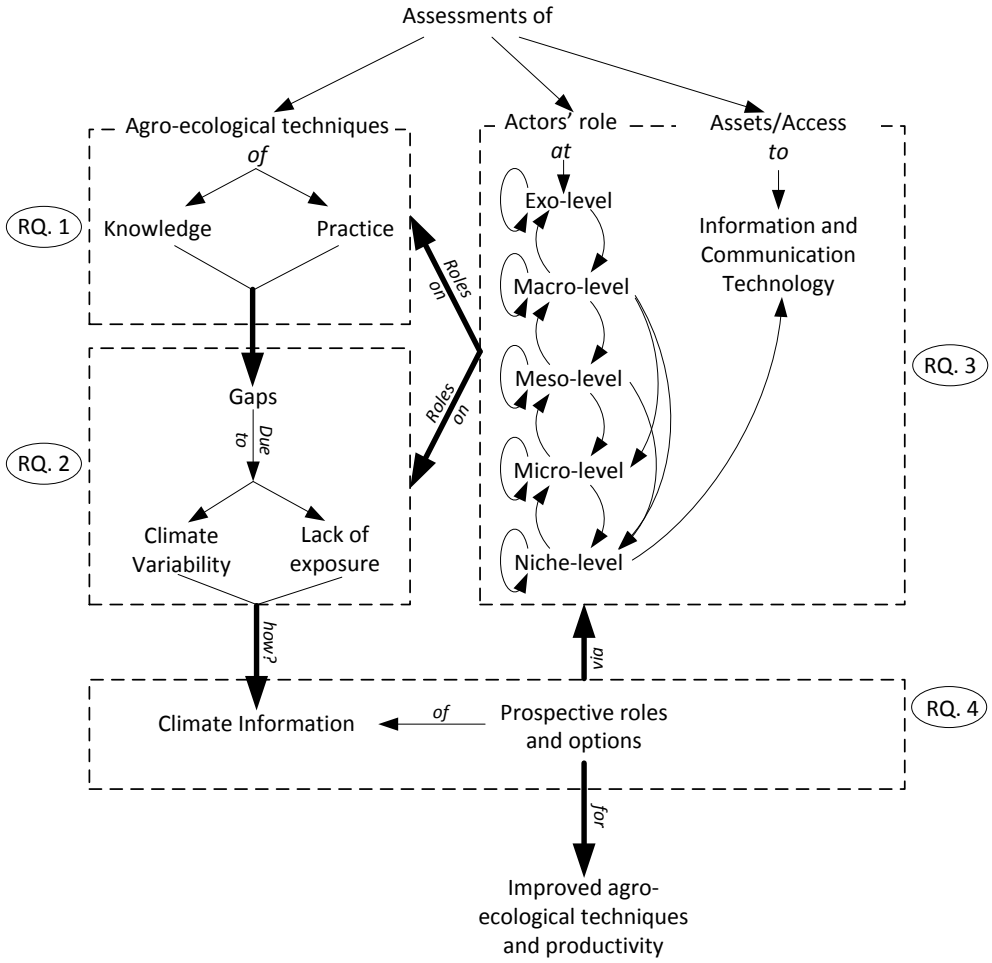


**Figure 2**. The research design and analytical linkage between research questions.
The four boxes are the focus of the research questions and the arrows indicate the flow of information (thinner-lines within each research question) and analytical linkages between each entity/research question (heavy lines). (*Source*: Author)

## 1.5. Methodology

A mixed research approach, based on quantitative and qualitative analysis methods, was chosen using an unobtrusive approach to the AFRINT panel data and review of case studies.

The 2008 survey is chosen mainly because of its comprehensiveness in terms of focus areas, compared to the 2002 survey; hence it was chosen as a basis for selecting the research questions. With this fact in mind, seven questions were selected from the 2008 survey. The selected questions could be generalized and put as: "*Which agricultural techniques: - you have knowledge of, - already practicing, - reasons for not practicing, and - sources of information for the practices?"; "Have you received advices from extension staffs (governmental and/or non-governmental) any time in the past?*" and, "*Which technology options do you own and have access to?*"

### *1.5.1. Unobtrusive approach*

The quantitative analysis aspect of this thesis is based on an already collected data from AFRINT project surveyed in two rounds (i.e. 2002 and 2008). Moreover, the panel data was designed in four parts at macro- and micro-level studies, including purposive selections of countries, regions, and villages, to random selection of households in each village (Djurfeldt *et al*., 2011). Such secondary analysis of the existing data made the formulation of the research questions of my interest possible without having to go through the actual data collection process in the study areas (Lee, 2000).

### *1.5.2. Quantitative approach*

The primary data collected mainly through the AFRINT-II (2008) survey was analyzed in order to understand the existing knowledge and practice of improved agro-ecological techniques. The AFRINT cross-sectional panel data included a total of 20-regions, 103-villages and nearly 4,000-households in both rounds for all case countries to trace the villages and household-level effects of agricultural policies and other macro-level processes. In the case of Ethiopia, The AFRINT team's approaches included interviews with households, experts, and policy makers at all levels, secondary data sources, and field visits to 4-selected sites in Ethiopia: *Bako, Assebot, Bokoji and Yetmen* (Figure 3). 8-villages, totaling 322 (in 2002) and 476 (in 2008) households were contacted throughout all the case areas. Of which, 316-households participated in both rounds. The approaches covered diverse socio-economic, political, demographic and agro-ecological dimensions in the country and investigate how such factors favor or constrain agricultural intensification in Ethiopia with the main focus on the four common staple-crops: *Maize (in Bako), Sorghum (in Assebot), Wheat (in Bokoji)* and *Teff (in Yetmen)*. Percentage calculations of the responses on each variable were performed using statistical tools (Statistical Package for Social Sciences-SPSS), Spreadsheet (Excel) to plot the results and ArcGIS tool to map the study areas.

The AFRINT team proposed sixteen possible reasons (Appendix B) to investigate the limitations of knowledge as well as practice of agro-ecological techniques. The analysis of *gaps* between knowledge and practice of agro-ecological techniques considered farmers whose responses are based on the assumptions in Table 2.

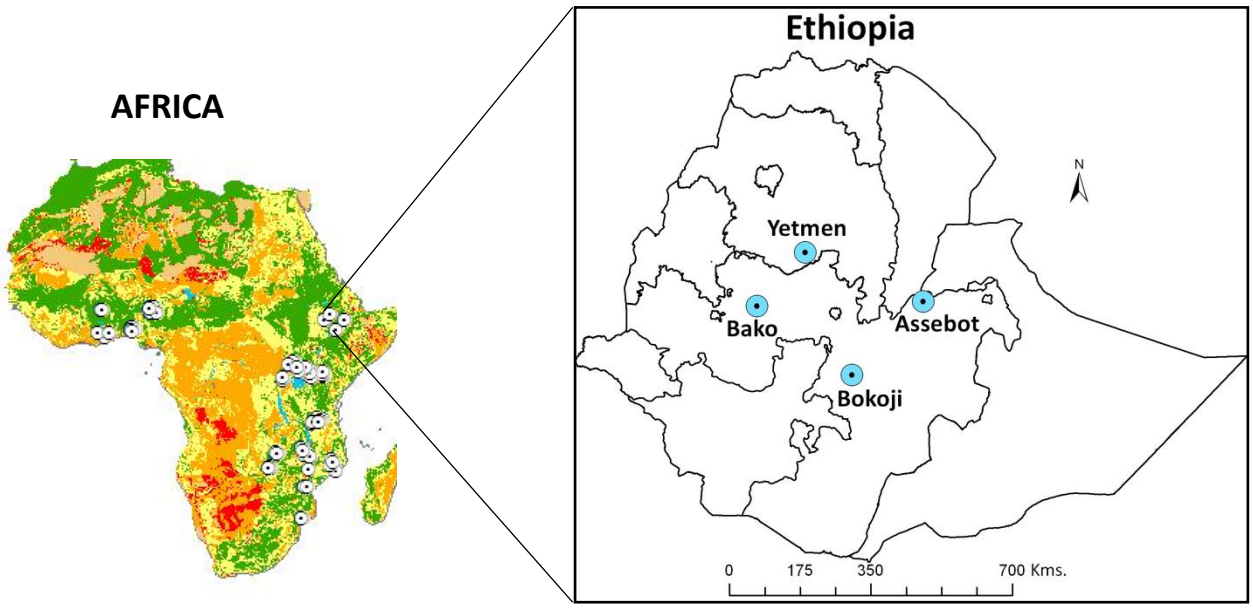


**Figure 3.** AFRINT study sites in Africa and Ethiopia.
(*Source*: Extracted from presentation of the research group on AFRINT, 2010)

**Table 2**. Possible scenarios of knowledge and practice of agro-ecological techniques among smallholders.

| Category | Knowledge | Practice |
|---|---|---|
| 1 | *High* | *High* |
| 2 | *High* | *Low* |
| 3 | *Low* | *High* |
| 4 | *Low* | *Low* |

Two assumptions are set here. First, intermediate responses [i.e. (*Some knowledge*, *Some practice*)] are not considered and *knowledge* and *practice* refer to the general information about the proposed agro-ecological techniques. Second, samples falling under the first (*High, High*), the third (*Low, High*) and fourth (*Low, Low*) categories are discarded for the *gap* analysis. The rationale for the second assumption is that, smallholders with high (sufficient) knowledge of farming techniques, would most likely to practice the techniques. This is then, not the concern of the thesis. The (*Low, High*) category sees farmers who have *low* knowledge of agro-ecological techniques but practice the techniques *very much*. In relation to the first assumption, the AFRINT questionnaires on knowledge and practice in question are general questions, not specifically to scientific or indigenous approaches. Therefore, it is assumed that farmers with low knowledge have low practice [referring to fourth category (*Low, Low*)] levels and there are no farmers with low knowledge and high [referring to third (*Low, High*)] levels of agro-ecological technique practices.

The second category (*High, Low*) is the focus of this thesis and refers to smallholders that have high knowledge of agro-ecological techniques but practice them less. Some cases studies from elsewhere pronouncing these groups of smallholders in Ethiopia will be presented. For instance, case studies in Egypt and Zambia (Deloitte, 2012) as well as in Uganda, Senegal and Malawi (IISD, 2011) show farmers that have access to infrastructure (both soft and hard) facilities are better-off than those who lack it. These are the most common farmers in Africa, especially in SSA (Djurfeldt *et al.*, 2011; Djurfeldt *et al.*, 2005; Mahmoud, 2007).

### *1.5.3. Qualitative approach*

This thesis picks concepts from two contesting camps on development and agriculture to emphasis on the issue of climate information services to smallholders in Ethiopia. The approach includes concepts existing between the adverse effects of climate change and adaptation mechanisms through timely climate information outreach to the general public, smallholders in particular. This approach is assumed to provide a better picture of the existing realities of the study areas (i.e. ontological implications) through unobtrusive means. Based on the understandings of these relationships, conclusions could be made by taking the importance of interactions between all actors responsible for the climate information disseminations (i.e. epistemological position) (Bryman, 2008). Literature reviews are used to explain the role of climate information services to advance knowledge of agro-ecological technique practice and deliver increased production.

## 1.6. Limitations

Geographical extent wise, the thesis focuses only on Ethiopia (Figure 3). However, some experiences were included from the other case countries of the AFRINT project. In terms of knowledge of the study sites, there were no physical visits or interviews conducted during the research process. The analysis was entirely based on unobtrusive assessment of the AFRINT 2008 survey data. Scope wise, the thesis focuses on how climate information could take part in the designing and implementation of improved agro-ecological techniques to benefit smallholder farmers in Ethiopia. In this thesis, climate information is not considered as a panacea to overcome the existing problem of smallholder farmers, such as being aid-dependent and limited to subsistence farming. However, it can be taken as part-and-parcel of the diffusions of ICT through extension programs, development of input-output markets and building networks and linkages, increase access to producers and buyers in the marketing chain, and capacity-building of smallholders and their associations (Djurfeldt *et al.*, 2011; UN, 2010).

# Part-II: Literature review

## 2.1. AFRINT project and its relevance to Ethiopia

The AFRINT team used comprehensive investigations of multi-casual and multi-dimensional models as the only way to explain the 1960s Asian agricultural development and attempting to replicate it to SSA, initially by taking 5-case study countries: *Ghana, Kenya, Malawi, Nigeria, and Tanzania*. Due to the financial pre-conditions and nature of the late grant, the project included the additional 4-countries: *Ethiopia, Uganda, Zimbabwe and Mozambique*. The countries are selected based on population density and their focuses on agriculture, while the households and farmers selection was based on stratified approaches.

The team proposed a purposive sampling method at all levels to capture suitable sites currently undergoing the Asian Green Revolution (AsGR) and excluded agriculture favorable areas as outliers and focused only on average to above-average rainfall and access to market areas in the selected countries (Djurfeldt *et al.*, 2011; Djurfeldt *et al.*, 2005). The result from the analysis of the Ethiopian case, however, revealed the sampled households are *better than average* (Appendix B). Therefore, the AFRINT surveys are not representative of households that are *average* or *worse than average*, and cannot be referred as *typical households* in the context of Ethiopia. Most of these farmers responded that their production was affected by the varying rainfall condition during harvest seasons and, like many smallholders in developing countries (Woodhouse, 2010), due to the distance they are situated from market places (AFRINT Database, 2011).

Unlike the AsGR which focused highly on the demographic factor, the AFRINT built its foundation on assessments of economic and political factors to study the potentials and prospects of AfGR. The project specifically focuses on the mostly produced and consumed staple-crops in the sampled countries based on the assessments of potentials ( first round) and challenges of the selected staple-crop intensifications (second round). In 2002, the priorities were on production volumes rather than prices and incomes, and the institutional environment for technology adoption was also a crucial component of the survey. While in 2008, the aim was a follow-up of the first round and analyzing the changes or gaps in staple-crop production with the help of selected variables. Systematic data collection schemes have been conducted for the sampled households to assure cross-sectional representativeness of the data in both rounds (Djurfeldt *et al.*, 2011; Djurfeldt *et al.*, 2005).

Accordingly, the team investigated the huge yield gap (i.e. the difference of potential and actual mean productions per hectare) of staple-crops. The proposed agro-ecological techniques were underutilized and farming operations merely support the livelihoods of smallholders. The comparative analysis

between 2002 and 2008 reveals a general decrease in farm sizes in all case countries and its distribution is uneven among smallholders. High crop values, such as Teff in the case of Ethiopia, took the attentions of few with better output in 2008 than in 2002. Some staple-crops, such as sorghum, have a significant low production per farm in all case countries, others (such as maize) show a variable trend of production per farm (AFRINT Database, 2011; Djurfeldt *et al.*, 2011; Djurfeldt *et al.*, 2008; Djurfeldt *et al.*, 2005).

Djurfeldt *et al.* (2008) argue that the importance of focusing on small scale farmers, not only as a viable strategy to reduce poverty and improve their livelihoods, but also for economic growth of the nation in the end. The authors defined agricultural dynamism to explain the yield increase not by expanding farming areas (extensification), rather through intensification. They used variables such as farm size, roles of staple-crop productions, and non-farm household incomes, to describe the agricultural dynamism in the study countries.

### *Relevance to Ethiopia*

The long and aged history of agricultural civilization with varying farming techniques, topographical situations as well as being a classic-aid recipient of Swedish Aid are the main criteria that made Ethiopia one study site for AFRINT team. Moreover, according to Djurfeldt *et al*. (2011), such series of panel data are important to understand the agricultural dynamism in a country like Ethiopia, where the attrition rate is exceptionally low (0.6% in 2008) when compared with other case countries (overall 20.6% in 2008). In the context of this thesis, attrition rate is the measure of the decline of smallholders from their farming activities, either by quitting farming, shifting of livelihood means, or death. These factors show the degree of livelihood stability of smallholders and are important to consider for series of studies.

One aim of the team is to assess the existing agricultural practices and quest to integrate these with modern approaches to improve production. According to the country level report for Ethiopia by Amha *et al.*, (2009) and Amha (2011), agricultural marketing is one stimulus on agricultural production. It plays two important roles in rural and economic development strategies in Ethiopia: with appropriate marketing services, it ensures high prices for producers and affordable prices to consumers. Hence, it is a medium to bring the producers, dealers, and consumers in contact with various time and space dimensions. Despite to some improvement in the marketing systems, there is still high potential and need for strategic interventions with regards to agricultural development in Ethiopia. In most parts of Ethiopia, farmers produce the most valuable cash crops (i.e. Teff and Wheat) and put these to market for the urban community; and in return, buy other staple-crop (i.e. Maize and Sorghum) for household consumptions.

The variability in yield production among smallholders in Ethiopia, according to the AFRINT team, could result from: the high-cash value of the staple-crops that stimulated many households to engage in production (Teff); decline of the total cultivated area (maize); the decrease in both the yield and harvest areas (Wheat); and, the arid nature of the area and the recurring bad weather conditions (Sorghum) (Djurfeldt *et al.*, 2011; Amha *et al.*, 2009). These results on these staple-crops could lead us to think about the importance of timely climate information outreach to smallholders in order to improve their farming operations and productivity. As pointed out in Figure 1, lack of advisory services on market conditions are the other major constraints that hinder many households from knowing what and when to sow (based on demands and seasons) (Salinger *et al*., 2000); which agro-ecological techniques to practice (for yield intensifications based on the existing situation) (Roncoli *et al*., 2009); when and how to harvest and dry; and in the end, when to supply it to market through appropriate means (Helms, 2007; WMO, 2007).

### 2.2. Improved agro-ecological techniques

The AFRINT team proposed 18-lists of improved agro-ecological techniques (Appendix A), which most of them played important roles during the AsGR in the 1960s. This thesis assesses the knowledge and practice of all these improved agro-ecological techniques in the study areas and considered 16 of the techniques for further analysis. These challenges to exercise the techniques vary from adaptation to climate variability, for instance *shortage of water* to other conditions related to knowledge such as the *not knowing* or *not exposed* to the techniques.

### 2.3. Climate Information

In the context of this paper, climate information is about increasing the adaptive capacity of actors at all levels engaged in the agricultural sector and constitutes timely weather and climate information that support smallholder farmers to adjust their farming operation and flexible decisions accordingly. These adjustments broadly categorized under three parts: agricultural advices on *weather and climate conditions* of the growing season, *technical and technological* inputs (extension services and access to ICT) on farming operations and *production decision* makings (related to market conditions) (Figure 1).

Some of these operations include the selection of seed types and when to sow, when and what kind of agro-ecological techniques to apply, and when to harvest and to channel the product to market based on the characteristics of the growing season (Salinger *et al.*, 2000). For the realization of climate information, ensuring enabling policy frameworks that put smallholders at the core, cooperation

between actors at all levels and technology diffusions to smallholders is unavoidable (Djurfeldt *et al.*, 2011; Josh *et al.*, 2003).

Climate change highly affects farmers in SSA as their livelihood is highly dependent on rain-fed mechanisms (WMO, 2001). In line with this, the World Meteorological Organization (WMO) suggested some adaptation mechanisms including: regular weather/climate advisories on farming, production and cropping systems and appropriate operational adjustments; on-line disseminations of climate information both in time and space dimensions; advising on the effective usage of seasonal forecasts on local, regional, national and international extents; promoting sustainable development through cooperation in bottom-up approaches; and most importantly, promoting climate information for socio-economic purposes and integration of socio-economic aspects with climate change impacts and vulnerability assessments (WMO, 2009; WMO, 2007).

A case study in Burkina Faso pointed out the difficulties faced by African smallholders to adjust their farming management strategies and practices in line with the available climate information, primarily due to lack of improved agricultural inputs, technology and institutional supports such as lack of land, man power, improved seed varieties, credit supports, and access to market and technical information from experts (Roncoli *et al.*, 2009). The study also underlined the considerable potential of climate information for the underserved to improve their agricultural production and food security, especially in arid and semi-arid areas where livelihoods are highly dependent on rain-fed mechanisms. Strengthening the resilience of households in these areas for any climate shock and its mitigation requires effective use of updated climate information. According to the study, information is inherent to the social dimension and is a fluid element that flows in the dynamic information environment to support the agricultural decision-making process, rather than being a simple technical concept. This environment constitutes the collective experience of rural producers, their empirical observations of the natural landscape, their cultural understandings of risk and uncertainty, and their networks of social relations and institutional linkages.

Comprehensive case studies by the International Food Policy Research Institution (IFPRI) across several developing countries of Africa and Asia confirmed the need for policy, land and infrastructure reforms, agricultural technologies development, and effective dissemination of climate information to the general public, smallholders in particular (Josh *et al.*, 2003).

Dzanku *et al.* (2011) also emphasized that the development of *hard* and *soft* infrastructures are necessary for diversification into self-sufficiency. Moreover, regular access to agricultural extension advice on improved agro-ecological techniques, participating in knowledge sharing workshops and being a member of farmers' associations at local levels is likely to increase staple-crop productivity through technology diffusions that accounts for the households' ability to meet its food requirements.

## 2.4. Role of actors

The proclamation 147/1998 of the Federal Democratic Republic of Ethiopia (FDRE) on cooperatives states:

> *"…it has become necessary to establish cooperative societies which are formed of individuals on voluntary basis and who have similar needs for creating savings and mutual assistance among themselves by pooling their resources, knowledge and properties; … has become necessary to enable cooperative societies to actively participate in the free market system."* (FDRE, 147/198)

Moreover, section 3 of the proclamation details the objectives of the established society: improving the living conditions of its members; promoting self-reliance among members; solving problems collectively; obtaining ICT means for its members; processing and mobilizing agricultural products; promoting teaching and training for its members (FDRE, 1998). In addition to this proclamation and the amended version following it on cooperatives (2004/402), the GoE promotes the right for actors to form associations at all levels and tie-up each other for a coordinated development works, such as in the agriculture sector.

According to the UN (2010), transfer of technology can basically occur at two levels. The first means are through the transfer of tacit know-how and skills between people internationally, regionally, nationally or between organizations. The other option is through increased specialization in the trade of raw materials and finished products which are causing a shift in production to locations that have economic advantages in many sectors, including agriculture. Both forms require a thorough investigation and exchange of researchers, with actor coordination at all levels, as to how local production could take part in the global production chain. The first form is recognized as the most effective form of technology and skills dissemination. The focus of this paper is to identify the main actors participating in the existing agro-ecological knowledge flow.

### *2.4.1. Niche-levels*

The definition of actors falling under this category is adopted from MoFED (2002). Accordingly, this level constitutes a person or group of persons, irrespective of whether related or not, who live together in the

same housing unit or group of housing units (neighborhoods) who have similar modes of living. In the context of this thesis, the nature of actors at the niche-level is characterized by the comprehensive relationships existing within households and between fellow farmers in a village. These range from passing on knowledge of specific farming practices within families to sharing of positive experiences between fellow farmers.

In reality, most of these actors are at the grass-root level and have limitations on their capacities and means to secure production beyond the needs of feeding their own family. The limitations range from lack of knowledge of improved agro-ecological techniques to difficulties of practicing them during harvest seasons. The gender factor in the management of both the household (i.e. as head) and farming operations is highly skewed towards men. In the 2008 survey shows, 17% of women were recognized as household heads and only 10% of women manage farming operations (AFRINT Database, 2011).

Moreover, the mechanisms for accessing or reaching information from the higher levels of actors are missing, leaving them isolated from the chain. These groups of the complex chain should be updated with information about the latest weather and climate information, improved farming practices such as farm-inputs, improved seeds, and fertilizer application. Moreover, making the financial services within their reach is a viable instrument in helping smallholders to break through the poverty cage and ensure food security (Amha, 2011). This leads to, according to Djurfeldt *et al*., (2011), increased household production, productivity, employment, income, consumption and empowerment of the underserved.

It is also important to recognize some of the smallholders' long-years of farming skills and integrate them with scientific techniques not only to improve their productivity but also as a recommended approach to cope with the changing climate. These skills of farmers should be linked with outputs of scientific research and policy makers to allow them learn from and build on the farmer innovations (FAO, 2012).

### *2.4.2. Micro-levels*

This refers to extension officers, farmers' associations, village level cooperatives, low-income entrepreneurs, and agro-processors who work close with smallholders to improve production and productivity at the household level. Farmers' associations refer to the lowest administrative units in a settled rural area with its own jurisdiction. These are associations of rural dwellers formed by villagers whose members are engaged either in agricultural and/or non-agricultural activities (MoFED, 2002).

In most developing countries such as in SSA, the biggest challenge of actors at this level is the limited support for appropriate capacity building programs from government, NGOs, financial, and academic

institutions (Djurfeldt et al., 2011). Extension officers, irrespective of their affiliation, must be acquainted with the most recent updates on improved agro-ecological techniques. The capacity building programs range from officers' self-awareness to the arrangements of infrastructure facilities to make households reaching and tracing possible. Empowering farmers' organizations through collective actions strengthens family farmers (at niche levels) with ranges of benefits including in key areas of AIS. According to the summary of FAO's e-mail conference on AIS and family farming, acknowledging farmers' organization to fully integrate AIS should be the concern of policy makers in rural development strategies (FAO, 2012). Therefore, making arrangements and diffusions of technology options to actors at this level is crucial for channeling the right information to the right target with the right means at the right time.

### *2.4.3. Meso-levels*

These actors are the most influential stakeholders in the context of Ethiopia. They are characterized by offering the most organized and accessible financial services to smallholders as well as to their associations (Amha, 2011; Amha et al., 2009). Some of these include credit bureaus, specialized consultancy firms, rating agencies, specialized auditors, training providers (at university level), certifying institutions and technical providers, organizations specialized in the whole sale funding and liquidity-pooling facilities and IT companies. The authors emphasize on the well-functioning meso-level actors in Ethiopia to improve the financial and the logistic needs of smallholder farmers. So far, very limited financial infrastructure reaches the poor and hence, their opening is important to the financial needs of the niches.

Establishing these functioning institutions not only secures the financial needs of niches, but also ensures financial confidences through affordable available technology options (Amha, 2011). These technology choices help farmers connected to the updated climate and market information of the growing season, with the sources of actors providing the information. One of these mechanisms to secure financial services to smallholders could be loan options as a means to having access to ICT (UN, 2010). To make the supports sustainable, these functioning institutions should go through their human, financial, and infrastructure capacity building routines with supports from the actors at higher levels such as from the GoE, NGOs, donors and other partners working at the national level (Djurfeldt *et al*., 2011; Helms, 2007).

### *2.4.4. Macro-levels*

The key actor at this level is the GoE which is characterized by the creation and outreaching of development policy strategies, legal and regulatory frameworks, capacity and infrastructure building for

institutions, organizations, cooperatives and associations all the way down to the grass-root level. The other actors at this level include the Central Bank of Ethiopia (CBE) which regulates all the financial flows in the country, National Meteorological Agency (NMA) of Ethiopia working under the Ministry of Water and Energy (MoWE), Agricultural and Rural Development Bureau (ARDB) working under the Ministry of Agriculture (MoA), Environmental Protection Authority (EPA). The Ethiopian Telecommunication Corporation (ETC) and Ethiopian Commodity Exchange (ECX) also play important roles for the implementation of policies.

These actors established partnerships among each other as well as with the lower level governmental offices, NGOs, and cooperatives working at national, regional, zonal, and local levels, even to households in some cases. One of such responsibility should be the understanding of the viability of climate information and its effective means of dissemination to smallholders. Such an understanding requires a platform for the provisions of ICT options to smallholders as well. These two tasks are not fully implemented in Ethiopia, hence the need to carry out this thesis and call on actors to take the initiative for the kick-off. Some of the actors at this level have the understanding of climate information, others have the finance means, and the rest engage in developmental works with smallholders. Hence, these actors should coordinate with each other for effective outsourcing of climate information to smallholders. For instance, NMA is the main source of climate information in Ethiopia and ECX has been recently laying the foundation to disseminate market and commodity exchange information directly to smallholders on a regular basis (ECX, 2009).

NMA is the sole provider of weather and climate related information in the country (NMA, 2012). The agency is responsible for timely regular seasonal weather and climate updates to the general public. The agro-meteorology department of NMA regularly disseminates reports based on a ten-daily, monthly, and seasonal (*Belg, Kiremt and Bega*) weather and climate scenarios to support farmers in their agricultural operations. These updates are important to assist planers, decision makers and other end-users to effectively mitigate the risks associated from the adverse effects of climate change and for maximized yield in the country. The bulletins are also vital to monitor the weather conditions of the growing season which have implications for the appropriate adjustment of the preparations of farming activities.

ECX is a new entity working under the federal GoE with the vision to unbind the traditional agriculture system by creating a new marketplace to serve all market actors including smallholders, traders, processors, exporters and consumers. In her Technology, Entertainment and Design (TED) speech, Dr. Eleni (founder and former CEO) underlined that ECX is the first partnership in Ethiopia that brings

together market actors, members of the exchange, and the GoE (TED, 2012). She added that ECX represents the future of Ethiopia which shows the need to create a networked working environment to ensure integrity, security, and efficiency to the market as well as to other forms of development activities in the country. ECX creates opportunities for unparalleled growth in the commodity sector and linked industries, such as transport and logistics, banking and financial services, and others. Most Ethiopian farmers are *small* both in terms of the lands they cultivate and the capital investment they allocate for their agriculture activities. Acknowledging the broad contributions to the economy of the country, ECX devised means to outreach market information to the grass root level in Ethiopia by establishing local internet cafes in the vicinity of farmers. Extension officers, agents, and civil society working at local levels can have easy access to such information as part of the advisory lists of services to smallholders in the area.

The Rural Development Strategy (MoFED, 2002) of Ethiopia states:

> *"Our agricultural production can achieve rapid and sustainable growth if it is based on producing more than the producers' own consumption and supplying the difference to the market. The life of the farmer can be continuously improved if he is able to produce at this level, sell his products and purchase ever-increasing volumes and types of commodities and services."* (MoFED, 2002)

It is clear to see that the policy direction to achieve economic growth is through the commercialization of smallholder agriculture. Dzanku *et al.* (2011) defined these policies and institutions as *soft*-infrastructures. They are the key entities that facilitate the financial needs of smallholders when effectively combined with the *hard*-infrastructures. The authors defined *soft*-infrastructure as institutions that facilitate market transactions, while *hard*-infrastructure is the physical facilities (e.g. roads). These infrastructures ensure the possibility of ownership and access to ICT options among smallholders. Having these platforms in place, smallholders are channeled to the updated climate and market information which has implications for their livelihood routines. Establishing these infrastructures is the responsibility of a state, such as the GoE.

In many respects, a country should work in collaboration with international organizations, NGOs, and cooperatives to meet these goals. By doing so, it advances its economic growth, securing the welfare of its citizens and establishing transparent institutions and policies. The next section discusses the role of these actors in the international domain.

### *2.4.5. Exo-levels*

Actors at this level include individual or groups of international organizations, communities and civil societies, NGOs, and donors that work with individual countries as a development partner. With the prospects of climate information, financial, and infrastructure supports, the discussion for this section focuses mainly on publications from WMO and outcomes of conferences and summits, for instance from the most recent G-8 summit held in Camp David.

WMO is a specialized agency of the UN and since its establishment in 1950, it has an authoritative voice on the state and behavior of the Earth's atmosphere, its interaction with the oceans, the climate it produces, and the resulting distribution of water resources. As weather, climate, and the water cycle cross-boundaries via nature, international cooperation at a global scale is essential for the development of meteorology and operational hydrology as well as to reap the benefits from their application (WMO, 2012). WMO calls for its member states to engage in international cooperation in the production and effective disseminations of climate information. Immense support has been given to its member states by providing meteorological related services to their national needs, including life and property protections, environmental safeguarding, and contributions to sustainable development programs (WMO, 2009; WMO, 2001). Through its Climate Information Prediction Services (CLIPS) program, for instance, WMO promotes the socio-economic well-being of communities, placing high emphasis on the agricultural sector in order to support the land and water management tasks. The agricultural meteorology program of WMO aims to promote economically viable and high quality production for sustainable development by harmonizing indigenous knowledge with meteorological services (WMO, 2007). This specialized program also fosters the understanding of use and values of climate information for services in planning and operational activities by end users, such as farmers (Stigter, 2010).

At the 38$^{th}$ Camp David Summit held from 18-19$^{th}$ of May 2012, the G-8 states and African leaders showed commitment to the New Alliance for Food Security and Nutrition, which is the next phase of the shared commitment to achieving global food security (NAFSN, 2012). The summit underlined the recognition of and ready to support the critical roles played by African smallholder farmers, especially women, in transforming agriculture and building thriving economies for the nation. Some of the shared values are to drive effective country plans and policies for food security, to strengthening role of private sector partners to increase investments where the conditions are right, and the commitments of the G-8 to expand Africa’s potential for rapid and sustainable agricultural growth.

## 2.5. Development and Disseminations of ICT

The United Nations (UN) acknowledges the contributions of smallholders to their country's economic growth and emphasized the creation of an enabling environment for technology and innovation focusing on smallholder farmers to effectively address the agricultural development constraints. The model put farmers at the core of the web of interactions and extends actors' roles, as well as multi-dimensional soft and hard-infrastructure facilities, from local to global scales. Isolating smallholders from such an environment limits their resilient capacities and make them susceptible to internal and external shocks. Moreover, focusing on smallholders must be ensured through networking all actors with the available technology options. This guarantees resources for building a complex multidimensional and dynamic range of knowledge, skills, actors, institutions, and policies designed to transform knowledge into useful processes, products and services to smallholders, and the agriculture sector in general (UN, 2010).

International cooperation is a stronger factor for the adoption, adaption and diffusion of new technology options into developing countries, such as Ethiopia, to benefit smallholder farmers' operations. The South-South cooperation is one such mechanism aimed at supporting African smallholders. The other option is the triangular cooperation in which case a country from the north agrees to support the South-South technology sharing efforts (UN, 2010; Roncoli *et al*., 2009).

ICT options can be used to reduce gaps in technical knowledge and capabilities, and in the maintenance, protection and continued use of indigenous knowledge for the management of natural resources (IISD, 2011). Isinika *et al.* (2011) highlighted the recent technology diffusions in Tanzania where mobile penetration and usage by the rural community is about 30% with a 10% annual increase between 2006 and 2009. These percentages increases lead up to a 1.2% rise in per capita GDP of the country. One such example of the mobile services widely used by the rural community is the Nuru-SMS platform, similar to Sokoni-SMS service of Kenya.

Case studies by IISD (2011) across three African countries (Uganda, Senegal and Malawi) show that ICTs are important options to strengthen the meteorological related data collection routines and fostering view gaps between indigenous adaptation techniques and new scientific knowledge. Moreover, the case studies emphasize on the need for the use of ICT for adaptation through the introduction of supportive policies, the developments of technical capacities and applications of updated technologies for monitoring, alert-mapping and information generation. ICTs also facilitate the sharing of research outcomes and successful community experiences. ICTs also play crucial role in coordinating actors at all

levels to avoid duplications, improve the availability of information, build capacities of individuals and institutions, and develop and share knowledge among stakeholders.

The report by Deloitte (2012) on case studies in Egypt, Kenya and Zambia suggest private sector partners and donors participation in the rural development strategies as an important agricultural policy instrument; agricultural hub as a way of strengthening the relationships between all actors for better outcome – i.e. full and sustained commitment from all the partners, including those "on the ground"; diffusions of ranges of technology options to sustain the agricultural routines than to overreliance on limited technology means; planning for ICT infrastructures, end user trainings, design and implementation of systems, on-going maintenance and supports; and, immense commitments to get projects off the ground with proper planning of the financial and any necessary legislation or regulations in place.

These facilities account for the increase access to information sharing for various purposes such as updated climate information and market conditions. The case studies also demonstrate farmers' need for quality services, such as reachable extension services, timely weather and market updates, and result oriented research outputs to optimize technology use and market opportunities.

### 2.6. Policy frameworks

The fundamental development strategy of the GoE is building a free-market economic system in the country that ensures rapid economic development, extrication from dependence on food aid, and poor people to be the main beneficiaries from economic growth (MoFED, 2005; MoFED, 2002). Specific to the agriculture sector, increasing agricultural production and productivity and ensuring food security are the key objectives of policy development strategies and programs in Ethiopia (Djurfeldt *et al.*, 2011; IMF, 2011). In its prominent economic policy and development strategies (IMF, 2011; MoFED, 2010; MoFED, 2005; MoFED, 2002), the GoE distinctly situate itself between the two camps on development in agriculture (Section 1.1) in three ways.

First (*inclining to the agricultural development ideologies of the WB, IMF and the likes*), the policy promotes industry-led and large scale commercialized agriculture reforms in the country as the only viable economic development strategy. This includes production of high value crops through improved agricultural techniques with large-scale farming schemes, with immense financial supports from the international community (MoFED, 2002; MoFED, 2010; IMF, 2011).

Second (inclination towards the *New left* camps), the GoE advocates deepening and strengthening the decentralization process. By doing so, it aims to create a participatory decision-making system, taking the lowest level actors (smallholders, in particular) as part of the domain for improved responsiveness and agricultural service delivery. In this regard, the government promotes coordination between actors in the broad-based development strategies and policies of the country in order to effectively overcome poverty. Moreover, the GoE unbound the decentralization of tasks and responsibilities from regional governments to Woredas and Kebeles. In its ambition to achieve the pro-poor growth strategy, the GoE also addresses the issues of dependency on rain-fed agriculture, which requires promotion of improved agro-ecological and farming operations such as small-scale irrigation scheme, water harvesting and formulating incentives to smallholders. The government is committed to taking the leading role on the pro-poor outcomes which result from such pro-poor strategies and stimulates other development partners to take part in the growth process that promotes decentralization, participation and ownership of resources. The later could be achieved from the decentralization of functioning units to the lower levels and through a participatory based consultation with locals and civil societies (IMF, 2011; MoFED, 2010; MoFED, 2005; MoFED, 2002).

Third (*mixing the ideologies of both camps*), the government prioritized agricultural research in support of improved farming operations to smallholders, such as menu based extension packages to enhance farmers' choice of technologies, water harvesting techniques, small scale irrigation, and increased water resource utilizations to ensure food security in the country as key policy instruments. The GoE acknowledges public, private, NGOs, donors and other stakeholders' as important developmental forces and partners (MoFED, 2005; MoFED, 2002).

# Part-III: Analysis and Result

The approach to assess knowledge and practice of improved agro-ecological techniques is based on the possible scenarios drawn in section 1.5.2 (Table 2). Specifically, households with the first (*High, High*), third (*Low, High*) and fourth (*Low, Low*) categories are excluded from consideration. Based on this assumption, the result from the analysis of knowledge and practice levels of agro-ecological techniques excluded Integrated Nutrient Management (INM) and Integrated Pest Management (IPM) from further analysis mainly because smallholders have better practice than knowledge of these techniques (not shown in Figure 4). That is, these two techniques fall under the (*Low knowledge*, *High practice*) categories of Table 2. Hence, these techniques are excluded from the analysis. Moreover, with the remaining 16 agro-ecological techniques, it is clear to observe that knowledge levels always exceed the practice schemes (Figure 4) and the percentage difference is always positive. In each of the plots, N/K/P refers to the total number of respondents that responded for the particular question.

For the 16 agro-ecological techniques, the *gap* between knowledge and practice is observed at varying scales. The most pronounced differences observed with Irrigation (K=98.3%/N=475 and P=5.3%/N=474), Rainwater harvesting (*K=85.7%/N=475, P=3.6%/N=439*), Fallowing (*K=89.1%/N=475, P=26.4%/N=474*) and Intercropping (*K=66.9%/N=475, P=14.7%/N=407*). The percentage differences between knowledge and practice (i.e. *K-P*) levels for the remaining agro-ecological techniques vary between 45.2% (for Pesticides) and 3.2% (for Improved fallowing).

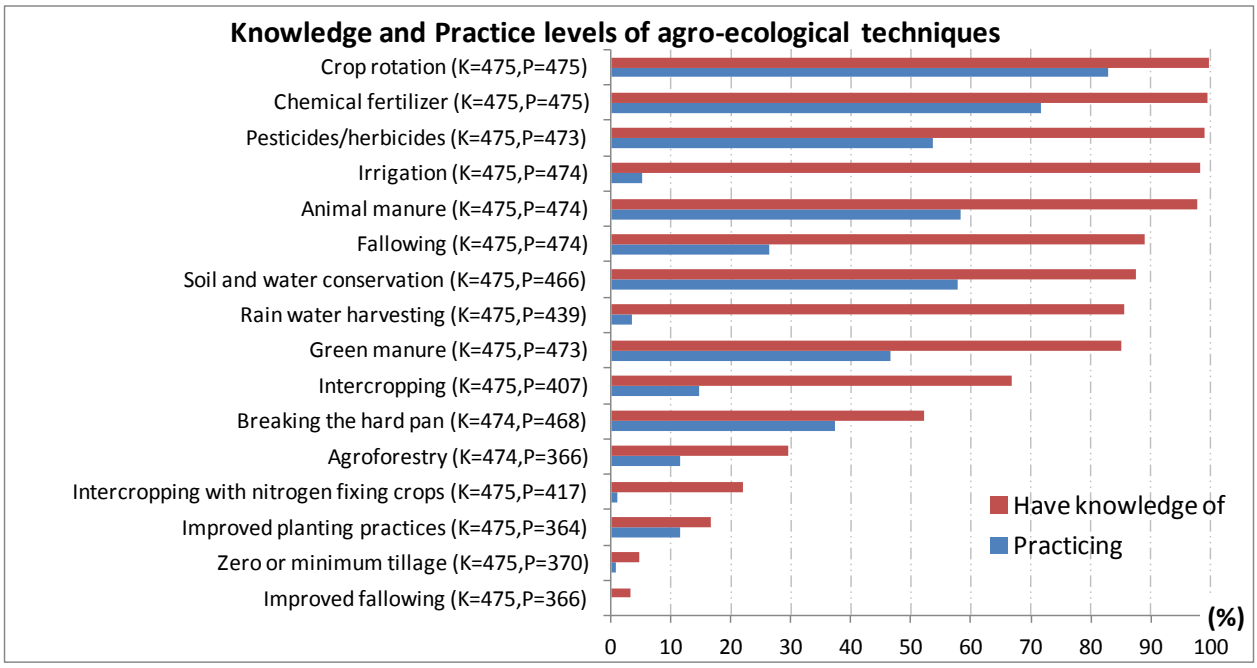


**Figure 4.** Knowledge and practicing levels of improved agro-ecological techniques in Ethiopia. The blue bars show the extents of practice and the reds show those smallholders who have knowledge of the particular techniques but never practiced it before. (*Source*: AFRINT Database, 2011)

Note on Figure 4 that, the sum of households' responses to knowledge and practice do not add to 100%. This could be easily explained with number of households that responded to the surveys. In many of the cases, some households didn't wish to respond. Moreover, for the gap analysis, the AFRINT survey included 16 factors (Appendix B) including the two reasons *"don't know"* why they don't practice the techniques and *as* "*Not applicable"* for reasons that the households don't want to say it.

Based on the assumption set earlier, the gap analysis deals with identifying the main factors that could account for the difference between knowledge and practice of the improved agro-ecological techniques (Figure 5). Of all the proposed agro-ecological techniques, the gap analysis between knowledge and practice for nine of techniques are related to the *level of exposure* to the techniques before. These techniques include Zero or minimum tillage (36.6%/N=325), Agro-forestry (33.2%/N=252), Improved planting practices (32.9%/N=356), Improved fallowing (32.8%/N=357), Intercropping (27.3%/N=406), Breaking the hardpans (25.5%/N=462). Significant number of farmers responded as having a shortage of water to practice Rainwater harvesting (23.8%/N=429) and Irrigation (21.1%/N=473) techniques.

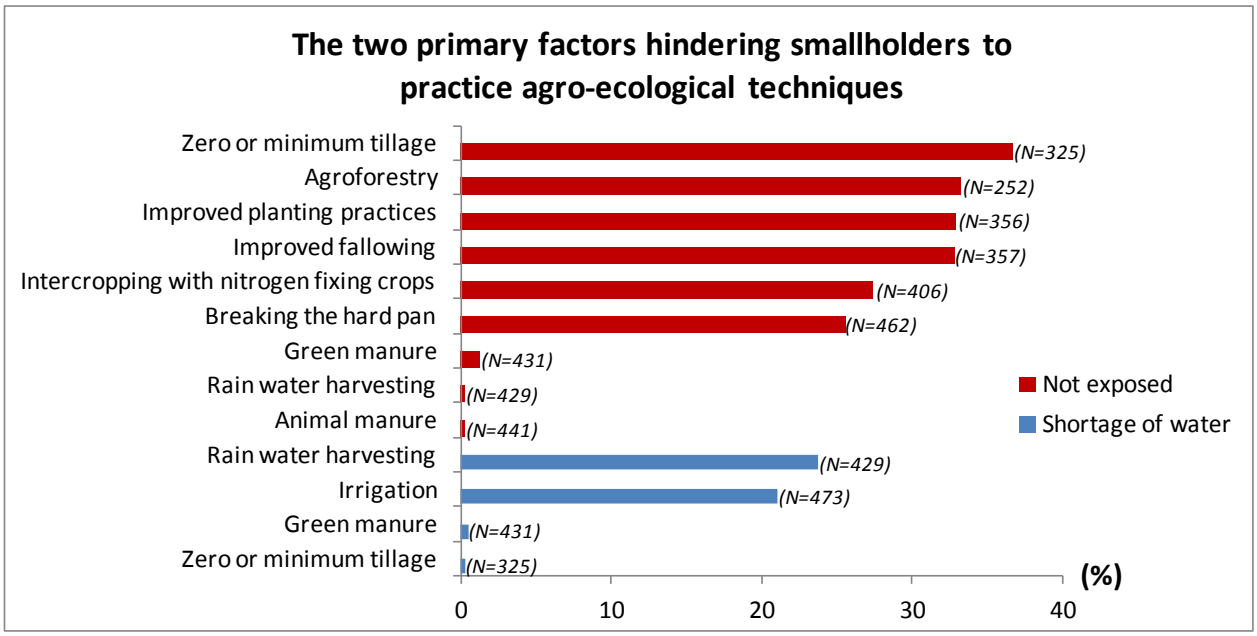


**Figure 5.** The most determining factors to practice improved agro-ecological techniques.
Lacks of Exposure/not knowing and water shortage are the two main reasons constraining smallholder farmers in Ethiopia from practicing the improved agro-ecological techniques identified in Figure 4. The bottom 3 show failure due to water shortage and the top rest show reasons due to lack of exposure/not knowing the techniques at all. (*Source*: AFRINT Database, 2011)

The other aspect of the analysis deployed in this thesis is investigation of the source of knowledge to the agro-ecological techniques. The analysis identifies three main actors that are common sources for

knowledge of the agro-ecological techniques. These are *family members*, *fellow farmers* and *extension officers*. Accordingly, the sources of information for the majority of the techniques are family members. For instance, source of knowledge for 13 out of 16 techniques are family members. More specifically, knowledge sources for Crop rotation (80%), Soil and water management (41%), Breaking the hard pan (35%), Animal manure (33%), Green manure (33%), Fallowing (24%) and Chemical Fertilizer (24%) were family members. Extension officers put their efforts to transfer knowledge for 5 out of the 16 techniques. These are, Intercropping with Nitrogen fixing crops (47%), Animal manure (36%), Zero or minimum tillage (19%), Soil and water conservation (14%) and Rain water harvesting (13%). Fellow farmers have contributed to share knowledge of Animal (7%) and Green (1%) manure, Soil and water conservation (2%) and Fallowing (1%) (Figure 6). In many parts of the world, extension officers play, and also expected to, a significant role in passing information and getting directly involved in the operations of farmers to improve production (UN, 2010). Ethiopia is no exception to such services. However, the result from the analysis reveals, the contributions of extension officers as a source for knowledge transfer to smallholders is not promising.

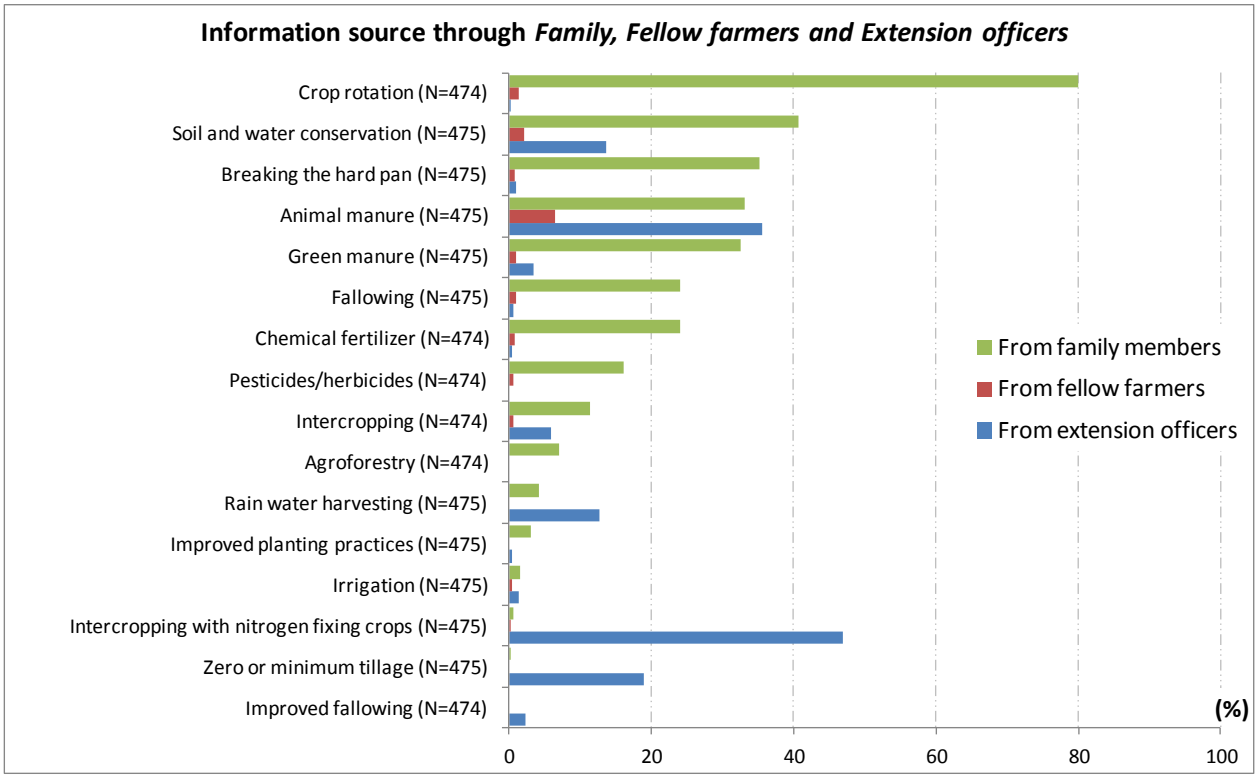


**Figure 6.** Knowledge of agro-ecological techniques through *family*, *fellow farmers* and *extension officers*. Of these three, the extents of knowledge transfer from family take the dominant portions (green bars) than from extension officers (blue bars) and fellow farmers (red bars). (*Source*: AFRINT Database, 2011)

One factor that accounts for the poor knowledge and skill contributions of extension officers to smallholders in Ethiopia, as elsewhere in many developing countries too (IISD, 2011; UN, 2010), is the affiliation where the extension officers are from. The next analysis focuses on the origins of institutions, *i.e governmental or non-governmental organizations*, which take the role of extension services to smallholders.

In the case of Ethiopia, extension officers are commonly affiliated either with governmental or non-governmental organizations. Knowing these divisions of extension services make the interventions for capacity building (in all forms of resources – human, material, financial, etc) easier.

Accordingly, the result of this particular analysis justifies that government related extension services are better-off than non-governmental supports. More specifically, 8% of farmers experienced *regular* visits, 70% of farmers had *rare* visits and 22% of farmers *never* experienced visits from extension officer that are affiliated to governmental institutions. On the other hand, *none* of the smallholders experienced *regular* visits of extension officers from non-governmental offices. However, 3% of the smallholders had *rare* visits and support from NGOs sources. The majority of the farmers (97%) had *no* visits of extension officers from NGO sources (Figure 7).

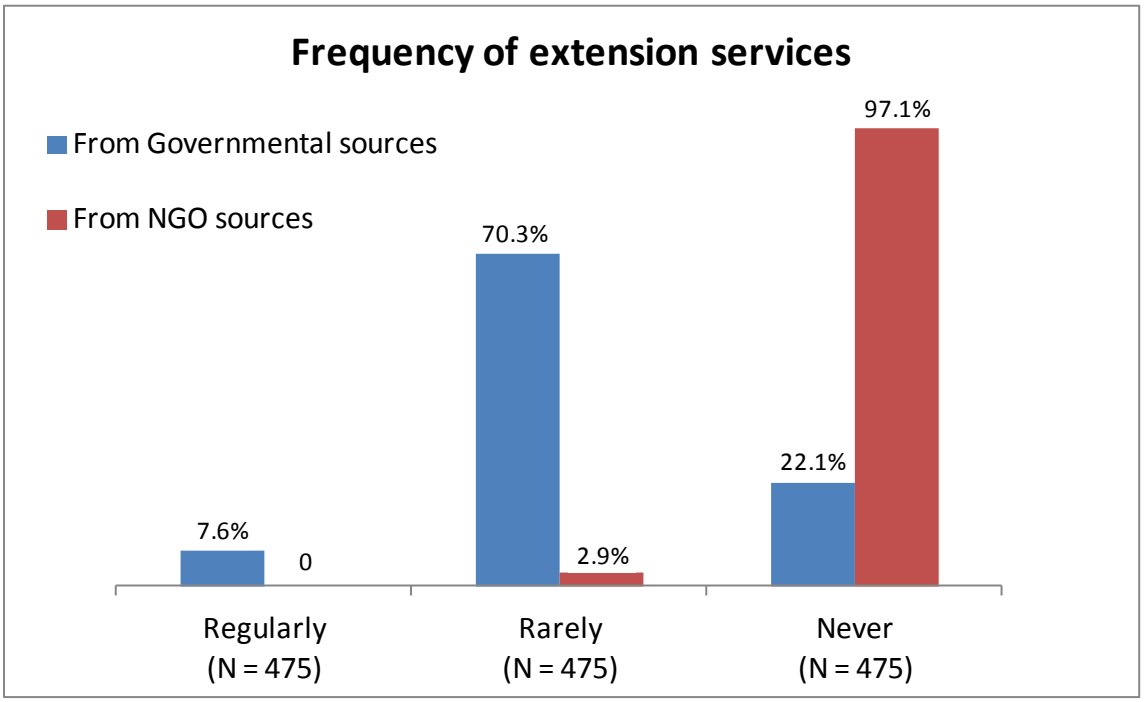


**Figure 7.** Frequencies of extension services from governmental and non-governmental sources. Extension services/officers from government (blue bars) have supported farmers better than the NGO (red bars) sources. (*Source*: AFRINT Database, 2011)

Knowing the most common sources of extension services in Ethiopia, it is also worth assessing the ICT access by smallholders. Such analysis is important as access to ICT infrastructures play crucial roles for knowledge transfers to smallholders. Accesses to ICT options are one means of channeling the available climate information from the source (Sulaiman *et al.*, 2012) and to help smallholders receive updated information on time (WMO, 2007; Salinger *et al.*, 2000).

The AFRINT team assessed as many fixed and stationary assets as smallholders might have including Wired electricity/power, Mobile or Stationary telephone, Diesel Power Generator or similar, Water Pipe to house, TV-set, Radio, Tape recorder, Bicycle, Sewing machine, Kerosene stove or other modern stoves. The analysis for the access to ICT only considers assets that have direct implications to ICT, most commonly known and used ICT sources among smallholders of Ethiopia including access to *Radio, Tape recorder, Wired-electricity/power, Mobile/stationary telephones* and *TV*. The result of the analysis reveals smallholders in Ethiopia generally have significantly low or no assets of or access to these ICT options (Figure 8). The most common ICT options among smallholders is access to Radio (37%), while none or very few farmers possess TV (less than 1%) or Mobile phones (4.2%).

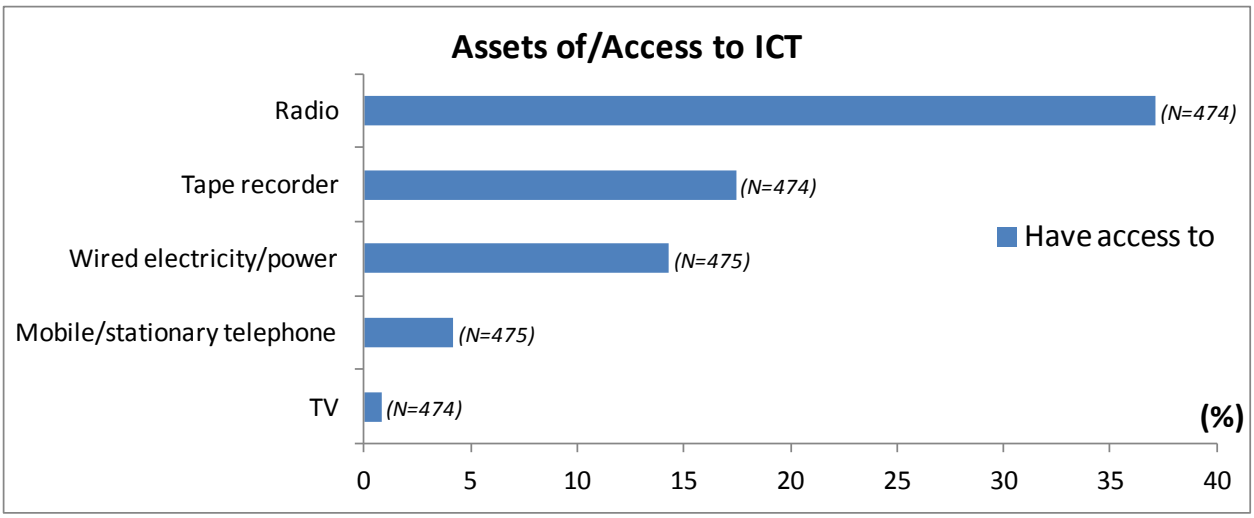


**Figure 8.** Assets of and/or access to ICT options among smallholders

These options play crucial role for timely information disseminations purposes. (*Source*: AFRINT Database, 2011)

# Part-IV: Discussions, Recommendations and Conclusions

## 4.1. Discussions

It is important to investigate the existing realities among smallholders for any positive changes in the outcome of their livelihood. One such analysis, which is the focus of this paper, is to investigate the existing knowledge and current practices of improved agro-ecological techniques among smallholder farmers in Ethiopia. Exploring the roles of actors and ICT options in strengthening the gaps of knowledge and practice are also pivotal. The following sections discuss the results obtained from Part III of this thesis and to answer the research questions of the thesis in their orders set in Table 1.

### *4.1.1. Knowledge and Practice*

The results on knowledge and practice of agro-ecological techniques reveal 11 out of 16 of the techniques are barely practiced (Figure 4). In all the 16 techniques, smallholders are aware of the techniques but have practicing limitations to the majority of them during harvest season. More specifically, out of the total number farmers surveyed, 5.3% of smallholders who are aware and also practice irrigation while 93% of these households know the technique, but never practiced it before. In similar talking, 82.1% (Rainwater harvesting), 62.7% (Fallowing) and 52.2% (Intercropping) of farmers know the techniques, but never practiced it before. The percentage difference between knowledge and practice (as for instance 3.2% for Improved fallowing), doesn't mean that the technique is highly known and practiced. As can be seen from Figure 4, Improved fallowing, Zero tillage, Improved planting and intercropping with Nitrogen fixing crop are among the least known and practiced group of techniques.

The implication of such results is that smallholders' productivity is affected by knowledge (such as for Improved fallowing, Zero tillage, improved planting techniques) and other constraining factors not associated with knowledge (such as Crop rotation, Chemical fertilizers, Pesticides, Irrigation, Animal manure few to mention). Before jumping to the investigation of these factors that constrain smallholders from practicing these techniques, it is important to understand what is mean by knowledge, information, and practice of agro-ecological techniques, as well as climate information in the context of this thesis.

Unlike information, knowledge is the basis for learning improved techniques that require cognitive learning skills through networking and institutional supports to ensure the right flow of access, use, dissemination, and application of the existing updated knowledge (UN, 2010). Information, on the other hand, is an inherent characteristic of a society and is a fluid element that flows in the dynamic information environment to support decision-making processes (Rocoli *et al*., 2009). These skills promote agricultural innovations that require effective combinations of actors, processes and new

technology outputs aimed at bringing the fragmented agrarian knowledge together (Sulaiman *et al.*, 2012). This leads to the understanding and practice of the acquired knowledge.

In terms of knowledge and practice of the improved agro-ecological techniques, smallholders need to have these inherent abilities and skills to make practicing possible and increase productivity. One such benefit could be the ability to easily understand the outreached climate information from sources to adjust their farming operations (Salinger *et al*., 2000). In a situation where such skill creates gaps of knowledge and limitation on practice, an assessment of the possible factors for the gaps is vital (Stiger, 2010; Stiger, 2008). The next section focuses on these gaps as the major constraining factors that limit smallholders in Ethiopia from effectively practicing the appropriate improved agro-ecological techniques.

### *4.1.2. Gaps*

The "gaps" has a contextual meaning referring to the possible factors for why smallholder farmers are constrained or not practicing the improved agro-ecological techniques in Ethiopia. The AFRINT team proposed 16 factors that could challenge smallholders in Ethiopia (Appendix B). Some of these factors include *affordability* (labor, time and financially), *relevancy*, demand for *community support*, *distances* (farming fields, markets), *access to resource* (land, water, seed varieties, animals) and *levels of exposures* to the techniques.

Of all these factors, the most determining variables that limits smallholders to practice the improved agro-ecological techniques is the level of exposure to the techniques. 9 out of 16 techniques are rarely or never practiced due to the lack of exposure or not knowing the techniques at all (Figure 5). Appropriate support from extension services could help smallholders transform these techniques from knowledge to actual practices (UN, 2010; Roncoli *et al*., 2009). The second factor is shortage of water due to climate variability. One mechanism to effectively mitigating this problem is to increase the level of awareness of smallholders' capacity with appropriate climate information. If, for instance, too much or too little rainfall is forecasted, then farmers can easily adjust their farming operations accordingly, e.g. whether to harvest water or not to (Stigter, 2008; WMO, 2007; Salinger *et al*., 2000).

Addressing these two factors to support smallholder farmers should be the core of any development strategies in Ethiopia, in particular related to the agricultural sectors. Equipping farmers with the necessary knowledge and the appropriate practices of the improved agro-ecological techniques should be at the center of rural agricultural development strategies in the country (Durfeldt *et al*., 2011; Amha *et al*., 2009; Djurfeldt *et al*., 2008). One possible approach is to organize peer-level meetings and workshops with smallholders for knowledge and information sharing (Roncoli *et al*., 2009). Knowledge

for most of the proposed improved agro-ecological techniques could be easily obtained from elder family members, educated members within households, sometimes from extension officers and to a lesser extent from fellow farmers (Figure 6).

It is also vital to improve the situation regarding the gender share of farming activities among smallholders. The AFRINT 2008 survey reveals household and farming managements are highly dominated by men. 17% of women contribute as head households and 10% for farming operations managements (AFRINT Database, 2011). The outcome from FAO's e-mail conference on AIS and family farming shows that greater recognition should be given to the central role that women farmers play in agriculture, rural development and food security (FAO, 2012). The conference participant emphasized the need for gender balances in the family farming and equal attentions for both men and women farmers by policy makers and development partners to overcome the gap existing between knowledge and practice of AIS.

Extension officers and institutions could take advantage of such knowledge transfer schemes and engage in organizing trainings to effectively integrate the deep-rooted traditional knowledge with improved agro-ecological techniques. The next section discusses the role of actors, in particular extension officers, as one possible way to address the knowledge and practice gaps of the agro-ecological techniques.

### *4.1.3. Extension Services*

This part of the analysis focuses on the contributions of extension officers to effectively provide the services, irrespective of the affiliations where the officers they belong to. The result for this analysis reveals, extension services are still beyond the reach of and not to the maturity levels to be able to benefit many smallholders in Ethiopia (Figure 6). The other important point to note from Figure 6 is the categorical choices for knowledge sharing by family and extension officers. Extension officers take part in agro-ecological techniques that mostly require technical routines, while families/fellow farmers play less of a role in these aspects. Knowledge sharing from family members or fellow farmers fall under those categories requiring the resource that smallholders have or can afford to.

Extension services are crucial for farmers to improve their farming operations (UN, 2010). The National Agricultural Research System (NARS) developed a framework to link the concepts of agricultural research sharing through technology transfer that leads to technology adoption and agricultural productivity growth. With the notion of filling the gaps of NARS-frameworks and recognizing the human resources critical to development and applications of technologies, Agricultural Knowledge and Information System

(AKIS) came up with a framework (UN, 2010). The AKIS-framework brought the idea of agricultural extension services which bring various actors together to generate the required knowledge that supports farmers in improving their agricultural performance.

Comprehensive and multi-dimensional extension services that can help smallholders to improve their farming operations, and hence their livelihoods, should be the focus of institutions (Djurfeldt *et al*., 2011; Djurfeldt *et al*., 2005). The next section discusses the role of governmental and non-governmental organizations and institutions working at local, regional and national levels with regards to improving extensions services to smallholders.

### *4.1.4. Non-/Governmental supports*

In the context of Ethiopia, governmental organizations and institutions, through local offices, are authorized to take the lead for the provisions of the extension services to smallholders. NGOs or other actors that are not affiliated with the government have less contribution in this regard and hence the need for the GoE's continued calls (IMF, 2011; MoFED, 2010; MoFED; 2002) to involve these development partners in the agricultural sector.

Having knowledge and understanding the determining factors that affect smallholders from practicing improved agro-ecological techniques may not necessarily ensure solutions to overcome smallholders' productivity challenges, nor does the provision of extension services (IISD, 2011). The result of the analysis reveals both governmental and non-governmental affiliated extensions supports to smallholders need for further provisions (Figure 7). Actors' role at all levels, especially at exo-level, plays crucial roles in solving financial and technical constraints to these institutions in countries such as Ethiopia. These financial supports in turn build the institutions' capacity to fully engage in agricultural development works such as extension supports to smallholders (Amha *et al.*, 2009). These activities could range from training extension officers to organizing workshops to smallholders to share experiences from experts as well peers about improved farming operations. Extension services trainings at officers or expert levels help officers or training participants with updated climate information on timely basis (Roncoli *et al.*, 2009). In addition to these factors, it is important to assess farmers' ICT options. Specifically, the analysis takes the assessments of assets of and access to ICT options. The next section discusses the results of this analysis.

### *4.1.5. Assets of/Access to ICT*

Assets of and access to range of technology options are the most appropriately and commonly used platforms to disseminate information to farmers (Deloitte, 2012; UN, 2010). If ICTs have to effectively contribute to putting new knowledge into use, the gap between knowledge and practice needs to be bridged (Sulaiman *et al.*, 2012). The AFRINT team surveyed the most commonly used ICT options that have roles on the farming operations among smallholders that includes Radio, Tape recorder, Wired-electricity/power, Mobile/stationary telephones and TV. The result of the analysis revealed, smallholder farmers in Ethiopia have limited possession and access to the ICT options (Figure 8).

These ICT options encourage farmers to get connected to the source of the updated information, such as climate information of the growing season. Emphasis should be given to the smallholders' assets of and/or access to ICT means to improve their farming operations well in advance (Delotte, 2012; IISD, 2011; UN, 2010; WMO, 2007; Salinger *et al*., 2000); to make markets at the reach of farmers, to link family and fellow farmers to each other and to extension agents, to improve farmers' technical knowledge (FAO, 2012).

Among the myriads of technological developments in the information and communication technology (ICT) sector, mobile phones are the most popular innovations and have had the most pronounced impact in developing countries (World Bank-IC4D, 2012). Mobile phones have begun to change the way stakeholders across the agricultural value chain make decisions regarding inputs, production, marketing, processing, and distribution—decisions that can potentially lead to greater efficiencies, reduced transaction costs, and increased incomes. For instance, as long as climate change is a concern, climate information updates on a regular basis requires access to ICT options like mobile phones and SMS platforms, as in Tanzania and Kenya (Aryeetey *et al*., 2011).

Prior to financial constraints, many of the countries in SSA put these options aside. According to the UN (2010), taking appropriate action on the diffusions of these technology options is both technically and financially feasible. International donors, NGOs, and other stakeholders need to support these countries in order to make smallholders the beneficiaries of the ICT options through the enabling policies and infrastructure of their own states.

To sum up, the major findings of the analysis of the selected questionnaire from the AFRINT 2008 survey could be demonstrated using simple causes-and-effects diagram (Figure 9).

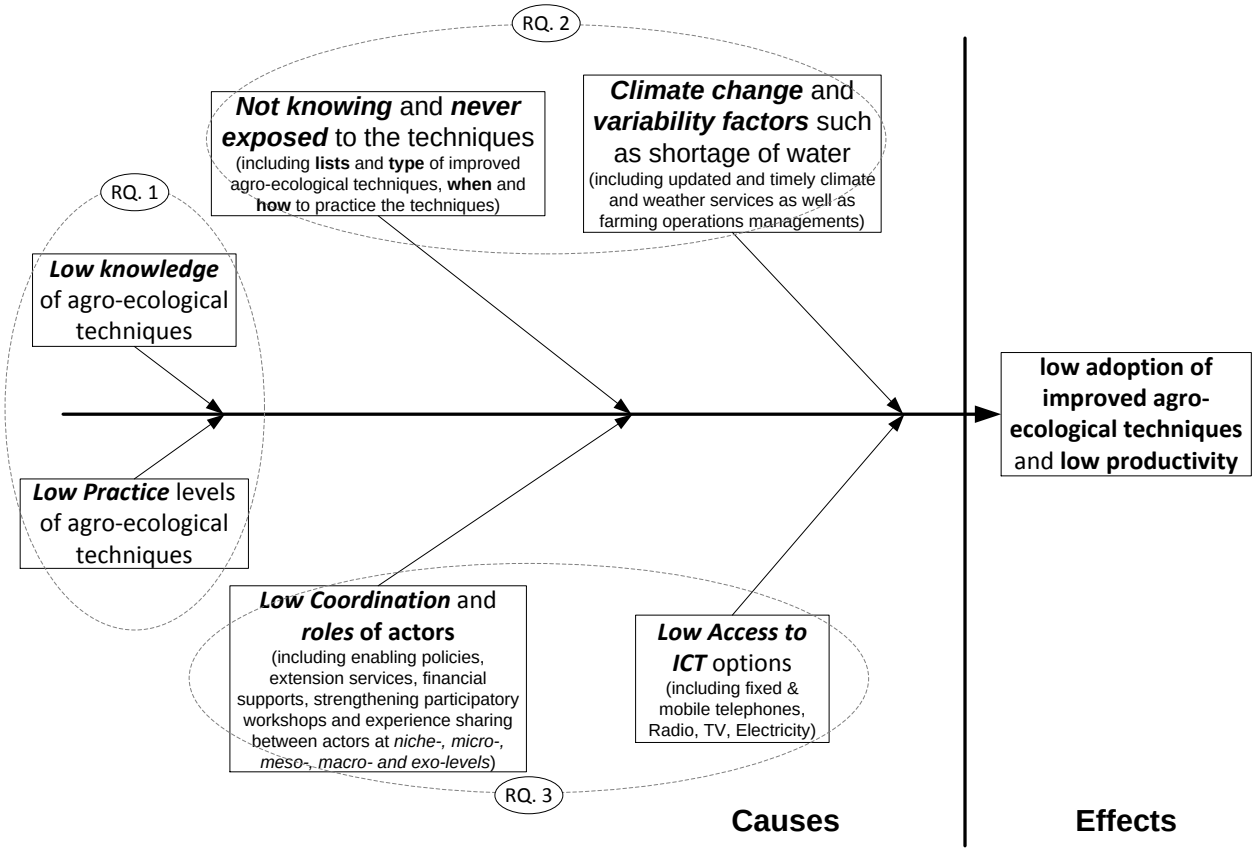


**Figure 9**. Causes and effects relationships of knowledge and practice of agro-ecological techniques, roles of actors and access to ICT in relation to the adoption of the techniques and agricultural productivity. The ellipses with dotted line represent RQ1, RQ2 and RQ3 of Table 1. (*Source*: Author)

Most parts of the discussion made so far in this section are specific to the Ethiopian case and are an attempt to answer the research questions formulated earlier in this thesis (Table 1). In an attempt to answer RQ4, it is also important to look at cases with a wider view to better understand the importance of climate information to smallholders. The following paragraphs discuss the global facts of climate information and its outreach to smallholders to improve productivity.

### *Global aspects of climate information*

In most developing countries where smallholders make up the majority, information communication is not evolved to a mature level (Aldrian *et al*., 2010). Its distribution is asymmetrical between urban and rural areas. It is localized to urban areas and is in contradistinctions to its form in rural areas in many respects. When, in some cases, information becomes accessible and reachable to the rural community, it is usually in a segmented form (Goddard *et al*., 2010).

At the global scale, WMO is the most notable UN-affiliated organization that has had voice on weather, climate, and hydrology systems since the beginning of the 1950s (WMO, 2012). Ever since its establishment, it engages in practical interventions and facilitations of cooperation between actors at all levels, both across geographical and hierarchical extents, promoting the development and disseminations of economic diversification means to increase economic resilience among the disadvantages, collect, analyze and disseminate past, current and projections of climate for practical adaptation strategies and action plans, and last but not least, promoting research.

The other important aspect to ensure the downscaling of climate information to smallholders is actors' cooperation at the global level. One such cooperation is the annual G-8 summit. Some of the outcomes from such summits, when effectively outsourced, play a crucial role in supporting the development works in countries such as Ethiopia. In his opening speech at the G-8 summit in May 2012, United States President Barack H. Obama II, remarked:

> *"… the G-8 member states started partnerships called -* ***a new alliance for food security and nutrition****, with African countries in pursuits of ambitious growth. ... one effective way to pull people out of poverty is to invest in their agriculture and to tap huge support to small-scale farmers. ...The new alliance has four core actors: the African states, donor countries, private sectors and civil societies/NGOs. ... The G-8 member states are committed to replenish the very successful global agricultural and food security program. ... 45 international donors committed to kick-off the new global effort. ...****We are going to speed-up innovation and development of new technology, better seeds, better storage that unleash huge-leaps in food production****. ...****We are going to tap mobile phone revolution in Africa, so that more data on agriculture whether it is satellite imagery or weather forecast, market prices are put in the hands of farmers. So farmers know what to do, what to plant, and when to sell.*** *....with this new initiative, we are boasting to lift the income of African smallholders."* (Barack H. Obama II)

He also underlined that the new alliance is not an empty promise and its kick-off is at a-hand-distance reach to developing nations such as Ethiopia to improve their ambitious agricultural development strategies and overcome their financial constraints.

The new Alliance is committed to the financial needs of the African states and seeks to maintain strong support to address current and future global food security challenges. These bilateral and multilateral assistances go along with the national plans of the African states (NAFSN, 2012). Ethiopia, as one of such financial beneficiary states, could take this opportunity to overcome the constraints due to the *soft*- and *hard*-infrastructure facilities bottle-necking the country and holding the bulk of its population below the average. Such supports are a boost for the country to downscale policy and technology diffusion strategies to include smallholders.

Emphasizing the need for giving attention to smallholders, Djurfeldt *et al*. (2011), in their publication dedicated to the task of alleviating poverty among African smallholders, noted:

> *"Poverty in Sub-Saharan African is a predominantly rural and agricultural phenomenon. The large majority of all poor are farmers and herders. … as long as the poor remain smallholders, alleviation of poverty remains agricultural task. …**a pervasive bias against the small farm sectors is a major hindrance to increase food security in Sub-Sahara Africa**."* (Djurfeldt *et al.*, 2011)

The moral of the remark is that effective poverty eradication means are those who take smallholders and their livelihoods into account; hence, policies and development works should put smallholders at the core of their processes.

Most developing countries have difficulties with agricultural related cooperation between actors at various levels. There should always be intermediate level actors responsible for effective transfer and facilities of climate information for smallholders (Stiger, 2008). Involving actors in the production and dissemination of updated climate information ensures the importance of communication for the desired outcomes. Such integrated works between actors make each participant accountable and responsible for the right information flow between the information sources and end users. Moreover, research and studies relevant to the climate information, especially in a Participator Rural Appraisal (PRA) means, have better results for farmers to understand the content of the information and how to apply the appropriate agricultural techniques in their farming operations (Roncoli *et al*., 2009).

The case study in Burkina Faso and a report by the UN reveal farmers who were aware of updated climate information by participating in workshops benefited from their farming operations. Moreover, smallholders should be at the hub of every new technology breakthrough aiming to increase agricultural productivity (UN, 2010; Roncoli *et al*., 2009). These information help farmers to understand the growing season conditions, appropriate farming techniques based on the conditions, and modifications to the already planned strategies in response to the updated information (Martinez *et al*., 2010; Marx *et al*., 2007). Most of these farmers responded as being satisfied by their decisions and appreciated the value of updated climate information for their farming operations.

In line with the mission of ECX, the report by UN (2010), Djurfeldt *et al*. (2011) and AFRINT country level report on Ethiopia (2009) all underlined the necessary conditions to enable smallholders to effectively participate in the marketing system of the country. These conditions are: access to agro-inputs; adequate storage capacity; up-to-date market information and extension services; access to formal markets; access to clustering and cooperative forms of organizations; access to credits.

## 4.2. Recommendations and Conclusions

Djurfeldt *et al.* (2011) and Amha *et al*. (2009) suggest a review of the whole economic policy process related to rural development strategies in Ethiopia. Moreover, special attentions must be given to meso-scale actors and logistic facilities to easily reach smallholders with the necessary knowledge, skills and financial needs. The GoE, through its agricultural development policy, states that unless industry (secondary-modern goods producing sectors) and services (tertiary-distributive and other services) grow in conjunction with agriculture (primary-agriculture and allied activities), it is not possible to ensure accelerated growth and sustainable development (IMF, 2011; MoFED, 2010; MoFED, 2005; MoFED, 2002).

In line with this, focusing on smallholder farmers contributes to the country's economic growth and food security (UN, 2010). In reality, it is common to observe smallholders being kept aside and given less attention to their contributions in the overall economic development plans of a country. Their "smallness" should not be measured both by their farming potentials and financial capitals; rather, it is due to their isolation from the available knowledge and information systems (Dzanku *et al*., 2011; Roncoli *et al*., 2009). The low levels of knowledge and practice of agro-ecological techniques could be scaled up through integrated supports of all actors with capabilities, secured financial benefits and diffusions of technology options (such as ICT) to smallholders (Marx *et al*., 2007). Such support of knowledge and skills to smallholders makes them learn how to fish rather than to wait for the fish.

Moreover, participatory workshops among all actors at all levels are relevant to integrate the indigenous knowledge and practices with scientific techniques, such as climate information production and dissemination (Roncoli *et al*., 2009; Stigter, 2008). These approaches, in turn, help the inclusion of isolated groups and promote a two-way communication between rural communities (i.e. the niches) and actors at local, regional, national and international levels (NAFSN, 2012; Stigter, 2010; Roncoli, 2006; Salinger *et al*., 2000). Moreover, better access of climate information and technical advices to smallholders is potentially cost-effective way of adapting to climate change and risk as well as means to reduce economic impact of droughts (World Bank, 2008).

The analyses from the AFRINT survey justify the limited participation of smallholders in advanced and expert level workshops. Most of these farmers perform their farming activities with the knowledge and skills gained from family members or fellow farmers (Figure 6) highly characterized by a men-dominated gender participation in household and farming managements. To the majority of the smallholders,

advanced information from the original sources, for instance about the weather conditions of the growing season and the accompanying adjustments on their farming operations, is hearsay.

The FAO's e-mail conference on AIS and family farming underlined, attentions should be given to the young members in the family as most of these groups show high tendency to shift to off-farming activities (FAO, 2012). This shift makes a huge gap between the indigenous knowledge and skills of elders and young people of the community. According to the participants of the conference, ICT supported agricultural operations, business oriented farming practices and defined social values for agriculture and farmers are some stimulants to keep the existing and to attract youth back to the agricultural sector.

For some developing countries, the prominent task is to produce and disseminate climate information in areas where indigenous climate knowledge is deeply-rooted where scientific based climate information is coarse in both time and spatial extents (Lybbert *et al*., 2007; WMO 2001). In such cases, local and regional actors play paramount roles in coordinating the isolated local community with the scientific community and the general public to ensure the reach of the improved climate information to smallholders. Some of such efforts could be organizing participatory awareness creation workshops (Roncoli *et al*., 2009) to the local community, organizing donors for financial supports to facilitate the infrastructure and technology diffusions in these areas (Dzanku *et al*., 2011), arranging capacity building programs for local and regional agricultural officers (Stinger 2008; Archer *et al*., 2007), and opening of functional financial services to smallholders to make access to finance within their reach on loan terms (Djurfeldt *et al*., 2011; Amha *et al*., 2009). In line with this, evidence from the AFRINT survey analysis uncovers the limited extension services support to smallholders in Ethiopia. Taking the closeness of Extension officers to smallholders for new approaches and skills in farming operations into accounts, immense work should be done on the agricultural extension services in Ethiopia to achieve a sustainable, broad-based economic growth (IMF, 2011; MoFED, 2005).

Smallholders could be supported with the transfer and adaptation of simple innovation technologies and operational knowledge to improve their livelihood (UN, 2010). Moreover, the social capital among many smallholders in Ethiopia is least developed, hence supporting farmers with simple knowledge of agro-ecological and technological services from higher levels is important. A long-run, specific training of extension services, organizing peer-level workshops, rural radio and TV assistances, mobile telephones, and computers and internet facilities (material as well as skill-wises) are the best instruments for smallholders sustainable farming operations (Deloitte, 2012). Simple knowledge and skill of community based mitigation practices and disaster preparedness information could be transferred to smallholders

via these media (Stigter, 2008). The report by IISD (2011) underlined the role of ICT to help rural farmers in Uganda to adapt to climate change; to address the importance of online knowledge platforms for the sharing of knowledge for adaptation in Senegal and across Africa; and to examine the value of community based participatory geographic information system analysis for water and resources management in Malawi.

With the emerging mobile phones and SMS platforms, diffusions into rural areas for timely information sharing purposes, as in Tanzania and Kenya, constraining factors that isolate farmers from the benefits of policy, and good advice on improved agro-ecological techniques will no longer be problems (Aryeetey *et al*., 2011). The education level of the households is the biggest challenge for technology diffusions to the rural community. This challenge, however, could effectively be addressed by extension officers and other responsible actors via in-person consultations, participatory workshops, and awareness creation programs with smallholders (UN, 2010; Roncoli *et al*., 2009; Stigter, 2008). In this regard, the AFRINT survey assessment for ICT means reveals smallholders have low or no assets of or access to these options (Figure 8). What are mostly common among smallholders are radio receivers (37.1%). In line with this, FAO (2012) underlined the role of Radios as these are the most widely acceptable by many farmers and available at low costs with options of broadcasting local languages. The other options, such as mobile phones, are still “urban-tales” and out of the reaches of millions of the rural smallholders in Ethiopia.

Fundamental changes in agricultural operations should go in-line with the changing climate to avoid a catastrophe (CGIAR, 2009). One instrument in addressing the need for change is effective information communications between actors at all levels (IISD, 2011). In the agricultural sector context, timely updates of weather and climate scenarios help farmers to adjust their farming plans in accordance with the weather and climate patterns of the growing season (WMO, 2009; WMO, 2007; WMO, 2001). What to expect, what to sow, manage means during the harvesting seasons, how and when to gather the production from the field, and when to channel it for markets are some of the plans that need communications between actors (Salinger *et al*., 2000).

Knowledge based investments assure the necessary adjustments on policy strategies towards a sustainable and equitable agricultural development (UN, 2010). Moreover, for broad-based economic growth strategies, increasing investments on science and technology accompanied by extension services to benefit smallholders is important (MoFED, 2010). Agricultural technologies are vital for sustainable rural development and farmers should benefit from the updated scientific knowledge in order to achieve high and stable yields and to build resilience to the changing climate (Marx *et al*., 2007). In addition to

this, the missing tally of African agricultural research is finding the right stimulus to bridge the updated research findings with product development initiatives (UN, 2010). With the invention of the ECX, opportunities are set for farmers to directly participate on the national market exchange (ECX, 2009). The ECX platform is an encouraging medium that steps smallholders forward to have access to the latest information about marketing conditions and the same platform could be used to disseminate climate information to farmers as well.

Finally, it is important to emphasize the need for integrated cooperation between the agricultural and other sectors to effectively apply the knowledge and experiences of actors at all levels to the benefit of smallholders and their role in the overall economic growth of the country. In the absence of such an enabling environment, potential end users of climate information may remain excluded from its benefits if their unique requirements are not at the hub of the development policy strategies.

### 4.3. Implication of the study to the sustainability science

This thesis demonstrates the major gaps existing between knowledge and skills of improved agro-ecological techniques resulting mainly due to climate variability and exposure levels to the techniques. Moreover, smallholders also have limited access of extension services and ICT options. One possibility to effectively overcome these challenges is to reach smallholders with climate information updates on regular basis. Doing so helps smallholders to plan their farming operations in advance. These include knowing appropriate type of farming techniques suitable for the growing season, what and how to sow, when to harvest and to channel the products to market. Sustaining such chained of farming operations becomes a challenge if smallholders are isolated from climate information updates.

The results of this thesis not only help smallholders to shift from subsistence mode of farming but also support decision makers to devise smallholders-centered policies and appropriate actions related to the agriculture sector. This plays crucial roles for the country to achieve sustainable economic development and growth through its agriculture sector. That said, the outcome of this thesis can help enhancing smallholders-centered sustainable agriculture development by:

- identifying linkages between climate information services, knowledge and skills of improved agro-ecological techniques;
- identifying core actors at all levels responsible for climate change adaptive capacity and its outreach;
- developing appropriate framework to increase skills of climate change and variability adaptation;
- demonstrating how to establish linkage between use of scientific and indigenous knowledge; and,
- facilitating the formulations of enabling policy environment at community and decision makers level.

## 4.4. Opportunities for further research

***Grips***

The rural and agricultural development policy of the GoE is criticized for limiting international donors, NGOs, and civil society from fully participating in the development programs aimed at improving the livelihoods of smallholders. The current working environment grips exo-level actors to channel through the complex government bureaucracy, if they want to support actors at regional and local levels. The potentials and challenges, the pros and cons, of having such a policy to ensure economic growth and food security for the nation, as the GoE claimed, requires a thorough investigation. This could be an opportunity for further research.

***Similar projects***

The Savannah Accelerated Development Authority (SADA) project of Ghana is a good example to demonstrate the prospects of two ways of communication between actors at all levels - from federal to the grass-root levels (SADA, 2012). Unlike the SADA project, the mode of communication in Ethiopia is one directional, top – down and usually limited to the same levels. Recommendations based on proof are vital for the GoE to review its agricultural development strategies to extend policies beyond papers.

***Socio-economic data***

It is important to conduct a survey on the general public about the understanding and use of climate information in their daily routines. This helps to incorporate the social science perspectives, such as norms and linguistic and cultural values of the society, which could increase the level of trusts on climate information outreaches. Lack or missing such basic socio-economic data could also cause completely wrong approaches in agro-meteorological designs due to completely wrong assumptions. Moreover, after improving, adapting and focusing rural information and education systems, information and communication technologies could play important roles in the livelihood of the rural community.

As a final remark, the FAO yield estimates for Ethiopia on the selected staple-crops in the study areas are higher than or different from the AFRINT estimates. This needs a careful investigation of the possible reasons for the variations (beyond the scope of this paper). Otherwise, one could tell different stories from the two data sources.

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## Appendix

**A.** List of agro-ecological techniques proposed by AFRINT team

The table also shows the chosen techniques (with marks on the right) to investigate the importance of effective climate information outreach to smallholders. The marked techniques fall either in the *climate variability* factors or *not knowing* the techniques categories.

| Proposed agro-ecological techniques by AFRINT team | Selected agro-ecological techniques for climate information gap analysis |
|---|---|
| Agro-forestry | √ |
| Animal manure | √ |
| Breaking the hard pan | √ |
| Chemical fertilizer | |
| Crop rotation | |
| Fallowing | |
| Green manure/compost/residue incorporation | √ |
| Improved fallowing | √ |
| Improved planting practices | √ |
| Integrated (Soil) Nutrient Management (INM) | |
| Integrated Pest Management (IPM) | |
| Intercropping | |
| Intercropping with nitrogen fixing crops (beans etc.) | √ |
| Irrigation | √ |
| Pesticides/herbicides | |
| Rain water harvesting | √ |
| Soil and water conservation (level bunds, grass strips, terracing etc.) | |
| Zero or minimum tillage | √ |

(*Source*: AFRINT Database, 2011)

**B.** List of factors proposed by the AFRINT team

The "**1st**" and "**2nd**" labels indicate the primary and secondary reasons (respectively) which limit smallholders from practicing the particular agro-ecological technique. The sample sizes are out of total AFRINT samples (N=476). (*Source*: Extracted from AFRINT Database, 2011)

| **No. ↓** | **List of factors/reasons** |
|---|---|
| **1** | Already practicing or not familiar |
| **2** | They are too labor consuming |
| **3** | They involve other extra costs which I cannot afford, e.g. inputs, animals, tools, logistics |
| **4** | I do not find it as a relevant technique for me, e.g. they do not seem to make a difference/they do not seem to have any effects on yields, etc. |
| **5** | They demand community efforts, which do not exist at this point |
| **6** | I used to practice the technique but have abandoned it for economic or labor reasons |
| **7** | I used to practice the technique but have abandoned it since it didn't have any positive effect on my crops |
| **8** | Distance of land from home |
| **9** | Shortage of land |
| **10** | Shortage of water |
| **11** | No access/Not available |
| **12** | Lack of exposure/Not known |
| **13** | Shortage of crop variety |
| **14** | Time consuming |
| **15** | Shortage of animals |
| **16** | Not applicable |

| **No →** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** | **16** | **Why?** | **Samples sizes** (N=476) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Crop rotation* | 82.9 | 0.2 | 0 | 0.4 | 0 | 0 | 0.4 | 0.2 | 0.2 | 0 | 0 | 0 | 15.6 | 0 | 0 | 0 | 1st | 467 |
| | 74.2 | 0.3 | 0 | 0.7 | 0 | 0 | 0.3 | 0.3 | 0.3 | 0 | 0 | 0 | 23.9 | 0 | 0 | 0 | 2nd | 306 |
| *Intercropping* | 43.7 | 6.8 | 6.5 | 23 | 0.3 | 0.8 | 6.8 | 0.3 | 0.3 | 0 | 0 | 0 | 11.5 | 0 | 0 | 0 | 1st | 382 |
| | 42 | 2.3 | 8 | 24.8 | 0 | 1.5 | 4.2 | 0 | 0.4 | 0 | 0 | 0 | 16.8 | 0 | 0 | 0 | 2nd | 262 |
| *Intercropping with nitrogen fixing crops (beans etc.)* | 50.2 | 4.7 | 5.7 | 7.4 | 0.2 | 0.7 | 3.2 | 0 | 0 | 0 | 0.5 | 27.3 | 0 | 0 | 0 | 0 | 1st | 406 |
| | 42.2 | 2.9 | 6.9 | 6.5 | 0 | 0.4 | 0.4 | 0 | 0 | 0 | 0.7 | 40.1 | 0 | 0 | 0 | 0 | 2nd | 277 |
| *Fallowing* | 35.3 | 3.4 | 3.7 | 1.9 | 0.9 | 14.8 | 0.2 | 0 | 39.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1st | 465 |
| | 16 | 1.7 | 7.6 | 7.3 | 1 | 1.4 | 0.7 | 0 | 64.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2nd | 288 |
| *Improved fallowing* | 65.3 | 0 | 0.6 | 0.6 | 0 | 0 | 0 | 0.3 | 0.6 | 0 | 0 | 32.8 | 0 | 0 | 0 | 0 | 1st | 357 |
| | 48.1 | 0 | 0.4 | 0.8 | 0 | 0 | 0.4 | 0.4 | 0.8 | 0 | 0 | 49 | 0 | 0 | 0 | 0 | 2nd | 239 |

*(continues…)*

*(… continued)*

| No → | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | Why? | Samples sizes (N=476) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Animal manure* | 63.5 | 16.8 | 8.8 | 1.4 | 0.5 | 3.6 | 0.5 | 2.5 | 0 | 0 | 0.5 | 0.2 | 0 | 0 | 1.8 | 0 | 1st | 441 |
| | 63.7 | 11.3 | 10.9 | 4.2 | 0 | 0.7 | 0.4 | 4.9 | 0 | 0 | 0.7 | 0.4 | 0 | 0 | 2.8 | 0 | 2nd | 284 |
| *Zero or minimum tillage* | 57.8 | 0.3 | 0 | 4.6 | 0 | 0 | 0 | 0.3 | 0 | 0.3 | 0 | 36.6 | 0 | 0 | 0 | 0 | 1st | 325 |
| | 40.7 | 0 | 0 | 0 | 0 | 0 | 0 | 0.5 | 0 | 0.5 | 0 | 58.3 | 0 | 0 | 0 | 0 | 2nd | 204 |
| *Breaking the hard pan* | 58 | 6.5 | 1.9 | 5 | 0.2 | 2.2 | 0.6 | 0 | 0 | 0 | 0 | 25.5 | 0 | 0 | 0 | 0 | 1st | 462 |
| | 51.1 | 3.2 | 1.8 | 1.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 42.1 | 0 | 0 | 0 | 0 | 2nd | 280 |
| *Green manure* | 60.6 | 20.2 | 5.6 | 4.6 | 3.9 | 1.9 | 0 | 0.5 | 0 | 0.5 | 0.5 | 1.2 | 0 | 0.2 | 0.5 | 0 | 1st | 431 |
| | 58.3 | 18.3 | 15.4 | 1.9 | 1 | 0.3 | 0.3 | 0.6 | 0 | 0.6 | 0.6 | 1.6 | 0 | 0.3 | 0.6 | 0 | 2nd | 312 |
| *Chemical fertilizer* | 83.3 | 0.7 | 2.2 | 0 | 0 | 0.2 | 0.5 | 0 | 0 | 0 | 12.8 | 0 | 0 | 0 | 0 | 0.2 | 1st | 406 |
| | 74.6 | 0.4 | 1.6 | 1.6 | 0 | 0.4 | 0 | 0 | 0 | 0 | 21 | 0 | 0 | 0 | 0 | 0.4 | 2nd | 248 |
| *Soil and water conservation (level bunds, grass strips, terracing etc.)* | 78.2 | 3.5 | 1.8 | 11.9 | 0.5 | 3.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.3 | 0 | 1st | 395 |
| | 90.7 | 1 | 3.9 | 0.5 | 2 | 0.5 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.5 | 0 | 2nd | 204 |
| *Improved planting practices* | 61 | 0.8 | 1.1 | 0.6 | 0 | 3.1 | 0.6 | 0 | 0 | 0 | 0 | 32.9 | 0 | 0 | 0 | 0 | 1st | 356 |
| | 44 | 0 | 0.9 | 2.6 | 0 | 1.7 | 0.9 | 0 | 0 | 0 | 0 | 50 | 0 | 0 | 0 | 0 | 2nd | 234 |
| *Integrated (Soil) Nutrient Management (INM)* | 67.7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.3 | 31.7 | 0.3 | 0 | 0 | 0 | 1st | 353 |
| | 51.1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.4 | 48.1 | 0.4 | 0 | 0 | 0 | 2nd | 233 |
| *Integrated Pest Management (IPM)* | 81.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2.1 | 15.7 | 0.6 | 0 | 0 | 0 | 1st | 331 |
| | 71.1 | 0.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3.3 | 24.2 | 0.9 | 0 | 0 | 0 | 2nd | 211 |
| *Agroforestry* | 37.8 | 1.1 | 2 | 22.4 | 2.3 | 0 | 0.9 | 0 | 0 | 0 | 0 | 33.2 | 0.3 | 0 | 0 | 0 | 1st | 252 |
| | 15.2 | 0.9 | 1.3 | 29.6 | 0.4 | 0 | 1.3 | 0 | 0 | 0 | 0 | 50.9 | 0.4 | 0 | 0 | 0 | 2nd | 230 |
| *Pesticides/herbicides* | 55.7 | 1.1 | 7.8 | 3.8 | 1.1 | 4.2 | 0.8 | 0 | 1.1 | 0 | 24.4 | 0 | 0 | 0 | 0 | 0 | 1st | 472 |
| | 43.8 | 2.5 | 4 | 7.7 | 1.9 | 2.5 | 0.6 | 0 | 1.5 | 0 | 35.5 | 0 | 0 | 0 | 0 | 0 | 2nd | 324 |
| *Rain water harvesting* | 7.7 | 31.7 | 3.7 | 9.1 | 18.6 | 1.6 | 3 | 0.2 | 0 | 23.8 | 0.2 | 0.2 | 0 | 0 | 0 | 0 | 1st | 429 |
| | 4.4 | 22 | 25 | 5.4 | 4.1 | 1 | 3.7 | 0.3 | 0 | 33.1 | 0.3 | 0.7 | 0 | 0 | 0 | 0 | 2nd | 296 |
| *Irrigation* | 5.5 | 13.3 | 19 | 0 | 38.9 | 1.3 | 0.2 | 0.4 | 0 | 21.1 | 0 | 0 | 0 | 0 | 0 | 0 | 1st | 473 |
| | 5.8 | 14.2 | 38.8 | 2 | 4.9 | 2.3 | 0.6 | 0.6 | 0.3 | 30.4 | 0 | 0 | 0 | 0 | 0 | 0 | 2nd | 345 |