Impact Assessment of Rainwater Harvesting Ponds: The Case of Alaba Woreda, Ethiopia

Rebeka Amha
ILRI, Addis Ababa, Ethiopia.
r.amha@cgiar.org

Abstract

Rainfall in the arid and semi-arid areas is generally insufficient to meet the basic needs of crop production. Thus, there is now increasing interest to the low cost alternative generally referred to as 'water harvesting' especially for small scale farming systems. In Alaba, even if government efforts of household level water harvesting schemes are wide spread, the performance obtained was not assessed. Due to this reason, there was a need to asses the impact of the existing rainwater harvesting systems in Alaba Woreda.

The study assesses the determinants of households' adoption of rainwater harvesting ponds, and its impact on agricultural intensification and yield in Alaba Woreda, southern Ethiopia. Results are based on data collected from a survey of 152 households and 1036 plots operated by the households. Households were stratified into those with rain water harvesting ponds and those without from which equal number of sample households ware drawn. Analysis of descriptive information (mainly focusing on cropping pattern) and econometric methods are used. Analysis of qualitative information supplemented the econometric results.

The finding in the cropping pattern shows that, farm households have started to grow new crops (vegetables and perennial crops) as a result of water availability from the water harvesting ponds. Results of Probit analysis on the determinants of adoption of rainwater harvesting ponds shows that household size, education status of household head, ownership of livestock (cattle, oxen and pack animals), homestead plots and type of pond explained adoption statistically significantly. Results of analysis of qualitative information, consistent, with the Probit model results, also showed that labor requirement, economic problem to use simpler water lifting and watering equipments, inability to easily understand the benefit of the technology and problems related with the structure of the RWH technology adopted were some of the major problems faced by households, and have a negative impact on the technology adoption rate.

The Ordinary Least Square estimation of the determinants of the value of crop production shows that adoption of RWH has a positive and statistically significant effect on value of crop production, after controlling for input use and other factors. This shows that RWH ponds have direct and significant impact on value of crop production. We also find that households with RWH technology use more labor and seed but less oxen power compared with those households who have not adopted the technology. Moreover, labor and seed inputs have positively significant impact on yield while the effect of oxen power is insignificant. These results show that in addition to its direct impact, RWH has significant indirect impact on value of crop production through its effect on intensity of input use.

Labor requirements and cost considerations appear to be important factors that influence household's adoption of RWH technology. This implies that research and development interventions need to take account of the labor and cost demands of the technology. The effectiveness of the technology adoption is mainly constrained by problems related to water lifting and watering equipments, and accidents occurring due to

absence of roof cover and fence to the ponds. This implies that support will be needed to provide affordable but improved water lifting and watering equipments, and give training to farm households on construction and use of roof covers and fences to the ponds. As households shift to high value but perishable commodities due to the RWH, emphasis needs to be given to marketing extension, especially in facilitating markets and market linkages to farmers.

Future intervention to promote RWH technologies need to provide due attention to quality, rather than focusing on the number of adopters. Households appear to neglect the community ponds since they focus on using cleaner water obtained from household ponds and other sources of clean water. In this process the community ponds are becoming a cause of health problems. Thus, it is important that appropriate attention be given to the community ponds as well.

Finally, it was found out that women are getting benefit from the technology adoption as any member of the family. Their participation in the technology adoption is mainly in watching the ponds. They also have contribution in planning and decision making stage, and in giving support during construction, maintenance and clearance of the pond. Female headed households are being constrained to be beneficiaries due to economic and manpower shortage.

1. Background

Ethiopia, like other Sub-Saharan African (SSA) countries, is an agrarian economy, with a very small industrial sector. The agricultural sector, on average, accounts for about 45% of the GDP, 90% of merchandise export earnings, 80% of employment, more than 90% of the total foreign exchange earnings, 70% of the raw material supplies for agro-industries, and is also a major supplier of food stuff for consumers in the country. Smallholders who produce more than 90% of the total agricultural output and cultivate close to 95% of the total cropped land dominate the sector. Agricultural production is highly dependent on the vagaries of nature with significant variability in production and actual production patterns (Demeke et al, 2005).

Due to population increase in the highland areas, more and more marginal areas are being used for agriculture which led to the degradation of the natural resources .One of the major challenges to rural development in the country is how to promote food production to meet the ever-increasing demand of the growing population. Rainfall in the arid and semi-arid areas is generally insufficient to meet the basic needs of crop production. In degraded areas with poor vegetation cover and infertile soil, rainfall is lost almost completely through direct evaporation or uncontrolled runoff. Thus, overcoming the limitations of these arid and semi-arid areas and making good use of the vast agricultural potential under the Ethiopian context, is a necessity rather than a choice. Thus, there is need for appropriate interventions to address the prevailing constraints using suitable technologies for improved and sustainable agricultural production.

With regard to agricultural water development, small scale irrigation seems to be preferred to large scale schemes. The reason for the preference of small-scale irrigation to large scale irrigation includes the high capital requirement and cost of constructing large scale scheme which can only benefit a fortunate few but easy adaptability of small scale irrigation (Turner, 1994).

There is now increasing interest to the low cost alternative generally referred to as ‘water harvesting’ especially for small scale farming systems. Runoff, instead of being considered as a problem, can be harvested and used for different purposes, which otherwise is lost and causes soil erosion. Various methods of rainwater harvesting are available, through which rainwater is captured, stored and used at times of water scarcity. Rainwater harvesting can be broadly defined as a collection and concentration of runoff for productive purposes like crop, fodder, pasture or trees production, livestock and domestic water supply (Ngigi, 2003).

Collection and storage of rainwater for different purposes has been a common practice since ancient times. The system was used thousand years ago in many parts of the world. There are also evidences indicating ancient churches, monasteries and castles in Ethiopia used to collect rainwater from rooftops and ground catchments. Birkas in Somalia region and different runoff basins in Konso are good examples of the traditional rainwater harvesting practices in Ethiopia. Moreover embankment and excavated ponds20 for agriculture use and water supply, runoff farming and various types of soil moisture conservation techniques for crop production could be mentioned as examples (Nega, 2004).

In Ethiopia, promotion and application of rainwater harvesting techniques as alternative interventions to address water scarcity were started through government initiated soil and water conservation programmes. It was started as a response to the 1971-1974 drought in Tigray, Wollo and Hararge regions with the introduction of food-for-work (FFW) programme which were intended to generate employment opportunities to the people affected by the drought. Since then, however, the interventions have been extended to the other parts of the country with very limited coverage. The low level of community participation and declining attention were some of the major reasons for the limited coverage (Ngigi, 2003).

After the fall of the military government, both the Transitional Government of Ethiopia (TGE), established in 1991, and the Federal Democratic Republic of Ethiopia (FDRE), established in 1995, have adopted an economic development policy to achieve food self sufficiency and sustainable development, based on a strategy called Agricultural Development-led Industrialization (ADLI) , which gives more emphasis to improvement in agricultural productivity. Besides, recognizing the problem of variability in the rainfall distribution in the country, the 1995 strategy advocates for water centered sustainable rural development (Desta, 2004). Based on this, several rain water harvesting technologies have been constructed by regional states, NGOs, communities, and individual farmers through out the country.

To mitigate the erratic nature of rain fall in the arid and semi-arid parts of the country, which threatens the lives of millions of people, a national food security strategy based on the development and implementation of rainwater harvesting technologies either at a village or household level was adopted after 1991. The Federal Government had allocated a budget for food security programs in the regions, an amount equal to ETB 100 million and ETB one billion during the 2002 and 2003 fiscal years, respectively. Of the total budget, most of it was used by regional states for the construction of rainwater harvesting technologies including household ponds, in collaboration with the Federal Ministry of Agriculture and Rural Development (Rami, 2003).

Even if government efforts of household level water harvesting schemes are wide spread in Alaba, the performance obtained was not assessed. Due to this reason, there was a need to asses the impact of the existing rainwater harvesting systems in Alaba Woreda to determine their effectiveness and sustainability. In addition, there was a need to assess the condition of indigenous rainwater harvesting

[20]According to (Nega, 2005) they are defined as follows.

Pond: is small tank or reservoir and is constructed for the purpose of storing the surface runoff

Excavated pond: is a pond type constructed by digging the soil from the ground

Embankment pond: type of pond constructed across stream or water course consisting of an earthen dam.

technologies and practices in Alaba. Hence, this study is aimed to fill this gap of knowledge in the region.

The purpose of impact assessment is to determine the welfare changes from a given intervention on individual, households and institutions and whether those changes are attributable to the project, programme, or policy intervention. Impact assessments are often undertaken ex ante, evaluating the impact of current and future interventions, or ex post, evaluating the impact of past intervention. It can also be made concurrently within the project cycle (Shiferaw et.al, 2005). Our focus in this study is the ex post impact assessment. Ex post assessment attempts to understand the pathway through which observed impacts have occurred and why interventions fail or succeed in attaining stated objectives. Hence, ex post assessments can inform policy choices as to whether related planned programme interventions should be discontinued, modified, improved or sustained in the future (Ibde).

Hence, this study is aimed at assessing the impact of rainwater harvesting ponds on crop yield using a quantitative approach supplemented by a qualitative approach in Alaba. In particular the study focuses on:

- Identifying the determinants of household decision to adopt rainwater harvesting ponds.
- Examining the impact of rainwater harvesting ponds on crop yield, input use and cropping pattern.
- Assess the constraints and options to improve rainwater harvesting ponds
- Assess the differential impact of the technology by gender
- Derive policy implications to improve the performance of the rainwater harvesting ponds.

The study is expected to identify problems encountered, so that possible measures are taken when these interventions are replicated in other parts of the Woreda or the country. Besides, being an empirical study it will help to add to the empirical literature that uses the combination of both quantitative and qualitative approach in assessing the impact of RWH technology interventions on agricultural production. Finally, understanding the impact of the RWH technologies on agricultural productivity and the determinant factors of rainwater harvesting ponds, which affect productivity or level of yield, is a vital issue for designing appropriate agricultural development policies and strategies, as well as technology interventions. Therefore, the outcome of this study may serve as a source of additional information which may be of significant use to policy makers and planners during the designing and implementation of RWH technology strategies.

The study was conducted amid some limitations. One of the limitations is the unavailability of base line data. Such data would reflect the condition of the farm household’s agricultural production process pre-technology intervention, and would have been helpful to compare more comprehensively and evaluate the relative effect of the technology intervention on agricultural productivity overtime. The other limitation of this study is related to the lack of accurate measures and valuation techniques to include the environmental benefits and costs that accrue from the RWH technology intervention.

2. Literature Review

Agriculture is the most water-demanding sector, in addition to being a major source of employment and a major contributor of the national gross domestic product (GDP) of many developing countries in Africa. Agriculture in Ethiopia provides 86 percent of the country’s employment and 57 percent of its GDP. Rain fed crop cultivation is the principal activity and is practiced over an area of 27.9 million hectares (ha) of land (Gebeyehu, 2006).

Some empirical studies suggest that irrigation has shown some positive impacts in increasing agricultural productivity and thereby increase the income of farm households, who participate in the irrigation schemes (FAO, 1993). In the context of farm households living in the Sub-Saharan African countries, irrigation has, however, proved costly and can only benefit farm households with large plots in addition to concerns related with the environmental and health side effects of the schemes.

Large-scale dam and irrigation projects have not been widely implemented in Ethiopia as they have often proved to be too expensive and demanding in construction and maintenance. Therefore, water harvesting tanks and ponds at the village or household level are proposed as a practical and effective alternative to improve the lives of rural people at little cost and with minimal outside inputs. In theory, household water harvesting can be done mainly through the effort of the individual farmer. Use of stored rainwater could supplement natural rainfall and make farming families less vulnerable to drought and therefore less dependent on outside help in harder times (Takele, 2002)

The experience in China on the development of rainwater harvesting shows that since the 1980's , Gansu, Sichuan, Guangxi, Guizhou and Yunnan provinces adopted rainwater harvesting techniques. To date, rainwater harvesting projects have been carried out in about 700 counties of 15 provinces in semi-arid and humid areas covering two million km 2 and with a total population of 0.36 billion. By the end of 2001, about 12 million water cellars, tanks and small ponds were built with a total storage capacity of 16 billion m3, supplying water for domestic use for 36 million people and supplemental irrigation for 2.6 million m2 of dry farming land. This has helped the people access water and engages in agricultural production hence improving food security and alleviating poverty. Rainwater harvesting has also been known to benefit ecological and environmental conservation (UNEP, 2005).

Impact of rainwater harvesting as shown in a case study of Mwala division, Kenya indicates that harvesting runoff water for supplemental irrigation is a risk-averting strategy, pre-empting situations where crops have to depend on rainfall that is highly variable both in distribution and amounts. By using underground spherical tanks having a combined capacity of 60 m3, seasonal water for supplemental irrigation for an area about 400 m2 was guaranteed. With rainwater harvesting, farmers have diversified to include horticultural cash crops and the keeping of dairy animals. For instance households with supplemental irrigation earn US$735(per ha) from cash crop compared with US$146 normally earned from rain fed maize. This has contributed to food security; better nutrition and higher family income (RELMA-in-ICRAF, 2004).

India has a long tradition of rainwater harvesting so much so that it is regarded as one of the dying tradition of the country21. However, it has been reviving apace in many parts of the country, particularly in rain scarce areas. Derwadi village, a village in the central state of Maharashtra, is one of such dry villages of India. A remote village with no assurance to drinking water, with farming being mainly rain fed based and agricultural production can't meet more than three-month food of the village, Derwadi used to be a desperate village with no employment opportunity for the community and where schooling is a distant dream for the kids of the community. The villagers established a link with an Indo-German watershed Development NGO called Watershed Organization Trust (WOTR), which later assisted them to construct contour trenches, farm and contour bunds, and check dams. A degraded land then stared to provide adequate water both for drinking and for irrigation, thus paving the way for transformation of the lives of the villagers. They not only managed to diversify from traditional pearl millet to other host of crops ranging from various vegetables to cotton, but also managed to produce the crops in surplus and be able to

[21] This document on India's experience is obtained from website www.rainwaterharvesting.org/rural, where an interesting account of experience with rainwater harvesting in more than 20 Indian villages is presented.

sell, perhaps for the first time, to big towns. They managed to send their kids to school. With the help of the NGO they also managed to form self help association that enabled them to organize and carry out such activities as construction of toilet, kitchen garden and improved cocking devices.

The other experience with rainwater harvesting from India is Gandhigram village of Gujarati state. This village is also one of the water scarce areas of the country, constantly suffering from acute water scarcity both for consumption and production. Assisted by a local NGO called Shri Vivekanand Research and Training Institute, the community started to build communal dams- small and big- in 1995 so as to store rainwater and use it during dry season. A committee was formed from among the beneficiaries to oversee the distribution of the water and maintenance of the dams. They evolved an interesting management mechanism where each household is asked to pay Rs 3 (equivalent of $0.067) per month for water supply for consumption purpose, and Rs 250(equivalent to $5.56) per ha for irrigation purpose. The community managed not only to secure sustained supplies of water for domestic consumption, but also was able to embark upon producing high value crops like ground nuts, wheat, onion and cumin. They managed to increase their agricultural yield and work availability has also increased for land less laborers. As it has become beneficial, the momentum for rainwater harvesting continued in the village as is evident from community's interest to increase the number of dams by constructing new ones. Interestingly enough, they are now on the stage of forming a cooperative for processing and marketing their agricultural products.

By the 1990's, Zambia's southern province was recording unprecedented levels of food insecurity, hunger and general poverty. Government food, seed and fertilizer relief support become the norm rather than the exception for many households. During the 2002/2003 season, over 12% of the farm households were estimated to have adopted conservation agriculture technologies which included the use of rainwater harvesting. This was estimated to involve at least 50,000 hectares. The experience of Zambia shows that crop yields have on the minimum doubled. Maize yield rose from under 0.5t/ha to above 2t/ha and cotton from 1.5t/ha to 3t/ha under conventional as compared to conservation agriculture respectively. This has been attributed to improved rainwater harvesting made possible by the planting stations and surface cover. Most farmers have diversified their cropping system to include crops such as maize, beans and sunflower. Increased production at the household level in the last five years has introduced the rapid re-birth of a cash economy among the communities. This has propelled private entrepreneurship in agricultural related trading. Large and small private entrepreneurs have emerged and are selling agricultural inputs and other household commodities as well as buying off the crop. Most households are able to put up for sale 20-30% of their produce. The ultimate effect is enhanced livelihoods (UNEP, 2005).

Hatibu et al (2004) tried to quantify the effect on farmers' income and living standards of different rainwater harvesting methods, taking two districts, Maswa from north and Same districts from Eastern parts, of Tanzania. All types, viz. in-situ, micro and macro catchments and rainwater harvesting with storage are all practiced in the two regions in descending order of prevalence; in-situ is more prevalent in both regions followed by micro and macro catchments, with rainwater harvesting with storage being the least. The harvested rainwater is used mainly to grow maize in Same area while it is used for rice in Maswa region. Good rainwater harvesting increases yield of maize (in Same area) by four fold of rain fed yield level, and two fold for rice (in Maswa area)(Ibid).

It is only recently that rainwater harvesting has started to receive significant attention from Ethiopian government though it has a long history. It has been regarded as one of the crucial tools to achieve food self-sufficiency, and is being implemented on a large scale particularly in water scarce areas of the country. As the phenomenon is quite recent, detailed study hasn't been made. However, some preliminary studies have been made on some parts of the country. Rami (2003) is one of such studies, and is basically an account of two weeks field visit in Amhara and Tigray regions. The emphasis is mainly on rainwater harvesting implementation related problems in the regions and the prospects of using it for the stated objective of attaining food self-sufficiency. It has been found that RWH is top of the agenda in the two regions, as is the case at national level, with some times over ambitious plans of constructing wells and ponds.

The success in attaining the planed amounts of tanks and ponds to be constructed and the perceptions of the beneficiaries are found mixed. Shortages of required construction raw materials, lack of timely dispersal of finance and shortage of skilled labor have been among the factors inhibiting the attainments of the stated goals. This is evident from Amhara region where it once was planned to construct 29005 tanks made of cement and plastic and 27955 wells were excavated for the purpose but only 12614 tanks were constructed. Furthermore, the tanks constructed so far are found to be substandard, many collapsed and majority leak and seep water, the main factor being lack of experienced masons and supervisors and mismatch between the type of soil in the area and the tank construction method. The tanks were first tested in Adama area and implemented in the two regions, with basically different soil structures from Adama area, without-taking into account the specificities of the two regions (Rami, 2003). In addition, most of the construction was assigned to each Woreda as a quota resulting in less attention being paid to quality as compared to number. Further, the implementation tended to be top-down approach, particularly in Amhara region, and this has also contributed its share to the problems (Ibid).

Besides, rainwater harvesting is found to have undesirable, but not unexpected, health side effects. For instance many people and livestock have been drowned into the tanks and ponds, with often no fences and live saving mechanisms like ladder and ropes (Ibid). It is also cited by people living near the ponds as a source of malaria out break. However, it doesn't mean that rainwater harvesting didn't have any positive effects on the community. It has enabled them to grow crops of short growing periods like vegetables. And some have had good experience, as is the case in Tigray region where, for instance, "a farmer and his wife were able within a single season to pay their old extension credit of more than 1000 Birr through the planting and sale of vegetables (cabbages, tomatoes, beans and peppers) (Ibid). The upshot is that rainwater harvesting is beset with challenges and can be an utter failure and end up in undesirable negative consequences if not cautiously approached. However, it can play immense role in helping attain food security if implemented with thorough consultations with the beneficiaries and is accompanied with other activities like afforestation and soil conservation and fertility enhancing practices.

The econometric approach has some limitations in accurately and fully measuring the changes resulting from NRM interventions, especially those changes which are non-quantifiable. Hence, as a remedy to the shortcomings of the econometric approach, at present ,researchers like Kerr et.al (2005) are advocating that better results could be obtained using an integrated quantitative and qualitative approach in assessing the impact of NRM interventions.

Kerr et.al (2005) employed quantitative analysis (as with and without design mainly employing instrumental variable approach) and also qualitative information to better understand interest in relation to relevant research questions, and to identify the projects' unintended consequences in evaluating the performance of watershed projects in India. Specifically, the study tries to identify: the successful projects, the approaches adopted which lead to the success and additional characteristics of particular villages' contribution to achieve improved natural resource management, higher agricultural productivity, and reduced poverty. The results of the study show that in both of the states, participatory projects combined with sound technical inputs performed better as compared to technocratic, top-down counterpart. Evidence also found on the existence of potential poverty alleviation trade-off during an effort to increase agricultural productivity and conserve natural resources through watershed development. Particularly, the empirical result indicates the existence of strong evidence on the skewed distribution of benefits towards largest land holders in projects, which are more successful in both conservation and productivity .The short-term costs imposed on 'losers' (i.e. the poor) may be substantial and projects would gain from a greater focus on mechanisms to share projects benefits (Shiferaw et.al, 2003).

Apart from the qualitative analysis approach used in the early periods, the literature on quantitative analysis approaches for assessing the impact of natural resource management policy or technology interventions can include the econometric approach (Shiferaw et.al, 2003).The commonly applied method in natural resource management intervention impact assessment, i.e., the econometric approach, is developed by linking the measures of current output, cost or profits directly to past research investments. In this approach, either a primal function, based on estimated production function, or a dual function, using a profit or cost function and their related system of supply and factor demand functions are employed. In general, once the econometric approach is adopted, the impact of the natural resource management technology or policy intervention is obtained by translating the parameter estimates of the function used, into economic benefit value (Shiferaw et.al, 2003).

For instance, Pender et al. (200l) employed a structural econometric approach, to explore the impact of land management and investment on the value of crop production in Uganda .The data for the analysis obtained from a survey of 451 households. Selected regressors include several variables at the village, household and plot levels. The study has shown that improvement in land management can lead to higher productivity and lower land degradation. Participation in technical assistance programs, pursuit of certain livelihood strategies, investment in irrigation, and promotion of more specialized production of cereals or export crops are found to achieve "Win-Win" outcomes, increasing agricultural productivity while reducing land degradation. The results of the study don't support the optimistic 'more people-less erosion' hypothesis, though the results are consistent with population induced agricultural intensification', as hypothesized by Boserup. In addition it indicates the need to make further research to identify profitable as well as sustainable land management options, as no land management practices except irrigation were found to be very profitable in the short-run (Shiferaw et.al, 2003).

Gebremedhin et al.(2002, 2000), have applied an econometric analysis to examine the nature and impact of community woodlot and grazing land management's respectively; and identify the determinant factors of collective action and its effectiveness, in Tigray, Ethiopia. Empirical results of the analysis indicated that, more collective action exists manage community woodlots in areas with intermediate population density. In relation to community grazing land management, results from the regression analysis depict that, while population pressure has resulted in reduction of violations of use restrictions of grazing land in areas with low and intermediate level of population density, intermediate population pressure has the tendency to reduce the development of use restrictions and the enforcement of penalties (Gebremedhin et.al, 2000). Besides, while negative relationship has been observed between communities access to market and household's contribution to collective action, tree planting, and the survival rate of trees (Gebremedhin et.al, 2002). However, the result from both studies reveal that, the presence of external organizations is negatively associated with the probability of community payment to guard, survival rate of trees, and collective action for grazing land management Gebremedhin et. al (2002, 2000).

3. Methods of the study

Sampling and data

The data for the analysis is obtained from a household and plot level survey in Alaba Woreda. The Woreda is located 310 km south of Addis Ababa and about 85km southwest of the Southern Nations Nationalities and Peoples Regional (SNNPR) state capital of Awasa. A semi-structured questionnaire has been employed to interview household heads.

A total of 152 households which are selected using a stratified sampling technique have been surveyed. Based on farming system practiced, the 73 peasant associations in the Woreda are stratified in to two, namely 43 peasant associations with Teff/ Haricot Bean Livestock and 30 peasant associations with Pepper/ Livestock farming system. From each stratum 2 peasant associations were selected randomly and the households within each of the four peasant associations were further stratified by adoption of RWH technology. In the end, from each of the four randomly selected peasant associations, a total of 38 households were randomly selected, where 19 of the farm households adopting the technology and 19 farm households without the technology stratum.

Moreover, interview has been done with experts working in the OoARD (office of Agricultural and Rural Development). Secondary data was also used from publications, books, articles etc. to supplement the data.

DATA ANALYSIS

Qualitative approaches are increasingly used in conjunction with quantitative approaches and such combinations can enhance the validity and reliability of impact evaluations. While quantitative approaches allow statistical tests for causality and isolation of programme effects from other confounding influences, quantitative methods excel at answering impact assessment questions about ‘what’ and ‘how much’, whereas qualitative methods are preferred for exploring questions of ‘how’ and ‘why’. A mix of quantitative and qualitative approaches is ideal because it provides the quantifiable impacts of the intervention as well as an explanation of the processes and relationships that yielded such outcomes (Shiferaw et.al, 2005).

Descriptive Analysis

This part mainly focuses on describing the impact of rainwater harvesting ponds on the cropping pattern. Cropping pattern of the farm household’s has been assessed based on the farming system.

Econometrics approach

Empirical model and econometric estimation

Since there is no predetermined model that can be used in the quantitative estimation, following Pender and Gebremedhin (2004), models for the use of inputs on each plot (from equation 2 up to equation 6); adoption of RWH ponds (equation 1); and the value of crop production on each plot in 2005/06 (from equation 7 to equation 9) are adopted in this study.

To identify the determinant factors that influence the farm households’ decision to adopt RWH pond or to invest on various types of RWH ponds, a probit model is estimated. Hence, a ***RWHp*** dummy variable (where 1=household with RWH technology and 0=household without RWH technology) is modeled as a function of village-level factors (X_V), plot-level factors (X_p), household-level factors (X_h) and pond type which can be plastic covered or concert basement (**P**).These can be written as follows:

$$RWHp = f (X_V, X_P, X_h , P) \ldots\ldots. (1)$$

Where, *Household- level factor (X_h) includes:*

- *Human capital (demographic features) - age, household size, educational status.*
- *Physical capital - land holding, value of all assets owned, value of livestock which includes oxen, packed animals, poultry, cattle etc.*
- *Social capital- membership in local organization and associations.*
- *Financial capital-households saving and credit access.*

Village-level factors (X_v) includes:

- *Indicators of agricultural potential: rainfall condition(here due to lack of adequate information at PA level, during estimation, location dummies has been used in order to capture the difference in rainfall, altitude, population density and other environmental factors for the four PAs included in the study).*
- *Household access to services and infrastructure: walking time from the farm household's residence to the nearest input/ output town market, village market, Cooperative shops and all-weather and seasonal road.*

Plot-level factors (X_p) - Natural capital

- *Indicators of quality of the plot (size of plot, slope of the plot, soil depth, soil type and soil fertility of the plot), how the household acquired the plot, the purpose for which the plot is used and walking time from farm household's residence to the plot in hours.*

In the crop production regression and input use regressions, a logarithmic Cobb-Douglas specification is used. This leads to a theoretically consistent specification for output and input demands, and reduces problems due to outliers and non-normality of the error term found when using a linear specification (Pender and Gebremedhin, 2004).

Thus, the use of inputs – Labor days/ha (**lnL**), Oxen power days/ha (**lnO**), Seeds kg/ha (**lnS**), use of Fertilizer (**F**), and use of Manure/Compost (**M/C**), are modeled as a function of explanatory variables including village-level factors (X_V), plot-level factors (X_p), household-level factors (X_h) and the predicted value of adoption of rainwater harvesting ponds (**RWHp**).The models for the variable inputs can be written as follows:

$$lnL = f (X_V, X_P, X_h, RWHp) \ldots\ldots\ldots. .(2)$$
$$lnX_K = f (X_V, X_P, X_h, RWHp) \ldots\ldots\ldots(3)$$
$$lnS = f (X_V, X_P, X_h, RWHp) \ldots\ldots\ldots (4)$$
$$F = f (X_V, X_P, X_h, RWHp) \ldots\ldots\ldots. (5)$$
$$M/C= f (X_V, X_P, X_h, RWHp) \ldots\ldots. .(6)$$

Where, ***ln*** *stands for logarithm*

The econometric model used depends on the nature of the dependent variable. For use of labor, oxen power and seeds on cultivated plots, the least squares regression is used while the regression equations for the variable inputs, fertilizer and manure/compost, Probit model is used since the dependent variable is dummy variable.

Finally, in assessing the impact of RWH ponds on agricultural output, the value of the agricultural output harvested from a plot is modeled in three different alternatives. First, a full model of the value of crop production from a plot is modeled as a function of village-level factors (X_V), plot-level factors (X_p) and household-level factors (X_h). Besides, the use of variable inputs Labor (**ln*L***), Oxen power (**lnO**), Seeds (**ln*S***), Fertilizer (***F***), Manure or Compost (***M/C***) and the predicted value for adoption of RWH ponds (***RWHp***) are included.A full model of the value of crop production from a plot can be written as follows:

$$LnY= f (lnL, lnO, lnS, F, M/C, X_V, X_P, X_h, RWHp) \ldots\ldots. (7)$$

However, in the second regression, household-level characteristics ($\boldsymbol{X_h}$) and adoption of RWH pond (***RWHp***) are omitted. This is because the effect of these variables on production may be indirectly through the use of inputs. Thus, the second - structural model of the value of crop yield is modeled as a function of all factor inputs by excluding household-level factors ($\boldsymbol{X_h}$) and adoption of RWH pond (***RWHp***) from the regression. Thus the second model of the value of crop yield from a plot is given as follows:

$$LnY = f(lnL, lnO, lnS, F, M/C, X_V, X_P) \quad \ldots\ldots (8)$$

The third model developed in this study for the value of crop production is a reduced-form equation, which includes all village-level, plot-level, household-level characteristics as explanatory variables and the predicted value for adoption of RWH ponds. However, it excludes the use of inputs like Labor (**ln*L***), Oxen power (**lnO**), Seeds (**ln*S***), Fertilizer (***F***) and Manure or Compost (***M/C)*** from the model. This specification can avoid the potential for endogenity bias. And also to examine the total effect of all factors on crop production, and whether it is a direct effect on production or indirectly through its effect on the use of inputs and adoption of RWH ponds.

The models for reduced- form specification of the value of crop production from a plot can be written as follows:

$$LnY = f(X_v, X_p, X_h, \mathrm{RWHp}) \quad \ldots\ldots (9)$$

In all cases, the least square regression was used to estimate the value of crop production.Generally, one important point that should be noted is that, for equation 2,3,4,7 and 8 robust regression is undertaken to avoid the hetroskedasticity problem that was observed during estimation. And also problem of multicolinearity and omission of variables has been checked.

Qualitative Analysis

These approach analysis the perception of experts and farmers regarding the constraints and opportunities of RWH technologies. The qualitative information was gathered using an open-ended question that was included in the questionnaire in order to augment the results of the econometrics analysis.

4. Results and Discussions

Impact on Cropping Pattern

As part of the assessment for the impact of RWH technology intervention on the farm household's crop choice decision, the study has employed a descriptive analysis of the crop mix for those with RWH technology in the different farming systems. Here, the crop types are classified into categories such as annual crops, perennial crops, vegetables, spices, others and no new crops. As can be seen from the table below, of the total number of the crop types sawn by all the sample households (382 plots), 188 observations are in the teff/haricot bean/livestock farming system category and 194 observations are under the pepper/livestock farming system category.

In the teff /haricot bean/livestock farming system, of the total *188* observations, 60.1% grow vegetables where as 4.3%, 6.9%, 4.3% represent annuals crops, perennial crops and spices, respectively. In the vegetable crop category cabbage, onions and carrot account 16.5%, 14.9% and 12.2%, respectively. On the other hand, in the pepper/ livestock farming system, of the total 194 observations 67% is vegetables category where as 6.2%, 4.1%, 2.1% represent annual crops, perennial crops and spices. In the vegetable category which have great share from the different classifications cabbage, beet root, tomato, carrot and onion, account for 16.5, 12.9, 10.3, 9.8 and 8.8 percent, respectively.

The result of the crop mix analysis imply that, the shift in farm household's crop choice decision towards highly priced and marketable agricultural products like vegetables and perennial crops or increment in the number of harvesting per year(intensification), could have a positive impact on the farm households income as well as level of living. However, the level and magnitude of benefit accrue to the farm household will significantly depend on market and infrastructure accessibility. This is because most of the crop categories sawn in farm households with rainwater harvesting technology are perishable; for example, vegetable represent the highest percentage of (60.1%) in Teff/Haricot bean/ livestock farming system and (67%) in pepper/ livestock farming system. Hence, unless these products are able to reach to consumers immediately after harvested, either their market value will decrease with time or it might be a loss to the farm household. Besides, an examination of the type of crops grown under the vegetable category witnessed that most farm households have concentrated on specific crops (tomato, cabbage, onions, and carrot) and the production and supply of these crops in large quantities might reduce the price of the commodities and there by affect the economic feasibility of the technology. Thus, effort should be made to supply variety seeds to farmers so as to diversify the type of crops grown.

Table 1: Types of crop grown after start to use the technology based on farming system

		Category of crop types grown						Total
Farming system	Type of crops grown	Nothing new	Annuals crops	Perennial crops	Vegetables	Spices	Others	
Teff/ Haric	No new crop grown	40 (21.3)						40
	Chat		1 (.5)					1
	Coffee			12 (6.4)				12
	Banana		1(.5)					1
	Sugarcane			1 (.5)				1
	Avocado		2 (1.1)					2
	Papaya		4 (2.1)					4
	Onions				28 (14.9)			28
	Ginger(Jinjible)				1 (.5)			1
	Pepper					6 (3.2)		6
	Carrot				23 (12.2)			23
	Tomato				7 (3.7)			7
	Cabbage				31 (16.5)			31
	Chilli Pepper					2 (1.1)		2
	Kale				4 (2.1)			4
	Sweet				1 (.5)			1

	potatoes							
	Garlic				3 (1.6)			3
	Beet root				15 (8)			15
	If other specify						6 (3.2)	6
	Total	**40 (21.3)**	**8 (4.3)**	**13 (6.9)**	**113 (60.1)**	**8 (4.3)**	**6 (3.2)**	**188**
Pepper/ liv	No new crop grown	38 (19.6)						38
	Chat		2 (1)					2
	Coffee			8 (4.1)				8
	Orange		1 (.5)					1
	Banana		2 (1)					2
	Pineapple		1 (.5)					1
	Avocado		2 (1)					2
	Mango		1 (.5)					1
	Papaya		2 (1)					2
	Onions				17 (8.8)			17
	Pepper					4 (2.1)		4
	Carrot				19 (9.8)			19
	Tomato				20 (10.3)			20
	Cabbage				32 (16.5)			32
	Lettuce/'Selata'/				5 (2.6)			5
	Kale				6 (3.1)			6
	'Kosta'				4 (2.1)			4
	Sweet potatoes				1 (.5)			1
	Garlic				1 (.5)			1
	Mandarin		1 (.5)					1
	Beet root				25 (12.9)			25
	If other specify						2 (1)	2
	Total	**38 (19.6)**	**12 (6.2)**	**8 (4.1)**	**130 (67)**	**4 (2.1)**	**2 (1)**	**194**

*The number in the bracket shows percentage value *The number out of the bracket shows frequency

Determinants of adoption of RWH pond, input use and crop yield

Determinants of Households Decision to Adopt RWH Pond

The estimation results of the Probit model for the determinants of household's decision to adopt RWH technology is presented in

Table 2. As can be shown in the table, from the locational dummies, Ulegeba Kukke shows stastical significance at 10% level. No association has been found between village level factors and technology adoption decision.

Household human capital

Household size is positively correlated with the adoption decision of rainwater harvesting ponds at 5% level of significance. This means households with large family size are more likely to adopt the technology since they can compensate costs involved in hiring labor for any activity that the technology demands. This implies that research and development interventions need to take account of the labor and cost demand of the technology. Households who can read and write, and those who are educated up to grade seven are more likely to adopt RWH. The positive association with the technology adoption can occur with the expectation that they can understand the benefit more easily and are more open to access information than illiterate households. This implies that expansion of education in the woreda will have a positive impact in increasing the adoption decision rate.

Household physical capital endowment

From the household physical resource endowment indicators included in the model, oxen, cattle and pack animals have depicted positive correlation with adoption decision of the technology. This indicates that adoption of the technology requires large resources, thus households with a better physical resource are more likely to invest on technology interventions than those with few physical resource. The positive correlation with oxen power may be due to households focus on agricultural production. However, it should be noted that the significant explanatory variables have insignificant effect in magnitude implying its less importance to make policy implication.

Plot level factors

Among the plot level factors, household decision to adopt RWH pond is more likely in homestead plot. The result indicates farm household's effort to fully utilize family labor so as to meet the human resource requirement during construction and utilization of water, thereby reduce the finance that could otherwise be needed for hiring labor. It can also show the capital constraint faced by households to buy modern water lifting equipment. The most interesting implication of this result is that, the accumulated water is used to produce crops with high market value rater than used as supplementary source of water during dry spells, as initially intended by government when the technology was introduced as country level. Ponds with concrete basement have shown stastically significant negative correlation with adoption of rainwater harvesting pond at 1% level. This implies that the higher cost involved in pond construction will result in less technology adoption decision.

Determinants of Agricultural Input Use

The estimation result for the agricultural inputs of: labor person days per hectare, oxen power days per hectare, seed - kg/ha, fertilizer and manure or compost is presented in Table 3.

Impact on use of Oxen Power

The estimation regression analysis also indicates that, adoption of rainwater harvesting technology has a negative stastically significant association with use of oxen power, more likely due to lower use of oxen power and more human labor on homestead plots where the technology is mostly adopted.

The locational dummies of Ulegeba Kukke, Andegna Hansha and Hamata are positively associated with value of oxen power used relative to Mudda Dinokosa. From the household access to services and infrastructure indicator, only nearness to village market is significantly correlated with more use of oxen power. Probably the correlation could be because of the possibility to get more seed and fertilizer enabling them to use more oxen power in order to increase their agricultural productivity. Moreover, it is shown that medium rainfall condition is positively correlated with the use of oxen power than low rainfall condition.

In the household level factors, household size, heads who can read and write, and those who are educated up to fourth grade are positively associated with the use of oxen power at 1% level of significance. This implies those households having large family size and educated members are more likely to use oxen power to utilize labor available in the family to produce more output. From the household physical resource endowment indicators, owned land has shown positive correlation with the use of oxen power at 5% level of significance, which implies that more oxen power will be used by heads who own more land. In addition, ownership of goats and sheep, and beehive are stastically significant at 10% level. The significance might imply household's involvement in sheep, goat or honey trading to get extra income and use more oxen power in order to increase agricultural production especially in cases when the household has large land size.

In relation to household head's membership in various associations, the study showed that relative to households with heads a member in association, households with heads not a member in associations are negatively correlated with oxen power use. This might imply, non-members may depend on activities that don't use oxen power as their source of livelihood. Farm households with saving have depicted significant negative association with oxen power use, more likely households with saving are engaged in livestock production, trading or use the money for health expenditure and for some other purposes.

The amount of oxen power used has shown significant positive association with flat and moderately sloped plots in comparison to steep plots. The result might indicate farmers risk aversion behavior due to crop failure which could be caused by high runoff problem. Plots with medium soil depth are less likely to use oxen power compared to plots with deep soil depth. Homestead plots have stastically significant negative correlation at 1% level. This means, it is less likely that households will use oxen power on homestead plots. However, the likely use of oxen power is shown to be significantly higher in crop land plots. An interesting result is found in the relationship between plot size and oxen power use, where larger plot size is significantly associated with lower oxen power use.

Impact on use of Seed

As expected the estimation of the regression analysis indicates that, adoption of RWH pond has stastically significant association with more likely use of seed. This could probably imply the impact of the RWH technology on crop production is indirectly through its effect on intensity of agricultural inputs.

The regression result depicts that no evidence has been found between locational dummies and amount of seed used. From the village level indicators, closeness to town and village market is significantly associated with more use of seed, probably the household heads are less likely to be engaged in non-farm labor employment and hence, more emphasis be given to crop production.

With respect to household size, large family size is significantly associated with more use of seed, probably indicating that the members in the household utilize labor by working in agricultural activity which demands more seed. From the education status, households with heads who can read and write, and those with formal education up to fourth grade have shown positive association with use of seed relative to illiterate headed households. Households endowed with large sized land are significantly associated with more use of seed. No significant correlation has been observed between social and financial factors, and amount of seed used. The result in the correlation between plot level factors and intensity in use of seed, more likely use of seed is shown on cropland and homestead plots.

Impact on labour use

As anticipated the estimation of the regression analysis indicate that, adoption of RWH technology has a positive stastically significant association with use of higher labor, most likely due to the higher level of labor requirement during watering , construction an other activities involved.

As can be seen from the result of the regression analysis, location dummy of Hamata PA is associated with more likely use of labor input at 5% level of significance. From the correlation between household access to infrastructure and service indicators and use of labor input, closeness to village market, town market and seasonal roads are associated with higher intensity in use of labor input. Probably household heads are engaged in farming activity by utilizing more seed, oxen and fertilizer use. Areas with high rainfall depict statistically negative association with labor input use, suggesting the need for more labor input in areas where there is low rainfall.

The result of the regression analysis shows that, a farm household with large family size has stastically significant association with use of more labor. Probably the positive correlation with labor input could be because of either inability of the economy to absorb the excess labor force in extended families or constrained by transaction cost in the labor market and there by the family members are compelled to engage in crop production at the existing plot. Stastically significant negative correlation exists between the age of the household head and use of labor input. That means older-headed households are less likely to supply labor.

Furthermore, in relation to the household physical resource endowment, ownership of more oxen power is likely to utilize more labor input than in cattle and pack animal ownership. This is probably due to complementarity. An important point that should be noted is the insignificant impact of this variables when consider the magnitude. In relation to household head's membership in local organization, the study witnessed that, members in Edir and other related local organization are more likely to use labor input than those who are members in Edir only. In addition, households with saving are less likely to use labor input, probably suggesting household's involvement in activities other than agriculture.

The result also shows a mixed correlation between plot level factors and labor input use. For instance, labor input use is significantly greater on plots with flat and medium slope than plots with steep slope, perhaps indicating farmers risk aversion behavior and their emphasis on short term benefit. Since steep sloped plots are more exposed to soil erosion problem. More over, less of labor input is used on inherited and plots with medium soil depth. Homestead plots have stastically significant negative association at 1% level. However, more use of labor input is observed on cropland plots. An interesting result is found in the relationship between plot size and labor input use, where larger plot size is significantly associated with lower labor input use.

Impact on use of Fertilizer

As can be seen on table 3, the adoption of RWH technology is shown to have insignificant impact on use of fertilizer suggesting that its impact on crop production isn't seen indirectly through its effect on fertilizer input.

From the village level factors, walking time to the nearest village market has a negative correlation with fertilizer use at 10% level of significance. That means households closer to the village market are more likely to use fertilizer. No evidence has been found on the existence of correlation between the likely use of fertilizer and factors like human, social and financial capital part of the household level indicators. Further more, strong positive correlation has been found between value of beehives and the likely use of fertilizer, which is perhaps due to households focus on beekeeping activity enabling them to buy more fertilizer using the incremental income.

In relation to the association between plot level factors and the likely use of fertilizer, crop land plots are shown to have positive association with the use of fertilizer at 1% level of significance. Less fertilizer use is observed on homestead plots due to more possibility to use manure or compost than buy fertilizer. In small plot size it is more likely to use higher amount of fertilizer which is mainly due to an increase in efficiency when household's own small sized plots. Moreover, plots closer to the residence of the farm household have depicted significant correlation with more likely use of fertilizer.

Impact on use of Manure or Compost

As can be depicted from table 3, adoption of RWH technology is found to have insignificant impact on manure or compost. No evidence has been found on the existence of correlation between the use of manure or compost and the locational dummies. From the locational dummies, household's nearness to village market, town market and seasonal road is more likely to use manure or compost inputs. Probably this is due to the use of more labor seed input when the household is closer to this services. In areas where there is high rainfall, more use of manure or compost is observed.

Further more, from the household level factors, households with large family are more likely to use manure or compost, probably due to the availability of labor to carry manure or compost to the farm land. With respect to educational status, household heads with formal education up to fourth grade are less likely to use manure or compost relative to illiterate heads. Most likely this could be affected either by educated headed households positive correlation with more likely use of fertilizer there by reducing the likely use of manure or compost , or these households are constrained by labor required to carry manure or compost to the farm.

In relation to household's physical resource endowment, ownership of large sized land is correlated with less likely use of manure or compost, probably due to its high demand for labor input to carry manure or compost to wider farm lands. Ownership of large number of oxen is correlated with more likely use of manure or compost. Those engaged in livestock production as shown by ownership of large number of cattle and beehives are less likely to use manure or compost.

With respect to the financial capital part, households who have access to credit are more likely to use manure or compost input. Probably due to the possibility of using the credit to buy seed, oxen etc. which might lead to demand more manure or compost .In addition, those with saving are also more likely to use manure or compost. Probably due to their preference to spent it on other things than on fertilizer by replacing it with manure or compost.

Finally, in relation to the association between plot level factors and the likely use of manure or compost, the result witnessed that, state owned and inherited plots are positively correlated with more use of manure or compost. On the other hand, on flat and moderately steep plots, households are more likely to use manure or compost than on those steep sloped plots, probably to avoid risk of crop failure. Medium soil depth is more likely to use manure or compost. Plots that are highly fertile are more likely to use manure or compost than those infertile once because it will be risky for the household to use the input on infertile plot than fertile once. Households are less likely to use manure or compost on cropland plots but more likely to use it on homestead plots, probably due to its closeness to the residence of the farm household.

Impact on Crop Yield

Table - 4 presents the full model of the value of crop yield (column-2). Here, variables such as household level factors; household – human, social, physical, and financial capital endowment; and adoption decision of RWH technology that were included in the unrestricted OLS regression have been found to be jointly statistically insignificant. In column – 3 and column– 4 results of the structural and reduced models are shown respectively.

The impact of adoption of RWH technology on crop production can be explained in two ways, directly or indirectly. The direct impact is, if the accumulated water is used to supplement the shortage of water during dry spell periods in rain fed crop production, where as the indirect impact is through its effect on intensity in use of agricultural inputs. The estimation result of the study indicate that, adoption of RWH technology is shown to be positively correlated with value of yield at 1% level of significance. This might imply that the direct impact of the technology adoption on crop production is significant. An examination of the indirect impact shows that, households with RWH technology are significantly correlated with higher use of labor and seed but lower use of oxen power than those without the technology. Intensity in use of labor and seed input has a positively significant impact on yield while oxen power has insignificant impact on yield.

As can be seen from the structural model for the value of crop yield, in the village level factors, seasonal road have negative stastical significance at 10%. With respect to the impact of plot fertility on value of crop yield, households are more likely to produce more output in moderately fertile plots than infertile once. As can be observed from the table, cropland and homestead plots are more likely to produce more yield. Besides, the result indicates the positive impact of use of labor, fertilizer and seed on value of crop yield. In the reduced model of crop yield, depicted in column 4 of table 4, village level factors, plot level factors, household level factors and household rainwater harvesting technology adoption decision were included in the regression and assessed with respect to their impact on the value of crop yield.

The village level factors don't explain variation in the value of crop production. Moreover, from the household level factors, household size has shown positive association with value of crop yield at 10% level of significance. This implies that households having large family size are more likely to produce more output. With respect to the impact of household physical capital endowment, greater ownership of cattle has shown association with higher value of crop yield (and stastically significant at 10% level).From the plot level factors included, state owned plot are more likely to produce more output than rented plots. Possibly indicating household's high future discount rate and become less likely to invest on productivity enhancing activities on rented plot. Plots with shallow and medium soil depth are less likely to produce more output than plots with deep soil depth. It is also shown that, cropland and homestead plots are more likely to produce more output compared with grazing, woodlots and spice plots. In addition, a negative significant association is observed between plot size and value of crop yield.

As can be depicted from the result of the reduced model, household family size is positively correlated with value of yield at 10% level of significance implying that large family will produce more output. From the determinant factors of input use table, households with large family size have shown significant association with use of higher labor, seed, oxen and more likely use of manure or compost. Intensity in use of labor has a positive impact on yield at 1% level of significance. This suggests that yield averages 11% higher per additional labor a household uses. Moreover, average yield increases by around 9% per additional seed amount used by the household. Even though fertilizer isn't significantly affected by household size, fertilizer is positively correlated with value of yield at 1% level of significance. That means yield is more likely to increase with more use of fertilizer input. Household age and education have insignificant impact on value of yield. However, household age has a significant impact on labor. Old age is negatively associated with labor input use. Educational status has a positive impact on seed and oxen input use.

Variations in resource endowment among households will obviously have an impact on the level of crop yield either directly or indirectly through their effect on the household's demand for agricultural inputs. Of the factors, which are used to measure household physical capital endowment, ownership of cattle has a positive impact on the value of crop yield. However, it has insignificant impact when consider the magnitude to make policy implication. Households with saving are negatively associated with labor and oxen inputs use. Probably they might prefer to be involved in non-farm activities. Credit access and saving have a positive impact on manure or compost input use. Household access to services and infrastructure facilitates the movement of inputs to and outputs from rural parts to towns, where large market is available. The regression result shows an increase in yield when the household is located closer to seasonal road and is stastically significant. Households closer to village market are able to use higher amount of seed, labor, oxen and more likely to use fertilizer and manure or compost input. In addition, households closer to cooperative shops and seasonal roads are more likely to use labor input and those nearer to town market are able to increase seed amount.

The result of the value of crop yield also shows that, state owned plots witnessed stastically significant association with higher value of crop yield. Probably, suggesting that farmers are more likely to invest on productivity enhancing activities on state owned plots. It is also shown that shallow and medium soil depth has stastically significant association with lower yield than on deep soil depth. Finally, crop land and homestead plots are shown to have positive association with value of yield.

Perceptions of the constraints and opportunities in adoption and use of RWH technologies

Farmers were asked to rank the purpose for which the accumulated water was used based on the amount of water utilized in each activity. As can be seen in table 5 below, households use the pond water for different purposes including as source of drinking water for animals and households. In addition to using the water for washing cloths and cooking, households use the water for nursering some plants, for vegetable and fruit production. About 40.8% of households responded that they use the water for vegetable production as a supplementary during dry spell periods to be their first choice. In the second rank, 27.6% of the households use the water for nursering. About 23.7% and 18.4% of the households use it for drinking and for livestock respectively.

Table 5. The purpose of the pond water

	Rank1	Rank 2	Rank 3	***Rank 4***
	Freq(%)	Freq(%)	Freq(%)	Freq(%)
For HHH drinking water	7(9. 2)	15 (19. 74)	**18(23.7)**	2 (2.6)
Drinking water for livestock	4(5. 3)	13 (17.11)	9(11.8)	**14(18.4)**
Nursering	26(34.2)	**21 (27.6)**	12 (15.8)	1(1. 32)
Vegetable production	**31(40.8)**	14 (18.4)	1 (1. 32)	3(3. 95)
Spices production	2(2.6)	1 (1. 32)		
Fruit production		2 (2.6)		
Washing cloths and food cooking	6(7.9)	10(13.16)	19 (25)	4(5. 3)
Total	76(100)	76(100)	59(77.6)	24(31.6)

Table 6 depicts cross tabulation of the type of RWH technologies adopted at plot level with their corresponding equipments used for water lifting and application. As shown in the table, 65.3% of the households represent those who adopted plastic-lined RWH pond and those waiting for plastic sheet. Concrete structures made of clay and/or cement accounts 34.7%. Of the total 47 households with plastic cover and none basement, 38.3% use metal Bucket for lifting and watering plants while 29.8% of the households use big plastic container '*Jerikan*'. Besides, households with concrete based ponds mainly use mental bucket followed by big plastic container, pulley and 'commendary' each accounting 20% of the households.

Table 6. Cross tabulation between type of RWH technology and type of water lifting equipments used

	Type of water lifting equipments used								Total
	Pulley	'Commendary'	Pot	Tridle pump	Jog	'Jerikan'	'Tanika'	Bucket	
Ponds covered with plastic and none covered basement	2(4.3)[b]	7(14.9)	2(4.3)		1(2.13)	14(29.8)	3(6.4)	18(38.3)	47(65.3)
% of Total	2.8	9.7	2.8		1.4	19.4	4.2	25	
Ponds with concrete basement	5(20)	5(20)		1(4)		5(20)	1(4)	8(32)	25(34.7)
% of Total	6.9	6. 9		1. 4		6. 9	1. 4	11.1	
Total	7(9.7)	12(16.7)	2(2.8)	1(1. 4)	1(1.4)	19(26.4)	4(5.6)	26(36.1)	72(100)

[b] Values in brackets are percentages.

In addition, the last raw of table 6 shows the distribution of each type of water lifting and application equipments used in the total 72 plots with RWH technology. Thus, from the total households with RWH technology majority of them (36.1%) use metal Bucket for lifting and watering plants followed by use of big plastic container (26.4%) and 'commendary' (16.7%).The highest percentage in the use of metal Bucket for water lifting and watering plants indicates the difficulty for a farm household in terms of time as well as labor days required to irrigate the entire plantation in the plot. This difficulty is due to lack of capital for buying or renting simpler equipments which is a major detrimental factor affecting the rater of rainwater harvesting technology adoption.

As can be seen on table 7 below, only 19.7% of the households that adopt the technology have a cover for their pond while 80.3% of them respond that they didn't put a cover for their ponds. This might result in lots of problems like accident on animals or kids, bad smell when the volume of water lowers which could be source of malaria, high evaporation rate. Of the households with a cover for their ponds 33.3% and 26.7% of them use wood (trees) and Satera respectively. Besides, 13.3% of them use Cob, wood with kenchibe and wood with Sinkita each. On the other hand, with regard to those who use fence to avoid risks, 68.4% of them use it while the rest 24 households don't use fence for their ponds. Most of the households use wood as a material to do the fence followed by using wood with kenchibe accounting 25% and 23.1% of them kenchibe alone.

Table 7. If the pond has a cover and fence

Does your RWH pond have cover?		If yes, what are the materials used?		Does the pond have fence to avoid risk?		If yes, what are the materials used ?	
	Freq(%)		Freq(%)		Freq(%)		Freq(%)
Yes	15(19.7)	Wood	5(33.3)	Yes	52 (68.4)	Wood(acacia tree)	20 (38.5)
no	61(80.3)	Cob	2 (13. 3)	no	24 (31.6)	Cob	2(3.85)
Total	76(100)	'Satera'	4(26.7)	**Total**	76(100)	'Kenchibe'	12 (23.1)
		Wood and 'kenchibe'	2(13. 3)			Cob and 'kenchibe'	3(5.77)
		Wood and 'Sinkita'	2(13. 3)			Wood and 'kenchibe'	13 (25)
		Total	15(100)			'Kenchibe' and thorn	2 (3.85)
						Total	52(100)

* Sinkita and kenchibe are kinds of bush trees. Satera is a grass material

Households with RWH technology were asked to list problems they encountered during implementation and utilization of the technology. These include problems related to RWH pond (33.7%), 37.9% of the total frequency of responses represents problems related with lack of equipments, 5.76% of responses mentioned problems related with agricultural inputs and 9.47% cited problems related with health. Thus, problem of equipment for water lifting and application is shown to be the dominant one with 37.9%.

Of the pond related problems, accident on animals and kids, absence of roof cover followed by quick dry up of the accumulated water problems take the highest share of 39.4, 36.8 and 14.4 percent respectively. The highest percentage observed in the accident could be due to absence of cover for the pond, absence of fence to the pond, and wrong location of the pond which might increase accident on kids due to closeness to the house. The high proportion of uncovered ponds could be due to lack of finance or may be due to less awareness given by the experts or probably due to weakness of the households. Quick dry up of the pond water could be related to the RWH technology or structural design of the technology which emanates from lack of extension workers with the necessary skill about the technology during construction or even lack of roof cover for the pond.

Furthermore, of the problems related to equipments used during pond utilization, the respondents mainly focused on the problem of water lifting equipment and lifting of water from the pond representing (around 78%). This is followed by problem of water application by using heavy materials reducing interest to produce vegetables in a wider place accounting around 42%.In summary, majority of the problems cited by respondent households revolves around two issues: those related to RWH ponds and equipment problems.

Possible solutions were suggested by households with RWH technology to overcome the aforementioned problems. Most of the solutions suggested focuses mainly on the need for government support in terms of finance, arranging training or experience sharing tour to household heads. Lack of equipments needed and problems related to RWH pond being the dominant problems observed, 81.5% of the households responded that they need government support or other organization to supply them with more simple modern materials either by sharing 50% of the cost or via long term credit so that they can produce more. About 40.8% of the households suggest support from government to avoid waste of labor power and time in the process of water application; we need more simple modern materials either in the market at lower cost or via long term credit since the price of water lifting and watering equipments are unaffordable at household level.

In addition, for problems related to RWH ponds, governments or other organizations help or credit to make them buy iron roof since other raw material don’t stay long and the need for professional help on the need of having cover and fence to minimize risk accounts 38.1% each. On the other hand, 18.3% indicates the need to have continuous assessment to have positive impact on how to use and produce in each season and will help to give solution for problems that household face.

Households with RWH technology were asked to list benefits they get after they start to use the technology, and in general the total frequency of responses (251) reported the benefits sited by farmers are classified in to four major categories. As can be seen from Table 8, these includes new things found after they start to utilize pond (48.21%), 39.4% of the total frequency of responses represents benefits related to water supply or availability, 11.6% of the responses mentioned benefits related with production side and 0.8% are those related to individual opinions.

Table 8. List of Benefits

Se.No		CATEGORY OF THE BENEFITS REPORTED				Total
		Water supply for	New things	Production side	Individual opinions	
1	domestic use	33 (43.4)				33 (13.15)
2	new food varieties in our diet		47(61.7)			47(18.73)
3	Reduce consumption expenditure by producing what we used to buy from the market		28(36.8)			28(11.16)
4	For animals especially for those who can't go long distance to drink water.	37(48.7)				37(14.7)
5	It was able to get water for households easily and timely	29(38. 2)				29(11.55)
6	Produce vegetable beyond home consumption and get money to be used for different purposes by selling the remaining amount.		26(34.1)			26(10.36)
7	Helps to use water for permanent plants during the dry season e.g. Chat, Coffee, Papaya etc			6(7.8)		6(2.39)
8	Enable us to produce more than once in a year by using the pond water during dry spell period			9(11.8)		9(3.59)
9	create new job opportunity by developing the habit of working in dry season and use their time better than before		20(26. 3)			20(7.97)
10	Can avoid dry up of pepper nursering by using water in the pond			14(18.4)		14(5.58)
11	The negative side out weights positive one because the pond construction isn't dome well and it has no plastic cover				1(1. 3)	1(0.4)
12	I'm glad that the pond isn't covered by plastic or cement basement because it will help not to create bad smell when small animals died				1(1. 3)	1(0.4)
	Total	99(39.4)	121(48.21)	29(11.6)	2(0.8)	251(100)

Of the new benefits observed, 61.7% of the households respond the existence of new food varieties in their diet while 36.8, 34.1 and 26.3 percent are reduction in consumption expenditure by producing what we used to buy from the market, produce vegetable beyond home consumption and sell the remaining to use the money for different purposes and creation of new job opportunity by developing the habit of working in dry season and use their time which isn't known before respectively. In addition, the existence of water in their compound was seen as beneficial for animals especially for those who can't travel long distance to drink water and help the household to get water easily and timely instead of holding heavy material for a long distance to fetch water with 48.7% and 38.2% respectively. Finally, from the production side, 18.4% of the households responded that it is used to avoid nursering of pepper from being dried while 11.8% of them responded that it helps to produce more than once in a year using the water during dry season and 7.8% use the water for permanent plants during the dry season.

Finally, half of the sampled households were asked about the factors hindering them from adopting the technology. Of the total responses reported, reasons mentioned related to lack of financial capital problems represent 41.8% particularly related to poor economic situation to cover cost involved in pond implementation. Besides, 17.2% of them are related with lack of knowledge and follow up on the technology and most people don't think that it will give that much benefit. Where as, problem of raw materials mainly due to unfair distribution of raw materials needed to take out the water inside, plot/farm land due to small size land around the homestead and other reasons which mainly includes less work initiation mentioned account for 10.7% each from the total responses reported.

Gender and RWH Technologies

At present, there is a growing tendency towards the adoption of low cost and simple alternative water management technologies like rainwater harvesting technologies. RWH technologies have the potential to contribute towards the Millennium Development Goals (MDGs) with a view of eradicating poverty and hunger, provision of safe drinking water and sanitation, ensuring environmental sustainability, promoting gender equity and women empowerment. It is one way of improving the living conditions of millions of people, particularly those living in the dry areas. Water scarcity especially for domestic and agricultural purposes compromises the role of women in food production. Hence, provision of water by promoting rainwater harvesting and management technologies reduces the burden on rural women and thus increasing their productivity.

This part tries to see the participation of women in male headed households in planning and decision making stage, construction, maintenance, clearance and watching stages. In addition, it will try to address the question if women are benefited and in what terms, and the reasons if they aren't benefited from adoption of the technology. Besides, female headed households were asked if they are selected as beneficiaries and how they are selected, and if not, why not. The constraints that they face to use RWH technology are also considered.

Most households replied that there is equal responsibility among women and men to participate in planning and decision making accounting for 85.5% of the total rainwater harvesting technology adopters. This is followed by 17.1% of households who have mentioned that during planning, the women suggest the time for the work to provide a better food service. With regard to construction, 57.9% of the households said that, women participated directly (by supplying water) and indirectly (by preparing food and coffee) for workers. And about 33% of the households suggested that, women assisted by providing the needed raw material (like stone, sand, cement from home to where they work etc) and removing the soil from around the pond to a bit far area.

In the case of women participation in maintenance, clearance and watching, 72.4% of the households responded that they mainly participate in watching kids and animals from getting into the pond accidentally since they spent most of their time at home. This is followed by their participation in cleaning the area of the pond accounting 55.3%. Women participation during the dry season to carry out soil or sand that enters into the ponds in rainy season has taken 50% of the household's response. And about 30% of the households participated in maintenance by bringing water, raw material, food service and protecting the pond from being destroyed.

In relation to female headed households, 67.1% of the households who adopt RWH technology responded that they aren't selected as beneficiaries whereas the remaining 32.9% replied that they are selected to be beneficiaries. Out of those households who responded that female-headed households are not selected to be beneficiaries, 68.6% of them mentioned that the main reason is economic and manpower problem. Less interest and initiation due to less participation in agricultural work account for 17.6% of the household's response. About 16% of the households responded that bias exists towards male headed households on the ground that the ladies can't go through the hard work, and the same percentage for the reason that they don't have anyone to teach them about its use and purpose indicating less knowledge about the work. On the other hand, out of those households who responded that female-headed households are selected to be beneficiaries, 52% said that government or agricultural extension is voluntary to give chance for anybody depending on their working ability in agriculture. About 44% replied that it depends on their capacity to cover cost involved in pond construction. Moreover, 36% of them responded that it is their own initiation that matters.

With regard to the benefits achieved by women from the adoption of the technology, about 78% of the households responded that they are beneficiaries in terms of reduction in expenditure by using vegetable produced for home consumption and selling the remaining. More over, 61.8% of the households consider the time saved that would have been wasted in fetching water and 22.4% on ability to eat different and new food varieties.

Generally, the result implies that women are getting benefit from the technology adoption as any member of the family. Their participation in the technology adoption is mainly in watching the ponds. They also have contribution in planning and decision making stage, and in giving support during construction, maintenance and clearance of the pond. Female headed households are being constrained to be beneficiaries due to economic and manpower shortage.

5. Conclusions and Recommendations

Conclusions

Due to population increase in the highland areas, more and more marginal areas are being used for agriculture which led to the degradation of the natural resources .One of the major challenges to rural development in the country is how to promote food production to meet the ever-increasing demand of the growing population. Rainfall in the arid and semi-arid areas is generally insufficient to meet the basic needs of crop production. In degraded areas with poor vegetation cover and infertile soil, most of the rainfall is lost through direct evaporation or uncontrolled runoff. Thus, overcoming the limitations of these arid and semi-arid areas and making good use of the vast agricultural potential under the Ethiopian context, is a necessity rather than a choice. Hence, to alleviate these development constraints, the Federal government and Regional states, and NGOs working in research and development, have invested huge resource on rainwater harvesting technology.

In this study, methodologies including descriptive(cropping pattern), econometrics and qualitative analysis are used to assess the determinants of households' adoption of rainwater harvesting ponds, and its impact on agricultural intensification and yield in Alaba Woreda, southern Ethiopia. Interview has also been done with experts on rainwater harvesting ponds.

The finding in the cropping pattern shows that, farm households have started to grow new crops (vegetables and perennial crops) as a result of water availability from the water harvesting ponds. The crops are those which are highly priced and marketable ones implying the potential of RWH technologies to enhance a farm household's income. However, the benefit depends on market and infrastructure accessibility, and diversification in the types of the crops. Results of Probit analysis on the determinants of adoption of rainwater harvesting ponds shows that household size, education status of household head, ownership of livestock (cattle, oxen and pack animals), homestead plots and type of pond explained adoption statistically significantly.

In accordance with government's target, the Ordinary Least Square estimation of the determinants of the value of crop production shows that adoption of RWH has a positive and statistically significant effect on value of crop production, after controlling for input use and other factors. This shows that RWH ponds have direct and significant impact on value of crop production. We also find that households with RWH technology use more labor and seed but less oxen power compared with those households who have not adopted the technology. Moreover, labor and seed inputs have positively significant impact on yield while the effect of oxen power is insignificant. These results show that in addition to its direct impact, RWH has significant indirect impact on value of crop production through its effect on intensity of input use.

Results of the qualitative information, consistent, with the crop mix and econometric results, also showed that households started to grow crops that weren't grown previously. In addition, it indicates that effectiveness of the technology adoption is mainly constrained by problems related to water lifting and watering equipments, and accidents occurring due to absence of roof cover and fence to the ponds. Generally, directly or indirectly, labor requirements and cost considerations appear to be important factors that influence household's adoption of RWH technology.

Recommendations

The benefit found from the high valued and perishable commodities due to RWH, depends on market and infrastructure accessibility, and diversification in the types of the crops. Thus, efforts should be made to assess various agricultural commodities as well as giving emphasis to marketing extension, especially in facilitating markets and market linkages to farmers.

The impact of household RWH technology adoption on the value of crop yield has been found to be stastically significant. Therefore, to mitigate the erratic nature of rain fall in the arid and semi-arid parts of the country, development and implementation of rain water harvesting technologies will be helpful to promote productivity and sustainable intensification of the rain fed agriculture.

However, the success of the technology adoption is mainly constrained by problems related to water lifting and watering equipments, and accidents occurring due to absence of roof cover and fence to the ponds. This implies that support will be needed to provide affordable but improved water lifting and watering equipments, and give training to farm households on construction and use of roof covers and fences to the ponds.

Labor requirements and cost considerations appear to be important factors that influence household's adoption of RWH technology. This implies that research and development interventions need to take account of the labor and cost demands of the technology.

RESULTS OF ECONOMETRIC ESTIMATION

Table-2 Determinants of adoption of RWH pond (Probit)

Explanatory Variables	Probit use of RWH technology		
	Coefficient (dF/dx) ‡	Z	P>z
Peasant association dummy,cf., Mudda Dinokosa			
Ulegebba Kukke	-0.0007837*	-1.85	0.065
Andegna Hansha	-0.0004302	-1.01	0.312
Hamata	-0.0003513	-0.72	0.472
Household access to services and infrastructure			
Walking time to the nearest town market (in hrs)	-0.0001269	-0.61	0.545
Walking time to the nearest village market (in hrs)	0.0001965	1	0.316
Walking time to the nearest cooperative shops (in hrs)	0.0001392	0.52	0.603
Walking time to the nearest all weather road (in hrs)	0.0002143	1.02	0.308
Walking time to the nearest seasonal road (in hrs)	-0.0000296	-0.06	0.954
Rain fall condition, cf., low			
Medium	-0.0004712	-0.84	0.401
High	-0.000446	-1.46	0.145
Household size	0.000111**	1.96	0.05
Age of household head (in Ln)	0.0002167	0.29	0.772
Education level of household head, cf., illiterate			
Read and write	0.0079635***	3.25	0.001
Up to 4th grade	0.0018686	1.44	0.149
Up to 7th grade	0.00026301*	1.86	0.063
Up to 10th grade	7.41E-06	0.01	0.991
Household resource endowment			
Land owned (in ha)	-0.000184	-0.85	0.395
Value of cattle (both local & cross bred cows, calves, heifers, yearling, bulls)	3.59E-07**	1.98	0.048
Value of oxen (local and breed)	5.24E-07**	2.2	0.027
Value of sheep and goat	-4.44E-07	-0.72	0.472
Value of pack animals (donkey, horse, mule)	6.69E-07*	1.88	0.06
Value of poultry (both local & improved)	2.19E-07	0.64	0.519
Value of beehives (improved, modified, traditional)	3.85E-08	0.27	0.79
Value of all assets owned (plow set, farm equip, motor pump, radio,..	-3.23E-08	-0.33	0.74
Household membership in local organization, cf., members in Edir and other local organizations			
Membership in Edir only	0.0002847	0.7	0.487
Household membership in associations, cf., association members			
No membership in association	-9.37E-06	-0.02	0.985
Household financial capital , 1= yes			
Household with credit Access,1= yes	-0.0000753	-0.17	0.865
Household savings, yes=1	-0.0002764	-0.71	0.478
How household acquired the plot, cf., rented and share cropping			
Allocated by the state	0.5627719	0.00	0.997
Inherited	0.5999944	0.00	0.998
Slope of the plot, cf., steep slope			
Flat	0.0044407	0.00	0.999
Moderate	0.0686505	0.00	0.999
Soil depth of the plot, cf., deep			
Shallow	-0.0002766	-0.32	0.751
Medium	-0.0001365	-0.11	0.912
Soil fertility level of the plot, cf., low fertility			
High fertility	0.0141321	1.25	0.21
Moderate fertility	0.0010029	1.11	0.267
Purpose for which the land is used, cf., grazing ,woodlots and spice land			
Cropland	-0.0002559	-0.33	0.74
Homestead	0.0695164***	4.8	0.000
Plot size in ha (in Ln)	0.0005554	0.94	0.345
Walking distance from household's residence to the plot (in hrs)	-0.00168	-0.72	0.472
Type of pond, cf., ponds with plastic cover and those without a cover			
Ponds with concrete basement	-0.377571***	-4.54	0.000
Number of observations	1036		
LR chi2 (41)	350.92		
Prob > chi2	0.0000		
Pseudo R2	0.6399		

*** is significant at 1%; ** is significant at 5%; * is significant at 10%

‡Reported coefficients represent effect of a unit change in explanatory variable on probability of adopting RWH technology.

Table – 3 Determinant factors of input use during 2005/06 agricultural fiscal year

Explanatory Variables	Ln (Seed/ha)	Ln (Oxen-days/ha)	Ln (Labor-day/ha)	Whether fertilizer were used	Whether manure/compost were used
Peasant association dummy,cf., Mudda Dinokosa					
Ulegebba Kukke	-0.245172	0.15099*	0.058052	0.0655231	-0.0197904
Andegna Hansha	0.214534	0.203828***	0.039733	-0.1935646***	0.079232
Hamata	0.001953	0.168604**	0.172659**	-0.1475076**	-0.0190538
Household access to services and infrastructure					
Walking time to the nearest town market (in hrs)	-0.104291**	-0.016135	0.020109	0.206203	-0.0265866*
Walking time to the nearest village market (in hrs)	-0.125701**	-0.072537***	-0.117138***	-0.0425217*	-0.0363848**
Walking time to the nearest cooperative shops (in hrs)	0.034241	-0.02963	-0.057824*	-0.0280787	-0.0054926
Walking time to the nearest all weather road (in hrs)	0.040986	-0.011034	0.022569	-0.0090631	0.0078478
Walking time to the nearest seasonal road (in hrs)	0.184175	0.097555	-0.110871*	0.0753763	-0.129366***
Rain fall condition, cf., low					
Medium	-0.084553	0.112657**	-0.054333	0.0087776	0.0026803
High	-0.091135	0.008501	-0.212387***	0.0527761	0.2818222***
Household size	0.026266*	0.021049***	0.043193***	-0.0024128	0.0094189*
Age of household head (in Ln)	0.125784	0.108762	-0.181818*	-0.0654953	0.0254648
Education level of household head, cf., illiterate					
Read and write	0.230052*	0.231572***	-0.087174	-0.0931605	0.0654167
Up to 4th grade	0.257753*	0.192213***	-0.078671	0.0288443	-0.0862418**
Up to 7th grade	0.083556	-0.024551	0.002305	-0.0171464	0.0307067
Up to 10th grade	0.071938	0.080617	-0.053017	-0.0293807	-0.0785635
Household resource endowment					
Land owned (in ha)	0.007845*	0.006203**	0.00167	0.0027194	-0.0037889**
Value of cattle (both local & cross bred cows, calves, heifers, yearling, bulls)	-1.73E-05	-5.90E-05	-6.98E-05***	4.99E-06	-0.0000345**
Value of oxen (local and breed)	4.28E-05	2.83E-05	4.82E-05*	0.0000103	0.0000485***
Value of sheep and goat	0.000167	0.000129*	-9.97E-07	-5.99E-06	-5.83E-06
Value of pack animals (donkey, horse, mule)	-0.000118	-0.000051	-8.93E-05**	7.97E-06	-5.84E-06
Value of poultry (both local & improved)	-0.000809	0.000172	0.000323	-0.00039	0.0003529
Value of beehives (improved, modified, traditional)	-0.00041	0.000376*	0.000197	0.0003235*	-0.0004251***
Value of all assets owned (plow set, farm equip, motor pump, radio, ...)	3.62E-06	-1.66E-05	-2.19E-05	7.05E-06	-3.57E-06
Household membership in local organization, cf., members in Edir and other local organizations					
Membership in Edir only	-0.215644	-0.115894	-0.210552***	-0.089469	0.0591204
Household membership in associations, cf., association members					
No membership in association	-0.094869	-0.191782***	0.042779	-0.0621948	-0.0014808
Household financial capital , 1= yes					
Household with credit Access,1= yes	-0.137139	0.070683	-0.06814	0.0624094	0.056192*
Household savings, yes=1	-0.072473	-0.327655***	-0.114424**	0.0126967	0.1128724***

Table – 3 continued

Explanatory Variables	Ln (Seed/ha)	Ln (Oxen-day/ha)	Ln (Labor-day/ha)	Whether fertilizer were used	Whether manure/compost were used
How household acquired the plot, cf., rented and share cropping					
Allocated by the state	-0.506682***	-0.141824*	0.084312	-0.1988535***	0.158752***
Inherited	-0.382232***	-0.169708**	-0.111456*	-0.1364283**	0.1498123**
Slope of the plot, cf., steep slope					
Flat	-0.119189	0.530278*	0.446515*	0.1701381	0.3856669*
Moderate	-0.10287	0.51544*	0.547266**	0.1265144	0.2790531**
Soil depth of the plot, cf., deep					
Shallow	-0.021532	0.129045	-0.117212	-0.0475644	0.2127672
Medium	-0.000324	-0.300583***	-0.315847***	0.0428845	0.1378711*
Soil fertility level of the plot, cf., low fertility					
High fertility	0.048873	0.101733	0.035063	-0.0829447	0.1586607**
Moderate fertility	0.144556	0.089368	0.062933	-0.0517906	0.479061
Purpose for which the land is used, cf., grazing ,woodlots and spice land					
Crop land	0.419156***	0.37224***	0.614584***	0.4647761***	-0.0924947**
Homestead	3.09079***	-0.340097***	-0.472505***	-0.5890224***	0.4247779***
Plot size in ha (in Ln)	-0.180882	-0.912926***	-0.779754***	-0.2589599***	0.539933
Walking distance from household's residence to the plot (in hrs)	3.312421	0.011153	-0.12605	0.2058507**	-0.1616669
Adoption of Rain Water Harvesting technology (predicted value), 1=yes	3.312421***	-0.291091*	0.265723*	0.1043238	0.0748814
Constant	4.448353***	4.83144***	6.78531***		
Number of observations	1036	1036	1036	1036	1036
F (41,994)	8.80	14.08	14.46		
Prob > F	0.0000	0.0000	0.0000		
R squared					
LR chi2 (41)				281.62	353.37
Prob > chi2				0.0000	0.0000
Pseudo R2				0.1964	0.3137

*** is significant at 1%; ** is significant at 5%; * is significant at 10%
Reported coefficients represent effect of a unit change in explanatory variable on probability of use of the mean of the data
Ln represents natural logarithm

Table – 4 Determinants factors of value of crop yield

Explanatory Variables	Ln (Value of yield/ha)		
	Full Model ‡	**Structural Model ¶**	**Reduced Model**
Peasant association dummy,cf., Mudda Dinokosa			
Ulegebba Kukke	-0.240465**	-0.16942**	-0.272749***
Andegna Hansha	-0.091321	-0.05626	-0.101886
Hamata	-0.332615***	-0.29741***	-0.387513***
Household access to services and infrastructure			
Walking time to the nearest town market (in hrs)	-0.037325	-0.02798	-0.037513
Walking time to the nearest village market (in hrs)	0.039986	0.041098	0.01502
Walking time to the nearest cooperative shops (in hrs)	-0.017744	-0.03863	-0.016557
Walking time to the nearest all weather road (in hrs)	-0.020955	-0.01405	-0.020943
Walking time to the nearest seasonal road (in hrs)	-0.13985*	-0.16159**	-0.083644
Rain fall condition, cf., low			
Medium	0.016212	0.01092	0.003531
High	0.10563	0.095822	0.08433
Household size	0.008924		0.015446*
Age of household head (in Ln)	-0.1558997		-0.13447
Education level of household head, cf., illiterate			
Read and write	0.007438		-0.059152
Up to 4th grade	0.064804		0.110153
Up to 7th grade	0.058197		0.079857
Up to 10th grade	0.123428		0.107066
Household resource endowment			
Land owned (in ha)	0.00154		0.0031
Value of cattle (both local & cross bred cows, calves, heifers, yearling, bulls)	4.44E-05*		4.55E-05*
Value of oxen (local and breed)	-3.44E-05		-1.22E-05
Value of sheep and goat	9.65E-05		8.20E-05
Value of pack animals (donkey, horse, mule)	8.94E-06		-3.14E-05
Value of poultry (both local & improved)	0.000275		0.00021
Value of beehives (improved, modified, traditional)	4.64E-06		-3.61E-05
Value of all assets owned (plow set, farm equip, motor pump, radio, ..)	-8.60E-06		-7.41E-07
Household membership in local organization, cf., members in Edir and other local organizations			
Membership in Edir only	-0.12421		-0.14033
Household membership in associations, cf., association members			
No membership in association	0.133489*		0.077884
Household financial capital , 1= yes			
Household with credit Access,1= yes	0.084706		0.045664
Household savings, yes=1	0.01175		-0.000479
How household acquired the plot, cf., rented and share cropping			
Allocated by the state	0.285989***	0.220717***	0.175439**
Inherited	0.14397*	0.09171	0.047545

Table – 4 continued

Explanatory Variables	Ln (Value of yield/ha)		
	Full Model	**Structural Model**	**Reduced Model**
Slope of the plot, cf., steep slope			
Flat	0.107935	-0.05085	0.157219
Moderate	0.213	0.052619	0.253161
Soil depth of the plot, cf., deep			
Shallow	-0.342699**	-0.2061	-0.276843*
Medium	-0.320594**	-0.2085	-0.269564*
Soil fertility level of the plot, cf.,low fertility			
High fertility	0.083002	0.12039	0.042061
Moderate fertility	0.10888	0.136898*	0.099062
Purpose for which the land is used, cf.,grazing ,woodlots and spice land			
Cropland	0.545698***	0.53749***	0.692927***
Homestead	0.22273*	0.273696***	0.376867***
Plot size in ha (in Ln)	-0.056483	-0.02842	-0.123963*
Walking distance from household's residence to the plot (in hrs)	0.085783	0.101174	0.077678
Labor-day/ha (in Ln)	0.101176***	0.110689***	
Oxen-day/ha (in Ln)	0.018104	0.006066	
Seed/ha (in Ln)	0.086711***	0.086715***	
Use of fertilizer,1= yes	0.164603***	0.171696***	
Use of manure/compost, 1= yes	-0.115259*	-0.11909*	
Adoption of Rain Water Harvesting technology (predicted value),1=yes	0.055424		0.510136***
Constant	6.686813*	6.272492***	7.859654***
Number of observations	1036	1036	1036
F (46,989)	8.11		
F(27,1008)		12.18	
F (41,994)			6.14
Prob > F	0.0000	0.0000	0.0000
R squared	0.125	0.0967	0.0953

*** is significant at 1%; ** is significant at 5%; and * is significant at 10%.
Ln= natural logarithm.
‡ Reported coefficients represent effect of a unit change in explanatory variable on probability of use of the mean of the data.
¶ Variables that were jointly statistically insignificant in the unrestricted OLS regression were excluded from the structural model

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Discussion on Theme 2: Irrigation Impact Poverty and Economy

Chair: Dr. Birhanu G/Medhin
Rapporture: Micheal Menkir

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

Questions and Discussions

2.1 What are the inefficiencies variables, that the government policy makers can take up and go for improvement

2.2 What is the level of inefficiency/efficiency within irrigated agriculture itself? Since it is obvious that the production level of farmers cannot fell on the frontier line. How much is the efficiency or inefficiency difference between irrigated and rainfed agriculture?

2.3 The year 2005/2006 was a high rainfall year; so percentage contribution of irrigation on GDP would be less than in a draught year.

Ans-yes analyses may have underestimated percentage contribution slightly. clearly the percentage contribution of irrigation varies b/n good and poor rainfall year

2.4 How sustainable is use of irrigation from experiences of salinity?

2.5 Development especially in high evaporation areas in large scale irrigation schemes. It is suggested that future studies should consider this aspect.

2.6 What should be the size of the sample area of irrigated agriculture to be representative to talk about its contribution the national economy (GDP)

2.7 Using chow´s test you were able to pool the data of Doni and Godino but not Batu Degaga. Does this mean features were behaving in the same manner? Given that their location is different.

2.8 Area expansion increases agricultural production which has some contribution to poverty reduction. However extensive agriculture has its negative impact on the natural resource i.e degradation. Your analysis is based on extensive agriculture rather it is better to consider intensive agriculture for land and water productivity development. Therefore how do you see the natural resource degradation and environmental deterioration in your poverty analysis

2.9 Efficiency issue should be seen with respect to rainfall availability. In Godino water is abundant, rainfall rich. Therefore irrigators are less efficient. However in Batu Degaga water is pumped and it has a cost. So this is incentive for higher efficiency. The area is also dry land with highly variable rainfall. Therefore while considering efficiency water availability and rainfall should be an important parameters.

2.10 Increase of water supply by 1 percent leads to 0.5 percent output what should be the limit o f applying more water, since over application will lead to miss management and inefficient water use. In the future farmers may be able to pay for the water they use for irrigation (from experience of other water scarce countries like Morocco, Jordan and Israel. Is there a possibility of using this in terms of cost recovery and operational and management cost of irrigation projects?

2.11 While talking about the need for irrigation need for the countries GDP growth. Are we considering other sectors using the same source like hydropower, water supply

2.12 Quality of water definitely decreases as consumptive use (irrigation) increases. so is not important to consider the decrease in the value of same volume of water in the future in calculating or equating monetary value of water?

2.13 How do you say that irrigation time increases production? Irrigation time usually depends on the stream size a farmer is receiving.

2.14 How is it possible that farmers located at the tail end of the system are less efficient and at the same time dry land farmers are more efficient. Answer- Found the comment valid but could not consider during the study due to the complexity of determining the volume of water received by a farmer. Answer , Tail end users are less efficient due to water limitation because of over abstraction of water by upstream users

2.15 In your recommendation you stated that households with access to irrigation will remain poor what does this indicate?

2.16 The reason for livestock absence is not only because of less grazing land but mainly due to sleeping sickness (Trzpanosomiassis), lowland livestock disease.

2.17 In your conclusion less choice is put as a negative aspect but we found those who specialised (follow one cropping pattern) are the richest of the beneficiaries as they can buy their food crops.

Ans- the livestock disease happened some 10 years ago, but now lack of grazing land is the main reason. And less choice of food is related to the education status

2.18 There is a confounding effect between irrigation and rain fed agriculture. Farmers with access to irrigation could be making more money or income from their rain fed production. How can we deal with this problem?

2.19 What are the differences between depth of poverty and severity of poverty? What are the parameters that are required to address these two terms?

2.20 What is the optimal investment cost per hectare of irrigation projects specially small scale projects

2.21 What are the inefficiency variables which can be taken by the government

2.22 Definition of technical efficiency. Due to inherent nature of inefficiency every farmers cannot fall towards the frontier line

2.23 There are different kinds of small scale irrigation which irrigation systems are viable from the 25 SSI

2.24 Did you see the effect of supplementary irrigation in your analysis

2.25 Have you considered the cost of the dam? Is the water free?

2.26 No one mentioned about sustainability of the irrigation projects. Salinity in middle awash valley....?

2.27 Why did you leave commercial farmer like the one in Maki Ziway area in your analysis

2.28 Change in quality of water what is the economic impact of low quality water

2.29 Input-output pricing are they incorporated in your analysis

2.30 How do you identify poverty in the beneficiaries of irrigation schemes

2.31 Female Household are they included? what is the finding with respect to Female households

2.32 What is the difference between depth and severity of poverty

2.33 Interaction between rain fed and irrigation systems. How do you deal with confounding effect

2.34 Do you see the size of irrigable land which should be allocated example in Tigray it is 0.2 ha if tit is more it is not manageable? So did you come across of such kind of analysis.

2.35 What is the limit for investment? what kind of marketing is essential to impact the GDP? The other problem is the discrepancy between land and water availability

2.36 Share cropping is widely practiced. farmers lease their land. Do you consider this when you talk of impact of irrigation

2.37 What is the reason behind for female household to be more food secured than male headed household?

2.38 In the Alaba presentation the positive impact of water harvesting structures is shown what about its impact on health? Is the adoption continued even after its introduction by the government?