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IMPACT ASSESSMENT OF RAINWATER HARVESTING TECHNOLOGIES: THE CASE OF ASTBI WOMBERTA WOREDA, TIGRAY, ETHIOPIA

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ABSTRACT

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 rain water harvesting technologies either at a village or household level has been promoted for improving productivity and sustainable intensification of the rainfed agriculture. This study examines the socioeconomic and biophysical factors affecting a farm household's RWH technology adoption decision in Tigray, Atsibi Womberta Woreda, northern Ethiopia; and the impact of the rainwater harvesting technologies on crop yield. The study develops a theoretical framework to test hypotheses and to investigate the determinants of household's RWH technology adoption decision, the determinants of yield differences across plots, and the impact of rain water harvesting ponds on crop production.

The factors are analyzed using plot-level data surveyed from 100 households, (52 households with RWH technology and 48 households without RWH technology). In this study, the econometric analysis adopts OLS and Probit models based on the nature of the dependent variables under investigation. Besides, to augment the results of the econometrics analyses descriptive, crop-mix, and qualitative analyses have been adopted.

The result of the crop-mix analysis showed that, a comparison of the "with" and "without" situation with respect to the crop type grown, based on the crop category, shows a major shift on farm household's crop choice decision from cereals and pulses towards perishable and perennial cash crops, including vegetables, spices, and fruits, and/or an intensification in agricultural production. The findings of the econometric analysis of the probit model shows credit access, plot size, plot proximity to residence, purpose of the plot, and savings as the major positive determinant factors of household's RWH technology adoption decision. Consistent with this, results of the analysis of qualitative information witnessed lack of capital, lack of plot or small plot size, and problems related with structure or design of the RWH technology adopted as the main problems facing households, and have a negative impact on the technology adoption rate.

Finally, results of the OLS estimation showed that, although the impact of most of the household-level factors was indirect through the factor inputs, except for seed, the impact of the other factor inputs is insignificant. However, household head involvement in non-farm labor, education level, greater ownership of oxen, and plot fertility have significant positive impact, while credit access, ownership of greater pack animals and small ruminants, and rented plots have witnessed negative impact on value of crop yield. Besides, the study has found no significant effect of RWH technology on value of crop yield. However, other interesting result implied from this study is that, though initially the RWH technology was introduced as a supplementary source of water for cereal and pulse crop production during dry spell periods, majority of the farm households have used the accumulated water for horticulture production. The agricultural intensification would in tern have positive potential to increase the income of farm households.

CHAPTER ONE: INTRODUCTION

1.1. BACKGROUND OF THE STUDY

Since ancient times, the rain fed agriculture has remained to be the mainstay of the livelihood of most rural poor people in many developing countries. However, these economies are characterized by diminishing natural resource base and environmental degradation coupled with high population pressure, lack of capital, inappropriate policies, and civil unrest. In particular, the irregularity and variability in the distribution of rainfall, especially in the semi-arid and dry sub-humid parts of the Sub-Saharan African countries, has made the sector unable to sustain food production to meet the increasing demand in the region. Freeman et. al (2005), as cited in Shiferaw et. al (2005), says recurrent drought and food insecurity has become a common phenomenon which threatens the lives of million of poor people in this region.

In such an environment, unless supplementary sources of water are used, traditional farming and animal production activities will not cope up with the ever increasing demands of the society. Hence, to address the aforementioned problem of the poor performance of the agricultural sector, national governments and non-governmental organizations have made various rehabilitation attempts. For instance, to reduce the variability of distribution of rainfall, efforts are made which range from construction of large scale dams to rain water-harvesting ponds for use at household level. To reduce land degradation, soil and water conservation activities, which include construction of stone bunds, terracing, and aforestation are undertaken.

For several reasons, most of the rehabilitation efforts have failed to attain the intended objectives in a sustainable way. Moreover most of the efforts undertaken by different agents were in a fragmented way and with different objectives. With regards 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 in Africa, include the high capital requirement and cost of constructing the latter scheme

Turner (1994), while Vaishnay (1994), cited easy adaptability of the former scheme and the socio-economic condition of the countries. It is also important to note that, in general, technological tools and natural resource management schemes that are developed and become successful in one region may not be suitable and successful in other agricultural system and environmental conditions.

Different writers including Bruins et al. (1986) and Gilbertson (1986), suggest the adoption of rain water harvesting technologies (RWH) as a means to cope up with shortage of water during dry spells and in a drought – prone and environmentally degraded areas. In this study RWH technology is defined following Ngigi, (2003), as the process of collecting, directing and concentrating all possible rain/runoffs for productive purposes, such as for domestic use and agricultural and livestock production.

Due to the severe environmental degradation, the erratic nature of the distribution of rainfall and other factors such as lack of capital, backward technology and inappropriate agricultural policy of the past regimes, the agricultural sector in Ethiopia has exhibited poor performance. Since the early 1960's the sector has failed to meet the food requirement of the people (Getahun, 2001), although it has been believed to be the mainstay for the livelihood of more than 85% of the population of the country. According to Getahun (2001), the food insecure people in the country comprises mainly of pastoralists and agro pastoralists concentrated in the arid and semi-arid parts of the country, farmers in drought-prone areas, small scale and resource poor farmers and the urban poor.

After the fall of the military socialist government, both the Transitional Government of Ethiopia (TGE), formed 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 development - centered sustainable rural development, Lakew (2004). Based on this, several rain water harvesting technologies have been constructed by farmers privately through out the country. Besides, the adoption of these technologies at household level has been promoted by regional states, NGOs, and communities.

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 rain water harvesting technologies either at a village or household level was adopted since 2002. The Federal Government has allocated a budget for food security programs to be implemented in the regions with an outlay of Birr 100 million and Birr 1 billion during the 2002 and 2003 fiscal years, respectively (Rami, 2003). Of the total budget, most of it was used by regional states for the construction of rainwater harvesting technologies in collaboration with the Federal Ministry of Agriculture (Rami, 2003).

Reports revealed by Ministry of Agriculture and Rural Development and Regional Bureaus show that until the fiscal year 2004 several water harvesting technologies were adopted by farmers (Lakew, 2004). These include 308,338 shallow wells, 205,787 household level structural storage ponds, 49,311 community ponds, 5,632 cisterns, development of 32,727 spring water, and 31,386 ha of traditional irrigation have been supported. Where, all the above water management activities have the capacity of irrigating around 93,326 ha of land and 732336 households will gradually benefit from the activities.

Shallow well is usually adopted in areas with abundant ground water and it is constructed by digging 3 to 15 m depth with the surface of the ground covered by cement or stones used for reinforcing the well shaft. The household pond is one of the structural storage RWH technologies with trapezoidal shape where water is directly harvested by runoff or taken from gully or stream with a diversion structures and stored in the pond to be used for supplementary irrigation. On the other hand, a community pond, which includes communal pond and a series of ponds basically differ from household ponds in their water storage capacity level.

A communal pond RWH technology is a deeply excavated half moon shaped storage with a bigger capacity than household ponds and it is constructed on a selected site within a village for collective use. The series pond system refers to a circular shaped chain of connected ponds for communal use. The series of ponds are constructed on suitable positions following an intermittent flood stream with the aim of collecting runoff at different points and flood diversion channels are constructed to each pond from the flood steam. The other type of water harvesting technology adopted is cistern. Cistern includes underground storage systems, such as a closed system having a circular shape which is made from reinforced concrete, and a cistern with a half circular shape with the surface of the ground covered by polyethylene or concrete and a plastic or thatched roof is used to cover the ground. Where as, spring water development refers to the construction of reservoirs on some suitable site with the aim of collecting the water runoff emanating from a spring using flood diversion channels.

The study area, Tigray is located in northern part of Ethiopia, extending from $12^{O}15'$ to $14^{O}50_{N}$ latitude and from $36^{O}27'$ to $39^{O}59'_{E}$ longitude and it is part of the Sudano–Sahelian zone (Gebremedhin, 2002). With a total area of 53,638 Sq. Km, according to a survey by Tigray Regional Office of Population (2002), the region has a total population of 4 million (Rami, 2003). The livelihood of more than 85% of this population depends on agriculture. The small landholder farmers characterize the agricultural sector and are highly dependent on natural resource, which in turn has severe impact on the natural resource base of the region. The main rainy season of the region is Kiremt (summer), which ranges from late June and ends early September, but it shows large variability in its distribution. The average rainfall of the region during the years 1968 to 1988 was 578mm and has a high coefficient of variation. According to Tassew (2000), the coefficient of variation is 28%, while the Tigray Regional Bureau of Water Resources estimates the coefficient of variation to range from 20% to 40%. The region has five administrative zones: Western, North Western, Eastern, Central, and Southern, which are further subdivided into districts, called Woredas. The particular site of the study area, Atsibi Womberta Woreda, is located in the Eastern Zone, north east of Mekelle.

Realizing the need for an integrated rural development, various natural resource management measures have been undertaken in the Tigray region by the Regional Bureau of Agriculture and Rural Development and other non-governmental organizations, such as Relief Society of Tigray (REST) and communities. Some natural resource management activities have been implemented in the region after the fall of the military regime: development of area enclosures and community woodlots; construction of stone bunds, check dams, micro-dams; river diversions; and reforestation (Gebremedhin, 2002; Rami, 2003). Besides, since the fiscal year 2002 the regional government has launched a RWH technology intervention scheme at household level, aiming at improving the availability of water, at dry spell periods, during the rainy season, and there by improve agricultural productivity.

1.2. STATEMENT OF THE PROBLEM

Land degradation and variability in annual rainfall are major problems facing the agricultural sector in the highlands of Tigray (Kinfe, 2002). The status of the natural resource base depletion in the region is well summarized in (Tassew: 2001 p.15), as follows:

> *"…. Much of the steep slopes have lost their protective cover. They are highly overused for cultivation and grazing of livestock. Grasslands have been overexploited. Soil run-off from slopes has caused severe erosion. Most of the soil is eroded by water and wind. The natural forest of the region has been destroyed mainly through encroachment of subsistence cultivation. … Aridification has increased due to clearing of natural vegetation such as forest, woodland, and bush land.*

The consequence of the natural resource base degradation in the region coupled with erratic rainfall, high population density, civil war, inappropriate policy of the past regimes, threatens the lives of millions of people, who depend heavily on the subsistent agriculture for their livelihood.

For instance, Gebremedhin, (2002) points out that, though there are few areas in the region which produce surplus during good rainfall years, the most part either produce a subsistence level or encounter a chronic food deficit during dry season. Rami (2003) also states that the recurrent drought occurring almost every 3-4 years in the region has made 621,000 households or 75% of the total population of the region food insecure, and their lives are seriously threatened by this phenomenon. However, there are also some positive development signs over the last ten years in the region.

Hence, in line with the Agricultural Development-Led Industrialization Strategy launched by the National Government since 1991, the Regional State of Tigray, consistent with the realities of the region and the fragility of the natural resource base in the region, had adopted a Sustainable Agricultural Development and Environmental Rehabilitation Strategy. The strategy aims at expanding small-scale irrigation and watershed management schemes, and thereby improves and stabilizes agricultural productivity and reverses environmental degradation.

For instance, Rami (2003) points out that since 1995, 50 micro-dams and 11 diversions were constructed by the regional state, Relief Society of Tigray (REST) and the communities. In addition to this, to reduce land degradation and conserve the water resource base different initiatives such as introduction of area enclosure and community woodlots; construction of stone bunds and check dams; river diversion and reforestation have been undertaken (Gebremedhin, 2002). To improve the agricultural productivity in the region, attempts are also made to introduce modern agricultural input and practices, to diversify the rural economy and to improve infrastructures in the rural area (Ibid, 2002), in line with the environmental rehabilitation activities. According to Rami (2003), the aforementioned efforts have a positive impact in improving the level of living of the households participating in the schemes, and reducing environmental degradation.

However, for several reasons most of the short term benefits obtained from these interventions fail to be sustained in the long run.

The widespread and recurrent drought encountered in the country on the one hand and the high cost of irrigation on the other hand have led the Federal Government and Regional States to give due emphasis to the potential of RWH technology intervention at household level. Hence, since 2002 the Regional State of Tigray has launched a RWH technology intervention scheme at individual household level. According to Mills (2004), in all parts of the region, the water collected in the rainy season is assumed to be used for supplementary irrigation to meet the gap during a dry spell periods as well as for multipurpose use such as domestic consumption, livestock watering, and small-scale irrigation. The final effect of the intervention was expected to improve agricultural production of the region during good rain fall seasons and secure crop production at times of dryer seasons and there by achieve the target set by the regional state to eradicate 88% of the food deficit in the region within three years (Rami, 2004). Thus, various forms of RWH technologies have been constructed by farmers with some technical and financial support by the Regional State, the Federal Government, and REST.

For instance, during the first fiscal year 2002, 27,000 shallow wells, and 39,000 trapezoidal ponds with polyethylene membrane have been constructed by farmers in collaboration with the Regional Bureau of Water Resources (ReBoW), Regional Bureau of Agriculture (ReBoA), and REST (Lakew, 2004). Initially when the rainwater harvesting technologies was introduced, the cost of construction was covered by the regional state, through labor paid in the form of food-for-work, while the cost of the polyethylene membrane was covered by REST. However, since the fiscal year 2003, the Regional State has decided that, except for the unable household heads, all households should use their own labor during construction without payment and the polyethylene membrane, which was previously given for free by REST, be bought on credit basis (Rami, 2004).

In addition to this, as it is cited by Mills (2004), under the three-year action plan (2003 – 2006) of the Tigray Water Resources Development Bureau, it was planned to construct 500,000 ponds and 6,000 shallow wells using manual labor, and 840 "series of ponds" using machinery. Moreover, about 16,667 foremen were expected to be trained for pond supervision at household levels (that is, during site selection and construction of RWH ponds) and 111 foremen for shallow well supervision.

However, there is little information and analysis on the feasibility and effectiveness of these rainwater harvesting technologies in the region. Besides, the impact and performance of the different RWH technologies has not been assessed. It is also important to undertake a detailed study to identify the determinant factors or incentives that affect a farm household's technology adoption decision and/or investment decision for maintenance of old RWH technologies. Hence, this study is aimed at contributing to fill this gap of knowledge in the region.

1.3. OBJECTIVES OF THE STUDY

The general objective of the study is to assess the overall impact of the water harvesting technology intervention on agricultural productivity using a quantitative approach supplemented by a qualitative approach. In particular the study focuses on:

1. identifying the determinants of household decision to adopt rain water harvesting technology.
2. identifying the determinants of yield differences across plots.
3. examining the impact of rain water harvesting ponds on crop production.
4. deriving policy implications to improve the performance of the rainwater harvesting ponds.

1.4. SIGNIFICANCE OF THE STUDY

A thorough understanding of the impact of the RWH technologies on agricultural productivity, and the farm household's income and welfare, and the determinant factors, 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. Besides, this study may add some value to the already existing methodological literature on assessing the impact of RWH technologies.

1.5. SCOPE AND LIMITATIONS OF THE STUDY

The case study was based on a one-time field survey of 100 farm households half of them using various types of RWH technologies in their agricultural production process. Substantial qualitative and quantitative information were gathered on agricultural production, the different aspects of the RWH technologies adopted, and problems related with the technology intervention. However, the study has the following 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 and the farm household's income and welfare. 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. Moreover, due to limited resources and timeframe, small sample size was used and the findings of this study must be cautiously interpreted relative to the data set utilized.

1.6. ORGANIZATION OF THE STUDY

The study comprises seven chapters. Chapter two deals with conceptual and theoretical underpinnings in impact assessment of RWH technology intervention on agricultural productivity and farm household's income and welfare, reviews empirical studies on impact of water, soil, and land management interventions. Chapter three presents review of the methodological literature on impact assessment, and outlines the specific models adopted in the study and their corresponding estimation methods employed for the empirical analysis. Chapter four and five presents discussion of the results of the descriptive and crop – mix analysis, and the econometric analysis respectively, while the qualitative analysis is discussed in chapter six. Finally, chapter seven presents the policy implications and conclusions of the study.

CHAPTER TWO: LITERATURE REVIEW

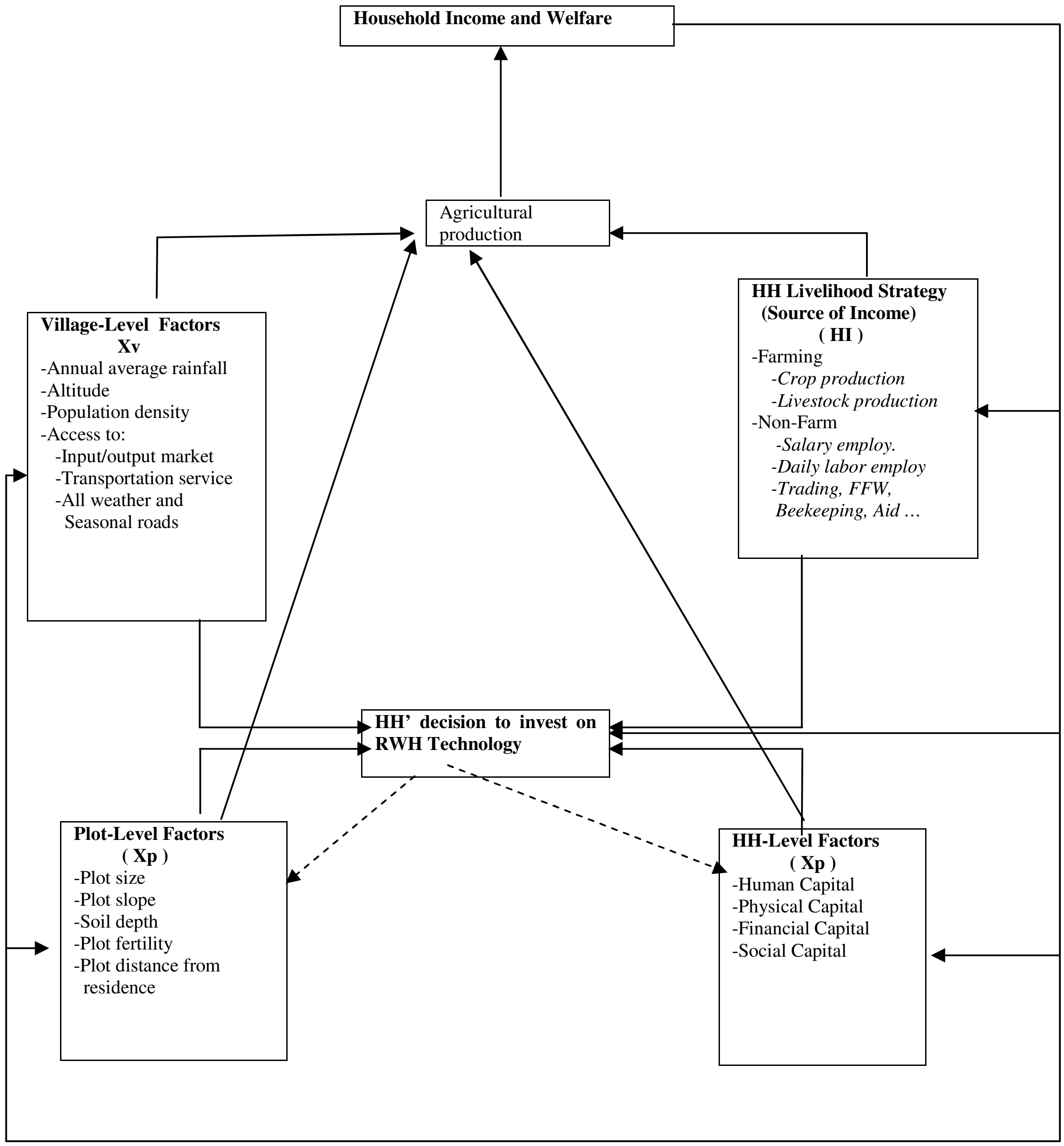
2.1. SURVEY OF THE THEORETICAL LITERATURE

2.1.1. CONCEPTUAL FRAMEWORK

The schematic representation given below shows the interrelationship among the various household-level, plot-level, village-level factors, the farm household's livelihood strategy, the farm household's production decision, and the decision to invest on RWH technology. As can be depicted from the figure, a farm household's decision on agricultural input use and adoption of RWH technology could be influenced directly by the household-level characteristics, the farm household's livelihood strategies, plot and village level characteristics, and the characteristics of the technology itself, which is going to be adopted. Besides, a farm household's decision to adopt RWH technology may be affected by previous year's agricultural yield harvested.

The household factors, which could influence the farm household's decision on input use and adoption RWH technology includes human capital (e.g. age, gender, educational status and/or training of household head, and household size), physical capital (e.g. land and livestock endowment), social capital (e.g. membership in organization and/or associations, and contact with agricultural extension program), and financial capital (e.g. Household's saving and access to credit). Moreover, the farm household's livelihood strategy, such as source of primary and/or secondary income of the household, will also have an impact on the farm household's decision.

Figure - 1 Schematic presentation of the relationships and interdependence among the various factors, agricultural output, and household income and welfare.



Key: Dashed lines represent indirect impacts of factors on yield.

Solid lines shop direct impact of factors on yield and RWH technology adoption decision.

The household's decision could also be affected by plot-level factors, such as the size, slope, soil depth, fertility, and relative quality rank of the plot. In addition to this, there are also village level factors, which could influence the farm household's investment decision, for instance, the level of annual average rainfall, the altitude of the village, population density, and access of the village to input/output market, transportation facility, and roads.

The characteristics of a particular RWH technology could also influence the decision to adopt the technology, as well as, the type of RWH technology to be adopted. These include its water holding capacity, the accessibility of the materials required for construction, the amount of area to be covered by water surface, and its durability. On the other hand, a farm household's decision to adopt RWH technology could have a direct influence on its livelihood strategies, which is manifested by the household's crop choice decision. Furthermore, the decision for this technology adoption could increase the farm household's agricultural yield by improving the availability of water during the dry spell periods at times, where rainfall stops earlier than the usual rainy season period.

However, as can be depicted from the figure, household-level factors could affect agricultural productivity indirectly through farm household's decision on the use of inputs and adoption of RWH technology. Moreover, the existing land tenure system in the country may influence agricultural productivity, but indirectly through its effect on the farm household's decision to invest on RWH technology and use of inputs such as fertilizer and improved seed.

2.1.1.1. RESEARCH HYPOTHESES

As can be depicted from the figure, the complexity of the interdependence among the different factors, made it difficult to take a separate examination of each factor under consideration. Hence, the paper emphasizes on the major factors.

Household Human Capital

The influence of household human capital characteristics on the use of agricultural inputs, investment on RWH technology, and crop production is mixed. For instance, educated household heads and larger household size (as larger family size could increase the possibility for some members of the household to engage in other non-farm source of income, like FFW, which may be used to buy seed and fertilizer), are expected to increase use of labor, seed, and fertilizer, which in turn could increase crop yield. On the other hand, older household head will have a positive influence on the amount of labor power and use of manure or compost inputs; however an indirect relationship is expected with amount of seed and use of fertilizer. Regarding sex of household head, female-headed households are expected to have a positive influence on the use of labor power and manure or compost. That is, because of the imperfect labor market, old age and female headed households are less likely to participate in non-farm activities to get additional income to buy inputs like improved seed and fertilizer.

The farm household's decision to adopt RWH technology may be influenced by the household's human capital factors in different ways. For instance, since the adoption of the RWH technologies require large amount of labor, especially during construction and watering, household size is expected to have positive relationship with the farm household's decision to adopt RWH technology, whereas, the age of the household head will have negative relationship. Besides, farmers with some level of education and/or training are more likely to accept new innovations and technology interventions than illiterate and/or farmers without any training. Hence, educational status of the household head is expected to influence the farm household's investment decision positively.

However, the direction of the relationship between the gender of the household head and the decision to adopt RWH technology can not be determined in advance. That is, in light of the labor power required for the adoption, male headed households are the ones who are more likely to adopt the technology than female headed households. But this depends on the net benefit obtained from the technology adoption and income that could be obtained from non-farm employment in the local labor market. For instance, there is a negative relationship between female headed households and household private investment on SWC (Kinfe, 2002). On the other hand, the imperfection in the local labor market, which is biased towards male labor, may make female household heads depend on farm employment. In such cases, female headed households are more likely to affect agricultural production and investment on NRM technology interventions than male headed households (Shiferaw et al., 2004). Hence, the relationship between gender of the household head and the decision for adopting the technology can not be predetermined.

Household Social Capital

The membership of household heads in organizations and/or associations (e.g. farmer's, women's, youth's associations, cooperative societies, e.t.c.), is expected to have a mixed effect on the intensity of agricultural inputs. That is, while household's membership in some of these institutions, like cooperative societies would have a positive impact on the amount of seed and use of fertilizer (as these inputs are distributed by this institution in the region), it may have an adverse effect on the labor power used (since most of the time households are ordered to contribute labor to the institutions, which in turn reduce the availability of person-days for farming activities). On the other hand, contact with extension program could increase the likelihood of use of fertilizer and improved seed, and there by could increase production.

On the other hand, membership in these institutions may have a positive influence on farm household's decision to invest on RWH technology. For instance, rural development programs and/or technology intervention schemes launched by government/NGOs/research institutions/ use these organizations and associations as ways of dissemination to reach the farm household. Besides, a farm household could learn and could be easily convinced by another farm household, who is a member in same organization and/or association and has adopted the technology. For example, evidence has been found on the existence of positive effect of institutions on private investment on SWC through mobilizing labor and investing on private land, and through its contribution of labor by the household to institutions (Kinfe, 2002). Furthermore, the existence of relationship or contact between farm household head and agricultural extension programs will create a favorable environment for the household to easily access new innovations and technology interventions, as well as, expertise supports. Thus, household head contact with agricultural extension program is expected to have a positive impact on its decision to invest on RWH technology.

Household Physical Capital

Household physical capital endowment – land, oxen, and cattle – would have a positive relationship with agricultural inputs, such as the use of fertilizer, manure or compost, and amount of oxen-days, although it may have indirect relationship with the amount of labor power used (since some labor power is devoted for herding the cattle).

Farm household's, who own a farmland, are more secured than households without farm land. Hence, any investment decision on farmland is directly related with ownership of the land. Moreover, the adoption of RWH technology requires large resources, thus farm households, who have better physical assets (e.g. oxen, cattle, and pack animals) are the ones who are more likely to invest on such technology interventions than households who lack or with few physical assets. Hence, a farm household's physical capital endowment is expected to have positive relationship with its investment decision on RWH technology. On the other hand, an empirical study in the region found no evidence on the existence of any significant relationship between clearly undefined land tenure and private investment on SWC, and also the study reveals inverse relationship between the level of household physical asset endowment (livestock except oxen) and investment on SWC.

Household Financial Capital

Household's endowment of financial capital (e.g. household saving and access to credit service), is obviously expected to have a positive relationship with agricultural input intensity (such as labor, oxen, seed, and fertilizer), and a farm household's investment decision on RWH technology. That is, households with savings and/or credit access could hire labor during farming and/or construction of the RWH technology, and have the purchasing power to buy oxen, seed, and fertilizer.

Household Livelihood Strategy (Source of Income)

The farm household's livelihood strategy or source of income includes cereal crop production, perishable and/or perennial crop production, livestock, beekeeping, trading, non-farm employment, daily labor employment, FFW, and aid or assistance. In relation to the relationship with the household livelihood strategy and use of inputs, farm households with farming, such as cereal, and perishable and perennial crop production as a primary livelihood strategy or source of income, are expected to have positive impact on the use of inputs than those households who have livelihood strategies other than farming. While the impact of those households with both farming and non-farm livelihood strategies on input usage can not be determined clearly.

In addition to this, in order to overcome and/or minimize the risk from a total loss or reduction in agricultural yield arising from the erratic nature of the rainfall distribution, most farm households adopt different livelihood strategies or sources of income. Thus, farm households with farming, such as cereal, perishable, and perennial crop production, and livestock production as a primary livelihood strategy or source of income, are more likely to adopt RWH technology than those with non-farm (beekeeping, trading, non-farm and/or daily labor employment, FFW, aid or assistance) as a primary source of income. For instance, Shiferaw et al. (2004) found negative relationship between off-farm income and household investment on NRM and land productivity. However, with respect to households with both primary and secondary source of income, while the household, whose primary and secondary sources are on farming, is expected to invest on RWH technology, a farm household that has both primary and secondary sources, but with one on the farming and the other on non-farming, the influence of household livelihood strategy on the household's decision to invest on RWH technology can not be determined in advance.

Access to market, transportation, and roads

Household access to infrastructure and services would have different influence on the intensity of agricultural inputs. For instance, while access to market and transportation facilities could increase the amount of seed and use of fertilizer inputs, they may have negative impact on labor power input (since they have an impact on the off-farm labor market and wage rate, which in turn increase the opportunity cost of farm labor). Besides, access to market could shift the crop choice decision of a farmer in to high value crops.

Most water management schemes launched in arid and semi-arid areas have the aim of improving the availability of water, and there by improving the level of living of the poor people, by increasing the amount of yield harvested, or by increasing the number of times harvested per year, or by encouraging farmers to shift to cash crops with high market value. But it will be difficult, if not impossible, to attain these objectives unless they are supplemented or integrated with better infrastructure, such as better access to input/output market, transportation and road facilities. Thus, access to market, transportation, and roads is expected to be directly related with a farm household's decision to adopt RWH technology.

Plot Level Factors

With respect to the influence of the characteristics of a plot on the households input usage, households with large size, very steep slope, and infertile plots are expected to intensify use of inputs (labor, oxen, and seed), where as those with plots closer to residence use more manure or compost. On the other hand, plot level factors (e.g. plot size, plot slope, plot distance from residence) may influence a farm household's decision to invest on RWH technology in different ways. For instance, if the RWH technology is constructed on the plot, some portion of the plot will be covered by water, and this decreases the area of the cultivable farmland, and there by the amount of yield that could otherwise be harvested from the total area of the plot. Thus, unless the gain that would be obtained by adopting the RWH technology more than compensates the loss from the decrease in the cultivable plot size, a farm household with small plot size will try to avoid or minimize the risk by deciding not to invest on RWH technology.

Besides, if the distance from the plot to the farm household residence is very long, members of the household may be discouraged, to fully use the available family labor power during watering and to efficiently use the water accumulated. This in turn may decrease the interest of the farm household to invest on RWH technology. Furthermore, the level of slope of a plot may influence the farm household's investment decision in different ways. That is, as we move upward, from plots with flat slope to plots with very steep slope, the level of runoff and erosion increases. On the other hand, the level of soil depth and water or moisture holding capacity of the soil decreases. Hence, to tackle these problems, farm households are compelled to invest on RWH technologies, where the level of influence being expected to be higher on farm households having a plot with very steep slope and decreasing as we move downwards. However, Kinfe (2002) has found that, private investment on SWC can increase when the land a household owns is in the flat slope but with medium and high erosion problems.

Rainwater harvesting (RWH Technology)

The adoption of RWH technology as a supplementary source of water in crop production is expected to increase the amount of labor power used, since households are forced to use more labor during water once they adopt the technology. The use of fertilizer is also expected to increase, as higher return for this input is obtained in plots with better moisture-irrigated farm lands. A farm household's decision to invest on RWH technology is expected to have a positive impact on the amount of agricultural yield harvested and/or the household's level of income and there by welfare of the household. Other explanatory factors remaining constant, soil quality and supplemental irrigation have a significant impact on land productivity (Shiferaw et al. 2004). That is, using RWH technology, a farm household could increase its agricultural yield, by improving the availability of water during the dry spell period at times, where rainfall stops earlier than the usual rainy season period (Rockstrom et al. (2001) as cited in Nigigi (2003)), and/or increasing the moisture of the soil and there by the productivity of the land indirectly by increasing the use of inputs (Pender and Gebremedhin, 2004). This increment in level of yield will in turn lead to higher level of income and well-being of the household.

In addition to this, if a farm household is able to accumulate enough water using one of the RWH technologies during the rainy season, it could grow perishable or perennial crops in the dry season, which have higher market values. Thus, the farm household could harvest twice or more per year, which enables the household to increase its annual income and improve its level of well-being.

In summary, the adoption of RWH technology is expected to improve the level of income and welfare of a farm household either by increasing the amount of yield harvested or the number of harvesting times per year, and/or by influencing the farm household to produce agricultural commodities with high market value.

2.1.2. THEORETICAL LITERATURE REVIEW

At present there is a growing tendency towards adoption of low cost alternative water management technologies, such as rain water harvesting technologies especially in the arid and semi-arid parts of the Sub-Saharan African countries. According to Ngigi (2003), and Boers and Ben-Asher (1982), rainwater harvesting is defined as a system or technique of collecting, storing and conserving rain/runoff water for some productive purpose, like for agricultural production, livestock rearing, household domestic consumption, e.t.c., in arid and semi-arid areas. In addition to stabilizing the variability of rain water distribution, since these areas are characterized by high but irregular rainfall, the rainwater harvesting technologies have the ability of reducing floods and soil erosion, increasing the fertility of the land, etc, and there by improve the level of living of subsistent farmers, adopting this technology intervention.

However, the sustainability and attainment of the long-term benefit of the RWH technology intervention depend on the farmer's commitment, perception and valuation of the benefits from such intervention. Moreover, this government or NGOs subsidized intervention may pose problems related with budget and incentive on the farmers and communities participating on the water management technology intervention after the subsidy ceases. Thus, it needs an examination of the incentive systems for private investment on rainwater harvesting technologies.

The rationale for farmers to make private investment in water management technology mainly depends on expected positive net private benefits that accrue from the investment. The benefit could be either in terms of increase in productivity or risk minimization and thereby stabilize the farm household's income. However, Pender and Kerr (1998) and Holden et al. (2001) as cited by Shiferaw et al. (2004) observe that in the developing countries economy, which is dominated by subsistent farmers with fragmented land, the farm household decision to invest in natural resource management is highly affected by the functioning of markets, particularly factor markets.

In economics, where the market for inputs (e.g. the market for labor, credit) and resources (e.g. the market for land, water, etc) are perfectly competitive, a farm household is assumed to make its production and consumption decisions separately (Tassew, 2000; Holden, 2003). The implication of the assumptions of perfect market and separability of production and consumption decisions is that the concern for the sustainable use of natural resource either as input in the production process or for final consumption can be handled by the market. Holden, (2003: p.60), points out that:

> *"In this case, poverty does not matter for investment decisions since well-functioning markets ensure optimal use of resources"*

On the other hand, in most of the developing countries the input and output markets may not be perfect and sometimes the markets for some factors of production may be missing, such as the market for natural resources. Different writers have cited various reasons for the existence of imperfect and/or missing input and output markets in these economies. The presence of transaction costs and rationing in the labor market may hinder the well functioning of the agricultural labor market (Tassew, 2000). Public ownership or common property of natural resources, such as land, forest, water etc., have the effect of underestimating or overestimating the real value of these resources and may result in missing market (Gebremedhin, 2002; Holden, 2003). Government subsides on fertilizers and pesticide may distort the agricultural input market. Besides, due to discriminatory financial market, which may be revealed in rationing and /or high interest rate, the credit market may not function well (Singh et al., 1986 as cited in Tassew, 2000).

In economies where the market is imperfect or missing, especially when factor markets are imperfect and/or missing, a farm household's production and investment decisions will not be separable from its consumption and labor demand decisions (Sadoulet and de

Janvry, 1995). The implication of the non-separability of the farm household's decision is that if factor markets are imperfect or missing, the decision-making household's optimal factor allocation price will be endogenous. According to Shiferaw et al. 2004: p.7)

> *"In this case, the nonseparability of production and investment decisions from consumption choices will imply that the endo*wment of labor, land, water for *irrigation and other fixed farm and household characteristics will determi*ne the *level of production and sustainability-enhancing investments."*

Similar to the economy of most developing countries the agricultural sector of Ethiopia contributes 56% of the GDP and employees more than 85% of the labor force in the country. On the other hand, the agricultural sector is dominated and characterized by subsistence poor farmers with fragmented plot farming under fragile natural resource base.

As it is discussed earlier, the rural economy of Ethiopia by and large and the study area, Tigray, in particular, is dominated by small land holder subsistent farmers, where agricultural productivity is very low, the basic agricultural input, that is, land is publicly owned. Besides, in comparison with other regions in the country, the natural resource base of the region is excessively degraded. Moreover, due to the high variability in the distribution of rainfall in the region, farmers have become susceptible to recurrent drought, which is occurring almost every three to four years in the region. Hence, most of the agricultural output produced by the farmers is used for self-consumption of the household (Tassew, 2000). As a result the input and output markets in the study area are far from perfect. Under such market conditions, the production decision of a farm household will definitely affect its consumption decision or vice versa. In other words, this means the production and consumption decision of the farm household are not separable.

2.1.2.1. THEORETICAL FRAMEWORK

Having the above discussion on the conceptual and theoretical literature review in mind, and the situation of the dominant decision-making unit in the study area under consideration, the theoretical underpinning of a farm household in the study area is given as a farm household decision-making unit under imperfect market conditions, or as non separable farm household model. In this section a non separable farm household model that can serve as a base for the empirical analysis will be developed. Thus, following Tassew (2000), Kinfe (2002), and Shiferaw et al. (2004) and rearranging to fit the situation and purpose of the study at hand a farm household model is used.

Assume that the farm household maximizes a utility function (***U***) derived from consumption of own agricultural output (C_q), consumption of purchased goods (C_m), leisure time (l_e), and fixed household characteristics (***H***) subject to the constraints imposed by its net income (***Y***), the production technology (***Q***), household time (***T***), land area (***A***).

Further, it is also assumed that the farm household's utility function is a quasi-concave, continuous and non-decreasing on the consumption goods and leisure time and is given by,

$$U = U\,(C_q, C_m, l_e; H) \;\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\; (1)$$

The farm household can allocate its total endowment time (***T***) into labor time allocated for on-farm activity (L_f), labor time supplied to off-farm activities (L_o), labor time allocated for constructing the RWH technology (L_{RWH}), and leisure (l_e). Besides, the farm household can hire labor (L_h) from the local market, either on the local market wage rate or on crop (output) sharing basis. Here, off-farm labor (L_o) includes family labor supplied to the local market on local market wage rate and on output sharing basis, and family labor supplied to food-for-work activities, which is commonly practiced in the region. Hence, the farm household's labor time equilibrium can be depicted by the following equation.

$$T + L_h = l_e + L_f + L_o + L_{RWH} \;\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\; (2)$$

The farm household's production technology is depicted by a closed, bounded, and convex production possibility set (***Q***) as follows:

$$Q\ (q_j,\ L_f,\ X_{ij},\ A_j,\ L_{RWH},\ RWH_T,\ X_h,\ X_p,\ X_v) \geq o \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \ (3)$$

where q_j represents the j^{th} agricultural output, L_f refers to the family labor used in the production of the j^{th} agricultural output, X_{ij} refers to the i^{th} farm input (such as manure, seeds, fertilizers and pesticides) used to produce the j^{th} output, A_j refers to the land allocated for producing the j^{th} agricultural output, L_{RWH} represents the labor time allocated for construction and maintenance of the RWH technology, RWH_T refers to the rainwater harvesting technology intervention adopted, X_h represents the farm households asset endowment and household characteristics, X_v represents the village-level factors, and X_p refers to farm plot characteristics.

Moreover, the land tenure system in Ethiopia is organized on public ownership system though there are farm land rent practices in the form of crop or output sharing. But for the purpose of simplicity, the farm household is assumed to be endowed a given and fixed land. Hence, the farm household's total fixed farm land area is equated with the sum of farm land areas (A_j's) allocated for each agricultural output j.
Where j = 1, 2, 3 ………J.

$$\Sigma^J_{j=1} A_j = A \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \ (4)$$

The farm household's income or cash constraint can be expressed by the following equation:

$$\Sigma^J_{j=1} p_j q(L_f,\ L_h,\ X_{ij},\ A_j,\ L_{RWH},\ RWH_T,\ X_p,\ X_v,\ X_h) W_o L_o - \Sigma_z \in_{(q,m)} P_z C_z - \Sigma^J_i P_i X_{ij} - W_h L_h \geq o \ \ldots..(5)$$

where P_j is the price of the j^{th} agricultural output, q and C_q are the proportions of the j^{th} agricultural output sold and used for own consumption, P_m is the price of consumption good purchased, C_m is the quantity of consumption goods purchased, P_i refers to the vector price of farm input $X_{I's}$ used to produce the j^{th} agricultural output, W_o is the market wage rate for the farm household labor supply for off-farm work L_o, and W_h refers to a wage rate of hired labor L_h.

Finally, the non-negativity constraints include:

$$C_q \geq 0; C_m \geq 0; q_j \geq 0; A_j \geq 0; L \geq 0; L_f \geq 0; l_e \geq 0; L_{RWH} \geq 0; L_h \geq 0; L_o \geq 0;$$
$$\text{and } RWH_T \geq 0 \ldots\ldots\ldots\ldots\ldots\ldots (6)$$

Thus, given the objective function and the constraints, the aim of the farm household is to determine the optimal points; for the level of consumption goods from its own agricultural output, the level of consumption goods purchased, for the labor hours to be allocated for farm activity, for the labor hours to be allocated for off-farm, for the labor hours to be allocated for construction and maintenance of RWH technology, and leisure, for the level of quantity of inputs and outputs, and for the level of sale of its agricultural output, which enables to maximize its utility function given by equation (1) subject to the constraints imposed by equations 2-6.

The Lagrangean form of the farm household's maximization problem can be depicted as follows:

$$L = U(C_q, C_m, l_e, H) + \square[\Sigma^J_{j=1} p_j q(L_f, L_h, X_{ij}, A_j, L_{RWH}, RWH_T, X_p, X_v, X_h) W_o L_o - \Sigma_z \in {}_{(q,m)} P_z C_z - \Sigma^I_i P_i X_{ij} - W_h L_h] \delta[\tilde{\square} \Sigma^J_{j=1} A_j] + \Phi[T + L_h - l_e - L_f - L_o - L_{RWH}] \text{-----------} \; (7)$$

where λ represents the Lagrangean multiplier for the marginal value of the farm household's cash, δ is the Lagrangean multiplier, which represents the shadow value of one unit of land used by the farm household, and Φ is the Lagrangean multiplier for the marginal value of the farm household's time. From the above Lagrangean function (7) the first – order, necessary, conditions for maximizing the farm household's utility function can be derived.

According to Chiang (1984) as cited in Tassew (2000), the first-order conditions derived from the Lagrangean function will also satisfy the second-order (sufficient) condition for the maximization problem as long as the assumptions made above on the utility and production technology functions hold.

By adding the first-order conditions for the multipliers, such as, λ,Φ, and δ,the optimal points, which maximize the farm household's utility function could be determined. In economies where the market is functioning perfectly the farm household model will be separable. Hence, econometric estimation of the farm household model can easily be made by decomposing the farm household model in to production and consumption systems, and using the standard producer and consumer approaches the two systems can be estimated independently (Sadoulet and de Janvry, 1995).

However, in economies where the input and/or output market are imperfect or missing the farm household production and consumption decisions will not be separable. Under such situation the optimal values, which maximize the farm household's utility function, should be obtained through econometric estimation of the reduced form equations, which are obtained by solving the first-order conditions, simultaneously. But these optimal values, which maximize the farm household's utility function, may not be analytically tractable due to endogniety problem of some of the prices. Thus, there will be two alternative estimation approaches. These are, either to use the reduced form equations by substituting predicted endogenous prices in place of the endogenous or implicit prices, or to use the reduced form systems of equations and include any other relevant variables, except for the prices, and solve these systems of equations simultaneously (Sadoulet and de Janvry, 1995; Tasew, 2000).

Therefore, since there is no predetermined model, here different models will be adopted depending on the nature of the dependent variables analyzed. While the utility maximization and first-order conditions are used to derive testable implications and to select variables for the equations to be estimated and interpreted.

2.2. REVIEW OF EMPIRICAL LITERATURE

Following, some of the empirical studies related to the study at hand either in the issues or methodologies used will be discussed. That is some of them focus on impact of water, soil, and other natural resource management interventions on agricultural productivity, and on the income and welfare of a farm household. While others could focus on identifying the determinant factors in a farm household decision to invest on NRM and technology interventions. Hence, here the studies will be reviewed starting from those which have employed an integrated econometric and qualitative analysis approach in impact assessment of NRM intervention.

Kerr and Chung (2005) have employed an integration of econometric and qualitative approaches to evaluate the performance of watershed projects in India, classified in to five categories[1] based on project implementing bodies. Specifically, the study tries to identify the successful projects, the approaches adopted which lead to the success, and additional characteristics of particular villages contributed to achieving improved natural resource management, higher agricultural productivity, and reduced poverty. The quantitative analysis was designed in a 'with and without' intervention method. Mainly it employs instrumental variables econometric approach supplemented by qualitative discussions aimed at understanding interest group's (such as women, shepherds, landless people, and farmers with and without irrigation) perceptions of project activities and impacts.

The results of the study show that in both of the states, participatory projects performed better as compared to technocratic, and best results can be achieved if participation is combined with sound technical inputs. Finally, evidence is 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

[1] These categories include ministry of Agriculture, Ministry of Rural development, NGOs, NGO- government collaboration, and a control group of non- project villages during the time of data collection.

of benefits towards largest land holders in projects, which are more successful in both conservation and productivity (Ibid.).

Shiferaw et al (2004) have also adopted econometric approach to examine the socio-economic and biophysical factors influencing farmers SWC investment decisions and the productivity benefits from watershed management interventions in the semi-arid tropics of India. Household and plot-level data was collected from 60 households in each group (within and outside the catchments). A system of structural equations related to land productivity, input use, resource investments, and land values were constructed in the analysis.

The result from the regression analysis indicated that, keeping other explanatory variables constant, soil quality, and access to supplemental irrigation have a significant effect on the productivity of land. The study also depicts the existence of negative relationship between off-farm income and resource investments and land productivity. Besides, the empirical result depicts that, the watershed management program has a greater impact on dry land crop in comparison with other crops. Finally, the study indicates that labor market imperfections, especially for female labor, are most likely to affect production and conservation investments than male labor (Ibid.).

Senkondo et al (2004), have made an impact assessment of RWH on agricultural production in semi-arid areas of Tanzania, with an objective of evaluating the profitability of the technology intervention, particularly on three crops (maize, rice, and onion) that are grown in the semi-arid parts of the country. The study has used primary data gathered from a total of 124 household's,[2] which are selected from three villages. In this study different project valuation methods has been employed. This includes Gross Margins (land and labor productivity), Net Present Value (NPV), Internal Rate of Return (IRR), and Benefit Cost Ratio (BCR)[3]. In addition to this, to test the viability of the

[2] Of the total sample size, 60 of them are maize producing households, where 30 of them are with RWH and the rest 30 households are without RWH. Besides, while all the other 64 households are with RWH, but with 30 households from rice producers and 34 from onion producing farm households.

[3] For the latter three measures discounting rates of 10% and 20%, with a time horizon of 10 years was adopted.

results obtained from the aforementioned measurements, the study has employed a Sensitivity Analysis.

The result from the study depicts that GM and returns to labor for all the crops under consideration are positive, though there was some variation in return of labor, that is, in comparison with the opportunity cost of labor, return to labor for maize and onion production is significantly higher than that of rice production. Besides, within the maize production, with RWH maize production category had higher returns to labor as compared with those without RWH category. With respect to the results of the investment analysis, the study indicated that maize production with RWH had positive NPV, B:C of greater than one and an IRR of 57%. Besides, in the with RWH paddy rice and onion production, the study indicated a positive NPV, B: C ratio greater than one for both crops, and an IRR of 31% and 38% for paddy rice and onion productions respectively.

Finally, the result of the Sensitivity Analysis, assuming a 20% change on the prices of inputs and outputs, indicated that while the project remains viable with respect to maize and onion production, paddy rice production was found to be highly sensitive to changes in both input and output prices, even at one and two percent change in price of inputs and outputs respectively.

Kinfe (2002) has adopted a structural model to examine the role of local institutions, and how they affect the farm household's private labor investment decision on SWC in the highlands of Tigray, Ethiopia, using household data collected from two Tabias, one with better market access and the other from a remote area. In the study, three structural models were constructed, which enable to examine the determinant factors of private investment on SWC and particularly institutions, the factors which influence the decision of institutions for supplying labor to the private owned land, and the factors that are determinants of the contribution to institutions/community.

The result of the regression analysis for the first model depicts the existence of negative relationship between private investment in SWC, and female-headed households and the level of household animal holding (excluding oxen). Besides, the study shows that private investment on SWC can increase when the land a household owns is in the flat slope but medium and high erosion problems. In addition to this, with regards to the relationship between being a member of institution and private investment on SWC, the estimated results indicate three different possible effects. That is, the existence of positive effect of institutions on private investment on SWC through mobilizing labor and investing on private land and through its contribution of labor by the household to institutions, while the third is a negative relationship but it is not significantly different from zero. With regards to relationship between clearly undefined land tenure rights and private investment on SWC, the study has found no evidence on the existence of any significant relationship (Kinfe, 2002).

Empirical results of the regression analysis from the second structural model depict negative relationship between households having a land with flat slope but high erosion problem and community investment, while positive relationship is observed between private investment and community investment in soil conservation. In addition to this, the empirical results from the third model depict that factors such as number of household members enrolled in institutions, food-for-work, number of female household members, and location of the Tabia are positively related with the contribution of the household to institutions. Moreover, the study shows that farm land with medium slope and erosion problem has a negative effect on the household's labor contribution. Finally, the study has found that the contribution of labor to the institutions is positive for the more remote Tabia (Ibid.).

Pender (2005) have employed a structural econometric approach to investigate the determinants of land management practices and their impact on agricultural production and land degradation in Uganda, using a village household and plot level data collected from 451 households. Hence, a system of seven equations were specified for the value of crop production, erosion, pre-harvest labor use, land management practices, proportion of plot area planted to different crops, the livelihood strategy pursued by the household, and participation of the household in various organizations or technical assistance programs.

The result of the study shows 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 (Pender, 2005). In addition to this, while the results of the study support the Boserups 'population induced agricultural intensification' hypothesis, no evidence was found which supports the 'more people-less erosion' hypothesis, (Ibid.).

T. Yuan et al. (2003) have made a study to evaluate the economic feasibility of agriculture with rainwater harvesting and supplemental irrigation in the semi arid regions of Gansu Province, China. In addition to this, dynamic economic indices such as financial net present value (NPV) and financial internal rate of return (IRR) have been used to compare each scheme of rainwater harvesting and supplemental irrigation.

The results of the study depict that better result can be attained if every open-air hardened surface is used to collect rainwater and rainwater catchments are established by utilizing unoccupied land. The result also reveals the direct relationship between adoption of water saving and prevent seepage techniques, and the benefits that accrue from harvested rainwater. Besides, the study shows the necessity of selecting crops with water requirement process that coincides with local rainfall events to maximize the return from investment. Finally, the result of the economic indices depicts that, of the different crops considered the economic indices for potato was found to be superior to spring wheat, corn and Wheat/corn intercropping, hence, potato production using rainwater harvesting and supplemental irrigation is found to be the best alternative for cropping systems in the area.

Shi and Kevin (2004) have adopted a static bio economic household model to examine the impact of a new policy measure, to convert slope-cultivated land into forest and pasture that has been introduced in Gezhenyan village in the Loess plateau of China since 2000 on household activities, land use choice, and land degradation. The simulation results of the study depict that although the new policy measures are effective in combating soil erosion, the sustainability of the results achieved is assured only if government subsidy given to farmers to encourage them to continue conservation is higher than the profit that could be obtained from slope fields before the conservation program. Besides, the study has indicated two alternative incentive policies to encourage farmers continue the conservation program even after the government subsidy is ceased. These includes policies which encourage and assist farmers to develop sedentary livestock by using crops produced from fields as well as fodder and forage grass from the converted slope fields, and/or policy measures that increase off-farm job opportunities or encouraging rural urbanization (Shi and Kevin, 2004).

Holden et al (2004) have applied a bio economic model to assess the potential of food-for-work programs to contribute to poverty reduction and natural resource conservation in the long run, in northern Ethiopia, particularly Tigray, using household level data. Specifically, the study had tried to explore how the out comes of food-for-work programs depend on the design of the program, market, and technology characteristics. Besides, it tries to indicate how such programs may crowed out or crowed in private investments and reveal factors that may pull in different directions.

Two bio economic models were employed in the study. The first one a simple static model of a farm household, is developed to examine the effects of FFW participation on household labor allocation to farming activities in an environment of missing markets for labor and land. The second one which is the dynamic, non separable household bio-economic model was developed to explore the dynamics of household welfare, land use patterns, and investment in soil conservation. Specially, the latter model is developed to assess the impact of FFW under three distinct scenarios such as when FFW employment is directed outside agriculture, when FFW employment is provided for conservation investment within agriculture, where in both cases it is assumed that access to off-farm employment is constrained and that conservation investment does not reduce initial yields. Finally, the third scenario is like the second scenario, but with no constraint to off-farm employment and with conservation investment reducing initial yields (Holden et al., 2004).

The results of the study indicate that although FFW programs have the potential to contribute for long-run development in an environment with imperfect or missing markets, poor design and implementation may easily reverse the results. In addition to this, the simulation results from the dynamic model depict that FFW programs targeted outside agriculture may reduce incentives for agricultural production and land conservation and therefore have negative crowding out effects. However, the study reveals that if FFW program is targeted at investment in land conservation, it may improve agricultural production in the long-run and lead to more sustainable production. Besides, it shows that conservation effect of FFW may be higher when the private incentives for conservation are lower (Ibid.).

CHAPTER THREE: METHODOLOGY AND SOURCE OF DATA

3.1. ANALYSIS APPROACH

At present many developing countries and NGOs are investing huge amount of capital in several technology interventions to increase agricultural productivity and/or diversify the source of income of farmers and there by reduce the level of poverty and natural resource degradation, especially in the arid and semi-arid regions. The livelihood of the majority of farmers in the developing countries depends on rain fed agriculture, but the sector has become a risky activity due to the erratic nature of the distribution of rainfall, especially in the arid and semi-arid parts of the Sub-Saharan African countries.

Although some empirical studies like FAO (1993) suggest that irrigation has shown some positive impacts in increasing agricultural productivity and there by increase the income of farm households, which participate in the irrigation schemes, in the context of farm households living in the Sub-Saharan African countries, irrigation has proved costly and can only benefit farm households with large plots. Besides, there are concerns related with the environmental and health wise side effects of the irrigation schemes.

The wider range influence and complexity in the transmission mechanism of technology interventions aimed at improving agricultural productivity on the welfare of the society and the ecological sustainability poses methodological difficulties on impact assessment researches. According to Freeman et. al (2005: p.3), the basic methodological problems are related to

> *"Interrelationships among natural resources, spatial and temporal dimension of impact, and valuation of environmental benefits and costs."*

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 be broadly classified in to three approaches. These are the economic surplus approach, Swinton (2005); the bio-economic approach, Holden (2003, and 2005), and Holden et. al. (2004), and Shi and Kevin (2004); and the econometric approach, Shiferaw et al. (2004), Gebremedhin et al. (2000 and 2002), Pender and Gebremedhin (2004), Kinfe (2002), and Pender et al. (2005). Moreover, to mitigate the limitations in the econometric approach, Kerr and Chung (2005) has adopted an integrated econometric and qualitative approach. Furthermore, since the last two decades, realizing the interrelationship among participatory natural resource management interventions, poverty reduction, and the livelihood of the target poor households, a sustainable rural livelihood approach is being advocated for assessing the impact of such type of interventions. Based on this classification, this section reviews and validates the different methodological approaches so as to select the one that suits the study at hand.

The economic surplus approach is based on the basic microeconomic principles of demand and supply. In this approach, the economic impact or economic surplus of an intervention is obtained by computing the total sum of consumer and producer net gains from technology induced shift in the supply curve (Shiferaw et. al 2005). However, unlike other technological intervention impact assessments, several factors hinder the application of the economic surplus approach in assessing the impact of interventions which involve natural resource management policy or technological change. Some of the reasons are related with problems in identifying the attribute for the impact, problem in measuring the value of an impact, and valuation problem of public goods and/or bads accruing from the change, (Swinton, in Shiferaw et. al 2005).

Realizing the aforementioned pitfalls in applying the economic surplus approach in natural resource management impact assessment, Swinton (2005) has made an attempt to integrate sustainability indicators into the economic surplus approach by estimating consumer willingness to pay for this benefits and then translating this estimated consumer WTP units into produced natural resource management impact units. Moreover, the study suggested an alternative method, that is, to use scoring or indexing method for a multiple criteria approach although this alternative approach has some pitfalls with regards to the arbitrariness of the weighting criteria used and lack of direct conversion of the score or index units into value units (Ibid).

The other commonly used approach for assessing the impact of natural resource management policy or technology intervention is the bio-economic model. This model is an applied programming model derived by integrating the biophysical processes with the socioeconomic behavioral models (Shiferaw et. al 2005; and Holden, 2003 and 2005; Holden et. al. 2004). The theoretical underpinning of the bio-economic model is a decision-making household, which can be treated as a separable household model or non-separable household model based on the nature of the input and output market of the economy under consideration. Hence, the household is assumed to be a rational decision-making unit with an objective function to be maximized or minimized, and constrained by the socio-economic and biophysical conditions. Besides, based on the time horizon considered for the impact assessment, the bio-economic model can be formulated as a static or dynamic model. The approach can be applied at different levels such as at household level, watershed level, village or community level, and regional level (Holden, 2003 and 2005; and Holden, et. al. 2004)

The third commonly applied method in natural resource management intervention impact assessment, the econometric approach, is developed by linking the measures of current output, cost or profits directly with past investments on interventions. 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 2005).

However, the econometric approach has also some limitations in accurately and fully measuring the changes resulting from NRM interventions, especially qualitative changes. Hence, as a remedy to the shortcomings of the econometric approach at present researchers, for instance Kerr and Chung (2005), are advocating that better results could be obtained using an integrated quantitative and qualitative approach in assessing the impact of NRM interventions.

Generally, each approach has its own advantages and pitfalls, the selection of which would remain on a case-by-case basis. The theoretical and empirical review in the preceding chapter and the subsequent validation made on the alternative methodological approaches underscore an integrated econometric and qualitative analysis approach to be more appropriate for assessing the impact of RWH technology intervention at household and plot level. Hence, on balancing the relative importance of the research objective and the desired level of precision required, and the limited budget and time, an integrated econometric and qualitative approach is used in this study.

3.1.1. MODEL SPECIFICATION

Analyzing the impact of rainwater harvesting technology intervention on the farm household's agricultural output requires examination of the net return gained from the technology intervention. According to Heckman cited in Kinfe (2002), in such cases two alternative approaches can be adopted. The first one is to adopt the treatment effect, that is, to test the impact of an intervention on participants in comparison with no intervention or alternative interventions, while the second is to use before and after approach, that is, to test the impact of intervention on participants in comparison with the situation of the participants before the intervention, using structural estimation.

However, most of the equations in the structural model are functions of both exogenous and endogenous variables. These endogenous variables are in turn a function of exogenous variables, which may also be in the model. As a result, the endogenous variables may create an endogeneity problem, and hence the standard ordinary least squares estimation approach can not be employed as it results in biased and inconsistent estimates.

Table - 3. 1. Description and Measurement of Variables included in the models

Variable Name	*Definition and Measurement*	*Number of observations*	*Mean (Standard error)*	*Minimum*	*Maximum*
Village – level Factors					
Peasant association or Tabia	Dummy variable for Peasant association or Tabia with, % of hhs				
	1= Felegewein_tabia_1	100	25.0% (25)		
	2= Adi Mesanu_tabia_2	100	25.0% (25)		
	3= Barka AdiSubha_tabia_3	100	25.0% (25)		
	4= Hayelom_tabia_4	100	25.0% (25)		
Household access to services and infrastructure	Walking time from the farm household's residence to the nearest, (in hrs.)				
	Market	100	0.977(0.0538)	.08	2.50
	Bus station	100	1.00(0.0643)	.08	3.00
	Cooperative societies shop	100	0.486(0.0308)	.08	1.33
	Seasonal road	100	0.471(0.044)	.08	2.50
	All weather road	100	0.502(0.0497)	.08	2.75
HH – Livelihood Strategy /Source of Income/	Dummy variable for Source of Secondary Income or livelihood strategy of the household with				
	0= No secondary livelihood strategy other than farming	100	79% (79)		
	1=Non-Farm labor employment	100	4.0% (4)		
	2= Trading & Handicraft	100	3.0% (3)		
	3= Cattle & Beekeeping	100	6.0% (6)		
	4= Food-for-work (FFW)	100	8.0% (8)		
HH – level Factors	*HH – Human Capital*				
	Household size, no	100	5.42(0.20)	1	11
	Age of HHH, Yr	100	52.22(1.43)	22	86
	Dummy variable for Female-headed households, 1=Female, % of hhs	100	23.0% (23)		
	Dummy variable for Education level of the farm household head with				
	1= Illiterate	100	47.0% (47)		
	2= Literate	100	25.0% (25)		
	3= Formal education above grade - 1	100	14.0% (14)		
	4=Extension training	100	14.0% (14)		
	HH – Physical Capital endowment				
	Land owned (state allocated & inherited), ha	100	0.4835(0.0271)	0.00	1.25
	Oxen, no	100	0.85(0.0716)	0	3
	Cattle (cows, calves, sheep, & goats), no	100	6.26(0.55)	0	30
	Pack animals (donkeys, mules, horses , & camels), no	100	0.79(0.13)	0	11
	Small ruminants, no	100	3.60(0.31)	0	15

Table - 3. 1. Continued

Variable Name	*Definition and Measurement*	*Number of observations*	*Mean (Standard error)*	*Minimum*	*Maximum*
	HH – Social Capital endowment				
	Dummy variable for household head membership in association &/or organization with % of hhs				
	0=Not a member of any ass & org	100	14.0% (14)		
	1= Farmers association	100	48.0% (48)		
	2= Women's association	100	19.0% (19)		
	3= Youth's association	100	8.0% (8)		
	4= Cooperative societies	100	11.0% (11)		
	Dummy variable for household head contact with extension program with, 1=Yes, % hhs	100	83.0% (83)		
	HH – Financial Capital endowment				
	Dummy variable for HH Credit access with, 1=Yes, % of hhs	100	71.0% (71)		
	Dummy variable for HH Savings with, 1=Yes, % of hhs	100	43.0% (43)		
Plot – level Factors	Dummy variable for How the household acquired the plot with				
	1= Allocated by the state	234	90.6% (212)		
	2= Inherited	234	3.4% (8)		
	3= Crop sharing or Tahlbti-local	234	6.0% (14)		
	Dummy variable for slope of the plot with, *% plots*				
	1= Flat	234	50.4% (118)		
	2= Moderate	234	39.7% (93)		
	3= Very Steep	234	9.8% (23)		
	Dummy variable for Soil depth of the plot with, *% plots*				
	1= Deep	234	14.1% (33)		
	2= Medium	234	59.0% (138)		
	3= Shallow	234	26.9% (63)		
	Dummy variable for Soil fertility level of the plot with, % plots				
	1= High fertility	234	12.0% (28)		
	2= Moderate fertility	234	69.2% (162)		
	3= Infertile	234	18.8% (44)		
	Dummy variable for the purpose for which the land is used with, % plots				
	1= Homestead	234	5.1% (12)		
	2= Rain fed Cultivation (Cropland)	234	94.9% (222)		
	Plot size (Total area of the plot used by the HH in 2004 agricultural Season), in ha. Ln (total area size cultivated)	234	0.2171(0.007)	.06	.50
	Walking time from the farm household's residence to the plot, in hrs.	234	0.2046(0.0234)	.02	3.00

Table - 3. 1. Continued

Variable Name	*Definition and Measurement*	*Number of observations*	*Mean (Standard error)*	*Minimum*	*Maximum*
Rainwater Harvesting Technology	Dummy variable for household adoption of RWH technology in the plot in 2004/05 agricultural production with, % plots (Use of RWH technology, 1=Yes)	234	22.2% (52)		
Use of inputs	Total amount of inputs used per each plot in 2004/05 agricultural production				
Labor, Ln (labor-person days/ha)	Amount of Labor power used, (person-days/ha)	234	74.747(3.28)	14.00	296.00
Oxen Power, Ln (Oxen-days/ha)	Amount of Oxen power used, (animal -days/ha)	234	12.462(0.471)	4.00	48.02
Seed, Ln (kg/ha.)	Amount of Seed used, (Kg/ha)	234	242.027(9.648)	8.00	1072.00
Use of Fertilizer	Dummy variable for household use of fertilizer with, 1=Yes, % plots	234	46.6% (109)		
Use of Manure/Compost	Dummy variable for household use of Manure or Compost with, 1=Yes, % plots	234	73.9% (173)		
Value of Crop Yield	The value of agricultural output produced per plot in 2004/05 agricultural production year, (ETB/ha)	234	2029.321 (119.292)	57.36	13312.00

Thus, since there is no predetermined model that can be used in the quantitative estimation following Pender and Gebremedhin (2004) the models given below (from equation 8 up to equation 12) for the use of inputs on each plot in 2004/05; adoption of RWH ponds in 2004/05 (equation 13), and the value of crop production on each plot in 2004/05 (equation 14 and 15) respectively are adopted in this study.

Similar with most developing countries, the agricultural sector of Ethiopia, and in particular the study area under consideration, is characterized by fragmented and small land holder farmers, and traditional farming technology. Hence, though many inputs could be listed, which are used in crop production, the main inputs used in crop production and which are analyzed in this study include labor, oxen power, seeds, fertilizer, and manure or compost. A farm household's decision in the allocation of its resource endowment either on the variable inputs used for agricultural production or other opportunities, or its decision on the amount used of the various inputs in crop production depends on several factors.

Therefore, the use of inputs – Labor days/ha ($\boldsymbol{LnL}$), Oxen power days/ha ($\boldsymbol{lnX_K}$), Seeds kg/ha ($\boldsymbol{LnS}$), use of Fertilizer ($\boldsymbol{F}$), and use of Manure/Compost ($\boldsymbol{M/C}$), are modeled as a function of explanatory variables including village-level factors ($\boldsymbol{X_V}$), plot-level factors ($\boldsymbol{X_p}$), household-level factors ($\boldsymbol{X_h}$), household income strategy ($\boldsymbol{H_I}$), and adoption of rainwater harvesting technology ($\boldsymbol{RWH_T}$). The village-level factors ($\boldsymbol{X_V}$) are average rainfall, altitude, population density (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), access of the village to market, transportation, and roads (walking time to the nearest woreda (district) town, market, public transport service, all-weather road, and seasonal road). The plot-level factors ($\boldsymbol{X_p}$) include type of land ownership, indicators of quality of the plot (size of plot, quality rank relative to the farm households' other plots, plot slope, soil depth, fertility). The household-level factors ($\boldsymbol{X_h}$) include physical capital (land and livestock owned), social capital (household head membership in various organizations and/or associations, and contact with agricultural extension programs), financial capital (household saving and access to credit), human capital (gender, age and education of household head, and household size). Household income strategy (H_I) includes factors (primary – households with farming as the only source of income and secondary sources – households with income other than farming – including non-farm labor employment, trading and handicraft, cattle and beekeeping, and food – for - work); and adoption of rainwater harvesting technology (RWH_T), (that is whether or not the farm household adopts RWH technology) .

The models for the variable inputs can be written as follows:

$$LnL = f\,(X_V, X_P, X_h, H_I, RWH_T) \ldots\ldots. (8)$$
$$lnX_K = f\,(X_V, X_P, X_h, H_I, RWH_T\,) \ldots\ldots. (9)$$
$$LnS = f\,(X_V, X_P, X_h, H_I, RWH_T) \ldots\ldots. (10)$$
$$F \;= f\,(X_V, X_P, X_h, H_I, RWH_T) \ldots\ldots. (11)$$
$$M/C= f\,(X_V, X_P, X_h, H_I, RWH_T) \ldots\ldots. (12)$$

To identify the determinant factors that influence the farm households' decision to adopt RWH technology or to invest on various types of RWH ponds, a probit model is adopted in this study. Hence, a RWH_T 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 household livelihood strategy (H_I). These can be written as follows:

$$RWH_T = f\,(X_V, X_P, X_h, H_I) \ldots\ldots. (13)$$

In assessing the impact of RWH technology on agricultural output, here 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), household-level factors (X_h), and household income strategy (H_I). Besides, the use of variable inputs Labor (L_f – it includes both family and hired labor), Oxen power (X_K), Seeds (**S**), Fertilizer (**F**), and Manure or Compost (**M/C**), and adoption of RWH technology (RWH_T) are included. However, in the second regression, I omitted household-level characteristics (X_h), type of land ownership, and adoption of RWH technology (RWH_T) variables the effect of these 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 such as Labor (L_f), Oxen power (X_K), Seeds (***S***), Fertilizer (***F***), and Manure or Compost (***M/C***), and plot-level factors (X_p), excluding the explanatory variable type of land ownership. Besides, explanatory variables such as household-level factors (X_h), household income strategy (H_I), and adoption of RWH technology (RWH_T) are excluded from the regression.

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, but it excludes explanatory variables, the use of inputs such as Labor (L_f), Oxen power (X_K), Seeds (***S***), Fertilizer (***F***), and Manure or Compost (***M/C***) from the model. The later specification can avoid the potential for simultaneity bias, and 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, household livelihood strategy, and the adoption of RWH ponds.

Thus, the structural and reduced-form models for the value of crop production harvested from a plot are written respectively as follows:

$$LnY = f(L_f, X_K, F, S, M/C, RWH_T, H_I, X_V, X_P) \ldots\ldots. (14)$$

$$LnY = f(X_v, X_p, X_h, RWH_T) \ldots\ldots. (15)$$

3.1.2. METHODS OF DATA ANALYSIS

Due to the methodological difficulties in assessing the impact of NRM interventions and limitations in data, the study has employed both analysis of descriptive information, econometric analysis, and analysis of qualitative information, though it mainly uses the econometric analysis. In general, three approaches, that is, descriptive, econometric, and analysis of qualitative data has been used.

3.1.2.1. DESCRIPTIVE AND CROP-MIX ANALYSIS

This part mainly focuses on analyzing the descriptive statistics of the whole data. Specifically, the data mainly contains information regarding household's socioeconomic characteristics including family size and label of education, livelihood strategy or source of income, access to infrastructure and social services such as roads, markets, credit and extension institutions, physical capital endowment such as land and livestock; membership in organizations and/or institutions. Besides, household's decision with regard to the use of inputs; labor, seed, oxen, fertilizer, manure or compost, and crop choice are analyzed. Perception of the farm household's both with and without RWH technology on adopting the technology, the implementation process, and problems encountered during and after implementation of the technology, and possible solutions to mitigate these problems were part of the data.

The data also contains the features of the RWH technology adopted in the household's in terms of type, size, construction inputs requirement, the location, source of capital to cover construction cost, and value of yield harvested per plot, using water accumulated in the RWH technology. In line with this, the data includes various features of plot-level factors, mainly with respect to the slope, soil depth, soil fertility, the purpose for which the plot was used, the size, and the distance of the plot from the farm household's residence.

Besides, the RWH technology intervention has been assessed with respect to its influence on the farm household's crop choice decision (crop mix). Here, the study has investigated whether there exists a change in farm household's crop choice after adopting RWH technology.

3.1.2.2. ECONOMETRIC ANALYSIS

For the use of variable inputs such as the use of labor ($\ln L$), oxen-power ($\ln X_K$), and seeds ($\ln S$) least squares regression is used while the regression equations for the variable inputs, fertilizer (***F***) and manure or compost (***M/C***) a probit model is adopted. Besides, in the regression equation for the adoption of rainwater harvesting technologies a probit model is used, where as for the value of crop production equation (***lnY***) least squares regression is used for the full model, structural, and reduced-form regression.

3.1.2.3. QUALITATIVE ANALYSIS

In order to capture any non-quantifiable changes observed which arise from the RWH technology intervention, the study has used analysis of qualitative information. The qualitative analysis is used to augment the results of the econometric analysis.

3.2. DESCRIPTION OF THE STUDY AREA, SAMPLING, AND DATA COLLECTION

The data for the analysis is obtained from a household and plot level survey in *Atsebi Womberta woreda*, which is found in the Eastern Zone of the Tigray Regional State and north east of the regional state's capital Mekelle. Most of the people in the *Woreda* are engaged in agriculture, mainly in cereal production and livestock. The *Woreda* is divided in to 16 PAs or administrative localities, called *Tabias*. Each *Tabia* has its own administration unit, called *Baito*. The altitude of the PAs in the *Woreda* varies from around 2000masl to 2800masl. The 16 *Tabias* in the *Woreda* are classified into two categories based on the farming system practiced in the area. Hence, 9 *Tabias*, which are above 2600 masl, are in the Pulse/Livestock farming system, while the other 7 *Tabias*, which are below 2600masl, are in the Apiculture/Livestock farming system. The annual average rainfall of the *Woreda*, for the years between 1994/95 to 2003/04, was 650mm with the lowest being 400mm in 1997/98 and the highest 800mm in the year 2000/01. However, the distribution is limited to the rainy season called *Kiremt*, which has three months, (June, July, and August).

A total of 100 households which are selected using a stratified sampling technique have been surveyed. Based on farming system practiced, the 16 peasant associations in the *woreda* were stratified into two, namely 9 PAs with Pulse/livestock farming system and 7

PAs with apiculture/livestock farming system. From each stratum two PAs are selected randomly and the households within each of the four PAs are further stratified by adoption of RWH technology. Finally, from each of the four selected PAs, a total of 25 households are randomly selected, that is, 13 of the farm household's from with RWH technology stratum and 12 farm household's from the without RWH stratum. Thus, survey is conducted on 100 households in 4 *Tabias (PAs)*. Two tabias are *Felegewein* and *Adi Mesanu*, from the Pulse/Livestock farming system, and the other two t*abias*, *Barka Adisubha* and *Hayelom* are from the Apiculture/Livestock farming system.

The first *Tabia*, *Felegewein*, which is located about 4.5 km from the *Woreda* central town, *Endaselasie*, has a relatively better access to market, transportation, and other services, than the second *Tabia, Adi Mesanu*, in the same farming system, which is located 5 km from the *Woreda* central town. While the former *Tabia* has a total of 2106 households, where 69.2% of them are male-headed and 30.8% of them are female-headed, the latter *Tabia* has 919 total households; of whom, 63.6% are male headed and the rest 36.34% are female headed households.

The other two *Tabias*, which are in the Apiculture/Livestock farming system, are *Barka Adisubha* and *Hayelom*. The former *Tabia* is located about 7 km from the *Woreda* central town, while the latter is 18 km far from the central town. However, in terms of access to market, transportation, and other services the latter is relatively better. The total number of households in *Barka Adisubha* is 1233, where 62% of them are male headed and 38% are female headed. Where as, in *Hayelom*, there are 1505 total number of households of which 67.3% and 32.7% households are male-headed and female-headed respectively.

Of the total households in each of the four *Tabias* under consideration, until the fiscal year 2004/05, 457, 460, 369, and 197 households from *Felegewein*, *Adi Mesanu*, *Barka Adisubha*, and *Hayelom*, respectively have adopted RWH Technology. A semi-structured questionnaire has been employed to interview household heads. Besides, secondary data on population and land size of the PAs under consideration is used from the district or *woreda* administration.

CHAPTER FOUR: SOCIO - ECONOMIC AND BIO – PHYSICAL CHARACTERSTICS

4.1. SOCIO-ECONOMIC ANALYSIS OF SAMPLE HOUSEHOLDS

The descriptive statistics of some of the household-level features are given in Table-4.1. The total sample households include *77.0%* male-headed and *23.0%* female-headed households. Besides, of the total 52 households with RWH technology *77.0%* are male-headed. The average family size for the sample households is *5.42*, which is slightly higher than the average for the region (*4.8*). Although the variation in mean family size among households in the two farming systems is very small, the variation among households "with and without" RWH technology is a little bit higher and it ranges from the lowest *4.92* for households without the technology to the highest 5.*88* in households with RWH technology.

The mean age of household head for the combined sample is *52.22* years, indicating farmers with more experience in farming are in the sample. As can be seen from the table the mean age of household heads shows some variation among the two categories of farming systems. That is, the mean age of household head in the pulse/livestock farming system was found to be around 49.5 years, while in the apiculture/livestock farming system it was about 54.9 years. A large percentage of the household heads were illiterate (*47.0%*), while those who read and write account *25.0%*. Those with formal education above grade one, and extension training accounts *14.0%* each. However, in terms of education wise distribution of household heads no significance variation or distribution pattern was depicted among the two farming systems and the "with and without" RWH technology categories.

Table - 4.1. Household characteristics distribution by farming system and adoption of RWH technology

Variables	*Pulse/Livestock farming system*	*Apiculture/Livestock farming system*	*Total*	*HHs with RWH technology*	*HHs with out RWH technology*	*Total*
HH Characteristics						
Sex						
Male	37† (37.0%) (48.1%)§	40 (40.0%) (51.9%)	77 (77.0%) (100.0%)	40 (77.0%)‡ (51.9%)	37 (74.0%) (48.1%)	77 (77.0%) (100.0%)
Female	13 (13.0%) (56.5%)	10 (10.0%) (43.5%)	23 (23.0%) (100.0%)	12 (23.0%) (52.2%)	11 (22.0%) (47.8%)	23 (23.0%) (100.0%)
Total	50	50	100	52	48	100
Household size	5.04¶ (.26)Π	5.80 (.31)	5.42 (.20)	5.88 (.26)	4.92 (.30)	5.42 (.20)
Household Head Age	49.54 (2.19)	54.90 (1.80)	52.22 (1.43)	52.35 (1.76)	52.08 (2.33)	52.22 (1.43)
HHH Education Status						
Illiterate	21 (21.0%) (44.7%)	26 (26.0%) (55.3%)	47 (47.0%) (100.0%)	19 (19.0%) (40.4%)	28 (28.0%) (59.6%)	47 (47.0%) (100.0%)
literacy (meserete timhirt)	14 (14.0%) (56.0%)	11 (11.0%) (44.0%)	25 (25.0%) (100.0%)	15 (15.0%) (60.0%)	10 (10.0%) (40.0%)	25 (25.0%) (100.0%)
Formal Education above grade one level	6 (6.0%) (42.9%)	8 (8.0%) (57.1%)	14 (14.0%) (100.0%)	8 (8.0%) (57.1%)	6 (6.0%) (42.9%)	14 (14.0%) (100.0%)
Extension training (SWC & animal health)	9 (9.0%) (64.3%)	5 (5.0%) (35.7%)	14 (14.0%) (100.0%)	10 (10.0%) (71.4%)	4 (4.0%) (28.6%)	14 (14.0%) (100.0%)
Total	50	50	100	52	48	100

Source: Own computation (for all tables included in the study).

† – The first row shows number of observations in each category (for all tables from Table – 4.1 up to Table – 4.9).

‡ – The percentage distribution of the variable from the total number of households with and without RWH technology (for all tables from Table – 4.1 up to Table – 4.9)

§ – The percentage distribution of the variable based on the farming systems and adoption of RWH technology and it is added horizontally (for all tables from Table – 4.1 up to Table – 4.9).

¶ – In variables with continuous data the value represents the mean of the observation of the variable under consideration under the different farming systems and adoption of RWH technology (for all tables from Table – 4.1 up to Table – 4.9).

Π – In variables with continuous data the values in brackets represent the standard error of the mean (for all tables from Table – 4.1 up to Table – 4.9).

Of the 100 households surveyed, majority of them (79.0%) have no secondary source of livelihood other than farming, while households with FFW, Cattle & Beekeeping, Non-farm labor employment, and Trading & Handicraft as a secondary source of income accounts *8.0%*, *6.0%*, *4.0%*, and *3.0%* respectively. Moreover, as can be depicted from table-4.2, the above percentages are almost equally distributed among the two farming systems and the "with and without" RWH technology categories. Therefore, besides for causal employment opportunities, pond development would increase the possibility of utilizing labor during non-agricultural periods. Given the scarcity of farmland in the region such development would also imply better utilization of labor during crop production.

Table - 4.2 Household livelihood strategy distribution by farming system and adoption of RWH technology

Variables	*Pulse/Livestock farming system*	*Apiculture/Livestock farming system*	*Total*	*HHs with RWH technology*	*HHs with out RWH technology*	*Total*
HH Livelihood Strategy						
No other secondary source of livelihood strategy	42 (42.0%) (53.2%)	37 (37.0%) (46.8%)	79 (79.0%) (100.0%)	39 (39.0%) (49.4%)	40 (40.0%) (50.6%)	79 (79.0%) (100.0%)
Non - farm labor employment	2 (2.0%) (50.0%)	2 (2.0%) (50.0%)	4 (4.0%) (100.0%)	2 (2.0%) (50.0%)	2 (2.0%) (50.0%)	4 (4.0%) (100.0%)
Trading & Handicraft	2 (2.0%) (66.7%)	1 (1.0%) (33.3%)	3 (3.0%) (100.0%)	1 (1.0%) (33.3%)	2 (2.0%) (66.7%)	3 (3.0%) (100.0%)
Cattle & Beekeeping	1 (1.0%) (16.7%)	5 (5.0%) (83.3%)	6 (6.0%) (100.0%)	4 (4.0%) (66.7%)	2 (2.0%) (33.3%)	6 (6.0%) (100.0%)
Food – For – Work	3 (3.0%) (37.5%)	5 (5.0%) (62.5%)	8 (8.0%) (100.0%)	6 (6.0%) (75.0%)	2 (2.0%) (25.0%)	8 (8.0%) (100.0%)
Total	50	50	100	52	48	100

With respect to household heads involvement in associations and/or organizations, about half (*48.0%*), of the surveyed households are members of farmer's association, followed by one-fifth of the sample households in women's association, and with the lowest being *8.0%*, who are member's of youth association, while *14.0%* of the household head's are not a member of any association and/or organization. In addition to this, in terms of household adoption of RWH technology, of the 48 households with farmer's association member heads, around 58% of them have RWH technology.

The percentage of household heads having contact with extension program was very high, accounting *83.0%* of the sample households. Moreover, household's contact with extension program has witnessed significant positive pattern with adoption of RWH technology. That is, of the total 52 sample households with RWH technology, 96% of them have adopted the technology (Table-4.3, column-5).

Table-4.3 Household social capital endowment and contact with extension program by farming system and adoption of RWH technology

Variables	*Pulse/Livestock farming system*	*Apiculture/Livestock farming system*	*Total*	*HHs with RWH technology*	*HHs with out RWH technology*	*Total*
HH Social Capital Factors						
HHH Membership in Institutions						
Not a member of any association or organization	6 (6.0%) (42.9%)	8 (8.0%) (57.1%)	14 (14.0%) (100.0%)	6 (6.0%) (42.9%)	8 (8.0%) (57.1%)	14 (14.0%) (100.0%)
Farmer's association	21 (21.0%) (43.8%)	27 (27.0%) (56.3%)	48 (48.0%) (100.0%)	28 (28.0%) (58.3%)	20 (20.0%) (41.7%)	48 (48.0%) (100.0%)
Women's association	11 (11.0%) (57.9%)	8 (8.0%) (42.1%)	19 (19.0%) (100.0%)	9 (9.0%) (47.4%)	10 (10.0%) (52.6%)	19 (19.0%) (100.0%)
Youth association	6 (6.0%) (75.0%)	2 (2.0%) (25.0%)	8 (8.0%) (100.0%)	2 (2.0%) (25.0%)	6 (6.0%) (75.0%)	8 (8.0%) (100.0%)
Cooperative societies	6 (6.0%) (54.5%)	5 (5.0%) (45.5%)	11 (11.0%) (100.0%)	7 (7.0%) (63.6%)	4 (4.0%) (36.4%)	11 (11.0%) (100.0%)
Total	50	50	100	52	48	100
HHH Contact with Extension Programs						
Yes	40 (40.0%) (48.2%)	43 (43.0%) (51.8%)	83 (83.0%) (100.0%)	50 (96.2%) (60.2%)	33 (68.7%) (39.8%)	83 (83.0%) (100.0%)
No	10 (10.0%) (58.8%)	7 (7.0%) (41.2%)	17 (17.0%) (100.0%)	2 (3.8%) (11.8%)	15 (31.3%) (88.2%)	17 (17.0%) (100.0%)
Total	50	50	100	52	48	100

Table-4.4 shows the financial capital endowment of the sample households. Hence, nearly three-fourth (*71.0%*) of the surveyed households has access to credit service (column-5 and column-6). In addition to this, of the total (71) households with credit access about 65% have adopted RWH technology, while only 6 households have RWH technology from a total of 29 households without credit access. In other words, of the total households with RWH technology around 88% of them have access to credit, most likely indicating positive association between credit access and adoption of the technology. On the other hand, from the total sample households, less than half of them (43 households) have savings (both in cash and kind). However, as can be seen from table-4.4 (column-5), of the total 52 households with RWH technology only one-third of them have savings.

Table - 4.4 Household financial capital endowment distribution by farming system and adoption of RWH technology

Variables	*Pulse/Livestock farming system*	*Apiculture/Livestock farming system*	*Total*	*HHs with RWH technology*	*HHs without RWH technology*	*Total*
HH Financial Capital Endowment						
HH Credit Access						
Yes	38 (38.0%) (53.5%)	33 (33.0%) (46.5%)	71 (71.0%) (100.0%)	46 (88.4%) (64.8%)	25 (25.0%) (35.2%)	71 (71.0%) (100.0%)
No	12 (12.0%) (41.4%)	17 (17.0%) (58.6%)	29 (29.0%) (100.0%)	6 (11.6%) (20.7%)	23 (23.0%) (79.3%)	29 (29.0%) (100.0%)
HH Savings						
Yes	23 (23.0%) (53.5%)	20 (20.0%) (46.5%)	43 (43.0%) (100.0%)	18 (34.6%) (41.9%)	25 (25.0%) (58.1%)	43 (43.0%) (100.0%)
No	27 (27.0%) (47.4%)	30 (30.0%) (52.6%)	57 (57.0%) (100.0%)	34 (65.4%) (59.6%)	23 (23.0%) (40.4%)	57 (57.0%) (100.0%)
Total	50	50	100	52	48	100

Resource endowment such as, land holding, oxen, cattle, pack animals, and small ruminants, vary both at farming system and in the "with and without" RWH technology category level. As can be seen from Table-4.5, consistent with the rapidly growing rural population, the average population density for all the PAs was *159.13 persons per Square kilometer*, though there was some variation among farming systems. The lowest is found in the apiculture/livestock farming system (137 *persons per Sq. km*), while the highest is in the pulse/Livestock farming system (181 *persons per Sq. km*). Consequently, the average land holding (includes both owned land-allocated by the PAs, and inherited land) in the sample households is very small, 0.4835 ha, and shows some variation between farming system and in the "with and without" RWH technology category. Particularly, higher average land holding (0.5369 ha) is depicted in households with RWH technology, relative to those without the technology (0.4258 ha).

Table - 4.5 Household physical capital endowment distribution by farming system and adoption of RWH technology

Variables	*Pulse/Livestock fs*	*Apiculture/Livestock fs*	*Total*	*HHs with RWH tech*	*HHs with out RWH tech*	*Total*
HH Physical Resource Endowment						
HH ownership of: (in no.)						
Land (allocated by PA & inherited)	.4600 (0.0378)	.5071 (0.0389)	.4835 (0.0127)	.5369 (0.0393)	.4258 (0.0356)	.4835 (0.0127)
Oxen	.72 (0.0905)	.98 (0.11)	.85 (0.0716)	.88 (0.11)	.81 (0.0925)	.85 (0.0716)
Cattle	6.64 (0.84)	5.88 (0.72)	6.26 (0.55)	7.54 (0.86)	4.88 (0.63)	6.26 (0.55)
Pack animals	.86 (0.23)	.72 (0.10)	.79 (0.13)	.96 (0.22)	.60 (0.11)	.79 (0.13)
Small ruminants	3.12 (0.41)	4.08 (0.46)	3.60 (0.31)	3.87 (0.47)	3.31 (0.4)	3.60 (0.31)
Population density	181.20 (11.55)	137.07 (9.97)	159.13 (7.9)	162.3 (11.20)	155.7 (11.25)	159.13 (7.9)

The endowment of oxen, which is the main agricultural resource for farm households in the area, is very low and it varies among farming systems. The average number of oxen per household for the combined sample was *0.85*, with the highest being in the apiculture/livestock farming system (0*.98*) and the lowest in the pulse/livestock farming system (*0.72*). According to an informal discussion with some agricultural extension workers during the household survey the low average oxen holding could be attributed to a practice that farmers do not keep oxen through out the year except for the agricultural season. That is, to minimize the cost of forage farmers in the study area buy oxen at the beginning of the agricultural season and sell them back after harvest. Besides, the relatively higher average oxen holding in the apiculture/livestock farming system, could be due to better grazing land attributed by the relatively low population density of the PAs in the apiculture/livestock farming system as compared to the other PAs in the pulse/livestock farming system.

Where as with respect to farm household's endowment of cattle (other than oxen), the average number of cattle per household for the whole sample was high (*6.26*). Besides, households with and without RWH technology have depicted large variation in terms of the average number of cattle per household owned. That is, the average number of cattle per household in the "with and without" RWH technology category was found to be around 7.5 and 4.9 respectively. In relation to household endowment of pack animals and small ruminants, the average number of pack animals and small ruminants owned by households was around 0.8 and 3.5, respectively.

The location of the farm household residence relative to important infrastructure and services can be depicted from Table-4.6. The average walking time to the nearest cooperative societies shop, seasonal road, and all weather road for a single-trip is almost equal (around *50* minutes), although there is little variation among the two farming systems. However, the combined samples mean of walking time for a single-trip for both the nearest market and public transport services is very high (above one and half hours), and it shows large variation among farming systems (above half an hour). For instance, while the average walking time to these services for households from PAs in the pulse/livestock farming system requires around two hours, it takes only about one hour and twenty minutes for farm households from the apiculture/livestock farming system.

Table - 4.6 Household access to market and other service by farming system and adoption of RWH technology

Variables	*Pulse/Livestock fs*	*Apiculture/Livestock fs*	*Total*	*HHs with RWH tech*	*HHs with out RWH tech*	*Total*
Village Level Factors						
Walking time to the nearest : (in hrs)						
Market	1.1600 (0.072)	.7950 (0.072)	.9775 (0.054)	.9631 (0.079)	.9931 (0.074)	.9775 (0.054)
Public transport service	1.1857 (0.092)	.8167 (0.083)	1.0012 (0.064)	1.0423 (0.096)	.9566 (0.085)	1.0012 (0.064)
Cooperative societies shop	.4883 (0.042)	.4843 (0.045)	.4863 (0.031)	.4304 (0.039)	.5469 (0.046)	.4863 (0.031)
Seasonal road	.4633 (0.06)	.4790 (0.065)	.4712 (0.044)	.3933 (0.052)	.5556 (0.071)	.4712 (0.044)
All weather road	.5503 (0.074)	.4530 (0.066)	.5017 (0.049)	.4237 (0.061)	.5861 (0.079)	.5017 (0.049)

Table-4.7 presents the descriptive statistics of the plot-level factors. The distribution of plots with respect to the type of land ownership, of the total 234 plots, around 90% is state owned (i.e., the plot is allocated by state or PAs), while 6% of the plot is rented (in a form of crop sharing basis) and the rest is inherited plot. In terms of the purpose for which the plots were used, majority of the plots (around 95%) in the sample are plots used for rain fed crop production, while the rest are homestead plots. Moreover, of the 52 plots with RWH technology, only 17% are plots used as homestead. Furthermore, the mean size of each plot used in the agricultural season of the year 2004 for the surveyed total 234 plots is *0.2171* ha., with only minimum variation among farming systems and in the “with and without” RWH technology categories.

On the average, the farm size (size of all plots publicly owned, inherited, and rented, which is used by the farm household during the 2004/05 fiscal year under study) for the sample households is around *0.5104* ha, which is well below the average farm size for the region (*0.97* ha). Moreover, the average farm size shows some variation among farming systems, with *0.48* ha in the pulse/livestock farming system and the highest in the apiculture/livestock farming system (*0.54* ha.), and ranges between households with a minimum farm size of *0.13* ha., and a maximum of *1.25* ha. With respect to average walking time from plots to the farm household’s residence, the average walking time for the total sample is around twenty minutes, with some variation among farming systems (about 10 minutes). But, the variation in average walking time in the "with and without" RWH technology is a little bit larger (around 15 minutes).

Table - 4.7 Plot characteristics distribution by farming system and adoption of RWH technology

Variables	*Pulse/Live stock fs*	*Apiculture/L ivestock fs*	*Total*	*HHs with RWH tech*	*HHs with out RWH tech*	*Total*
Plot Level Factors						
Type of Land Ownership						
Allocated by the state	105 (44.9%) (49.5%)	107 (45.7%) (50.5%)	212 (90.6%) (100.0%)	49 (94.2%) (23.1%)	163 (69.7%) (76.9%)	212 (90.6%) (100.0%)
Inherited	5 (2.1%) (62.5%)	3 (1.3%) (37.5%)	8 (3.4%) (100.0%)	2 (0.04%) (25.0%)	6 (2.6%) (75.0%)	8 (3.4%) (100.0%)
Crop sharing /locally Tahlibti	6 (2.6%) (42.9%)	8 (3.4%) (57.1%)	14 (6.0%) (100.0%)	1 (0.02%) (7.1%)	13 (5.6%) (92.9%)	14 (6.0%) (100.0%)
HH use of the land						
Rainfed Cropland	109 (46.6%) (49.1%)	113 (48.3%) (50.9%)	222 (94.9%) (100.0%)	43 (82.7%) (19.4%)	179 (76.5%) (80.6%)	222 (94.9%) (100.0%)
Homestead	7 (3.0%) (58.3%)	5 (2.1%) (41.7%)	12 (5.1%) (100.0%)	9 (17.3%) (75.0%)	3 (1.3%) (25.0%)	12 (5.1%) (100.0%)
Total	116	118	234	52	182	234
Walking time from plot to residence (in hrs)	.1513 (0.0162)	.2569 (0.0365)	.2046 (0.0203)	.0891 (0.0102)	.2375 (0.0255)	.2046 (0.0203)
Size of each Plots (in hectare)	.2080 (0.0103)	.2260 (0.0097)	.2171 (0.0071)	.2212 (0.0182)	.2159 (0.0075)	.2171 (0.0071)
Total land cultivated by a HH (plots allocated by PAs, inherited, and rented) in 2004 agricultural season.	.4825 (0.0389)	.5383 (0.045)	.5104 (0.0265)	.5441 (0.0378)	.4740 (0.0365)	.5104 (0.0265)

With respect to the level of slope the surveyed households asked to classify their plots in three categories. Hence, of the total 234 plots *50.4%* of them are classified as flat, while *39.7%* and *9.8%* are classified as moderately steep and very steep, respectively. Besides, the 52 plots with RWH technology are distributed in to 53% flat, 37% moderately steep, and around 10% very steep. Where as, in terms of the level of soil depth, the households have leveled the total number of plots in to deep, medium, and shallow representing *14.1%*, *59.0%*, and *26.9%*, respectively of the plots. In addition to this, majority of the RWH technology has been adopted in plots with medium soil depth (around 60%).

Table - 4.8 Plot slope, soil depth, and fertility characteristics distribution by farming system and adoption of RWH technology

Variables	*Pulse/Live stock fs*	*Apiculture/L ivestock fs*	*Total*	*HHs with RWH tech*	*HHs with out RWH tech*	*Total*
Plot Quality Indicators						
Plot Slope Level						
Flat	52 (22.2%) (44.1%)	66 (28.2%) (55.9%)	118 (50.4%) (100.0%)	28 (53.8%) (23.7%)	90 (38.5%) (76.3%)	118 (50.4%) (100.0%)
Moderately steep	52 (22.2%) (55.9%)	41 (17.5%) (44.1%)	93 (39.7%) (100.0%)	19 (36.5%) (20.4%)	74 (31.6%) (79.6%)	93 (39.7%) (100.0%)
Very steep	12 (5.1%) (52.2%)	11 (4.7%) (47.8%)	23 (9.8%) (100.0%)	5 (9.6%) (21.7%)	18 (7.7%) (78.3%)	23 (9.8%) (100.0%)
Plot Soil Depth Level						
Deep	15 (6.4%) (45.5%)	18 (7.7%) (54.5%)	33 (14.1%) (100.0%)	8 (15%) (24.2%)	25 (10.7%) (75.8%)	33 (14.1%) (100.0%)
Medium	66 (28.2%) (47.8%)	72 (30.8%) (52.2%)	138 (59.0%) (100.0%)	30 (58%) (21.7%)	108 (46.2%) (78.3%)	138 (59.0%) (100.0%)
Shallow	35 (15.0%) (55.6%)	28 (12.0%) (44.4%)	63 (26.9%) (100.0%)	14 (27%) (22.2%)	49 (20.9%) (77.8%)	63 (26.9%) (100.0%)
HHH Perceived Plot Fertility Level						
High fertility	9 (3.8%) (32.1%)	19 (8.1%) (67.9%)	28 (12.0%) (100.0%)	8 (15.5%) (28.6%)	20 (8.5%) (71.4%)	28 (12.0%) (100.0%)
Moderate fertility	80 (34.2%) (49.4%)	82 (35.0%) (50.6%)	162 (69.2%) (100.0%)	36 (69%) (22.2%)	126 (53.8%) (77.8%)	162 (69.2%) (100.0%)
Infertile	27 (11.5%) (61.4%)	17 (7.3%) (38.6%)	44 (18.8%) (100.0%)	8 (15.5%) (18.2%)	36 (15.4%) (81.8%)	44 (18.8%) (100.0%)
Total	116	118	234	52	182	234

In relation to plot fertility level, which is based on the farm household's perception, plots are categorized as *69.2%* moderately fertile and *12.0%* as highly fertile, while *18.8%* as infertile. Moreover, most of the RWH technology has been adopted in plots perceived as moderately fertile (around 70%).

Table-4.9 presents the descriptive statistics of farm household input use decision and level of yield harvested from each plot. Hence, the average amount of seed used per hectare for the surveyed households is around *242* Kg/ha with minimum variation among farming systems. However, the variation in the average amount of seed used per hectare among the "with and without" RWH technology is large. That is on average households without RWH technology are 50 Kg/ha higher in use of seeds, than those with RWH technology, possibly indicating the shift in crop choice of households with RWH technology from cereals and pulses to vegetables. The mean oxen power-days used per hectare for the combined sample is around *12* oxen-day/ha with only minimum variation among the farming systems and the "with and without" RWH technology categories. With respect to labor usage (during pluoghing, weeding, watering, and harvesting), the average labor person-days for the total sample households is around *75* person-days/ha, with higher variation among the "with and without" RWH technology categories. For instance, the average labor person-days/ha used in households with RWH technology is by 20 person-days/ha higher relative to households without RWH technology.

Table - 4.9 Household input use and value of crop yield earned during the year 2004, by farming system and adoption of RWH tech.

Variables	*Pulse/Live stock fs*	*Apiculture/Li vestock fs*	*Total*	*HHs with RWH tech*	*HHs with out RWH tech*	*Total*
HH Input Use						
Fertilizer						
Yes	47 (20.1%) (43.1%)	62 (26.5%) (56.9%)	109 (46.6%) (100.0%)	36 (69.2%) (33.0%)	73 (31.2%) (67.0%)	109 (46.6%) (100.0%)
No	69 (29.5%) (55.2%)	56 (23.9%) (44.8%)	125 (53.4%) (100.0%)	16 (30.8%) (12.8%)	109 (46.6%) (87.2%)	125 (53.4%) (100.0%)
Manure or Compost						
Yes	90 (38.5%) (52.0%)	83 (35.5%) (48.0%)	173 (73.9%) (100.0%)	42 (80.8%) (24.3%)	131 (56.0%) (75.7%)	173 (73.9%) (100.0%)
No	26 (11.1%) (42.6%)	35 (15.0%) (57.4%)	61 (26.1%) (100.0%)	10 (19.2%) (16.4%)	51 (21.8%) (83.6%)	61 (26.1%) (100.0%)
Total	116	118	234	52	182	234
Labor (person – days/ha)	75.75 (4.38)	73.76 (4.89)	74.75 (3.28)	91.05 (7.09)	70.09 (3.64)	74.75 (3.28)
Oxen (power – days/ha)	13.06 (.68)	11.87 (.65)	12.46 (.47)	13.51 (1.18)	12.16 (.50)	12.46 (.47)
Seed (kg/ha)	236.69 (13.85)	247.27 (13.48)	242.03 (9.64)	202.92 (16.39)	253.20 (11.37)	242.03 (9.64)
Value of Crop Yield (Birr/ha)	1701.26 (166.75)	2351.82 (165.94)	2029.32 (119.29)	2290.95 (321.45)	1954.57 (122.86)	2029.32 (119.29)

In relation to the use of modern fertilizer households have used fertilizer in around half of the plots (*46.6%*) during 2004 agricultural fiscal year, and of these around 57% are in the apiculture/livestock farming system. Furthermore, from the total 52 plots with RWH technology, fertilizer has been used in about 70% of them. Another important information that can be depicted from Table-4.9, is that around three-fourth (*73.9%*) of the surveyed households have used Manure or Compost. In terms of the value of crop yield harvested in the year 2004 agricultural season, the average estimated value of crop yield per hectare for the surveyed plots is found to be *2029* Ethiopian Birr[4] (ETB)/ha, with large variation

[4] The official exchange rate averaged 8.60 ETB per U.S. dollar in 2004. In computing the value of crop production, average agricultural producer price index of the eastern zone of Tigray region, where the study area is located, is used based on survey by CSA.

among farming systems. The variation among farming systems range up to *650* Birr/ha, with the lowest (around *1701* Birr/ha) being in the Pulses/Livestock farming system and the highest (*2351* Birr/ha) in the Apiculture/Livestock farming system. Moreover, on average the estimated value of crop yield per hectare in plots with RWH technology is 336 Birr/ha higher than those without RWH technology.

4.2. RESULTS OF THE CROP - MIX ANALYSIS

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 to compare the crop mix in a "with" and "without" RWH technology situation. Here, the crop types are classified in to six categories such as cereals, pulses, fruits, vegetables, spices, and others (forage, grass, & trees). As can be seen from Table-4.10, of the total number of times of the crop types sawn by all the sample households (*251*), while *110* observations are in the "without" RWH technology category, *141* observations are under the "with" RWH technology category.

However, in the "without" RWH technology category, of the total *110* observations, only crop types within cereal and pulses category are sawn, where about *90%* of them are cereals, while *10%* of them are pulses. In the cereals crop category barley and wheat represent *48%* and *24%* respectively. Whereas in the case of the pulses category, fenugreek and horse beans represent *5.5%* and *4.5%* respectively.

On the other hand, in the "with" RWH technology situation, crop types from all the crop category including cereals, pulses, fruits, vegetables, spices, and others, are sawn. Of the total *141* observations in the "with" RWH technology category, vegetables, cereals, pulses, spices, fruits, and other crop categories, represent *62%*, *16%, 7.8%, 7.8%, 2.8%*, and *1.4%* respectively. Besides, within the vegetables category, vegetable types such as tomato, lettuce, cabbage, onion, potato, and others, in order of their share, represent *14, 11.3, 9.2, 7.8, 7.1*, and *7.1* percents respectively.

Table-4.10 Crop-Mix: Households crop choice decision after RWH technology adoption.

Crop Type	*Households without RWH technology*			*Households with RWH technology*						
	Crop category			Crop category						
	Cereals	Pulses	Total	Cereals	Pulses	Fruits	Vegetables	Spices	Others	Total
Teff	11 (11.1)		11 (10)	3 (13)						3 (2.1)
Barley	53 (53.5)		53 (48.2)	12 (52.2)						12 (8.5)
Wheat	27 (27.3)		27 (24.5)	5 (21.7)						5 (3.5)
Maize	1 (1)		1 0.9)	2 (8.7)						2 (1.4)
Zengada	1 (1)		1 (0.9)							
Dagussa	1 (1)		1 (0.9)							
Oats	5 (5.1)		5 (4.5)	1 (4.3)						1 (0.7)
Horse beans		5 (45.5)	5 (4.5)		3 (27.3)					3 (2.1)
Chick peas					1 (9.1)					1 (0.7)
Linseed					6 (54.5)					6 (4.3)
Field peas					1 (9.1)					1 (0.7)
Fenugreek		6 (54.5)	6 (5.5)							
Mango						2 (50)				2 (1.4)
Orange						2 (50)				2 (1.4)
Potatoes							10 (11.1)			10 (7.1)
Onions							11 (12.2)			11 (7.8)
Spinach							16 (17.8)			16 (11.3)
Tomato							20 (22.2)			20 (14.2)
Cabbage							10 (11.1)			10 (7.1)
Beetroot							2 (2.2)			2 (1.4)
Carrot							3 (3.3)			3 (2.1)
Lettuce							16 (17.8)			16 (11.3)
Pumpkin							2 (2.2)			2 (1.4)
Green pepper								7 (63.6)		7 (5)
Black pepper								2 (18.2)		2 (1.4)
Ginger								2 (18.2)		2 (1.4)
Gesho									1 (50)	1 (0.7)
Forage									1 (50)	1 (0.7)
Total	99 (90)	11 (10)	110 (100)	23 (16.3)	11 (7.8)	4 (2.8)	90 (63.8)	11 (7.8)	2 (1.4)	141 (100)

CHAPTER FIVE: ECONOMETRIC ANALYSIS

5.1. DETERMINANT FACTORS OF HOUSEHOLDS DECISION TO ADOPT RWH TECHNOLOGY

The estimation results of the probit model for the determinants of household's decision to adopt RWH technology is presented in Table-5.1. As can be observed from the Table, no strong association has been found between household characteristics (family size, and sex and education status of household head) and technology adoption decision. That is, statistically significant negative correlation is depicted only with old age headed households (but it is statistically significant only at 10% level), probably older-headed households discount the future more than young headed households; hence they are less likely to undertake risky investments.

Furthermore, of the household physical resource endowment indicators included in the model, only size of land owned has shown positive correlation with RWH technology adoption decision, though it is statistically significant at 10% level only, possibly indicating farmers with small plot size doubt on the profitability of adopting the RWH technology and hence trying to reduce risk of loss of yield that could otherwise be harvested from the portion of the farm land covered by water surface.

Table-5.1 Determinants of adoption of RWH technology (Probit)

Explanatory Variables	Probit Use of RWH technology		
	Coefficient (dF/dx) ‡	z	P>|z|
Tabia (PA) dummy, cf., Felegewein_tabia_1			
Adi Mesanu_tabia_2	-0.03216	-0.47	0.636
Barka Adisubha_tabia_3	0.04564	0.56	0.573
Hayelom_tabia_4	0.03326	0.4	0.69
Walking time to the nearest, (hrs)			
Market	-0.05418	-0.86	0.391
Public transport service	0.07329	1.32	0.186
Cooperative societies Shop	-0.15979	-1.62	0.106
Seasonal road	-0.08608	-0.63	0.531
All weather road	0.12129	1	0.318
Household livelihood strategy, cf., No secondary livelihood strategy other than farming			
Non-farm labor employment	0.04605	0.35	0.73
Trading & Handicraft	0.17107	0.48	0.633
Cattle & Beekeeping	0.11761	1.03	0.304
Food-for-work	0.05597	0.56	0.573
Ln (household family size)	0.10886	1.59	0.112
Female-headed households	0.23242	1.17	0.244
Ln (age of household head)	-0.18543*	-1.8	0.071
Household head Education status, cf., Illiterate HHH			
Literate	0.00662	0.09	0.928
Formal education above grade-1	-0.06681	-1.24	0.214
Extension training	-0.02858	-0.5	0.619
Household resource endowment			
Land owned, ha.	0.87486*	1.63	0.103
Oxen, no.	-0.00408	-0.08	0.933
Cattle-cows, sheep, goat, calf, no.	0.00574	1.16	0.246
Pack animals-horse, mule, donkey, camel, no.	-0.00987	-0.62	0.538
Small ruminants-chickens, beehives, no.	-0.00179	-0.23	0.816
Household head membership in association &/or organization, cf., Not a member of any ass/org			
Farmers association	0.00911	0.14	0.888
Women's association	-0.09245	-1	0.316
Youth's association,	0.03661	0.22	0.826
Cooperative societies	-0.04737	-0.68	0.497
Household head contact with extension program, 1=yes	0.08697	1.59	0.111
Household credit access, 1=yes	0.09833**	2.17	0.03
Household savings, 1=yes	-0.15171***	-2.61	0.009
How household acquired the plot, cf., Inherited			
Crop sharing or Tahlbti-local	0.11894	0.46	0.645
Allocated by the State	0.03372	0.27	0.784
Plot slope-level, cf., Flat			
Moderate	0.05795	1.08	0.281
Very steep	0.12989	1.11	0.268
Plot soil depth, cf., Deep			
Medium	0.05324	0.68	0.498
Shallow	0.21763*	1.65	0.099
Plot fertility-level, cf. High fertility			
Moderate fertility	0.13047	1.28	0.201
Infertile	0.12686**	2.04	0.042
Use of plot, cf. Homestead			
Crop land	-0.44332***	-2.89	0.004
Ln (total area size cultivated), ha.	-0.17272	-1.48	0.14
Walking time from residence to the plot, hrs.	-0.64019***	-2.79	0.005
_cons			
Number of observation	234		
LR chi2(41)	77.97		
Prob > chi2	0		
Pseudo R2	0.3145		
. estat gof			
Pearson chi2(168)	143.28		
Prob > chi2	0.9169		

*** is significant at 1%; ** is significant at 5%; and * is significant at 10%.
‡ Reported coefficients represent effect of a unit change in explanatory variable on probability of adopting RWH technology. Ln= natural logarithm.

The result of the regression analysis also depicts that, households with credit access are more likely to adopt RWH technology than those without access (and it is statistically significant at 5% level), perhaps witnessing the existence of imperfect capital market. But, households with savings are significantly less likely to adopt RWH technology (and it is statistically significant at 1% level), suggesting that poorer households are targeted for the RWH technology.

Furthermore, among the plot level factors a statistically significant association is only observed between technology adoption decision and plot-level factors - soil depth, fertility level, purpose for which the plot being used, and plot distance from residence. That is, households are more likely to adopt RWH technology in plots with shallow soil depth relative to plots with deep soil depth (but only statistically significant at 10% level). Consistent with the above result, the probability of farm household RWH technology adoption decision seems to increase with decline in plot fertility level as perceived by farmers and it is statistically significant; probably indicating farmers attempt to reduce risk of loss of yield that could otherwise be harvested from the portion of the farm land covered by water surface in plots perceived as highly fertile.

Household decision to adopt RWH technology is more likely a plot being a homestead plots. Consistent with this result, technology adoption decision seems to increase as the distance of the plot from residence decreases. The above two results indicate the farm households effort to fully utilize family labor so as to meet the human resource requirement during construction and utilization of the water, and there by reduce the finance that could otherwise be needed for hiring labor.

5.2. DETERMINANT FACTORS OF AGRICULTURAL INPUT USAGE

Estimates of the determinant factors in a farm household's decision to use as well as its magnitude of agricultural inputs: labor – person days per hectare, oxen – oxen power days per hectare, seed – kg/ha, fertilizer, and manure or compost is presented in Table-5.2.

<u>Use of Seed (Kg/Ha)</u>

The results of the regression analysis depict a mixed relationship between farm household access to infrastructures and services, and the amount of seed used. For instance, closeness to cooperative societies shop and all weather road is significantly associated with use of less amount of seed – kg/ha, while nearness to seasonal road is strongly correlated with higher amount of seed, probably the household heads are less likely to engage in non-farm labor employment and hence, more emphasis be given to crop production. Besides, of the location dummies only Hayelom PA dummy has shown statistically significant correlation with less amount use of seed.

Furthermore, weak correlation has been found between household livelihood strategy and the amount of seed used, as significant correlation is only witnessed between household head participation in food-for-work and higher amount use of seed. Most likely, these households use farming as their primary livelihood strategy as the food-for-work programs are scheduled in months outside of the farming season. In relation to household head sex, a statistically significant positive association is found between female-headed households and higher amount use of seed, possibly female – headed households give more emphasis to crop production, but in order to compensate the labor constraint they may be using higher amount of seed. On the other hand, old age household heads have shown a statistically significant negative association with amount of seed used per hectare.

With respect to education status, households with heads having some form of education – literate (who can read and write), with formal education above grade one level, and with extension program training have shown significant association with less amount use of seed, relative to illiterate-headed households, possibly household heads with some education or training have better access to engage in other non-farm activities. Furthermore, households endowed with physical capital resources have shown varying impacts on the amount of seed used. For instance, households – who own more oxen and small ruminants, have witnessed statistically significant positive association with higher amount use of seed, perhaps these households mainly focus on crop production. But, significant negative relationship is depicted between household cattle ownership and the amount of seed used; probably households with more cattle could be mainly engaged in livestock production and hence, give less emphasis for crop production.

In relation to a household head's membership in various institutions, the study witnessed that relative to households with heads not a member of any institution, households with heads a member in women's association, youth's association, and cooperative societies are negatively correlated with the amount of seed used. However, the intensity in use of seed is significantly higher on households who have contact with extension programs; may be agricultural extension workers have influenced the farmers to apply modern agricultural input such as improved seed. Furthermore, households with credit access have depicted negative correlation with amount of seed (but statistically significant at 10% level only). On the other hand, farm households having savings – in cash or kind, have depicted significant positive association with the amount of seed used, most likely this could be those households with savings are engaged in livestock production, but use this additional income to buy more seed so as to compensate the use of lesser other inputs.

The result also shows a mixed correlation between plot-level factors and intensity in use of seed. For instance, the amount of seed used is significantly greater on plots with flat slope than plots with moderate and very steep slope; perhaps indicating farmers risk aversion behavior and their emphasis on short term benefits. Moreover, lesser amount of seed is used in moderately fertile plots relative to highly fertile plots. However, rented plot (in the form of crop sharing – locally called Tahlbti, commonly practiced in rural parts of the region) is strongly correlated with use of higher amount of seed, relative to inherited plots. A less intuitive result is the relationship between plot size and the amount of seed used. That is, the amount of seed used declines with an increase in the size of plot, though only statistically significant at 10% level.

Use Of Oxen Power (Oxen power– Days/Ha)

The result of the regression also depicts of the household access to infrastructure and service indicators, only nearness to market has significantly correlated with use of lower oxen – days/ha, suggesting the oxen rent market (practiced in crop sharing basis) is more successful in correcting the extent of oxen market imperfection in most rural areas. Besides, location dummies of PAs, Adi Mesanu, Barka Adisubha, and Hayelom PA dummy have shown statistically significant positive association with the amount of oxen used, relative to Felegewein PA. With respect to the correlation between household livelihood strategy and intensity in use of oxen power negative significant relationship has been found. That is households with heads engaged in secondary source of income activities such as cattle and beekeeping and food-for-work are correlated with lower use of oxen, relative to households with no secondary source of income other than farming. While the former could indicate the emphasis given to livestock production, the latter may show the imperfect oxen market.

Moreover, households both with credit access and with savings – in cash or kind have depicted statistically significant negative association with amount of oxen power days/ha used, probably suggesting the existence of factors other than capital affecting the oxen rent market. In relation to the correlation between plot-level factors and intensity in use of oxen power, the amount of oxen power used has shown significantly greater positive association with flat sloped plots in comparison with moderately and very steep plots; similar with the explanation on the use of the amount of seed input the result may be indicating farmers risk aversion behavior due to crop failure. A less intuitive result is the relationship between plot size and use of agricultural inputs, where larger plot size is significantly associated with lower oxen power use.

Table-5.2 Determinant factors of Input Use, during 2004 Agricultural Fiscal Year

Explanatory Variables	Ln (seed/ha)	Ln (Oxen-day/ha)	Ln (Labor-day/ha)	Whether fertilizer were used ‡	Whether manure/compost were used ‡
Tabia (PA) dummy, cf., Felegewein_tabia_1					
Adi Mesanu_tabia_2	-0.04597	0.07706*	0.22056**	-0.0022	-0.04322
Barka Adisubha_tabia_3	0.09734	0.0678*	0.04945	-0.00561	-0.15418
Hayelom_tabia_4	-0.62827***	0.13441***	0.23214**	0.38969**	-0.21651
Walking time to the nearest, (hrs)					
Market	-0.18729	0.07055*	0.0028	0.54411**	-0.00833
Bus station	-0.16842	-0.0407	0.00928	-0.47066**	0.01625
Cooperative societies Shop	0.34851**	-0.01334	0.01263	-0.6407***	0.15287
Seasonal road	-0.78631***	-0.08151	0.09508	-0.11012	-0.20982
All weather road	0.64782***	0.0334	-0.25834	0.33127	0.19089
Household livelihood strategy, cf., No secondary livelihood strategy other than farming					
Non-farm labor employment	-0.14819	-0.07383	-0.06039	-0.3755*	-0.09259
Trading & Handicraft	-0.19366	-0.11724	0.12011	0.31047	-0.0212
Cattle & Beekeeping	0.24247	-0.1623***	0.051	0.1672	0.07189
Food-for-work	0.33205*	-0.09149*	0.02168	0.24935	-0.05094
Ln (household size)	0.07157	0.01093	0.21542**	0.2521*	0.13269
Female-headed households	0.53582**	-0.03592	-0.05565	0.59122*	0.0432
Ln (age of household head)	-0.65447***	0.01535	0.05768	0.59847**	0.06648
Household head Education status, cf., Illiterate HH					
Literate	-0.268*	0.04742	0.07744	-0.29873**	0.06907
Formal education above grade-1	-0.26722**	0.02298	-0.15314*	0.26726*	-0.22506**
Extension training	-0.24349*	0.19345***	0.13993	-0.09035	-0.00223
Household resource endowment					
Land owned, ha.	0.62164	0.28176	0.74305	-0.51827	0.52
Oxen, no.	0.23173**	0.03296	0.0169	-0.0145	0.17446**
Cattle - cow, sheep, goat, calf, no	-0.03598***	0.00065	0.00389	0.01934*	-0.0029
Pack animals - horse, mule, donkey, camel, no.	-0.04739	0.00846	-0.00608	0.02668	-0.0069
Small ruminants-chickens, beehives, no.	0.04362***	-0.00112	0.02552**	-0.01452	-0.02038*
Household head membership in association &/or organization, cf., Not a member of any ass/org					
Farmers association	-0.13748	0.05086	-0.04749	0.04281	0.07937
Women's association	-0.83594***	0.10998	0.14313	-0.34127	0.109
Youth's association,	-0.8771***	0.06244	-0.3357*	0.64017***	-0.12317
Cooperative societies	-0.43623**	-0.02611	-0.3018**	0.0234	-0.24529
Household head contact with extension program, 1=yes	0.27024*	0.01329	-0.05205	0.29033**	0.13212
Household credit access, 1=yes	-0.19396*	-0.04799*	0.08715	0.30107**	0
Household savings, 1=yes	0.49794***	-0.132***	0.06302	-0.3352***	0.06102

Table-5.2 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., Inherited					
Crop sharing or Tahlbti-local/	0.55077*	-0.05658	0.30509	0.03483	-0.90485
Allocated by the State	-0.256	-0.09809	0.07948	0.27745	-0.34424*
Plot slope-level, cf., Flat					
Moderate	-0.21337**	-0.0944***	0.06327	-0.22134*	0.06364
Very steep	-0.48234***	-0.11456**	0.08006	0.07169	0.01246
Plot soil depth, cf., Deep					
Medium	0.07182	0.05807	-0.00126	-0.24863	-0.07552
Shallow	0.14592	0.0367	0.07992	-0.16683	-0.13218
Plot fertility-level, cf., High Fertility					
Moderate fertility	-0.29339*	0.00453	-0.05326	0.15127	-0.05459
Infertile	-0.16108	0.03581	0.04592	0.0345	-0.0713
Use of plot, cf., Homestead					
Crop land	0.23984	0.05891	-0.09577	-0.145	-0.14303
Ln (total area size cultivated), ha.	-0.39578*	-1.0322***	-1.0504***	0.02299	-0.00599
Walking time from residence to the plot, hrs	-0.17423	0.06838*	-0.19098**	0.12769	-0.4214***
Use of RWH technology, 1=Yes	-0.14333	-0.01567	0.15521**	0.28246***	-0.0173
_cons	7.59878***	0.49049	1.43712*		
Number of observation	234	234	234	234	234
F(42,191)	3.49	59.28	9.67		
Prob > F	0	0	0		
R-squared	0.4344	0.9288	0.682		
LRchi2(42)				105.26	71.42
Prob > chi2				0	0.0031
Pseudo R2				0.3256	0.266

*** is significant at 1%; ** is significant at 5%; and * 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= natural logarithm.

Use Of Labor Power (Person – Days/Ha)

The results of the regression analysis also show that, a farm household with large family size has statistically significant association with use of more labor. Probably the strong 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 compelled to engage in crop production at the existing plot. With respect to education status, as expected household heads with formal education above grade one level are associated with less amount of labor relative to illiterate-headed households. Possibly this could be due to bias in the labor market towards educated or skilled labor in comparison to illiterate or unskilled labor. Besides, location dummies of Adi Mesanu and Hayelom PAs have shown statistically significant positive correlation with the amount of labor used, relative to Felegewein PA.

In relation to a household head's membership in various institutions, the study witnessed that, both membership in youth's association and cooperative societies are correlated with less use of labor, relative to households with heads not a member of any institution, perhaps indicating these households are engaged mainly on non-farm activities. In addition to this, households endowed with greater small ruminants have shown statistically significant association with intensity in use of labor, consistent with the explanation on the use of oxen draft power these households may be using the small ruminants as a secondary livelihood strategy.

A less intuitive result is the relationship between plot size and use of agricultural inputs, where the effect of plot size on the amount of labor is negative. On the other hand, plots closer to the residence of the farm household have depicted significant correlation with use of higher labor; probably witnessing the favorable situation for households to use every available family labor in crop production, especially during weeding and harvesting. Finally, as anticipated the estimation of the regression analysis indicated that, adoption of RWH technology has a positive statistically significant association with use of higher labor, most likely due to the higher level of labor requirement during watering plants.

<u>Use Of Fertilizer</u>

Table - 5.2 also depicts the existence of mixed correlation between household access to infrastructure and service indicators and use of fertilizer. For instance, while closeness to market is associated with less likely use of fertilizer, households' proximity to public transport service and cooperative societies shop are correlated with more likely use of fertilizer; most likely because fertilizer is distributed at cooperative societies shop. Moreover, location dummy of Hayelom PA is associated with more likely use of fertilizer, relative to Felegewein PA.

Furthermore, weak correlation has been found between household livelihood strategy and the likely use of fertilizer, as significant correlation is only witnessed between household head involvement in non-farm labor employment and less likely use of fertilizer, probably these households use non-farm labor employment as their primary livelihood strategy and hence crop production is given less focus. In addition to this, household size has depicted a positive association with the probability of use of fertilizer, though it is only significant at 10% level. This is consistent with the earlier explanation on the use of labor input that, the higher use of labor in the household could indicate the level of emphasis given to crop production and any additional income earned by a member of the household could be used to buy modern agricultural inputs such as fertilizer.

Surprisingly, older-headed and female-headed households have shown a statistically significant positive association with the probability of use of fertilizer. Probably the positive association with use of fertilizer could show the emphasis that older-headed and female-headed households have gave to crop production, but to reduce the risk of crop failure they may be using fertilizer more than the optimal level. With respect to education status, as expected household heads with formal education above grade one level are more likely to use fertilizer, while literate-headed (only read and write) households are correlated with less likely use of fertilizer, both relative to illiterate-headed household.

Perhaps this could be due to the higher probability for educated household heads to engage in non-farm activities, but at the same time the household could use the additional income to buy fertilizer.

In relation to a household head's membership in various institutions, the study witnessed that, membership in youth's association has exhibited positive association with probability in use of fertilizer, relative to households with heads not a member of any institution and the relationship is statistically significant. Furthermore, the likely use of fertilizer is significantly higher on households who have contact with extension programs, may be agricultural extension workers have influenced the farmers to apply modern agricultural inputs such as fertilizer and improved seed. As can be seen from the regression results, households endowed with more cattle are correlated with more likely use of fertilizer. As anticipated, households with access to credit are 30% more likely to adopt fertilizer than those without access (and it is statistically significant), probably suggesting the existence of imperfect capital market. On the other hand, farm households having savings – in cash or kind, have depicted statistically significant negative relationship with the probability of use of fertilizer.

In relation to the correlation between plot-level factors and the likely use of fertilizer only plot slope level has shown significant association. That is, plots with moderately steep slope are correlated with less likely use of fertilizer relative to plots with flat slope and it is statistically significant at 10% level, suggesting farmers risk aversion behavior, and their emphasis on short term benefits. Finally, as expected the estimation of the regression analysis indicated that, adoption of RWH technology has a statistically significant association with more likely use of fertilizer. This could probably imply the impact of the RWH technology on crop production is indirectly through its effect on intensity of agricultural inputs.

Use Of Manure or Compost

As can be depicted from Table - 5.2, column-5, no evidence has found on the existence of correlation between the likely use of manure or compost and factors such as, village level factors, location dummies, household characteristics – family size and sex and age of household head, household livelihood strategy, and household head membership in institutions.

With respect to education status, as expected household heads with formal education above grade one level are less likely in use of manure or compost relative to households with illiterate heads. Most likely this could be affected either by educated-headed households' positive correlation with more likely use of fertilizer and there by reducing the likely use of manure or compost, or these households are constrained by the labor required to carry manure or compost to the farm land. In relation to household physical resource endowment, ownership of large number of oxen is correlated with more likely use of manure/compost, while ownership of large number of small ruminants is associated with less likely use of manure/compost.

Finally, in relation to the association between plot-level factors and the likely use of manure or compost, the result witnessed that, publicly owned plots (plots allocated by the State) are strongly correlated with less likely use of manure or compost relative to inherited plots. On the other hand, plots closer to the residence of the farm household have depicted significant correlation with more likely use of manure/compost, suggesting the favorable situation for livestock owned by the household to drop their dung on plot closer to residence without the need to carry.

5.3. DETERMINANT FACTORS OF CROP YIELD

Table - 5.3 presents the full model of the value of crop yield (column-2). Here, variables such as household distance to market and other infrastructures; household level factors; household – social, physical, and financial capital endowment; and household livelihood strategy indicators that were included in the unrestricted OLS regression have been found to be jointly statistically insignificance. While in column – 3 and column – 4 results of the structural and reduced models are shown respectively.

As can be seen from the structural model for the value of crop yield Table - 5.3, only the amount of seed used in the production explain the variation in crop yield to a significant extent. For instance, the amount of seed used has large and statistically positive impact, quantitatively with elasticity 0.21 (at 5% significant level). However, the impact of agricultural inputs such as oxen draft power and labor on value of crop yield is statistically insignificant and quantitatively small. Besides, the result indicates that the impact of use of fertilizer and manure/compost on value of crop yield is negative, suggesting more than optimal use of these inputs which in turn reduce the economic return.

With respect to the impact of plot slope level on value of crop yield; both plots with very steep and moderately steep slopes are significantly associated with 50% and 22%, respectively lower value of crop yield relative to plots with flat slope (and both of them are statistically significant at 5% level), probably depicting the lower use of inputs in these plots (Table-5.2) lowering land productivity. Location dummies for Adi Mesanu and Hayelom PAs have exhibited statistically significant correlation with higher value of yield, relative to Felegewein PA location dummy. On the other hand, no significant correlation has been found between value of crop yield and plot characteristics such as plot soil depth, perceived plot fertility level, the purpose of the plot, plot size, and plot distance from residence, controlling other factors.

In the reduced model of the value of crop yield, depicted in column 3 of Table - 5.3, household access to various services and infrastructures; household characteristics; household – social, physical, and financial capital endowments; household livelihood strategy; plot level factors; and household RWH technology adoption were included in the regression and assessed with respect to their impact on the value of crop yield.

As can be seen from the table, most of the variables used as indicators of household access to market and infrastructures do not seem to explain variation in the value of crop production. A significant but counter intuitive correlation is observed only between households further away from all weather roads and higher value of crop yield. The higher value of crop yield could be households further away from all weather roads focus more on crop production, reflected by the higher amount use of seed (Table-5.2). However, location dummies for Adi Mesanu and Hayelom PAs seem to explain the variation on value of crop yield to a significant extent, relative to Felegewein PA location dummy.

Moreover, of the household characteristics only household head education status has shown statistically significant association with value of crop yield. That is, relative to illiterate-headed households, both literate-headed households and households with educated heads (with formal education above grade one level) are significantly correlated with higher value of crop yield. The result also shows that, both households with non-farm labor employment and food-for-work secondary livelihood strategy are significantly associated with higher value of crop yield, relative to households with no secondary livelihood strategy other than farming. Probably, household heads with some education and experience in non-farm activities have more opportunity to assess markets and hence, they focus more on production of highly priced crops which enables them earn higher value of yield.

Table - 5.3 Determinant factors of value of crop yield, during 2004 Agricultural Fiscal Year

Explanatory Variables	*Ln (Value of Yield/ha)*		
	Full Model	Structural form ¶	Reduced form
Tabia (PA) dummy, cf., Felegewein_tabia_1			
Adi Mesanu_tabia_2	0.36177*	0.35666**	0.41176**
Barka Adisubha_tabia_3	0.07619	0.20944	0.14735
Hayelom_tabia_4	0.71376***	0.74287***	0.65041***
Walking time to the nearest, (hrs)			
Market	-0.27151		-0.28649
Bus station	-0.05796		-0.11498
Cooperative societies Shop	0.05123		0.13725
Seasonal road	0.14559		-0.07374
All weather road	0.56569*		0.70702**
Household livelihood strategy,cf., No secondary livelihood strategy other than farming			
Non-farm labor employment	0.74163**		0.67163**
Trading & Handicraft	0.24432		0.13707
Cattle & Beekeeping	0.01687		-0.0175
Food-for-work	0.5127**		0.54394**
Ln (household size)	0.08694		0.11601
Female-headed households	0.43533		0.52891
Ln (age of household head)	-0.29056		-0.45667
Household head Education status, cf., Illiterate household head			
Literate	0.37299*		0.3429*
Formal education above grade-1	0.36546**		0.29906*
Extension training	0.06373		0.12293
Household resource endowment			
Land owned, ha.	-2.27805*		-1.89192
Oxen, no.	0.2989**		0.36978***
Cattle - cow, sheep, goat, calf, no	0.01919		0.01088
Pack animals - horse, mule, donkey, camel, no.	-0.08389*		-0.09203*
Small ruminants, no.	-0.05733**		-0.04386**
Household head membership in association &/or organization, cf., Not a member of any ass/org			
Farmers association	-0.09837		-0.11374
Women's association	-0.37247		-0.50859
Youth's association,	-0.35042		-0.57411
Cooperative societies	0.11895		-0.0205
Household head contact with extension program, 1=yes	-0.34758*		-0.29026
Household credit access, 1=yes	-0.21737		-0.29103**
Household savings, 1=yes	0.11769		0.17765
How HH acquired the plot, cf., Inherited			
Crop sharing or Tahlbti-local	-1.10153**		-0.96136**
Allocated by the State	0.00735		-0.09176

Table - 5.3 Continued

Explanatory Variables	Ln (Value of Yield/ha)		
	Full Model	Structural form	Reduced form
Plot slope-level, cf., Flat			
Moderate	-0.11847	-0.24693**	-0.21576
Very steep	-0.24911	-0.40835**	-0.07138
Plot soil depth, cf., Deep			
Medium	-0.1803	0.02524	-0.12004
Shallow	-0.17364	-0.16571	-0.09776
Plot fertility-level, cf., High fertility			
Moderate fertility	0.08899	0.06514	0.0135
Infertile	0.0237	0.05699	0.00653
Use of plot, cf., Homestead			
Crop land	0.16169	0.25173	0.25515
Ln (total area size cultivated), ha.	0.54743	-0.00652	-0.22297
Walking time from residence to the plot, hrs.	-0.11378		-0.12141
Ln (seed/plot-ha), Ln (kg/ha.)	0.24587**	0.21599**	
Ln (Oxen-days/plot-ha)	0.55582	0.34529	
Ln (labor-person days/plot-ha)	0.09091	0.01915	
Use of Fertilizer, 1=yes	-0.04146	-0.02892	
Use of Manure/Compost, 1=yes	-0.04915	-0.01447	
Use of RWH technology, 1=Yes	0.13291		0.09404
_cons	6.47321***	4.71708***	8.77154***
Number of observation	234	234	234
F(47, 186)	2.87		
F(16, 217)		3.85	
F(42, 191)			2.88
R-squared	0.423	0.221	0.3878
Adj R-squared	0.2738	0.1635	0.2532

*** 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.

With respect to the impact of household physical capital endowment, greater ownership of oxen has witnessed correlation with higher value of crop yield (and statistically significant at 1% level). On the other hand, ownership of greater number of pack animals and small ruminants are associated with lower value of crop yield, with the parameter estimates being statistically different from zero (at 10% and 5% levels respectively). Moreover, households with credit access are associated with 25% lower value of crop yield than those without access, despite the fact that credit access is associated with more likely use of fertilizer. Surprisingly, no statistically significant correlation was found between household social capital factors and value of crop yield.

Moreover, most of the plot level factors included in the model do not seem to explain variation in the value of crop production that is only type of plot ownership has shown correlation with value of crop yield. In this respect rented plots (an arrangement usually practiced in the region on crop sharing basis, locally called Tahlbti) is correlated with lower value of crop yield (and statistically significant at 5% level) relative to inherited plots, possibly indicating household high future discount rate and become less likely to invest on productivity enhancing activities on rented plot. Finally, controlling for other factors no statistically significant evidence was found on the impact of household adoption of RWH technology on value of crop yield, suggesting the impact on value of crop yield is indirectly through its effect on agricultural inputs usage.

CHAPTER SIX: QUALITATIVE ANALYSIS

6.1. RESULTS OF THE QUALITATIVE ANALYSIS

Farm households using a RWH technology were asked about the specific RWH technology type they adopted, the selection of site, the problems encountered during implementation and utilization, and possible solutions to tackle the problems. Besides, households without RWH technology were also asked about their reasons for not adopting the technology. Out of the 52 households included in our survey around 73% of the households adopted plastic-lined RWH pond, 11.5% of them have used concrete structures made of clay and/or cement, and the rest 15.4% used other RWH technologies such as reservoirs. In relation to selection of a specific type of RWH technology, 41 (almost 80%) households respond that, they have chosen themselves, while 11 households respond that they were selected by extension workers. Moreover, the selection of specific sites for the RWH technology (Table – 6.1), was mainly done by the head of the household (about 62%), while 36% of the households respond it was selected by agricultural extension workers based on technical criteria, and only one household reported that the site was selected by the people who construct the pond.

Table - 6.1 Site selections for the RWH technology

Responsible body for site selection	Frequency	Percent
Household head	32	61.5
Agricultural extension agents	19	36.5
The people who construct it	1	1.9
Total	52	100.0

Furthermore, farmers were asked what criteria they used during the site selection process. Hence, while 34 households respond location of the plot from residence as major criteria, distance to a nearest drainage was cited as criterion by 13 households, plot size was used as a major criteria by 3 households, and 2 households respond no specific criteria was used during site selection (Table – 6.2).

Table - 6.2 Criteria used during site selection for the RWH technology

Se. No.	*Reasons for site selection*	*Frequency*	*Percent*
1	The location of the plot	34	65.4
2	Distance to the drainage	13	25
3	Size of the plot	3	5.8
4	No specific criteria	2	3.8
	Total	52	100.0

Table – 6.3 depicts, a cross tabulation of the distribution of RWH technologies adopted with their corresponding equipments used for water lifting and application. Of the total 38 households with RWH pond with plastic cover, around 66% use container or jar for lifting and watering plants; while 7 (18.4%) households use motor pump. Besides, in the second category – households with a RWH pond without plastic cover, container/jar and motor pump are used by 2 households each; where as from the third category, each motor pump and container/jar are used by three households.

In addition to this, the last raw of Table – 6.3 shows the distribution of each type of water lifting and application equipments used in the total 52 households with RWH technology. Thus, from the total households with RWH technology majority of them (around 58%) use container/jar for lifting and watering plants, followed by use of motor pump (23%), and use of hand pump and tridle pump each representing 7.7 % of the households. The highest percentage in use of container/jar 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. In this regard an estimation cited in Rami (2003), show that, assuming a farmer could haul about 3 cubic meter per day in to a plot, to irrigate a plantation in a half-hectare just once, it takes a farmer no less than 10 days of hard work. This could probably be due to lack of capital for buying or renting motor pumps, or difficulty to afford the price or rent of motor pumps; and this result is consistent with the latter discussion on the problems sited by households. Hence, this situation could serve as a major detrimental factor which affects the rate of RWH technology adoption.

Table - 6.3 Type of RWH technologies adopted with their respective water lifting and application equipments used

Se. No.		Type of water lifting and application equipments used						Total
	Type of RWH technology adopted	Tridle pump	Motor pump	Wind pump	Hand pump	Egyptian shaduf	Container or Jar	
1	Ponds with plastic cover	3 (7.9)[a]	7 (18.4)	1 (2.6)	2 (5.3)		25 (65.8)	38
	% of Total	5.8	13.5	1.9	3.8		48.1	73.1
2	Ponds without plastic cover	1 (16.7)	2 (33.3)			1 (16.7)	2 (33.3)	6
	% of Total	1.9	3.8			1.9	3.8	11.5
3	Reservoirs		3 (37.5)		2 (25.0)		3 (37.5)	8
	% of Total		5.8		3.8		5.8	15.4
Total		4 (7.7)	12 (23.1)	1 (1.9%)	4 (7.7)	1 (1.9)	30 (57.7)	52 (100.0)

[a] Values in brackets are percentages.

Another related point is that farm households were asked to list the reasons for adopting a specific type of RWH technology; with respect to this as can be seen in Table – 6.4, households with RWH pond with plastic cover respond better storage capacity and easy to use or it doesn't require special skill during lifting and watering in use for farming, as the two major reasons with a frequency of 20 and 18, respectively. Moreover, these two reasons are sited as the main reasons for adopting both pond without plastic cover and reservoirs.

Table - 6.4 Type of RWH technology adopted and reasons for adopting the specific RWH technology

Se. No.		Reason in selecting a specific RWH technology type adopted							Total
	Type of RWH technology adopted	Because it is cheap	Easy access to get the raw materials required for constru	Easy to use in farming	Large water storage capacity	Low labor power requirement	Experts advised me to construct that type of pond	It is durable	
1	Ponds with plastic cover	5 (9.4) [a]	4 (7.5)	18 (34.0)	20 (37.7)	4 (7.5)	1 (1.9)	1 (1.9)	53
	% of Total	7.0	5.6	25.4	28.2	5.6	1.4	1.4	74.6
2	Ponds without plastic cover			6 (75.0)	2 (25.0)				8
	% of Total			8.5	2.8				11.3
3	Reservoirs		1 (10.0)	3 (30.0)	4 (40.0)	2 (20.0)			10
	% of Total		1.4	4.2	5.6	2.8			14.1
Total		5 (7.0)	5 (7.0)	27 (38.0)	26 (36.6)	6 (8.5)	1 (1.4)	1 (1.4)	71 (100.0)

[a] Values in brackets are percentages.

In addition to this, farmers were asked to rank the purpose for which the accumulated water was used based on the amount of water utilized in each activity. Hence, Table – 6.5 depicts that, 40 households respond use of the water for horticulture production as their first choice, while 11 households rank the use of the water as a supplementary source of water for the rain fed crop production during dry spell periods as first. Besides, use of the water for forage preparation and source of drinking water for the household and livestock were ranked as the second purpose by 24 and 5 households, respectively.

Table - 6.5 Household rank of the purpose for which the accumulated water was used.

Use of the water accumulated in the RWH technology	*Use of water rank1 Frequency (%)*	*Use of water rank2 Frequency (%)*	***Use of water rank3 Frequency (%)***
For crop production	11 (21.2)	9 (17.3)	5 (9.6)
For horticulture production	40 (76.9)	11 (21.2)	3 (5.8)
Source of drinking water for the HH and Livestock	1 (1.9)	5 (9.6)	18 (34.6)
For forage preparation	-	24 (46.2)	10 (19.2)
Other	-	1 (1.9)	1 (1.9)
Total	52 (100)	50 (96.2)	37 (71.2)

Households with RWH technology were asked to list problems they encounter during implementation and utilization of the technology, and in general the problems sited by farmers can be classified in to six major categories. As can be seen from Table -6.6, these include; problems related with pond (31.8%), 17.6% of the total frequency of responses represents problems related with the plastic sheet cover of the pond, 15.4% of responses mentioned problems related with the finance and labor required for the technology, 8.8% represents problems related with the plot/farm land, and 6.6% sited problems related with water lifting & watering equipments, while 18% respond no specific problem.

Moreover, of the pond related problems mentioned (column – 4 of Table - 6.6), safety of children and animals, and quickly drying up of the accumulated water problems take the highest share around 42 and 21 percents, respectively. This indicates the existing problem either in choice of the appropriate RWH technology or structural design of the technology which emanates from lack of extension workers with the necessary skill about the technology during construction. Furthermore, of the problems cited related to the plastic sheet lined in pond, the respondents mainly focused on the durability problem of the plastic sheets, representing (around 94%). The other problem cited with large frequency is difficulty to cover the finance and labor required for the technology at household level. In summary, majority of the problems cited by respondent households circulates on two issues, lack of capital and extension workers skilled with RWH technology.

Table - 6.6 Cross tabulation of the problems encountered during adoption and utilization of RWH technology.

Se No.	*List of problems*	*CATEGORY OF THE PROBLEMS REPORTED BY THE HOUSEHOLDS SURVEYED: PROBLEMS RELATED EITH:*							*Total*
		No specific problem	Pond	Water lifting & watering equipments	Plastic sheet cover of pond	Plot/farm land size	Labor requirement	Regulations & others	
1	I don't know	17 (18.7)							17 (18.7)
2	children and animals might be drowned		12 (41.4)						12 (13.2)
3	It dried up quickly		6 (20.7)						6 (6.6)
4	It becomes favorable host for reproduction of rodents		4 (13.8)						4 (4.4)
5	Cracking in concrete structures, made of cement		3 (10.3)						3 (3.3)
6	The amount of water is not sufficient		2 (6.9)						2 (2.2)
7	Rodents affecting yield, specially vegetable		2 (6.9)						2 (2.2)
8	Lack of improved equipments for water lifting & watering			4 (66.7)					4 (4.4)
9	The power of the motor pump is low			1 (16.7)					1 (1.1)
10	Very expensive rent of motor pump			1 (16.7)					1 (1.1)
11	The plastic sheets easily punctured				15 (93.8)				15 (16.5)
12	Shortage in supply of plastic sheets				1 (6.3)				1 (1.1)
13	Lack of improved equipments for digging stony farmlands					6 (75)			6 (6.6)
14	Small plot size					1 (12.5)			1 (1.1)
15	Distance to the field					1 (12.5)			1 (1.1)
16	It requires huge finance & human resource						12 (85.7)		12 (13.2)
17	The work & its application is cumbersome						2 (14.3)		2 (2.2)
18	Obligation of the household to contribute labor to other activities							1 (100)	1 (1.1)
19	Total	17 (18.7)	29 (31.8)	6 (6.6)	16 (17.6)	8 (8.8)	14 (15.4)	1 (1.1)	91 (100)

In addition to this, the responses of the 48 households, who do not adopt RWH technology, on the factors hindering them from adopting the technology is presented in Table – 6.7. The reasons listed by respondent households can be summarized in to reasons related with plot/farm land, household head personal problem, lack of knowledge about RWH technology, lack of financial capital, and household RWH technology preference. Of the total frequency of responses (91) reported, reasons mentioned related to plot/farm land represents (25%), and it includes lack of plot, small plot size, distance from residence to plot, and unsuitable soil texture. Besides, responses related to the RWH technology, particularly lack of know-how about the technology and its benefits represents 22% of the total reasons reported. Where as, lack of capital and technology choice reasons mentioned with 18 and 8 percentages, respectively of the total responses reported.

Table – 6.7 Reasons for not adapting RWH Technology (for households without RWH technology)

Reasons affecting household RWH Technology adoption decision	Category of reasons for not adapting RWH Technology						
	Personal reasons	Plot reasons	Lack of financial capital	Lack of knowledge about RWH technology	Technology preference	Other	Total
Lack of plot or farmland		6 (40) (10.2)					6 (10.2)
Lack of know-how about RWH technology				11 (84.6) (18.6)			11 (18.6)
Lack of capital for constructing pond			11 (100) (18.6)				11 (18.6)
Mainly engaged in other non-farm activities						1 (100) (1.7)	1 (1.7)
Handicapped	1 (7.1) (1.7)						1 (1.7)
Age	6 (42.9) (10.2)						6 (10.2)
Temporary health problem	6 (42.9) (10.2)						6 (10.2)
The distance from home to the plot is very large		2 (13.3) (3.4)					2 (3.4)
Prefer to use river diversion using my own motor pump					3 (60) (5.1)		3 (5.1)
The plot is not suitable for constructing pond		2 (13.3) (3.4)					2 (3.4)
Lack of know-how about the benefits of the RWH ponds				2 (15.4) (3.4)			2 (3.4)
Prefer to adopt RWH technologies other than ponds					2 (40) (3.4)		2 (3.4)
Small farmland or plot size		5 (33.3) (8.5)					5 (8.5)
Lack of courage to construct RWH ponds	1 (7.1) (1.7)						1 (1.7)
Total	14 (100) (23.7)	15 (100) (25.4)	11 (100) (18.6)	13 (100) (22)	5 (100) (8.5)	1 (100) (1.7)	59 (100) (100)

Finally, the possible solutions suggested by households with RWH technology to overcome the aforementioned problems are presented in Table – 6.8. Here, households have cited several possible solutions with a total frequency of around 78, but as can be depicted from the column headers of Table-6.8, they can be summarized in to solutions suggested to tackle problems related to construction cost of the technology, structure and design of RWH pond, plastic sheets, site selection, and water lifting and watering equipments. Hence, as can be depicted from the last row, majority of the solutions suggested circulates mainly on the need for government support in terms of finance and arranging training or experience sharing tour to household heads. The higher percentage suggestion for government support (around 25%) probably indicates construction cost of the RWH technology and price of water lifting and watering equipments are unaffordable at household level.

Table – 6.8 Possible solutions suggested by households who use RWH Technologies.

List of possible solutions suggested by households with RWH Technologies	Solutions to problems related with								Total
	No specific solution	RWH pond	Plastic sheets	Site selection	Construction and watering equipment	Cost of the RWH technology	Agricultura l inputs	Other problems	
I don't know	21 (100) (26.9)								21 (26.9)
Ponds should either be covered or fences be constructed		11 (64.7) (14.1)							11 (14.1)
Supply of motor pumps with higher capacity					1 (20) (1.3)				1 (1.30)
The site for the pond should be selected by experts				5 (100) (6.4)					5 (6.4)
Reserve plastic membranes should be prepared for replacement			3 (60) (3.8)						3 (3.8)
Better to use cements instead of plastic membranes			2 (40) (2.60)						2 (2.60)
Gov't should support us motor water pumps					4 (80) (5)				4 (5)
Immediate legal action should be taken on those who deliberately								1 (33.3) (1.3)	1 (1.3)
Orders from officials should be minimized								1 (33.3) (1.3)	1 (1.3)
Pesticides, insecticides, & other chemicals should be provided							1 (50) (1.3)		1 (1.3)
Training & experience sharing tours should be prepared for farmer		5 (29.4) (6.4)							5 (6.4)
Gov't should help us with improved equipments, for digging & watering						10 (50) (12.8)			10 (12.8)
Gov't should cover some portion of the cost						10 (50) (12.8)			10 (12.8)
It would be better if additional land is distributed								1 (33.3) (1.3)	1 (1.3)
Better to construct ponds with high water holding capacity		1 (5.9) (1.3)							1 (1.3)
It would be better if variety seeds be provided to farmers							1 (50) (1.30)		1 (1.3)
Total	21 (100) (26.9)	17 (100) (21.8)	5 (100) (6.4)	5 (100) (6.4)	5 (100) (6.4)	20 (100) (25.6)	2 (100) (2.6)	3 (100) (3.8)	78 (100) (100)

CHAPTER SEVEN: KEY FINDINGS AND IMPLICATIONS

7.1. KEY FINDINGS AND IMPLICATION OF THE CROP – MIX ANALYSIS

The result discussed in section – 4.2 on the impact of RWH technology adoption on a farm household's crop choice decision, based on "with" (a total of 110 observations) and "without" (a total of 141 observations) RWH technology situation, has shown a major shift from crops under cereal (90%) and pulses (10%) category to vegetables (*62%*), cereals (*16%*), pulses (*7.8%*), spices (*7.8%*), fruits (*2.8%*), and other crop categories(*1.4%*).

Two major implications can be depicted from the crop mix analysis. Comparing the "with" and "without" situation with respect to the crop type sawn, based on the crop category, either a major shift on farm household's crop choice decision, from cereals and pulses towards perishable and perennial cash crops, including vegetables, spices, and fruits or an intensification in agricultural production per year can be depicted. The other important information generated from this analysis is that, farm households have started to grow crops which were not previously grown in the area such as perennial crops or fruits (including mango and orange) for commercial purposes, though its percentage is still very small.

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 or increment in the number of harvesting per year (intensification), could have a positive impact on the farm household's 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. That is, as can be seen from the previous paragraph, of the crop categories sawn in farm households with RWH technology, most of them are perishable; for instance, vegetables which represent the highest percentage (*62%*). On the other hand, the combined samples mean of walking time for a single-trip for both the nearest market and public transport services is very high (above one and half hour). Hence, unless these products are able to reach to consumers immediately after harvested, either their market value will decrease with time or in the extreme case it will be a loss to the farm household. Besides, the market value of these perishable products and there by income of the farm households could increase with improvement in their ability to supply their agricultural products to near by markets and towns with large population.

Besides, an examination of the type of crops grown under the vegetable category witnessed that most farm households have concentrated on specific crops (tomato, lettuce, cabbage, onions, and potatoes) 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.

7.2. KEY FINDINGS AND IMPLICATION OF THE ECONOMETRIC ANALYSIS ON HOUSEHOLD DECISION TO ADOPT RWH TECHNOLOGY

As it is discussed previously in chapter five, there are several determinant factors that could affect a farm household's decision to adopt a RWH technology and in this part only the key findings and their implication, of the factors included in the hypothesis are presented.

Household Characteristics

Of the household-level factors only age of the household head has significant association with the household's decision to adopt RWH technology. In this respect, old-age headed households are 18% less likely to adopt RWH technology than young age headed households. The result may imply that, older household heads are more skeptical about the long term benefit of the technology or they discount the future more than young headed households; hence they are less likely to undertake such kind of investments.

Household Physical capital endowment

Where as, with respect to the impact of household physical resource endowment on a farm household RWH technology adoption decision, only ownership of larger farm land has depicted positive correlation with higher probability of technology adoption decision. This could possibly indicate farmers with small plot size have higher degree of risk aversion relative to households owning large farm land.

Household Financial Capital endowment

With respect to the impact of household financial capital endowment on his/her decision to adopt RWH technology, estimation result of the study shows the existence of positive and statistically significant correlation with access to credit. That is, households with credit access are 10% more likely to adopt RWH technology than those without; perhaps suggesting the existence of imperfect capital market. On the other hand, households with savings are 15% less likely to adopt RWH technology than those without savings; suggesting those poorer households are targeted for the RWH technology.

Plot level factors

Of the various plot-level factors, which are hypothesized to affect the household's decision to adopt RWH technology; only factors related with plot soil depth, plot fertility, purpose for which the plot is used, and plot distance from residence have shown statistically significant correlation. Thus the study indicate that, households are less likely to adopt RWH technology in plots with deep soil depth relative to plots with shallow soil depth, and also households decision to adopt RWH technology is 12% more likely on plots perceived as infertile than those perceived as highly fertile; probably suggesting due to farmers higher degree of risk aversion behavior, it is less likely that the RWH technology be constructed in fertile plot relative to infertile plots.

With respect to the purpose of the plot, household decision to adopt RWH technology is 44% less likely a plot being a cropland than plots used as homestead; perhaps suggesting in order to use all available family labor, specially during watering, households prefer homestead to cropland for adopting the RWH technology. The other most interesting implication of this result is that, the accumulated water is used to produce crops with high market value, but in small amounts (since farmers usually use their homestead to grow marketable crops even before the introduction of RWH technologies), rather than as a supplementary source of water during dry spells, as initially intended by government, when the technology was introduced at country level.

Furthermore, in line with above results, the likely of household decision to adopt RWH technology on a plot is 64% lower 1 hour further a plot is located from residence; consistent with the above explanation, the result may imply the farm households decision to fully utilize family labor so as to met the huge human resource requirement during construction and utilization of the water, and there by reduce the finance that could otherwise be needed for hiring labor. This might probably indicate the capital constraint facing households for buying modern water lifting machines and watering equipments.

7.3. KEY FINDINGS AND IMPLICATION OF THE ECONOMETRIC ANALYSIS ON CROP PRODUCTION

As it is presented in chapter five, there are several factors, which affect or determine the level of crop yield, directly or indirectly and/or in different directions and magnitude. Hence, in this part only the key findings and implication of the factors included in the hypothesis are presented.

Household Characteristics

As can be depicted from the result of the reduced model, the direct impact of household family size, household head sex and age on value of crop yield was found to be insignificant. In Table-5.2, households with large family size have witnessed significant association with use of higher labor and more likely use of fertilizer. However, the intensity in use of labor have quantitatively small (elasticity = 0.09), but statistically insignificant impact on value of crop yield; perhaps suggesting the inability of the economy to absorb the available excess labor force and/or imperfect labor market and coupled by the existing small land holding in the region, farm households with extended families are forced to use every available family labor in a small farm land which in turn has resulted in lower return to labor input.

Unlike the findings of Shiferaw et al (2004), for the semi-arid tropic of India; and Pender and Gebremedhin (2004), for Ethiopia, particularly the highlands of Tigray; the study found no statistically significant evidence on the direct impact of female-headed households on value of crop yield, relative to male – headed households. But, the positive statistically significant effect of female-headed households on use of agricultural inputs such as seed and fertilizer could possibly indicate the impact on value of crop yield indirectly through agricultural inputs. As can be depicted in Table-5.2, female – headed households are associated with higher use of seed and more likely use of fertilizer relative to male – headed households. One explanation could probably be the existence of adverse selection in the labor market, which is biased against female labor, and hence, households might be compelled to depend primarily on farming as their livelihood strategy and more focus is given to crop production. However, only intensity in use of seed is observed to increase the value of crop yield significantly.

However, household head education status has shown statistically significant positive association with value of crop yield. That is, relative to illiterate-headed households, both literate-headed households and households with educated heads (with formal education above grade one level) are significantly correlated with higher value of crop yield. Probably indicating household heads with some education have more opportunity to assess markets relative to illiterate-headed households. Hence, they may focus more on production of highly priced cash crops which enables them earn higher return.

Household Physical capital endowment

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 oxen, pack animals, and small ruminants have significant but mixed impact on value of crop yield. For instance, the value of crop production averages 37% higher per additional oxen a household owns, but 9% lower per additional pack animal a household owns, and 5% lower per additional small ruminant a household owns. The impact of greater ownership of oxen which explain the variation in value of crop yield significantly may imply that the market for oxen is imperfect; besides, even the informal oxen rent arrangement (usually practiced in the region on crop sharing basis) is unable to facilitate farm households' access to oxen power and stabilize the variation among households. On the other hand, while the negative impact of ownership of pack animals on value of crop yield could perhaps suggest that, these households are engaged in trading activities and less emphasis is given to farming; the negative impact of ownership of higher small ruminants on value of crop yield is unclear, since it has statistically significant positive impact on intensity of use of inputs including seed and labor (Table-5.2).

Household Financial Capital endowment

As hypothesized, the impact of household financial capital endowment as measured by household credit access and savings is on intensity of input usage, which in turn improves crop productivity. However, households with credit access have witnessed significant association with 20% and 5% lower use of seed and oxen, respectively, but with 30% more likely use of fertilizer than households without access. Surprisingly, the estimation result (Table-5.3) depict that, households with credit access are associated with 25% lower value of crop yield than those without access. Perhaps indicating farmers are using fertilizer above the optimal level in order to minimize the risk of crop failure rather than increasing agricultural productivity.

Household Livelihood strategy

In relation to the effect of household livelihood strategy on the value of crop yield, households with secondary livelihood strategy such as households with their heads engaged in non-farm labor employment and food-for-work are significantly associated with higher value of crop yield, relative to households with no secondary livelihood strategy other than farming. Similar with explanation on the impact of household education status, this result may imply that, household heads with some experience in non-farm activities have better opportunity to assess markets and hence, earn higher value of yield by focusing on production of highly priced crops.

Household access to market, transportation, and roads

Household access to market and well developed infrastructure facilitates the movement of inputs to and outputs from rural parts to towns, where large market is available. The study finds that, although factors included in the estimation such as walking time to market, public transport service, and seasonal road have the expected sign, they are statistically insignificant. A counter intuitive result found in this study is the value of crop yield averages 70% lower 1h closer a household is located to all weather road, and it is statistically significant. The higher value of crop yield could be households further away from all weather roads focus more on crop production, reflected by the higher amount use of seed.

Plot level factors

The result of the value of crop yield also shows that, of the plot level factors included in the reduced form model only land ownership form has witnessed significant association with value of crop yield. That is, rented plots (in crop sharing arrangement usually practiced in the region) have statistically significant association with lower value of crop yield than inherited plots, suggesting farmers are less likely to invest on productivity enhancing activities on rented plot relative to owner operated plots. While estimation results of both the structural and reduced form of the value of crop yield shows that, of the plot level factors included in the models statistically significant negative association was witnessed between plot slope level and value of crop yield in the structural model only. As can be depicted from Table-5.2, both plots with very steep slope and moderately steep slope are correlated with lower use of inputs such as seed, oxen draft power, and fertilizer. Consistent with this result plots with very steep and moderately steep slope have depicted statistically significant association with lower value of crop yield, relative to plots with flat slope. Probably implying the lower use of inputs in these plots resulting from the risk averse behavior of farmers to use more input on relatively less fertile plots, is lowering the economic return of the plots.

Rainwater harvesting technology (RWH) adoption

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 associated with 10% higher value of crop yield, but statistically insignificant; perhaps suggesting the direct impact of the technology adoption on crop production is minimal.

An examination of the indirect impact shows that, households with RWH technology are significantly correlated with 15% higher use of labor and 28% more likely use of fertilizer, than households without RWH technology. However, the intensity in use of inputs resulted from adoption of the RWH technology, did not bring significant improvement in the value of crop yield. For instance, the impact of labor in the value of crop yield is quantitatively small, while the impact of use of fertilizer on crop production is negative, and both are statistically insignificant. One explanation could be, the increment in labor use may be in the technology adopted, since more labor – person days is required during utilization of the accumulated water, particularly during water lifting and watering, which may reduce the appropriate level of labor needed in other activities of the production process. While the negative return of fertilizer could imply excess use of fertilizer on crops such as vegetables (since most households with the technology have started to grow vegetables) reducing the economic return of intensification.

7.4. KEY FINDINGS AND IMPLICATION OF THE QUALITATIVE ANALYSIS

Result of the qualitative information gathered from the household survey reveal that, decisions regarding the type of RWH technology adopted and site selection were made by household heads, indicating either lack of adequate extension workers or even the available extension workers lack skill related with the technology. Hence, issues related with level of water run off and designs of the pond were not taken in to account during decision. This in turn might pose problem on the economic and environmental feasibility of the technology that has a detrimental impact on the technology adoption rate.

In addition to this, although the two major criteria used by most households for selecting a specific RWH technology (water holding capacity and friendly use of the technology) could be considered as a sign of positive attitude towards the RWH technology on the side of the farmers, the criteria used by majority of the households during site selection (distance of the plot from residence – 65%) and the type of machine and equipment used for water lifting and watering in most households (container or jar -58%) could indicate the inability of farm households to afford cost of water pump machines and plastic pipes, and this might have an impact on the efficient utilization of the accumulated water.

The other interesting information implied from this analysis is, though initially the RWH technology was introduced as a supplementary source of water for crop production during dry spell periods, majority of the farm households have used the accumulated water for horticulture production. This is consistent with the results obtained in the econometric analysis of the probit model for the determinant factors for household decision to adopt RWH technology (i.e., higher probability of farm household decision to adopt RWH technology in homestead plot than crop land plot) and the crop – mix analysis which depict a shift in a farm household crop choice decision from cereals and pulses to vegetables, spices, and fruits.

Finally, the problems encountered during construction and utilization of the RWH technologies could be summarized in to problems related with RWH technology, the plastic sheet covers, expensiveness of water lifting and watering equipments, financial and human resource requirements, plot/farm land size and soil texture.

7.5. CONCLUSIONS

The erratic nature of rainfall and natural resource degradation are major bottlenecks in effort to enhance agricultural productivity, which in turn threatens the lives of millions of people in the country, and particularly the study area, Tigray. Hence, to relax these development constraints, the Federal government and Regional states, and NGOs working in research and development, have invested huge resource in various yield-enhancing and RWH technologies (ranging from large dams to RWH ponds at household level). However, the impact of these interventions on agricultural productivity and level of living at household-level is minimal.

In this study, methodologies including descriptive, crop mix, econometric, and qualitative analysis; are used to assess the impact of various factors hypothesized to affect farm household decision to adopt RWH technology and agricultural productivity.

Results of the crop – mix analysis as indicated by the shift in farm household’s crop choice decision towards highly priced and marketable agricultural products; witnessed the potential of the RWH technologies to enhance a farm household’s income as well as level of living ,though there is some variation among farm households. However, the level and magnitude of benefit accrue to the farm household will significantly depend on market and infrastructure accessibility, and diversification in the type of these highly priced agricultural products supplied. Thus, efforts should be made to assess the demand for various agricultural commodities as well as to create a market linkage either through cooperative societies – serving as a bridge between farmers and the traders or final consumers in near by towns, or other means.

The findings of the estimation results of the probit model indicate that, household access to credit, household proximity to cooperative societies, farm land size, homestead plots, and distance of the plot from residence are the most important factors that determine household's decision to adopt RWH technology. Besides, the analyses of the qualitative information depicts that, lack of capital, lack of extension workers skilled with RWH technology, and expensiveness of water lifting and watering equipments are the major factors which affect the efficient utilization of the water and the technology adaptation rate.

Having a farm household with limited resources on the one hand and a technology to be adopted which require large amount of financial and human resources on the other hand, the necessity of credit becomes inevitable. However, the amount of credit that a farmer could get from rural credit institutions is insufficient to cover the cost of construction and equipments. Moreover, due to the nature of the investment, returns from adoption of the technology are obtained at least after a year, but this situation do not suit with the credit provision system of rural credit institutions. Thus, efforts should be made to facilitate credit access specifically oriented for the technology adoption and with the terms of loan designed to fit to the nature of the investment and the living conditions of the farm households.

Furthermore, plots usually classified as homestead are small in size, closer to residence, and which are not used to grow main cereal crops. Hence, the positive significant impact of plot size, plot used as homestead, and plot proximity to residence on household technology adoption decision could have two implications. The first implication could be a support of the neo-Malthusian argument on population-induced agricultural intensification. On the other hand, the result could indicate the risk aversion behavior of farm households, arising from a loss of yield from reduction in farm size that could otherwise be harvested, if the technology is located in main farm land other than homestead. This implies farm households have some skepticism on the profitability of the technology.

In addition to this, the problems mentioned related to pond by the surveyed households, such as safety problems and water holding capacity is mainly structural design problem of the technology adopted. Hence, these problems supplemented by the fact that most of the households have selected the site for the technology themselves, indicates lack of extension workers skilled with the technology. Thus, there is a need on the part of the responsible government bodies, NGOs and research institutions, and other stake holders working in this area to provide training to extension workers.

The Ordinary Least Square estimation of the structural and reduced models for the value of crop yield found that the factors included in the regression: household - human, physical, social, and financial capital endowment; livelihood strategy; access to market, transport services, and infrastructures; adoption of RWH technology; and plot characteristics; do not seem to explain the variation in value of crop yield to a significant extent.

The analysis indicate that, oxen ownership, households further away from all weather roads, owner-operated and inherited plots, are the most important factors that explain variation in value of crop yield among plots. Here, although most of the household - human, physical, social, and financial capital endowment; livelihood strategy; access to market, transport services, and infrastructures have significantly increase the intensity in use of agricultural inputs, they are not reflected in increment in value of crop yield. That is only the amount of seed used has positive impact on value of crop yield. For instance, the return in crop yield from the intensity in use of fertilizer input is negative, probably suggesting in order to reduce the risk of crop failure, farmers were using more than optimal levels of fertilizer. That is the high intensity of fertilizer use on the one hand and the shift in farmers' crop choice towards vegetables indicates the use of more fertilizer is lowering the economic returns from intensification. Thus, there is a need to rationalize the level of use of the input.

Finally, the findings of the estimation results of the reduced model indicate that the direct impact of household RWH technology adoption on the value of crop yield is quantitatively small and statistically insignificant. On the other hand, with respect to its indirect impact on value of crop yield, although adoption of RWH technology has increased the intensity in use of agricultural inputs such as labor – person days/ha and fertilizer, it is not translated in to higher value of crop yield. In addition to this, although initially the RWH technology was introduced as a supplementary source of water for crop production during dry spell periods, from the results of all the crop-mix, econometric and qualitative, it can be concluded that majority of the farm households have used the accumulated water for horticulture production.

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