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Agricultural Water Management and Smallholder Rice Production in Ethiopia

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Ethiopian Development Research Institute
and
Japan International Research Centre for Agricultural Sciences

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(JIRCAS)

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Acronyms

AWM	Agricultural Water Management
BOARD	Bureau Of Agriculture And Rural Development
CSA	Central Statistical Agency
DAS	Development Agents
EDRI	Ethiopian Development Research Institute
EIAR	Ethiopian Institute Of Agricultural Research
ETB	Ethiopian Currency Birr
GDP	Gross Domestic Product
GTP	Growth And Transformation Plan
HA	Hectare
IFPRI	International Food Policy Research Institute
JICA	Japan International Cooperation Agency
JIRCAS	Japan International Research Centre For Agricultural Sciences
MASL	Meters Above Sea Level
MOARD	Ministry Of Agriculture And Rural Development
MOFED	Ministry Of Finance And Economic Development
NGO	Non-Governmental Organizations
NRRDSE	National Rice Research And Development Strategy Of Ethiopia
PAS	Peasant Associations
R&D	Research And Development
SAA/SG2000	Sasakawa Goblal 2000
SSI	Small-Scale Irrigation
SNNPR	Southern Nations And Nationalities And Peoples Region
UN COMTRADE	United Nations Trade Statistics (Website)
USAID	United Sates Agency For International Development
USD	United States Dollar
WHTS	Water Harvesting Technologies
WUA	Water Users' Association

Abstract

The increasing rice production in Ethiopia has economic advantages to smallholder farmers, but the rainfall variability and shortage, which constrains yields, on the one hand, and the increasing import demand because of the incompetent lower quality local rice, on the other, are the existing challenges. Production under rainfall shortage and variability demands a corresponding advance in water-use to improve output and yield. These issues invite a closer look into an essential aspect of rice production called AWM. With the main objectives of exploring the categories of AWM in smallholder rice-producing areas and estimating the share of irrigated and rain-fed rice, and several other interesting objectives, this study used qualitative and quantitative primary data collected in 2014 from two regions for analysis. The findings mainly indicate that: (1) supplementary-irrigated AWM is the dominant rice farming system accounting for 77% of the rice production, followed by rain-fed (17%) and full-irrigated (5%); (2) the expansion rate of rice production is highest in supplementary irrigated rice production than in rain-fed, pointing to the high potential expansion in wet lands, logged-water and flood areas and river bunks. (3) In 2012/13 & 2013/14 the income of users of supplementary irrigation users exceed that of the pure rain-fed users on average by two-folds. The income difference as well as the profitability indicates that if irrigation financers support the investment on irrigation for rice production, farmers have the incentive to sustain the AWM (by paying for operation and maintenance) from their rice income. (4) More than marketing constraints, rice producing farmers underlined the challenges in production- including weeds, land constraint, fertilizer, lack of seed varieties, pests, and rice diseases, which are equally important in each category of AWM; (5) Labor shortage is mentioned by only 15%, implying not a serious problem, contrary to the labor requirement that is observed in other irrigated farming; (6) average rice yield is 4.5 ton/ha, a minimum of 0.9 ton/ha and a maximum of 11.1ton/ha. Specifically, the yield differences between irrigated and supplementary irrigated rice is quite substantial. (7) Based on the series of assessments in several areas indicate micro-irrigation can be used for supplementary irrigation in rice production, which can be achieved by improving its construction and use. (8)About 33% of the interviewed farmers faced water conflicts, and 86% of them stated that water-share is the major cause, followed by depletion of water source, though in some sub-districts WUAs are available to solve the conflicts. The findings can be used to enhance and rice production of smallholder farmers and make competent to the imported rice. The study is unique in that the irrigation technology is individual small-scale irrigation technology unlike the case of medium and large-scale irrigation that is common in several part of the world.

1. Background

1.1 Introduction

Agriculture contributes to the Ethiopian Economy about 42 percent of the GDP in 2012/13 (MoFED, 2013). About 85 percent of the employment of the labour force and nearly 90 percent of the source of foreign exchange currency are also dependent on this sector. Within agriculture, crop productions contribute the lion share with cereals playing substantial role. Cereal production contributes 30% to the overall GDP, 62% of the agricultural GDP, 40% of the food expenditure, 60% of the calorie intake, 60% of the rural employment, and 80% of the total cultivated area. Though agriculture plays such an important role in its contribution to the economy, challenges limit its potential contributions. One of these challenges is the moisture stress that encounters Ethiopian smallholders in crop production.

The moisture stress caused by rainfall shortage and variability result in low yields compared to other countries. This means that during sufficient rainfall year, the agricultural sector performs well and the food security and income of the (rural) population improves whereas during a bad rainfall year imports of grain would be inevitable. However, even in a good rainfall year, cereal productivity is relatively low due to low application of modern inputs. Nearly 40% of the farmers use fertilizer and less than 5% use improved seed due to weather risk and other factors (Spiegel et al. 2011). As an alternative, Ethiopian farmers in a relatively water abundant areas started to produce rice which has a yield advantage and sufficient to feed household members. Farmers choose to produce rice mainly because of its yield advantage and better relative price compared to many other cereals.

In recent years, the production of rice is expanding at a high rate in terms of area coverage, number of sub-districts and number of farmers. The CSA 2011/12 data indicates that the area allocated to grow rice at national level grows from 6,241 hectare in 2005 to 47,739 hectares in 2009, more than six folds expansion. During the same period, output grew from 11,244 to 103,126 tonnes. Because of its extraordinary expansion and the fact that rice answered the food security question of a number of farmers, rice is named as a "millennium crop" by the Government of Ethiopia. Of course, rice consumption demand[1] is also steadily increasing. For the consumption, the country mainly depends on imported rice (Annex 1). The UN Comtrade data indicates imported rice increased from 17,514 tonnes in 2005 to 88,000 tonnes in 2012, a fivefold increases with an average annual growth rate of 35 percent. With the increasing import of rice, the share of its value in the total value of all imported cereals is also increasing. For instance, in 2010, 2011 and 2012 the share of value of rice imports was 7%, 10.6% and 13.7%

[1] For instance, the average annual rice supply during 2004-2009 was 14,000 tons of which domestic production and imports accounted for 39% and 61% respectively. Per capita rice consumption fluctuates from year to year, with an average of 0.19kg or about 0.12% of total cereal consumption (USAID, 2010).

respectively in the total value of imports of cereals[2] (Annex 2) which shows an increasing trend of rice demand for consumption.

Based on its potential contribution to food security of Ethiopian smallholders, the Government of Ethiopia realized the need to promote and support rice production. In the new millennium, there is an effort towards boosting the production of the new crop. Accordingly, the government put in place a strategy to support the production of rice and documented the National Rice Research and Development Strategy of Ethiopia (NRRDSE). The strategy targets transforming production into profitable and modern and double area and output by 2014 and quadruple them six folds by 2019. In other words, the objective is to increase rice output involving both yield and area expansion. Mainly, yield is supposed to increase from 3 tonne per hectare to 4 tonnes per hectare in 2014 and then to 5 tonnes per hectare in 2019. According to CSA 2012/13, the total area and output in 2012 of rice is, however, only one-third of what is planned by NRRDSE, i.e. about 41.8 thousand hectare and 121 thousand tones, with a promising change in the average yield, like the one found out in this study because of the use of supplementary irrigation. It looks challenging to achieve the 2014 targets and this study focuses on agricultural water management (AWM) as one of the major constraints of rice production.

1.2 History of rice production in Ethiopia

Some studies (e.g. Gebey et al. 2012) discussed the history of rice (*Oriza Sativa*) production in Ethiopia. These documents identify two sources of rice species in Ethiopia. The first is a wild rice in Fogera plain in the 1970s as a basis for the introduction of rice, whereas the second discusses that rice came to Ethiopia with the technical support of North Korean experts at the end of 1970s and with the support of those experts research on rice was initiated at Jigna in Dera sub-district and Shega in Fogera cooperatives. This discontinued after 1991 with the change of government and collapse of cooperatives. After this an expert[3] collected seeds from Jigna Peasant association (PA) and multiplied and distributed to farmers. Following this effort, the Adet Agricultural Research center released three other rice varieties called Gumera, Kokit and Tigabe, and rice extension service was given attention in the 1990s within six kebeles (Gebey et al. 2012) and the extension system was promoting rice production. Gradually, the farmers in the six PAs started to produce and consume rice with increasing taste and preferences. Note that whereas this is how rice was started in northern Ethiopia, rice production in Chewaka in southern Ethiopia was started differently. In Chewaka a farmer who settled from Hararge started to produce rice by using the seed he brought from Hararge. In the year following, other farmers followed his experience and adopted to produce rice. After looking at the good start of farmers, agricultural experts, researchers (e.g. Bako Agricultural Research Centre) and other stakeholders (e.g. Sasakawa Global 2000) contributed to the expansion of rice production in Chewaka and other Zones of Oromia and in SNNPR.

[2] The values of imported rice during 2010, 2011 and 2012 were 26,130, 50,260 and 57,049 USD and the respective value of cereal imports were 374,359, 471434 and 416,652 USD (UN Comtrade).
[3] The agricultural expert is Getachew Afework from Agriculture Bureau of North Gondar.

In 1993, the area covered with rice in 6 peasant associations (PAs) in Amhara region reached 6 ha and a total of 16 tonnes of rice was produced. After ten years, in 2002, Sasakawa Global 2000 (SG2000) visited research centers and several rice producing farmers in the Fogera plain, and also Pawe Agricultural Research Center to learn more about the status of rice research and production (Aberra and Zewde, 2011) and from the visit found out that: 1) rice crop in the Fogera plains enabled farmers to become food self-sufficient. 2) In Fogera plains a food shortage existed mainly due to the seasonal flooding of the farmlands in the past. From these findings SG2000 decided: a) to assist the national research and extension systems in the re-introduction, field-testing, and transfer of Improved rice production technologies; and, b) to popularize rice production among smallholder farmers in other localities that have similar ecologies; and, c) chose Oromia zone of Amhara Region for intervention. In the mean time, SG2000 consulted the director of SG2000 Guinea[4] who has expertise knowledge and experience in rice research and production, to help push further the research and popularization of rice in the country. Because of this effort the director and expert sent rice varieties to SG2000 in Ethiopia including NERICA types. The Ethiopian Institute of Agricultural Research (EIAR) started testing rice and introduced also several varieties. In this way, SG2000 continued to popularize rice crop in the north, central, southwestern, and southern Ethiopia in 2002.

With these starting measures, SAA/SG 2000 has assisted some farmers establish on-farm demonstrations of X-Jigna, Pawe 1 and locally produced rice varieties with improved crop management practices in southern and south western Ethiopia. Moreover, different rice varieties such as NERICA 1-4, SUPERICA 1 were also tested under different environments. This includes testing under irrigated condition in Werer and Gode and under rain-fed condition in Fogera in 2004 and 2005. In addition to the seed varieties, SAA/SG2000 facilitated demonstration and popularization of rice varieties to areas such as the Ethiopian plateaus, settlement areas of Chewaka[5] in Illubabora zone of Oromiya, Guraferda in SNNPR, and irrigated areas of Werer in Afar and Gode in Somali regions. Because of the demonstration, popularization, and subsequent activities, rice has become a cosmopolitan crop in Ethiopia (Abera and Zewde, 2011).

After those and other similar efforts of several stakeholder institutions in 2005 rice production was expanded to an area of 6871 ha and to output of 28,877 tonnes, with the engagement of about 12,770 smallholders (Gebey et al. 2012), with the support of research and extension system. During this period, alongside with the government and other NGOs, the role that JICA played to support rice related activities has been substantial. In 2009, rice production got popular in all regions and area and production expanded many folds (both CSA and MoARD data) and attracts the attention of the government and other stakeholders. In 2010, the government learned the importance for and potential of rice production and established a national steering committee to promote research and development (R&D). The committee developed the National Rice Research and Development Strategy of Ethiopia (NRRDSE) to make sure that the country

[4] Tareke Berhe (PhD) the Country Director of SAA/SG 2000 Guinea in 2002.
[5] In Chewaka, an individual farmer, who is a settler from Hararge, started to produce using his own seed and other farmers followed him. Later on other seed variety is distributed (SUPERICA 1/Chewaka).

benefits from rice. It is approved on February 2010 with clear targets of area and output expansion.

1.3 Why is the focus on agricultural water management?

It is discussed above that crop production is a means of livelihood for Ethiopian smallholder farmers though it is limited to relatively low yield and quality due to several factors. Though gradually improving, yields are limited to[6] low level mainly because of the low application rate of modern inputs such as fertilizer and improved seed possibly caused by moisture stress and other factors. Several attempts have been exerted to redress the problem of moisture stress that increases risk on spending on modern inputs. Irrigation is one of these measures. Recently, farmers are encouraged to invest in small-scale irrigation. Unless long-lasting measures are taken to decrease moisture stress, cereal yield could remain low and in a growing population, low yield is a concern.

Even though a room is available to increase yield in conventional cereals, recently farmers started rice and its production increased from 15,460 tons to 887,400 tons between 2005 and 2010 and rice producer farmers increased from 18,000 to more than 465,000 during the same period (Mohapatra, 2010)[7]. The spectacular increase of rice production lately stimulates to study inputs (e.g. seed varieties), water, harvest technologies and markets. With respect to AWM, rainfall shortage and variability are typical constraints, whereas the increasing rice production critically demands a corresponding advance in water use to improve output and yield. Of course farmers invest their resources in small-scale irrigation schemes such as rainwater harvesting technologies (WHTs) to overcome moisture stress and to increase output and yields in cereal production. Rain WHTs such as the use of ponds, shallow wells, flood (spate irrigation) and river diversion were stimulated by the Ethiopian government since early 2000s to mitigate moisture stress. With the objective of reducing moisture stress by using WHTs, a number of water ponds were constructed at national level. After adopting them, the smallholder farmers started to use the harvested water mainly for high-value crops production, such as fruits and vegetables. However, the way these technologies are introduced by itself had problems and after the adoption of the technologies, disadoption happened. Even though substantial disadoption happened in a number of areas, in other areas its use and adoption continued (Wakeyo, 2015). For instance, in the rice producing areas, farmers use supplementary irrigation technologies (logged water from lakes, flood diversion or spate irrigation), river diversion, *river plus motor* irrigation, shallow-well, ponds, springs) for supplementing irrigation to overcome rainfall shortage. A few areas use full irrigation for rice production in Gambella and Somale (Abera and Zewdie, 2011) and the share full irrigation in total output in 2010 is only about 5.4% which means that major rice producing areas are in the highlands. With increased use of the small-scale

[6] FAOSTAT indicates wheat, maize and rice yield in Ethiopia was 2.21,3.0 and 2.89 ton/ha respectively in 2012 which amount to only a quarter, one eighth, and a quarter respectively of the top wheat, maize and rice yield countries (8.4, 25 and 9.5 ton/ha respectively) in the world.

[7] Mohapatra (2010) cited the MoARD data which is different from the on estimated by CSA.

irrigation, production has changed. Therefore the study focuses on the AWM in the majority of the rice producing areas than a few full-irrigated areas.

Rice is a water intensive cereal and several issues are interesting in relation to AWM in rice production in Ethiopia. First, both rain-fed and irrigated (e.g. logged-water) are used. Better AWM preserves moisture and keeps environmental balance in areas adjacent to water-bodies. In these kinds of areas water-shortage, conflicts and ecological imbalance could occur. With a proper AWM, it could be possible to handle them and improve rice output and yield. Second, Small-scale irrigation (SSI) are supplementary sources of water in upland rice production and they have interesting characteristics as supplementary water sources. For instance, private farmer's schemes fit to the land tenure, affordable and manageable by small-holders and suitable to collect excess run-off water. Third, in Ethiopia, in addition to the irrigated production (logged-water), much production is carried out in rain-fed areas. In those areas, yield is less than the national average by 9% in 2007 and 19% in 2008 (MoARD data). Several factors cause yield differences, and among them the AWM, weather and seed varieties could be crucial.

Another issue is that in the newly rice-producing areas, WHTs could be used as an alternative water-source for farmers. From previous studies (e.g. Wakeyo, 2012; Sidibe, 2005) and experiences on WHTs (assessments carried from 2004 to 2013 in Ethiopia) encouraging benefits were obtained from harvested water (e.g. Tesfay, 2008). However, the challenge is how to sustain the WHTs schemes. Among others, improper construction could be a limiting factor. From field assessments, EDRI and JIRCAS team understood that flaws in their structure limit their sustainable use and AWM. Previous studies investigated the socio-economic factors crucial for the sustainability of WHTs (e.g. Wakeyo and Gardebroek, 2015; Mekonnen and Gezahegn, 2008) but neglected the construction (e.g. structure and design) aspect. Unless the improvement in socio-economic aspect such as labor shortage is supplemented by improvement in the structure and design, the benefits from these SSIs could collapse and beneficiary famers could loss the benefits and enter into food insecurity and poverty. Sustained use due to the improvement of the physical structure of the schemes could supplement rain-fed rice and other crops production. Of course, in addition to the best practices in Ethiopia, the use of WHTs in Ethiopia can benefit from international experiences. African and Asian countries such as Ghana, Sri Lanka, are using WHTs with varying experiences in rice production and they could be sources of experiences. JIRCAS is also developing a manual of use of WHTs for rice production in African countries.

Stimulated by these basic issues, this study tries to answer the following research questions. First, evidences indicate that rice production in Ethiopia is increasing. How the AWM is categorized in rice production and what does the rate of expansion in each category and yield differences look like? What alternative water sources and small-scale irrigation are available for the rice production and how is the rate of expansion in each AWM category? AWM (e.g. irrigation, drainage) involves a number of specific activities and how is it carried out in Ethiopia? Some small-scale irrigation WHTs are currently in use and others can be potentially used to fill the moisture stress gap in rice production. What construction improvements are possible and how can WHTs such as ponds can be used in a sustainable way? This study tries to respond to those research questions.

2. Objectives

The general objective of this proposed study is to investigate the AWM in rain-fed and supplementary irrigated smallholder rice-producing areas, with a due attention to Small-scale irrigation technologies to curb the negative effect of weather variability and shocks in rice production. The specific objectives include:

1. Explore the categories of AWM in smallholder rice-producing areas and estimate the share of irrigation and rain-fed in total rice output and justify yield differences.
2. Investigate the pattern of water source in the rice-producing *areas* and simulate the rate of expansion of irrigated and rain-fed production.
3. Investigate AWM in small-scale irrigated rice-production.
4. Investigate construction dynamics and effective use of ponds in crops production and explore the construction factors driving successes and failures.

3. Methods and Sample Areas

3.1. Methods

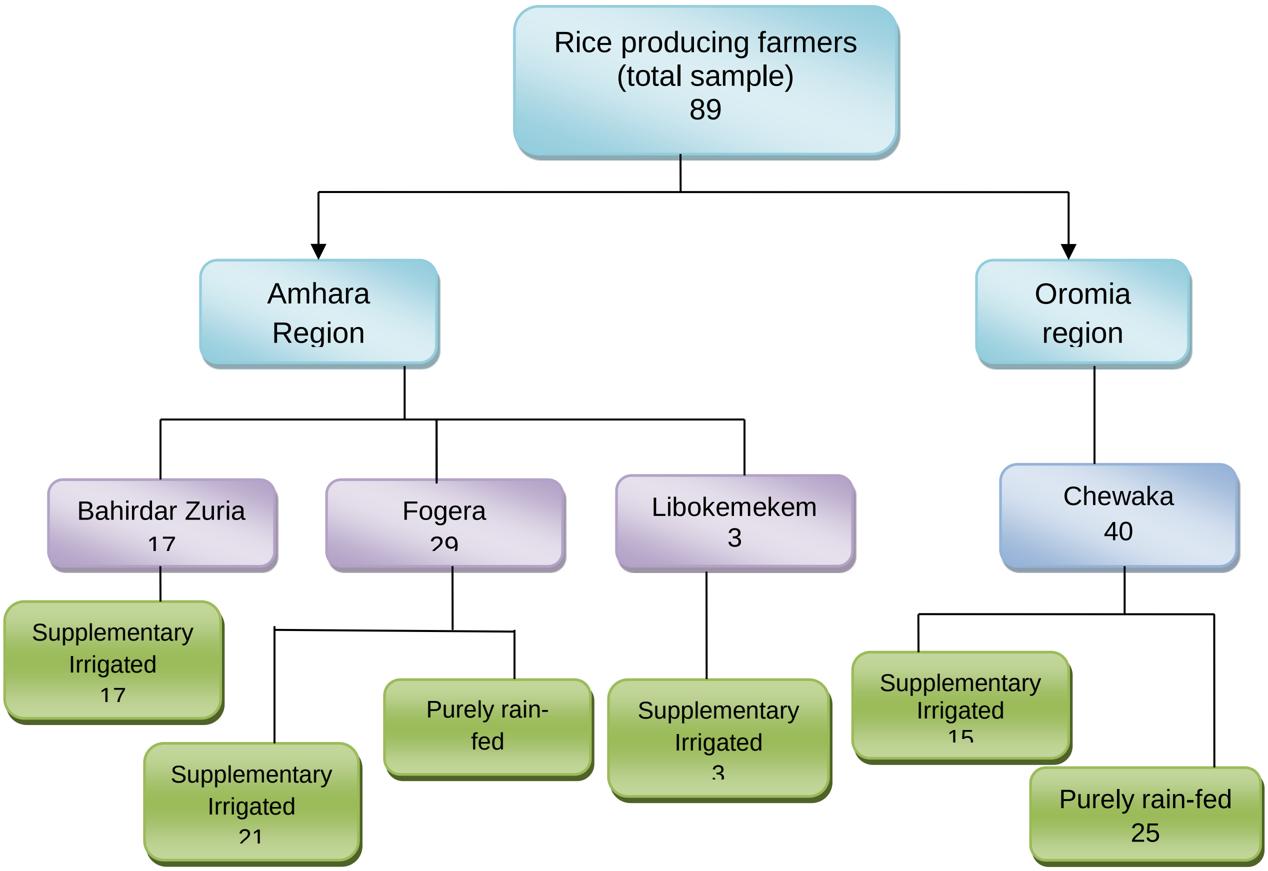
To address those objectives related to AWM, due to the limited resources, some primary quantitative data is collected. The analysis of this data is supplemented with qualitative analysis. Farm households, farmer group discussion, information from experts in public institutes and previous projects are targeted source of qualitative information to look into the AWM and other issues in rice production.

For the analysis, 3 data sources are used. 1) Interview (a survey) of 89 farmers in 4 rice producing sub-districts. In selecting sample PAs for interview, we used stratified sampling depending on their water use (supplementary irrigated and rain-fed). Then, sample households in the PAs are again stratified according to their water access and use condition to grow rice. Overall, we took: a) Five PAs from Fogera, Libokemekem and Bahirdar Zuria sub-districts in Amhara Region. From these sub-districts a total of 49 households are randomly selected and interviewed, (see Figure 1). Similarly, b) three PAs were taken from Chewaka in Ilu Aba Baora Zone of Oromia Region based on their water access and use conditions in rice production. From the three PAs, households are stratified according to their water use, and then a total of 40 rice producing farmers are randomly selected for interview (Figure 1).

The interview applies a standard questionnaire focusing on: a) household characteristics, land, labor, input and output. b) water-use: irrigation water source, volume of water, irrigation and farm equipment, water-saving, use for full or supplementary irrigation, possibility of expansion to larger area, constraints, conflicts around water use in rice production. 2) Work visit for assessment and discussion with the experts of BoARD at sub-districts; discussion with Bako Agricultural Research Center, Chewaka Irrigation Agency, regional BoARD, and discussion with farmers are carried out to capture qualitative information. The assessments done in several parts of Ethiopia continuously from 2005 to 2013 and are sources of information with respect to small-scale water uses.

3) Review of literature and secondary information.

Figure 1: Distribution of sample rice producing farmers by region and sub-districts



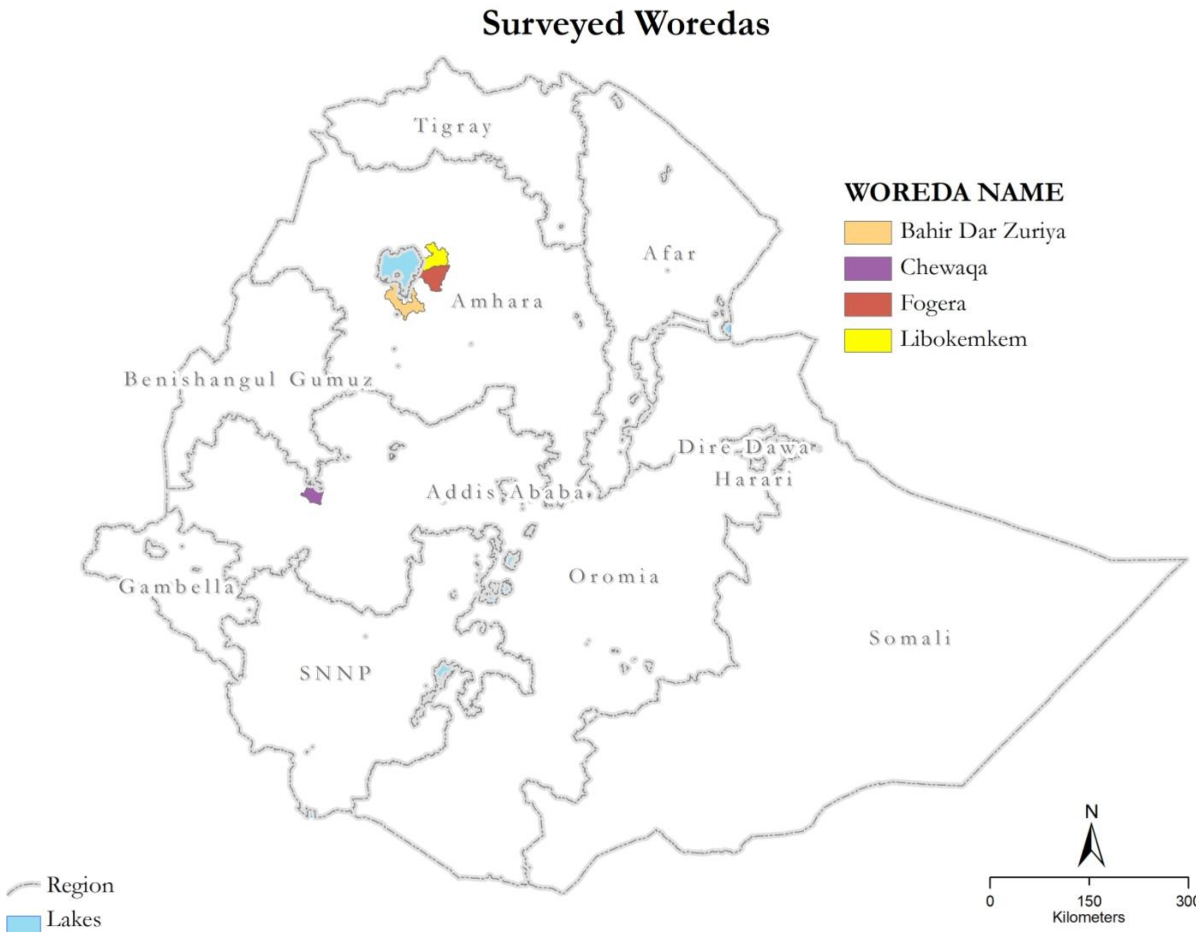
To deal with the first objective, based on the survey data collected from 89 sample farmers, the analysis focused on the categories of water uses in supplementary irrigation and rain-fed. Yield differences in rain-fed and supplementary irrigated rice production are estimated based on the survey data. To achieve the second objective, the primary and secondary data from several sources and parameters from sample statistics are used to estimate the share of rain-fed, supplementary irrigation and full irrigation rice production at national level. The available national information simply categorizes rice production in to rain-fed and irrigated, neglecting the supplementary irrigated one. This helps to compare questions related to the expansion of rice production in Ethiopia in irrigated and rain-fed areas. In the past, there is no clear information on the level of adoption of rice production in each category. Identifying the dominant number of new entrants in each of them helps to predict the direction and volume of future production, the required seed varieties, pesticide and herbicide to deal with the weather shocks. To clearly understand direction of increasing rice production, it was essential to take sample also from newly rice producing areas and then simulate it. For this purpose, checklists are prepared and the number of farmers, the total area and output in a sub-district is collected and forecast is simulated to estimate the rate of expansion in rain-fed and supplementary irrigation areas. The third objective tries to reveal the role of small-scale irrigation and AWM in rice production. The study assesses rice producing areas the types of AWM schemes. The analysis depends on the data obtained from the filled questionnaire. During the assessment, we identified the types of water sources and discussed irrigation and drainage related activities (months of water shortage, WUA, water saving, conflicts). The final objective requires assessing pond-structures in several sub-districts, which are rice and non-rice producing. However, the use of ponds for rice production is not found in the sample areas. The study discusses the experiences obtained from the assessment (the weaknesses in construction and uses of ponds, dynamics of design, supply and use of plastic geo-membrane, site selection, etc) in the areas visited in July and before that to suggest the effective kinds of ponds for rice and other crop production.

3.2. Study Area

Overall, several regions produced and contributed to national production of rice in 2010. The lion share is in Amhara 40%, followed by SNNPR 27.18%, Somale 13.33%, Oromia 7.23 %, Gambella 1.6 %, Tigray 1.14% and Benshangul-Gumz with 0.41%, (NRRDS, 2009). The sample for this study is taken from 4 sub-districts in 2 regions. These include 3 from Amhara region (Fogera, Libokemekem[8], and Bahirdar Zuria) and 1 from Oromia region (Chewaka). From each sub-district, 2-3 PAs are randomly selected as samples to access farm households producing rice. To explore the last objective related to the sustainability of WHTs, we use 5 sample sub-districts from 3 regions in line with the 2013, 2010 and 2005 assessments. These include Fogera, Bahirdar Zuria (Amhara), Dugda and Bora (Oromia) and Mareko and Alaba Special Sub-district from SNNPR.

[8] It is necessary to make careful interpretation of the results in case of the low sample Libokemekem.

Figure 2: Survey sub-districts of agricultural water management in rice production in Ethiopia, 2014



3.3. Sample's characteristics

To provide a picture about the overall population of the rice producing areas, we summarized in Table 1 the characteristics of the sample farmers. The sample rice producers are taken from two agro-ecologies that farmers classify themselves into. The mid-high altitude (*woyna dega*) and the low lands (*Kola*). Samples from Amhara region are in mid-high altitude (*woynda dega*), ranging from 1790 to 1857 MASL, whereas Chewaka, a sample from Oromia, is within a low land warm ecology (*kola*) in a range of altitude of 1199 to 1395 MASL. Average rainfall in the samples sub-districts of Amhara region is about 1550 (for Bahirdar) and 600-800 mm in sample sub-district of Chewaka.

The socio-economic characteristics data indicate that the average age of the selected farmers producing rice is 40, ranging from 36.4 in Chewaka to 44.4 years for Bahirdar Zuria farmers. Table 1 summarizes the socio-economic variables. Among others the table indicates that: 1) in the sample households on average the proportion of male adults exceed the proportion of female adults (54% vis-à-vis is 45%), which is in line with Tsega et al (2013); 2) In the main rice producing sub-district Fogera, average landholding is the least of all, indicating that there is a need to increase yield instead of expansion. 3) About 75% of the farmers face land shortage in general and 91 percent for rice production (Table 1). 4) Except in Chewaka, livestock size is high (average 17.3). 5) About 95% of the farmers in Chewaka do not have oxen whereas 80% of the selected farmers have greater than two oxen in Amhara region.

Table 1: Average characteristics of sample households

Item	**Sub-district**				**Total**
	Chewaka	*Fogera*	*Libo kemekem**	*Bahirdar Zuria*	
Age	36.40	42.20	42.70	44.40	40.00
Gender	0.93	0.96	1.00	1.00	0.96
Household size	6.60	5.50	9.00	5.80	6.20
#. of Male	3.63	3.30	4.30	3.30	3.50
#. of Female	3.00	2.30	4.60	2.50	2.70
Age groups					
16-65 Male	1.40	1.59	1.00	1.24	1.42
16-65 Female	1.30	1.38	1.33	1.18	1.22
Education, 0=illiterate	0.33	0.45	0.00	0.29	1.31
Landholding	2.00	1.17	1.58	1.31	1.60
Faced land shortage? 1=yes	0.75	0.90	1.00	0.82	0.82
Faced land shortage for rice prod?1=yes	0.90	0.93	1.00	0.88	0.91
# of livestock	12.50	17.70	17.70	16.40	15.10
# of oxen	0.05	1.90	2.00	2.06	1.08
Can you sell your rice easily? % of yes	84.60	83.30	100	37.50	75.60
Did you receive credit in 2012/13? yes (%)	32.50	3.04	0.00	58.80	27.00

* Low sample size; Source: author's computation from survey data

The summary table also indicates that (6) on average, 75.6 percent of the farmers sell their output easily and 91% of the farmers rated market availability for rice is high and only 6 percent of them rated low. However, from our assessment we understood a relative price difference between sample sub-districts. For instance the average price of one kilogram of rice in Chewaka is only 5.5 Birr whereas the same kg of rice in Bahir dar Zuria, Fogera and Libokemkem is sold for Birr 11.0, 10.0 and 11.5 respectively indicating substantial price differences. The large price difference is not due to quality difference alone. Farmers mentioned lack of trashing (milling) machine is an important reason. Often, businessmen mill the rice and grab the benefit that could goes to farmers because of unavailability of the machine at a reasonable price.

Table 1 also indicates that (7) credit is not available often when farmers want. In 2012/13, only 27% of the farmers receive credit. In 2013/14, most farmers received credit for agricultural input such as fertilizer and business such as animal husbandry.

4. Review of Previous Studies

The literatures on rice productions in Ethiopia are not extensive. Similarly on AWM are embarrassingly limited. The only document that provides a simple highlight on the rice ecologies and water use in rice production is the strategic document that divides the rice agro-ecologies in Ethiopia as highland rain-fed, lowland rain-fed, and irrigated areas (EIAR et al, 2010). The compiled documents reflect the challenges and opportunities of rice in Ethiopian agricultural development and to some extent highlight the potentials of production, but none of them reflected the AWM in rice production which is a challenge. The focus of the document is on seed varieties, popularization of rice production the R&D issues, etc. This document considers rice production in Ethiopia is fully rain-fed and neglected the use of supplementary irrigation as a mechanism of reducing moisture stress. Similar to the (EIAR, 2011), the (EIAR, 2012) addressed several issues around the agricultural extension in rice production but in Ethiopia, it neglected to assess the role of extension in AWM.

Another study (Astewel, 2010) focused on the marketing and profitability of rice production in Fogera and found out that: 1) market information access, quantity of rice produced, total value of livestock unit and extension contact with farmers increase household's probability of selling rice. 2) Household head's education level and total quantity rice produced were positively affecting the level of rice sale. 3) Increase in family size decreases the volume of rice supply to the market per household. 4) The study also found out that (quantity produced is jointly affected both the probability of market participation and volume of supply. 5) The cost benefit analysis of rice production shows that rice production is a profitable business for farmers in line with Astewel (2010).

Heluf and Mulugeta (2006) also studied the effects of mineral nitrogen and phosphorous fertilizers on yield and yield components of flooded lowland rice on vertisols of Fogera Plain. Mainly they found out that maximum grain yield was obtained with the combined application of 60 kg N and 13.2 kg phosphorous per hectare.

Similarly, Tsega et al (2010) studied socioeconomic characteristics of smallholder rice production in Ethiopia using a national survey data and found out from their study among others that: 1) with respect to the commercial behavior of farmers the result indicated though the proportion of farmers using own seed is high, there is an increasing trend in buying and selling as the proportion of farmers who buy rice seed has increased from 10.6 in 2008 to 14.4% in 2010 and who sell seed increased from 12.5 in 2008 to 14.2% in 2010 at national level. At regional level, there is considerable variability following the use of different varieties. 3) Respondents were asked for what purpose they used the rice they produced and in 2010. About 27.4, 68.7, 2.2, and 1.7 percents of the respondents reported that they use what they produced only for family consumption, family consumption and sale, for sale only and for other purposes respectively. In 2009, the respective figures are 26.9, 67.5 1.8, and 3.8%.

Nicol (2012) studied the yield of Ghana upland rice and found out that the the average rice yield in 10 regions vary from 122 in Central to 2.97tonne/ha in Volta region with an overall average of 2.39/ha in 2009, and remarked that the rice yield varies with the level of rainfall availability. Bruton (2010) suggested that yields may not rise (goal of irrigation cannot be achieved) if modern inputs such as fertilizer and improved seed and the techniques of production are not integrated to irrigation. JIRCAS (2012) indicated that water shortage and soil fertility (low nutrient), which are interrelated problems, and plant disease cause low yields.

A number of references on small-scale irrigation are consulted. Most of them are not directly relating to the AWM in rice production. However, they reflected the potential importance in the future in a country of high rainfall variability and rainfall shortages.

5. Analysis of Results

5.1 Types of AWM technologies, share of upland and irrigated rice and yield differences

5.1.1 Explore the AWM of Ethiopian smallholders in rice-producing areas: Types of AWM technologies

In the assessment of the AWM technologies in rice production in Ethiopia, we found 3 types of water uses, namely rain-fed, supplementary irrigation and full irrigation. Rain-fed and supplementary irrigated rice productions are practised in two categories of areas: 1) upland rain-fed and supplementary irrigated; 2) lowland rain-fed and supplementary irrigated rice. Other than these two categories, fully irrigated rice is practised in a few areas in Afar, Somale and Gambella (Teshome and Dawit, 2010).

It is essential to discuss the types of water uses at plot levels. The rain-fed or upland rice areas of Ethiopia include rice production in altitude ranging from 1000 to 2000 meters above sea level/masl (Sihahi, 1994). Within this general range, two upland rice growing altitude categories can be demarked: the upland rain-fed rice growing areas with altitude range of greater than 1500 and the lowland rain-fed upland rice category within altitude range of less than 1500 masl. In the upland rain-fed rice growing category, we find the Northern Ethiopia rice growing areas such as most areas in Fogera, Bahirdar Zuria (Bahirdar surrounding), Libo kemekem, Gonder surrounding, Dera, whereas some lowland rain-fed variety are found in some of these sub-districts (e.g. Kidist Hanna PA in Fogera), Gebey et al. (2012).

In those areas, farmers know from experience that the rainfall is sufficient to grow rice and the rice seed variety they grow by applying supplementary irrigation. In other areas such as Chewaka, farmers use SUPERICA which is a relatively water stress tolerant. In addition, when they have water sources such as logged-water from river, they use the rice variety suitable to water abundant irrigation but this seed variety difference due to water use is in a very low proportion at present in Chewaka. Expert estimation indicates that about 65% of the farmers in Chewaka produce rice in pure rain-fed condition whereas 35% of them produce in logged-water (supplementary-irrigated) condition.

Table 2: Types of AWM technologies used (by region)

Types of AWM technologies	Region		Total
	Amhara	*Oromia*	
River based and flood diversion	20	0	20
Ground water	3	0	3
Natural Reservoir	1	0	1
River + motor pump	12	0	12
logged water	6	15	21
Other	1	0	1
sum	43	15	58
Rain-fall	6	25	31
Total	49	40	89

Source: Author's computation from survey data

In this kind of survey even though the distribution of the technologies of small-scale irrigation in AWM has a pattern which is summarized in (Table 2), expert evaluations of the three PAs provide us with the overall picture of the distribution of the technologies by sub-district. Accordingly, based on survey expert assessment of each sub-district, in Bahirdar Zuria (surrounding Bahirdar) sub-district, 80 percent of the rice growing farmers use flood diversion (spate irrigation) to supplement their upland rice farming, 20 percent of them use pumps (10 percent) and the remaining 10 percent have the location advantage to use the logged water. On the other hand, in Libokemekem, 60 percent of the rice producers use logged water, 20% of them use motor pumps to drag from river, and 10 percent of them use flood-diversion to supplement their rain-fed rice growing. Though it is shaky, the data organized in a sub-district indicate this tendency.

Furthermore, the interview of experts at the sub-district BoARD indicates that in three sub-districts (Fogera, Bahirdar Zuria and Libo kemekem) on average only 4% of the rice farmers use only rain-fed to grow rice whereas 96% of them supplement upland (rain-fed) rice with supplementary irrigation.

5.1.2 Rice Yield differences

In Chewaka, yield is computed for two rice growing categories of households. These are pure upland rain-fed category and apparently supplementary irrigation user categories. The finding indicates that in this sub-district, average yield ranges from 0.94 tonnes per ha to 11.1 tonnes per ha[9], with an average of 4.6 tonne per ha. In one of the sample PAs found in the sub-district, rice producers apparently[10] use supplementary irrigation from logged-water source around a small river near the town of Chewaka. Surprisingly, their yield is different from the rice grown by pure rain-fed (without the supplementary use of logged water).[11] For those farmers who grow rice on the logged-water, the computed average yield is 5.05 tonne per ha with a maximum of 9.4 tonne per ha whereas in non-user of supplementary rice producers the average is 4.3 tonne per ha with a maximum of 11.1 tonne per ha (Table 3). Though the yield difference is computed under uncontrolled condition (uncontrolled for other factors influencing yield e.g. farm management), the effect of supplementary irrigation in lowland where the average rainfall is only 600-800 mm cannot be neglected.

Table 3: Yield difference between pure rain-fed and supplementary rice production (kg/ha)

woreda	type of water use	Mean	N	Std. Dev	Minimum	Maximum
Chewaka	Rain-fed	4346.5	24	2733.1	940.0	11115.4
	Supplementary irr	5047.6	16	2079.8	1230.8	9200.0
	Total	4626.9	40	2487.9	940.0	11115.4
Bahirdar zu	Supplementary irr	3500.0	17	1252.3	1200.0	6061.5
	Total	3500.0	17	1252.3	1200.0	6061.5
Fogera	Rain-fed	3678.1	7	1235.1	2000.0	6000.0
	Supplementary irr	5416.8	22	1887.3	2800.0	10666.7
	Total	4997.1	29	1889.9	2000.0	10666.7
Libokemekem	Supplementary irr	5804.4	3	962.0	4880.0	6800.0
	Total	5804.4	3	962.0	4880.0	6800.0
Total	Rain-fed	4195.6	31	2472.3	940.0	11115.4
	Supplementary irr	4773.2	58	1908.8	1200.0	10666.7
	Total	4572.0	89	2126.1	940.0	11115.4

Source: Author's computation from survey data

On the other hand, in Amhara region, the overall average yield is 4.5 tonnes per hectare, with a maximum of 10.7 tonnes and a minimum of 1.2 tonnes per ha (see Table 4). But in the region the majority of the sample farmers (86%) use supplementary irrigation. Similar to the case of Chewaka, the yield difference between rain-fed/upland and supplementary irrigated rice is substantial. Those who use supplementary irrigation reported 5.4 tonne/ha yield, compared to

9 Farmer whose name is Zekeriya harvested 1445 kg of rice (SUPERICA) from a 0.125 ha of land. So the yield is 11.1 tonne per ha in 2006. Surprisingly, he uses rain-fed to grow rice.

10 They do not invest in irrigation but use logged-water as supplementary and yield difference is observed.

11 Note that the yield difference is observed with a reasonable sample proportion of 15:25, supplementary: irrigated to rain-fed rice producers proportion.

non-users with 3.7 tonne/ha yield (Table 4). In the region the supplementary irrigation is based on different types of small-scale irrigation technologies (Table 3).

Table 4: Comparison of rice yield with sub-districts

Sub-district	Region	Mean rice yield (kg/ha)	N	Std. Deviation	Minimum	Maximum	Mean rice yield (tonne/ha)
Chewaka	Oromia	4,626.9	40	2487.9	940.0	11,115.4	4.63
	Total	4,626.9	40	2487.9	940.0	11,115.4	4.63
Bahirdar zu	Amhara	3,500.0	17	1252.3	1,200.0	6,061.5	3.50
	Total	3,500.0	17	1252.3	1,200.0	6,061.5	3.50
Fogera	Amhara	4,997.1	29	1889.9	2,000.0	10,666.7	5.00
	Total	4,997.1	29	1889.9	2,000.0	10,666.7	5.00
Libokemekem	Amhara	5,804.4	3	962.0	4,880.0	6,800.0	5.80
	Total	5,804.4	3	962.0	4,880.0	6,800.0	5.80
Total	Amhara	4,527.1	49	1803.8	1,200.0	10,666.7	4.53
	Oromia	4,626.9	40	2487.9	940.0	11,115.4	4.63
	Total	4,572.0	89	2126.1	940	11,115.4	4.57

Source: Author computation from survey data

In Bahirdar Zuria and Fogera, many of the farmers grow rice under flood and logged-water. The yield and the seed varieties used are different under this water use category.

Rice farmers in the sample PAs of both Amhara and Oromia use three different varieties of rice including X-jigna, NERICA 4 and SUPERICA. Among the interviewed 89 farmers, to the question that what kind of rice seed variety they used in 2013/14 production year, 39 of them responded that they use X-Jigna, 10 of them NERICA 4 and 40 of them SUPERICA. The role of seed as a factor of yield difference is discussed in Khush (1995). The difference in the seed varieties could be responsible for the difference in yields. In this regard, in Amhara region where rice has been already grown more than 20 years, farmers already learned the kind of seed that delivers highest yields among the chosen ones. In addition, the farmers in the area have an opportunity to choose seed varieties which is not available in other upland and low land areas. The data indicates that farmers around Fogera and surrounding have been using 4 kinds of seed varieties whereas in Chewaka the seed varieties used in the sub-district is only one. Rice grows well in waterlogged conditions and seed varieties can grow at high altitudes in cold weather (Nigussie et al. 2008). In Chewaka, which ranges in altitude of 1199 to 1395 masl, both rain-fed and supplementary types of rice are grown. Similarity, in Gurra farad sub-district of SNNPR is ranging from 648 to 2330 masl. The type of rice grown is improved NERICA and SUPERICA-1 varieties and the yield in 2009 was 3.2 tonnes/ha.

In addition to the difference in seed varieties, availability of rainfall and supplementary irrigation sources are also important (Table 3). As the data indicates the farmers in North Ethiopia use different kinds of supplementary irrigation mainly river sources, flood, and logged water and ground water sources, and users of supplementary irrigation harvest higher yield compared to pure rain-fed.

The third yield factor is fertilizer. The difference in yield could be caused by the use or non-use of fertilizer and the amount of the recommended quantity applied per ha (Table 5). Table 5 indicates the average quantity of fertilizer used by rice growing farmers in the sample areas.

Table 5: Average quantity fertilizer used for rice kg/ha in 2012/13 by sample sub-districts

Woreda	Mean	N	Std. Deviation
Chewaka	183.37	40	122.35
Bahirdar zu	5.66[12]*	17	23.32
Fogera	193.95	29	545.67
Libokemekem	64.44	3	26.94
Total	148.86	89	326.96

Source: Computation from survey data

The computed average rice yield for farmers who use fertilizer is 5.3 tonnes per ha, whereas for farmers who do not use fertilizer is only 3.9 tonnes per ha, (only 73% of the possible yield). Other studies carried out in the sample areas confirm that the role of fertilizer in yield difference is substantial especially when the combination of fertilizer is used (Heluf and Mulugeta, 2006). JIRCAS (2012) underlines that lack of nutrients is a factor causing low yields in African rice production.

Table 6: Comparison of yield among users and non-users of fertilizer (kg per ha)

Fertilizer use Status	Sub-district	Mean	N	Std Dev.	Minimum	Maximum
Non-users	Bahirdar zuria	3504.3	16	1293.2	1200.0	6061.5
	Fogera	4933.4	10	1354.9	2800.0	7248.0
	Libo kemekem	4880.0	1	na	4880.0	4880.0
	Total	4084.6	27	1452.2	1200.0	7248.0
Users	Chewaka	4626.9	40	2487.9	940.0	11115.4
	Bahirdar zu	3430.8	1	na	3430.8	3430.8
	Fogera	5030.6	19	2152.8	2000.0	10666.7
	Libokemekm	6266.7	2	754.3	5733.3	6800.0
	Total	4784.2	62	2339.1	940.0	11115.4

Source: Computation from survey data

The soil fertility could be also factors responsible for yield differences. The field assessment around Chewaka indicates that the soil is very fertile and even without fertilizer the average yield can be high. In the data we do not have sufficient observation for non-users of fertilizer in Chewaka to compare the yield difference between users and non users of fertilizer because all farmer in Chewaka use fertilizer. Again soil fertility index is not available to see if it affects yields.

[12] The low average use-rate is because only one farmer uses fertilizer in the sub-district and 16 others don not use it for rice production.

However, the average yield difference between user and non-users of fertilizer can be attributed to the soil characteristics in case of Fogera (which have sufficient observation to compare) to soil fertility difference. For non-users of fertilizer in Fogera, rice yield is 4.5 which is still very high, though lower than that of only fertilizer users i.e., 6.7 tonnes per ha. In addition to seed variety, fertilizer use/non-use, and soil fertility difference, yield difference could be due to other factors such as irrigation use and farm management.

5.1.3 Estimate the share of irrigation and rain-fed in total rice output

Documents indicate that a substantial portion of Ethiopian rice production is upland and lowland rain-fed. No document estimated the share of irrigation. In this study, because water is a scarce resource, the study of AWM takes into account the supplementary water used in rain-fed rice growing and therefore supplementary irrigation is considered than categorizing all rice production as purely rain-fed/ upland. This means that within the upland rice production, the share of pure rain-fed and supplemented rain-fed has to be separated to see some important characteristics of rice production and AWM.

The approach to follow in estimating the share of pure rain-fed and supplementary irrigation rice at national level follows a three step procedure. The first is estimating the users of supplementary irrigation from the sample households. The second one is to take the list of rice producing areas from documents and use the household based parameter (obtained from the survey data) to estimate the quantity of rice produced in each sub-district. Then the national share of irrigated and rain-fed rice can be estimated by multiplying the sample parameter with the total production in a specific region. After these steps, the share of fully irrigated, supplementary irrigated and rain-fed rice produced is estimated.[13]

Full Irrigated Rice

Documents indicate that full irrigated rice is produced in two regions of Ethiopia in 2009 namely, Gambela and Somale. In somale (Gode area) and Gambella region the total rice produced was reported for 2009 and estimated for 2010. The estimated share of full irrigation in the total national rice production therefore depends on the total production of 2010 for the two regions. In 2010, the total rice produced is estimated to be 146,566 tonnes (Table 7). Of this, the share of fully irrigated rice (produced in Somale and Gambela) is only 5.6%, which is the share of fully-irrigated rice at national level.

Purely Upland/ Rain-fed Rice and Supplementary-irrigated upland Rice

A look into previous assessments, the local and regional interview data from checklist and the estimated parameters from the survey data indicate the level of rice produced by supplementary

[13] The estimated shares would be more precise than this one which is based merely on the data from Chewaka, if the remote areas of South and West of Chewaka (Oromia and SNNPR) were assessed.

irrigation and pure rain-fed. So they can be separately estimated. In Amhara region, the assessment and the interview of the regional experts indicate 94 percent of the rice produced is supplementary irrigated in sub-districts such as Fogera, which produce the lion share of the rice output in the country.

The document obtained from Amhara indicates that 27 sub-districts produce rice. Those sub-districts are located in areas close to the predominantly rice producing areas of Amhara Region. The majority of them produce supplementary-irrigated upland rice. The yields in those sub-districts also indicate that they fall within the range of less than fully irrigated but greater than purely rain-fed rice (MoARD, 2012).

It is recalled that in the sample areas of Amhara region, the survey expert estimated that about 94% of the rice production are using supplementary irrigation (section 5.1.1). Slightly relaxing the expert-estimated 94 percent to 90 percent (because the other areas are relatively far from water-logged areas) that farmers in the closer (to logged-water) sub-districts in Amhara Region produce supplementary-irrigated rice whereas 10 percent use purely rain-fed rice production system. We use this parameter to estimate the purely upland and the supplementary irrigated rice from the total rice produced in Amhara Region in a particular year.

Figure 3: Rice field in Fogera- January 2014

Picture taken by survey expert

In Oromia, Chewaka is the leading rice producer in quantity. It is a third sub-district at national level in terms of total production. Even though the rice grown in Chewaka, is *SUPERICA/Chewaka*, farmers use the location advantage of logged water. The expert assessment of the Woreda indicates that 65 percent of the total rice output is purely rain-fed grown rice whereas 35% is supplementary irrigated rice because of the availability of logged-water that supplements the upland rice at the time of water shortage. To the West (Oromia region sub-districts) and South (SNNPR sub-districts) of Chewaka, rice is widely produced. Because rainfall increases to the South and West of Chewaka, the proportion of supplementary irrigated and pure rain-fed rice can be estimated at 30 percent and 70 percent respectively. The slight difference from that of Chewaka (which is 35:65) is because rainfall is assumed to increase to the West of Chewaka. This means in areas South and West of Chewaka, 30:70 proportions can be used for the sub-districts of SNNPR and other zones of Oromia to estimate the rice volume produced by a specific AWM in a particular year. Documents also pinpoint to the Chewaka kind of rice seed variety in South and South West areas of Ethiopia (e.g. MoARD, 2012; EIAR, 2011). Based on these parameters, the pure rain-fed and the supplementary-irrigated rice produced in all regions are summarized in Table 7.

Table 7: Estimated upland and supplementary irrigated rice produced*

Region	Share of rainfed rice (%) (a)	Share of supplementary irrigated rice (b)	Share of full irrigated rice (c)	Rice output of the region in 2010 (d)	Estimated total rain-fed/upland rice output (MOA) 2010		Estimated total Supplementary irrigated upland rice output, 2010		Share of full irrigated rice output MOA (2010)	
					tonne (e)	% ($f=e/\sum e$)	tonne (g)	% ($h=g/\sum g$)	tonne (i)	% ($j= g/\sum g$)
Amhara	10.0	90.0	0.0	121489	12149	46.0	109340	93.5	0.0	0.0
Oromia	65.0	35.0	0.0	11484	7465	28.3	4019	3.4	0.0	0.0
SNNPR	70.0	30.0	0.0	6630	4641	17.6	1989	1.7	0.0	0.0
Tigray	100.0	0.0	0.0	2080	2080	7.9	0.0	0.0	0.0	0.0
Beni-gumz	90.0	10.0	0.0	656	66	0.3	590	0.5	0.0	0.0
Somale	0.0	0	100.0	4227	0.0	0.0	0.0	0.0	4227	51.3
Gambella	0.0	21.0	79.0	5072	0.0	0.0	1065	0.9	4007	48.7
Total	0.0	0.0	0.0	151638	26401	100.0	117003	100.0	8234	100.0
Percentage of output in each category				151638	26401	17.4	117003	77.2	8234	5.4

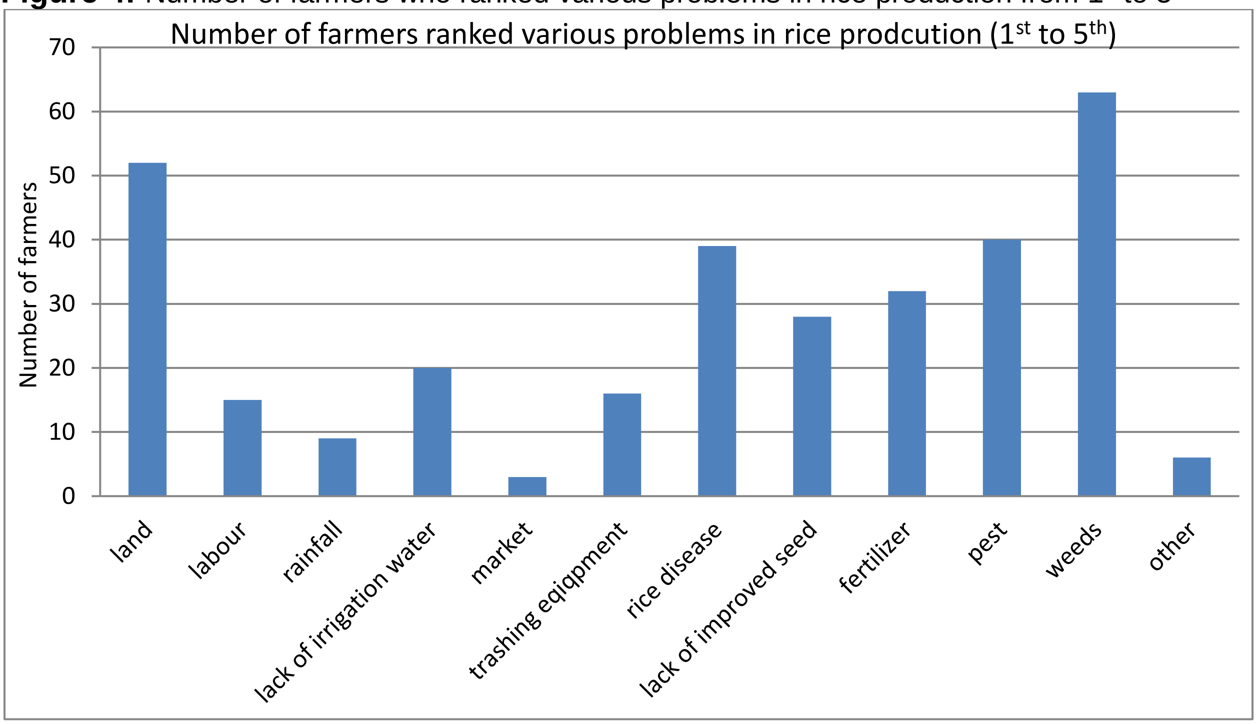
*Gambella and somale estimates are full irrigated rice output

We cannot find the 2012/13 rice production report from MoARD, and instead we use the national rice produced data of MoARD for 2010 separated by region (Table 7) to estimate the quantity of output by source of water (by types of AWM practises).

Accordingly, the average share of pure rain-fed (upland), supplementary irrigated, and full irrigated rice in the total rice produced in 2010 is 77.2 percent, 17.4 percent and 5.4 percent respectively. The respective rice produced in each of these AWM systems are 26401 tonne, 117,003 tonne and 8234 tonnes (Table 7).

On the top of this, the data indicates that about 98% of the selected farmers responded that they would expand their rice farm and production if it is not for land constraint. The document obtained from Bahirdar Zuria BoARD also indicates 11 PAs will start to produce rice in the coming season using supplementary irrigation. This indicates that expansion is expected in the coming years. In rice production, farmers listed several constraints challenging rice production. Among which weeds, land, pests, rice disease fertilizer (similar to the findings of JIRCAS, 2012) and lack of improved seeds limit rice production (Figure 2). Rainfall shortage is mentioned by less than 10% of the farmers and so it is not a major problem, unlike the conclusion of JIRCAS (2012).

Figure 4: Number of farmers who ranked various problems in rice production from 1^{st} to 5^{th}



Source: author's summary from survey data

The support of the government institutes for the expansion endeavour is positive. For instance, the explanation from the Bureau of Irrigation agency in Chewaka indicate that n 4 of the 28 PAs in the sub-district have potentials and demand to grow rice by irrigation and the bureau of irrigation Agency is working to implement it in 2013/14. In Chewaka, farmers who are currently using full irrigation for vegetables are not willing to use it for rice because of the cost of irrigation. In those four PAs, growing other vegetables by irrigation is not economical and the choice of farmers is to grow rice. The support of these farmers by Irrigation Agency is an interesting initiative towards AWM.

5.2 Water sources in rice-producing areas and the rate of expansion of irrigated and rain-fed rice

5.2.1 Pattern of water source in rice producing areas

The technology choice depends on the accessible water source, the purpose of use of the irrigation water and the cost of irrigation technology. This includes the cost of extracting and distributing irrigation water (Wakeyo and Fujimoto, 2017). The sources of water include river water, wetlands, flood (spate), ground water, logged water, fog, dew, etc. Among these sources, in the country as a whole ground water is underdeveloped except in a few areas of East Hararge, Central Oromia (following the bank of Awash), around Chencha in SNNPR, lake Zuway areas, etc. Logged water is around rivers and lakes such as Tana, Abaya, Haiyk, Lake Zuway, Awash and other rivers. However, only a few of these kinds of ground water schemes are used for rice production.

Contrarily, spate irrigation is much common in a few areas and the total land developed with spate irrigation is not more than 200,000 hectares. The communal spate irrigation in Dodota-Sire (Arsi), West Hararge highlands, Raya valley, (Wakeyo and Fujimoto, 2017), Fogera, are a few of them. However, it is observed that in the sample areas, river based floods are also very common.

In Ethiopia, the lion share of water-source goes to rivers. Substantial share of the irrigated lands are river-based, but they are also not used for rice production. The river sources can be categorized in to two- gravity based river and *river plus motor* irrigation facilities. The gravity based one is the most widely used irrigation. Mainly, the river basin of Awash is the most developed one since 1960s in its upper, middle and lower Awash valleys in the lowlands and Woliso, Bora and Adama areas. It is used to produce sugarcane, cotton, fruits and vegetables in large scale prodcurtion. Following Awash, there are other smaller rivers including Legeramis (in Harar), Elele, Hassen Usman, Azule (Arsi), Meki (Central Oromia), Beles (Gojam), Jema (North Shoa & West Gojam), Tekeze and Mereb (Tigray), Wabeshebele (Somale Region), Bilate Genale (Oromia and Somale), Bambasi and many others (in Benishangul-Gumz), etc are most exploited than the big ones. On the other hand, *river plus motor* irrigation is started and widely used on Genale River (Somale and Oromia), Awash River (in the highland and the rift valley in central Oromia), and on Wabi Shebele River (Somale), etc. can also be mentioned.

Even though river based irrigation are expanded at this level, only a few of the big rivers are used for large-scale rice production but not in small-holder rice production. In most of the cases, the river based irrigation is used to produce fruits and vegetables, which is remarked by farmers that it is economical to allocate the water in this way (assessment in Chewaka). In Fogera and Libokemkem, located away from the water-logged areas, farmers use *Gumara* and *Rib* Rivers for supplementary irrigation. Overall, the water-source used for supplementary irrigated rice is summarized in Table 8.

Table 8: Water sources of supplementary irrigation in upland rice producers

Water source	Number of users	Percent
River based and flood diversion	20	34.5
Ground water	3	5.2
Natural Reservoir	1	1.7
Logged water	16	27.6
River + motor pump	3	5.2
River, River + motor	3	5.2
River, natural reservoir + motor	6	10.3
River, River + motor, Lake + motor	1	1.7
River and logged water	3	5.2
River+ Motor, Logged water	1	1.7
Lake + motor, logged water	1	1.7
Total	**58**	**100.0**

Source: own computation from the survey data

The table indicates that river and flood diversions are the major sources of supplementary irrigation. Farmers responded to the question that which kinds of water source are they using for irrigation, 35 percent of them indicated that they use river and flood diversion. Other farmers (29%) mentioned river based technology (e.g. *river plus motor*- picture 1). Overall, river and flood diversion are the supplementary irrigation water-sources for about 63.8 percent of the sample farmers. Other water sources include logged water (27.6%) and ground water (5.2%). The sources of supplementary irrigation in the sample areas are river, flood diversion and logged (wet land) water sources.

Figure 5: The use of motor + river for rice production in Fogera

Photo taken by survey expert: motor + river on Rib River (Libokemekem)

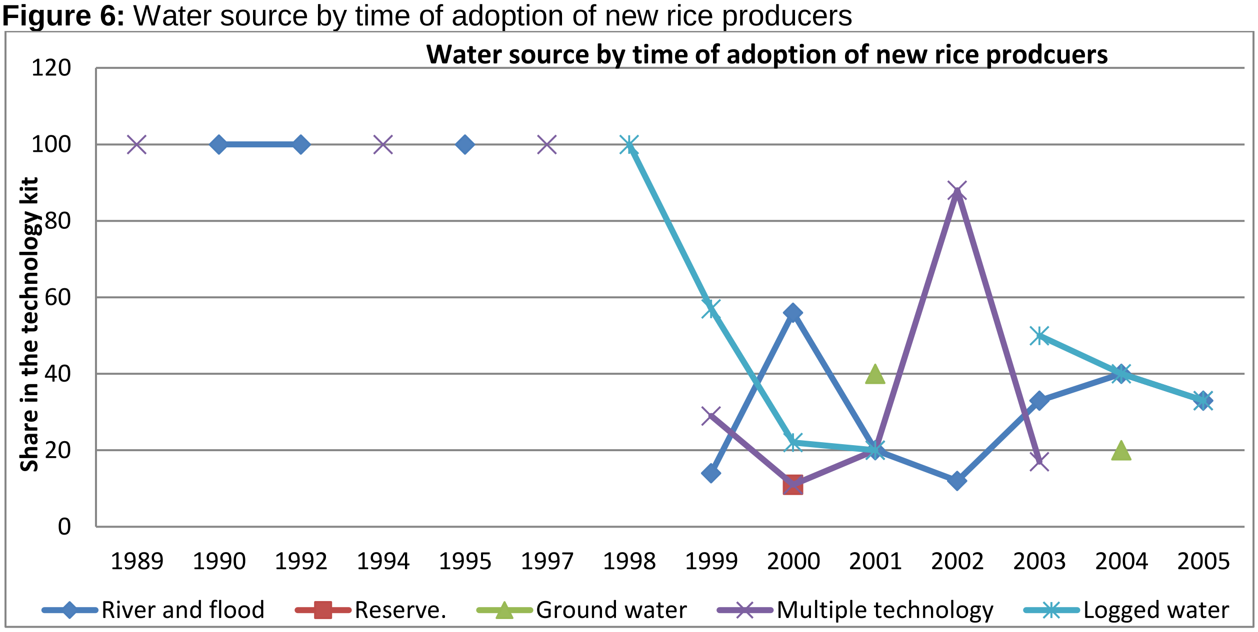
Also, we tried to relate the water source with the time that farmers started rice production (Table 9 and Figure 5) to understand the relationship between the expansion of rice production and the targeted water resource. The table indicates, among others that: 1) the dependence on river and flood diversion alone to adopt rice production has declined after 1998. 2) Instead of depending on a single small-scale irrigation, the use of multiple technologies has increased by new adopters. 3) Ground water and reservoirs are generally underused in rice production and adoption. 4) The overall tendency is that no single source is targeted, though the role of river and flood diversion is dominant.

Table 9: Source of supplementary irrigation over time of adoption of rice production

Water Source	**Percentage of farmers selected in the sample who use each water source for irrigation (over years)**													
	1989	1990	1992	1994	1995	1997	1998	1999	2000	2001	2002	2003	2004	2005
River and flood		100	100		100			14	56	20	12	33	40	34
Reservoir									11					
Ground water										40			20	
Multiple technol.*	100			100		100		29	11	20	88	17		33
Logged water							100	57	22	20		50	40	33
Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100

*Multiple technologies include the combination of several water sources and motor pumps

Figure 6: Water source by time of adoption of new rice producers



In the case of full irrigation in rice production in Somale, Gambella and Afar regions, river water is the major source (100%) of irrigation. This engulfs the irrigated rice production in Gode (Somale region) and Akobo River (Gambela region).

5.2.2 Rate of expansion of irrigated and rain-fed production

For several reasons, rice production is expanding in Ethiopia at a superior rate compared to other crops. The expansion involves both the area and the newly adopting farmers.

To show the rate of expansion and water source, we will focus on the sample areas. In the four sample sub-districts, within ten years period (2004/05 to 2013/14), the number of rice growing PAs, the size of rice land and number of rice producing farmers grew on average by 44, 136, and 88 percents respectively[14]. Obviously, variations exist among the sub-districts and the variables themselves. For instance, in Chewaka, there is no change in the number of PAs who adopted rice, but the number of farmers who grow rice increased two folds percent and the size of rice land grew by six folds (Table 10). The same tendency is true for Libo kemekem.

On the other hand, in Fogera and Bahirdar Zuria, the major change is in the number of PAs producing rice and number of farmers (Table 10). In these sub-districts, the number of PAs producing rice, the number of farmers newly adopting rice (especially in Fogera) and the area under rice increased substantially compared to that of other two sub-districts. In Fogera and Chewaka, all PAs adopt rice production whereas in the other two sub-districts still there is a high potential for adoption

[14] Note that rice production expanded by 35% as of 2010.

Table 10: Number of rice producing PAs, land-size, farmers and output quantity and the changes in sample sub-districts (2004/05-2013/14)

Name of sample Sub-district	Tot. No of PAs	2004/2005				2013/2014				Percentage Change			
		No. of rice growing PAs	size of land (ha)	No. of rice farmers	Output ('000 Q)	No. of rice growing PAs	size of land (ha)	No of rice farme-rs	Out put (ton)	No of rice growing PAs	size of land	No of rice farmers	Out-put
Fogera	34	14	6872	12162	28.9	34	16705	21565	146647	143	143	77	408
Bahirdar Z	32	3	32	128	1.60	8	450	720	29250	167	1306	463	1728
Libokem	29	12	9000	7300	7.20	12	10444	9384	887790	0	16	29	23
Chewaka	28	28	2183	5333	114.06	28	15071	15071	101431	0	590	183	11
Total	124	57	18087	24923	864.54	82	42670	46740	1165118	44	136	88	35

Source: author's summary from checklist information obtained from sub-district BoARD

In the sample areas, the research team asked the officials at sub-district level to gather information on the number of rice producing PAs in the sub-district, size of land and number of rice producing farmers, and the change in rice output (Table 10). In addition, in the questionnaire, the year in which the farmers started rice production is included for interview. Based on these data from two sources, the changes are computed and summarized in table 11.

Table 11: Number of sample farmers and the year they started rice production by AWM category

Year	Chewaka			Bahir dar Zuria			Fogera			Libo kemekem			Total		
	R	S	T	R	S	T	R	S	T	R	S	T	R	S	T
1996/97		2	2					2	2					2	2
1997/98		2	2					2	2					2	2
1998/99															0
1999/00		2	2					2	2					2	2
2000/01															0
2001/02		1	1								1	1		1	1
2002/03		1	1					1	1					1	1
2003/04															0
2004/05		1	1								1	1		1	1
2005/06		2	2											2	2
2006/07	10	7	17		1	1		1	1				10	7	17
2007/08	5	9	14		1	1	1	6	7		1	1	5	9	14
2008/09		5	5		2	2		2	2					5	5
2009/10	3	7	10		7	7	1		1				3	7	10
2010/11	5	6	11		1	1	1	3	4				5	6	11
2011/12	6	6	12		3	3	3	1	4				6	6	12
2012/13	1	6	7		3	3		1	1				1	5	6
2013/14	1		1				1		1					1	1
Total	24	16	40		17	17	7	22	29	0	3	3	31	58	89

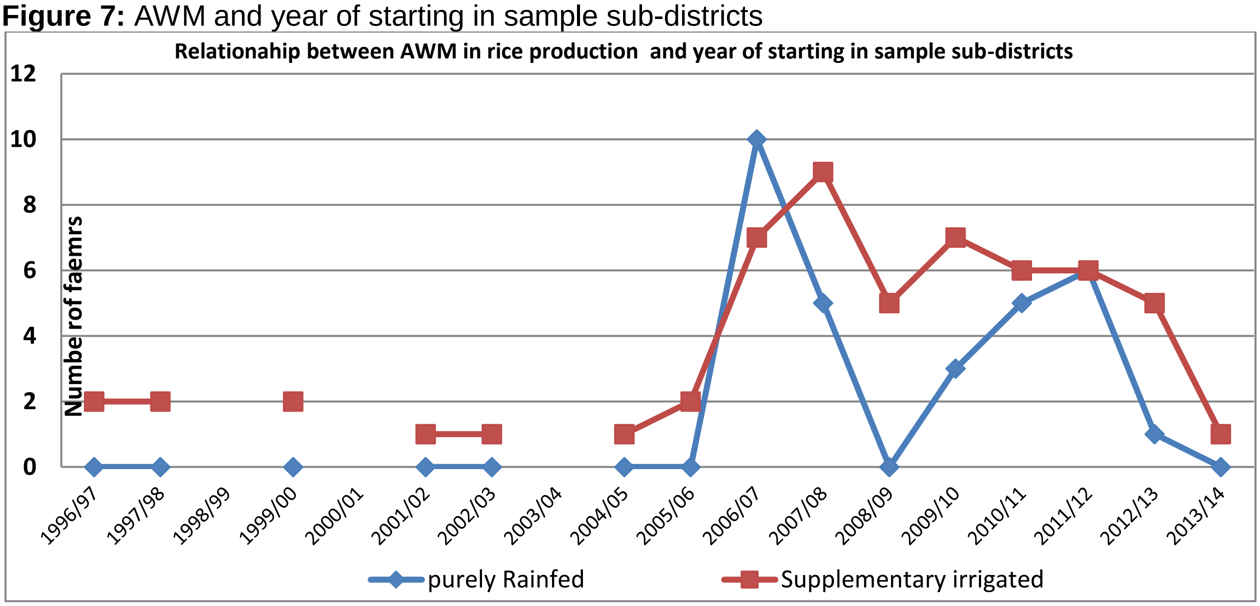
Source: author's summary from survey data

*Note that R: rain-fed/Upland rice and S: supplementary irrigated are AWM categories; T: total.

Table 11 indicates several interesting patterns: 1) the theory of adoption also works for the adoption of rice and the theoretical S-curve applies (Shah et al, 1995), (see figure 4 & 5). Before 1996/97, the adoption of rice production was very low. After 2006/07 because of unknown factor, the adoption started to increase. For both pure rain-fed (upland) rice production, 2006/07-2012/13 were years of high adoption (Figure 4). 2) In all sub-districts, rice production is started with the use of supplementary irrigation. This could be because farmers try to avoid risk in adopting new crop and technology (Feder et al. 1985; Koundouri (2006). 3) Adoption rate is smoother in supplementary water source for rice production than in pure rain-fed/upland rice, again indicating the risk reducing role of supplementary irrigation. 4) Factors that change the game of adoption of rice production can be speculated. Among them, the major one is the availability of new seed varieties. Encouraging government policy, complementary farm and irrigation technologies, increased market demand could also play roles. 5) The graph in Figure 7 and 8 depict that a kind of shock decreased adoption of rice production in 2008/09. During this shock year, both supplementary-irrigated and rain-fed are affected by the shock, but the effect of the shock in supplementary-irrigated users is less than that of the pure rain-fed (see figures 4 and 5). This shows better risk management in the case of supplementary irrigation than in pure rain-fed rice production.

Our objective in this section is to find the pattern of water use of new adopters of rice production. From the graph in Figure 4, we can compare the pattern of the water-use in rice production. The comparison indicates that most of the newly adopting farmers use supplementary-irrigated production than pure rain-fed, which answers one of the objectives of this study. Note that Figure 4 and 5 are drawn based on the statistics in table 11.

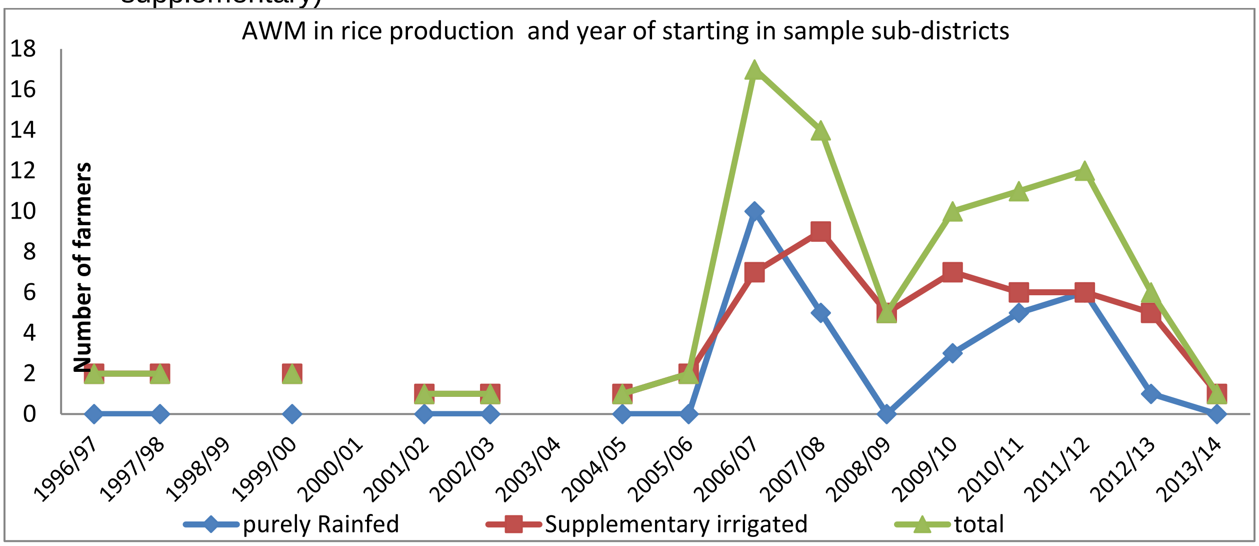
Figure 7: AWM and year of starting in sample sub-districts



Source: Graph drawn from table 11

The sum of rain-fed and supplementary irrigation also lay within the S-curve adoption theoretical framework. In the figures, the 2013/14 is the lowest adoption year, because we interviewed the already producing farmers, but most of them adopted after 2005. The expert assessment also indicates farmers that do not start to produce rice are looking for opportunities to adopt. The data found Bahirdar Zuria sub-district BoARD shows this kind of adoption demand.

Figure 8: AWM and year of starting rice production by sample farmers (rain-fed & supplementary)



Source: Graph drawn from table 11

However, the interview of the sub-district BoARD experts indicate that constraints hindering the adoption of rice production include: 1) water constraint: farmers at a distance from major water bodies and they cannot afford to drag water. 2) lack of seed: Farmers who can grow upland rice cannot make it because of the lack of suitable seed variety. The available seed variety requires more water and only farmers who have access to water to supplement the rain-fed production rice can grow rice. 3) Distance from water source: including river, spate flood, etc and lack of finance to drag the water from a distance. To learn more about the constraints, have a look at Figure-2.

Most of the other constraints such as labor shortage, over logging of water and conflicts in water share, etc do not hinder adoption. Rather they challenge the farmers that already producing rice.

Overall, the finding indicates that the expansion of supplementary irrigation in rice production system is higher compared to pure rain-fed rice production system.

5.3 Small-scale irrigation and AWM in rice production

5.3.1 The use of small-scale irrigation WHTs in rice production as a water source and way of curbing rainfall variability

In this section, the degree of use of small-scale irrigation WHTs in rice production is discussed. The level of irrigation use involves various issues. Among others, the months of rainfall shortage, the types of irrigation technologies used the number of farmers using the SSI (WHTs), the seed variety of rice that requires supplementary irrigation and the level of investment related to irrigation.

In the survey questionnaire, farmers were asked to list the months of rainfall shortage in rice production in the order of severity. The response of the sample farmers is summarized in table 12. The summarized report indicates that 52 (80%) of the farmers who faced rainfall shortage pointed out that September is the worst month of rainfall shortage. Among these respondents, nine are no supplementary irrigation users. Basically, in September the Ethiopian winter ends and rainfall decreases, posing a threat at the ripening of cereals including rice. Following this month, October is the month of rainfall shortage as depicted by 7.7 percent of the farmers. Finally, August is rated as the third month of rainfall shortage, which could be taken as a month of variable rainfall because August is normally a month of heavy rainfall in Ethiopian winter. Rainfall in this month is expected with higher degree of confidence than other months.

Overall, September, October and August are the months of rainfall shortage and variability in rice production. Other months are not much related to ripening of cereals; rather they are months of ploughing and preparing a plot for rice production.

Table 12 indicates that 65 of the 89 farmers (73%) face rainfall shortage when they are producing rice by rain-fed[15].

Table 12: Months of rainfall shortage listed by farmers producing rice in sample sub-districts

Months	Chewaka	Bahirdar zu	Fogera	Libokemekem	Total	Percent
September	7	17	25	3	52	80.0
October	1	0	4	0	5	7.7
February	1	0	0	0	1	1.5
April	1	0	0	0	1	1.5
May	2	0	0	0	2	3.1
June	1	0	0	0	1	1.5
August	3	0	0	0	3	4.6
Total	16	17	29	3	65	100.0

Source: Author's computation based on survey data

[15] Of the 65 farmers, 17 of them (26%) are rain-fed farmers who face rainfall shortage in rice production.

In the next question, farmers were asked whether they invest on irrigation for rice production. Assuming that the irrigation used is to curb the problem of rainfall shortage and variability, we asked them what the benefit of irrigation and we listed a number of benefits of irrigation they mentioned. About 17 of them (29%) remarked that irrigation helped them decrease the risk of rainfall shortage and variability whereas others mentioned other benefits such as increase yield, food security, increase income, etc.

As a means to access irrigation, farmers were also asked if they invested in irrigation in the last five years. Only 17 (24%) of farmers responded that they invested in irrigation in the last five years, implying that majority of the farmers invested before five years or a few of them invested in expansion, maintenance, or multiple technologies. The average money that they invested is 1511 ETB (78.3 USD)[16] with the lowest 200 Birr and a highest of 4000 Birr (227USD).

Another question was asked on the type of irrigation technology farmers were employing. It is possible to understand that the irrigation technologies are private small-scale irrigation than conventional communal irrigation. Based on this question and survey experts' observation, the technology used is summarized in table 13. The table mainly indicates that private investments vary with sub-district.

Table 13: Percentage of farmers who use various kinds of small-scale irrigation for rice production by sample sub-districts

	River and Flood diversion (river logged)	River + motor	Ground water	Logged water (lake)	Natural Reservoir
Chewaka	100%				
Bahirdarzuria	80%		5%	10%	5%
Fogera	30%	10%	5%	65%	
Libokemekem	30%	10%		60%	
Average	57.5%	10%	5%	45%	5%

Source: Author's computation based on survey data

Table 13 indicates that river and flood diversion and logged-water around rivers, and logged-water around natural reservoirs are major water sources for supplementary irrigation.

In a proper definition, WHTs are ponds, shallow-wells often, and flood/stream or river diversions. Among those types of water harvesting the flood diversion from rivers and streams and natural reservoirs dominate as a water source for supplementary irrigation. WHTs such as ponds and shallow-wells are not common for supplementary irrigated upland rice production in Ethiopia. In other words, the finding indicates that flood and logged-water from rivers and rainfall are the most important sources of supplementary irrigation used for rice production by the sample farmers.

[16] One Ethiopian Birr is 0.0519 USD at the time of the survey i.e. January- February 2014.

The interviews of farmers and experts indicate that the use of ponds is not economical. Three major reasons are mentioned. 1) Vegetables fetch profitable prices compared to rice and it is more advantageous to use ponds for vegetables than for rice. 2) Farmers remarked that they lack the appropriate seed variety that ripens in short period and growing vegetables twice is more economical than waiting rice for long time in a season. 3) Also some farmers face market trouble. Because of lack of trashing machine, quality of their rice is low. Also, some seed varieties do not have good tastes. These factors decrease the demand for their rice and make the business unattractive, and push them to drop producing irrigated rice.

In rice production, the available seed varieties affect the choice of irrigation technology. In lowland and warm environment where sufficient rainfall is available, SUPERICA is grown in Chewaka, Gureferda[17], etc. In areas where sufficient surface water or the choice of supplementary irrigation is available, the chosen seed variety is different. In North Ethiopia where rice growing has been carried out for longer time, NARIKA 4 and the local varieties x-jigna are common. These rice varieties require more water than the SUPERICA that is common in Chewaka. Because the former varieties need more water than the latter, farmers use supplementary irrigation to overcome rainfall shortage and variability.

5.3.2 Agricultural water management in small-scale irrigation

According to Bati et al (2007), Agricultural water management is defined as managing water use in agriculture which includes a of spectrum of deliberate human actions designed to optimize the availability and utilization of water for agricultural purposes (crops, tree crops and livestock) from rain-fed to irrigated agriculture. According to the above definition it includes agronomy, soil and water conservation, rainwater harvesting, irrigation and drainage, interventions such as integrated watershed management and other water and land management aspects.

In this section, some aspects of AWM in rice production are discussed based on the survey data and other information. The previous discussions (section 5.2) involve just the comparison of the fully rain-fed/upland rice and the supplementary-irrigated rice. The discussion on AWM in this section specifically involves water source in the past and now, rain-fall shortage and variability, types of irrigation used (in fact discussed previously), labor scarcity, number of plots, distribution of water, conveyance equipment (ownership, uses, prices), sources of energy, water saving, training, role of WUAs, institutional framework and support, conflicts, climate change and water related diseases.

Generally speaking, the water use for rice production in Ethiopia is based on two sources of water. One is the rainfall (rain-fed/upland) and the second one is irrigation water sources to supplement rainfall. About 25 of 58 selected farmers mentioned that they were using rain-fed

[17] A farmer in Chewaka underlined that the taste, quality and weight of irrigated rice is special, but could not use full irrigation for rice because of lack of invested irrigation scheme in Chewaka.

before 2005, 33 of them mentioned they were using both supplementary and rain-fed to produce rice. If there is a shift from one to another source over time, the expected one is from rain-fed to supplementary irrigation. Among the later group, only 6 shifted from rain-fed to supplementary, but the data indicates no shift from supplementary to rain-fed irrigation. Note that about 80% of the farmers reported that the month of severe rainfall shortage is September (followed by October and August) and the expected rainfall in August is relatively unreliable. At any time of the rice growing period, farmers could face rainfall shortage and variability other than these months. A question was asked to learn how rainfall shortage was a problem. Among the 88 selected farmers who responded to the question, 50 (56.8%) stressed that they faced rainfall shortage whereas the remaining 38 (43.2%) did not face rainfall shortage.

Regarding the current water use, on average about 57 percent of the 58 farmers who use supplementary irrigation for rice production apply river water, river-side floods, and *river plus motor*; about 28 percent use logged water, 9 percent use both river and logged water and about 7 percent use mainly ground water. An interesting question is then because most farmers are using river and shareable water and because of the lack of defined water rights, conflicts could be common.

As far as there is water sharing among farmers, there should be a mechanism of managing the resource and the sharing directives. One mechanism is the institutional role of water users' association (WUA) or farmers' organization. In the survey, a question is asked if the water use by farmers involves WUA. The summarized data indicates that a total of 42 farmers responded to the question, from which 19 of the farmers responded yes. Most of the selected farmers are in Amhara region (94%) and many of them are in Fogera sub-district. To the question that asks if the farmer is a member of WUA, 19 of them responded yes (15 of them are in Fogera and 3 of them are in Libokemekem) and the starting time of the membership falls within 1996 to 2012. The observation of the survey expert indicates that: 1) the WUAs contribute to the fair use of irrigation water among farmers; 2) plays a role in solving minor conflicts in water use and when the conflict cannot be solved with the executive members of the WUAs, the WUA passes it to the sub-district administration. 3) The organization has no written rule, no membership fee and integration in to the farmers' water use behavior is very weak, but they have elected coordinators who run the water affairs. For that matter some farmers do not know if they are a member the WUA. Experts mentioned that the elected coordinators often fail to provide decision because of lack of written rules. 4) Other informal organization are available in Fogera, Bahirdar Zuria and Libokemekem.

Regarding conflicts on water use, 29 of the selected farmers responded that they face conflicts, where 20, 6 and 3 of them in Fogera, Bahirdar Zuria and Libokemekem respectively and the major causes of conflict they mentioned are water sharing (25 of them i.e. 86%) and .the depletion of water from the source (14% of them). Other possible causes such as timing of water release/use, membership fee & punishment are not mentioned by the respondents. To solve the conflict, the farmers listed several ways: negotiating in team; negotiating among each other; kebele officials facilitate ways of negotiation; through punishment according to the rule of the WUA community; resolve the problem through local elders; solving by sub-district officials; and amicably. Because the weak power of the WUA, a number of the conflicts are solved at higher level of authorities than by the WUAs themselves, but about 71% of the respondents rated the role of their WUAs in solving conflicts is to be medium (not low or high).

To the question that who distributes the water of the schemes to the members (Table 14), the majority of the farmers responded that members of the WUAs do the work in turns (37%) and a few responded (13%) individual farmers by themselves run it and the most farmers responded water sharing is not applicable because they use their own scheme of irrigation and drainage privately.

Table 14: Who distributes the water of the schemes to the members?

Distributer	N	Percent
An individual	6	13.0
Members in turn	17	37.0
Other	6	13.0
Not applicable	17	37.0
Total	46	100.0

Source: computed from the survey data

To the question whether the farmer has any conveyance equipment of irrigation water, 43 of the farmers responded, and among them only 12(28%) reported the type of conveyance equipment they are using. Eleven of the 12 own motor pump and one farmer reported he has hand pump (Table 15).

Table 15: Type of conveyance equipment

Type	N	Percent
Motor pump	11	91.7
Hand pump	1	8.3
Total	12	100.0

Source: computed from the survey data

The motor pumps were bought in various years since 1990 (Table 16) and 5 of the 11 motor pumps (45%) were bought in 2008 and 2009. The ownership of the motor and hand pumps is that 7 are private, 4 are owned by cooperatives and one is rented. In the last sections, it is discussed that about 25% of the farmers have invested or constructed various irrigation schemes in the last five years, but the investment does not include the purchase of motor pumps.

Table 16: Year of purchase of motor pumps

Year	N	Percent
1990	2	18.2
1996	1	9.1
2001	2	18.2
2002	3	27.3
2003	1	9.1
2004	1	9.1
2005	1	9.1
Total	11	100.0

Source: computed from the survey data

Among the sample farmers, 33 of them (57%) responded to the question regarding the source of energy they use. To this question, 30 of them (91%) reported that they are using furrow and only one has reported to use fuel, and another 2 reported that they use other source of energy.

Rice production is relatively a new technology so that training and orientation about technologies including irrigation are essential. Training plays an important role in AWM. To the question that is asked whether the farmers got training in rice production, only 32 of the 80 farmers (40%) replied that they took training. This means that the majority of the rice producers (60%) do not have training in rice production which would improve the management and role of facilitating production. The training opportunity is better in Chewaka (53%) compared to most of the other sub-districts. These who responded that they took training indicated that the major training provider is the sub-district BoARD (87%) and only one farmer reported NGO as a training provider. Farmers were also asked whether they get supports from BoARD in rice production. About 50% responded yes, with no big variation among sub-districts. A related question is on the number of visits by extension agents (Development agents/DAs) per month (Table 17). The majority of the farmers (65%) responded that DAs visit only once in a month to advise them about rice production and of the remaining farmers, 18% of them responded the DAs never visit them at all.

Table 17: How often per month does a DA visits you to advise you about rice production?

Number of visits	**woreda**				**Total**	**Percent**
	Chewaka	*Bahirdar zu*	*Fogera*	*Libokemekem*		
0.00	16	0	0	0	16	20
0.25	0	2	3	2	7	8.8
1.00	21	9	21	1	52	65.0
2.00	0	3	2	0	5	6.3
Total	37	14	26	3	80	100.0

Source: computed from the survey data

In AWM, the number of rice plots owned by farmers could affect the management time and resources. To the question asked about the number of rice plots in 2013/14, 60 of the 88 (68%) farmers responded that they have only one and 18 (20%) have two plots but the rest had 3 to 7 rice plots (11%), (Table 18). The fact that most farmers have a relatively few plots seems an advantage compared to the predominantly large number of farmers producing various crops in the country. When we compute the average rice plot-size of the selected farmers with one plot, we found 0.21ha, with the smallest 0.06ha and the largest 1ha. For farmers with two rice plots, the average is 0.59ha and for those who own more than two plots the average is 0.96ha (but very small N).

Table 18: Number of plots owned by selected farmers in 2013/14

Number of plots	Chewaka	Bahirdar zu	Fogera	Libokemekem	Total
1.00	38	13	9	0	60
2.00	2	4	11	1	18
3.00	0	0	3	0	3
4.00	0	0	5	1	6
7.00	0	0	0	1	1
Total	40	17	28	3	88

Source: author's summary from survey data

Farmers were also asked if they faced irrigation water shortage and 77 of them responded. Of those respondents, 58 of them (75%) reported that they face water shortage. The largest proportion of the respondents is observed in Fogera and Libokemkem (100%), followed by Chewaka (60%) and Bahirdar Zuria (56%). This means that the irrigation water-shortage is observed in sub-districts where irrigation is carried out in high proportion. This could imply that if it is not for water-shortage many farmers could use irrigation and twice and three times of production could also be possible.

Famers were asked if they know something about climate change. About 84 percent of the farmers responded yes they know something about climate change. Of those who responded no, the highest proportion is observed in Chewaka (30%) where the proportion of illiterate is relatively high and where rain-fed rice production is common. Another reason could be that Chewaka's farmers are settlers who move from another zone to the area before about ten years and could not perceive climate changes in the sub-district. To a question following the measure taken by farmers to mitigate climate change, the majority of the farmers responded that they planted trees (62%) with little choice of using irrigation, changing cropping pattern and water harvesting (only 15%).

As a major issue in AWM, farmers were also asked about water saving. About 68 farmers responded to the question about how they save water. The mechanisms that have been used by about 97% of them are constructing water-ways by cement, plastic, etc. It is observed in the field that farmers have constructed water ways to preserve water in their plots and also as a way of drainage, an interesting mechanism of AWM. Other mechanisms like decreasing evaporation and watering in the evening are not mentioned at all, possibly because of the surplus water during the winter season.

In AWM, the most important input is labour. An important question that is asked is the proportion of labour time allocated for irrigation. As the computed figure from the survey data indicated that 70 of the selected farmers responded. Among those who are using irrigation and responded, the proportion of labour time allocated for irrigation on average for all sub-districts is about 5% (Table 19), from 0.4% to a maximum of 50%, (Table 400).

Table 19: Proportion of labor time of irrigation in the total labor time for rice production

Woreda	Mean	N	Std. Deviation
Chewaka	4.0	30	9.9
Bahirdar zu	5.6	14	1.8
Fogera	5.5	23	4.3
Libokemekem	6.0	3	0.0
Total	4.9	70	7.0

Source: author's summary from survey data

The variation among regions with respect to the average percentage of labour time used for irrigation is low (less than 6% for all regions), (Table 20). A limitation here could be that is that labour time of AWM may not be clarified for respondents.

Table 20: Percentage of labor time for irrigation in the total labor used to produce rice

Percentage	Chewaka	Bahirdar zu	Fogera	Libokemekem	Total	Percent
0.00	22	0	4	0	26	37.1
0.40	0	0	1	0	1	1.4
2.00	0	1	0	0	1	1.4
3.00	0	0	3	0	3	4.3
4.00	0	1	1	0	2	2.9
5.00	2	6	4	0	12	17.1
6.00	0	3	0	3	6	8.6
7.00	0	2	3	0	5	7.1
8.00	0	0	3	0	3	4.3
10.00	4	1	3	0	8	11.4
18.00	0	0	1	0	1	1.4
20.00	1	0	0	0	1	1.4
50.00	1	0	0	0	1	1.4
Total	30	14	23	3	70	100.0

Source: Author's computation from survey data

The compiled survey data also indicates that (Table 21) about 37 percent of the respondent farmers face disease. Among irrigation users the percentage of the farmers who face a disease is about 25%. This is similar to the finding in the study conducted in 2005 (Gezahegn et al, 2006). The proportion is higher in the non-irrigation using areas because of the favourable climate for the reproduction of malaria (Chewaka: 75%) and lower in other areas. However in Chewaka, the warm natural ecology invites malaria and this imposes difficulty to understand the impact of environmental burden on the AWM.

Table 21: Response to the question whether farmers face disease due to irrigation

	woreda				Total	Percent
	Chewaka	Bahirdar zu	Fogera	Libokemekem		
No	5	15	14	2	36	63
Yes	15	0	6	0	21	37
Total	20	15	20	2	57	100

Source: Author's computation based on survey data

Finally, the principle of AWM advocates the integration of the income of farmers producing rice with the irrigation and related activities and expenditures. To sustain irrigation, farmers have to get market and earn a reasonable income (Wakeyo et al. 2016) to maintain schemes in time. Questions were raised to farmers about the revenue they earn from rice production in 2012/13 and 2013/14 and other benefits they accrue to rice production. The computed average revenue income from rice production indicates rice producers on average earn 14,908 Birr (847 USD), with the lowest revenue income of zero and the highest revenue income of 103,000 Birr (5,852 USD). With respect to revenue income: (1) among sub-districts, a high variation in income exists. The sub-district with lowest average revenue income is Bahirdar Zuria (4161 Birr) in 2012/13, followed by Chewaka (4,334 Birr) and the highest average revenue income from rice is Libokemekem (82,937, but very low sample size). The lowest revenue income in Chewaka can be due to the lowest price, rice variety, quality and lack of trashing machine. Of course, the data also indicates that farmers using supplementary irrigation in Chewaka earn highest average revenue income (7,812 birr or 444 USD) with a lowest and highest 12,166 birr (691 USD) and 53,010 birr (3013 USD), respectively unlike the respective average, lowest and highest revenue income of rain-fed rice growing farmers. The difference in revenue income among supplementary irrigation and rain-fed rice producers is clear and it is true for all sub-districts (Table 22).

Table 22: Average Revenue Income from rice production in 2012/13 with AWM category

Woreda	AWM category	Mean	N	Std. Dev.	Minimum	Maximum
Chewaka	Rainfed	1762.9	23	1224.3	0.0	4000.0
	Supplemntary Irr	7812.6	17	12166.9	0.0	53010.0
	Total	4334.1	40	8411.3	0.0	53010.0
Bahirdar Zuria	Supplemntary Irr	4160.5	17	5948.6	0.0	19500.0
	Total	4160.5	17	5948.6	0.0	19500.0
Fogera	Rainfed	12201.7	7	6027.0	3886.0	21456.0
	Supplemntary Irr	34934.5	21	26754.5	4400.0	103000.0
	Total	29251.3	28	25274.1	3886.0	103000.0
Libokemekem	Supplemntary Irr	82937.7	3	14861.9	67113.0	96600.0
	Total	82937.7	3	14861.9	67113.0	96600.0
Total	Rainfed	4198.7	30	5368.2	0.0	21456.0
	Supplemntary Irr	20447.9	58	26832.2	0.0	103000.0
	Total	14908.4	88	23266.3	0.0	103000.0

Source: author's computation from survey data

Farmers in Fogera, earn an average of 29,251 Birr (1662 USD), with the lowest 3886 Birr and the highest Birr 103,000 in 2005.

Table 23: Average revenue Income rice producers earn from rice production in 2012/13 (Birr)

Woreda	Mean	N	Std. Deviation	Minimum	Maximum
Chewaka	4,334.0	40	8,411.3	.0	53,010.0
Bahirdar Zuria	4,160.5	17	5,948.5	.0	19,500.0
Fogera	29,251.2	28	25,274.1	3,886.0	103,000.0
Libokemekem	82,937.7	3	14,861.9	67,113.0	96,600.0
Total	14,908.4	88	23,266.2	0.0	103,000.0

Source: author's computation from survey data

The income variation is also interesting to see in terms of AWM category. In addition to the variation in revenue income by sub-district, (2) rice farmers who use supplementary irrigation earn more average revenue income than farmers who use only rain fed to produce rice. The average revenue income of farmers who use supplementary irrigation in 2012/13 was birr 20,447 whereas the average income that rain-fed farmers earned was 4,199 Birr. In Chewaka and Fogera farmers that use supplementary sub-district earned an average revenue income of Birr 7,813 and 34,934 respectively, whereas these using rain-fed earned 1,763 and 12,202, respectively.

Compared to 2012/13, the average revenue income of the rice producing farmers increased to 17,956 (940USD[18]) in 2013/14, (compare Table 23 and 24) from 14,908 Birr (847USD). The increase in income is about 20%, which is substantial rise. From the computed statistics, the rise in average revenue income is attributed to the more than average rise of the revenue income of Chewaka (78%) and Bahirdar Zuria (123%). In both years, farmers earned up to 103,000 Birr (5854 USD) from rice production.

Table 24: Revenue Income from rice production in 2013/14 with AWM category

woreda	N	Mean	Std. Deviation	Minimum	Maximum
Chewaka	40	7,748	15,899	690	96,900
Bahirdar zu	17	9,285	5,675	3,450	27,000
Fogera	28	32,711	27,685	4,000	103,000
Libokemekem	3	65,467	56,700	0	98,900
Total	88	17,956	25,328	0	103,000

Source: author's summary from survey data

Similar to the case of 2012/13, higher average revenue income and growth were reported by the users of supplementary irrigation compared to the users of rain-fed farmers (Table 25) in Chewaka and Fogera, the major rice producer area. Again in 2013/14, the difference between the average revenue income of rain-fed and that of supplementary irrigated rice producers is high, similar to that of 2012/13. In 2013/14, the average income for the respective categories of rice producers is 7,665 against 23,552, the lower one being for pure rain-fed rice producers.

[18] The exchange rate is on average 19.1 Birr/USD in 2013/14 and 17.6 Birr/USD in 2012/13.

Table 25: Revenue income from rice production in 2013/14 with AWM category

woreda	Type of water Use	N	Mean	Std. Dev	Minimum	Maximum
Chewaka	Rainfed	23	4124	7872	690	39600
	Supplemntary Irr	17	12651	22057	800	96900
	Total	40	7748	15899	690	96900
Bahirdar zuria	Supplemntary Irr	17	9285	5675	3450	27000
	Total	17	9285	5675	3450	27000
Fogera	Rainfed	8	17845	13293	4293	42227
	Supplemntary Irr	20	38658	29897	4000	103000
	Total	28	32711	27685	4000	103000
Libokemekem	Supplemntary Irr	3	65467	56700	0	98900
	Total	3	65467	56700	0	98900
Total	Rainfed	31	7665	11132	690	42227
	Supplemntary Irr	57	23552	28979	0	103000
	Total	88	17956	25328	0	103000

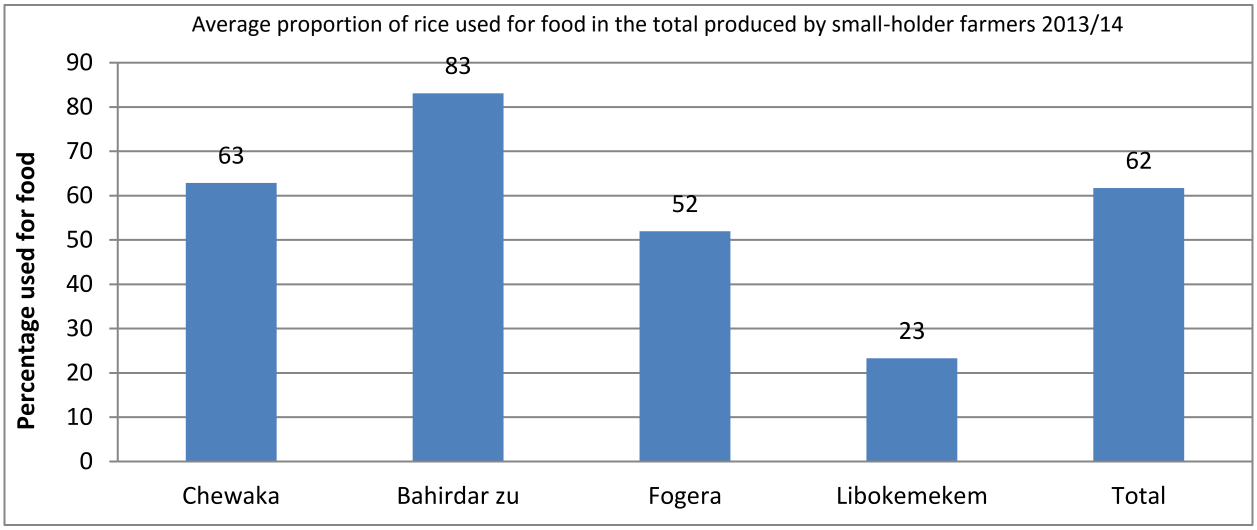
Source: Author's computation based on survey data

Given the relatively lower cost (e.g. labour) incurred in rice production than in other crops (e.g. teff), no question that farmers earn attractive income from rice production and they are rational to grow rice. In addition, users of supplementary irrigation earn more income than that of purely rain-fed users. The implication of the higher revenue income of the respondent farmers from rice production indicates that if government, donors, NGOs, and other irrigation financers consider investment in irrigation to support rice producers, as irrigation users, rice producers can sustain the use of irrigation and AWM by paying for maintenance of irrigation schemes. This is because in Ethiopia small-scale irrigation has been chosen by the majority of the cooperating sponsors and the government as strategic interventions to address food security and livelihood problems.

Even though fully-irrigated rice production by using private SSI-scheme is not economical like in irrigated vegetables, farmers use supplementary irrigation or rain-fed rice because of its food security, income source and yield advantages. The survey data indicates that 87.3%, 69.8%, 45.8% and 29.2% farmers ranked food-security, income, yield and asset-creation benefits of rice production. With respect to food security, the fact that on average 61.7% of the farmers use rice for food confirms that rice plays a big role in food supply. But the confirmation varies with sub-districts from an average of 23.3 in Libo kemekem (but very low sample size) to an average of 83% in Bahirdar Zuria (Figure 6). Note that about 31% of the farmers use the rice that they produce all in all for consumption. This indicates that despite the fact that there is high market problem in rice production, farmers give high value to it. This finding coincides with Astewel (2010) finding that the increasing and relatively high average revenue income with the relatively low cost of labor is a precondition for profitability in rice production. In addition, he found that family size affects the share of rice consumption compared to marketing rice, which is similar to the finding of this study.

On the other hand respondents also indicate that on average they use 41% of their output for market. The variation with sub-district is high and ranges from 22 percent in Bahirdar Zuria to 56% percent in Fogera (ignoring the low sample size of Libokemekem).

Figure 9: Average proportion of the rice used for food of the total produced by small- holders



Source: Author computation based on survey data

5.4 Effective standard of WHTs in rice and other crop production, Construction dynamics of ponds and factors of success and failure

5.4.1 Effective standards of WHTs in rice and other crop production

This sub-section discusses small-scale irrigation of WHTs based on field visits. The researcher could not find farmers using ponds for rice production. The AWM is rather using other kinds of supplementary irrigation practises and using ponds cannot be addressed using the collected data. However, based on the field assessment of the use and construction of ponds at various times, documents and previous research done by the researcher, the use of WHTs for other crops is discussed. By doing this the author reflects the potential for the use ponds and other WHTs in Ethiopia and elsewhere. At the end, we make a brief highlight about WHTs other than ponds.

During early 2000s, WHTs were proposed at a household level as a practical alternative to improve the livelihood of the farmers and reduce food insecurity. Even though water harvesting is not entirely new, it received policy backing and has been implemented on a massive scale since early 2000s. Varying level of WHTs, material and financial input have been a developed in many regions of the country (Gezahegn et al 2006). This indicates that both traditional WHTs and standardized modern WHTs have been used in Ethiopia.

Water harvesting technology is defined a general term for collecting and concentrating water into a particular area, where the collected water is either directly applied to the crop field (in-situ water harvesting also called runoff farming) for immediate use by the crop or stored in different structures for different use (Irrigation, livestock and domestic use) during dry spell period. The major types of WHTs are, 1) Surface and groundwater harvesting, which includes: a) deep well b) shallow-well, and c) river, stream, spring; 2) flood harvesting (rainwater harvesting): includes ex-situ water harvesting. The storage media of WHTs include, a) above ground storage (ponds – dugout types, embankment dams, reservoirs and tanks made of concrete or metal – mostly for domestic use and gardening, b) underground storage (underground tank also called Cistern, different shapes [(hemispherical, spherical cylindrical, cone, dome, trapezoid]); c) In-situ water harvesting storage media; and d) diverting to farm land and storing in the soil profile. It also includes for recharging the groundwater table – storing in the aquifer for later withdrawal (Gezahegn et al. 2006).

When the program of WHTs was launched in 2002 and 2003 in Ethiopia, the observed WHT structures on the ground include ponds, shallow-wells and flood, stream or small river diversions.[19]. Ponds were favoured and targeted to serve the purpose of accumulating water so that farmers supplement rainfall in the production of rain-fed crops. It was estimated that at national level ponds were estimated to be 70% of the WHTs constructed and shallow-wells 20% and flood and diversions (5%) (Gezahegn et. al. 2006). During 2002-2005, at national level about 510,000 ponds were constructed. After farmers started to use the WHTs, it was found out over 74% in Tigray, 89% in Amhara, 69% in Oromia and nearly 81% in SNNPR allocate the water use from water harvesting to the production of horticultural crops (Gezahegn et al. 2006) than the use for cereals to overcome the ripening period. This was because farmers found out that it is economical to use the limited quantity of water for high-value crops than cereals which are not economical to use at low quantity of water. In some of the sample rice producing areas, a similar conclusion is reached by farmers that in water-scarce to use harvested water for rice is not economical (e.g. in Chewaka). This choice of the farmers is supported by the lack of the necessary rice seed that ripens shortly and inability to grow rice twice a year as they do with the high-value vegetables.

When we come to the designs of ponds for production of high value crops and for other purposes, the standard set in the manual of the MoARD was a trapezoid pond to hold 60cubic meter of harvested water. This means that at the time plastic geo-membrane was also designed to construct a pond sufficient to accumulate this quantity of water. Irrigation engineers estimated that the plastic sheet holds pond water for at least 10 years and the finding in the field assessment in July 2013 indicates the plastic sheet is serving for more than 11 years (since 2002) with a maintenance cost of about 2-11% of the investment cost per annum (Wakeyo, 2012). The size and shapes vary with locality. For instance in East Ethiopia, trapezoid is still favoured but with increased width, length and height (getting narrow at the bottom), unlike the one used in SNNPR which is designed by the MoARD. Regarding the shapes of ponds also, we observed that trapezoid is not the only option. Therefore, from the field visit in 2013 and before that (in 2007, 2009, 2010) no standard shape and size for ponds and farmers can design it according to the resource they have, availability of plastic sheet, material of construction, and the experience around their locality.

However, after observing experiences from early adopters and best practises, adopting farmers started to design their own ponds of different shape and size. In field assessments, for instance

[19] The diversions are also called traditional irrigation (Gezahegn et al. 2006).

farmers increased the size of their ponds to hold about 111 m^3 and up to 300 m^3 of water. In addition to the change in design, farmers started to grow algae to protect evaporation of the limited quantity pond water. The field visit in 2013 indicates that: 1) farmers still use ponds for the production of high value crops; 2) the plastic geo-membrane is serving more time than estimated by engineers; 3) In addition to plastic geo-membrane ponds (plastics are used to seal the bottom of a pond), cement ponds are also still used. Differently, farmers use of ponds that have no plastic or cement ceiling on the floor. Therefore the choice of shape and size of ponds varies with the locality and the best experiences observed. 4) Optimizing flood flow to ponds is achieved by site selection by farmers and experience also matters in this regard.

Figure 10: Two of the various shapes and sizes of ponds constructed by (2007), Awbere

In this study, it is found out that because of the economic reason already explained, farmers are not using ponds for supplementary irrigation to produce rice. However, there is a potential for the use of less expensive ponds in water abundant areas that produce rice. In water abundant areas (in areas of logged water) less expensive ponds can be continuously filled and the quantity of water that they hold could be sufficient to supplement rice production, but the ponds filled with water in this way has to be supplemented with motorized pumps for conveyance. Otherwise it is cumbersome to distribute the water. In addition, to make the use of ponds economical, the ponds have to be low cost in general.

In water abundant areas of rice production such as the flood diversion and shallow wells around the sample districts in Amhara region, WHTs are used extensively for rice production. There is no specific design for the water use. Often floods are diverted to the rice fields by a simple construction supported by soil, stones, gullies and the levies/borders separating plots (picture 1). In the rice field, water ways are stripped to trap and keep the water in the field. 2) the fields are drained in water surplus areas. 3) The logged water creates burden on planting and farmers use oxen-power to plant rice in a muddy and water logged paddy field.

Figure 11: Strips of water way in a plot (Quhara Abo, Michael), in Fogera (flood in situ)

For supplementary irrigation in rice production, shallow -wells are designed in different depth based on the water table in the locality. Often around water bodies, motor pumps are linked to the well. In areas where high amount of water is used to develop fields, the role of motor pumps is substantial. Some farmers choose not to use the WHTs due to their low capacity to buy motor pumps even though motor pumps are subsidized.

5.4.2 Site selection, Design, and Construction Dynamics of WHTs ponds

Because of their potential advantage in rice production, in this section we discuss the dynamics of pond construction in Ethiopia. In the construction of ponds for accumulating water for agricultural production, the initial approach was based on as per the standard manual. The manual was developed more based on the experience of other countries (China and India) than the local and traditional ones used in Borena Zone of Southern Oromia during over the last 5 to centuries. The shape (trapezoid shape that is wide at the mouth and narrow at the bottom), site selection (often in areas that targets flood collection, water flow is easy, and by road sides for instance), bottom sealing (from available local and low cost materials), without any coverage because in the highlands evaporation is low and it was not a concern.

Field experiences of farmers and experts brought reasons to digress from the manual approach. For instance, due to the complex field reality, site selection goes in the wrong direction. One reason is the complexity in the landholding and use in relation to adjacent plot owner. Second, because of the limited experience of the experts and development agents, decision about site selection was difficult. For instance some farmers started to locate their ponds in situ their plot and in land scarce areas decreased planting area for cereals though it was meant to supplement rainfall. In addition, the distance between the plots suitable for the intended crop or vegetable and the site where the pond is located could not decrease the labour time of the farmer. In labour deficit farmers this creates difficulty. After trials, ponds become useless during the low experience period. This means that due to improper site selection and other difficulities, most of the ponds left non-functional and contributed to abandoning the WHTs.

Similarly, the ineffective and wrong use of the silt trap which was supposed to play role in filtering water stimulated failure. The construction of ponds that is expected to get filled with flood water mainly involves a strict use of the silt trap. The silt trap has its own design problem. In our field visit in July 2013, we observed that: 1) the silt trap of a cement pond was wrongly positioned (a site selection and design problem). 2) It is often not cleaned and this halted entrance of water in to the pond. 3) The farmers were not sufficiently oriented about the role of the silt trap. 4) The attached conveyance equipment, treadle pump, was also ineffective due to labor shortage.

In addition to the site selection problem, the construction material passed through a dynamic process to get the heart of the farmers. First, ponds with plastic geo-membrane, cement and without ceiling were constructed. Due to cracking of cements, and the leakage of ponds without sealing, the ponds could not accumulate water for longer period. Gradually, farmers start to appreciate plastic-ponds. Unfortunately, 1) by the time they realize this advantage through experience, shortage of plastic sheet. Plastic sheet/geo-membrane is imported items and it is not easy to have enough of them. 2) the initial distribution of plastic sheets was not well assessed. It was distributed from the center to the sub-districts almost equally and in areas of high demand shortage happened whereas in areas of low demand, the plastic sheet was accumulated and it decayed.[20] The shortage of plastic sheet was a serious and farmers raise it to visitors as a serious problem. Up to now, plastic sheet shortage is seldom solved and the shortage decreased the adoption and increased the disadoption of pond. In areas where plastic sheets are available adoption continued but in other areas, when the earlier plastic-sheet exhausted, disadoption happened (Wakeyo and Gardebroek, 2015). Disadoption was rapid in areas where unsealed ponds were constructed.

Gradually, farmers add their own innovative constructions and improved their ponds. Growing algae on the pond water to protect evaporation, the use of elevated containers to link it to tubes and transport it to the plot are some of them. Innovative ways of water saving similar to drip irrigation in some areas were marvelous (Wakeyo and Gezahegn, 2008).

Overall, in areas where the use of irrigation water, production and output market are integrated, the ponds and other WHTs are working well. Adoption of ponds has continued, and the import and distribution of plastic sheets with the support of the regional government is still alive (e.g. in Mareko areas /SNNPR/ where we visited in July 2013). However, in areas where the integration is little and support of local governments is little, disadoption happened and the use of WHTs is already forgotten.

As a conclusion to this section, the use of ponds has evolved with its interesting dynamics and based on experiences, if it is stimulated in areas where rainfall variability and water shortage is

[20] In the compound of Dugda Bora Sub-district BoARD, a number of plastic-sheet stayed unused for long time and it decayed. In the sub-district ground water use is more common than any other technologies.

severe, it plays role in rice and other crop production. The best practices of the WHTs should not be ignored particularly in smallholder agriculture in Ethiopia where drought shock is a problem for decades and where the share of irrigated production is very low (less than 5%).

5.4.3 Engineering factors driving successes and failures of WHTs

The engineering aspect of the constriction of WHTs and other irrigation schemes is critically important and in the last section it is extensively discussed based on our field visit and observation with the hydrologist and irrigation engineer from JIRCAS. Introducing the technology alone is not enough. Irrigation engineers have to evaluate and re-evaluate the technologies and provide the necessary advises. The site selection, silt-trap mechanism in ponds, the site selection of shallow-wells, cost minimizing low cost schemes helps framers to use irrigation. These issues cause failures in some areas of Ethiopia where the use of water is essential.

In this study, findings indicate that farmers who are using supplementary irrigation in rice production are advantageous in production and yield. Ethiopia has no sufficient capacity to finance large irrigation projects that suits the small-holder farmers. The best option is to stimulate the already started WHTs in a systematic and well managed manner. Essentially, the use of these technologies in rice production could bring the desired target of rice output and yield.

6. Discussion and Conclusions

This study had a broad objective of looking into the agricultural water management (AWM) in rice production in Ethiopia. The Issue of AWM often been neglected because of the misunderstanding that rice always grows in water abundant areas and the moment farmers choose to grow rice is the moment that the problem of water shortage is solved. However, AWM is complex and it involves a number of important issues including the choice of the farming system, water sources, seed varieties suitable to the level of water availability, labour and other inputs, water-sharing, conflicts, market availability and income returns (which are basic to sustain production of rice and also operation and maintenance of irrigation schemes), issues of economic decision to grow rice or other crops at individual and communal uses of water are issues of concern. On the top of this, the broad perspectives of expansion of rice at national and regional and sub-district levels has several implications because of their relationship to water use, inputs (including fertilizer and seeds), extension services and public incentives, contribution to farmers' food-security, national food supply, infrastructure, private sector engagement and environmental aspects. Furthermore, because of the increasing importance that rice gained around farmers by answering the question of food security and poverty reduction, the government paid attention to it and approved a strategic plan called National Rice Research and Development Strategy of Ethiopia (NRRDSE) for rice and named it a millennium crop and set area, output and yield targets.

Because of these vital roles and the attention paid to rice production, the study specifically selected the issue of AWM which is often neglected, and responded to important research questions based on the statistical fact analysis of 89 sample households from two regions and 4 sub-districts, discussion with farmers, stakeholders and secondary sources of information. The findings indicate that rice production is expanding at a unique rate in Ethiopia among others because of the yield, income and food security advantages; and supplementary irrigated AWM is the dominant rice farming system accounting for 77.2 percent of the total rice production, followed by rain-fed (17.4 percent) and full irrigated (5.4 percent) and the expansion rate of rice production is highest in supplementary irrigated rice production than in rain-fed, pointing to the high potential expansion in wet lands, logged-water and flood areas and river bunks. In case of Ethiopia, the use of ground water for this purpose is highly limited in rice production. For the said supplementary irrigation, about 55 percent of the farmers use rivers and river based flood and logged-water and about 44 percent of them use non-river logged-water source.

With respect to income (revenue income) and profitability in rice production, the analysis shows that in 2012/13 and 2013/14 the income of users of supplementary irrigation users exceed that of the pure rain-fed users on average by two folds. Because of the relatively low cost of labour and other inputs, the profitability of rice in supplementary irrigation is substantial and profitability studies discussed it (e.g. Astewel, 2010). Importantly, the income difference between pure rain-fed rice producers supplementary irrigation users as well as the profitability indicates that if irrigation financers support the investment on irrigation for rice production, farmers have the incentive to sustain the AWM (by paying for scheme operation and maintenance) from their rice income. This is because for rice farmers, lack of market is as such not a big problem except the lack of trashing machine which can be solved with the engagement of private sector. Of course the price difference caused by quality difference due to the lack of the trashing machine is substantial (more than 50%) and requires attention. Rice producing farmers underlined the problems of production more than that of marketing. Major constraints in production include weeds, land constraint, fertilizer related problems, and lack of seed varieties suitable to the farming system, and pests and other rice diseases and these are equally important in both categories of AWM. In rice AWM and production, labour shortage is as such not a serious problem and it is mentioned by only 15% of the rice farmers. This is surprising as it is contrary to the labour requirement that is observed in other irrigated farming (e.g. vegetable), which are labour intensive.

The finding also indicates, the average overall rice yield of the entire sample households is 4.5 tonnes/ha with a minimum of 0.9 tonne/ha and a maximum of 11.1 tonnes/ha. Specifically, the yield difference between irrigated and supplementary irrigated rice production is substantial. The average of rain-fed rice yield is 4.2 tonnes/ha and that of supplementary irrigated ones is 4.8 tonnes/ha. However, a high variation of the yield between sub-districts depending on fertilizer use-non-use, soil fertility and other unobserved factors. For instance, in Chewaka the average yield of purely rain-fed producers is 4.3 tonnes /ha, but that of supplementary irrigation users is 5.05 tonnes/ha. In Fogera, the yield for pure rain-fed producers is 3.7 tonnes/ha whereas that of supplementary irrigation users is 5.4 tonnes/ha.

With respect to types of small-scale irrigation water harvesting technologies, the finding based on the series of assessments in several areas indicate that WHTs (e.g. ponds) can be used for supplementary irrigation in rice production rather than in full irrigation, and this can be achieved if site selection, design, sealing material availability and conveyance equipment problems are properly addressed.

The study also reveals findings in other aspects of AWM including water saving, water user association and the role in AWM, water distribution, conflicts in water use, adoption of rice production. For example, 33% of the interviewed farmers faced water conflicts and 86% of them stated that water-share is the major cause, followed by depletion of water source (3%). In some sub-districts water user association committee are available to solve conflicts but some members do not know even they are members.

Policy makers, research institutes, and other stakeholders can read and use the findings to understand agricultural water management in rice production of smallholder farmers. The study is unique in that the irrigation technology is dependent on individual small-scale irrigation technology unlike the case of medium and large-scale irrigation that is common in several part of the globe.

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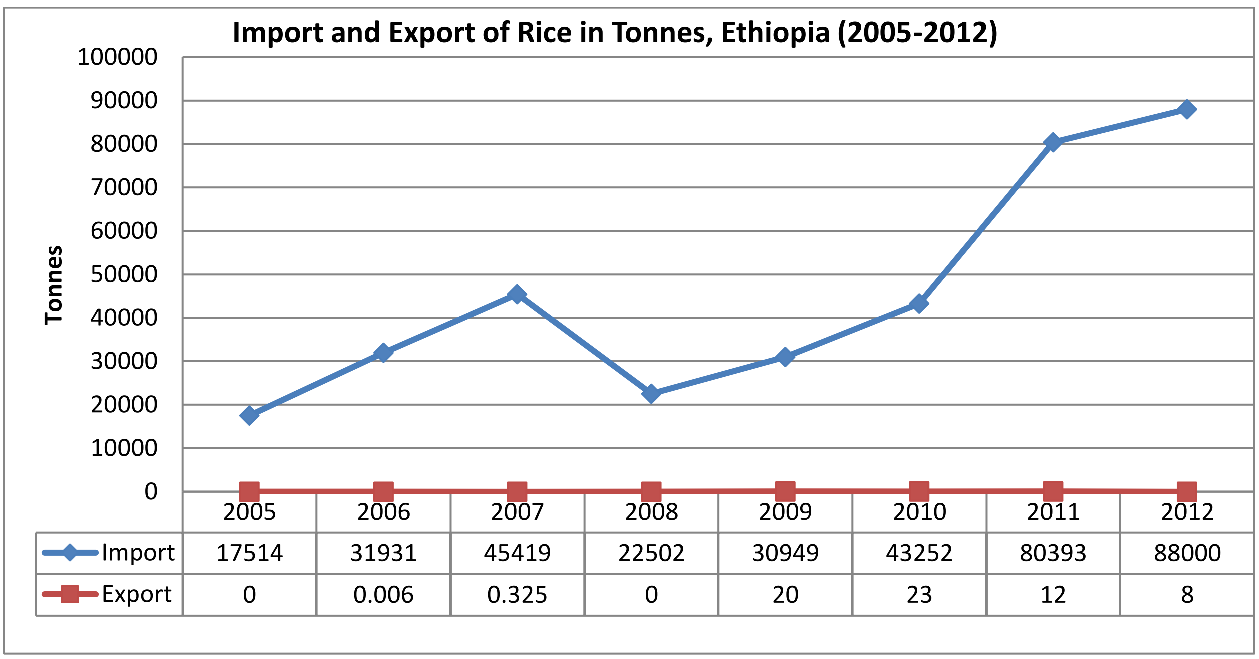
Appendices

Appendix 1: Projected National rice area and production in Ethiopia 2009-2019

Year	Area	percentage growth	Rice output (tonne)	percentage growth	Targeted Rice yield(tonne/ha)	Yield increase (%)
2009	155,886		498,332		3.2	
2014	463,604	200.00	1,887,784	200.00	4.1	27.4
2019	773,504	200.00	3,958,323	200.00	5.1	25.7

Source: National Rice Research and Development Strategy of Ethiopia

Appendix 2: Total import and export volume of rice, Ethiopia (2005-2012)



Source: UNcomrade website

Appendix 3: Categories of AWM and yields in rice production (tonnes per ha)

	Rain-fed (upland)	Supplementary irrigation (lowland rice)	Fully irrigated
2009	2.7 tonnes per ha	3.2 tonnes per ha	4 tonnes per ha
2014	4.6 tonnes per ha	6.1 tonnes per ha	ha

Source: author's computation from survey data