Mekelle University
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Groundwater resource exploitation, financial feasibility, value and impact on livelihood: Evidence from Haromaya Wereda, Eastern Ethiopia

By
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DECLARATION

I, Kassahun Mamo, do hereby declare that the thesis entitled **"Groundwater resource exploitation, financial feasibility, value and impact on livelihood: Evidence from Haromaya Wereda, Eastern Ethiopia"** submitted in partial fulfilment of the requirements for the award of the degree of Master of Science in Economics (Development Policy Analysis) to College of Business and Economics, Mekelle University, through the Department of Economics, is original work and it has not been presented for the award of any other degree, diploma, fellowship or other similar titles, of any other Universities or Institutions.

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CERTIFICATION

This is to certify that this thesis entitled **"Groundwater resource exploitation, financial feasibility, value and impact on livelihood: Evidence from Haromaya Wereda, Eastern Ethiopia"** is an authentic work of Mr. Kassahun Mamo Geleta, Id. No. CBE/PR183/03, who carried out the research under my guidance. Certified further that to the best of my knowledge the work reported here does not form part of any project report or thesis on the basis of which a degree or award was conferred on an earlier occasion on this or any other candidate.

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ABSTRACT

It is a well established fact that groundwater irrigation development has positive impact for enhancement of production and consequently improving the livelihood of users, although it could lead to over-exploitation of the stock. But there is lack of systematic evaluation of the groundwater irrigation. This study tries to estimate the optimal depletion rate of the resource and its impact on the livelihood of users. In addition, financial viability and monetary value of groundwater irrigation is assessed using three criteria of cost-benefit analysis and Residual Imputation Method, respectively. For this end a survey of randomly selected 200 households which comprised of 100 users and 100 nonusers from midland agro-ecological zone and from the lowland agro-ecological zone (50 from each) respectively was used. This was complemented by secondary data from various sources. The survey was done in Haromaya wereda, eastern Ethiopia, for 2011/12 season. From the spreadsheet optimization, it is found that the smallholder farmers of the area have been utilizing the resource less than the optimal rate and the resource is safe at its current stand. However, when the groundwater use expansion plan is considered the resource is under a serious danger to provide the safe yield for future generation. From private investor point of view investment on the development of shallow wells and borehole is financially viable in all criteria used in this study and it is also revealed that a liter of water from these structures has values of 0.015 and 0.012 Birr, respectively. In all descriptive analyses, irrigation beneficiaries have better expenditure per adult and net income from the sale of their produces as compared to the non irrigation users. All the matching methods show that the borehole irrigation users have more than 284 Birr larger average expenditure per adult per annum than the non irrigation users. However, there is no strong evidence for the difference in expenditure per adult equivalent between households who have access for shallow well and for rain fed users. In addition, the incidences of poverty as well as income inequality measures indicate that groundwater irrigation development through shallow well and borehole brought a significant impact on the poverty reduction. It is obtained that 54 percent of the rain fed dependent individuals spend below the local poverty line where as only 31 and 22 percent of shallow well and borehole irrigation users spend below the poverty line. In terms of poverty gap and severity of poverty measurements, users are better off as compared to the non users. The study also explored correlates of household level poverty and found that among others the larger land holding in *hectare, livestock, agricultural hand tools and non-farm income the better welfare of the households. On the other hand, variables like consumer-worker ratio, age of household head and number of adult male have negative correlation with household welfare. Based on these empirical findings, the following policy recommendations are forwarded; improve watershed management, expansion and improvement of wells, expansion of rural electrification, technical support to the farmers.*

Key Words: *Groundwater, dynamic optimization, financial viability, matching estimator, regression analysis, poverty, residual imputation method, Haromaya, Eastern Ethiopia.*

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Kassahun Mamo

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LIST OF ACRONYMS

ATE	Average Treatment Effect
ATT	Average Treatment effect on the treated
ATU	Average Treatment effect on the untreated
Birr	Ethiopian currency
BCR	Benefit Cost Ratio
BMC	Billion Meter Cube
CSA	Central Statistics Agency
DA	Development Agent
DASP	Distributive Analysis Stata Package
FGD	Focus Group Discussion
GOE	Government of Ethiopia
GTP	Growth and Transformation Plan
GW	Groundwater
Ha	Hectare
IIA	Independence of Irrelevant Alternative
IRR	Internal Rate of Return
IWMI	International Water Management Institute
Kebelle	The smallest administrative unit
MDGs	Millennium Development Goals
MoWE	Ministry of Water and Energy
NBE	National Bank of Ethiopia
NPV	Net Present Value
Oromifa	Local language
PA	Peasant Association
PASDEP	Plan for Accelerated and Sustainable Development to End Poverty
PVNB	Present Value of Net Benefit
PSM	Propensity Score Matching
SSA	Sub Saharan Africa
UN	United Nation
Wereda	District

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CHAPTER ONE

INTRODUCTION

1.1. Background of the Study

Ethiopian economy is predominately traditional agriculture which is highly dependent on the windfall and disadvantage of nature. The sector takes the majority of the work force and the lion share in the GDP of the nation. It contributes about 90% of export earnings and supplies about 70% of the country's raw material requirement for large and medium sized agro-based industries (Tesfay, 2008).

Despite the fact that it has larger share in the national economic activity, its contribution is not commensurate with the expectation. This is due to the fact that the sector is still in its lowermost stage because of different factors. According to Awulachew, Erkossa, and Namara (2010); markets are underdeveloped, federal and regional-level public and private sector partners lack capacities to implement, some gender imbalances continue to be unaddressed, safety nets account for a large proportion of agricultural spending, irrigation potential remains underdeveloped, shortages of improved inputs hinder growth, and key areas of the enabling environment require improvement are some of the reasons for low level development of the country agriculture. Hagos et al., (2006) also indicated that though the majority of the working force is engaged in agriculture, increasing food insecurity and hunger has been the rule rather than the exception for many years.

Therefore, transforming the traditional type of agricultural system to the modern one is indisputable to enhance the livelihood of the majority of smallholder farmers living in developing countries in general and Ethiopia in particular, whose well being is highly volatile with the rainfall variability and climate change. The enhancement of this sector is also necessary to make the sector that consistent with its position in the economy. Introducing irrigation technology for those small holder farmers is considered as one of the ways to minimize poverty, if not eradicate, particularly for the area where moisture is rare and rainfall is highly variable. World Bank (2004) reported that in the current period water resource development for irrigation and its management remains at the center for growth, sustainable economic development, and poverty reduction. According to Awulachew *et al.,* (2010), developments of irrigations have taken place with the rationale of;

- increased productivity of land and labor, which is especially pertinent given future constraints from population growth
- reduced reliance on rainfall, thereby mitigating vulnerability to variability in rainfall
- reduced degradation of natural resources
- increased exports
- increased job opportunities, and promotion of a dynamic economy with rural entrepreneurship.

Groundwater is lately considered as one of the means of getting water for irrigation use. Given that the potential exists, groundwater provides numerous benefits to human being by taking it via natural springs or artificially created different means to tap the water into surface. Some of the benefits of groundwater resource are potable (or domestic) use, agricultural activities, industries and service sectors. Historically, Fetter (2001) indicated that the practice of using groundwater has been started a long years back at early age of human development. According to him the most widely used technique to tap water in ancient period is 'Qanat', which is the horizontal excavation beside the hill.

Despite the fact that it has such a long history its use was limited until different quantitative methods of groundwater exploitation have been developed by different hydrologists and enables to use groundwater like never before for its various aspects of life. In this regard Asian countries have a successful history as compared to other least developed countries of the world, particularly Sub Saharan Africa (SSA). As Shah (2010) explained, South Asia's groundwater boom threatened the resource but liberated the small holder farmers and made famines history. But this is not the case for SSA; most of the countries in this region remain vulnerable to famine.

Those Asian countries aggressively developed different irrigation technologies in order to enhance their agriculture and empower themselves to feed their ever expanding population, though for many years the irrigation development investment has focused on the surface water. However, during 1970s large scale surface water irrigation has been slowed down and in the next two decades the groundwater irrigation development has started flourishing in the world agricultural development. As Hussain and Hanjra (2004) described, private investments in groundwater based irrigation have increased significantly during the 1980s and 1990s.

In Ethiopia, considered as the “water tower of Africa”, despite the fact that there is larger potential for groundwater, it has been overlooked for many years and it is still mainly used for drinking water supply which takes care of 70% of rural water supply and plays a major role for major cities (MoWE, 2011). Estimation of Awulachew *et al.,* (2010) suggested that groundwater irrigation potential of the country is more than 1.1 Mha and also confirmed that recent information indicates that Ethiopia’s groundwater potential could be significantly higher than currently estimated, this 1.1 Mha estimate can be refined in the future when more relevant information can be generated through further research and study.

But groundwater use for irrigation purpose is still very minimal. According to the ministry strategic frame work the country has estimated potential of the resource from 12 to 30 BMC which is after the upward adjustment of frequently quoted 2.6BMC (MoWE, 2011). As compared to its potential the country requires very small amount of irrigation development in order to make its population free from famine vulnerability. According to Shah (2010), Ethiopia likely needs only 3 to 5 Km^3 of groundwater irrigation to drought proof its agriculture.

Inspite of the fact that groundwater has various advantage over surface water irrigation its development in Ethiopia has different constraints. According to Awulachew *et al.,* (2010) some of the constraints are;

- ✓ Costly development and operations is considered as one problem. Depth of access can increase investment requirements, since the average cost of per hectare of groundwater development, including operation, is two to four times higher than for surface water irrigation (e.g., stream diversion). This is especially true for deep wells, which are expensive to develop and operate.
- ✓ Lack of a comprehensive understanding of Ethiopia’s groundwater resources also considered as another problem. Information regarding aquifer characteristics, delineation, available water, sustainable recharge amount, etc., is limited and not well understood due to complex Ethiopian geology and lack of studies.

- ✓ Difficulties and costs related to the need for specialized equipment (e.g., deep drilling rigs) and specialized and well-trained staffs (e.g., well drillers).

Though the above constraints are there, the groundwater irrigation development has received better attention in recent years, particularly after the announcement of water harvest program in 2004 (Alemayehu, 2011). Those developments of groundwater irrigation in different well structure are financially viable (Hagos et al., 2006; Tesfay, 2008; Yirga, 2011) and improve the livelihood of the users. In this regard, groundwater irrigation development in Haromaya *Wereda* has reached 11,210 private and communities' wells beneficiaries' and 10,021 ha of land is covered under groundwater irrigation development (Haromaya Wereda Administration Office, 2011).

Despite the positive contribution of the development of groundwater irrigation there is almost no knowledge or research in Ethiopia on the distribution of groundwater, rates of recharge, and other issues that are essential for groundwater sustainability and protection (Awulachew *et al.*, 2010). Haromaya *wereda* is not an exception in this regard. This calls for the knowledge which indicates the proper use of the resource in a sustainable manner.

1.2. Statement of the Problem

Subsistence agriculture is the main stay of rural households in most of least developed countries that put small holder farmers on the arena of extreme poverty. The agricultural activities of those small holder farmers is characterized by high dependence on erratic rain fall, consume the great proportion of their produces, very limited access for off-farm activity, means of self employment alternatives, marginalized from social and economic infrastructures and the like. The country is following Agricultural Development Led Industrialization (ADLI) policy, which provides a key role for agriculture, but the sector is still on its lower stage and the expected link of the sector with other sectors is meager.

This level of agricultural development exposes the population of the country for recurrent and catastrophic drought that is printed in bold in the mind the majority of the world population while they are thinking about the country. Since the country gives leading role for the agricultural sector which is highly dependent on weather condition, shrinking of the country economy is inevitable when the climatic condition is adverse. So adoption of agricultural technologies, like small scale and large scale irrigation, which reduce the risk of volatile weather condition, is indisputable. Groundwater resource is one of the means for such irrigation development.

Though the resource has various uses in agricultural development, household consumption and business activities and its development is ever expanding in the world particularly for Asian countries, Ethiopia has nearly ignored it for many years. Due to this its expected benefits for economic development (like agriculture, live stock, and industry), environmental protection as well as potable use for its population are not fulfilled in line with the potential. Groundwater has created the miracles of accelerated agricultural production in the economies of India, China, South Asia, North Africa and the Middle East (MoWE, 2011). But it is not the case for Ethiopia.

In addition to this incompetence of the country in the utilization of groundwater, the protection policy of the resource from the tragedy of common, since the resource is open resource, is not clearly indicated at the country level. Eastern part of the country, Haromaya wereda in particular, is not an exception regarding to inefficient use of this overlooked resource for small scale irrigation until 2004 announcement of water harvesting program, which has left some positive impacts in many parts of the country (Alemayehu, 2011). Since then there is some indication of improvement on the use of the resource for irrigation.

That inspires researchers to conduct research about the groundwater potential of the area and evaluate its management aspects. As Alamirew and Berressa (2010) indicated, the watershed groundwater status is in good stand based up on their analytical tools. Mohammed (2006) also indicated that the area’s problem is not the availability of the water rather poor management of it.

However, so far no research has been conducted that quantify the livelihood impact of the groundwater irrigation use on the small holder farmers and the value of water that is used for irrigation use in the area. Moreover, the dynamic optimal rate of the resource use using the dynamic programming tools is not performed with the exception of comparison of the recharge and withdrawal rate of the resource by different researchers like Alamirew and Berressa (2010) and Adem (2011). In addition groundwater could harvested, storage and conveyed using various technologies. The cost-benefit analysis of these technologies was hardly done for policy recommendation and for decision rule in the area.

To fill these gaps this research envisage to evaluate the financial viability of investment on groundwater irrigation development, estimate the value of the groundwater when it is used for irrigation purpose, quantify the impact of groundwater irrigation on the livelihood of users based on impact evaluation tools and also scrutinize and compare the incidence and intensity of poverty that prevails in the users and non users.

It was also reportedly said that the resource utilization practice of the area is not good and also blamed for the death of Lake Haramaya. According to Alemayehu (2011), the intensive use of the resource without proper water resources management practice in the area is feared to bring ecosystem disturbance. By considering this issue this research also tries to figure out the optimal level of utilization of the groundwater that enables to use the resource in a sustainable manner using dynamic optimization technique.

1.3. Objectives of the Study

Ethiopia has enormous amount of small holder subsistence farmers. The ongoing Growth and Transformation Plan (GTP) has given due emphasis for small scale irrigation development (MoFED, 2010). This plan is envisioned to improve the livelihood of the rural poor by enhancing agricultural productivity via small scale irrigation and better provision of agricultural inputs.

One of the ways of developing small scale irrigation is to use groundwater source at household level. To do so, various research works are needed to support the effort to make the rural poor life better off. So the overall objective of this research is to make micro level assessment of groundwater irrigation development and quantify the optimal rate of the resource depletion, its financial viability and impact on the livelihood of the users based on different indicators. This general objective of the research has different specific objectives. These are:

1. To gauge the optimal level of groundwater utilization that enables the users to use the resource in a sustainable manner.

2. To investigate the financial viability of investing on groundwater wells for irrigation use through the tools of Net Present Value (NPV), Internal Rate of Return (IRR) and Benefit Cost Ratio (BCR) as well as the monetary value of a unit of groundwater when it is used for irrigation.
3. To measure the contribution of access to groundwater wells on the household welfare.
4. To compute the average value of net income from the sale of their produce for the irrigation users and compare it with that of rain fed dependent producers.

1.4. Research Hypotheses

This thesis focused on determining the optimal use of the resource, estimate benefit-cost of different groundwater storages, value groundwater irrigation and assess impact of groundwater irrigation on the livelihood of the small holder farmers in Haromaya wereda. For the evaluation of the aforementioned objectives the following workable hypotheses are developed.

H1: Current groundwater use of the area is in line with the optimal rate.

H2: Investment on groundwater irrigation development is financially viable in the area.

H3: Groundwater irrigation beneficiaries have larger expenditure per adult equivalent on average as compared to the rain fed dependent farmers.

H4: Groundwater irrigation beneficiaries are better off in terms of their net income from the sale of their produce (marketable output).

H5: Possession of groundwater well for irrigation purpose has a significant and positive impact on reduction of poverty.

H6: Income distribution is better with in households who have access to groundwater irrigation than the income distribution for those who have no access.

1.5. Scope and Limitations of the Study

1.5.1. Scope of the Study

In the study area, groundwater is not only an economic issue but also comes into picture in social interaction of the population. It causes dispute for many farmers. This research is confined only in the investigation of the impact of groundwater use on economic aspect and during optimal use determination only the groundwater potential and its irrigation use is considered. While dealing with livelihood of the rural farmer's statistical aspect of their well being i.e. well being that can be measured in terms of their income, expenditure and asset is considered.

1.5.2. Limitation of the Study

The money metric measure of welfare suffers from problem of overlooking non monetary aspect of poverty. This paper is also not free from this shortcoming. In addition, the conclusion reached in this study cannot be generalized at the country level because as it is expected it lacks external validity. Groundwater could be used as a source of drinking water, for industrial use and for irrigation. This study is limited to explore different issues of groundwater used for irrigation. The other uses are not addressed. Moreover, groundwater quality could be affected by externalities, e.g. pollution. The quality issue is not addressed in this paper. Finally, climate change on groundwater availability is not assessed.

1.6. Significance of the Study

To enhance the under developed agricultural practices, providing irrigation technology is one of the means. In the past two regimes, irrigation is mainly focused on river diversion which require huge amount of investment that has great financial pressure on the country's underdeveloped economy. In the current regime, however, groundwater has started to receive attention for its additional use other than a source for provision of potable water for the population. On its strategic document of Plan for Accelerated and Sustainable Development to End Poverty (PASDEP) the government set a target of achieving 430,061 ha of irrigable land a large part is covered by surface irrigation where as some part is also left for groundwater irrigation (MoWE, 2011). To utilize the groundwater potential in line with the expectation, it calls for many researchers to investigate it scientifically and forward some policy recommendations.

Hence, research is required to evaluate micro base impact of groundwater irrigation at different parts of the country. Based on the aforesaid reasons the central theme of the research to provide well studied impact evaluation of groundwater irrigation and its optimal rate of depletion. The policy maker would be benefitted from the research by using it as an input for their policy design and consequently the population at large will be benefited from the policy, which is the ultimate end. In addition, the paper can be used as an input for other researchers to look the research gaps like the non economic aspect of groundwater irrigation development.

1.7. Organization of the Paper

The paper comprises of five chapters. The first chapter deals with the background information of groundwater irrigation development and statement of the problem that explains why does this research need to be conducted. In addition, the chapter consists parts explain the key research hypotheses and questions, objective of the study, scope and limitation of the study, significance of the study and this subsection.

The second chapter is allotted for the brief review of theoretical and empirical literatures which are related to the matter of groundwater irrigation development and its consequence impacts particularly from the micro aspect.

The next chapter, research methodology, explains description of the study area, methods of data collection and sample design for the survey households. In addition the theoretical frame work and its application analytical techniques used in this paper are presented.

Chapter four presents the outcomes of the empirical data analysis using the tools presented in chapter three. In different section of this chapter, various outputs with their respective interpretation have been presented. By its different sections; descriptive statistics of demographic and socio-economic characteristics of the survey households, the optimal depletion rate of groundwater, the financial viability of wells, impact of groundwater irrigation on the livelihood of the users using matching method, poverty analysis of different groups of the survey households and correlates of poverty have been discussed using the first hand information of the survey and secondary data from various sources.

Based on the results and discussions, chapter five provides the overall conclusions of the paper and draws policy implications. In addition, rooms for further research have been pointed out in this chapter.

CHAPTER TWO

LITERATURES REVIEW

2.1. Groundwater and Agriculture

Groundwater is used for irrigation (agricultural activities), domestic use and as an industrial input. In this part of literatures review, attempt has been made to assess different literatures about groundwater use for irrigation practices in different contexts.

2.1.1. Groundwater and Agriculture in Different Parts of the World

Together with the rapid growth of the world population the demand for food has been increase in recent history. To fulfill this demand increase agricultural production and productivity through irrigation technology took place. Job (2010) explained that over the period from about 1950 to 1975, an estimated 1000 large dams were completed each year. But those developments of surface water irrigation face a lot of problem. Sunquist (2006) explained that during the first part of 1990s decade, each year saw approximately 260 large dams coming on line. Additionally, these dams on average fill in with sediment at the rate of about 1% annually. This decline in dam construction represents a major factor for shift to reliance on groundwater as a source for irrigating farmland. Brown (2004) also put in a plain word that because water from rivers in the world's major agricultural zones has been completely utilized, further expansion of irrigation has drawn on groundwater.

Inspite of the fact that groundwater can be used for different purposes for human activities its agricultural and potable use outweigh others. Agricultural use for the production of food for the ever expanding human population is important. World population is expected to grow at a rate of 1.1% annually from 2002 to 2030, while food production is forecast to increase at a rate of 1.5% per year during the same period (FAO, 2002). But such growth of the food production may not be attainable in the least developed countries. According to Job (2010), 60% of their agricultural production for least developed countries is dependent on rain fed system that increases vulnerability of their population to different shocks and catastrophes which are caused by climatic variability. The above arguments indicate that looking for groundwater for agricultural use is unquestionable.

This source of water has several advantages over other type of water sources. According to Job (2010), groundwater has several advantages for water supply:

- Easily accessible and capable of being captured and managed by individuals or small groups of people.
- Available over extensive areas, most often being developed where needed, rather than installing long transmission lines, and in a staged approach.
- Less expensive and less capital intensive to develop than surface water in most situations.
- More reliable in dry seasons or droughts because of the large storage capability.
- Generally of adequate chemical and microbiological quality with little treatment needed if unpolluted.
- Less affected by catastrophic events.
- Often uniquely provides people with limited means, the capability to sustain life in locations having less essential resources and constrained opportunities.

Because of the aforementioned advantages and its requirement for agricultural production system the world use it extensively, particularly for agricultural activities. Asian countries have a success history on reducing vulnerability, as opposed to SSA, by developing groundwater irrigation together with other green revolution technologies. Shah (2010) reported that there is more than 280 km^3 of groundwater development every year. According to the World Bank Agricultural Investment Source Book (2004) report, Asian countries have a well developed experience in this regard as compared to others as it is presented below.

Indian experience in year 2002

- One-half of the total irrigated area relies on groundwater wells
- 60% of irrigated food production is from groundwater
- 10.5 million dug wells and 6.7 million shallow tube wells in 1994
- Shallow tube wells doubled every 3.7 years from 1951 to 1991
- Overexploitation in some states has been significant with water tables declining

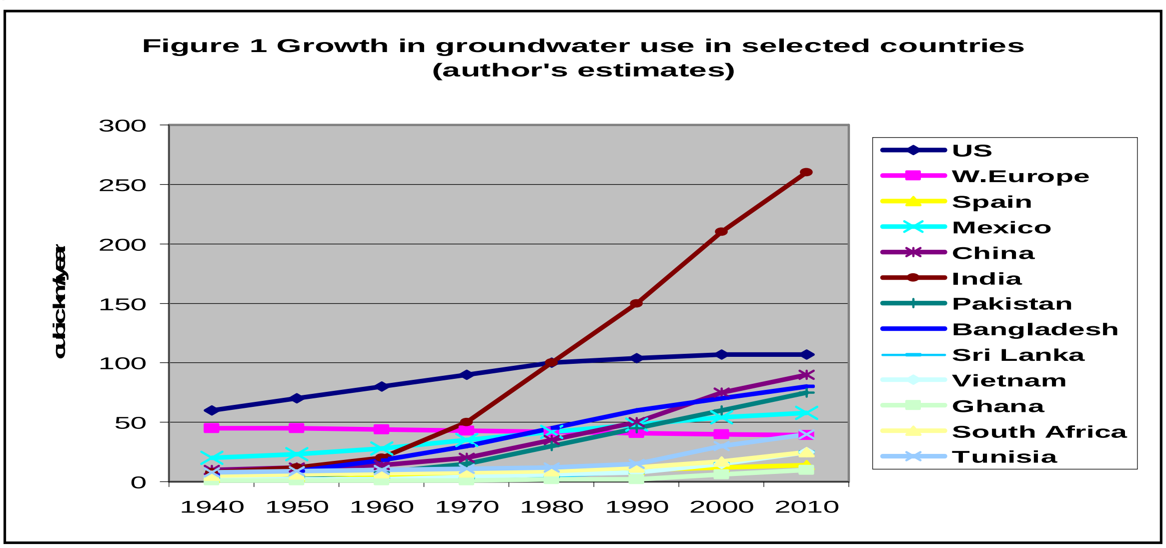
China in 2002

- Groundwater at present is the major source of irrigation in Ninjin County
- Rapid increase in irrigated areas resulted in overexploitation of groundwater with serious environmental consequences

- Density of tube wells greater than one per 5 ha with average depth to water level increasing from 3.7 to 7.5 m over 30 years
- One-tenth of the wells go dry in summer
- Farmers' use of plastic tube to convey water has reduced water loss, but basin irrigation still inefficient using twice the standard for North China
- Irrigation is 30% of total farm production costs
- Overexploitation of groundwater resulted in declining profitability because of greater water lift costs and poorer quality water
- Salt content of groundwater increasing soil salinity
- Area facing critical groundwater recharge problem and groundwater use is unsustainable

These two countries together with USA and Pakistan constitute the major users of groundwater for irrigation purpose. FAO (2003) reported that out of agricultural lands irrigated, "India has over 50% of its area irrigated from groundwater, followed by the United States (43%), China (27%), and Pakistan (25%). This trend is clearly indicated in the following graphical illustration used by Shah (2010), which is depicted in figure 2.2 below. This ever expansion of groundwater use threaten the resource, particularly for Asian countries. However, in most of least developed countries, particularly SSA groundwater use is found at starting stage. These countries, including Ethiopia, can use their groundwater potential without threatening the resource. In these countries a development of groundwater has a promising impact for the eradication of poverty for smallholding farmers without overexploiting the resource (Shah, 2010).

Figure 2.1: Growth in Groundwater use in Selected Countries



Source: Ali, 2011

The major reasons for low level of groundwater development in SSA, according to Shah (2010), are:

- High cost of maintenance and repair for shallow wells and boreholes,
- No economics of scope as Asian countries,
- Capital scarcity and poor credit access,
- High cost of pumps, pipes, drilling rigs and labor,
- Poor availability of spare parts and skill.

Obuobie and Barry (2010), also explained that in SSA, the cost of constructing boreholes and wells are generally high, compared to China and India. The high cost has been attributed to factors such as (i) lack of economy of scales and competition in well construction, due to absence of a large private-sector market for domestic and irrigation wells (ii) high excise duties on imported drilling equipment and pumping plant, and no significant local manufacture even of spares (iii) corruption in the letting and execution of well drilling contracts and (iv) inappropriate well design and excessive drilling depth for some hydro geological conditions. They also considered it as one of the setback for achieving MDGs.

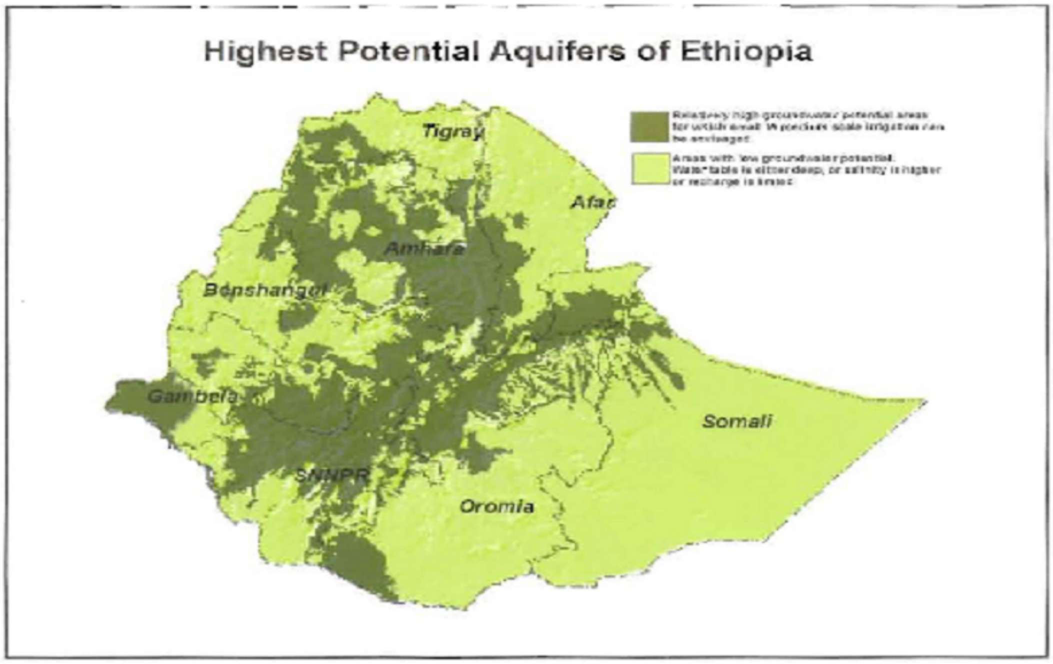
2.1.2. Groundwater and Agriculture in Ethiopia

Despite the fact that surface water irrigation has been practiced for long period of time since the imperial regime, ground water potential of the country hardly known, until recently, and its exploitation was ignored for many years. During the imperial regime there was a large scale surface water irrigation that has envisaged promoting the traditional agricultural sector into a modern sector. As Tesfay (2008) explained the main purpose of irrigation development in Ethiopia was to provide industrial crops to the growing agro-industries in the country and to boost export earnings.

This type of irrigation development required huge amount of outlays as compared to groundwater irrigation development and also totally ignored the micro irrigation development. So in order to solve the financial pressure of the huge outlays for surface water irrigation Ethiopia started to look over the groundwater potential. In the country water centered development strategy groundwater has paramount importance and the current regime has ambitious plan to use the groundwater potential of the country. As frame work of the MoWE

(2011) shows, the country groundwater potential is enormous as the following figure illustrates.

Figure 2.3: Groundwater Potential of Ethiopia



Source: Seifu Kebede as cited in MoWE, 2011

In the figure deep green represents relatively high groundwater potential areas for which small to medium scale irrigation can be envisaged. On the other hand the light green represents the area with low groundwater potential because of the water table is either deep, or salinity is higher or recharge is limited (MoWE, 2011).

Despite the fact that the country has possessed 12 to 30 BMC potential of groundwater (MoWE, 2011) the usage is still at its modest stage. This is due to different factors; lack or limited capacity of the necessary equipment for the development of groundwater, and deficiency in human resource are the major ones. According to MoWE (2011), strategic frame work description there are 25-60% vacancies for Regional Water Resource Bureaus and particularly the need for drillers, hydrologists and water supply engineers is very high. Awulachew *et al.*, (2010) also share these constraints of groundwater irrigation development.

Though the above limitations are there, a number of ambitious projects for groundwater irrigation have been conceptualized (MoWE, 2011). It also states that in those ambitious projects the government envisaged to use the groundwater more intensively in irrigation development together with the potable water projects.

Even though the emphasis has been improved now there are lots of shortcomings regarding to the resource utilization. Water quality mapping has not started yet and monitoring of groundwater level is not done systematically. There are different piecemeal efforts in groundwater monitoring but no central guideline nor is the organizational responsibility for groundwater monitoring clear (MoWE, 2011).

Currently, there are ongoing groundwater development projects as it is tabulated here under in table 2.1.

Table 2.1: Projects under Study and Design

#	Name of the Project	Start-Complete Period (E.C)	Feasibility Study	Budget (million Birr)	Source of Fund
1.	Ada GW development study project	1998-2002	completed	141	GOE
2.	Aladige GW development study project	1998-2002	completed	90	GOE
3.	Mekelle and Surrounding GW development study project	2001-2003	On progress	50	GoE
4.	Upper Tekeze GW development study project	2000-2002	On progress	50	GoE
5.	Teru GW development study project	2000-2002	On progress	40	GoE
6.	Wolkite-Ambo GW development study Project	2001-2003	On progress	40	GoE
7.	Ketar GW development study project	2001-2002	On progress	5	GoE
8.	Ogaden GW development study project	2001-2006	On progress	60	USA

Source: Ministry of Water and Energy, 2011

In addition to the aforementioned study and design of groundwater irrigation development there are different groundwater irrigation development projects under construction which are financed by the government of Ethiopia and the bilateral and multilateral agreement with different stakeholders. The detail of the groundwater projects which are under construction are tabulate below in table 2.2.

Table 2.2: Groundwater Projects under Construction

#	Name of the Project	Start-Complete (E.C)	Construction Work	Budget (million Birr)	Source of Fund	Developed Area so Far	Planned to Developed	Beneficieries
1	Kobo Trial GW construction project	2000-2001	completed	10	GoE and Hungary Government	30ha	300ha	90HHs
2	Kobo Girana GW Design and Development Projects	1998-2003	90% completed	171	GoE	30ha	17000ha	68000HHs
3	Raya GW design and construction project	1998-2003	90% completed	233	GoE	267ha	18000ha	72000HHs

Source: Ministry of Water and Energy, 2011

2.1.3. Groundwater and Agriculture in the Study Area

Groundwater exploitation is rapidly growing mainly for irrigation in Haromaya wereda. Currently there are 11,210 private and communities' wells beneficiaries' households in the *Wereda* and it was also reported that 10,021 ha of land is covered under groundwater irrigation development (Haromaya Wereda Administration Office, 2011). In addition the *Wereda* administration has prepared the five years plan for the expansion of groundwater irrigation development as it is shown in table 2.3.

In the area the groundwater use practice is ever expanding due to different reasons. According to Alamirew and Beressa (2010), due to rapid population growth in Haromaya Watershed, Harar and its surroundings, the exploitation of groundwater resources has increased substantially upon drilling new wells in the last five- ten years. And the personal comment of Alemayehu (2011) also indicates that in Haromaya Wereda and its neighbor Wereda, Kombolcha up to 6,000 new wells have been constructed.

From the key informant interview it was understood that the groundwater potential is still unexplored. The most important problem of the area particularly, Melka Gemechu, for the utilization of groundwater potential is the knowledge of the farmers to identify the groundwater potential. As MoWE (2011) explained in its strategic framework the knowledge gap of groundwater resource is incomplete for the larger part of the country. This is not an exception for the study area.

Table 2.3: Groundwater Irrigation Development in Haromaya Wereda

#	Type of work	Unit of measurement	2003 to 2007 E.C Plan	2003 E.C. plan	2003 E.C. Implementation	2004 E.C. plan
1	Private Borehole	number	7,400	900	700	1,200
2	Community well	number	45	5	5	7
3	Private Shallow well	number	17,500	2,900	2,800	3,200
4	Community well maintenance	number	70	10	8	12
5	Provision of Dynamos	number	1,500	260	-	250
6	Provision of motor pump	number	750	200	-	280
7	Training	number	1,500	200	200	250

Source: Haromaya Wereda Administration Office, 2011

The ever expansion of groundwater development creates a fear for the sustainability of the resource. For Alamirew and Beressa (2010), over-pumping of the groundwater is feared to have overarching adverse consequences. However the empirical investigations so far done in the area show that the resource is safe. According to Mohammed (2006), at present, the amount of natural recharge in the basin is more than the abstraction. Out of the mean annual rainfall of the study area (770.5 mm) 594.6 mm of the precipitation is lost as actual evapotranspiration. The amount of groundwater that is currently being used for domestic and non-domestic purposes in the watershed is 24.3 % of the total infiltration. The net total amount of water which is actually available to recharge the groundwater circulation within the Lake Haromaya watershed is 75.7 % of the total infiltrated water. And also Alamirew and Beressa (2010), in their estimation using Chloride Mass Balance (CMB) concluded that the groundwater resource of the area is safe as it stands.

Despite the evidence of safe stand of the resource, the study area is reportedly accused for the poor management of water resource and most literatures indicate that poor management of natural resource in the area claimde for the death of Lake Haromaya. For Mohammed (2006), at present, the problem is not lack of water; it is rather poor management of the resource could bring danger for the future generation as far as the resource is concerned. This is mainly due to lack of groundwater management regulation.

2.2. Groundwater Resource and its Optimal Use

Due to rapid growth of population the potable and other usages of groundwater raise the question of the sustainable use of the resource. As the Year of Planet Earth (2005) indicated demand for water is rising as population, economic activity and agricultural irrigation grows. However, worldwide resources of accessible water are decreasing, due to overuse or pollution. The balance between demand (consumption) and supply (resource) is becoming unstable. More than 30 countries suffer from serious chronic water shortage, and groundwater is increasingly being used to cover the demand.

To avoid this imbalance, Job (2010) suggested for safe yield method of using groundwater. Safe yield is defined as "the amount of water [that can be] withdrawn from [an] aquifer roughly equals the amount of water returning naturally or artificially to the aquifer over an extended period of time" and "can be withdrawn from the aquifer without producing an undesired effect".

By considering this threat, some correction measures are taken in some sectors but not in all sectors. According to Year of Planet Earth (2005), agriculture is the greatest single worldwide consumer of water (70%), followed by industry (20%) and homes (10%). Considerable efforts have been made to reduce consumption in industry and homes; but much remains to be done in improving the efficiency of irrigation.

The report also added that no matter what conservation measures are taken, the extraction of groundwater is largely unavoidable because it is considered as cost-effective water supply. Advances in drilling, well construction and pumping technologies - as well as increasing electrification in rural areas – mean that ever-increasing volumes of groundwater are being exploited or depleted without adequate planning.

US Geological Survey (2003) defined depletion of groundwater as a term often defined as long-term water-level declines caused by sustained ground-water pumping. And the depletion of water increases the following effects

I. As the depth to water increases, the water must be lifted higher to reach the land surface. Thus, power costs increase as groundwater levels decline. It may no longer be economically feasible to use water for a given purpose.

II. Reduced surface-water flows because in most areas, the surface- and ground-water systems are intimately linked.

III. Land subsidence: It is “a gradual settling or sudden sinking of the Earth’s surface owing to subsurface movement of earth materials.”

IV. Deterioration of water quality: Under natural conditions the boundary between the freshwater and saltwater tends to be relatively stable, but pumping can cause saltwater to migrate inland, resulting in saltwater contamination of the water supply.

To avoid these problems the use of groundwater should be on sustainable basis. Job (2010) provides the concept of sustainable development for the use of this resource. That states that sustainable development is “development that meets the needs of the present without compromising the ability of future generations to meet their own needs”.

Conrad (1999) also indicates that for the sustainable use of this resource spread sheet dynamic optimization can be used to gauge the optimal rate of the resource that can sustain to serve the present as well as the future generation. In this study the dynamic optimization of groundwater irrigation use is done based on the Conrad (1999) renewable resource optimal use manipulation based on spreadsheet optimization.

2.3. Financial Viability of Groundwater Irrigation Development

Groundwater could be harvested by digging wells. Water is conveyed using pump lines, a furrow or manually using beckets. Water will be applied to crops using various technologies. Whatever technology you use to store, convey or apply water is decided to cost benefit analysis (CBA), although it is not always applied.

According to Job (2010), many decisions related to the protection of groundwater in the 1970s and 1980s were not informed by a rigorous or systematic evaluation of costs and benefits. Now-a-days, cost benefit analysis is used as an information source as well as decision tool.

CBA is the mechanism used to compare the financial cost with the financial benefit or the economic cost with the economic benefit for decision rule. According to Curry and Weiss (1994), there are four main elements of a project resource statement: Investment cost, operating cost, working capital cost and benefits. All of them, most of the time, described at annual basis. What CBA does is compare these costs and benefits through the tools of financial or economic viability measures and provide information for decision.

CBA calculation for groundwater started back in 1936. Job (2010) explained that a principal basis of CBA is found in the United States Flood Control Act of 1936, stating an economic criterion of: “the benefits to whomsoever they accrue are in excess of the estimated costs” for projects to improve navigable waters, tributaries, and watersheds.

According to Gittinger (1982), in economic aspect of investment evaluation the focus is on the social costs and benefits of a project, which may often be different from its monetary or financial costs, and benefits. The financial analysis views the project form the participants (or owners) point of view, while the economic analysis form the society’s point of view. There are two methods for measuring the worthiness of investment: undiscounted & discounted methods. But two issues must be considered. First, there is no one best technique for estimating project worth; each has its own strength & weakness. Second, these financial and economic measures of investment worth are only tools of decision-making, i.e., they are necessary conditions & are not sufficient condition for final decision. There are many other non- quantitative and non-economic criteria for making final decision of whether to accept or reject a project.

Since the undiscounted measures of investment worthiness lack the consideration of taking time value of money into account the discounted measures are mostly used as a means of CBA. Curry and Weiss (1994) states that the most commonly used tools of the second category are Net Present Value (NPV), Internal Rate of Return (IRR) and Benefit Cost Ratio (BCR). All these are defined and explained in chapter three. Each has its advantage and disadvantage and needs to be used in a different ways for decision making. However, where resource statements are drawn up using the same information and assumptions, these three criteria yield the same decision for single investment.

According to Gittinger (1982), NPV states that the present value of expected future net cash flows, discounted at the costs of capital, less the initial outlay and IRR is the interest rate which equates the present value of cost and benefit. From the same category BCR denotes that the ratio of discounted values of benefits and costs.

The discounting project worthiness measurements are used for the valuation of investment in groundwater and surface water irrigation project in Ethiopia. Hagos et al., (2006) used these three criteria to evaluate the financial viability of irrigation development in ponds and wells and they have found that investment in both of them is financially viable in all criteria though the return is by far better for the latter.

Tesfay (2008) also use these three criteria to measure both financial and economic viability of investing on shallow wells, deep wells and ponds. From the investigation the former two are financially viable at 8 as well as 10 percent where as the later is nearly at breakeven at 10 percent though it is profitable at 8 percent.

Yirga (2011) in his study on Northern Ethiopia use these criteria for the evaluation of financial and economic viability of groundwater irrigation development for both from private investors' and public investment point of view. He concluded that groundwater irrigation development is economically and financially viable and it is an important tool for agricultural development process in northern Ethiopia.

Generally, many empirical investigations indicate that investing on irrigation development is financially viable. To check the financial worthiness of investing in groundwater irrigation development the above three measurement tools are used in this study. These are used in this study because of their advantage of giving weight for the time value of money during the evaluation of investment worthiness.

2.4. Value of Groundwater in Irrigation Use

It is known that agriculture is the major user of the world fresh water. Because of the expanding world population the fresh water available for human for various activities becomes scarce. This situation calls for the valuation of water resource for its proper use. Tsur (2005) indicated that water prices serve as signals of the value of the scarce resource and induce users of various sectors to utilize water accordingly. However, there is no universally agreed means of measuring water value. According to Tsur and Dinar (1997), the existing water pricing methods include;

Volumetric: Water is charged based on direct measurement of volume of water consumed. Variations of the volumetric approach include: (1) indirect calculation based on measurement of minutes of known flow (as from a reservoir) or minutes of uncertain flow (proportions of a flow of a river); and (2) a charge for a given minimal volume to be paid for even if not consumed.

Output/input: Irrigation water is charged on per output basis (irrigators pay a certain water fee for each unit of output they produce) or by taxing other inputs (irrigators pay a water fee for each unit of a certain input used).

Area: Water is charged per irrigated area, depending on the kind and extent of crop irrigated, irrigation method, the season of the year, etc. In many countries, water rates are higher when there are storage works (investment) than for diversions directly from streams. The rates for pumped water are usually higher than for water delivered by gravity. In some cases, farmers are required to pay the per area charges also for the non irrigated areas.

Block-rate: This is a multi-rate volumetric method, in which water rates vary as the amount of water consumed exceeds certain threshold values.

Two-part tariff: This involves charging irrigators a constant marginal price per unit of water purchased (volumetric marginal cost pricing) and a fixed annual (or admission) charge for the right to purchase the water. The admission charge is the same for all farmers. This pricing method has been advocated, and practiced, in situations where a public utility produces with marginal cost below average cost and must cover total costs (variable and fixed).

Betterment levy: Water fees are charged per unit area, based on the increase in land value accruing from the provision of irrigation.

Water markets: Such markets exist in different forms throughout the world. They may be formal or informal, organized or spontaneous. Their participants may trade water rights (e.g., the right to purchase some quantities of water at a particular price during specific periods of time), or they may trade water at the spot price or for future delivery. In some countries, markets for water or water rights have been formed and determine water prices.

In addition to the explained methods of water valuation, **Residual Imputation Method** is the most common and simple measure of irrigation water. According to Ashfaq, Jabeen, and Baig (2005), the technique for determining the shadow prices (for un-priced input) is called the

"Residual Imputation". The method is simple and, under certain specified conditions, is applicable for estimating the value of resources used in production.

Young (2005) also explained that if appropriate prices can be assigned to all inputs but one, and certain other assumptions are met, then the residual of the total value of product is imputed to remaining resource. Mesa-Jurado, Berbel, and Pistón (2005) also explained that this method try to value irrigation water as the residual of total value of output after deducting the whole outlay for the entire inputs included in the production system except water input.

Despite this method is very simple to value irrigation water, it has certain limitation (Young, 2005). These are

i. The problem of exact exhaustion of the total product.
ii. The question whether prices equal marginal value product except for the one whose value is being estimated.
iii. The problem of omitted variables (Are all inputs with positive MVP properly accounted for?).
iv. Problems of estimation when price supports, subsidies, or other exogenous influences are exerted on production.

This residual imputation method of valuation of groundwater is used in this study because of its simplicity and its information requirement for the analysis can be collected from sample households recall capacity.

2.5. Poverty, Poor and Income Distribution

The most common definition of poverty is in terms of money or money metric aspect. According to World Bank (2005), Poverty is "pronounced deprivation in well-being." The conventional view links well-being primarily to command over commodities, so the poor are those who do not have enough income or consumption to put them above some adequate minimum threshold. Poverty is absence or inadequacy of diets, amenities, standards and services which allow people to follow the customary behaviors which is expected of them by virtue of their membership of society (Tesfay, 2008).

In addition to the money metric measure of poverty there are wider scopes to measure human well being. According to World Bank (2005), the broadest approach to well-being (and poverty) focuses on the "capability" of the individual to function in society. The poor lack key capabilities, and may have inadequate income or education, or be in poor health, or feel powerless, or lack political freedoms. Many scholars try to measure this feature of the poor by different measures.

The most common measure of poverty measurement is head count ratio. According to Bardhan and Udry (1999), for a long time, the common practice in measuring poverty has been to count the numbers of people who fall below some poverty line (defined with varying degrees of arbitrariness) for income or consumer spending. Some adjustments are usually made to the poverty line in terms of changes in cost-of-living or household demographics. But this measure has a lot of short coming; it doesn't show us the severity of poverty as well as inequality among the poor. All people below the poverty line are treated equally i.e. those just below the poverty line and extreme poor are treated equally in this measure. The shortcoming of this poverty measure provokes scholar to find out other measures of poverty that can escape this pitfalls. Then literatures have therefore moved towards more sophisticated measures.

For a non-negative living standard indicator (say, consumption) *y* distributed with density *f(y)*, and with a poverty line *z*, the poverty measure *P* is given by

$P = \int_0^z \left(\frac{z-y}{z} \right)^{\alpha} f(y)dy \quad , \alpha \geq 0$ When α is 0, *P* is the same as the head-count measure; and when α is 1, *P* is what is known as the poverty gap index (therefore depending on the distances of the poor below the poverty line as well as on the number of the poor). As α increases, *P* becomes increasingly sensitive to the living standard indicator of the poorest people. (Foster, Greer, & Thorbecke, 1984).

Income distribution is a broader concept and it also a good measure of income inequality among different segment of the society. It is measure of distribution of wealth over different groups. According to World Bank (2005), inequality measures are often calculated for distributions.

The most common measures of inequality or income distribution are the Lorenz curve and the Gini-coefficient. The former, according to World Bank (2005), is the graphical measure of income inequality where as the later in the numerical expression of the former. In this study also the welfare comparison of groundwater irrigation users and non-users is done based on these two measures of poverty and inequality. The detail of these two measure also presented in chapter three because they are used for the analyses of household level poverty for groundwater irrigation users and non users. This method was selected in this study because it enables to measure the gap as well as the severity of poverty in addition to the head count measure.

2.6. Groundwater Irrigation Development and Poverty Reduction

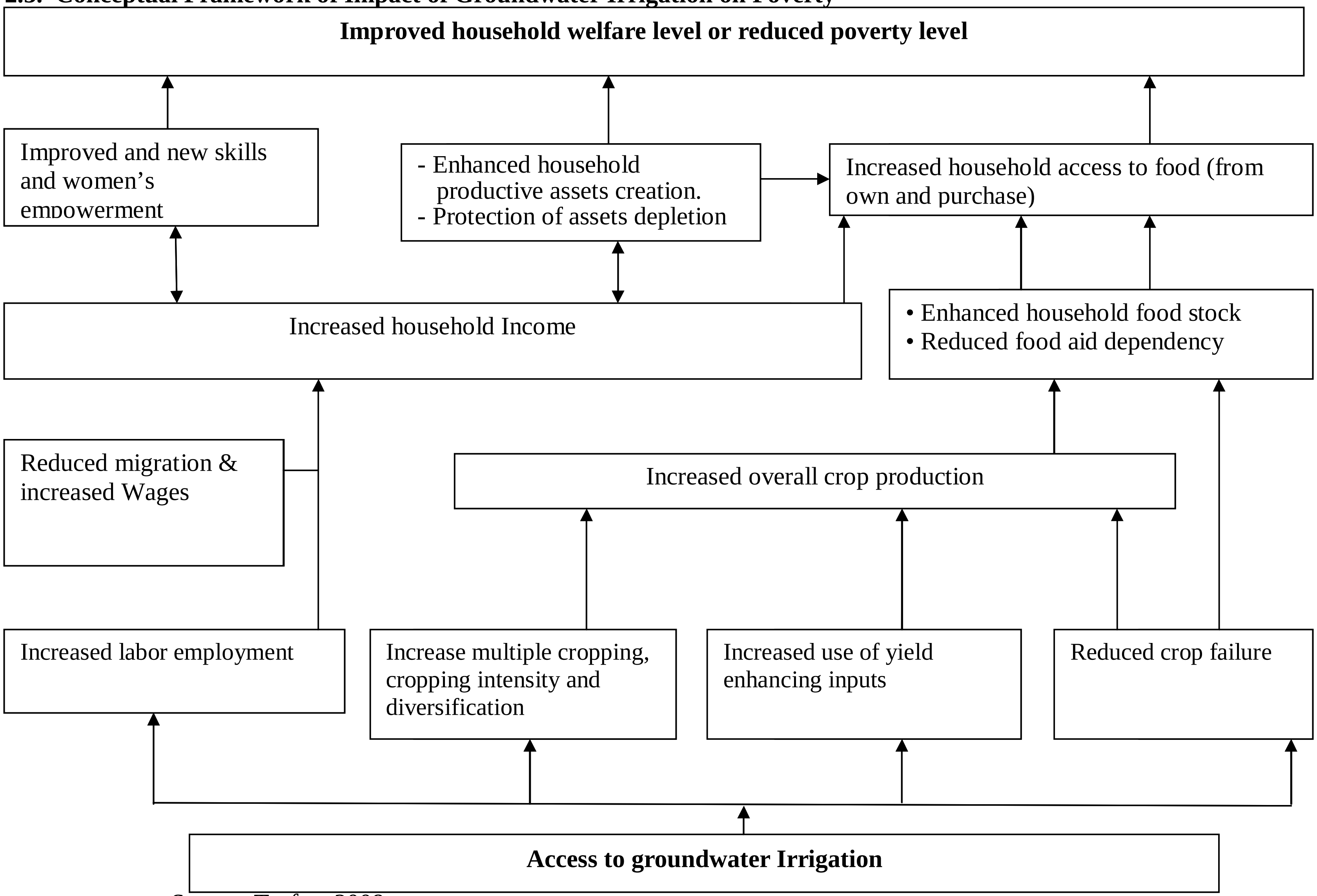
Despite the fact that there is consensus on tackling poverty is necessary to enhance the well being of the poor, there is no agreement which development strategy is best to achieve this goal. In addition to this disagreement, the equity and efficiency issue is one of the debatable issues in development strategy. As Bardhan and Udry (1999) explained, this issue is reflected in a running policy debate over the last twenty-five years on the relative importance of market driven growth trickling down to the poor versus a programme of massive and direct intervention to help the poor.

But because of the fact that the poor are not equally competent to share the benefit from the growth of a country due to various reasons, pro poor development strategies are necessary. Small scale groundwater irrigation development is one of the means of such intervention to tackle poverty. This is due to the fact that irrigation development has direct and indirect welfare impact on the users. Most literature focused on the direct benefits of increase crop yield and farm income (Tesfay, 2008). According to Hagos, Makombe, Namara, and Awulachew (2009), irrigation has both macro level as well as micro level impact. In the former level benefit irrigation investments act as production and supply shifters, as they push the production frontier to a higher level and render production possible and thereby have a positive effect on economic growth where as for the latter category benefit it enables smallholders to diversify cropping patterns, and to switch from low-value subsistence production to high-value market-oriented production. Hussain and Hanjra (2004) also explained the micro level benefit as irrigation can benefit the poor specifically through higher production, higher yields, lower risks of crop failure, and higher and all year round farm and non-farm employment.

Tesfay (2008) also constructed the conceptual frame work of these direct and indirect benefits of irrigation for the reduction of poverty which is illustrated in figure 2.1 below, which simplifies the analysis of linkage between irrigation and poverty.

Access to irrigation increase labor employment, it is due to the labor demand for the construction of irrigation and different agricultural activities which in effect reduce migration and increase wage consequently household income will be increased. The other direct benefits of irrigation is, increase overall production because of its contribution for multiple cropping, crop intensity, diversified crop production, increase use of yield enhancing input and reduce the risk of crop failure. The combined effects of the above benefits lead to enhanced household food stock and reduce food aid dependency. Increment of household income together with enhanced household food stock improve household welfare or reduce poverty through improvement and creation of new skill, women empowerment, enhance household production asset creation, protect household assets depletion and increase household access to food from both own product and purchased food items.

Fig 2.3. Conceptual Framework of Impact of Groundwater Irrigation on Poverty



Source: Tesfay, 2008

Like any other development strategies the result of groundwater irrigation development on eradication of poverty is mixed. According to Rosegrant and Everson (1992) (As cited in Tesfay, 2008), there is no positive relationship between reduction of poverty and irrigation development in India and China. Similarly Hagos *et al.*, (2006) confirmed that even though groundwater wells could be financially viable if they operate successfully, there is no strong statistical evidence for difference in welfare between groundwater irrigation users and non users in Northern Ethiopia.

In contrary to the aforesaid results there are a lot of literatures which explain a positive contribution of irrigation development for poverty reduction. Tesfay's (2008) result indicates that groundwater irrigation development, particularly deep well has significant role in alleviating poverty, increasing income, household productive assets building, and the creation of rural farm employment in Ethiopia. And he also confirmed that groundwater irrigation users have relatively less severe poverty as compared to the non users.

In addition to its direct contribution, groundwater development has income enhancing impact for the rural poor. As Tesfay (2008), explained groundwater development has the following impact on the rural labor. The first is irrigation facilities, like wells, require labor for their construction and maintenance. Secondly, increases in multiple cropping (both dry and wet season cultivation), cropping intensity, and crop diversification as a result of access to irrigation also motivate higher farm labor employment, in-migration and higher wage rates. Some of the above results are explained through descriptive statistics. The other approaches used in the study to compare the poverty impact of irrigation between users and non users are the Foster, Greer and Thorbecke (FGT) (Foster et al., 1984) and Propensity Score Matching (PSM). The study through its FGT poverty analysis confirmed that the incidence, depth and severity of poverty for deep well and shallow well irrigation farmers were significantly lower than non irrigation farmers in 2005/06 production year. Similarly in PSM, which incorporates nearest neighborhood and Kernel matching methods, deep well and shallow well irrigation households have significantly higher consumption expenditures per adult compared to the non irrigation user households.

CHAPTER THREE

RESEARCH METHODOLOGY

In this chapter the description of the study area, how data is collected, types of data, time and means of data collection is presented. In addition to this the detail description of methods and techniques of data analysis are presented.

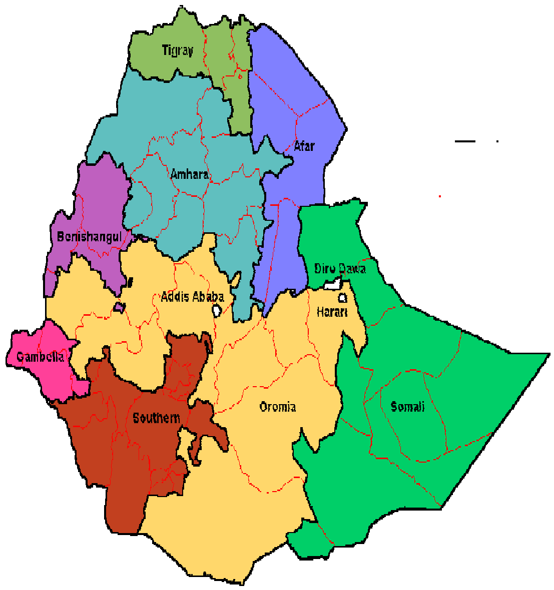
3.1. Description of the Study Area

3.1.1. Location and Physical Characteristics of *Haromaya Wereda*

Haromaya, which is situated in the eastern part of Ethiopia, is one of the *weredas (districts)* of East Hararge zone of Oromia regional state. It lies between 9^0 22' 03"- 9^0 27' 12" N latitude and 41^0 58' 14" – 42^0 05' 26" E longitude (Mohammed, 2006). It is situated on the main road from Addis Ababa to Harar town at a distance of 505 km from Addis Ababa and 20 km north-west of Harar town and the altitude of the *wereda* ranges between 1980 and 2343 m.a.s.l. (Harar Water Supply and Sewages Authority & Karamara Engineering Consultancy, 2006). Haromaya *wereda* is consists of 33 (13 of them are lowland) PAs and 2 kebelles (both of them are midland) and it is bordered by Kurfa chelle, Kersa, Dire Dawa, Kombolcha and Harari region in south, west, north, east and south east directions, respectively. This can be shown from the location map of the *wareda* in map 3.1.

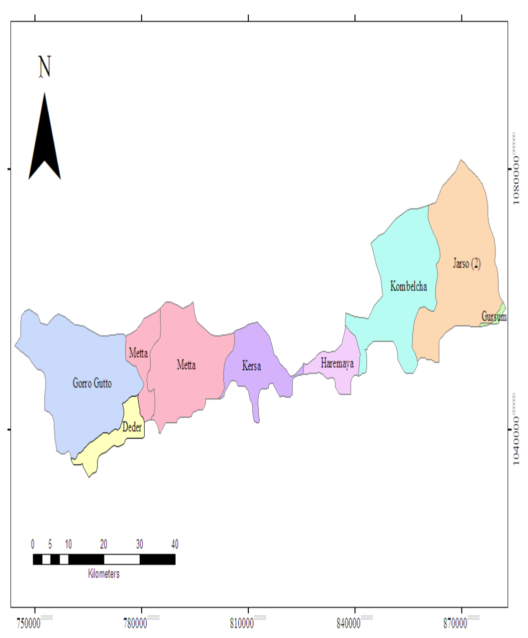
3.1.2. Demographic and Socioeconomic Characteristics of *Haromaya Wereda*

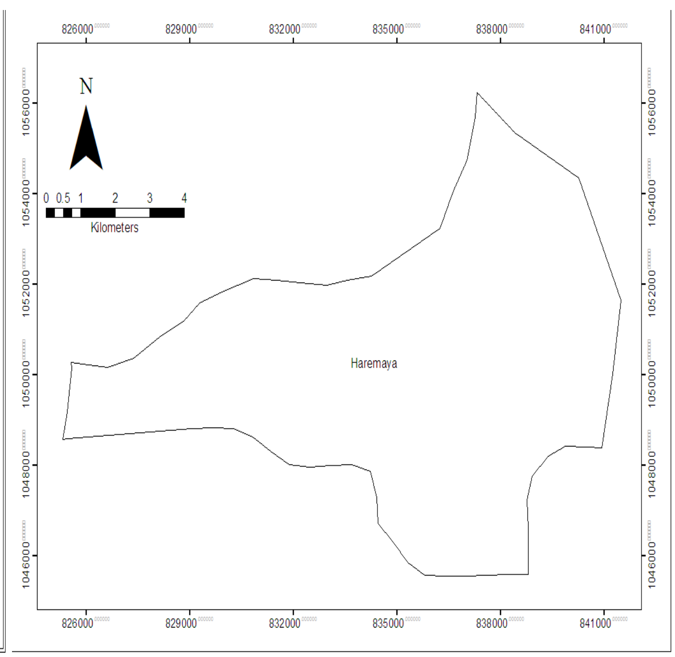
Haromaya *wereda* is 15^{th} populous *wereda* among 245 *weredas* of Oromiya regional state. But in terms of density it is the second in the regional state after Deder, which is also found in East Hararghe (Ethiopian Demography and Health Report, 2008). According to CSA Statistical Report of the 2007 Population and Housing Census, the *wereda* has a total population of 271,394. Out of which 138,376 (51 %) are male and 133,018 (49%) are female. The majority of the *wereda* population live in rural areas which constitute 220,408 (81.2%) of the total where as the urban dwellers are only 50,986 (18.8%) of the total. The great majorities of the households residing in the *wereda* are engaged in subsistence and cash crop agriculture and livestock rearing. Farming is practiced through rain fed as well as irrigation mainly to cultivate maize, sorghum, and chat (Harar Water Supply and Sewages Authority and Karamara Engineering Consultancy, 2006).



1. Geographical map of Ethiopia, in which Oromia regional state is shaded with yellow color

2. Oromia regional state map: East Hararghe zone is located in the most east of the region (purple color)





3. East Hareghe zone Location map: Haromaya *Wereda* is located in the center (light purple color)

4. Map of Haromaya *Wereda*

Sources: 1. http//www.ethiopiscollege.org.et 2. Demographic and health report, 2008
3 and 4: Adem, 2011.

Map 3.1: Location of the study area in Ethiopia

3.2. Methods of Data Collection

To satisfy the objectives of the research there are different quantitative analyses that are supported by various quantitative and qualitative data from primary and secondary data sources. One part of the analyses is identifying the quantifiable difference of well being between users and non users of groundwater irrigation. In addition, the optimal depletion rate, value and financial viability of groundwater are estimated. To have a comprehensive input for these analyses both primary and secondary data source are employed.

3.2.1. Primary Data Collection Methods

Primary data were collected using the following tools;

Household Survey: To investigate the livelihood difference between users and nonusers of groundwater irrigation structured interview schedule has been used that explains household detail, household expenditure, household asset base, mode of agricultural production, composition and type of agricultural output and source and amount of income of the household. It is known that, poor rural household do not keep records of their income and expenditure. So the household survey was entirely depending on recall method. In addition to the investigation done on home to home basis local market prices were used to calculate the revenue as well as expenditure of the subjected households.

For the survey structured questionnaire was used, its detail in English and oromifa (local language) is attached in annex 11 and annex 12, respectively.

Picture 3.1: Enumerator during the household survey

Key Informant Interview: In order to enhance the researcher knowledge about the area, to get some technical knowledge and to get better explanation about practice of groundwater irrigation that cannot be explained by farmers unstructured interview was used to gather information from the wereda's irrigation experts, agricultural bureau officers and most importantly from the development agents of different peasant associations.

Picture 3.2: Discussion with DAs of Damota PA

Focus Group Discussion (FGD): The study area is known for overnight chat chewing ceremony, locally called "Katira", on which large number of villagers assembles together and various social and economic issues are discussed. The researcher, enumerators and development agents (DAs) participated many times on the discussion and information about pros and cons of groundwater irrigation from both users and non users is gathered.

Picture 3.3: Focus Group Discussion During the night with farmers, enumerators and DAs

Direct observation: In addition to the aforesaid methods of primary data collection direct personal observation about asset holding, dwelling, mode of irrigation and other indicators of well being have been directly observed by the researcher. Some of these are supported by photographs.

3.2.2. Secondary Data Collection Method

Secondary data sources are also used as an input for the analyses of some objectives and to scrutinize the research gap regarding the subject. The secondary data, which was collected by different participants in IWMI's assessment of groundwater overdevelopment in Eastern Ethiopia, has been also used intensively in the quantitative data analysis. In addition, reports of Haromaya Wereda Administrative Bureau and Haromaya *Wereda* Agriculture Bureau, documents from Haramaya University library, different publication of IWMI and World Wide Web are used as source of secondary data.

3.3. Sampling Technique for Household Survey

Haromaya wereda is purposefully selected because of it groundwater potential and its extensive use. Recently it was reported that up to 6,000 new wells have been constructed in the *wereda* and its neighboring *wereda,* Kombolcha (Mr Taye Alemayehu, pers comm. May 2011). The *Wereda* is classified in two agro ecological zone namely '*Woina Dega*' (mid highland) and '*Kolla*' (low land). In order to make the sample very representative for the *wereda* two peasant associations (PAs) have been incorporated, one from each agro ecological zones. But during selection of the PAs those who have lower utilization experience (8 from low land and 3 from midland) were purposefully excluded. And two PAs, Damota from the midland and Malka Gemechu from the low land have been selected randomly.

The number of households who are users of groundwater irrigation are very few as compared to non users**.** In terms of number, from the total 1074 households in Damota PA only 250 have groundwater well whereas in Melka Gemechu out of the total 1053 households only 206 of them have groundwater well. Therefore, instead of following proportional sampling for each group, the researcher has found it more useful to take a sample size of 50% from irrigation users and 50% from non user, which was done to increase the share of groundwater irrigation users in the sample for the analysis. During the analysis, this is corrected by applying corresponding sampling weights for all observations, which is assigned for each observation based on the calculation of quotient of percentage in the population and percentage in the sample. Based on the manipulation the groundwater irrigation users received the weight of 0.47 ($\frac{\frac{250}{1074} X100}{\frac{50}{100} X100}$) and 0.40 ($\frac{\frac{206}{1053} X100}{\frac{50}{100} X100}$) in Damota and Melka Gemechu, respectively. By the similar procedure the non users received the weight of 1.53 ($\frac{\frac{824}{1074} X100}{\frac{50}{100} X100}$) and 1.6 ($\frac{\frac{847}{1053} X100}{\frac{50}{100} X100}$) in Damota and Melka Gemechu, respectively. Since STATA has an advantage of incorporating the weight option in all matching estimation, regression and FGT models, the corresponding sampling weights have been incorporated during the analysis in all analyses with the exception of descriptive statistics, which has no weight option.

From each peasant association 50 irrigation users and 50 non users or 200 households from the two PAs have been selected. Those households have been randomly selected from the list of households which is available in the selected peasant association DA offices after users and non users had been identified by DAs.

3.4. Methods of Data Analysis

3.4.1. Optimal Depletion Rate of Groundwater from the Well

One of the specific objectives of this study is the valuation of optimal rate of groundwater depletion. In this research, Microsoft excel spreadsheet has been employed for the determination of the optimal use of groundwater extraction and compare it with the current state of the resource exploitation. This spreadsheet model of optimization that has been used in this study has the following brief procedures (Meissner & Nguyen, 2010).

Specifying the Objective Function

Objective function is a function that is to be optimized in an optimization problem. In the context of this research the objective function is the present value of cumulative net benefit from the abstraction of groundwater for irrigation purpose. It can mathematically be defined as

$PVNB_t = \pi(Y_t, X_t) = \rho^t(pY_t - cY_t / X_t)$ where

t is time period in years,

$PVNB_t$ is the present value of net benefit at time t,

ρ discounting factor,

Y_t is the abstraction amount of groundwater for agricultural use at time t,

X_t is the stock of groundwater and

p and c are a per unit price and cost of groundwater when it is used for irrigation

The objective is maximizing the cumulative benefit of each year benefit from the use of groundwater for irrigation purpose.

Specifying the Decision Variables

This stage requires identification of variables which are involved in objective function as well as in the constrained function of groundwater utilization. The decision variables involved in the spreadsheet are stoke of groundwater in liters, the growth rate of stoke, the amount of water abstraction, years, price and cost of a unit of groundwater, discount rate and discounting factors. The data for these required variables for the dynamic optimization problem are gathered from the household survey and the secondary data sources which are explained before.

Specifying the Constraint

The restraints are available in terms of physical resource that must be considered during optimization of the objective function of groundwater abstraction. In our optimization problem the restrictions are the amount of abstraction and stoke of the resource should be non negative. In addition, it is assumed that the resource is renewable resource or it should be positive at the final year we considered in the spreadsheet dynamic optimization.

Solve the Model

The spreadsheet model finally optimize the rate of groundwater depletion that maximize the cumulative net present value which is obtained from the resource abstraction either through graphical user interface method or writing commands. In this study the graphical user interface has been used because it is more convenient. The final step of the optimization technique is to find the optimal value for $PVNB = \sum_{t=0}^{t=20} \rho^t (pY_t - cY_t / X_t)$ through excel solver.

3.4.2. Economics of Groundwater Wells/Financial Viability

To answer the question of financial viability of investing on groundwater irrigation development different measurement techniques are employed. Because of its consideration of time value of money the paper gives due emphasis for the discounting measure for the evaluation of worthiness of well construction from the financial point of view.

Discounting is essentially a technique that changes future benefits and costs to their 'present worth'. The rate used for discounting is called discount rate. This valuation technique requires setting of the discount rate for both financial analysis and economic analysis. The most common methods of discounting measures of project worthiness have been used in this study.

3.4.2.1. Net present value

The net present value of an investment proposal is the present value of expected future net cash flows, discounted at the costs of capital, less the initial outlay. As per Gittinger (1982) mathematical notation;

$$NPV = \sum_{t-1}^{n} \frac{At}{(1+r)^t} - I$$

NPV= net present value

A_t = net cash flow for the year t

I = cost of capital for the establishment of well

n = life of the well

Curry and Weiss (1994) states that the decision criterion using the NPV can be expressed formally as; at a discount rate r, if NPV>0, accept the project proposal and if NPV< 0, reject the project proposal. Where as if NPV=0, the project will have no net effect whether it is accepted or not.

3.4.2.2. Internal Rate of Return (IRR)

The internal rate of return is defined as the rate of discount, which brings about equality between the present value of future net benefits and initial investment. It is the value of *r* in the following equation. As per Gittinger's (1982) mathematical notation;

$$I = \sum_{t=1}^{n} \frac{At}{(1+r)^t}$$

I = investment cost

A_t = Net benefit for year t

r = IRR

n = Life of the project

According to Curry and Weiss (1994), the decision rules for this discounting measure are if IRR is greater than the considered interest rate accept the project proposal and if IRR is less than the considered interest rate reject the considered project. On the other hand if IRR is equal to the considered interest rate the project will have no net effect whether it is accepted or not.

3.4.2.3. Benefit Cost Ratio

The third discounted measure of well establishment worth is the benefit-cost ratio. This is the ratio obtained when the present worth of the benefit stream is divided by the present worth of the cost stream. The mathematical formula is given below as per Gittinger (1982).

$$B-C = \frac{\sum_{t=1}^{n} \frac{Bt}{(1+r)^t}}{\sum_{t=1}^{n} \frac{Ct}{(1+r)^t}}$$

Where - B_t = are the benefits in period t

C_t = are the costs in period t

n = project life

r = discount rate

The formal selection criterion for the benefit-cost ratio measure of well worth is to accept all independent well constructed with a benefit-cost ratio of 1 or greater.

3.4.3. Residual Imputation Method

For the valuation of groundwater, which is used for irrigation, the study uses the residual analysis with great care to minimizing its limitations explained in the second chapter. It is a method of assigning the residual value of total output after assigning their respective values for all inputs included in the production system except the water that has been considered. According to Young (1979), if appropriate prices can be assigned to all inputs but one, and certain other assumptions are met, then the residual of the total value of product is imputed to remaining resource.

Mesa-Jurado, Pistón, Giannoccaro, and Berbel (2008) explained that the hypotheses underlying the residual value method are part of the neoclassical economic theory, i.e. producers maximize profits and the total value of the product may be assigned to each input according to the marginal productivity.

Mathematically expression of the production function

$$Y = f(X_M, X_{lab}, X_K, X_L, X_W) --------------------- (1)$$

Where Y is aggregate output, X_M is all material inputs which includes seed, fertilizer and pesticide, X_{lab} is labor input both family labor and hired labor, X_K capital input X_L is land input and X_W is water input.

From the above the total value of output can be

$$(Y.P_Y) = (MVP_M.X_M) + (MVP_{lab}.X_{lab}) + (MVP_K.X_K) + (MVP_L.X_L) + (MVP_W.X_W) --- (2)$$

Where $Y.P_Y$ is the total value of output and MVP_i is the marginal value product of each factor. Based on the assumption of total value of the product may be assigned to each input according to marginal productivity or based on other hypothesis of profit maximizing behavior, therefore we deduce the optimum solution as the point where farmer will consume each factor up to $MVP_i = p_i$. This consideration reduced equation (2) into the following form

$$(Y.P_Y) = (P_M.X_M) + (P_{lab}.X_{lab}) + (P_K.X_K) + (P_L.X_L) + (P_W.X_W) ------------- (3)$$

From equation (3) it is possible to find out the value of water as a residual value if the value of output and the value of all other inputs are determined correctly. The value of water becomes $(Y.P_Y)-(P_M.X_M)-(P_{lab}.X_{lab})-(P_K.X_K)-(P_L.X_L)=(P_W.X_W)-------(4)$ and the price of water through the straight forward computation becomes

$$P_W=\frac{(Y.P_Y)-(P_M.X_M)-(P_{lab}.X_{lab})-(P_K.X_K)-(P_L.X_L)}{X_W}------------------(5)$$

3.4.4. Estimated Impact of Groundwater Irrigation

Impact evaluation is used to measure the average difference of welfare indicator variable, which is expenditure per adult equivalent, between groundwater irrigation users and non users. It serves to answer the question what is the quantified effect of a certain program with respect to the outcome variable. This evaluation is difficult because of the requirement of double existence of individual or group in order to measure the gap which is created by the intervention. However, double existence of individuals or group is hardly possible. As Khandker, Gayatri, and Hussain (2010) explained the difficulty of double existence, the main challenge of an impact evaluation is to determine what would have happened to the beneficiaries if the program had not existed. That is, for example, one has to determine the per capita household income of beneficiaries in the absence of the intervention. It has a problem of missing data.

In order to solve this problem of impact evaluation recent literature use propensity score matching which is developed by Rosenbaum and Rubin in 1993 (Tesfay, 2008). Propensity score matching (PSM) uses non-parametric regression methods to construct the counterfactual under an assumption of a selection on observables.

3.4.4.1. Impact Measurement Using Matching Estimator

The paper has used matching method on propensity score, which helps to solve impact evaluation problem of groundwater irrigation use. The common feature of all types of treatment evaluation is, they face the problem of finding valid counterfactual, which was solved by propensity score matching (PSM). For Becker and Ichino (2002), PSM is a way to “correct” the estimation of treatment effects controlling for the existence of confounding factors based on the idea that the bias is reduced when the comparison of outcomes is performed using treated and control subjects who are as similar as possible.

As Becker and Ichino (2002) explained, since matching subjects on an n-dimensional vector of characteristics is typically unfeasible for large n, this method proposes to summarize pre-treatment characteristics of each subject into a single-index variable (the propensity score) which makes the matching feasible.

In this analysis, two groups of households are compared. The first group of household who are entitled for groundwater irrigation and actually have are considered as treatment group where as other group of household who are entitle to have but actually they have-not are considered as a control group. The two groups of people who have similar household observable characteristics are used for the matching strategy.

For the evaluation of impact, average treatment effect is three types viz; average treatment effect on treated (ATT): which indicate average impact of the program for those exposed to it, algebraically denoted by $\overline{ATT} = \frac{1}{N_T}\sum_{i=1}^{N_T}\left(y_i^T - y_i^C \mid T\right)$. The average treatment effect on the untreated (ATU): program impact among those who have not been treated, which is denoted by $\overline{ATU} = \frac{1}{N_c}\sum_{i=1}^{Nc}\left(y_i^T - y_i^C \mid C\right)$ and average treatment effect (ATE): the most commonly used treatment effect definition, which is corresponding to average program effect for the entire population and its mathematical denotation is $\overline{ATE} = \frac{1}{N}\left[\sum(y_i^T - y_i^C \mid T) + \sum(y_i^T - y_i^C \mid C)\right]$. However the study uses the first one for comparing the impact of groundwater on the users and non users by using the tools of PSM.

The outcome variable used in the PSM estimation is total expenditure per adult equivalent, which is the quotient of total expenditure and household size per adult equivalent. The adult equivalent is calculated based up on the rate adopted from Dercon and Krishnan (1998) which is attached in annex table 1.

PSM relies on the two assumptions of matching which are unconfoundedness and overlap (Moreno Sera, 2007).

Unconfoundedness assumption, also called as independent of irrelevant alternatives (IIA), explained that exposition of individuals for groundwater irrigation is independent of his/her potential outcome. It is very crucial in the evaluation of impact. This assumption provide strong support for matching based on propensity score is the same as matching based on covariate or observable household characteristics (Moreno Sera, 2007).

The second assumption is ***over lap*** assumption, which indicates if there are treated and untreated individual or households who are exposed to groundwater irrigation and those who are not, there must be overlap between treatment (or user) and comparison(or non users) samples based on observable characteristics. This is formally what we call *common support*. Imposing the common support condition in the estimation of the propensity score may improve the quality of the matches used to estimate the ATT (Becker & Ichino, 2002). The common support area is the area where the propensity score of participant and non participant are overlapped.

Despite the fact that matching estimation of average treatment effect can be done by matching on **covariates** or based on observed characteristics, such kind of matching suffer from inequality of treated and untreated in the common support and consequently discard unmatched observation which has a problem of loss of information. With rich data set this method is very appropriate (Moreno Sera, 2007).

The binary choice model (Becker & Ichino, 2002; Wooldridge, 2000) provides the opportunity to identify the probability of participation on our subject of the study in our case the probability of having groundwater irrigation access. The dependent variable regresses up against the observable household characteristics.

In this research the logit model has been used for the estimation of the probability of having well or not based on observable household characteristics. In other words possession of well regress up against agro-ecology, sex of household head, age of household head and its square, education of household head, family size, consumer worker ratio, number of agricultural hand tools per workers.

This is done for by combining borehole and shallow wells to describe access to groundwater irrigation. In addition, boreholes and shallow wells irrigation were used separately to define access after the test of structural difference between the two well strucres is made using likelihood ratio (LR) test.

To test for pooling states, for our case pooling the households who have shallow well and those who have borehole, is to test for the equality of all regressor coefficients apart from the intercept. Mathematically for any two states *s* and *b*, to test the null hypothesis $\tilde{\beta}_s = \tilde{\beta}_b = \tilde{\beta}_w$ which indicates that the coefficients of shallow well, borehole and the well in combination are equal. This can be done by the straight forward likelihood ratio test. The mathematical definition of the likelihood ratio (LR) test statistic (Wooldridge, 2000; Gujarati, 2004; Cramer, 2003) is $\lambda = 2[LL_U - LL_R]$ with U and R for the unrestricted and the restricted models respectively.

The program *pscore.ado*, which is used in this analysis, estimates the propensity score and tests the balancing hypothesis (Becker & Ichino, 2002). Acoording to them the steps of the algorithm which *Pscore.ado* follows are:

1. Estimate a binary choice model, it is logit in this research,
2. Split the sample in k equally spaced intervals of the propensity score, where k is determined by the user and the default is 5,
3. Within each interval test that the average propensity score of treated and control units do not differ,
4. If the test fails in one interval, split the interval in halves and test again,
5. Continue until, in all intervals, the average propensity score of treated and control units do not differ,
6. Within each interval, test that the means of each characteristic do not differ between treated and control units. This is a necessary condition for the balancing hypothesis and
7. If the means of one or more characteristics differ, inform the user that the balancing properties are not satisfied and that a less parsimonious specification of $h(x_i)$ is needed.

Finding the propensity score for each observation is not enough for ATT. According to Becker and Ichino (2002), the probability of observing two units with exactly the same value of the propensity score is in principle zero since $p(x)$ is a continuous variable. So we should look at into other alternatives.

For many literatures there are four types of matching mechanism which overcome the aforementioned pitfall. According to Khandker *et al.*, (2010), the estimators are denoted by $\overline{\beta}_{PS}^{ATT} = \sum_{i \in \{T \cap S^*\}} (y_i^T - \overline{y}_j^C) \frac{1}{N_T^*}$. In each case the method of choosing comparison group is differing how they define the "closeness". Those four types of matching estimators that define "closeness" differently are presented here under and all are used in the matching estimates of ATT in this study. They are;

Nearest neighbor matching: method of taking outcome groundwater irrigation of the closest comparison denoted by $M_i = \{ j \in C \mid j = \min \| P_i - P_j \| \}$, where $\| P_i - P_j \|$ represent the Euclidian distance. The method tries to match one treatment group individual with that of the control group individual which is the nearest of all that is measured in absolute value. However, this matching technique suffers from biasness which is arising from the possibility of matching very different propensity score of groundwater exposure.

The other alternative matching techniques is ***radius/caliper method*** which can minimize the pitfall of the previous technique by introduce tolerable level of distance and the match of individual i can be denoted by $M_i = \{ j \in C \mid j = \min \| P_i - P_j \| < \varepsilon \}$ where $\varepsilon \succ 0$, tolerable distance, determined by the researcher's subjective judgment.

The third type is ***stratification or interval matching***: In this method, first the common support area divided into different strata and then calculates one mean treatment effect for each interval. If we consider only the treated the result is ATT where as if we consider all in the interval ATE. Assume if we divide the common support into finite number of strata ATT for interval number k can be denoted by $\overline{ATT}_k = \left(\sum_{i \in k} y_i^T \frac{1}{N_{T \in k}^*} \right) - \left(\sum_{j \in k} y_j^c \frac{1}{N_{C \in k}^*} \right)$ and consequently the overall ATT will be given by; $\overline{\beta}_{IM}^{ATT} = \sum_{k=1}^{I} \left(\overline{ATT_k} \ X \ N_{T \in k}^* \right) \frac{1}{N_T^*}$. It is the non-parametric estimation of ATT.

The final matching technique considered in this study is ***Kernel or local linear matching***. Its matching criteria is $M_i = \left\{ j \in C \,|\, \left| \frac{P_i - P_j}{h} \right| \leq 1 \right\}$, where h the band width and greater weight placed on comparison observations with propensity score closer to P_i. This means that all treated are matched with a weighted average of all controls with weights that are inversely proportional to the distance between the propensity scores of treated and controls (Becker and Ichino, 2002).

According to Moreno Sera (2007) the estimate based on this method or criterion is represented by $\overline{\beta}_{KM}^{ATT} = \frac{1}{N_T^*} \sum_{i \in \{T \cap S^*\}} \left(y_i^T - \frac{\sum_{j \in C(P_i)} y_j^C K\left(\frac{P_j - P_i}{h_n} \right)}{\sum_{j \in C(P_i)} K\left(\frac{P_j - P_i}{h_n} \right)} \right)$.

These four methods have their own estimated value but none of them are universally advantageous over the others. So the researcher found it advantageous to use them in combination.

3.4.4.2. Poverty and Inequality Measurements

For the analysis of poverty and inequality which decompose into groups of groundwater user and non Foster, Greer and Thorbecke (FGT) (Foster et al., 1984) and Gini-coefficient have been utilized to measure inequality (World Bank, 2005). The former can be used after the determination of poverty line; if the household spend below it a household is considered as poor because that expenditure is insufficient to meet the food and other basic needs requirement that is considered as a minimum subsistence level. The poverty line which is used in this study is Bogale's (2011) estimate of poverty line for Eastern Hararghe. The mathematical notation of poverty can be expressed as:

$$P_\alpha = \frac{1}{N} \sum_1^N \left(\frac{G_i}{z_i} \right)^\alpha, (\alpha \geq 0), \text{ where}$$

$P_\alpha = poverty \quad measure, \quad z = poverty \quad line,$

$G_i = the \ difference \ between \ income / \exp enditure \ per \ capita \ and \ poverty \ line,$

$N = Total\ \ population$

$\alpha = weight\ \ attached\ \ to\ \ the\ \ severity\ \ of\ \ \ poverty$

The commonly used values of α are 0, 1, and 2. When we set α equal to 0, P_0 indicates the headcount ratio, which measures percentage of population that falls below the stated poverty line for their living.

On the other hand, when we set α equal to 1 and 2, we obtain the poverty gap and severity of poverty index respectively. They are also denoted by P_1 and P_2. The latter two, unlike the head count measure have the advantage of giving more weight for the poorest segment of the group.

Gini-coefficient is the most widely used single measure of inequality (World Bank, 2005). It is an extension of the Lorenz curve analysis of inequality. Gini-coefficient provides a numerical value of the quotient of area A and the summation of area A and B i.e. $\frac{A}{A+B}$. The higher the value means the farther the curve from the perfect equality line that indicates there is unequal income distribution for the group or the country. It is graphical representation is discussed in the discussion part.

3.4.4.3. Correlates of Poverty

After quantifying the impact of groundwater irrigation on users as compared to the non users using matching, and estimating poverty and inequality indices, the study identifies correlates of livelihood of households by controlling various covariates, including access to groundwater, using OLS regression. The most commonly used indicator of household well being is the log value of the ratio of household expenditure and the general poverty line. As per World Bank (2005), typical multiple regression equation, as applied to poverty analysis, would look something like this: $\log(y_i / z) = \alpha_0 + \alpha_1 X_i^1 + \alpha_2 X_i^2 + ... + \alpha_n X_i^n$ where z is the poverty line, *yi* is (per capita) income or consumption, the X_j^ns are the "explanatory" variables or correlates of poverty and the α_j are the coefficients that are to be estimated. These coefficients in the above equation are the partial correlation coefficients that reflect the degree of association between the variables and level of welfare and not necessarily their causal relationship (Hagos et al., 2006). The *yi/z* is in log form, which is a common way of allowing for the log normality of the variable.

The most common determinants or correlates of poverty mainly categorize into community level determinants, household level determinants and individual level determinants. The explanatory variables that are used in this regression analysis are; land holding, live stock in Tropical Livestock Unit, non farm income, agricultural hand tools per worker, sex of household head (dummy), years of education for household head, number of adult male, number of adult female, consumer-worker ratio, age of household head, age of household head square, agro ecology (dummy) and distance to the nearest market.

As a complimentary for this analysis the multicollinearity test based on Variance Inflation Factor (VIF) and specification tests have been done. According to Gujarati (2004), VIF shows how the variance of an estimator is inflated by the presence of multicollinearity. It is defined as $VIF_j = \frac{1}{(1-R_j^2)}$ where R_j^2 is the coefficient of determination that is obtained when the continuous explanatory variable is regressed against all the other explanatory variables. When VIF increases with R_j^2 collinearity will increase. According to Gujarati, as a rule of thumb, if the VIF of a variable exceeds 10, which will happen if R_j^2 exceeds 0.90, that variables are said to be highly collinear.

CHAPTER FOUR

4. RESULTS AND DISCUSSIONS

4.1. Descriptive Statistics of the Survey Data

4.1.1. Demography and Socioeconomic Characteristics of the Study Area

In this part of the study attempt has been made to describe the detail about the characteristics of households included in the survey, their social indicators and variables that indicate their economic status.

In this part of descriptive statistics more emphasis is given to household demographic characteristics like family size, age of household head, number of dependent family member, number of male adult, number of female adult, number of actively working member, consumer-worker ratio. This is analyzed under the category of the all sample based on users and non users and also users and non user with the same agro ecological zone.

The respondents included in the survey have years of age ranges from 16 to 80. From which 68% or 136 of them are within the age range of 30 or more. Regarding to the gender base classification 8 (4%) of the respondents are female headed household. Average household size of the study area is 5.8 which is larger than the 4.9 national average rural family size of CSA (2008). The result is in line with Ethiopian Demography and Health Report (2008), which ranks the *wereda* one of the densely populated areas of the country and the second densely populated *wereda* in the regional state.

From the two agro-ecological zone included in the study the midland (Damota) has slightly larger average household size (6.4) as compared to the lowland (Melka Gemechu) average household size (5.19). This may be due to the conducive climate nature of the midland. From the total family size adult constitute 45 % on average, from which male adult take the larger proportion throughout the study area (percentage of average adult member (2.63) from the total family size).

In terms of active participation in own farm or outside work, the overall sample has an average size of 2.76 that is slightly smaller than Damota's average but larger than Melka

Gemechu's average, in which they have registered an average size of 3.07 and 2.46 respective. Throughout the survey area a single actively working member supports more than two consumers. From the overall survey for a single actively working member there are 2.47 consumers on average, which is slightly smaller than Damota's average but larger than Melka Gemechu's average. All the difference in demographic variable between the two PAs are significant with the exception of consumer worker ratio as it tabulated here under in table 4.1.

Table 4.1: Demography of the Household Based on Agro Ecology

Indicator variables	Description	All	Damota	Melka Gemechu	t-test
Average Family size	All dwellers in the household	5.8 (0.17)	6.4 (0.16)	5.19 (0.19)	3.79***
Average Family size per adult equivalent	Family size after adult equivalent conversion	4.82 (0.15)	5.39 (0.24)	4.26 (0.17)	3.86***
Average number of dependent member	Members who are not involved in farm and outside work	3.03 (0.16)	3.34 (0.26)	2.72 (0.17)	1.99**
Average Adult Member	Members above the age of 18	2.63 (0.11)	3.13 (0.19)	2.13 (0.09)	4.76***
Average Number of male adult	Male members above the age of 18	1.42 (0.08)	1.75 (0.13)	1.10 (0.08)	4.35***
Average Number of female adult	Female members above the age of 18	1.21 (0.05)	1.38 (0.10)	1.03 (0.03)	3.46***
Average Number of Actively working member	Members who are involved in farm and outside work	2.76 (0.11)	3.07 (0.19)	2.46 (0.10)	2.80***
Average Consumer-Worker ratio	The quotient of family size and actively working member	2.45 (0.11)	2.63 (0.2)	2.27 (0.09)	1.61

** significant at 5 %   ***significant at 1%

Source: Own Sample Survey, 2011

With respect to the type of irrigation technology they use demographic characteristics of the households are presented below in table 4.2. It reveals that on average variables like family size, dependent member, total adult member, male adult member and actively working member irrigation users registered larger value than the non users but the two demographic variables female adult member and consumer worker ratio is larger for rain fed dependent households. This indicates that household with larger number of actively working and adult member are better in adoption of groundwater irrigation technology. However the two types of irrigation i.e., shallow well and borehole groundwater users have relatively comparable value regarding to these demographic variables.

Table 4.2: Demography of the Household Based on Access to Irrigation

Indicator variables	Borehole owners (n=41)	Shallow well owners (n=53)	Rain fed (n=100)
Average Family size	6.09 (0.23)	6 (0.36)	5.56 (0.23)
Average number of dependent member	3.38 (0.32)	2.93 (0.28)	2.89 (0.22)
Average Adult Member	2.68 (0.25)	2.7 (0.20)	2.58 (0.14)
Average number of male adult	1.49 (0.16)	1.59 (0.18)	1.33 (0.09)
Average number of female adult	1.19 (0.11)	1.12 (0.06)	1.25 (0.08)
Average Number of Actively working member	2.72 (0.17)	3.07 (0.33)	2.67 (0.13)
Average Consumer-Worker ratio	2.45 (0.15)	2.38 (0.20)	2.49 (0.18)

Source: Own Sample Survey, 2011

As far as educational level of users and nonusers are concerned, there is more number of illiterates for non users. In this regard Melka Gemechu has larger number of illiterate than Damota. In elementary education larger proportion is from irrigation users throughout the study. However, households with secondary and higher education larger proportion is from rain fed dependent farmers (see table 4.3).

Table 4.3: Education of the Household Based on Area

Indicator variables	All		Damota		Melka Gemechu	
	User	Non users	User	Nonusers	Users	Nonusers
Number of illiterate	49	64	16	20	33	44
Elementary	42	32	28	26	14	6
Secondary	3	2	3	2	0	0
Above secondary	0	2	0	2	0	0

Source: Own Sample Survey, 2011

From the above table those who have better education involve in non-farm activities and they didn't spent enough time in their farm for the groundwater irrigation adoption.

Economic related variables like average asset holding, average agricultural hand tools, agricultural hand tools per worker and number of live asset in terms of Tropical Livestock Unit (TLU), which is adopted from Mukasa-Mugerwa (1981) as per the detail in annex table 2, are significantly higher for groundwater irrigation users than the non users. However there is no significant difference in average land holding between the two groups as the detail is presented below in table 4.4.

Table 4.4: Economic Indicators Based on Area

Item	Combined N=194	User N=94	Nonuser N=100	Mean Difference	t-value
Average total Asset Holding (Birr)	179,695.8 (7319.22)	223,828.7 (10880.83)	138,211 (7885.762)	85,617.72 (13320.18)	6.4277***
Average Land Holding (ha)	0.56 (0. .02)	0.58 (0.034)	0.55 (0.03)	0.036 (0.03)	0.76
Average Agricultural Hand tools (number)	5.17 (0.2)	5.86 (0.33)	4.52 (0.23)	1.34 (0.4)	3.38***
Average Agricultural Hand tools per Worker	2.2 (0.09)	2.37 (0.13)	2.05 (0.13)	0.32 (0.19)	1.72*
Live stock in TLU	1.86 (0.09)	2.09 (0.14)	1.65 (0.11)	0.43 (0.18)	2.4***

*significant at 10 %   *** significant at 1%

Source: Own Sample Survey, 2011

4.2. Groundwater Irrigation Practice in the Study Area

For the all households included in the survey groundwater irrigation is used in the case when the rain fall is relatively scarce, which indicates that irrigation technology is complementary rather than substitute for rain fed agriculture for smallholder farmers in the area. It was confirmed by the *wereda* irrigation experts and farmers during the survey.

In the area, groundwater irrigation practice has been started few years ago, according to the explanation of the area development agents. In Damota the effort to tap the water is not hard as compared to the Melka Gemechu. It may be due to the altitude advantage of the former that the groundwater can be reach within a few meters below their feet in most cases. It may also has some geological reason. Due to this reason the way they protect the well very different from the Melka Gemechu. In Damota, since it is relatively less tiresome task to tap the water their effort to construct protection for the well is not common. On the other hand in Melka Gemechu most of the wells are prepared with the formal retaining wall that can protect the well structure for longer period. The common types of well structure in the two PAs are shown below in picture 4.1.

Picture 4.1: One of well prepared groundwater wells (Upper left) and the most commonly used type of groundwater well (upper right) in Damota and the most common type of borehole in Melka Gemechu (bottom).

The distribution of well structure indicates that the majority of the shallow wells i.e., 27 or 65.85% of the total (41) shallow well are concentrated in Damota where as the majority of the borehole i.e., 33 or 62.26% of the total 53 boreholes are concentrated in Melka Gemechu. The tables below (4.5) demonstrate the distribution of well structure between the two PAs.

Table 4.5: Distribution of well Structures

Types of well	Damota		Melka Gemechu		Total
	Number	percentage	Number	Percentage	Number
Shallow well	27	65.85	14	34.15	41
Bore hole	20	37.74	33	62.26	53
Total	47	50	47	50	94

Source: Own Sample Survey, 2011

All the shallow well and the boreholes are hand dug and the construction of the well in most cases is done without the retaining wall. From the personal observation there is only few construction of the well with a well constructed retaining wall particularly in Damota PA.

In the area groundwater irrigation practice is done through the means of furrow system. All irrigation users confirmed that they are using this irrigation practice. This system of irrigation is considered as inefficient in the utilization of the water resource as compared to other type of irrigation method like drip.

4.2.1. Challenges of Groundwater Irrigation in the Area

The most rated serious problem reported by the surveyed household in the two PAs is the cost of fuel; this problem is even severing for the Melka Gemechu because there is no electrification for that PA with the exception that some individual stretch private line from the neighboring PAs. This situation creates a financial pressure for those involved in the groundwater irrigation and also it creates a great challenge for those who are willing to engage in. Out of the total irrigation users in the matched data, which is 94, 59 or 62.77% of them rated that cost of fuel is the most serious problem in the groundwater irrigation and 20 or 21.28% of irrigation users rated repair and maintenance cost of motor pumps is the most important problem. For the remaining 15 or 15.96% of the users land availability, lack of family labor, shortage of working capital and access to market are considered as the most important challenges for groundwater irrigation development.

Another most important challenge in the development of groundwater irrigation in the area is the knowledge gap of the farmer to identify potentially reach areas as far as the resource is concerned. This problem is even intensified for farmers of the low land, Melka Gemechu, the place where two or more trials are common before the groundwater is exposed. This situation has great financial as well as physical pressure for the farmers and it is one of the hindering factors for those rain-fed dependent producers to come into irrigation technology. They strongly urge the expertise knowledge from the concerned body. Box 4.1 below clearly shows their strong desire for the support.

Box 4.1

Two young farmers in Melka Gemechu PA ask the researcher to report for the concerned body that the most serious problem of the area is lack of knowledge of identifying the place where better water potential is available. They repeatedly said that "the only support we want from the government is to tell us, via experts, the place where the better groundwater potential is available." They concluded that "We don't need more!"

4.3. Optimal Use of Groundwater Resource in the Study Area

In the study area the most common practice of irrigation is furrow, which is classified as one of inefficient water exploitation irrigation technology as compared to drip irrigation**.** Carreira *et al.,* (2006) explained that furrow irrigation as opposed to drip irrigation does not pose great concerns in terms of water evaporation. This is due to the fact that the efficient water management practice like drip irrigation are capital intensive, which is hardly affordable for small holder farmers of the area. In this section attempt has been made to evaluate the current status of utilization vis-a-vis the optimal harvesting of groundwater resource in the area.

To measure the optimal harvesting rate of the resource different first hand information of the survey and secondary data from various sources has been used. For this analysis assumptions and procedures of renewable resource of Conrad (1999) are intensively used and MS excel spreadsheet dynamic optimization is used as analysis tools.

4.3.1. Objective Function

The objective function to be maximized is the present value of stream of net benefit drawn from groundwater irrigation, which is a function of groundwater stock and abstraction amount that leads to the steady state use of groundwater. The function adopted from Conrad (1999) for renewable resources is $\pi(Y_t, X_t) = pY_t - cY_t / X_t$, where π is the net benefit from irrigation, Y_t is amount of abstraction of groundwater for irrigation purpose, X_t is the amount of groundwater stock, p is unit value of groundwater and c is per unit cost of groundwater both of them are in liter. For this computation, parameters p and c are estimated from the cross section data of household survey.

During the survey the users are asked that how many minutes or seconds are required to fill a container, which has a capacity of 20 liter from the well. Based on the information discharge rate per second of groundwater was taken. For those who cannot describe the discharge rate accurately, enumerators' measure of the time period or seconds required to filling the 20 liter container from the well and the discharge rate per second of the well is taken from that measurement. Then the discharge rate per second is converted into hour by simple multiplication by taking the standard conversion rate of time. The questionnaire also incorporates the question regarding to how many times and for how long the farmers water their irrigable land during a single harvest season. Multiplying this value with the hourly discharge gives us the total annual water abstraction of each well/farmer included in the survey. So from this cross section data attempt has been made to estimate Y_t.

p or value of groundwater per liter is calculated based on residual imputation method, which is presented below for the two types of well structure. That is 0.015 and 0.012 Birr for shallow well and borehole, respectively. To value it as single unit the weighted average of the two was taken. Since the selection of the shallow well and borehole owners is random, the selected sample has been considered to represent the overall distribution of wells in the study area. From the 100 groundwater irrigation users included in the sample 43 of them have shallow wells and the remaining 57 have boreholes. And the weighted price of groundwater per liter calculated as 0.43*0.015 +0.57*0.012=0.013 Birr.

Regarding to per liter cost of groundwater, the quotient of total cost of groundwater investment and its total water abstraction during its life span is taken. The total cost of groundwater is calculated as the present value of initial investment, maintenance cost and operation cost throughout the life span. The total water abstraction from each well structure is taken as the multiplication of average annual water abstraction of the well structure and its life span. The lifespan estimation of shallow well and borehole is taken from Tesfay (2008), which is 12 and 25 years, respectively. Based on this information the unit cost of groundwater is calculated as follows in table 4.6.

Table 4.6: Per Unit Cost of Groundwater in Irrigation Use

Well type	NPV of cost of groundwater (8%)	NPV of cost of groundwater (10%)	Average annual water abstraction (liter)	Life span water abstraction (liter)	Cost per liter in Birr	
					8%	10%
Sallow well	109,990.78	105,588.17	3,033,582	36,402,984	0.003	0.0029
Borehole	143,698.23	131,327.80	2,596,134	64,903,350	0.0022	0.002

To represent the cost in single value the weighted average of the two is taken as above and value of 0.0025 and 0.0024 Birr are found at 8 and 10 percent discount rate per annum respectively.

4.3.2. Recharge Rate, Withdrawal Rate and Uncertainty

The spreadsheet optimization also requires the growth rate of the water stoke, the discount rate and discounting factor. For the estimation of the growth rate of the stoke of groundwater the estimation of Water Works Design and Supervision Enterprise (2002), which is 672,750 m^3 within $10Km^2$ total area of catchment, the estimation of Harar Water Supply and Sewages Authority and Karamara Engineering Consultancy (2006), which is 1,150,000 m^3 within $17Km^2$ total area of catchment and the estimation of Alamerew and Berressa (2010), which is 6,381,213 m^3 within $52Km^2$ total area of catchment have been used. In order to make the three estimations comparable the later two estimations were converted into $10Km^2$ and they gave 676,470.59 and 1,227,156.35 m^3 respectively. Based on those estimations within a year the groundwater stock has been grown by 10.24% on average.

To estimate the 2011 or 0 year stoke of the two PAs considered in this study, the analysis use simple conversion of Adem's (2011) estimation, which is 10,060,000 m^3 within 258 Km^2 total area, to the total area of the two PAs. The area coverage of Damota and Melka Gemechu is 920 and 1160 respectively, 2080ha in combination. The corresponding square kilometer value is 20.8Km^2 in combination. Based on their area the recharge estimation can be adjusted for the two PAs by taking the groundwater potential estimate of Adem (2011). The corresponding estimate for 20.8Km^2 area coverage of Damota and Melka Gemechu became 811,038.76 m^3. This value is taken as the base year groundwater potential of the study area during the analysis.

Abstraction or withdrawal of groundwater in the study area is computed as the average annual withdrawal of the 100 well owners, which is 1,248,378 liters per annum, multiplied by 456 wells of the two PAs. The total liter of abstraction in the area becomes 569,300,000 liters. This value considered as the initial value of abstraction for the spreadsheet which is subject to change in the optimization algorithm.

To incorporate uncertainty 47 years of rainfall data of Haromaya substation, the detail is attached in annex table 3, was taken. From this rainfall data the probability of getting rainfall above the mean rainfall is calculated. From the 47 years annual rainfall 18 of them were below the average rainfall of the area, which is 674.26mm/year, and the remaining 29 years registered above the given average. Based on the above information, the probability of getting more annual rainfall than the area average is 29/47 or 0.62. This probability value is incorporated in the spreadsheet estimation through the growth rate parameter, which is the multiplication of this probability and the annual growth rate of recharge estimated. The consideration of this probability enables us to integrate uncertainty in the estimation. Based on the growth rate of stock and the probability, growth rate parameter, r , in the spreadsheet became 0.62*10.24%= 6.35% per annum.

4.3.3. Discount Rate and Discounting Factor

The other parameters presented in the spreadsheet are the discount rate and the discounting factor. Like finite horizon, the infinite horizon of discounting factor follow convergent geometric series as it is proved by Conrad (1999). The two parameters are denoted by δ and

ρ respectively. One of the controversial tasks in the dynamic optimization is assigning the discounting rate which can be used as an exact measurement of time value of benefit streams (capital). For the selection of discount rate the NBE (2010) report of the minimum lending interest rate 8% per annum is used as a discount rate. In order on to check the sensitivity 10% interest rate per annum is also considered. And the discounting factor $\rho = 1/(1+\delta)$ also adjusted based on the discount rate selection.

4.3.4. Optimal Depletion Rate of Groundwater and its Algorithm

During the optimization the lifespan of the groundwater and the constraints function have been clearly defined. The lifespan of the groundwater wells has been computed as the weighted average of the life span of the shallow well and bore hole. Since the selection of the shallow well and borehole are random, it has been considered as their number represent the overall distribution of wells in the study area. Then the weighted average computed as 0.43*12 +0.57*25=19.41. This figure is used to estimate the optimal depletion rate by considering the resource should be available at the end of this lifespan. Therefore, the time period considered in the optimization is 20 years.

The initial setup of the spreadsheet with the said parameters is presented in the table 4.7 below. In the table Y_t and X_t are rate of withdrawal and the water potential of the area respectively and $PVNB_t$ is present value of net benefit in year t. The objective function to be maximized is the sum of each year cumulative benefit i.e., $PVNB = \sum_{t=0}^{t=20} \rho^t (pY_t - cY_t / X_t)$

Table 4.7: Initial Tableau for the Spreadsheet Dynamic Optimization at 8%

Initial Table at 8%			
P	0.013		
C	0.00250		
r=	0.0635		
δ=	0.08		
$\rho =$	0.925925926		
t	**Yt**	**Xt**	**PVNBt**
0	569,300,000	811038760	7,400,900.00
1	569,300,000	293,239,721	6,852,685.18
2	569,300,000	348,010,994	6,345,078.87
3	569,300,000	406,260,242	5,875,073.03
4	569,300,000	468,208,317	5,439,882.44
5	569,300,000	534,090,095	5,036,928.18
6	569,300,000	604,155,366	4,663,822.39
7	569,300,000	678,669,782	4,318,354.07
8	569,300,000	757,915,863	3,998,475.99
9	569,300,000	842,194,070	3,702,292.58
10	569,300,000	931,823,944	3,428,048.69
11	569,300,000	1,027,145,314	3,174,119.15
12	569,300,000	1,128,519,592	2,938,999.22
13	569,300,000	1,236,331,136	2,721,295.57
14	569,300,000	1,350,988,713	2,519,718.12
15	569,300,000	1,472,927,046	2,333,072.33
16	569,300,000	1,602,608,464	2,160,252.16
17	569,300,000	1,740,524,651	2,000,233.48
18	569,300,000	1,887,198,516	1,852,068.04
19	569,300,000	2,043,186,172	1,714,877.81
20	569,300,000	2,209,079,044	1,587,849.83
		PVNB	**80,064,027.12**

The cell to the right of *PVNB* is the cell in which maximization of cumulative net benefit has been taking place and it is the sum of the streams of present value of net benefit from year 0 to year 20 which is $\pi(Y_t, X_t) = pY_t - cY_t / X_t$ for each year. These present value of net benefit with the present value operator becomes $\pi(Y_t, X_t) = \rho^t (pY_t - cY_t / X_t)$. After giving the objective function i.e., the cumulative net benefit of all years and the three constraint functions namely; non negativity constraint of the stock of the resource and withdrawal amount of water and the resource should not be depleted entirely. Then the final optimal solutions from the excel spreadsheet solver are obtained for the two specified discount rates. In the above initial table the total withdrawal of year 2011 is assigned as initial value for each year but it is subject to change during the algorithm. If the withdrawal is constant throughout the life span and other things are remain unchanged the area generate 80,064,027.12 Birr of net benefit from groundwater irrigation development which lesser than the optimal benefit.

Table 4.8: Spreadsheet Optimal Solution at 8% Discount Rate

Optimal Table at 8%			
P	0.013		
C	0.00250		
r=	0.0635		
δ=	0.08		
ρ =	0.925925926		
t	**Yt**	**Xt**	**PVNBt**
0	862,539,712	811,038,760	11,213,016
1	840,818,260	9	9,909,277
2	820,705,796	76,492,733	9,147,098
3	802,083,138	154,854,446	8,277,353
4	784,839,954	235,425,179	7,499,450
5	768,874,021	318,550,141	6,802,676
6	754,090,761	404,581,345	6,177,666
7	740,402,561	493,879,021	5,616,231
8	727,728,301	586,813,302	5,111,196
9	715,992,867	683,765,769	4,656,271
10	705,126,733	785,131,077	4,245,931
11	695,065,491	891,318,581	3,875,322
12	685,749,529	1,002,754,101	3,540,167
13	677,123,641	1,119,881,606	3,236,700
14	669,136,704	1,243,165,071	2,961,595
15	661,741,387	1,373,090,342	2,711,910
16	654,893,879	1,510,167,076	2,485,045
17	648,553,593	1,654,930,772	2,278,691
18	642,682,955	1,807,944,924	2,090,800
19	637,247,184	1,969,803,217	1,919,552
20	632,214,057	2,141,131,860	1,763,325
		PVNBt	**105,519,274**

Based on the initial tableau optimization is done for the cell that represent the cumulative net benefit of all years by adjusting the withdrawal amount of groundwater.

The result obtained at 8% discount rate, as it is presented above in table 4.8, indicates that the optimal rate that must be used for irrigation purpose should be larger than what the study area irrigation users are currently used, which is 569,300,000 liters. It indicates that the society can use the groundwater up to the 862,539,712 liters at year 0 but that should be decreased over time. If the society uses the resource in line with the optimal rate, within 20 years they can generate 105,519,274 Birr of net benefit. There is slight change at 10 % discount rate.

Table 4.9: Spreadsheet Optimal Solution at 10 % Discount Rate

Optimal Table at 10%			
P	0.013		
C	0.00240		
r=	0.0635		
δ=	0.1		
ρ=	0.909090909		
t	**Yt**	**Xt**	**PVNBt**
0	862,539,713	811038760	11,213,016.27
1	835,881,565	8	9,658,211.45
2	811,646,875	81,429,429	8,720,173.02
3	789,615,352	163,913,367	7,712,246.11
4	769,586,667	247,892,965	6,833,294.63
5	751,378,806	333,803,428	6,065,112.59
6	734,826,180	422,076,560	5,392,272.88
7	719,778,348	513,143,602	4,801,681.33
8	706,098,499	607,437,515	4,282,202.09
9	693,662,267	705,395,571	3,824,346.70
10	682,356,609	807,461,677	3,420,014.15
11	672,078,735	914,088,705	3,062,273.45
12	662,735,212	1,025,740,857	2,745,182.21
13	654,241,104	1,142,895,924	2,463,634.47
14	646,519,186	1,266,047,609	2,213,233.21
15	639,499,257	1,395,707,860	1,990,183.49
16	633,117,506	1,532,409,207	1,791,202.60
17	627,315,916	1,676,707,145	1,613,444.43
18	622,041,741	1,829,182,600	1,454,435.77
19	617,247,037	1,990,444,431	1,312,022.70
20	612,888,217	2,161,132,007	1,184,325.07
		PVNBt	**91,752,508.61**

Relatively similar result also obtained when the discount rate is changed from 8% discount rate per annum to 10% discount rate per annum as optimal rates is shown in table 4.9 above.

As the above table indicates, the optimal withdrawal of groundwater start at 862,539,713 liter per annum, which is also larger than the current use, and should decrease over time. If the groundwater use of the area is in line with the optimal output the society can generate 91,752,508.61 Birr of net benefit.

The area has been utilizing the resource at lesser rate than the optimal and at its current stand the resource is safe in both 8 and 10 percent discount rate. However, the *wereda* administration has a five years plan of increase the number of private and community well by 24,900 and 45 respectively, which is around 222.12% growth rate in terms of number as we compare with the current 11,210 private and community wells in the *wereda*. Based on the assumption that all PAs are equally benefited from the plan and the current five years plan will continue in the same manner the groundwater use after 20 years in the two PAs become over 61 billion liters per annum which is by far larger than the optimal depletion rates at 8 and 10 percent discount rate as well as the overall recharge rate in the area. This indicates that the groundwater resource is under risk in the near future.

Generally, it can be concluded that the current use of the groundwater in the study is not a threat for the resource. This result is in line with different studies conducted in the area like Alamirew and Beressa (2010) and Mohammed (2006), which indicated that resource is safe at its stand. But it is under serious risk in the near future. This will be even worse when the nonagricultural consumptive uses of groundwater (potable and industrial) are incorporated.

4.4. Economics of well

4.4.1. Type, Distribution and Establishment Cost of Wells

Based on the literatures, like World Vision report on groundwater extraction technology, the demarcation between shallow well and borehole is 50 feet or 15 meter. In this study also wells which have 15 or more depth are considered as borehole and the remaining categorize as shallow well or traditional well. From the descriptive statistics below in table 4.10 the average depth of well as well as the average establishment cost of well is larger for Melka Gemechu PA, the low land area. Similarly the maximum depth of the well structure and the maximum cost of establishment is larger for Melka Gemechu, which are consistent with the previous discussion.

Table 4.10: Depth and Establishment Cost of Well Based on Area

Category	Average depth(in meter)	Minimum depth(in meter)	Maximum depth(in meter)	Average establishment cost (in Birr)	Min. well establishment cost (in Birr)	Max. well establishment cost (in Birr)
All sample	16.09	2	50	19076.38	1500	80000
Damota	12.89	2	30	14117.02	1500	60000
Melka Gemechu	19.3	5	50	19076.38	2000	80000

Source: Own Sample Survey, 2011

In terms of well structure shallow wells, as it was expected, have significantly lower average establishment cost than the borehole in the context of all sample and Melka Gemechu by more than 10,423 and16,182 Birr respectively. However, the two well structures have no significant cost difference in Damota. The details of these features are presented below in table 4.11.

Table 4.11: Average establishment cost based on depth of groundwater (in Birr)

Type of well	**All**	**Damota**	**Melka Gemechu**
Total	16596.7 (1519.29)	14117.02 (1590.27)	19076.38 (2556.77)
Shallow well	10719.51 (1554.99)	12277.78 (2258.93)	7714.286 (1025.38)
Borehole	21143.21 (2229.69)	16600 (2096.87)	23896.67 (3280.97)
Mean difference	-10423.7 (2882.18)	-4322.222 (3187.48)	-16182.38 (5111.89)
t-test	-3.62***	-1.35	-3.16***

***significant at 1%

Source: Own Sample Survey, 2011

4.4.2. Net Present Value of Wells

To measure financial viability of well establishment Net Present Value (NPV) is calculated. To do so, data from household survey and secondary source is used. In addition, information from the key informant interview and focus group discussion has been taken as an input for this analysis. Further more for the calculation of the NPV the following simplifying assumptions are taken into account.

For the shallow well users the average farm size is 0.56 ha where as for borehole users the average farm size is 0.59ha. To make them comparable all the financial viability tests have been computed based on one hectare basis. To do so, all costs and benefits are converted into one hectare basis.

- Discount rates are chosen for this analysis based up on the NBE (2010) reported interest rates, which are 8, 12.25 and 16.5 percent for the minimum, average and maximum lending interest rates.
- By considering the price of output and the price of input are changed in the same manner the revenue generated from the sale of produces and the expenditure on different inputs for the production are increase in the same proportion. Due to this assumption price change is not considered in this analysis.
- The agricultural hand tools are expected to tear out in five years period and it is considered to be changed by both groundwater irrigation users and non users after 5 years of usage.
- Both well are assumed to have repair and maintenance cost starting from their second year operation. It is taken as 1% of the investment cost. This estimation is taken from Tesfay (2008) estimate based on the actual cost spent by 10 of his sample respondents.
- Though in the case of bad weather season the net incremental benefit will be wide between groundwater irrigation users and rain-fed dependent agriculturalist it is also assumed that the difference in the net benefits of the two groups assumed to be the same throughout the life span of both types of wells.

After these assumptions are made the computation of NPV together with IRR and BCR are done. For the computation of the net benefit without well, the average net benefit which is generated by rain fed farmers is considered. In this manipulation the difference between the average of crop value in year 2003 E.C. and the corresponding year average input costs of rain fed dependent producers are taken as a net benefit without well. In order to make it comparable with irrigation users the net benefit for rain fed dependent producers incorporates the average expenditure on agricultural hand tools. The average total income from cash crop is 48,765.24 Birr and the average expenditure per hectare on improved seed, hiring labor, agricultural hand tools, hiring oxen, pesticide and fertilizer are 826.09, 2329.62, 1237.65, 61.67, 228.64 and 3470.77 Birr respectively. And the corresponding net income from the sale of outputs is 40,610.8 Birr per hectare.

The detail of the cash flow is attached in annex (table 4 for shallow well) and its result shows that shallow well investment is profitable from private investors point of view. The cumulative net present value for the shallow well is found to be 182,883.50, 169,788.64 and 134,598.14 Birr at 8, 12.25 and 16.5 percent interest rate respectively from the considered one ha plot of land. This net present value result is by far larger than similar results in the northern part of Ethiopia (Hagos *et al.*, 2006; Tesfay, 2008; Yirga, 2011). The main reason for the huge gap is the farmers in the study area produce a cash crop whose demand is increasing in the local as well as in international market. So from financial (private) point of view investing in shallow well is profitable if it is combined with growing high value crops by this financial viability criterion.

The NPV financial viability measurement of investment on borehole groundwater irrigation development also indicates that investment on the development of this well structure is financially profitable; as its detail cash flow projection as well as NPV result is reported in annex table 5. From one hectare of plot of land the cumulative net incremental benefit for borehole irrigation users are 179,579.02, 118,083.13 and 81,307.29 Birr at 8, 12.25 and 16.5 percent interest rates, respectively. So from farmers' point of view, investing on borehole drilling for irrigation use is also financially viable in this financial viability criterion.

4.4.3. Internal Rate of Return (IRR)

The internal rate of return of groundwater irrigation development in the area, like the NPV, is very high because of the very nature of high value cash crop production practice. This is for both shallow well and borehole groundwater irrigation development. For the former the IRR is 174% where the later has IRR value of 61%. For both type of wells the internal rate of return measurement indicates that groundwater irrigation development is financially viable in the area.

4.4.4. Benefit-Cost Ratio (BCR)

This measure of financial viability also reinforces the explained results. In all the three types of interest rate used in this part of the study the benefit cost ratios are above one for both types of wells, which indicate that from a single Birr expenditure in groundwater irrigation development more than one Birr benefit can be generated. At the minimum lending interest rate, 8% per annum, irrigation development through the means of shallow well and borehole have 1.46 and 1.27 value of benefit cost ratio, respectively. At 12.25% interest rate per annum, the benefit cost ratios of shallow well and borehole irrigation development, 1.43 and 1.24 values of benefit cost ratios have been found. On the same token from the maximum interest rate (16.5% per annum) considered in the study the shallow well and borehole irrigation development have the benefit cost ratios of 1.4 and 1.21 respectively.

Generally all the three measures of the financial viability show that investing on groundwater irrigation development in both shallow well and borehole type is financial viable.

4.5. Value of Groundwater in Irrigation Use

In this part of the analysis attempt has been made to measure the monetary value of groundwater, which is used for irrigation. The method used for the valuation is Residual Imputation Method (RIM). But to do so, it was difficult to value unpaid family labor and land that has been used in the production system. In order to solve these difficulties the following correction measures have been taken.

The value of unpaid family labor is computed as the multiplication of average payment of hired labor and the adult equivalent of family labor in the considered household. Here we employ the standard conversion factor of Di Falco and Veronesi (2011) where an adult female and children labor are converted into adult male labors equivalent at 0.8 and 0.3 rates, respectively. The average payment for hired labor for rain fed dependent households is 1605.40 Birr where as the average payment of hired labor for the shallow well users and borehole users are 1490.12 and 1744.34 Birr, respectively. Based on these considerations the family labor received the corresponding value during the analysis.

The other difficulty for the calculation of all expenditures of factors of production is the valuation of land. To measure the value of the land, there are two alternatives either use the local rent rate of land and similar Residual Imputation Method (RIM). However, the former is difficult to get because the locality is not practicing the land renting with the exception that there is some share cropping transaction among farmers. Due to this reason RIM was used for the rain fed dependent farmers and that residual value of land is taken as the opportunity cost of land. This valuation creates the advantage of excluding the value of untraced factors of production value from inclusion in groundwater valuation. This is because if there is such kind of factors their value is traced in the value of land and consequently they are excluded from value of groundwater during subtraction. Based on this consideration, RIM of valuation of groundwater that is used for irrigation through the means of shallow well and borehole is manipulated as follows (see table 4.12 for shallow well).

Table 4.12: Residual Value of Shallow Well Irrigation Water

Average farm output value and cost in year 2003 E.C in Birr/ha		Source of Data
Type	**Amount in Birr**	
Gross value of output	119,102.10	Output x market prices of local market survey.
Material Inputs		
Fertilizer Pesticide Seed	3,600.10 349.03 896.77	By recall method from farmers By recall method from farmers By recall method from farmers
Labor Input		
Hired labor Family labor	2,655.9 8,180.41	By recall method from the farmers Family adult equivalent labor X average wage rate of hired labor
Other Factors		
Hand tools (20% depreciation) Oxen expenditure	20% of 1510.35=302.07 24.39	Flat rate depreciation of hand tools By recall method from farmers
Land		
Opportunity cost of land	57,412.44	Residual value of land for rain fed agriculturalist
Residual Value of water(V)	45,680.99	
Amount of water used in liter (A) on ha basis	3,033,582	Farmers' best guess and enumerators' measurement.
Residual value of water in Birr/liter=V/A	**0.0150584**	

Although the average groundwater use of borehole owners is larger than the average groundwater use of shallow well owners, which are 1,256,794 and 1,151,968 liters respectively, the hectare base conversion is larger for the shallow well owner because they have smaller farm land size on average. This argument is also valid for gross value of output. Based on the manipulation presented above in table 4.14 the value of a liter of groundwater from shallow well is 0.015 Birr when it is used for irrigation.

A similar manipulation for borehole groundwater irrigation users reveals that a liter of groundwater used for irrigation has a monetary value of 0.012 Birr. The summary of the result and the manipulation procedures is presented here under in table 4.13.

Table 4.13: Residual value of Borehole Irrigation Water

Farm revenue and Cost in year 2003 E.C in Birr/ha		Source of Data
Type	**Amount in Birr**	
Gross value of output	104,233.1	Output x market prices of local market survey.
Material Inputs		
Fertilizer Pesticide Seed	3,487.74 204.32 771.93	By recall method from farmers By recall method from farmers By recall method from farmers
Labor Input		
Hired labor Family labor	2519.28 7912.60	By recall method from the farmers Family adult equivalent labor X average wage rate of hired labor
Other Factors		
Hand tools (20% depreciation) Oxen expenditure	20% of 1400.01=280.01 0	Flat rate depreciation of hand tools By recall method from farmers
Land		
Opportunity cost of land	57,412.44	Residual value of land for rain fed agriculturalist
Residual Value of water(V)	31,644.698	
Amount of water used in liter (A) on ha basis	2,596,134	Farmers' best guess and enumerators' measurement.
Residual value of water in Birr/m^3=V/A	**0.01218916**	

4.6. Contribution of Groundwater Irrigation on Livelihood of Users

4.6.1. Effect of Groundwater Irrigation Use on Crop Value

Since the average land holding of users and non users are comparable, which are slightly larger than one half hectare, the average crop value of the two groups are compared. The three most common type of crop in the study area; maize, sorghum and chat. The first two are for home consumption where as the later is the main cash crop in the area. As table 4.14 clearly shows from the matched data, which includes 194 of the 200 households surveyed, the average net income from the crop sale is significantly larger for users than the non users. This gap is relatively wider for Melka Gemechu for the very reason that the area is low land and those who have access to irrigation get a better advantage in their production system. In addition the nearest market of the PA, Aweday, is the known chat market for local users and exporter that provides a greater market advantage for those who can produce throughout the year.

Table 4.14: Average Net Income Earning from Crop Cultivation Area wise Comparison

Indicator Variables	All		Damota		Melka Gemechu	
	User (n=94)	Nonusers (n=100)	User (n=47)	Nonusers (n=50)	Users (n=47)	Nonusers (n=50)
Average net income from crop (Birr)	29,756.32 (1754.92)	16,252.25 (1039.98)	28,368.52 (2924.58)	16,566.71 (1890.78)	31,144.12 (1953.45)	15,937.79 (889.55)
Mean Difference	13,504.07 (2011.2)		11,801.81 (3440.96)		15,206.34 (2104.02)	
t-value	6.7***		3.42***		7.22***	

***significant at 1%

Source: Own Sample Survey, 2011

The indicated difference is also confirmed by the mean separation test based on the irrigation technology they use as it is presented in the table below (Table 4.15). There is significantly high difference in terms of annual net income from the sale of crop, which is 13,158.56 Birr, between borehole owners and rain fed dependent producers. The same significantly larger difference also obtained between shallow well users and rain fed dependent producers, which is around 13,096.67 Birr. On the other hand there is no significant difference in the net income from the sale between the shallow well users and borehole users.

Table 4.15: Mean Separation Test for Net Income from The Sale of Crop Produces.

	Pair wise comparison between					
	Shallow well irrigation users(n=41)	Rain fed (n=100)	Borehole irrigation users(n=53)	Rain fed(n=100)	Shallow well irrigation users(n=41)	Borehole irrigation users(n=53)
Mean annual crop value	30,785.03 (2382.8)	17,626.48 (992.76)	30,723.15 (2550.99)	17,626.48 (992.76)	29,653.45 (2311.79)	29,835.9 (2566.785)
Mean Difference	13,158.56 (2172.06)		13,096.67 (2300.89)		61.89 (35)	
t-test	6.0581***		5.6920***		-0.0173	

***significant at 1 %

4.6.2. Effect of Groundwater Irrigation Use on Household Expenditure

As it is shown below in the table 4.16 irrigation users are better performers than the non users throughout the study area as far as annual total expenditure and total expenditure per adult equivalent are concerned. Irrigation development provides larger average total expenditure difference (2,721 Birr) between the two groups of farmers in Melka Gemechu, which is low land, than the mid land Damota's farmers (1,800.68 Birr). In the area groundwater irrigation users have significantly larger amount of total expenditure per annum than the non users.

Table 4.16: Average Household Expenditure Comparison by Area

Indicator Variables	All		Damota		Melka Gemechu	
	User	Nonusers	User	Nonusers	Users	Nonusers
Average total expenditure (Birr)	9,267.935 (378.59)	7,007.04 (277.14)	9,434.86 (544.25)	7,634.18 (434.28)	9,101.01 (531.18)	6,379.91 (325.12)
Mean difference	2,260.89 (465.2)		1,800.68 (692.1)		2,721.1 (614.47)	
t-value	4.86***		2.6***		4.42***	

***significant at 1 %

Similarly average expenditure per adult equivalent is better for well owners in the comparison of shallow well owners, borehole owners and rain fed dependent farmers as it was tabulated in table 4.20 below. The average value of expenditure per adult equivalent for the rain fed dependent households is 1734.46 Birr which is the least of the three. In the pair wise comparison of shallow well and borehole irrigation users, the former is better in the Melka

Gemechu study area and in the overall sample context. However, in Damota the reverse is true. From the total households 19 (9.8%) of the matched households who possess shallow well and 30 (15.46 %) of households who possess borehole are spend less than the sample average expenditure per adult equivalent, which is 1893.13 Birr. On the other hand, 69 (35.57%) of non users household spend less than the sample average expenditure per adult equivalent. This indicates that non users are the least performer regarding to the welfare indicator variable as it is shown in the table below in table 4.17.

Table 4.17: Average Expenditure per Adult Equivalent Survey Group Comparison

Category of household	All		Damota	Melka Gemechu
	Amount in Birr	% of household spend less than total average(from total matched sample)		
Shallow well	2079.34	9.8	1794.14	2629.37
Bore hole	2048.47	15.46	2033.82	2057.35
Non-users	1734.46	35.57	1695.61	1773.32
Total average	1893.13		1792.77	1993.5

In order to decide whether the indicated difference in average expenditure per adult equivalent between users and non users is significant or not the mean separation test is performed and the details are presented in table 4.18.

Table 4.18: Mean Separation Test for Pair wise Comparison

	Pair wise comparison between					
	Shallow well users (n=41)	Rain fed (n=100)	Borehole users (n=53)	Rain fed (n=100)	Shallow well users (n=41)	Borehole users (n=53)
Mean expenditure per adult equivalent	2,079.34 (144.79)	1,734.46 (95.12)	2,048.47 (143.39)	1,734.46 (95.12)	2,079.34 (144.79)	2,048.47 (143.39)
Mean Difference	344.88 (175.12)		314.0055 (167.20)		30.87 (206.9)	
t-test	-1.97**		-1.88*		0.15	

* Significant at 10% ** Significant at 5%

From the mean separation test result in table 4.18 above, both borehole and shallow well irrigation development have significantly higher contribution for average expenditure per adult equivalent over the non users. From the two types of groundwater development shallow well has 345 Birr larger average expenditure per adult equivalent where as borehole irrigation development has 314 Birr more expenditure per adult equivalent over non irrigation producers. However, there is no significant difference between shallow well users and borehole users in terms of expenditure per adult equivalent.

4.6.3. Impact of Groundwater Irrigation on Household Welfare

In this section the average difference of the outcome variable, which is expenditure per adult equivalent per annum using matching estimation has been compared. The reason for taking expenditure as a measure of household welfare is that it has some advantage over income. As World Bank (2005) indicated, income has different shortcomings to take it as welfare indicator some of these are; appropriate time period for its definition is not clear, problem of measurement for example many farmers that reported negative cash income may in fact have been building up assets and truly had positive income. Another problem is income has different reasons to be understated.

On the contrary, consumption has numerous advantages over income as an indicator of household welfare. The basic reason is; in contrast to income, consumption is relatively stable and households can easily able to recall their expenditure than their earnings. Another consideration in this study is expenditure per adult equivalent. It is because unlike expenditure per capita, which treats all members of the household equally, it gives different weight for members. The later solve the bias of the former by giving the relative weight for the member as per their gender and age based on Dercon and Krishnan (1998). The detail of the conversion rate is attached in annex table 1.

The weights, which are manipulated in chapter three, are taken in to account in this analysis for the determination of probability of participation in all the three categories discussed below. But in the matching estimation it is not considered. It is because, with the option of calculating bootstrap standard error STATA does not function with weight. Khandker *et.al.*, (2010, p.185) indicated that estimating ATT with or without weights does not affect the results.

The estimation is done in sequence of; first by comparing both borehole owners and shallow well owners in combination with those who produce their product through rain fed system only. The next estimation is done to compare two groups those who are owners of borehole and those of rain fed dependent households. Finally, comparison is made between those who own shallow well and rain fed dependent households. The latter two are done after testing separate treatment (structural change) between shallow well and borehole users.

4.6.3.1. Impact of Groundwater Irrigation on Household Welfare in Combination

I) Estimation of Probability of Participation for Groundwater Irrigation in Combination

For the determination of probability of participation different variables are considered. In the selection of those variables different related literatures are referred and the area specific situation is also taken into account. Variables which jointly affect participation (access to groundwater irrigation) and outcome (expenditure per adult equivalent) variables are selected for this estimation. The estimated result of logistic regression for the determination the variables which affect the probability of having groundwater well or not is tabulated in 4.19.

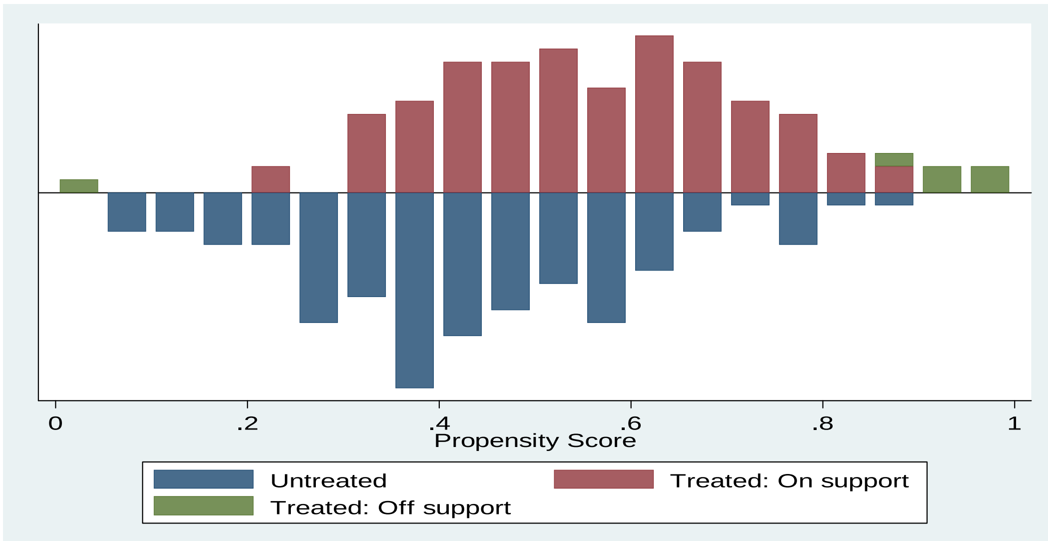
Table 4.19: Logistic Regression Estimates of the Probability of Participation

Variables	Coefficient	Robust SE	Z-value
Agro ecological zone(reference= lowland)	0.18	0.389	0.47
Sex of household head(reference= female-headed)	1.82	1.17	1.54
Age of household head	-0.13	0.068	-1.91*
Age of household head square	0.00099	0.0007	1.34
Education of household head	-0.07	0.061	-1.09
Family size	0.3660492	0.107	3.40***
Consumer-worker ratio	-0.389875	0.14	-2.72***
Agricultural tools per worker	0.3666486	0.11	3.30***
Constant	-1.756444	1.63	-1.07
Pro >Chi 2		0.005***	
Wald chi 2(8)		21.91	

*significant at 10%   ***significant at 1% and SE is standard error

The above result shows that age of the house hold head, family size, consumer worker ratio and agricultural tools per worker have significant effect on the household to participate or not in groundwater irrigation. Age of household head and consumer–worker ratio negatively affect the participation where as family size and agricultural tools per worker positively affect the probability of participation in groundwater irrigation. On the other hand, other variables included in the estimation do not show strong evidence on their effect on the probability of participation in groundwater irrigation. Based on participation estimation, common support is defined as below.

Figure 4.1: Common Support Area of the Sample Household



The common support lies within interval of [0.01344287, 0.95350183] and also confirmed that the balancing property is satisfied, which indicates within the common support area the observable characteristics of groundwater irrigation users and non users are similar. The corresponding common support area graphical representation above in figure 4.1 indicates that out of 200 households included in the sample 6 of them are outside of the common support where as the remaining 194 are included in the common support.

II) Impact of Groundwater Irrigation in Combination

Different matching estimators are used to quantify the difference between groundwater irrigation users and non users in term of the outcome variable. Table 4.20 demonstrates that the average treatment effect of participating in groundwater irrigation is significant.

All four estimators confirmed that participation has a significant effect on ATT. During the estimation comsup option, which restrict the estimation in the common support, is used rather than dropping off support observations. It is done because dropping of off support observation leads to high quality matches may be lost at the boundaries of the common support and the sample may be considerably reduced (Becker and Ichino, 2002). In the nearest neighbor matching estimation groundwater irrigation users have significantly higher value of expenditure per adult equivalent per annum, which is amounted 319 Birr on average, than the non irrigation users or household who depend their agricultural production on rain fed system.

The Kernel matching method revealed that there is a significant difference, at less than 1%, in expenditure per adult equivalent per annum between groundwater irrigation users and the non users. From the result users have on average 297 Birr more expenditure per adult than the non users.

Radius and stratification matching methods also reveal that the treated household has a better expenditure per adult equivalent per annum than the non-treated on average. A 0.1 bandwidth is considered in this method and it significantly, at less than 5% level, confirmed that there is an average of 277 Birr difference between the groundwater irrigation users and non users. On the same token, the stratification matching method shows that there is a significant difference, an average of 324 Birr, in expenditure per adult equivalent between groundwater irrigation users and nonusers.

Table 4.20: Estimates of Matching Methods to Measure Impact of Groundwater Irrigation on Household Welfare

Matching method	Number of matched observation		Difference of Average expenditure per adult equivalent per annum (in Birr)	Bootstrap Standard Error	t-test
	Treated	Control			
Nearest Neighbor	100	48	319.529	184.641	1.731*
Kerner	100	100	297.976	99.040	3.009***
Radius	99	100	277.284	128.780	2.53**
Stratification	98	102	324.752	140.241	2.316**

*significant at 10%   **significant at 5%   ***significant at 1%

In addition to this pooled analysis, separate analyses also done for each type of well structure after the necessary test had been done. To check structural change, separation of wells into shallow well and borehole or pooling them was tested. According to Cramer (2003), in the interest of parsimony data should be pooled together unless they are significantly different for the purpose of the analysis. This issue was first tackled by Hill (1983) in a study of female labor participation in underdeveloped countries, and a statistical test has been provided by Cramer and Ridder (1992).

For the likelihood of the restricted model, the above logit model result has been considered because all groundwater irrigation users are used in the same category. The econometric estimate of this restricted estimation and the unrestricted one are attached in the annex table 6 and 7 respectively. The likelihood value of the restricted model is -93.19, which represent pooled likelihood value in this analysis and denoted by $\log L_P$.

The unrestricted model is treat the shallow well and borehole owners separately and the corresponding multinomial model for the probability of being rain-fed dependent house hold, shallow well owners and borehole owners. The likelihood value of the later multinomial model, which is -119.96, has been taken as the log likelihood value of the unrestricted model.

The likelihood value of restricted model requires further manipulation (Cramer, 2003), by taking the likelihood ratio of the pooled regression and the number of households who own shallow well and borehole. Mathematically, $LogL_r = \log L_p + (n_s \log n_s + n_b \log n_b - n_t \log n_t)$, where n_s, n_b and n_w number of shallow well owners, borehole owners and the total groundwater irrigation users respectively. It was indicated the number of shallow well owners and borehole owners are 43 and 57 respectively. Therefore $LogL_r = -93.19 + (43\log 43 + 57\log 57 - 100\log 100)$ = -161.5 and the corresponding LR test statistics is $\lambda = 2[-119.96 - (-161.5)] = 83.08$.

Since degree of freedom is the number of slope coefficient in the unrestricted model (Cramer, 2003) which is 16 in our case. And the null hypothesis is rejected at 1% level of significance. This indicates that the restriction is soundly rejected, and the distinction of groundwater irrigation users in to shallow well and borehole owners is a significant improvement over the combination analysis. And then the following separation analysis has been performed.

4.6.3.2. Propensity Score Matching Estimates of Borehole Irrigation Impact

I) Estimation of Probability of Participation for Borehole Groundwater Irrigation

Only using data of borehole users, as the participation equation is reported in table 4.21; family size, consumer worker ratio and agricultural tool per worker have strong effect on the probability of participation in this irrigation technology. Consumer-worker ratio has a significant (5%) negative impact where as the other two have a significant (1%) positive impact on probability of participation. However there is no strong evidence of other variables on the probability of participation. The common support area derived from the participation equation lies within the interval of [0.008980, 0.962].

Table 4.21: Logistic Regression Estimates of the Probability of Participation in Borehole Groundwater Irrigation

Variables	Coefficient	Robust SE	Z-value
Agro ecological zone(reference= lowland)	-0.29	0.47	-0.62
Sex of household head(reference= female-headed)	1.41	1.21	1.17
Age of household head	-0.12	0.08	-1.46
Age of household head square	0.001	0.0009	1.09
Education of household head	-0.1	0.073	-1.40
Family size	0.38	0.11	3.34***
Consumer-worker ratio	-0.39	0.15	-2.56**
Agricultural tools per worker	0.4	0.12	3.25***
Constant	-2.15	1.79	-1.20
Pro >Chi 2		0.0152**	
Wald chi 2(8)		18.95	

***significant at 1%, **significant at 5% and SE is standard error

II) Impact of Borehole Groundwater Irrigation

Table 4.22 below displays that the average treatment effect of using borehole for irrigation purpose has significant contribution for the difference in expenditure per adult equivalent per annum between the borehole groundwater irrigation users and those who rely their agricultural production system on rain fed.

This result is similar in almost all estimators. The nearest neighbor matching estimate significantly pointed that on average borehole irrigation users have an average of 418 Birr more expenditure per adult equivalent per annum than the rain fed dependent agricultural households. Similar strong evidence also comes from the Kernel estimate which reveals that there is an average of 331 Birr difference in expenditure per adult equivalent per annum between the two groups.

The last two rows in the table provide the results of the estimation of ATT based on radius and stratification matching estimate. The former pointed that there is on average 288 Birr difference in the two groups regarding to the expenditure per adult equivalent, however the result is not significant at higher level it may be due to the size of the bandwidth 0.1. In the case of 0.25, bandwidth, the ATT difference of 285 Birr is significant at 10%. On the other hand the last matching estimator displays that there is an average of 375 Birr difference between the two groups regarding to the outcome variable, which is significant at 5% level.

Table 4.22: Estimates of Matching Methods to Measure Impact of Borehole Groundwater Irrigation on Household Welfare.

Matching method	Number of matched observation		Difference of Average expenditure per adult equivalent per annum (Birr)	Bootstrap Standard Error	t-test
	Treated	Control			
Nearest Neighbor	57	35	418.196	229.324	1.824*
Kerner	57	100	331.161	167.007	1.983**
Radius	57	100	284.783	149.12	1.91*
Stratification	55	145	374.759	171.696	2.183**

**significant at 5%   *significant at 10%

4.6.3.3. Propensity Score Matching Estimates of Shallow well Irrigation Impact

I) Estimation of Probability of Participation for Shallow Well Groundwater Irrigation

In this participation equation, sex of house head is not estimated by stata because there is no female headed households who possess shallow well in the sample. In this estimate probability of participation is significantly affected by the age of household head, family size, consumer-worker ratio and agricultural tools per worker. This indicates that the higher the age of the household head the lower chance to participate in groundwater irrigation (shallow well) and the higher number of consumer worker ratio also reduce the probability of participating in groundwater irrigation. On the other hand, larger family size and agricultural hand tools per worker improve the probability of participating in groundwater irrigation. But other explanatory variables which are listed in table 4.23 do not show strong evidence on their impact on the probability of participation in shallow well groundwater irrigation. From this participation equation, the common support area is within the value of [0.01634537, 0.71770599].

Table 4.23: Logistic Regression Estimates of the Probability of Participation in Shallow Well Groundwater Irrigation.

Variables	Coefficient	Robust SE	Z-value
Agro ecological zone(reference= lowland)	0.72	0.507	1.41
Sex of household head(reference= female-headed)	-	-	-
Age of household head	-0.17	0.088	-1.91*
Age of household head square	0.001	0.0008	1.43
Education of household head	-0.04	0.07	-0.50
Family size	0.35	0.1379	2.55**
Consumer-worker ratio	-0.4	0.231	-1.72*
Agricultural tools per worker	0.34	0.145	2.34**
Constant	-0.07	1.75	-0.04
Pro >Chi 2		0.0087***	
Wald chi 2(7)		18.83	

***significant at 1%, **significant at 5%, *significant at 10% and SE is standard error

II) Impact of Shallow Well Groundwater Irrigation

In contrary to the combined data and borehole groundwater irrigation estimation of ATT, in this estimation all matching methods show that there is no significant difference on the welfare indicator, which is expenditure per adult equivalent per annum between shallow well groundwater user and rain fed dependent farm households (see table 4.24).

Table 4.24: Estimates of Matching Methods to Measure Impact of Shallow Well Groundwater Irrigation on Household Welfare

Matching method	Number of matched observation		Difference of Average expenditure per adult equivalent per annum (Birr)	Bootstrap Standard Error	t-test
	Treated	Control			
NN	43	26	-34.207	265.161	-0.129
Kerner	43	91	243.963	192.049	1.270
Radius(0.1)	42	91	218.956	169.075	1.295
Stratification	42	146	278.556	181.667	1.533

Generally, from the matching estimation results it is concluded that borehole owners have significantly better welfare than the rain fed dependent households. However, there is no strong evidence for the difference between shallow well owners and rain fed dependent households as far the welfare indicator variable, expenditure per adult equivalent, is concerned.

4.7. Poverty Comparison of Groundwater Irrigation Users and Non Users

In order to measure the extent of poverty among different groups, groundwater irrigation (disaggregated by type) users and non users as explained before, Foster, Greer and Thorbecke (FGT) model is used.

4.7.1. Poverty Line Determination

For the analysis of poverty of the three groups considered in this study, the poverty line estimated by Bogale (2011) is used. In his analysis of poverty and its covariates among smallholder farmers in the Eastern Hararghe highlands, he has estimated that household expenditure on basic needs, including those on food, clothing, housing, education and medical care is 1468.00 Birr per annum per adult equivalent. This estimation is considered because of the fact that it is a better poverty line estimate as compared to national poverty line because it considered the area's special features.

4.7.2. Poverty Index Comparison of Groundwater Users and Non users

By taking the poverty line into account, the FGT model is used to scrutinize the level of poverty in the matched sampled households depend upon their groups; rain-fed, shallow well groundwater irrigation users and borehole groundwater irrigation users. During this analysis, as it was explained before, weights of observations are considered. The estimation result of the FGT model for all the three indices are presented together below (see table 4.25). And the estimated results are also attached in annex table 8.

Table 4.25: Poverty and Inequality of the Sample Household Based on Use of Agricultural Technology

Household group	**Head count ratio (P_0)**	**Poverty gap index (P_1)**	**Severity of poverty Index (P_2)**
Rain fed (n=100)	0.54	0.13	0.04
Shallow well users (n= 41)	0.31	0.07	0.02
Borehole users (n =53)	0.22	0.05	0.02
Over all sample (n=194)	**0.48**	**0.12**	**0.04**

As table above clearly shows, overall sample yields the head count ratio of 0.48. It explains that around 48% of individuals in the overall sampled households spent less than what they would need to meet the minimum living standard requirement. By decomposing the result into rain fed dependent household, users of shallow well groundwater and users of borehole groundwater a larger proportion of rain fed agriculturalist (54%) spent below poverty line for their basic needs. On the other hand from shallow well groundwater irrigation and borehole groundwater irrigation users only 31 and 22 percent of the population live below the poverty line.

Poverty gap index and severity of poverty are estimated and those results also reinforce the severity of poverty among rain fed agriculturalist than those who have irrigation access. From the overall sample estimate of poverty gap, on average index 11.6 percent of the poverty line amount or (170 Birr) is required to take out the poor above the said poverty line in the study area. But for rain-fed agriculturalist require more than this amount. For them, on average, 13% of the poverty line (or 191 Birr) is required to break the poverty trap. On the contrary shallow well irrigation users and borehole irrigation users require only 7.1 % (104 Birr) and 5.2% or (76 Birr) respectively on average to come out of poverty.

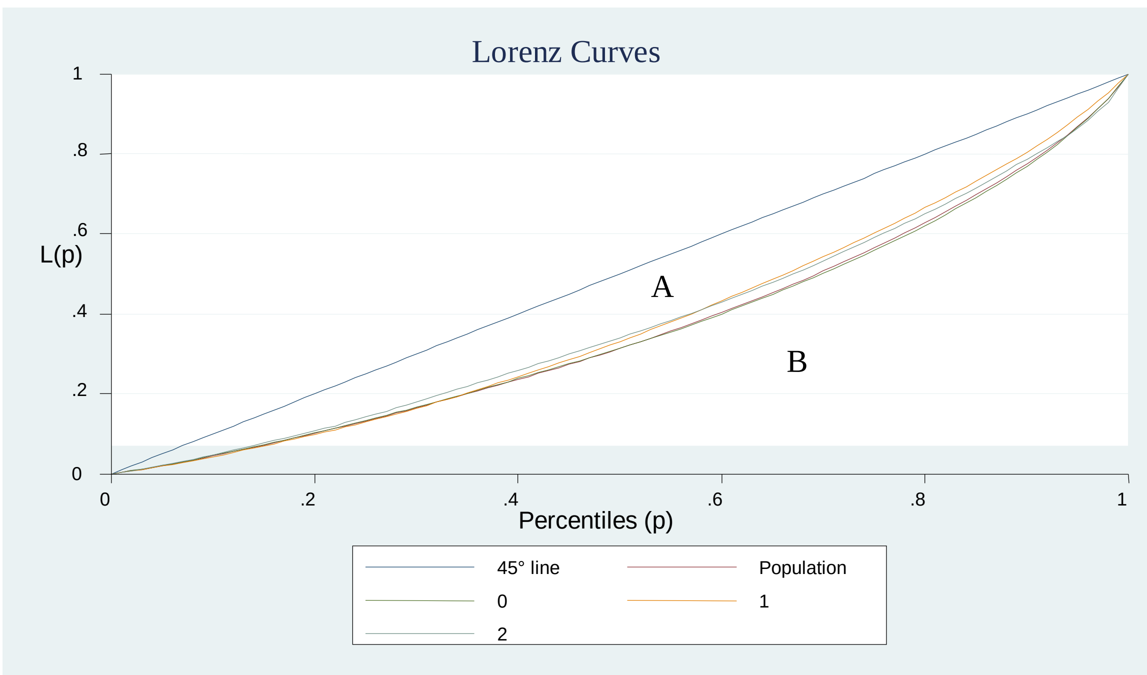
Though it lacks intuitive appeal (World Bank, 2005), similar results are also obtained from the severity of poverty index which is presented on the right most column of table 4.25. Poverty is most severe for rain fed agriculturalist followed by shallow well groundwater irrigation users.

Generally groundwater irrigation access, particularly through boreholes, reduces vulnerability to be poor in all measures of FGT model. In other words individuals who are relied on rain fed for their agriculture are prone to be stuck by the poverty trap.

4.7.3. Inequality Index Comparison of Groundwater Users and Nonusers

Similar result is also obtained based on the inequality measurement. However, the graphical measure of the Lorenz curve, as explained in chapter two, is difficult to interpret the difference in income distribution for the three groups; namely rain fed dependent, shallow well owners and borehole owners due to the reason that their Lorenz curves cross each other as it is depicted below in figure 4.2. In the figure the category 0, which is stand for rain fed dependent producers, where as 1 and 2 are for shallow well and borehole irrigation users respectively are depicted together with the overall sample expenditure per adult equivalent distribution.

Figure 4.2: Lorenz Curve of Rainfed, Shallow well and Borehole



But the Gini coefficient measurement, which is the quotient of A and A+B for each group considered, clearly indicates that income inequality is severe with in the rain fed dependent producers. However, the two groups of well owners have relatively comparable distribution as table 4.26 clearly shows.

Table 4.26: Comparison of Income Distribution Based on Irrigation Technology

Household group	Gini Coefficient Index
Rain fed (n=100)	0.2728
Shallow well users (n= 41)	0.2387
Borehole users (n =53)	0.2390
Over all sample (n=194)	**0.2699**

Generally, the analytical tools used in this section indicate that the possession of groundwater has better advantage to enhance the welfare of the household as compared to rain fed dependent agricultural production system.

4.8. Covariates of Household Poverty

In this section attempt is made to identify the correlates of poverty in order to make the poverty analysis complete. Hagos *et al.,* (2006) argued that, the simplest way to analyze the correlates of poverty is using a regression analysis of welfare indicator against household and demographic factors, specific individual/household head characteristics, asset holdings, village level factors, and policy related variables. Based on this rationale the model is specified as follows.

4.8.1. Model Specification

The dependent variable is the welfare indicator $LogW_i$ which is constructed from the logarithm of expenditure per adult equivalent (y_i) divided by the poverty line (z). That means $W_i = {y_i}/{z}$. To identify the correlates of poverty, logarithm of welfare indicator variable is regress up against different covariates of poverty in OLS regression. Denoting all explanatory variables as X_i , the following equation specify the model used in this section.

$$Log\,W_i = \beta' X_i + \varepsilon_i \text{ ---------------------- } (6)$$

Left hand side term of Equation (6) is constructed by the logarithm of the quotient of the households' expenditure per adult equivalent per annum and the local poverty line. And the right hand side explanatory variables are: a) household characteristics and demographic variables like sex, age and years of education of household head, number of adult labor (by sex), consumer-worker-ratio b) Asset holding and income sources like agricultural hand tools per worker, number of live stokes in Tropical Livestock Unit (TLU), land holding and non farm income c) geographical location of the households like agro ecological zone, distance to the nearest market. In this empirical model specification the relevant variable, access to credit, is not included because in both PAs the whole sampled households are Islamic religion followers. They do not take credit for their agricultural activities. In addition, since the data used in this regression analysis is the matched data the well owner ship variables are excluded because of expected endogeneity.

Partial correlation coefficient, β, tells us the association between the welfare indicator and the explanatory variables not their causal relationship. The detail list of explanatory variable and their description are presented as follows;

x_1= land holding

x_2 = live stock in TLU

x_3= non farm income

x_4= agricultural hand tools per worker

x_5=sex of household head (dummy); 1 if male 0 other wise

x_6 =years of education for household head

x_7=number of adult male

x_8=number of adult female

x_9 = Consumer-worker ratio

x_{10} =Age of household head

x_{11} =Age of household head squared

x_{12} =Agro ecology (dummy); 1 if ‘Weina Dega’ 0 if ‘Kolla’

x_{13} = Distance to the nearest market (in km)

4.8.2. Hypotheses of the Regression Model

The explanatory variables which are included in the model are based on the expectation which is summarized below.

Land holding (x_1) livestock in TLU (x_2) non farm income (x_3) Agricultural hand tools per worker (x_4)

With the assumption that households who possess larger land can produce better consequently enhance the family income (if the produce is sold) or increase the household consumption (if it is consumed at home). In any direction the welfare of the household will increased. Positive coefficient is expected from x_1. On the same token larger number of live stocks in TLU (which is calculated based on Mukasa-Mugerwa (1981)) enhances the welfare of the household by their income generating activities and provision of consumption goods. Positive sign coefficient is also expected from this variable. Similarly, from variable non-farm income a positive sign is expected. And agricultural hand tools are the major input for the locality agricultural system. With the assumption of the larger number of hand tools the better the production system, which enhance the household income consequently positive sign is expected from the coefficient of the variable.

Sex of household head (x_5)

Because of the long trend of agricultural practice and biological difference it is expected that male headed households are more productive than the female headed hoseholds. Since female headed households are considered as a base in the specification, positive sign is expected from the coefficient of this dummy variable.

Years of education for household head (x_6)

Based on the assumption that the educated the household head the more ready to receive agri-technological innovation that are also expected to have a positive impact on production. Consequently a positive sign is expected from this variable coefficient.

Adult laborers -male (x_7) and female (x_8)

If there is large number of adult members in the household in either gender indicators the welfare of the household. If he is male the agricultural productivity expected to be increase if she is female in addition to support the outside work there is enhancement of activity which are taking place at home. Positive sign is expected from both variables' coefficients.

Consumer-worker ratio (x_9)

With the assumption of larger consumers reduce the household expenditure per adult equivalent for each member consequently reduces the welfare of the household. From this assumption negative sign expectation for the coefficient of the variable is made.

Age of household head (x_{10}) and Age of household head square (x_{11})

The larger the age of the household head the better experience for the agricultural production system but if the age is very old that will bring physical challenge for agricultural activity. Based on this expectation the coefficient of age of household head expected to have a positive sign but its square is expected to have a negative sign.

Agro ecological zone (x_{12})

This dummy variable incorporate the two agro ecological zones namely 'Weina Dega' or mid land and 'Kolla' or the lowland. It is known that this is high rain fall variability and low annual rainfallfor the later as compared to the former that negatively affect the agriculture production. Positive sign is expected for this dummy because 'Kolla' is considered as a base.

Distance to the nearest market (x_{13})

Regarding to this variable two contradictory assumptions are considered. The first one is for household who are selected from the Melka Gemechu should travel around 17 Km to sale their product but the market they reach is one the largest chat market in the country, Aweday. In the contrary, Damota PA's households travel relatively lesser distance on average but the market is not promising like Aweday. So no sign expectation is set regarding to this variable.

4.8.3. Variables Descriptive Statistics and OLS Regression Result

Before the regression is executed descriptive statistics of covariates of poverty for the surveyed households the variable definition and their descriptive statistics are tabulated in table 4.27 below during this descriptive and regression analyses the off-supported 6 households are excluded in order to make the regression analysis on the matched data only.

Table 4.27: Variables and their Descriptive Statistics

Variable Description	Mean	Std. Dev.	Min	Max
Dependent variable				
Logarithm of welfare indicator $Log\, W_i$	0.15	0.46	-0.8	1.6
Explanatory Variables				
Land holding	0.56	0.32	0.125	2
Live stocks in TLU	1.86	0.27	0	7.2
Non-farm income	687.32	5246.75	0	70000
Agricultural hand tools per worker	2.20	1.3	0.33	6
Sex of household head (reference= female-headed)	0.96	0.2	0	1
Years of education for household head	1.96	2.85	0	15
Number of adult male	1.42	1.08	0	7
Number of adult female	1.2	0.72	0	5
Consumer-Worker-Ratio	2.45	1.55	1	17
Age of household head	36.38	13.12	16	80
Age of household head squared	1494.86	1133.14	256	6400
Agro ecology (reference= lowland)	0.5	0.5	0	1
Distance to the nearest market	11.81	5.97	2	20

In this regression estimation, the explained weight of observations which are used so far also taken into account. The regression model estimates are presented below in table 4.28 and it indicates that the overall model F calculated is significant at less than 1% level of significance. This indicates that the variables which are included in the regression model have coefficients, which are jointly different from zero value. Because of the incorporation of the sampling weight the standard error presented in the table is the robust one. So hetroskedasticty is not a problem anymore and the related multicollinearity test also performed. For the measurement of multicollinearity Variance Inflation Factor (VIF) has been used.

In the empirical result with 6.37 average value of VIF, there is no severe multicollinearity among the explanatory variables all of them have the value less than 3, with the exception of the expected household head age and household head age square variables. The estimate of the VIF is also attached in annex table 10. In addition from Ramsey RESET test the specification of the model has no problem of omitted variables which is significant even at less than 1% p-value.

Most of the variables' coefficients have the expected sign. With the exception of years of education for household head, number of adult male and age of household head and its square all the variables comes up with the expected sign despite some of them are highly insignificant as it is observed from the table 4.28.

Table 4.28: Regression result of welfare indicator ($Log W_i$)

Variable description	Variable name	Coefficient	Robust Standard Error
land holding	farmsize	0.25	0.09***
live stocks in TLU	tlu	0.058	0.025 **
Non-farm income	ofi	0.000005	0.000003*
agricultural hand tools per worker	agritools_per_worker	0.103	0.02***
sex of household head (reference= female-headed)	sexhh	0.13	0.126
years of education for household head	educationhh	-0.0037	0.012
number of adult male	number_adultmale	-0.058	0.03*
number of adult female	number_adultfemale	0.0015	0.045
Consumer-worker ratio	c_w_r	-0.1	0.03***
Age of household head	agehh	-0.04	0.01***
Age of household head squared	age2	0.0003	0.0001***
Agro ecology (reference= lowland)	agroecology	0.01	0.079
Distance to the nearest market (in km)	mrtdiskm	-0.004	0.007
Constant		1.01	0.3***
Number of Observation		194	
F(14,185)		12.22***	
Prob >F		0.0000	
R^2		0.4709	

*significant at 10% **significant at 5% *** significant at 1%

From the above table, as it was hypothesized the variable landholding has positive and highly significant, with p-value less than 1 % level, association with the households' welfare. That indicates that households with larger size of land perform better in terms of the welfare indicator. Similarly, variable which measures live stocks in TLU shows the expected sign and it is also significant at less than 5%. This indicates that there is significant welfare difference between those who possess larger number of live stokes and those who have lesser. The variable nonfarm income also shows a positive and significant, at p-value less than 10%, association with the household welfare. This indicates that households who have a non farm income perform better in their welfare measurement. The other variable in this category, agricultural hand tools per worker, come up with the expected sign and highly significant result, with p-value less than 1%, as it was hypothesized. The variable is included because of the fact that it is the most widely used input of agricultural production in the area and highly essential in the production system. More precisely, it is very difficult to cultivate the local cash crop, *chat*, without the use of the hand tools locally called '*Me'encha*'. From the obtained result it can be concluded that households who possess larger agricultural hand tools per worker are better off in terms of the welfare indicator as compared to those who have less.

Regarding to the variables like sex of household head and years of education of the household head insignificant result is obtained. The outcome indicates that sex of household head and years of schooling of the household head has no significant association with the household welfare indicator.

From the household demographic variables number of adult male has negative and significant outcome. The result indicates that households who have large number of adult member have deteriorated welfare as compared to those who have lesser. This is in opposite direction with theoretical expectation. This is due to the fact that the locality agricultural practices, particularly production of chat, require less physical exertion that can be done even by non adult member who have better contribution for welfare measurement. In addition larger number of adult male leads to over consumption of the commercial crop (particularly chat). Consequently the better welfare is associated with the lesser number of adult male. The other related variable, number of adult female, is insignificant in this empirical model. This indicates that there is no significant variation of welfare between households those who have larger number of female adult member and those who have less. Another household composition variable consumer worker ratio has the expected negative sign and also highly significant (with p-value less than 1%). This implies that the larger number of consumer worker ratio, the significantly deterioration of welfare of the households as compared to those who have lesser.

Age of household head variable coefficient has statistically significant, with p-value less than 1 %, and negative, which indicates that the higher the household head age the more the welfare of the household is deteriorated. And also the result of household head age square is significant and positive. So the empirical models that shows the "U shaped" age poverty relation like Tesfay (2008), which indicates poverty is high in early age become lower at middle age and become increase in later ages, are not applicable in this area context. Rather the larger age of household head the more deteriorated welfare (poverty) for the household. The inverted “U shaped” age poverty relation is the feature of the study area.

The two geographical location related variables give insignificant result that indicates that weather the household is located in the midland or low land and whether it is near to the market or not has no significant association with the welfare of the household. Regarding to the former, it is in the contrary to the expectation. It was expected that midland has a better welfare effect than low land because of its better rainfall benefit for the agricultural practices. In this area agro ecology has no association with the household welfare. The variable distance to the nearest market also has no significant association with the welfare of households.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

In this chapter the overall conclusion is presented based up on the analyses conducted in the previous chapter and relevant policy implications are drawn from the conclusion. In addition, based up on the researcher observation in the area the research gaps are identified and pointed out for further researches.

5.1. Conclusions

Though the agricultural sector has received the leading role in Ethiopian economy, its contribution for the improvement of welfare of the population and to help them to escape from the widespread poverty and food insecurity trap is still meager. The dominance of traditional agriculture, which is frequently affected by erratic weather condition, could be one reason for this poor performance.

Groundwater irrigation development is one of the means of escaping the small holder farmers from this nature dependent agricultural production system. A recent plan (FDRE, 2010) stipulates that currently the development of such type of small scale irrigation receives a better attention throughout the country. In Haromaya *wereda*, an extensive effort was made by small holder farmers to access different well structures after the 2004 national water harvesting plan was launched. However, there is very limited effort to systematically assess the impact of groundwater irrigation development on the sustainability of the resource, the financial feasibility of investing on it, the monetary value of the groundwater when it is used for irrigation and impact of the development on the welfare of the users.

To bridge these gaps, this research came up with aims to measure the optimal rate of the groundwater use; to evaluate the financial viability of investing on groundwater irrigation development, to monetize the value of groundwater that is used for irrigation purpose and to explore the impact of the development of groundwater on the livelihood of smallholder farmers in the area. For the investigation firsthand information was collected from 200 households who are reside in two peasant associations in Haramaya *Wereda*, East Hararge zone of Oromia regional state. Both were selected randomly from their agro-ecological zones after the exclusion of PAs, which have poor experience in groundwater irrigation. In addition, secondary data from various sources was also employed in this study.

During the investigation different workable hypotheses which explain groundwater irrigation users are better off in average value of expenditure per adult equivalent (welfare) and net income as well as they are better off in poverty and inequality measurements were tested. In addition attempt was made to give answer for optimal rate of groundwater use, financially viability of groundwater irrigation development and the monetary value of groundwater. For the analyses of the empirical data; matching estimation, OLS regression, the poverty analysis tools of FGT and Gini-coefficient, descriptive statistics, spreadsheet dynamic optimization and financial viability analysis of NPV, IRR and BCR were used.

The investigation based on spreadsheet dynamic optimization analysis revealed that the rate of groundwater use is smaller than the optimal value in both 8% and 10% discount rate in year 2011, as it has been confirmed that the resource is safe at its stand from different previous findings. However, when the five years plan of the *wereda* was taken into account, it has a plan to increase the number of wells by more than 222% after five years that can make the abstraction rate more than the optimal as well as the total recharge rate of the area. The result clearly indicates that the resource is under serious risk in the near future.

In the study area, investing on the development of groundwater irrigation is found financially viable in all the three evaluation criteria considered in this study. In the NPV and BCR analyses the NBE minimum, average and maximum lending interest rate were used. In those analyses both investments in shallow well structure and bore hole structure are found financial viable. This result is also reinforced by IRR evaluation on which both shallow and bore hole well structures attain more than even the maximum lending interest rate, which is 16.5 percent per annum. The result indicated that investing on shallow well and borehole irrigation development is financially viable up to 174 and 61 percent interest rate per annum, respectively.

Moreover, in this study, the monetary value of a liter of groundwater, when it is used for irrigation through the means of shallow well and borehole is found that 0.015 and 0.012 Birr, respectively. It was done using residual imputation method.

The empirical investigation in the area also showed that the borehole groundwater irrigation development has brought a considerable positive impact for the user in terms of annual net income from agriculture and expenditure per adult equivalent. The latter was confirmed in all matching estimations. All results indicated that borehole groundwater irrigation users have significantly larger average annual net income than the rain fed dependent producers. The difference is larger than 13,000 Birr. All matching estimations also revealed that there is more than 284 Birr average difference in expenditure per adult equivalent between borehole groundwater irrigation users and non irrigation users.

In addition, the two poverty profile measures used in this study reinforced the aforesaid result regarding to the borehole type groundwater irrigation development. The three measures of FGT i.e. the head count ratio, poverty gap index and poverty severity index, indicated that the users are better off as compared to the non users. Out of borehole groundwater users only 22% of them spend below the used local poverty line, 1468 Birr. On the other hand, the larger proportion of the rain fed dependent households, which is 54%, spend less than the said poverty line. This difference was also shown in the poverty gap index estimate, on which the borehole groundwater irrigation users and rain fed dependent household score 5.7 and 13 percent respectively. In terms of the other related measurement of income distribution, the Gini-coefficient, borehole groundwater irrigation users has a smaller value (0.24) as compared to 0.27 of the non users. This indicates that borehole groundwater irrigation development has an impact of converging income inequality.

In addition to the afore explained quantitative results, the owners repeatedly explained on the open-ended questions that most of them change their practice of producing once in a year in to two or more times a year. So it is concluded that the investment of micro base groundwater irrigation development through borehole is a better option for poor households to reduce the poverty.

On the other hand, though shallow well groundwater irrigation development is financially viable in all the three tools of financial viability measures used in this study and also show that it has a better advantage in providing annual net income based up on the descriptive analyses, in the econometric analysis of matching method, it does not reveal a strong evidence for the difference in wellbeing between the user and rain fed dependent producers. But regarding to the poverty profile measures (FGT) as well as the income inequality measure (Gini-coefficient) they are a better performer than the non irrigation users.

Finally, the study tried to identify correlates of poverty. All the household asset holding and income source variables i.e., land holding, livestock in TLU, agricultural hand tools per worker and nonfarm income have significant and positive correlation with household welfare. From the household composition variable number of adult male has significant and negative correlation with the household welfare. In addition it is also found that households with high consumer-worker ratio and larger age of the household head are found to be worse off.

Generally, groundwater irrigation development particularly through the means of borehole has better contribution in enhancement of the household welfare and income and it can also reduce household poverty. In addition it is confirmed that investment for this development is financially viable. However, the resource exploitation in the area may not be in sustainable manner i.e., the resource is at serious risk in the near future. So expansion of groundwater irrigation is advisable to alleviate poverty and food insecurity without deteriorating the sustainability of the resource.

5.2. Recommendations

Based on the conclusion reached so far through different analytical tools the following policy implications are forwarded.

Watershed management and introduction of efficient irrigation practices

Since the area groundwater resource has lower growth rate of recharge as compared to the planned abstraction rate, the resource is under risk in the near future. It calls for policy to use the resource in a sustainable manner. To keep the groundwater sustainability of the catchment and maintain its safe yield for future generation, artificial recharge and watershed management should be implemented. For the enhancement of the recharge rate through various environmental conservation methods like afforestation and protection of water runoff to increase the infiltration of rainfall that can increase the groundwater potential is necessary. In addition in the study area the type of irrigation is furrow, which is highly inefficient as compared to drip irrigation and it is also confirmed from the personal observation, key informant interview and FGD. So it is highly recommended to introduce a better irrigation technology that can make the resource utilization efficient and to reduce the abstraction rate from each well. In addition the government should provide additional incentive for farmers to adopt water saving technologies.

Expansion and improvement of wells

As it was explained groundwater irrigation development of deep wells have a significant and positive impact on the improvement of livelihood of smallholding farmers throughout the study because of its better capacity of holding water even in the dry season. So it is advantageous for the society if government and nongovernmental concerned body to support the expansion of deep groundwater wells. It was found out that harvesting groundwater is financially viable by all measures. This means that groundwater tapping technologies could be installed by external agencies (government and NGO) but farmers could be asked to recoup cost of establishment. Thus, institutionalizing cost recovery scheme is possible and necessary. In addition to the expansion of wells it is worthwhile to improve the depth of the shallow well to prevent them from dehydrating during scarce rainfall seasons. But it should be done with great care based on periodic assessment of the groundwater potential and the recommended level of abstraction to maintain the resource for the future generation.

Expansion of rural electrification

The most rated serious problem of the irrigation users households included in the survey is fuel cost. It creates a financial pressure on the society and hinders the promising investment of groundwater irrigation development. Therefore, rural electrification should get too much emphasis as a prerequisite for the expansion of new groundwater wells and to improve the existing ones. This is advantageous for the country as opposed to subsidizing the fuel for the farmers when the potential of the country for hydroelectric power and the volatile nature of oil price in the international market are taken into account.

Expertise knowledge and technical support

Like most area of rural household the knowledge gap of the farmer about the resource is very wide. It calls for a strong research and extension network to participate in the development of groundwater irrigation through the provision of expertise knowledge particularly in the identification of the place where a better water access can be achieved. In addition to this, the technical support also required to create awareness for the farmers to improve the depth of their wells, particularly for shallow well owners, to enhance the capacity of their wells in terms of its water provision capacity.

Policy design that enhances household asset holding and encourages non-farm activities
From the correlates of household poverty it has been showed that larger holding of household asset and non farm income are correlated with better household welfare. This empirical result calls for designing programs and strategies to ensure household's access to assets and non-farm employment opportunities these could be important instruments in reducing poverty in the area.

5.3. Rooms for Further Research

- Groundwater irrigation development is not only an economic issue rather it is a multifaceted concern in the study area. It is a means of dispute for the farmers in the area. From interviews with the *wereda* experts it is understood that because of the knowledge gap, it is a common practice to dug wells close to others' wells, the place where the existence of water is very sure. This creates grabbing of the existing water among wells and cause conflict among farmers. This is repeatedly reported to the *wereda's* irrigation experts. This is the potential threat for the groundwater irrigation development in the area particularly when the expansion rate of groundwater wells is taken into account. So dealing with social aspects of groundwater development and point out the appropriate groundwater development regulation to solve this problem is needed to be studied.
- The other issue which calls for further research is the wide gap between the net income from crop cultivation and total annual expenditure reported by the respondents. This requires further investigation for the saving habit of farmers in the area.
- In the dynamic optimization of the groundwater depletion the discharge or abstraction rate is calculate based up on the recall method and the enumerators manual measures. If appropriate instruments are used in further investigation of groundwater a relatively accurate rate of optimal depletion rate of the resource can be obtained.

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APPENDICES

Annex Table 1: Equivalence scale

Years of Age	Male	Female
0-1	0.33	0.33
1-2	0.46	0.46
2-3	0.54	0.54
3-5	0.62	0.62
5-7	0.74	0.70
7-10	0.84	0.72
10-12	0.88	0.78
12-14	0.96	0.84
16-18	1.14	0.86
18-30	1.04	0.80
30-60	1.00	0.82
60 plus	0.84	0.74

Source: Dercon and Krishnan cited in Tesfaye, 2008

Annex Table 2: TLU Conversion Factors used in the Survey

Class/species	TLU conversion unit
Oxen	1.1
Cow	1.0
Heifer	0.5
Young Bull	0.6
Calves	0.2
Sheep	0.1
Goats	0.1
Donkeys	0.5
Horses	0.8
Mules	0.7
Camel	1.25
Chicken	0.013

Source: Mukasa-Mugerwa, 1981

Annex table 3: Rainfall data of Haramaya Area

Element:	Monthly Rainfall													
Region:	Hararghe													
Station:	ALEMAYA COLLEGE													
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual mm/year	
1954	0	0	0	0	0	0	208.9	0	158.2	0	15.1	0	382.2	
1955	126.5	0	31.4	75.8	31.2	28.2	116.2	155.4	211.9	0	20.5	45.2	842.3	
1956	0	0	0	0	0	0	0	0	0	56.6	14.7	22.4	93.7	
1957	19	36.1	53.2	94.7	163.2	59.7	145.4	151.2	19.3	54	0	29.5	825.3	
1958	15	51	65	47	26.7	91.5	166	168	161.9	44.5	0	0	836.6	
1959	22.5	0	19	94	43	43.5	0	65.5	74	62.5	17	0	441	
1960	3.5	1	227.3	43.2	108.5	43.8	197.2	141.7	65.1	10	0	12	853.3	
1961	7	0	0	192	166	86.2	153	143.2	190	0	36	0	973.4	
1962	0	0	0	0	0	0	0	0	0	0	0	0	0	
1965	0	0	0	0	32.1	30.5	27.4	111.2	56.9	33.4	44	0	335.5	
1966	0	67	14	63.7	51	144.5	95.3	500.2	108.3	59	0	0	1103	
1967	0	0	53.7	158.3	107.7	47	151.7	228.2	250.3	112.3	104.5	0	1213.7	
1968	0	191	103	143.2	153.3	128	98.2	112.2	101.6	4	45	39.5	1119	
1969	3	0	31.4	82.5	81	37.5	118.5	168	57.7	17	7	0	603.6	
1970	67	16	68.5	38.3	71	25	0	0	0	0	0	0	285.8	
1971	0	0	55.6		54		127.3	124.6	105		16.6	3.7	486.8	
1972		55.3	25.2	47.8	73.6	116.6	91	0	0	0	0	0	409.5	
1974	0	42.9	45.1		142.6	86.1	121.3	118.2	126.3	4.9	0	0	687.4	
1975	0	0	0	0	0	59	0	0	0	0	0	0	59	
1976	0	10.5	40.9	133.8	0	0	41.1	0	0	0	0	0	226.3	
1977	0	0	0	0	0	0	0	0	0	0	0	0	0	
1979	39.5	31	53.1	41.9	177	55.3	80.9	0	0	0	3.5	17.9	500.1	
1980	0	10.5		74.2	22.3	53.9	69.1	95.9	127	35	58.2	0	546.1	
1981	4.2	8.4	239.2	168.3	120.2	16.2	122.7	204.7	142	15.2	2.6	0	1043.7	
1982	3.7	58.5	61.6	92	141.7	31.2	85.4	122.1	87.6	158.8	38.1	11	891.7	
1983	0	25.7	13.3	80.9	0	75.3	116.1	305.2	152.4	23.5	4.2	0	796.6	
1984	0	0	0	26.7	167.7	72.9		101.6	108.4	0	17.5	6.7	501.5	
1985	0	0	46.9		87.6	29.7	88.3	90.2	69.6	9.9	6.3	0	428.5	
1986	0	38.6	14.1	153.9	110.1	80.8	66	161.4	96.7	34	5.8	0	761.4	
1987	0	8.1	180.2	148.6	248.2	29.6	63.3	123.2	111.9	31	2.7	0	946.8	
1988	9.8	43.8	30.4	154.3	31.3	54.1	101.5	180.7	212.1	41.9	0	6	865.9	
1989	0	14.4	154.9	114.5	69.4	52.6	104	146	104.4	41.2	3.6	45	850	
1990	1.7	73.1	45.4	137.1	59.6	54.1	80.9	154.7	133.8	53.3	0	7	800.7	
1991	0	51.7	136.2	73.2	58.6	25.7	109.1	107	120.1	25.8	0	52	759.4	
1992	0	11	18.2	85.2	65.1	68.3	77.5	97.6	107.1	36.6	10.4	4.1	581.1	
1997	0.0	0.0	78.1	124.6	155.9	59.8	148.7	0.0	61.7	203.8	60.4	16.1	909.1	
1998	86.5	51.0	33.7	59.9	55.4	24.8	128.5	110.4	175.7	54.0	21.3	0.0	801.2	
1999	0.0	3.7	68.3	71.3	77.4	30.0	95.2	238.6	139.0	135.7	15.6	4.9	879.7	
2000	0.0	0.0	6.3	137.6	95.1	18.9	82.7	141.5	109.4	0.0	104.2	0.0	695.7	
2001	0.0	18.8	56.6	94.0	146.2	0.0	111.3	217.7	54.6	24.9	0.0	0.0	724.1	
2002	17.9	0.6	56.3	84.4	47.9	43.3	64.8	165.3	83.4	21.7	0.0	21.5	607.1	
2003	3.6	16.4	25.1	142.2	19.2	62.5	106.6	272.4	77.2	0.2	0.0	40.7	766.1	
2004	38.2	0.0	27.4	215.1	39.7	25.3	74.2	116.4	126.7	43.8	33.6	4.5	744.9	
2005	0.5	2.0	39.9	119.5	198.3	23.5	68.1	132.2	154.4	17.0	11.9	0.0	767.3	
2006	4.0	35.9	49.2	187.0	71.4	74.1	108.6	191.4	180.4	111.6	1.6	88.4	1103.6	
2007	0	3.5	25.4	142.7	55.7	61.4	196.5	110.5	136.9	27.1	6.5	0	766.2	
2008	5.5	0.0	0.2	26.6	179.0	106.3	131.3	120.6	170.2	14.1	120.6	**0.0**	874.4	
													31690.3	674.2617

Source: Ethiopian Metheorological Ageny Haromaya substation, 2011

Annex Table 4: NPV of Shallow well per hectare of plot of land

Year	1	2	3	4	5	6	7	8	9	10	11	12
Investment Cost	57574.42	0	0	0	0	0	0	0	0	0	0	0
Maintenance cost	0	575.7442	633.31862	696.650482	766.3155302	842.9470832	927.2417915	1019.965971	1121.962568	1234.158825	1357.574707	1493.332178
Operation cost	5707.72	5707.72	5707.72	5707.72	5707.72	5707.72	5707.72	5707.72	5707.72	5707.72	5707.72	5707.72
Input costs												
Seed	896.77	896.77	896.77	896.77	896.77	896.77	896.77	896.77	896.77	896.77	896.77	896.77
Labor	2655.9	2655.9	2655.9	2655.9	2655.9	2655.9	2655.9	2655.9	2655.9	2655.9	2655.9	2655.9
Expenditure on agricultural tools	1510.35	0	0	0	0	1510.35	0	0	0	0	1510.35	0
Oxen	24.39	24.39	24.39	24.39	24.39	24.39	24.39	24.39	24.39	24.39	24.39	24.39
Pesticide	349.03	349.03	349.03	349.03	349.03	349.03	349.03	349.03	349.03	349.03	349.03	349.03
Fertilizer	3600.1	3600.1	3600.1	3600.1	3600.1	3600.1	3600.1	3600.1	3600.1	3600.1	3600.1	3600.1
Total Input cost	9036.54	7526.19	7526.19	7526.19	7526.19	9036.54	7526.19	7526.19	7526.19	7526.19	9036.54	7526.19
Total cost	72318.68	13809.6542	13867.22862	13930.56048	14000.22553	15587.20708	14161.15179	14253.87597	14355.87257	14468.06882	16101.83471	14727.24218
Crop value	92004.38	92004.38	92004.38	92004.38	92004.38	92004.38	92004.38	92004.38	92004.38	92004.38	92004.38	92004.38
Net benefit	19685.7	78194.7258	78137.15138	78073.81952	78004.15447	76417.17292	77843.22821	77750.50403	77648.50743	77536.31118	75902.54529	77277.13782
Net benefit with out well	40610.8	41847.65	41847.65	41847.65	41847.65	40610.8	41847.65	41847.65	41847.65	41847.65	40610.8	41847.65
Total cost and benefit without well	112929.48	55657.3042	55714.87862	55778.21048	55847.87553	56198.00708	56008.80179	56101.52597	56203.52257	56315.71882	56712.63471	56574.89218
Net Incremental Benefit	-20925.1	36347.0758	36289.50138	36226.16952	36156.50447	35806.37292	35995.57821	35902.85403	35800.85743	35688.66118	35291.74529	35429.48782
NPV (8 %)	182,883.50											
NPV (12.25 %)	169,788.64											
NPV (16.5 %)	134,598.14											
IRR	174%											
BCR (8 %)	1.46											
BCR (12.25 %)	1.43											
BCR (16.5 %)	1.40											

Annex Table 5: NPV of Borehole per hectare of plot of land

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Investment C	61101.91	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Maintenance cost	0	611.0191	672.12101	739.33311	813.26642	894.59306	984.05237	1082.4576	1190.7034	1309.7737	1440.7511	1584.8262	1743.3088	1917.6397	2109.4037	2320.344	2552.3784	2807.6163	3088.3779	3397.2157	3736.9372	4110.631	4521.6941	4973.8635	5471.2498
Operation cost	5698.15	5698.15	5698.15	5698.15	5698.15	5698.15	5698.15	5698.15	5698.15	5698.15	5698.15	5698.15	5698.15	5698.15	5698.15	5698.15	5698.15	5698.15	5698.15	5698.15	5698.15	5698.15	5698.15	5698.15	5698.15
Input costs																									
Seed	771.93	771.93	771.93	771.93	771.93	771.93	771.93	771.93	771.93	771.93	771.93	771.93	771.93	771.93	771.93	771.93	771.93	771.93	771.93	771.93	771.93	771.93	771.93	771.93	771.93
Labor	2519.28	2519.28	2519.28	2519.28	2519.28	2519.28	2519.28	2519.28	2519.28	2519.28	2519.28	2519.28	2519.28	2519.28	2519.28	2519.28	2519.28	2519.28	2519.28	2519.28	2519.28	2519.28	2519.28	2519.28	2519.28
Expenditure on agricultural tools	1400.01	0	0	0	0	1400.01	0	0	0	0	1400.01	0	0	0	0	1400.01	0	0	0	0	1400.01	0	0	0	0
Oxen	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pesticide	204.32	204.32	204.32	204.32	204.32	204.32	204.32	204.32	204.32	204.32	204.32	204.32	204.32	204.32	204.32	204.32	204.32	204.32	204.32	204.32	204.32	204.32	204.32	204.32	204.32
Fertilizer	3487.74	3487.74	3487.74	3487.74	3487.74	3487.74	3487.74	3487.74	3487.74	3487.74	3487.74	3487.74	3487.74	3487.74	3487.74	3487.74	3487.74	3487.74	3487.74	3487.74	3487.74	3487.74	3487.74	3487.74	3487.74
Total Input cost	8383.28	6983.27	6983.27	6983.27	6983.27	8383.28	6983.27	6983.27	6983.27	6983.27	8383.28	6983.27	6983.27	6983.27	6983.27	8383.28	6983.27	6983.27	6983.27	6983.27	8383.28	6983.27	6983.27	6983.27	6983.27
Total cost	75183.34	13292.439	13353.541	13420.753	13494.686	14976.023	13665.472	13763.878	13872.123	13991.194	15522.181	14266.246	14424.729	14599.06	14790.824	16401.774	15233.798	15489.036	15769.798	16078.636	17818.367	16792.051	17203.114	17655.283	18152.67
Crop value	78155.83	78155.83	78155.83	78155.83	78155.83	78155.83	78155.83	78155.83	78155.83	78155.83	78155.83	78155.83	78155.83	78155.83	78155.83	78155.83	78155.83	78155.83	78155.83	78155.83	78155.83	78155.83	78155.83	78155.83	78155.83
Net benefit	2972.49	64863.391	64802.289	64735.077	64661.144	63179.807	64490.358	64391.952	64283.707	64164.636	62633.649	63889.584	63731.101	63556.77	63365.006	61754.056	62922.032	62666.794	62386.032	62077.194	60337.463	61363.779	60952.716	60500.547	60003.16
Net return with out well	40610.8	41847.65	41847.65	41847.65	41847.65	40610.8	41847.65	41847.65	41847.65	41847.65	40610.8	41847.65	41847.65	41847.65	41847.65	40610.8	41847.65	41847.65	41847.65	41847.65	40610.8	41847.65	41847.65	41847.65	41847.65
Total cost and benefit without well	115794.14	55140.089	55201.191	55268.403	55342.336	55586.823	55513.122	55611.528	55719.773	55838.844	56132.981	56113.896	56272.379	56446.71	56638.474	57012.574	57081.448	57336.686	57617.448	57926.286	58429.167	58639.701	59050.764	59502.933	60000.32
Incremental net Benefit	-37638.31	23015.741	22954.639	22887.427	22813.494	22569.007	22642.708	22544.302	22436.057	22316.986	22022.849	22041.934	21883.451	21709.12	21517.356	21143.256	21074.382	20819.144	20538.382	20229.544	19726.663	19516.129	19105.066	18652.897	18155.51
NPV (8 %)	179,579.02																								
NPV (12.25 %)	118,083.13																								
NPV (16.5 %)	81,307.29																								
IRR	61%																								
BCR (8%)	1.27																								
BCR (12.25%)	1.24																								
BCR(16.5%)	1.21																								

Annex Table 6: Estimation result of Restricted Model

Logistic regression	Number of obs	=	**200**
	Wald chi2(**8**)	=	**21.91**
	Prob > chi2	=	**0.0051**
Log pseudolikelihood = **-93.188143**	Pseudo R2	=	**0.1030**

well	Coef.	Robust Std. Err.	z	P>|z|	[95% Conf.	Interval]
Agroecology	**.1846636**	**.3895229**	**0.47**	**0.635**	**-.5787871**	**.9481144**
sexhh	**1.821707**	**1.179116**	**1.54**	**0.122**	**-.4893186**	**4.132732**
agehh	**-.1308589**	**.0684142**	**-1.91**	**0.056**	**-.2649483**	**.0032306**
age2	**.0009943**	**.0007437**	**1.34**	**0.181**	**-.0004632**	**.0024519**
educatonhh	**-.0676539**	**.0618814**	**-1.09**	**0.274**	**-.1889392**	**.0536315**
famsize	**.3660492**	**.1076726**	**3.40**	**0.001**	**.1550149**	**.5770836**
consumer_w~o	**-.389875**	**.143319**	**-2.72**	**0.007**	**-.670775**	**-.108975**
agritools_~r	**.3666486**	**.1109813**	**3.30**	**0.001**	**.1491292**	**.584168**
_cons	**-1.756444**	**1.635081**	**-1.07**	**0.283**	**-4.961144**	**1.448256**

Annex Table 7: Estimation result of Unrestricted Model

```
. mlogit irrigation Agroecology sexhh agehh age2 educatonhh famsize consumer_worker_ratio agritools_per_worker [pw= weight]
```

Multinomial logistic regression	Number of obs	=	**200**
	Wald chi2(16)	=	**.**
	Prob > chi2	=	**.**
Log pseudolikelihood = **-119.95768**	Pseudo R2	=	**0.1000**

irrigation	Coef.	Robust Std. Err.	z	P>|z|	[95% Conf.	Interval]
1						
Agroecology	**.7893009**	**.4866251**	**1.62**	**0.105**	**-.1644667**	**1.743069**
sexhh	**18.88814**	**1.743566**	**10.83**	**0.000**	**15.47082**	**22.30547**
agehh	**-.1636458**	**.0876788**	**-1.87**	**0.062**	**-.335493**	**.0082014**
age2	**.0012081**	**.0008949**	**1.35**	**0.177**	**-.000546**	**.0029621**
educatonhh	**-.0422669**	**.0715851**	**-0.59**	**0.555**	**-.1825711**	**.0980373**
famsize	**.3576852**	**.1365636**	**2.62**	**0.009**	**.0900254**	**.625345**
consumer_w~o	**-.4360959**	**.2557269**	**-1.71**	**0.088**	**-.9373114**	**.0651197**
agritools_~r	**.3397936**	**.1382547**	**2.46**	**0.014**	**.0688194**	**.6107679**
_cons	**-18.9981**	**.**	**.**	**.**	**.**	**.**
2						
Agroecology	**-.2212059**	**.4624323**	**-0.48**	**0.632**	**-1.127556**	**.6851447**
sexhh	**1.380423**	**1.192539**	**1.16**	**0.247**	**-.9569106**	**3.717756**
agehh	**-.1066623**	**.0810929**	**-1.32**	**0.188**	**-.2656015**	**.052277**
age2	**.0008184**	**.0009012**	**0.91**	**0.364**	**-.000948**	**.0025848**
educatonhh	**-.1147316**	**.0758351**	**-1.51**	**0.130**	**-.2633657**	**.0339025**
famsize	**.383856**	**.1135642**	**3.38**	**0.001**	**.1612743**	**.6064377**
consumer_w~o	**-.3652233**	**.1273309**	**-2.87**	**0.004**	**-.6147874**	**-.1156593**
agritools_~r	**.3882094**	**.1143426**	**3.40**	**0.001**	**.164102**	**.6123168**
_cons	**-2.458005**	**1.776243**	**-1.38**	**0.166**	**-5.939377**	**1.023368**

(irrigation==0 is the base outcome)

Annex Table 8: FGT Estimation Result

```
. dfgtg totexp_per_adultequiv, hgroup(irrigation) alpha(0) pline(1468)

    Decomposition of the FGT index by groups
    Poverty index   :  FGT index
    Sampling weight :  weight
    Group variable  :  irrigation
    Parameter alpha :  0.00
```

Group	FGT index	Population share	Absolute contribution	Relative contribution
0	**0.539056**	**0.796031**	**0.429105**	**0.891267**
	0.049998	0.023434	0.041740	0.024234
1	**0.305419**	**0.091408**	**0.027918**	**0.057986**
	0.073133	0.015015	0.008190	0.017349
2	**0.217060**	**0.112561**	**0.024433**	**0.050747**
	0.057902	0.016553	0.007503	0.015883
Population	**0.481455**	**1.000000**	**0.481455**	**1.000000**
	0.041386	0.000000	0.041386	0.000000

```
. dfgtg totexp_per_adultequiv, hgroup(irrigation) alpha(1) pline(1468)

    Decomposition of the FGT index by groups
    Poverty index   :  FGT index
    Sampling weight :  weight
    Group variable  :  irrigation
    Parameter alpha :  1.00
```

Group	FGT index	Population share	Absolute contribution	Relative contribution
0	**0.130310**	**0.796031**	**0.103731**	**0.893413**
	0.015852	0.023434	0.012982	0.027491
1	**0.071330**	**0.091408**	**0.006520**	**0.056157**
	0.021570	0.015015	0.002262	0.019886
2	**0.052018**	**0.112561**	**0.005855**	**0.050430**
	0.015907	0.016553	0.002003	0.017737
Population	**0.116106**	**1.000000**	**0.116106**	**1.000000**
	0.012995	0.000000	0.012995	0.000000

```
. dfgtg totexp_per_adultequiv, hgroup(irrigation) alpha(2) pline(1468)

    Decomposition of the FGT index by groups
    Poverty index   :  FGT index
    Sampling weight :  weight
    Group variable  :  irrigation
    Parameter alpha :  2.00
```

Group	FGT index	Population share	Absolute contribution	Relative contribution
0	**0.041993**	**0.796031**	**0.033427**	**0.897004**
	0.007028	0.023434	0.005680	0.033673
1	**0.023302**	**0.091408**	**0.002130**	**0.057157**
	0.009233	0.015015	0.000919	0.025209
2	**0.015176**	**0.112561**	**0.001708**	**0.045839**
	0.006272	0.016553	0.000754	0.020835
Population	**0.037266**	**1.000000**	**0.037266**	**1.000000**
	0.005726	0.000000	0.005726	0.000000

Annex Table 9: Estimation result of the OLS regression based on matched data

```
. reg  logw    farmsize tlu ofi  agritools_per_worker sexhh educatonhh number_of_adultmale number_of_adultfemale    c_w_r agehh age2 A
> groecology mrtdiskm [pw= weight]
(sum of wgt is   1.9743e+02)

Linear regression                                      Number of obs =     194
                                                       F( 13,   180) =   12.22
                                                       Prob > F      =  0.0000
                                                       R-squared     =  0.4709
                                                       Root MSE      =  .34849
```

logw	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
farmsize	.2480285	.0900201	2.76	0.006	.0703981	.4256588
tlu	.0575906	.0252702	2.28	0.024	.0077266	.1074545
ofi	5.34e-06	2.98e-06	1.80	0.074	-5.28e-07	.0000112
agritools_~r	.1028392	.0234058	4.39	0.000	.0566541	.1490243
sexhh	.1322326	.1263086	1.05	0.297	-.1170033	.3814686
educatonhh	-.0036808	.0120894	-0.30	0.761	-.027536	.0201745
number~tmale	-.057493	.0317667	-1.81	0.072	-.120176	.00519
number~emale	.0015388	.0452664	0.03	0.973	-.0877823	.0908599
c_w_r	-.1077486	.027471	-3.92	0.000	-.1619553	-.0535419
agehh	-.0443924	.012787	-3.47	0.001	-.0696242	-.0191607
age2	.0003482	.0001271	2.74	0.007	.0000975	.0005989
Agroecology	.010025	.0793439	0.13	0.900	-.1465388	.1665889
mrtdiskm	-.0041106	.006813	-0.60	0.547	-.0175543	.0093331
_cons	1.012196	.3108768	3.26	0.001	.3987639	1.625627

Annex Table 10: VIF Estimate of the OLS regression and RESET test

```
. vif
```

Variable	VIF	1/VIF
agehh	33.00	0.030303
age2	32.79	0.030495
Agroecology	2.68	0.372767
mrtdiskm	2.19	0.456090
number~tmale	1.89	0.529491
educatonhh	1.59	0.628016
number~emale	1.50	0.667730
agritools_~r	1.27	0.785254
c_w_r	1.27	0.790335
tlu	1.23	0.810949
farmsize	1.18	0.845080
sexhh	1.15	0.869082
ofi	1.02	0.976363
Mean VIF	6.37	

```
. ovtest

Ramsey RESET test using powers of the fitted values of logw
       Ho:  model has no omitted variables
                 F(3, 177) =      5.12
                  Prob > F =      0.0020
```

Annex 11: English Questionnaire

Household Survey of Groundwater Socio-economics in Sub-Saharan Africa

1. Name of the Investigator:____;
2. Mobile # with country code: ______________________________________
3. Name of the respondent:__________________ HH ID ________________
4. Male/Female:__________; Age: _____years; years of education:_________
5. Village________________; District________________;
6. Province/Zone/Region_______________; Country:_____________________
7. Mobile Number: Country code: _________; Mobile Number:_________________
8. Household details:

#	Name	Age(Years)	Sex 1=Male2=Female	Education level [1] illiterate; [2] religious education [3] adult education; [4] elementary [5] secondary [6] other (specify)	Skill	Relationship to the respondent	Occupation: [1] education; [2] farming own land; [3] labor for other farmers; [4] non-farm casual work; [5] small trade/enterprise [4] regular job; [5] retired	Is the member available for work on the household farm? [a] full time; [b] part time; [c] not at all
1								
2								
3								
4								
5								
6								
7								
8								
9								

9. Household Asset Base:

#	Asset	Detail	Approximate replacement value[1]	Detail	Response
1	Dwelling	Thatched roof: [1] mad & bricks [2] ; Tin roof:[3]mad & bricks[4]			
2	Total Farm Land held	Acres/ ha		Do you have formal title? Yes=1 No=0	
	Total Farm Land cultivated	Acres/ ha		# of parcels	
3	Large livestock				
4	Small livestock				
5	Work animals				
6	Groundwater structure/s	Borehole [1] Open well [2]			
7	Manual pump:	[1] foot pump; [2] hand pump; [3] rower pump; [4] other, pl specify			
8	Motor pumps	Electric [1] Diesel [2] Petrol[3]			
9	Flexible rubber pipes	meter			
10	Bicycle	Treadle[1] Other[2]			
11	Pesticide Spraying pump				
12	Mobile phone				
13	Motor cycle				
14	Motor car				
15	Color TV				
16	Transistor radio				
17	Agricultural hand tools				
18	Other specify				

[1] To find the replacement value, you may ask: "How much would it cost to buy/acquire/construct this now?"

10. Household consumption expenditure

Commodity	Unit	Cost per unit	Total expenditure
Teff			
Wheat			
Maize			
Sorghum			
Barley			
“Shiro’s” cereals			
Other, specify			
Pepper			
Carrot			
Cabbage			
Letus/ “Salata”			
Tomato			
Potato			
Other, specify			
Meat			
Egg			
Milk/butter			
Food consume outside			
Red pepper			
Sugar			
Salt			
Coffee			
Alchol			
Oil			
Clothing			
Bedsheet and/or Blanket			
Soap/washing powder			
Kerosene			
Fuel wood			
Water			
Furniture			
Travel expense			
Communication/tel			
Electricity			
School fee/book/Uniform/stationary			
Health			
Religious and community contribution			
Other specity			

11. Irrigation Profile:

Mode of water access for crop cultivation	Source of Irrigation water: 1. own well; 2. own borehole; 3. community borehole; 4. small reservoir; 5. canal 6. river/stream Other, specify	Lifting device: 1. bucket 2. manual 3.motor pump; 4.electric pump	Means of Water transport from source: 1. earthen field channels; 2. lined channels; 3.flexible rubber pipes Other, specify	Water application to crops: 1. furrows; 2.basin; 3. drips; 4. sprinklers Other, specify
Rainfall	NA	NA	NA	NA
Groundwater				
Other (specify)				

12. Cost of well establishment & withdrawal rate and cost

Well	Cost of well establishment (in Birr)	Recharge rate/ sec	Withdrawal rate/ sec	Decrease in depth this year compared to last year (in Meters)	Increase in withdrawal cost this year compared to last year (%)	Impact on neighboring well 0= None I can observe, 1= Decrease of well depth, 2= Increase of well depth	If Decreased neighboring well depth, indicate by what %	Ownership 1= Private, 2= Community 3= public 4= Free access 5= other (specify)	Is there well in your neighbor 1= Yes 0=No	Distance in meter
1										
2										
3										

13. Water availability (# months) in year ________ Is there change of water availability over last 5 years? 1= Yes, No=0. If Yes, explain in what way. ___________________________________
14. Characterize water accessibility: 1= household level, 2= community level. 3=other (specify) and has accessibility changed over last 5 years? 1= Yes, No=0. If Yes, explain in what way. _________________________________

15. Economics of Irrigation Farming:

# Plot	Crop type	Area planted (Hectares)	Opportunity cost of land* (in Birr)	Irrigated 1= Yes, No=0	Operation & maintenance cost of the water structure (in Birr)/year	Establishment cost (e.g. orchids and other perennials)	quantity of seed (in kg)	Value of seed (price/kg (in birr))	Quantity of labor MD**	Value of labor MD (in Birr)	Quantity of oxen days ***	Value of oxen days (in Birr)	Quantity of pesticide/insecticide (in kg/ lit)	Vale of pesticides/insecticides (in Birr)	Quantity of fertilizer ****(in kg)	Value of fertilizer (in Birr)	Number of times the crop was watered till harvested (in hr)	Total hours of pump operation for irrigation during the growing cycle	Pumping/Withdrawal cost/ hr (in Birr)	Total Production (kg)	How much of it is consumed at home?	Total income from the sale of crop in local currency*
1																						
2																						
3																						
4																						
5																						

*It could be renting or sharecropping cost
** Labor man days (hired/family) used during preparation, planting, irrigation, harvesting and trashing labor time.
*** Oxen days used for plowing, cultivation, trashing, etc.
**** Includes UREA and DAP.

16. Have ever face a problem to sale your produce? 1=Yes 0= No
17. How much distance do you travel to the nearest market (in KM) to sale your produce?______________________
18. Do you have access to farm loan? 1=yes   0=No
19. Did you have enough food to cover all your need during the last twelve months? 1= yes 0= No if no for how many months?___________________

20. Questions for Rain fed Farmers:

#	Question	Response	Remark
1.	What are the crops that you grow without any irrigation?		
2	How many rain fed crop cycles can you grow within one year?		
3.	In the last five years, how many years of good rainfall season did you have?		
4	If you were offered an irrigation source of your choice, how would you rank the following? (1= most preferred; 5= least preferred	Rank	
	a. Government canal irrigation scheme		
	b. Canal drawn from a small reservoir		
	c. Own well, motor pump and 500 feet of rubber pipe		
	d. Own well, treadle pump and 500 feet of rubber pipe		
	e. Motor pump, 500 feet of rubber pipe to be used on a small reservoir or stream, canal or a community pond		

21. Questions for Motor Pump Irrigators

#	Question	Response	Remark
1	What is the capacity of your pump (horsepower or KV)		
2	What does it use as the source of power? Diesel, Petrol or Electricity		
2	When did you acquire it? (Year)		
3	What was the total investment you made in pump, pipes and the water source?		
4	From where did you acquire the pump and pipes?		
5	Who assisted you in acquiring the pump and pipes?		
6	How much subsidy did you receive in the cost of pump, pipes and water source?		
7	How many other farmers in your neighborhood use similar motor pump for irrigation?		
8	Please indicate the names of family members (or # from table under question 8) who help you in managing irrigation during growing season.		
9	Do you find motor pump irrigation profitable?		
10	What are the **three** most important limiting factors in expanding irrigation? [a] land availability; [b] family labor; [c] fuel cost; [d] repair and maintenance of the motor pump; [e] working capital; [f] market for the produce; [g] any other (pl specify.		
11	What is the most serious problem you face in your irrigation agriculture?		

22. Now we will ask you about the household's livestock income in 2003 E.C.

Items	Number owned	Quantity sold	Price of animal	Number of units sold (in Kg or Ltr)	Price /unit***	Water input *	Source of water**	Water fee (Birr)	Labour input (# days)	Fodder		Veterinarian & medicinal expense (in Birr)	Other inputs (supplements)	
										Quantity	Value in Birr		Quantity	Value in Birr
Oxen														
Cows														
Heifer														
Bulls														
Sheep														
Goat														
Donkey														
Camel														
Horse/ mule														
Poultry														
Beehives														
Honey														
Meat														
Milk and butter														
Hides & skins														
Egg														
Other, specify														

***Water input:** 1= domestic source, 2= irrigation source, 3= other system,

**** Source of water:** 1 = pond, 2 = well, 3 = spring, 4stream, 5= dam, 6= domestic, 7=other, (specify),

*** If more than one unit sold, give average price

23. Now we will ask you about whether you participated in non-farm employment and earned some income in 2003 E.C. [Please first ask type of employment and then the rest]

Source	**Who earned (HH member ID)**	**# of months per yr**	**Quantity**	**Unit***	**Total # of days**	**Price per unit**	**Wage (cash) in Birr**	**Wage (kind) in Birr**	**Net Income (= wage or price (in Birr) x quantity or #days or months)**
Employment									
Food for Work									
Cash for work									
Hire out labor									
Part time job									
Renting out land									
Hiring out oxen									
Other, specify									
Transfers									
Remittance income									
Food aid									
Government Transfers (pension, compensation, etc)									
Assistance from relatives/neighbors									
Others, specify									
Self employment									
Sale of Firewood									
Sale of Handicraft									
Sale of beverages									
Chat trading									
Other petty trade									
Village shop									
Stone mining									
Gold picking									
Animal fattening									
Sand trading									
Other, specify									

***Unit:** Kg, Litres, Koti, Timad, Tsimad, etc.

24. Do you think the irrigation is making (will make) a contribution to improvement in your livelihood? Yes= 1, No=0 [if No skip to Q. 26]

25. If yes to Q. 24 in what ways?

____
____
____

26. If No to Q. 24, why not?

____
____
____

27. Which production technologies do you think is most promising in your community?

Type: 1. Treadle (manual) pump
2. Motor pump with diesel
3. Motor pump with petroleum
4. Motor pump with electricity
5. Rainfed

28. Why?

____
____

29. Was any member of the household sick during last year? Yes=1, No=0 [if no this is the end of the interview, thank the respondent!]

30. If yes to Q. 29, what was the type of sickness?
Illness: 1=Diarrhea, 2=Dysentery (acute diarrhea), 3= Trachoma, 4= Skin/rash problem, 5= Schistosomiasis, 6= Malaria, 7=Respiratory problem, 8= Common cold, 9= other, specify

Thank you for your attention!!!

Annex 12: Oromiffa Questionnaire

Ummatoota sahaaraa gadi jiraniif faayidaa bishaan boollaa(bishaan lafa keessaa), qo'annaa abbaawarraa irratti taasifamu.

1. Maqaa Qo'ataa:____;
2. Lakk.mobayilii koodii Biyyaa wajjin ______________________________________
3. Maqaa Gaafatamaa:___________________Koodii Warraa _________________
4. Dhiira/dhalaa :___________; Umrii:_____waggaa; waggaa barumsaa:_________
5. Ganda_________________;Araddaa _________________;
6. Godina/Naannoo________________; Biyya ______________________
7. Lak. mobaayilii:Koodii biyyaa __________; lakk. mobaayilii:__________________
8. Maatii :

#	Maqaa	Umrii(waggaa)	saala1=dhiira 2=dhalaa	Sadarkaa barnootaa [1] kan hin baranne; [2] barnoota Amantaa [3] barnoota Ga'umsaa; [4] sadarkaa Tokkoffaa [5] sadarkaa lammaffaa [6] kan biroo(ibsii)	Ogummaa	Waliti dhufeenya gaafatamaa wajjin qabdu	Dalagaa : [1] barnoota ; [2] qonna ofii ; [3] qotee bulaa biraaf mindeeffamee tajaajila ; [4] hojii qonnaan alaa ; [5] daldala xixiqqaa [6] hojii dhaabbataa ; [7] sooramaa	Miseensi hojiiqonnaarratti kan argamu [a] yeroo hundaa; [b] yeroo tokko tokko [c] sirumaa
1								
2								
3								
4								
5								
6								
7								
8								
9								

9. Bu’uura Qabeenya maatii:

#	Qabeenya	Ibsa	Gatii tilmaamaan[2]	Ibsa	Deebii
1	Mana jirenyaa	Mana citaa: [1] dhoqqee & bulookkettii [2] ; Qorqoorroo:[3]dhoqqee & bulookkeettii[4]			
2	Lafa qonnaaf ooluu danda’u	Akres/ ha		Waraqaa ragaa qabdaa? eeyyeen=1 lakki=0	
	Lafa qotame	Akres/ ha		# qoqqoodama lafaa	
3	Loon gaanfaa (gurguddoota)			Akaakuu	
4	Loon (xixinnoo)			Akaakuu	
5	Kotte-duudaa			Akaakuu	
6	Caasaa bishaan boolla	Gadi fagoo [1] Boolla [2]		Metira	
7	Maashina bishaanii kan humna namaatin hojjetu :	[1] miilan; [2] harkaan; [3] meeshadhaan ; [4] kan biroo (ibsi)		birandii	
8	Motora bishaani	Elektrika [1] benzila [2] gaazii[3]		biraandi	
9	Ujummoo laastikii	meetira		birandii	
10	Saayikilii	Peedala [1] Kan biraa[2]		Birandii	
11	Afuuftuu qoricha aramaa			Birandii	
12	Bilbila mobaayilii			Birandii	
13	Saayikilii Motoraa			Birandii	
14	Konkolaataa			Birandii	
15	Televizhinii halluu			Birandii	
16	Raadiyoonii			Birandii	
17	Meeshaa qonnaa kan harkaa				
18	Kan biroo(ibsi)				

[2] Gatii tilmaamaa argachuuf,gaaffii: “meeshaa kana bituuf /ijaaruuf/argachuuf qarshii hammam barbachisa?”

10. Baasii maatii

Meeshaa	hamma	Gatii/hamma	Baasii wali gala
Xaafii			
Qamadii			
Baqqolloo			
Mishingaa			
Garbuu			
Midhaan shiroo			
Kan biroo(Ibsi)			
Corqaa			
Kaarota			
Raafuu			
Salaaxa			
Timaatima			
Dinnicha			
Kan biroo (ibsi)			
Foon			
Killee			
Aannan/dhadhaa			
Nyaata alaa nyaatamu			
"Barbarree"			
Shukkaara			
Ashaboo			
Buna			
Dhugatii alkoolii			
Zayita			
Uffata			
Uffata qorraa/ Blanket			
Samunaa(daakuu)			
Gaaza Adii			
Muka boba'aa			
Bishaan			
Meeshaa manaa			
Baasii wal-qunnamtii(konkolaata)			
Wal-qunnamtii/bilbila			
Elektrikii			
Baasii barnootaa			
Fayyaa			
Amantii fi baasii ummataa			
Kan biroo(ibsi)			

11. Haala jal'isii:

Akaakuu bishaan omishaaf oolu	Madda bishaan jal'isii 1. boolla dhuunfaa; 2.boolla gadi fagoo kan dhuunfaa ; 3. kan walii galaa(gadi fagoo); 4. boolla bishaan qabdu ; 5. booyii 6.laga Kan biraa(ibsi)	Meeshaa bishaan ittin baasan 1. meshaan 2. harkaan 3.motora 4.elektrika	Karaa ittin maddarraa bishaan fudhatan: 1. booyii; 2. booyii plastikkiin uwwifame 3. Ujummoo plaastiki Kan biraa(ibsi)	Haala ittin bishaan obaasan: 1. faroo 2.bishaan yaa'aa 3. curuurraa 4. isprinkilarii Kan biraa(ibsi)
Rooba	Hin jiru	Hin jiru	Hin jiru	Hin jiru
Bishaan boolla				
Kan biraa(ibsii)				

12. Baasii bishaan boollichaa ittiin uumamee & saffisa ittiin waraabamuu and baasiisaa.

boolla	Baasii boolli ittiin qotamu(qarshiidhaa nnidhan)	Saffisa haaromsaa /sek	saffisa itti waraabamu/ sek	Hir’ina gadi fageenya bara kanaa kan bara darbeewajjin yoo wal bira qabamuqqabamuo	Dabalata gatii bishaan baasu kan bara darbeen wal bira qabamee (%)	Boolla ollaarratti rakkoo qabu 0= hin hubannee, 1= gadi fagenya hir’isa , 2= gadi fagenya dabala	Yoo gadi fagenya boolla olla hir’sa ta’e parsanti hangamiitin	Qabeenyummaa 1=kan dhuunfaa, 2= kan waliini 3= kan ummataa 4= kan hundumaa 5= kan biro(ibsi)	Boolli olla kee jiraa 1= eyyeen 0=hin jiru	Fageenya meetiraan
1										
2										
3										

12. Argamsa bishaanii (# ji’aan) waggaatti ________ waggoota shanan darban keessa jijjiiramni argamsa bishaanirratti jiraa? 1= eyyeen, hin jiru=0. Yoo eyyeeni ta’e, haala kamiin______________________
14. Bishaan haala kamiin isin gaha: 1= sadarkaa maatiitti, 2= sadarkaa walii galaatti 3=kan biraa(ibsi) fi haalli kun waggoota shanan darbaniif jijjiiramee jiraa? 1= eyyeen, hin jiru=0. Eyyeen tanaan haala akkamiitiin? __________________________________

15. Qabeenya jal'isii qonnaa

#lafa qotame(plot)	Akaakuu oomishaa	Bal'ina lafaa(Hektaaran)	Gatii bakka bu'uu* (qarshiidhaan)	Jal'isiidhaan 1= eyyeen, lakki=0	Gatii adeemsa fi supphaacaasaa bishaanii (qarshiidhaan)/waggaatti	Gatii unkuraa	Hamma sanyii (kg)	Gatii sanyii (qarshii/kg (birriidhan))	Hamma hojjettootaa hojiirratti bobb'an goyyaa hojiitti(MD**	Gatii hojjettoota (qarshiidhaan)	Hamma qotiyyoota guyyaan ***	Gatii qotiyyoota guyyaan (Birriidhan)	Hamma qorichaa (kg/ lit. dhan)	Gatii qorichaa (qarshiidhaan)	Hamma xa'oo ****(kg dhaan)	Gatii xa'oo (qarshiidhaan)	Sanyiin faca'ee hanga haamamutti yeroo meeqabishaan obaafama(sa'aatitti)	Waqtii tokkotti pumpiin bishaanii jal'isiidhaaf sa'aatii meeqa fayyadaa(sa'aatin)	Gatii bishaan ittin bahu sa'aatitti birridhan	Ida'ama omishaa (kg)	Hammaam manattii fayyadamtu?	Galii omisharraa argattan(birridhan*
1																						
2																						
3																						
4																						
5																						

*gatii yoo kireeffame ykn yagutoo kenname baasuu
** humna namaa guyyatti(miindaa/maatii) qophiif,oomishaaf,jal'isiif, funaansaaf fi ayiidaaf fayyadamu.
*** humna qotiyyo guyyaatti qoonnaaf, ayidaa fi k.k.f oolu
**** UREA, DAP dabalatee .

16. Oomisha kee gurguruuf rakkinni si qunnamee beekaa? 1=eyyeen 0= lakki
17. Gabaa dhiyootti gurguruuf fageenya hammam deemta(KM)?______________________
18. Liqii qonnaa argattee beektaa? 1=eyyeen 0=lakki
19. Oomishni oomishte waggaa guutuu si gahaa? 1= eyyeen 0= lakki. lakki yoo jette ji'a meeqaafiree?___________________

20. Gaaffii qootee bultoota roobatti fayyadaman illaallatu:

#	Gaaffii	Deebii	Yaadannoo
1.	Jal'isii malee oomishni oomishtu maal maal faadha?		
2	Waggaatti yeroo meeqa oomishta?		
3.	Waggoota shanan darban keessa rooba gaarii kan itti argatte isaan kami?		
4	Carraan jal'isii osoo siif mijeeffamee sadarkaa ati laattuuf? (1= sirrittin filadha ; 5= hin filadhu)	sadarkaa	
	f. Jal'isii booyii kan motummaa		
	g. Kuusaa bishaanirraa booyiidhaan kan jal'ifame		
	h. Boolla dhuunfaa, motora bishaanii,fi ujummoo pilaastikii dheerinniisaa fitii 500kan ta'ee		
	i. Boolla dhuunfaa, motora humna namaan hojjetuu,fi ujummoo pilaastikii dheerinniisaa fitii 500kan ta'e		
	j. Motora bishaanii, fi ujummoo pilaastikii dheerinniisaa fitii 500kan ta'ee fi kuusaa bishaanii/lagarratti, booyii/boolla uummataatiif kan fayyadu		

21. Gaaffii warroota motora bishaaniitti fayyadamaniif dhiyaatu

#	Gaaffii	deebii	Yaadannoo
1	Humni motoraa hammamii? (humna fardaa ykn KV)		
2	Maddihumna motora keetii maali? benzila,gaaza or Elektirikii		
2	Yoom bitatte? (baraan)		
3	Baasii walii gala kan pampii,ujummoo fi madda bishaanii meeqa?		
4	Eessaa bitte?		
5	Yeroo bittu eenyutu si gargaare?		
6	Gargaarsi motummaan bittaaf siif kenne hammami?		
7	Naannoo keetitti motora walfakkataa qotee bultootni fayyadaman hammamii?		
8	Jal'isiitti yeroo fayyadamtuu maatii keessaa namni sigargaaru jiraa? (Maqaa ibsi)		
9	Motorri kun bu'a-qabeessaa?		
10	Jal'isii babal'isuuf rakkinni gurguddoon jiran maal faadha? [a] argamsa lafaa; [b] hajjetoota maatii; [c] gatii boba'aa; [d] gatii suphaa [e] qarshii adeemsa hojii; [f] hanqina gabayaa ; [g] kan biraa(ibsi)		
11	Rakkoo cimaan jal'isiirratti si mudate jiraa?		

22. Gaaffii waa’ee galii loonii kan bara 2003 E.C ilaallatu.

Akaakuu loonii	Hamma (lakkoofsaan)	Hamma gurgurame	Gatii loonii	Hammaa gurgurame (in Kg or Ltr)	Gatii tokkoo***	Argamsa bishaani *	Madda bishaanii **	Kanfaltii bishaanii (qarshiidhaan)	Humna namaa (#guyyaan)	Nyaata looni		Gatii qorichaa fi yaalii(birriidhaan)	Kan biraa	
										Hammaa	gatii		hammaa	gatii
Qotiyyoota														
Saawwan														
Raada														
Mirgoo														
Hoolaa														
Re’ee														
Harroota														
Gaala														
Fardeen/gaangee														
Lukkuu														
Gaagura kannisaa														
Damma														
Foon														
Aanaan fi dhadhaa														
Gaanfaa fi gogaa														
Killee														
Kan biro (ibsi)														

***Argamsa bishaanii:** 1= kan manaa, 2= madda bishaan jal’isii, 3= Mala kan biroo,

**** madda bishaanii:** 1 = bishaan boollaa, 2 = bishaan Eelaa, 3 = burqaa, 4 laga, 5=hidha, 6= kan manaa, 7=kan biro(ibsii)

*** yoo tokkoo ol gurgurame gatii giddugalaa caqasaa

23. Gaaffii warreen hojii qonnaan alaarratti hirmaatanifi, bara 2003tti galii argatan gaafatamu[dursa akaakuu hojii irratti hirmaatanii gaafadhu, ergasii kan hafe]

Madda	**Galii kan argatu (lakk. Enyummaa miseensa maati)**	**# ji'aa, waggaa keessatti**	**Hamma**	**Safartuu ***	**Guyyaa walii gala**	**Gatii tokkoo tokkoo**	**Mindaa(qarshiin)**	**Mindaa(meeshaa dhaan)**	**Galii cuunfaa(= minada(qar.) x hammaa ykn #guyyaaykn ji'a)**
Dalagaa									
Nyaata dalagaadhaaf									
Qarshii dalagaadhaaf									
Miindeffamuun									
Hojii yeroo boqonnaa									
Lafa kireessuun									
Qotiyyoo kireessuun									
Kan biraa, ibsi									
Kennaa									
Qarshii firarraa ergamuu									
Gargaarsa nyaataa									
Kennaa Motummaa (fak.sooromaa)									
Gargaarsaa ollaa fi fira dhiyoorraa									
Kan biraa									
Hojii dhuunfaa									
Qoraan gurguruun									
Gurgurtaa hojii harkaa									
Dhugaatii gurguruun									
Jimaa/caatii/ gurguruun									
Daldalaa xixinnoo									
Kusaa meesha									
Dhagaa baasanii									
Warqee mala aadaatiin									
Loon furdisuu									
simintoo gurguuruu									
Kan biraa, ibsi									

***safartuu:** Kg, Litira, Koti, Timad, Tsimad, etc.

24.Jal’isiin haala jiruu fi jireenya keetii jijjire jettee ni yaaddaa ? eeyyeen = 1, lakki =0 [lakki taanaan gara gaaffii 26tti darbi]

25. Deebiin gaaffii 24ffaa eeyyeen yoo ta’e haala akkamiitiin?
____
____
____

26. Deebiin gaaffii 24ffaa lakki yoo ta’e maaliif hin fooyyessine?
____
____
____

27. Hawaasa kessaniif tekinooloojiin baay’ee gaarii ta’e kami?
akaakuu:

1. Pampii bishaanii kan humna namaatiin hojjetu
2. Pampii bishaanii kan motoraa ta’ee beenzilaan kan hojjetu
3. Pampii bishaanii kan motoraa ta’ee gaazaan kan hojjetu
4. Pampii bishaanii kan motoraa ta’ee elektirikaan kan hojjetu
5.Roobaan

28. Maaliif?
____
____

29. Maatii kee keessaa bara darbe kan dhibame jiraa? Eeyyeen =1, lakki =0 [lakki taanaan kun dhuma gaaffii kootiiti waan ta’eef, galatoomaa]

30. Deebiin kee eeyyeen taanaan, dhibeen isaa maal ture?
Dhukkuboota: 1=baasaa, 2=baasaa hamaa , 3= Tiraakoomaa, 4= dhibee gogaa , 5=dhibee qaama haaraa baasuu, 6= busaa , 7=dhukkuba garaa keessaa , 8= utaalloo, 9= kan biraa, ibsi

Deebii nuuf kennitaniif baay’een isin Galateeffadha !!!