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ADDIS ABABA UNIVERSITY

SCHOOL OF GRADUATE STUDIES
FACULITY OF BUSINESS AND ECONOMICS

PRODUCTIVITY AND ECONOMIC BENEFITS OF FLOOD RECESSION AGRICULTURE VIS A VIS IRRIGATION FARMING USING A LINEAR PROGRAMMING APPROACH: A CASE STUDY IN FOGERA WOREDA OF SOUTH GONDAR ZONE

BY

YIRGEDU MILIKET

A THESIS SUBMITTED TO ADDIS ABABA UNIVERSITY SCHOOL OF GRADUATE STUDIES IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTERS OF SCIENCE IN ECONOMICS (NATURAL RESOURCE AND ENVIRONMENTAL ECONOMICS)

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"Productivity and Economic Benefits of Flood Recession Agriculture Vis A Vis Irrigation Farming Using a Linear Programming Approach: A Case Study in Fogera Woreda of South Gondar."

By

Yirgedu Miliket Ademe

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Dedicated to my brother Yekoye

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ACRONYMS

JICA	Japanese Integrated Corporation Agency
WB	World Bank
SADC	Southern African Development Community
LP	Linear Programming
MOTAD	Minimization of Total Absolute Deviation
PASTOR	Pasture and Animal System Technical coefficient generator
REALM	Regional Economic and Agricultural Land Use Model
GAMS	General algebraic modeling systems
DPPC	Disaster Prevention and Preparedness Commission
PAs	Peasant Associations
Ha	Hectare
HHs	Households
LPM	Linear Programming Model
TLU	Tropical Livestock Unit
SG2000	Sassakawa Global 2000
NERICA	New Rice for Africa
RRP	Regional Rice Program
MoWR	Ministry of Water Resources
BCM	Billion cubic meters

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Abstract

The flood recession agriculture around Lake Tana is an important means of living for the residents in the plains of Fogera, Dembia and Alefa. Even though the recession zone has this advantage and is also a home of various species of birds and plants it is also believed that there will be a better use of water leading to high productivity through irrigation schemes. In order to do this the Ministry of Water Resources plans to construct Dams around the major tributary rivers of Lake Tana.

This study focuses on analyzing differences in farm income due to practicing flood recession agriculture and irrigation using linear programming model with a data collected from 7 selected Kebeles of Fogera Woreda of South Gondar zone in Amhara regional state.

The result shows that an average household practicing irrigation gets an annual income more than double that of the income from flood recession farming.

However before going to implementation of the plan, it is important to look consciously at various socio economic as well as environmental benefits and costs of flood and irrigation farming.

Key words: flood recession agriculture, irrigation, rain-fed agriculture, mathematical linear programming.

1. INTRODUCTION

1.1. Back ground and motivation for the study

Water resources provide important benefits to human kind, both commodity benefits and environmental values. Demand for water is increasing in the world especially in developing countries. This growing water demand implies that pressure on water availability will mount; hence a need for efficient water allocation is a must.

Flood recession zones are often seen as wastelands that have no value and are best converted by drainage to allow agriculture or grazing. Such conversion may create some new benefits such as increased food production and grazing, but will generally cause the loss of many other benefits.

This study was motivated by two main concerns: the flood recession agriculture around the Lake Tana basin its water use and the plan of dam construction for a better use of water and high productivity with irrigation schemes. These two issues defined the research problems to be addressed.

1.2. Statement of the problem

Lake Tana is the largest fresh water body in Ethiopia (area is 3156 km^2) accounting for 50 percent of the total inland water and a source of the Blue Nile. The lake and its wetlands have a multipurpose value for the surrounding area. It is used as a home of the various plants and unique endemic species of fish, an important bird nesting and sanctuary area, home of the historic Orthodox Church monasteries, the largest wetland area that supports different livelihoods of indigenous people, habitat of the Fogera cattle breed unique in the country, water supply, transportation, major tourist attraction, adding quality of life to Bahir Dar residents, source of hydroelectric power, waste processing and others (Dejene, 2003).

The area of Lake Tana waters catchments vary during the rainy season and the dry Season. The water level is less sensitive to rainfall variation and changes in catchments characteristics. But the outflow from the lake shows significant variation relative to the rainfall variations. The estimated in flow to the lake is between 9.38 and 12 bcm and the out flow is estimated to be 3.48 bcm (Kebede et al, 2005). When the level increases in the rainy season and to some extent due to the regulation weir (Chara Chara dam), part of Bahir Dar Zuria, Denbia, Fogera and Libokemkem Woredas are affected by seasonal flooding. The rise of the level brought about inundation of cropped area, grazing lands, residential area, access roads etc; consequently loss of crops, abandoning of homes, proliferation of incidents of malarias etc became the cyclic problems affecting the area. Despite these damage, farmers who live around the Lake get the opportunity to produce various crops (especially crops which need much water, like Rice) using either the outflow water from the lake or the flood from tributary rivers. After the rainy season passes the flood will reduce gradually and the land will have abundant water, which is convenient for farming activities. Only farmers who have land in the recession zone have the access to crop their lands.

The level of the lake water is declining day to day due to the Tis Abbay I and II hydropower (which decreases the lake water sometimes even below the minimum level) and Chara Chara weir (management problem) is creating a problem for the transportation service (an interview with the GM of Tana Maritime transport enterprise) which is important for the living of people in the islands. In addition to the existing facts the intended Tana Beles transfer project may also alter the level of the Lake. If the flood water can be collected in a reservoir, it is assumed that, it can increase the water level by decreasing the rate of evaporation via less surface area. The Ministry of Water Resources, with a fund from donors such as World Bank, has a plan to construct a dam on the main tributaries of Lake Tana such as Gumara and Rib for this reservation purpose and there will be also formation of irrigation canals so that farmers can practice irrigation. Here farmers without land in the flood zones will also be benefited from irrigation. Even though the formation of dams and irrigation canals will have this importance, there are also some benefits which may be forgone. First, inundated areas which are homes of various birds and plants will be destroyed; farmers, with land in the recession zone, will no more use these areas as flood farming zones. Secondly, farmers are paying nothing to practice flood retreat agriculture except their labour and input cost like fertilizer and seeds. Even though the cost of dam construction and irrigation canals is going to be covered by the government (funding agencies); farmers are obliged to cover the operation and maintenance cost of irrigation canals during the implementation period.

1.3. Research Questions

To deal with the research problem the following research questions were addressed

- What change will bring the practice of irrigation on resource (land and labour) use of farmers?
- How much significant is the change in income of the smallholder farmers due to switching from recession to irrigation agriculture?
- Does the productivity of major resources, land and labour change due to a change in farming system or cropping system?

1.4. Objective of the Study

It is important to undertake ex-ante analysis on the impact of switching from recession to irrigation (construction of dams) agriculture on the livelihood of the community. The general objective of the study is to compare the income change as a result of switching from flood recession to irrigated agriculture using a linear programming approach.

The specific objectives are:

- To undertake a comparative analysis of the contribution of flood recession agriculture and irrigation to the income of the farming community, using rain-fed agriculture as common for both systems
- To look at the labour and land productivity in each farming system
- To make policy recommendation for better use of the scenario that yields higher income for farmers

1.5. Hypothesis

The income from irrigation is higher than the income from recession agriculture.

1.6. Significance of the Study

One essential step towards achieving sustainable development is economically efficient use and management of natural resource (Mohan, 93). Changes in ecological processes, arising as a consequence of the change in flow regime, can have profound social and economic consequences for people dependent on the natural resources and ecosystem functions of floodplains and wetlands to sustain their livelihoods.

This study will be important to the policy makers and development planers as well as farmers to compare which of the two options give more benefit and environmentally suitable. In addition, it will serve as spring board for further study.

2 LITREATURE REVIEW

2.1. Flood occurrence and its impact

Flood which is the inundation of normally dry land occurs when flow in the river exceeds the capacity of the channel and water spills onto the floodplain. But some times the channel and floodplain merge seamlessly and there is no distinct boundary where it will be difficult to define a critical level above which a flood occurs.

Floods affect more people world-wide like any other natural hazard. For instance Acreman (2000) states that in 1998 in China flood killed 3000 people, affected the well being of millions of others and caused $20 billion worth of damage. Likewise in Woredas around Lake Tana (Libokemkem, Fogera, Dembia and Achefer) 17,411 households and 17015.5 ha of land (see appendix 3) were affected by the flood during the Year 1998 (Cherie & Belachew, 2000).

In contrast, flooding makes rivers and flood plains amongst the most fertile, productive and diverse ecosystems in the world. According to Acreman (2000) flood plain natural resource systems are defined by two interrelated characteristics; flood tolerance and flood dependence.

- **Flood-tolerance**:-mechanisms evolved to tolerate the environmental stress associated with flooding, such as the physical disturbance of seeds and seedlings and the low oxygen content of water logged soils.
- **Flood dependence**: - through this adaptation, the continued functioning of these systems depends on regular seasonal flooding. The more regular the floods, the more these systems can be described as flood dependent, and the more the communities living in the flood plains have evolved livelihood strategies dependent on this regular flooding

communities living in and around regularly inundated flood plains have adapted their patterns of land use to take advantage of these natural resource systems.

Acreman calls Recession zone, the area covered by the flood and then exposed as the floods recede to the main channel or lost through evaporation and/or seepage, as "*the key to the productivity of the flood plains*". It supports a range of habitats and is the area that can be expected to be flooded during most years.

A case study on Tana River, in Kenya shows that about 115,000 people benefited from flood recession farming and about 53,500 from fishing (50,000 for subsistence and 3,500 for commercial use), 39,500 people benefited from fuel wood, timber & non-timber forest products and about 176,000 people used the flood zone for pastoralism (JICA, 1997 cited in Acreman, 2000).

In general, floods are neither inherently good nor bad; they are good if flood waters provide recession agriculture, support fisheries and improve soil fertility. How ever they will be bad if people are displaced & die, communicable diseases are transmitted, or industrial and residential property and infrastructure or flood resources are damaged or destroyed.

According to the World Bank (2005) Lake Tana development potential classification report, surplus producing rain- fed agriculture in the plains of Eastern & Northern parts of the Tana Basin, shorter duration of rainfall and irregular with a significant period of flooding is common. The area includes the Fogera, Dembia, Bechign, Alefa & Achefer plains which are currently in a highly flooded zone by the over flow of water from the major tributaries.

During rainy season, Gumara and Rib Rivers carry high flows and spill their banks in their last reach before meeting Lake Tana. The situation is further aggravated when Tana level also goes up and thus a sizeable area of the command is inundated. This is because of the inadequate section of the river as well as flat gradient in this reach. This situation is also exasperated by the deposition of the sediment on its lowest flat reaches.

Recession agriculture, which covers about 7000 ha on average, is being carried out along the shores of the lake in these flood plains using the residue moisture following the recession of the reservoir water. The size of the recession farming area and people engaged varies depending on the out flow of water. If there is heavy rain during the season the outflow will be high and covers large area. Cereals like Maize & Finger millet and Teff are the major crops produced using the flood recession system. The system of farming is that during the dry season when the water decreases slowly farmers will saw crops which are suitable for the season and on the other time when the rest of the land is free of the water they will do the same with another crop. The beneficiaries are people who own land on the flooded zones, excluding those people with land out side the flood zone.

2.2. Dams and Economic Development

Proponents of dams believe that dams have many benefits, among which increased water availability for domestic and industrial purposes, increased agricultural production, because of the availability of reliable irrigation water protection from floods and droughts generation of hydroelectric power, navigation and overall regional development which improves the quality of life of the people, including women (Biswas, 2004). They argue that of course as other big infrastructure developments dams also have benefits as well as costs but the overall benefits outweigh the cost. To justify this it is good to mention the case in the Senegal River (Acerman, 2000).

During the construction of the Manantali dam on the Senegal River, there was a fear that the cessation of floods would have a devastating effect on livelihoods. However after filling the reservoir and testing the spill way in 1991, floods have been broadly in line with a hydrograph designed to flood 50,000 ha, and exceeded it in years of good rain fall, while avoiding damaging second peaks. An average of 58,000 ha has been cultivated by recession cropping, a marked increase on drought years before the dam, while irrigation has also increased. Even though the livelihoods of trans-human herders have been damaged by reduced access to pasture and to water, the recession cropping has not been damaged.

The opponents in the contrary argue that dams bring distractive losses to the society, and these societal and environmental costs far out weigh the benefits they can contribute (Biswas, 2004). One of the major negative impacts associated with dams and reservoirs are permanent loss of productive lands, forests, grazing and settlement areas and displacement of people from the proposed reservoir area as well as from the command areas.

There are also experiences which justify the opponents' view. (Acreman, 2000) showed that recession farming can be considered as part of a flood management when there is good mechanism to treat the flood. He justified it by mentioning the case of Bangladesh. In Bangladesh farmers use a "*flood proofing approach*" which accepts flooding and takes a "*flexible approach*" to protection based on the cost and risk of protection rather than trying to protect every thing.

A case study from Tana River in Kenya has showed that when the dam was constructed those Farmers who were benefiting form the flood (about 115,000 people engaged in flood recession farming, about 53,500 for commercial use and 176,000 pastoralists) have had to diversify in to activities such as casual labour, small-scale trading and charcoal burning; as well as long-term dependence on food aid.

The pongolapoort dam in South Africa for example, was partly responsible for high labor migration out of the phongolo flood plain from the 1950's on wards.

The effects of the dam construction on the Atbara river sudan force 5% of the population for migration /left the area/ with in 15 years after the dam construction and some villages completely disappeared, whilst others were severely depopulated.

In the lowland, Awash River Basin of Ethiopia, famine was associated with recent encroachment of pastures by irrigation schemes and with reduced river flooding caused by construction of Koka dam (Helmut, 1982). In general, the impacts of dams on livelihood outcomes are evident through changes in income, environmental sustainability, well-being & vulnerability i.e. dams have both negative and positive impacts on livelihood depending on the situation.

2.3. Economic Viability of smallholder irrigation

Various studies have been done so far on socio-economic impact of smallholder's irrigation. In Zimbabwe small holders' irrigation development has achieved higher yield than rain-fed dry land yields in communal areas and are also financially viable (Rukuni, 1984; Ruigu and Rukuni, 1990).

FAO's report on socio-economic impact assessment of Hama Mavhaire, Hoyuyu 5 and Nyaitenga, irrigation schemes in Zimbabwe also justify this: "Farmer incomes from irrigated agriculture are significantly higher than incomes of dry land farmers". Levels of inputs in terms of quantity are higher in irrigation schemes than in dry land areas, suggesting that there is more intensive crop production in irrigation schemes than in dry land agriculture.

This report also shows that using the income figures from the three schemes for 1996, the returns to labor were Z$ 117 per person per day for Hama Mavhaire, Z$ 376 for Hoyuyu 5 and Z$ 234 for Nyaitenga. This is much higher than the average of Z$ 21 per person per day paid in the Zimbabwean industry for non-skilled labor. From a social point of view farmers in an irrigation scheme were found to be far much better off than laborers in urban industries who are faced with a lot of other demands such as rent, water and electricity charges

In the same report it is further pointed out that smallholder schemes can be even more viable if aspects such as reduction in drought relief handouts, employment creation and reduction of rural to urban migration are considered in the economic analysis of these schemes. With a more integrated approach smallholder irrigation can be the basis for rural development and improved standards of living among Zimbabwe's rural communities.

The report, however, identified a number of constraints, which are hampering smallholder irrigation development in Zimbabwe. Some of them are: the high cost of capital investment in irrigation works for the poor farmers, poor rural infrastructure (roads, telecommunications and electricity) to facilitate input procurement and produce marketing, Lack of reasonably priced appropriate irrigation technology and lack of decentralized irrigation service companies to give back-up service in rural areas.

Mupawose (1984) also assessed the economic viability of smallholder irrigation schemes in Zimbabwe. The researcher pointed out that certain smallholder schemes have failed and are under-utilized due to poor management, lack of inputs and irrigation experience by farmers.

SADC report in 1992 reported that most new smallholder irrigation schemes in the Southern Africa region will not cover the cost of development and operation and are therefore uneconomic. The report further suggested that these schemes have a negligible impact on the national and household food security.

In Gambia, a study of irrigation scheme in the village of Chakunda, Webb (1991) lists some of the benefits of irrigation:

- Increased income which spent on increased expenditure, investment, construction and trade.
- Backward and forward linkages: traders were reportedly coming to purchase irrigation produce (Rice) and in turn sell cloth, jewelry and other consumer items.
- Increased material wealth both at the village and household level, this was in the form of construction of a large mosque built through farmers' donations and an improvement of the village clinic and increased wealth could be seen in 55 houses built in the village, fourteen with corrugated metal roofing.

However, in the same report Webb pointed out that some of the irrigation schemes collapsed because of frequent pump breakdowns due to poor operation and maintenance, Poor design of canal structures and Pest infestation of crops. This indicates that with the construction of irrigation canals there is a need to create awareness among the society on how to maintain and operate them.

In India, Sing and Misra (1960) compared the Sarda Canal irrigation and non-irrigating villages and showed the benefits of irrigation in terms of improved crop productivity and employment creation to communal people. They also made the following observations:

- Gross farm output per acre is 8.6% higher in the canal-irrigated villages than outside.
- The crop produce as distinct from the total farm output is 5.5% more with canal irrigation than without, mainly due to the cropping pattern under irrigation incorporating cash crops. The value of crop produce sold per acre is 48% higher in the canal-irrigated area than outside. This was again attributed to the superior cropping pattern incorporating cash crops.
- Total inputs per acre are 3.7% higher in terms of quantity in the canal-irrigated area than non-irrigated.
- Payment to outside labor, including casual and permanent farm servants, is about 21% more in irrigated areas than outside.

Lange (2000) looks at the smallholder farmers of South Africa and points out that the cost of irrigation equipments as a limiting factor. The other factor for adoption of irrigation technologies is its manageability. If water is available and easy to apply, then farmers will use more than is necessary. Technology adoption is therefore promoted by effective technology, easy to apply in the desired amount, easy to operate and maintain with local resources and should be affordable (ibid). He also points out that lack of interaction between farmers and technical advisors as a factor. This is due to farmers' lack of skills and experience and agents lack of commitment and/or back-up to interact.

In general, reviewing various literatures indicates varying and sometimes contradicting views on the economic viability and socio-economic impact of smallholder irrigation development. Some literatures have pointed out that smallholder irrigation schemes are agriculturally, financially and economically viable while other literatures argue that such projects are not viable.

2.4. Application of Linear Programming Model in Agriculture

Individual farmers must repeatedly make decisions about what commodities to produce, by what method, in which seasonal time periods and in what quantities. These decisions are subject to constraints and uncertainties/risks. Researchers use linear programming method to work in the optimization problem and to look at the decision of farmers with the given constraints.

Hazell and Norton defined linear programming (LP) as a method of determining a profit maximizing combination of farm enterprises that is feasible with respect to a set of fixed farm constraints. And according to them, for a given farm situation the LP model requires specification of:

1. The alternative farm activities, their unit of measurement, their resource requirements and any specific constraints on their production
2. The fixed resource constraints of the farm
3. The forecast activity returns net of variable costs

Kehkha. et. al. (2005) used a MOTAD risk-programming model to look at the effects of risk on cropping pattern and farmers' income in Ramjerd and Sarpaniran districts in the province of Iran. Using 194 farmers the result shows that variability of crops gross margins or outcomes has a significant effect on cropping pattern, but it varies over different farmers and regions with various conditions. More over it was found that farm plans with more number of crops have a lower return but high degree of certainty. In other words diversification is an important tool for farmers' to increase income certainty and to make trade-offs between risk and expected income. The study also found that government intervention and policies have enhanced the competitive position of some crops and fixing them in cropping pattern.

As a recommendation the study puts set of appropriate policies such as crop insurance, agricultural input and output price policies to be investigated and applied in the study region.

Bouman et.al (1999) used linear programming to quantify the effect of degradation of naturalized pasture overtime and to explore options for restoration by sustainable legume-based pastures in beef production systems in the northern Atlantic Zone of Costa Rica where beef cattle's ranching is the main land use activity. In the area, according to the study, beef cattle production is characterized by low levels of external inputs, no fertilizers applied low levels of technology and consequently low production and returns per unit area. In the study, a technical coefficient generator called PASTOR (pasture and Animal System Technical coefficient generator) was developed to compute input and output coefficients for a number of alternatives for each of beef production system components (which generate the marketable meat, pastures supplying feed and characterized by a soil-N balance and feed supplements providing an additional source of feed). The study used two linear programming models; one at a field level which used to maximize economic surplus (value of meat production minus all costs of inputs and labor) of a beef production system on a given piece of land. And the second a more complex model for the whole region REALM (regional economic and agricultural land use model) which maximizes regional economic surplus (sum of all output values of crop and livestock minus total input and labor costs) by selecting cropping, forestry and beef breeding and fattening options from a large number of alternatives.

The study concluded that few farmers in the northern Atlantic zone adopt grass-legume pastures since they realize that naturalized pasture yields higher than the economic break-even level for conversion to grass-legumes. Other factors which affect adoption were pointed out as absence of institutional credit to cover increased costs, lack of technical knowledge and insufficient experience.

Linear programming technique was used to develop farm plans for a 470-acre model farm in Mason County, Illinois (Papst and Swanson 1970). These farm plans give the highest net return above variable costs for each of four basic situations: no irrigation, 150 acres irrigated, 287 acres irrigated, and 437 acres irrigated (using both large and small systems). The labor available on the farm is one full-time operator plus one full-time hired man for all or a part of the year [480 hours of labor per month except for May-August (130/week)]. In the study livestock and pasture enterprises were not considered in order to simplify the study and also because irrigators indicated that decisions regarding irrigation do not affect livestock choices. The results indicated that cucumbers and green beans had first priority for land that was irrigated. However, because of contract restrictions and labor requirements for these crops, corn occupies over one-half of the irrigated land when equipment is available to irrigate 437 acres. The highest return plans were found to be relatively insensitive to changes in relative prices and yields. There was a declining rate of return on added investment in irrigation equipment as the area irrigated increased; the rate of return on equipment to irrigated the first 150 acres was 37%, while the rate of return on the added investment necessary to irrigate 150 additional acres form a base of 287 acres was only 7%.

A study by Upcraft et.al (1989) shows that the main crops irrigated in the UK are potatoes, sugar beet and field-grown vegetables which have a high water in-take. In order to avoid the risk of low yields and low returns as a result of insufficient rainfall during the growing season irrigation, most commonly practiced using mobile hose roll-rain gun irrigators, (known as supplementary irrigation) is used. In the study a mixed linear programming model was used to answer when each field should be irrigated, how much water should be applied and which field should be irrigated first on a particular day and to produce optimum irrigation schedules. The objective function maximizes the financial return from irrigation over a short term (7 days) subject to equipments, labor and water availability.

Revision of different literatures tells us that linear programming is used as a major instrument to solve problems and to justify some ambiguous statements. How ever the use of LP is not very common and there are no much works using it in Ethiopia.

2.5. Application of Linear Programming model in Ethiopian Agriculture; an empirical evidence

Tilahun (1990) has used linear programming algorithm in a study to answer the question why irrigation projects are operating below the required/expected economic efficiency and often leading to wastage of resources. The objective of the study was to analyze the planning and implementation of Hidi irrigation project (Debre Zeit) with the aim of: determination of optimum cropping plans for the integrated agricultural system, approximation of an economically efficient level of farm families that could be adequately supported by the project and investigation the effects of irrigation on farmers' incomes and resource use efficiency.

To answer the question with the above specific objectives, the researcher has used a linear programming algorithm with data that integrated the rain-fed and irrigated agriculture.

The project area contains 1799 ha of land among which 1710 ha (95%) is under cultivation. A sample of 80 individuals was taken for the study.

Findings showed that 1030 ha irrigated area couldn't be fully used by the existing farm families. According to the study, even though each family could earn more than double net farm income than by the optimal solutions of the rain-fed models, under-utilization of irrigation resources makes this version of the plans to fail.

In the study the results of the LP models indicated that 353 additional families could be allowed to participate together with the existing 633 families leading to a substantial improve in resource utilization and income.

Shiferaw & Holden (1997) used linear programming model to make a farm household analysis of resource use and conservation decisions. The study developed a non separable farm household model (based on LP) to analyze resource use and conservation decisions of smallholders and to model consumption and production decisions interdependently in the Ethiopian highlands. In the study a socio-economic survey data conducted in 1994 in 3 peasant associations of Ada Woreda (East Shewa zone of Oromia region) with a sample size of 120 households was used.

The whole farm model, with 202 activities and 150 constraints, was identified which maximized annual net returns defined as current net return (on-farm and off-farm) less the present value of future income loss caused by yield losses resulting from current soil erosion (user costs) subject to various farm-level resource supply and behavioral constraints.

Based on the data, peasant's short and long- term responses to alternative scenarios that incorporate the user costs of soil erosion at varying levels of average anticipated effects of conservation on production, discount rates and planning horizons were analyzed. The result shows that the strong need to introduce dual-purpose conservation technologies that conserve the soil while also enhancing crop yields in the short-term to make conservation attractive to the smallholder. According to the study, in the short run, when the small holder is not internalizing the user costs of current production, no land conservation is likely to occur unless conservation technology is enhancing productivity. Under various assumptions and constraints faced by peasant households, even in the long run, conservation fails to be a preferred option when average expected yields with conservation are lower or even the same as that without conservation. The other variable raised as a discouraging factor for conservation was sufficient credit availability for smallholders. Without provision of sufficient credit to smallholders, high fertilizer price following structural adjustment programs and removal of input subsidies is likely to discourage conservation.

Kassie & Holden (2005) used a bio-economic linear programming model to look at the impact of forage legumes-cereals intercropping on household income and soil conservation. The research was done based on experimental data and a data collected from 87 farmers by the Adet Agricultural research centre in Bahir Dar zuria Woreda, West Gojjam zone of Amhara regional state. The model consisted of 3 scenarios: the existing/actual situation i.e base model without legumes, the model with legume (plan I) and model with legume and with additional of crossbred cow in order to maximize farm income. Using generalized algebraic modeling systems (GAMS), the following results were found. Legumes-cereals intercropping increased farm income while reducing pressure on the land resource and this income will further increase when it is combined with crossbred cows for milk production. The other finding is that the introduction of legumes in to the production system will decrease the marginal productivity of grazing land due to availability of hay from intercropping, which reduces overgrazing.

The study concluded that development interventions that consider forage legumes will achieve a double advantage of enhancing the livelihood of rural households and minimization of soil erosion/ land degradation.

3. METHODOLOGY

3.1. Description of the Study Area

The Fogera plains lie to the east of Lake Tana, near the town of Woreta, which is the capital of the Woreda, on the road from Bahir Dar to Gondar, 582 km from Addis Ababa. Fogera Woreda is well known for its recession zone on which farming, fishing and cattle herding is practiced. This area mainly consists of a flat, open plain across which the Rib River flows into Lake Tana. The Gumera River forms the southern boundary. Both rivers originate on the high plateau to the east, and as they reach the plains the gradient decreases and they form meanders. During and after the rainy season, as the Rib River approaches the level of Lake Tana, water overflows its banks and floods the surrounding area. The perennial Gumera River also overflows its banks as it approaches the lake, but causes less flooding than the Rib. Fogera, Libokemkem and Dembia Woredas, border and/or share a vast plain where drainage is extremely poor are frequently affected by over-bank spills of the Gumera and Rib rivers that expose them to serious flooding (DPPC, 1997). A perennial swamp has been formed around the mouths of these rivers. Lake Tana, which forms the western boundary of this area, also floods up to 1.5 km inland during the rainy season. During the dry season, the water retreats and the flooded area is used for seasonal grazing and retreat cultivation. The extent of the marsh depends on the amount of rain, as no other surface water feeds it.[1]

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[1] http://www.birdlife.org

Map of Flood-prone Woredas and Kebeles Around Lake Tana

Data Source: Central Statistics Authority and Ethiopian Mapping Agency
Map Produced by ENTRO, Dec 2005

3.2. Sampling Techniques

The survey was conducted in 200 selected households with in selected Kebeles of Fogera Woreda. The selection was undertaken purposely based on households' participation in irrigation and flood recession farming systems.100 households per farming system were sampled and a detail interviews were undertaken. To select the 100 households for the two systems, a multistage sampling procedure was used.

- **For households engaged in flood recession agriculture:**

Samples for flood recession farming beneficiaries were selected based on number of beneficiaries in the kebele i.e. large numbers of respondents from Kebeles which have many beneficiaries and less number of respondents from kebeles which have small beneficiaries. There are 25 Kebeles in Fogera Woreda and among which only nine Kebeles are in the flood zone. Out of the nine, 4 of them Shega, shina[2], Wagetera and Kidist Hana are in the high flood zone with 3753[3] beneficiaries. A sample of 100 respondents was taken from these 4 kebeles and from each Kebele farm households who practice flood farming were selected. Based on percentage calculation the following number of respondents were taken from each Kebele.

2 Even though Nabega Kebele is a highly flooded area, it was impossible to include it in the survey due to high flooding at the time of data collection. Instead, shina Kebele was taken into consideration.

3 The number is based on 2004/05 data from the Woreda Bureau of Agriculture.

Table 1: List of selected Kebeles and their sample taken

Kebele	**Number of beneficiaries**	**Percentage from sample total**	**Sample taken**
Shega	1625	43.3	43
Wagetera	1215	32.4	32
Kidist Hana	596	15.9	16
Shina	317	8.4	9
Total	**3753**	**100**	**100**

Source: Fogera Woreda agricultural office

- **For households engaged in irrigation:**

Among the remaining 16 Kebeles which are not in the flooded zone (except shina which was included due to better irrigation practice), 4 rural Kebeles and with high participation in irrigation practices were selected. Based on the 2005/06 Woreda agricultural office data, Tihua-Abua, Kuhar-Micael, shina and bebeks have a better experience in irrigation practicing and get more benefit from irrigation. A sample of 25 households engaged in irrigation has been taken from each of the 4 Kebeles.

3.3. Source and Type of Data

Even though, the major data source is primary secondary data was also used as well. And the main data required for the study include:

- Available resources such as cultivated crop land, labor, draft oxen, number of cows, pack animals
- Crop produced with rain-fed, irrigation and flood recession farming systems and their resource requirement for each period.
- Market prices and variable costs
- Subsistence requirements

The primary data was collected using structured questionnaire (the medium of communication was Amharic) from selected rural households of a randomly selected households in the purposely selected Kebeles in Fogera Woreda of south Gondar zone of the Amhara region. 7 experienced enumerators from Fogera Woreda Agricultural office, all with Diploma and above, and 2 supervisors (including the researcher) worked in data collection. A one day training was given for the enumerators about the content of the questionnaire and on how to address the questions. The data has been collected form 18 October up to 03 November 2006.

3.4. The Empirical Model

The ultimate goal of any new planned agricultural scheme is to produce the highest crop yields using the available resource efficiently. Farmers will practice irrigation when they perceive that its benefits will outweigh its costs. According to Lagat et.al. (2003), it is the interaction of two opposite forces (incentives and disincentives), which creates tensions that motivate action resulting in change, thus practicing. Here farmers make the decision of practicing based upon an objective of income maximization. It is postulated that the farmers practice irrigation if income from it is higher than income from the common rain-fed farming system. There are numerous models used for farm planning. However, the selection depends on data requirements and their availability, budget, time and other research facilities allocated to the study (Ahmed et.al, 2005).

3.4.1. The objective function

Linear programming model (LPM) was applied with a major objective of maximizing farmers' income with a comparative analysis of flood recession farming and irrigation farming taking rain-fed agricultural farming system as common for all.

LP is an optimization technique which is most efficiently applied in cases where decisions require a choice among large number of alternatives and where the objective function and the constraints (i.e. input-out put) can be approximated by linear functions of the decision variables (Upton (1979) cited in Tilahun, 1990, El-Kassar ,2006).

It is common to use linear programming techniques at farm household level to analyze the impact of technology adoption on household income and environmental concerns and where a single cropping year cross section data does not permit econometric estimation (Ahmed et.al, 2005, Kassie & Holden, 2005). The basic linear programming model in this study is drawn from that of Hazell and Norton (1986) with some modifications with respect to the underlying assumptions and setting of constraints based on the work of Kassie & Holden, 2005.

The LP model maximizes gross margin (total revenue minus total variable costs) of individual households from crop and livestock production subject to various fixed resource constraints.

The main constraints are:

- Maximum cultivable and grazing land available
- Maximum family labor available
- Maximum oxen labour available
- Maximum available working capital for agricultural production.
- Minimum family subsistence requirements
- Available credit

Based on the above constraints, the specific model has the following structure:

$$MaxII = \sum_{j=1}^{m}\sum_{k=1}^{B} P_{jk}Q_{jk}. - \sum_{i=1}^{h}\sum_{j=1}^{m} P_{ji}X_{ij}A_{j} + \sum_{l=1}^{D} P_{l}X_{lcs} + \sum_{p=1}^{L}\sum_{l=1}^{D} P_{pl}.Q_{pl} - \sum_{g=1}^{E}\sum_{l=1}^{D} P_{gl}X_{gl} - iBOW$$

Subject to:

Land constraints: $\sum_{j=1}^{m} A_{j} \leq L$

Pasture land constraints: $A_{p} \leq pasl$

Human labour constraints: $\sum_{s=1}^{4}\sum_{j=1}^{m} L_{sj} A_{j} + \sum_{s=1}^{4} L_{sl} X_{l} \leq L_{s}$

Draft power constraints: $\sum_{s=1}^{3}\sum_{j=1}^{m} w_{sj} A_{j} \leq O_{s}$

Animal feed constraints and balance: $\sum_{j=1}^{m} N_{nj} A_{j} \pm N_{nj}^{ps} \geq \sum_{l=1}^{D} n_{rl} X_{l}$

Home consumption: $Q_{j}^{c} \geq Q_{j}^{mr}$

Crop balances: $$\sum_{j=1}^{m} q_{jk} A_j - Q_j^s \geq Q_j^{mr}$$

Livestock balances: $$y_{pl} X_l - sale_{pl} \geq Q_{pl}^c$$

Livestock replacement and culling rate:

$$cur_l X_l - X_l^{culs} \geq 0$$

$$cur_l X_l - X_l^R \leq 0$$

$$sur_l X_l - X_l^{surs} \geq 0$$

Capital constraint: $$\sum_{j=1}^{m} k_j A_j + \sum_{l=1}^{D} k_l X_l - BOW \leq OF$$

Credit limit: $$BOW \leq CRL$$

Where;

Q_{jk} = total quantity of output k produced by crop j activity and available for sale

P_{jk} = price of output type k (grain and fodder) from crop j activity

P_{ji}= price of input i (fertilizer and seed) used by crop j activity

X_{ij}= level of input i used per hectare by crop j activity

A_j= level of crop j activity in hectare

P_l = selling price of type l livestock

X_{lcs}= number of heads of type l livestock available for sale (culled(c) and surplus stock (s))

P_{pl}=selling price of type p (milk and butter) livestock product produced by type l livestock

Q_{pl}= quantity of livestock product p from type l livestock

P_{gl}= price of livestock variable input g used by livestock type l

X_{gl}= number of heads of type l livestock using type g livestock input

iBOW=amount of borrowing with interest i

L= total cropland available in hectare

A_p= total pastureland used for grazing

Pasl=total pastureland (communal and private) available to farmers

L_{sj}= the number of labour man-days required per ha by crop j during period s

L_{sl}= the number of human labour hours required to keep available livestock stock during period s

L_s= total human labour hours available during period s

W_{sj}= the number of oxen pair hours required per ha by crop j during period s

O_s= total number of oxen pair hours available during period s

N_{nj}= amount of fodder type n (hay , protein, and energy) per ha produced by crop j activity

N_{nj}^{ps} =Amount of fodder sold (s) or purchased (p)

n_{rl}= quantity of fodder type n required per head by livestock type l

Q_j^c= the level of household consumption of crop j activity

Q_j^{mr} = household subsistence (minimum) requirement from crop j activity

q_{jk} = per hectare yield of crop j activity

Q_j^s = quantity of crop j sold (s)

y_{pl} = yield of animal product type p from type l livestock activity

X_l = number of type l livestock

$Sale_{pl}$ = sale of animal product type l livestock activity

Q_{pl}^c = type p product from type l livestock that is consumed by household

Cur_l = culling rate (cur) from type l livestock

X_l^{culs}= number of culled animal sold (culs) from type l livestock

X_l^R = number of type l livestock born and reared on the farm to replace(R) culled livestock type l

sur_l = number of surplus stock(sur) over replacement from type l livestock

X_l^{surs} = number of surplus stock sold (surs) from type l livestock

k_j = working capital requirements for crop j production

k_l = the working capital requirements for type l livestock

BOW = amount of borrowing

OF = amount of own fund available

CRL = credit limit

Table 2: Tabular representation of the linear programming equation

		Activities								
		Production			Buying	Selling	Feed consumption	Home consumption	Borrowing(BOW)	RHS
		Crop& feed	Grazing	Livestock, product & transfer	Feed	Crop, fodder, livestock & livestock product				
Objective: Max. gross farm income	Birr	-Cj		-Cj	-Cj	Pj			-i	=Z
Constraints	Unit	Ha		Head/kg	Kg			Kg/liter	Birr	
Cropland	Ha	+1								$\leq L$
Pasturelands	Ha		+1							$\leq Pasl$
Feed consumption(hay)	Kg						+1			$\leq Max$
Human labour	MD	+A								$\leq L_s$
Ox labour	OD	+A								$\leq O_s$
Home consumption	Kg							+1		$\geq Min$
Capital constraint	Birr	+A		+A	+A				-1	$\leq OF$
credit limit	Birr								+1	$\leq CRL$
Crop & feed balance	Kg	-A	-A		-1	+1/+A	+1	+1		<=>0
Livestock balance	Head			-(+)A/-(+)				+1		≤ 0

3.4.2. Description of Activities

In the study the variable cost section of the objective function coefficients refers to include cropping, livestock feed supply, selling, purchasing, borrowing and consumption activities. The major activities used in the model are:

Crop production: The production activities in the model includes 7 major crops (Rice, Maize, Finger millet, Teff, Barley and Chick pea) and Onion with and without fertilizer using rain-fed, flood recession and irrigation systems. Crop yield refers to output net of seed requirements this is done since farmers, most of the time, use their own local variety seed from previous production for the following season.

Livestock rearing: livestock are kept on a very small scale and has relatively little contribution to the farm family income. Oxen, being the major means for plough, are dominant in livestock enterprise. On average an individual household has 2 oxen, 2 cows, and 1 donkey or the equivalent, 4.1 tropical livestock unit (TLU), defined as an animal of 250 kg live weight. With regard to farm inputs, no modern farm machinery is used except some farmers used pedal pump for Onion production with irrigation. Farmers do not use fertilizer as a major input in their production.

Sales and purchase: refers to the selling and purchasing activities undertaken for crops, livestock and fodder with in a household in a year base using an average price calculated based on 2004/05 and 2005/06 price data from the Woreda agriculture office (see annex 1&2). Selling activity is constrained by subsistence food requirement of households i.e. households will engaged in selling if and only if they have surplus product out of their consumption need.

Consumption: it includes the annual consumption requirement from each crop and livestock products for a household.

3.4.3. Description of Constraints

Land constraints: it includes farmers' cropping land and private and communal grazing land. Total cropped land in hectare must be less than or equal to the total land available for cultivation and total land used for grazing must be less than or equal to the total land available for grazing in hectare.

On average a representative household in the study area has 1.3 ha cultivated land and 0.2 ha private grazing land. In total there are 7 constraints related to land in the model.

Crop production balance: refers to the different types of crops that farmer's produce and their minimum consumption requirement and sold amount with in a year base. The total amount produced for each individual crop minus the amount sold must exceed or must be at least equal to the minimum consumption amount required per crop.

Labor availability: there may be family as well as hired labor used in the production process. Here exchange labor should be included since farmers highly used exchange labor. In the data collection process farmers will be asked how much labor was used in each activity (land preparation, sawing, weeding, harvesting and threshing), the number of days they were working and how much family and hired labor was used.

Oxen labor constraint: it stands for the pair of oxen power used for the plough (Kassie and Holden, 2005). The equation is formed in such a way that a pair of oxen (raised or purchased) delivers as much as human labor days/hours in a month during the plough season.

Table 3: Resource constraints used in the model for a representative household

Resources	unit	Total available	Remark
Human labour available	Days	209	with 7 hours/day there will be 1463 hours available
Oxen days (Os)	Days	104	728 hours available
Crop land	Ha	1.3	
Pasture land	Ha	0.7	
Own fund (working capital) available	Birr	2405	
Animal feed subsistence	Kg	8942	Its is calculated based on TLU
Minimum subsistence annual crop requirement	Kg	964	Rice, Maize and Finger millet take the lead in consumption with 502, 210 and 123 kg respectively

Source: own data computation

Credit constraint: availability of credit is the other factor that has an impact on farmers' productivity. In addition to their own fund, farmers need credit access for the purchase of farm inputs such as fertilizer, improved seeds, animal fodder and the like. The maximum borrowed amount will be equal to the credit limit.

Animal feed constraints: it is calculated taking in to account the availability of animal feed from both communal and private grazing land and additional feeds from residuals like weed and crop residues (Kassie and Holden, 2005). The amount of fodder collected from each crop production in addition to purchased one or less of sold must be equal or higher than the amount of fodder required for the total livestock of an individual household. Fodder requirement per livestock varies based on their function, class and age group (Kearl, 1982; MAFF, 1984; Nordblom et al., 1992 cited in Kassie & Holden, 2005).

Livestock product balance: refers to the balance between consumption, production and marketing activities of livestock products in a year base. The assumption is that the total livestock product from each livestock less sale of the product must exceed or at least be equal with the household's minimum subsistence requirement of that product.

Livestock transfer constraint: refers to the replacement and disposal of culled animals through sale.

Annual Subsistence Requirement: refers to the minimum subsistence requirement of an adult on a year base. The calculation has been made based on Grayseels's and Anderson's (1983) calculation where 200 kg of cereals, 50 kg of pulses and 30 kg of milk are assumed as average annual subsistence requirements per adult equivalent (Grayseels and Anderson, 83 cited in Kassie and Holden, 2005). The assumption here is that households eat much of a crop when its production is higher and lesser amount if it is produced in a lesser amount. Each household has a family size of 4 adult equivalents on average and need 964 kg of cereals, 120 liter of milk and 1034 kg of dung for fuel annually.

3.4.4. Model Scenarios

There are 2 scenarios in the model

Base plan: In this plan the gross income from rain-fed farming plus the recession agriculture practice with livestock income used as a basis for comparison with irrigation agriculture

Plan I: this plan maximizes gross farm income from irrigation & rain-fed with existing resources and with livestock rearing income.

4. Data Analysis and Discussion

4.1. Socio Economic Characteristics

The plains support a large population of an indigenous breed of cattle, Fogera, named after the area. Cattle-farming is still a major activity, but crop cultivation has become increasingly important. In the 1970s, an agricultural research station was established at Woreta to promote Rice as a crop (World Bank, 2005).

The population size of the Woreda is about 241,488 based on the 2005/06 record of the Woreda agricultural office. Out of this population, 212,670 live in the 25 PAs and the rest 28,818 in Woreta town. As the Lake Tana hydrometric data shows, many peasant associations situated on the shore of Lake Tana are at level lower than the maximum flood levels (Adugna & Solomon, 2000). In the PAs there are 42764 household among which 38472 are men headed and the remaining being headed by women. Out of these PAs only 9 of them are in the flood zone, which have a population of 76,596. On average about 7500 households benefited from recession agriculture annually.

Table 4: Flood inundated Kebeles in the Woreda

No	Kebele	Total population (number)	Land used for flood agriculture (ha)		HHs engaged in flood recession agriculture (number)	
		1998	1997	1998	1997	1998
1	Tihua-Abua	11046	120		210	
2	Shega	7074	920.5	965	1625	1023
3	Deba sebatira	8111	120	177.75	411	838
4	Nabega	10513	564	1940	1549	2619
5	Rib Gebrial	7294	85.25	240	187	870
6	Shina	9383	136.25	1.5	317	399
7	Bebeks	6911	0.8		9	
8	Kidist Hana	7061	155.5	131.25	596	698
9	Wagetera	9203	463.75	807.15	1215	3483
Total		**76596**	**2566.05**	**4262.65**	**6119**	**9930**

Source: Fogera Woreda agricultural office

The major crops that farmers produce in Fogera woreda are Rice, Maize, Finger millet, Teff, Vetch and chick pea. Farmers also produce Noug, Lentil, Barley, Emmer wheat and wheat in a lesser amount. Onion is a major cash crop produced through irrigated farming systems in the woreda. The soil type is mainly vertisols and fluvisols(a flood deposit/sediment soil) in areas near Lake Tana.

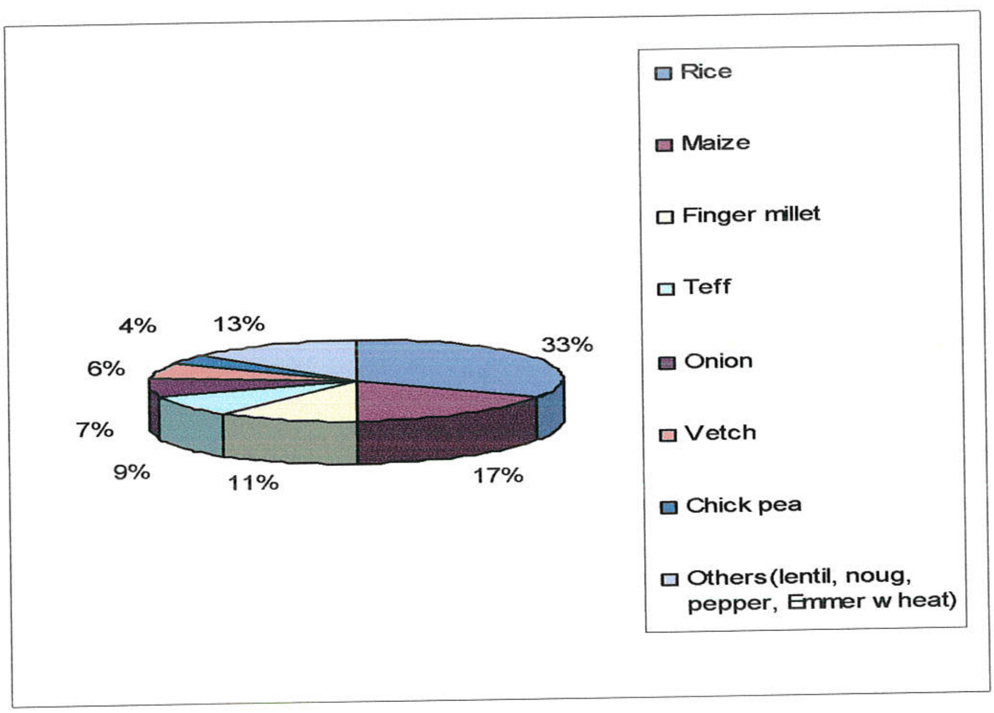
4.2. Descriptive analysis

4.2.1. Land use and crop pattern

Based on the survey result, in the Woreda, farmers use their crop land to cultivate different crops using the rain-fed, flood recession as well as irrigation farming systems. Among the three farming systems, rain-fed farming takes the lead in land use with 66.5%. And the rest 19% and 14.5% of farm households' crop land is covered by flood recession and irrigation farming systems respectively.

When we look at the crop pattern, Rice as the major crop in the Woreda covers about 33% of farmers' crop land followed by Maize (17%), Finger millet (11%) and Teff (9%). Crop pattern in hectare of major produced crops in the Woreda from the sampled households is shown below in the pie chart.

Figure 1 crop pattern in hectare (%)



Source: own data computation

4.2.2. Land productivity

The Amhara region, especially Fogera Woreda is the highest Rice producing area among other areas in the country next to Gambella which produces 4800 kg/ha (see the annex). The survey result shows that production of Rice gives the highest yield in selected Kebeles of the Woreda. The result indicated that 2446 and 3298 kg of Rice per hectare can be produced using flood recession and rain-fed farming systems respectively. Based on the sampled Kebeles, most of the production is undertaken using rain-fed farming (83%) followed by flood recession farming (12%). The Sassakawa Global 2000 (SG2000)/ Ethiopia; Regional Rice Program (RRP) 2006 4^{th} quarter report also justifies the above result. The RRP research result shows that in Amhara region Rice producing areas 36000 kg/ha of Rice can be produced using rain-fed system. The major Rice seed varieties in the country in general and in the Woreda in particular are NERICA, Suparica and X-jigna.

When we look at the productivity of other crops, Maize takes the leading position. From a hectare of land it is possible to produce 2210, 1726 and 1729 kg of Maize in irrigation, flood recession and rain-fed farming systems respectively without using fertilizer. However when fertilizer is used in rain-fed farming system 2229 kg of Maize can be produced per hectare of land. This gives 503 kg of additional Maize over the rain-fed production without fertilizer. The straw yield varies due to fertilizer use and among the farming systems (see annex 1). For instance it is possible to get 1349 kg and 1738 kg of Maize straw without and with fertilizer respectively using rain-fed farming system and the straw yield increases to 1679 kg without fertilizer using irrigation farming system. Productivity of each crop with fertilizer and without fertilizer is listed in the table below.

Table 5: crop productivity with and without fertilizer

No	Crop	Crop yield (kg/ha)					
		Without fertilizer			With fertilizer		
		Irrigation	Flood	Rain	Irrigation	Flood	Rain
1	Teff	-	1035	796			
2	Maize	2210	1726	1729			2292
3	Finger millet			1531			1669
4	Rice		2446	3298			
5	Vetch	1018	866	873			
6	Chick pea	914	1686	973			
7	Barley			2061			
8	Onion	7080					

Source: own data computation

Base plan

This plan consists of flood recession farming with the common rain-fed farming system. Maize and Rice are the major flood zone crops which account for 36 and 20 percent of crop land respectively. Farmers also produce Teff (17%), Chick pea (7.5%), Vetch (4%), Finger millet (3%) and other crops (8.5%) of their crop land in the flood zone. Even though Maize covers the largest area, Rice takes the highest part in productivity per hectare. On a given unit hectare of land it is possible to produce 2446 kg of Rice while productivity of Maize from the same hectare of land is 1726 kg.

Improved plan

This plan refers to production using irrigation instead of flood recession farming. The major crops in irrigation farming system are Onion, Maize and Vetch which covers 50%, 16% and 7%

of households' farm land respectively. In productivity Onion takes the lead 7080kg/ha followed by Maize 2210 kg/ha. Using half of their land for cash crops like Onion will alter the cropping as well as consumption pattern of farmers and they may need to purchase cereals for consumption.

4.2.3. Labour utilization

In the farming system there are 4 periods. These periods are ploughing, weeding, harvesting and threshing. Each period needs a large amount of human labour. In the study labour requirement for each period by farming system (not by crop type) was calculated. The traditional rain-fed farming system needs 17, 53, 22 and 14 labour days for ploughing, weeding, harvesting and threshing respectively for each hectare of land. The higher labour for weeding is due to Rice. Rice needs a higher amount of labour for weeding and it is also highly produced using rain-fed farming system. In flood farming system for the same hectare of land and for the above mentioned periods (in the same order) 18, 28, 24 and 16 human labour days are needed. When we come to the irrigation farming system the labour requirement is more than double of that required for the flood farming system. This implies that farmers who practice irrigation need more labour days than those farmers who use the traditional method of farming. The opportunity cost of labour may not be considered here since most of the farmers in the area do not participate in non farming activities.

4.3. Model of Data analysis

In the data analysis a generalized algebraic modeling system (GAMS) was used to estimate the result (see annex 7). GAMS is a high-level modeling system for mathematical programming problems which consists of a language compiler and a stable of integrated high-performance solvers. GAMS is tailored for complex, large-scale modeling applications, and allows the user to build large maintainable models that can be adapted quickly to new situations. Two separate models were developed for the base plan and the improved plan.

4.4. Model Results and Discussions

4.4.1. Generated gross income

Base plan

The base plan incorporated rain-fed and flood farming with other farm activities. The result shows that in this plan, with the existing resources a representative household will get an annual gross income of 5557 Eth birr. From this total income 2714 birr is generated from sale of Rice and the rest from hay and livestock production which includes selling of surplus & culled livestock, selling of milk and milk product.

Table 6: households' gross farm income

	Base plan	Improved plan
Farm income	5557	11893
Crop	5260	11596
Livestock	297	297

Source: model estimation

Improved plan

This plan consists of rain-fed and irrigation farming with livestock rearing. When households shift to this system their income will increase by more than double (from birr 5557 to 11893). Like the base plan income generated from livestock and livestock products is also included here. Here the major source of income is Onion. On average a representative household will get 5978 Eth Birr from Onion sale.

4.4.2. Marginal productivity of resource

Table 7: marginal value productivity of resources

Resources	Base plan	Improved plan
Cultivated land(Birr/ha)	5499	15611
Grazing land (Birr/ha)	507	507
Human labour (Birr/man-day)	26	57
Oxen labour	60	60

Source: model estimation

Table 7 shows that the marginal value productivity of land increases by more than double from 5499 in the base plan to 15611 in the improved one. This is because farmers who practice irrigation allocate almost half of their holdings for Onion cultivation which is a highly productive cash crop. When we come to grazing land, an individual farmer on average can rent a hectare of grazing land for 507 Eth birr annually. The marginal value productivity of oxen doesn't show any change and it is not that much higher. This is because rental of oxen is not common practice in the area. When we come labour productivity, taking a household having 3 family members able to work and 209 working days on average it is possible to get a farm income of Eth Birr 26 per day in the base plan and 57 in the improved plan. This indicates that taking utilization of the major resources land and labour in to consideration, the improved farming system gives a better result for farm households.

4.3.3 Land use

Table 8: model estimated values of land use (in hectare)

Crop	Base plan	Improved plan
Teff	0.050	0.057
Rice	0.973	0.152
Chickpea	0.02	0.034
Maize	0.122	0.092
Vetch	0.034	0.029
Barley	0.017	0.017
Finger millet	0.08	0.074
Onion	-	0.844

Source: model estimation

Table 8 above shows how land is allocated among crops for both the base and improved plans. In the base plan more land is allocated for Rice followed by Maize and Finger millet. These three crops are highly suitable for and productive in flood recession zones. The model result also shows that Rice is a major source of income for farmers engaged in flood recession farming. More land is allocated for Onion (a major cash crop) followed by Rice and Maize in the improved plan.

When we look at the annual income of farm households in selected Kebeles of Fogera Woreda, it is much higher than other Woredas in the region and it is also higher than an average representative household in Ethiopia. This is due to high productivity of Rice and Onion in the Woreda.

4.5. Sensitivity Analysis

The linear programming model assumes a linear input-output relation with no variability how ever many of the coefficients used in the model are in reality subject to variation. Sensitivity analysis involves changes to model coefficients within reasonable bounds of the original estimate and is often used to determine if the result of representative plans will be affected. It is possible to assess the stability of the objective values and cropping patterns in both scenarios. Since the price of inputs like fertilizer and improved seeds are assigned by the government (kassie and Holden, 2005), change in the out put price of major crops is used as a tool for sensitivity analysis.

Since Rice is the major crop in the Woreda its price change was taken to look at income sensitivity. A 50% reduction in the price of Rice decreases the income of the base plan by 56% (from birr 5557 to birr 2452). The effect of Rice price change in household's income (by %) is listed in the table below.

Table 9: percentage reduction in price of Rice and its impact on income of the base plan

scenario	% Price reduction in Rice and reduction on income			
	10%	25%	30%	50%
Base plan	5557 to 4919 (11.5%)	5557 to 3991 (28%)	5557 to 3683 (34%)	5557 to 2452 (56%)
Improved plan	No effect	No effect	No effect	No effect

For instance a 25% price reduction will bring 28% reduction in annual income of the household in the base plan rather the same price reduction will bring no change in the annual income of the same household practicing irrigation. This is because Rice is not an irrigation crop rather Onion is a major irrigation crop. But it was not possible to take Onion price to measure the sensitivity analysis for both scenarios since it is not produced using flood recession zone. Therefore Rice, which is highly produced with rain, which is common for both plans, is taken as an alternative.

If we take Onion price reduction to look at its effect on income of the improved plan we will get the following results

. Table 10: Percentage reduction in Onion price and its impact on income of the improved plan

Scenario	% Price reduction in Onion and % reduction on income			
	10%	25%	30%	50%
Base plan	No effect	No effect	No effect	No effect
Improved plan	11893 to 10428 (12.3%)	11893 to 8235 (31%)	11893 to 7506 (37%)	11893 to 4588 (61%)

Table 10 shows that a price reduction in Onion has a significant effect on the income of a household engaged in irrigation practicing. For instance a 10% price reduction brings a 12.3%

(1465 Eth Birr) reduction in the income of the household. And the reduction in income gets high when the price decreases more (there will be a reduction of 61% on income with a 50% reduction on Onion price).

In general the same percentage price change will bring significant change in the income of the improved plan than that of the base. This may be because the improved plan is mainly focus on cash crops while the base plan focus on consumption crops and sell is available if there is excess production from consumption. However price sensitivity of Onion may affect the living condition of households. Therefore farmers should form cooperatives which find market for their product, gather information market conditions and create a link with other cooperatives for information exchange.

5. SUMMARY, CONCLUSION AND POLICY RECOMMENDATIONS

5.1. SUMMARY AND CONCLUSION

The water level of Lake Tana is characterized by seasonal fluctuations attributed to the increase in inflows during rainy season and reduction during dry season respectively. When the level increases in the rainy season and to some extent due to the regulation weir (Chara Chara dam), part of Bahir Dar Zuria, Denbia, Fogera and Libokemkem Woredas are affected by seasonal flooding. The rise of the level brought about inundation of cropped area, grazing lands, residential area, access roads etc; consequently loss of crops, abandoning of homes, proliferation of incidents of malarias etc became the cyclic problems affecting the area. Despite these damage, farmers who live around the Lake get the opportunity to produce various crops (especially crops which need much water, like Rice) using either the outflow water from the lake or the flood from tributary rivers. After the rainy season passes the flood will reduce gradually and the land will have abundant water, which is convenient for farming actives.

The main focus of the study was on assessing the benefit/income contribution of irrigation farming in comparison with flood recession farming in Fogera Woreda of South Gondar Zone. Various literatures also revised to look at country experiences in flood as well as irrigation farming practice.

Using a household data from selected kebeles of the Woreda, a linear programming analysis was undertaken using GAMS software. The result shows that the benefit from irrigation outweighs the benefit from that of flood recession farming Rice and Onion being the major income generating crops for flood and irrigation farming systems respectively. Even though irrigation gives the higher income for farmers, it needs more labour, water availability and improved inputs than the flood and rain-fed farming systems. High water use for irrigation may have a negative impact on streams, lakes and rivers which are mainly used in the community as a drinking water for both people and livestock.

In general, an intervention to wards irrigation practicing which takes water, labour, land and improved inputs availability in to consideration will result in improving living condition of the community in addition to avoiding flood disaster in the woreda.

5.2. POLICY RECOMMENDATIONS

The flood zone has many advantages such as it is a home of the various flora-fauna and unique endemic species of fish, an important bird nesting and sanctuary area, it supports different livelihoods of indigenous people. Papyrus about 4 m tall and an essential for making the local reed boats called 'tankwas' and used for matting, fencing and roofing, is found in the shorelines of lake Tana. Currently the marshes are decrease in extent due to drainage and the recent expansion of seasonal cultivation and irrigation practicing.

Therefore the researcher believes that before going to the implementation of irrigation farming via dam construction, it is recommended:

- To undertake a conscious overall socio economic study in the area which will help to avoid unnecessary complains from the community who are supposed to be beneficiaries of the system during the time of implementation. For instance there were complains during 1998 flooding from peasant associations around Lake Tana which were safe before the construction of Chara Chara dam (weir). Mismanagement of the Chara Chara flow regulation weir gates was one reason for the overflow. These gates were not fully opened in1996 while the problem was severe. Therefore people working in the operation should be familiar with reservoir operation and should have information access on changes of the water level.
- The study shows that irrigation farming needs more labour time (more than double of that of rain-fed and flood recession farming), improved inputs like seed, fertilizer and pesticides and technical skills. Therefore to make irrigation more effective, easily availability of these resources is a condition.

- To have the updated environmental condition such as current status of river flows, the annual mean rainfall and temperature which is necessary to calculate the rivers inflow and outflow condition before planning for further use.
- To assess the existing activities around the supposed to be irrigated areas which will help to compare benefits and costs of the existing and planned activities
- To form farmers' cooperatives which can work on market assessment and which can create a link with other cooperatives and gather information in market conditions. In addition these cooperatives also work with agricultural bureaus on what to do for better productivity and on how to disseminate agricultural inputs.

References

Biswas, A., 2004. Is The Global Debate On Dams Relevant? Asian Water at vikass@singnet.com.sg.

MoWR, 1998. Abbay River basin integrated development master plan project various volumes.

Dejene, E., 2003. Lake Tana biodiversity potentials and threats. Amhara Regional Agricultural Research Institute (ARARI), Bahirdar.

Acreman, M., 2000. Managed flood releases from reservoirs: issues and guidance prepared for thematic review II.1: Dams, ecosystem functions and environmental restoration a contributing paper for the World commission on Dams. DFID, Environment Research program infrastructure and urban development division, Wallingford UK.

J. Lagat, J., Ithinji, G. and Buigut, S., 2003. Determinants of the adoption of water harvesting technologies in the marginal areas of Nakuru District, Kenya: the case of Trench and Water Pan Technologies. EAJRD

Bird Life International, 2005. Fogera plains important Birds area of Ethiopia. http://www.birdlife. org.

Kebede, S., Travi, Y, Alemayehu, T. and Marc, V., 2005. Water balance of Lake Tana and its sensitivity to fluctuations in rainfall. Science direct, Journal of Hydrology.

World Bank, 2005. Tana-Beles development program, pre-identification mission.

EEPCO, 2005. Lake Tana multi-purpose project Salini construttori Studio Pietrangeli Rome.

MoWR, 2005 Tana-Beles water systems: an overview of water resources, development potentials and issues.

Lake net, 2004. Lake Tana symposium addressed by David Read Barker. Bahirdar University, Bahirdar.

Belachew, A. & Cherie, S., 2000. Report on environmental impact assessment due to the rising level of Lake Tana. Addis Ababa.

Kehkha, A, Mohammadi, G. and Villano, R., 2005. Agricultural risk analysis in the far province of Iran: a Risk-programming Approach. Working paper series in agricultural and resource economics, University of New England

Papst, W. and Swanson, E., 1970. A linear programming analysis of irrigation in Mason County. Illinois Agricultural Economics, Vol. 10, No.1. January 1970.

Upcraft, M., Noble, D and Carr, M., 1989. A mixed linear programming for short-term irrigation scheduling. The journal of the operational research society, vol. 40, no. 10 October, 1989.

Disaster prevention and preparedness commission, 1997. A report on flooding and warning given to flood prone areas. Addis Ababa.

Shiferaw, B. & Holden, S.T., 1997. A farm household analysis of resource use and conservation decisions of smallholders: an application to highland farmers in Ethiopia. Discussion paper #D-03/1997, Department of Economics and Social Science, Agricultural University of Norway.

Tilahun, F., 1990. Economics of irrigation planning: prospects for resources use optimization. The case of Hidi irrigation project (Debre Zeit). MA thesis, Alemaya University School of Graduate Studies.

Kassie, M. and Holden, S. T. ,2005. The Economic Potential of Forage Legumes Adoption in the Ethiopian Highlands. Department of Economics and Resource Management Norwegian University of Life Sciences.

Lange, M., 2000. Promotion of low-cost and water saving technologies for small-scale irrigation. FAO, irrigation technology transfer in support of food security.

Helmut, K., 1982. Development, drought and famine in Awash Valley of Ethiopia. African Studies review vol.25, No. 4 December 1982.

FAO, 1997a. Assessment of the socio-economic impact of smallholder irrigation development on smallholder farmers in Zimbabwe: A report prepared by R. Dhlodhlo for FAO.

Mupawose, R., 1984. Irrigation in Zimbabwe: A broad overview. African regional symposium on smallholder irrigation. University of Zimbabwe

SADC,1992. SADC Regional irrigation development strategy: Zimbabwe Country Report. Harare, Zimbabwe

Hazell, P. B. R., and Norton, D. R., 1986. Mathematical programming for economic analysis in agriculture. Macmillan Publishing Company, New York

Sing, V. and Misra, N., 1960. Cost benefit analysis: A case study of the Sarda canal irrigation project. India

Webb, P., 1991. When projects collapse: Irrigation failure in the Gambia from a household perspective. Journal of International development Vol. 3, No. 4. July Institute, Washington D.C.

Ruigu, G. and Rukuni, M., 1990. Irrigation policy in Kenya and Zimbabwe: Proceedings of the second intermediate seminar on irrigation farming in Kenya and Zimbabwe. Juliasdale, Zimbabwe. 26 - 30 May 1987

Rukuni, M. 1984a. Cropping patterns and productivity on smallholder irrigation schemes: African regional symposium on smallholder irrigation. University of Zimbabwe

(SG 2000) Sasakawa Global 2000, 2006. Regional Rice Program (RRP) 20006 4th quarter report

Bouman, B., Nieuwenhuyse, A. and Ibrahim, M., 1998. Pasture degradation and restoration by legumes in humid tropical Costa Rica. Tropical grasslands (1999) volume 33, 98–110

El-Kassar, G. M., 2006. Improvement of Water Value for the Operation of New Irrigation Projects in Semi-Arid Areas. National Water Research Centre, NWRC, Cairo, Egypt

Annexes

Annex 1

Average Crop and fertilizer price

no	Product type	Price per quintal		Average price
		2004/05	2005/06	
1	Teff	234	276	255
2	Barley	155	163	159
3	Chickpea	190	210	200
4	Maize	131	126	129
5	Rice	203	233	218
60	Finger millet	156	171	164
8	Vetch	152	159	156
7	Onion	210	246	228
8	Fertilizer: urea Dap	330 389	330 389	330 389

Source: Fogera Woreda agriculture office

Annex 2

Average livestock price used in the model

Livestock	Selling/ purchase Price for the year		Average price
	2004/05	2005/06	
Ox	900	100	950
culled ox	600	600	600
Bull	800	800	800
Cow: improved	200	2500	2250
Local	1100	1200	1150
Culled cow	600	600	600
Heifer: improved	1000	1000	1000
Local	500	600	550
Donkey	250	300	275
Hen	10	12	11
Cock	13	15	14
Chicken	9	10	9.50
Butter	20	28	24

Source: Fogera Woreda agriculture office

Annex 3

Grain and straw yield kg/ha

No	Crop	Crop yield (kg/ha)						straw yield (kg/ha)					
		Without fertilizer			With fertilizer			without fertilizer			With fertilizer		
		Irrigation	flood	rain	Irrigation	Flood	Rain	irrigation	Flood	Rain	irrigation	flood	rain
1	Teff	945	1073	796	NA	NA	NA	851	1066	717	NA	NA	NA
2	Maize	2210	1726	1729			2292	1679	1492	1349	NA	NA	1738
3	Finger millet	NA	NA	1531	NA	NA	1669	NA	NA	4179	NA	NA	4556
4	Rice		2446	3298					3308	4461	NA	NA	NA
5	Vetch	1018	866	873	NA	NA	NA	777		906	NA	NA	NA
6	chick pea	914	1686	973	NA	NA	NA	813		866	NA	NA	NA
7	Barley	NA	NA	2061	NA	NA	NA	NA	NA	3908	NA	NA	NA
8	Onion	7080											

Source: own data computation

Annex 4

Rice producing regions in Ethiopia and productivity per hectare in 2006

No.	Region	Size (ha)	Production (tons)	Productivity (tons/ha)	No. of farmers
1	Amhara	15392	554,112	3.6	46228
2	Oromia	886	23,922	2.7	3504
3	Somali	28	1,456	5.2	150
4	South/SNNP	2423.5	46,046	1.9	4863
5	Gambella	80	3,840	4.8	160
6	**Total**	**18781.5**	**629,376**	**3.4**	**54830**

Source: Sassakawa Global 2000 4th quarter report, 2006

Annex 5:

Woredas affected by flood in 1998

woreda	Affected people			Flooded agricultural land (ha)
	Family heads	Family	Total	
Fogera	6618	27370	33988	4934
Libokemkem	5261			4377
Denbia	5057	22472	27529	7433
Achefer	80	320	400	47
Total	17016	50162	61917	16791

Source: Adugna Belachew and Solomon Cherie (2000)

Annex 6

A questionnaire prepared to under take a study on Flood Recession Agriculture and Irrigation practicing in selected Kebeles of Fogera Woreda in South Gonder Zone Amhara regional State

This is an academic paper from Addis Ababa University School of Graduate Studies Department of Economics for the Partial fulfillment of MSc in Economics. The purpose of the questionnaire is used to look at the income effect of irrigation practicing in comparison with flood recession agriculture and the traditional rain-fed farming.

Your responses are confidential (won't be passed to third parties) and will not be associated with your name. Thank you in advance for your cooperation.

1. Enumerator's name___________________
2. Date of data collection_________________

I. Background Information

1. Household head's name(don't force she/he to mention)______________
2. Respondent's name(different from family head)_________________
3. Household address

   Woreda___________ Kebele ____________ village___________

4. Household's religion_________________
5. Own cultivated land(use local units)__________________(check with table one)
6. Rent in cultivated land(use local units)________________(check with table one)
7. How many own plots do you have? ____________________
8. How many rented in plots do you have? ________________
9. Own grazing land holding(use local units)________________

Part one: Agriculture

Chapter one: agricultural land use

Table 1: Input-output table for the last harvesting season

Plot no	Plot location name	Plot status 1.owned 2. rented in 3.rented out	Plot size(ha)	Soil type	Type of farming 1. rain-fed 2. recession 3. irrigation	Crop type	Seed use (kg)		Fertilizer use(kg)		Other input use (pesticide, herbicide) (ETB)	Mnaure (kg)	Total produced (qt)	Amount Paid for rent (qt)	Product net of rent (qt)
							Impro ved	local	urea	dap					

Chapter two: Labour Utilization

This part will be used for each plot and crop produced in the last cropping season on activity basis. The plot number and name should be in the order of table one. Labour utilization will be measured on man labour days worked for each individual.

Table 2

Plot no	Plot location name	Crop type	Ploughing						Weeding						Harvesting						Threshing					
			Own family labour		Other familiy labour		Total		Own family labour		Other familiy labour		Total		Own family labour		Other family labour		Total		Own family labour		Other familiy labour		Total	
			no	day	no	day	no	day	no	day	no	day	no	day	no	day	no	day	no	day	no	day	no	day	no	day

Chapter 3: crop production and use

Table 3: crop produced in the last cropping season (2005/06) and amount used (for each column) will be listed in this table

Crop types	Amount produced (quintal))	Amount sold (quintal)	Amount retained for seed (quintal)	Average annual consumption (quintal) for the last 5 years
Rice				
Teff				
Wheat				
Chickpea				
Onion				
Maize				
Finger millet				
Vetch				
tomato				
noug				
lentil				
Emmer wheat				
pepper				
Barley				
Others specify				

Chapter 4: Crop Residue

Table 4: Crop residues households got will be listed in this table

Benefit	Type	Unit	Amount	Remark
fuel	dung			
Animal feed	Grass			
	Straw: Teff			
	Rice			
	Finger millet			
	Barley			
	Vetch			
	Maize			
	Chick pea			
	Others specify			
Soil fertility	manure			
	Others			

Chapter 5: Annual consumption expenditure

1. How sustainable is production in your locality
   a. Always enough only for subsistence
   b. There is always extra for sale
   c. Sometimes the family purchased additional food for consumption
   d. Sometimes there is extra for sale
   e. others/ please specify
2. If your answer for 1 is 3 fill the table below

Table 5: Food purchase expenditure

Type	Last years own produced consumption		Purchased for consumption		
	amount	unit	amount	unit	Total expense(birr)
Rice					
Teff					
Wheat					
Chickpea					
Onion					
Maize					
Finger millet					
Vetch					
tomato					

noug					
lentil					
Emmer wheat					
pepper					
Barley					
Wheat					
Milk					
Butter					
Meat					
Egg					
Tella					
Soft drinks					
Coffee& tea					
Sugar					
Salt					
Food oil					
Pepper& spices					
Others specify					

Chapter 6: Fuel consumption and other miscellaneous expenses

Does the family purchase the following household consumption items last year?

Table 6

	Items	unit	amount	Total expenditure (in Birr)
Fuel consumption items	Charcoal			
	Fuel wood			
	Dung			
	Kerosene			
	Others			
Lightening	Match			
	Dry cell battery			
	Candle			
	Lantern			
	Others/specify			
Detergents	powder soaps (Omo, Arial)			
	Soap			
	Others/ specify			
Animal feed	Noug cake			
	Grass			
	Straw			
	Others/specify			

Part two: household wealth, agricultural and non-agricultural income

Chapter 1: family list and family code

List family members in the table with the following order &code

A. household head B. wife

C. children D. other individuals who live with the family

Table 7

no	Family code	Main responsibilities	Sex 1. Male 2. Female	Age
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				

Chapter two: Livestock holding for the last two years

Table 8

No	Type of animal	Number Owned		Remarks
		2004/05	2005/06	
1	Oxen			
	Steers			
2	Cow:			
	2.1.Improved 2.2.Local			
3	Heifer:			
	3.1.Improved 3.2.Local			
4	Donkey			
5	Horse			
6	Mule			
7	Goat			
	7.1. doe 7.2. Ram			
8	Sheep			
	8.1. Ewe			
	8.2. Ram 8.3. Lamp			

9	Hen			
	Cock			
	Chickens			
10	Beehives:			
	9.1.Modern 9.2. Local			
11	Other specify			

Chapter 3: credit

Do you have taken credit for the last production season?

A. yes B. no

If the answer is yes, fill the following table

Table 9

Source of credit	Credit amount		Purpose of credit
	In birr	In kind	1. product expansion 2. animal rearing 3. purchase of additional food 4. purchase of animal food

Chapter 4: non farm income

Does the family have had non farm income in the last production season?

A. yes B. no

If yes mention the amount got (in Birr) ________________

Thank you

Questionnaire for Kebele Leaders and Development Agents (DAs)

Amount of households in the Kebele__________

1. Amount of wage rent(in Birr) in the Kebele__________

2. Livestock price(in Birr) for the years 2004/05 and 2005/06

No	Type of animal	Price in Birr		Remarks
		2004/05	2005/06	
1	Oxen			
	Old oxen			
	Steers			
2	Cow:			
	2.1.Improved			
	2.2.Local			
	2.3. old cow			
3	Heifer:			
	3.1.Improved			
	3.2.Local			
4	Donkey			
5	Horse			
6	Mule			
7	Goat			
	7.1. doe			
	7.2. Ram			

8	Sheep			
	8.1. Ewe			
	8.2. Ram 8.3. Lamp			
9	Hen			
	Cock			
	Chicken			
10	Beehives:			
	10.1.Modern 10.2. Local			
11	Milk/litre			
	Butter/kg			
	Honey/kg			
	Egg/number			
12	Other specify			

3. crop price per quintal for the years 2004/05 and 2005/06

no	Product type	Price per quintal		Remark
		2004/05	2005/06	
1	Teff			
2	wheat			
3	Barley			
4	peas			
5	bean			
6	lentil			
7	Chickpea			
8	Maize			
9	Rice			
10	Finger millet			
11	Emmer wheat			
12	noug			
13	Onion			
14	Vetch			
15	pepper			
16	potato			

Annex 7

```
$Title household level income maximazation model
* Model crop production using Rain and Irrigation
* life sapn of cow 15 years & ox 8 years

SET I  CONSTRAINTS      /CLAND          CROP LAND
                         CPASTLAND      COMMUNAL PASTURE LAND
                         LAB1           LABOUR PLOUGH ONE
                         LAB2           LABOUR PLOUGH TWO
                         LAB3           LABOUR PLOUGH THREE
                         LAB4           LABOUR WEEDING
                         LAB5           LABOUR HARVESTIN
                         LAB6           LABOUR THRESHING
                         OXD1           LABOUR OXEN ONE
                         OXD2           LABOUR OXEN TWO
                         OXD3           LABOUR OXEN THREE
                         CREDIT         CREDIT
                         WCAP           WORKING CAPITAL/

 V  ACTIVITIES      /TEFRWO          TEFF PRODUCTION RAIN NO FERTILIZER
                     TEFSB           TEFF SUBSISTENCE
                     TEFC            TEFF CONSUMPTION
                     TEFS            TEFF SALE
                     MAIZIWO         MAIZE PRODUCTION IRRIGATION NO FERTILIZER
                     MAIZRWO         MAIZE PRODUCTION RAIN NO FERTILIZER
                     MAIZRW          MAIZE PRODUCTION RAIN WITH FERTILIZER
                     MAIZSB          MAIZE SUBSISTENCE
                     MAIZC           MAIZE CONSUMPTION
                     MAIZS           MAIZE SALE
                     MAIZSD          MAIZE SEED
                     VEIWO           VETCH PRODUCTION IRRIGATION NO FERTILIZER
                     VERWO           VETCH PRODUCTION RAIN NO FERTILIZER
                     VESB            VETCH SUBSISTENCE
                     VEC             VETCH CONSUMPTION
                     VES             VETCH SALE
                     RIRWO           RICE PRODUCTION RAIN NO FERTILIZER
                     RISB            RICE SUBSISTENCE
                     RIC             RICE CONSUMPTION
                     RIS             RICE SALE
                     BARLRWO         BARLEY PRODUCTION RAIN NO FERTILIZER
                     BARLSB          BARLEY SUBSISTENCE
                     BARLC           BARLEY CONSUMPTION
                     BARLS           BARLEY SALE
                     FMRWO           FINGER MILLET PRODUCTION RAIN NO FERTILIZER
                     FMRW            FINGER MILLET PRODUCTION RAIN WITH FERTILIZE»
R
                     FMSB            FINGER MILLET SUBSISTENCE
                     FMC             FINGER MILLET CONSUMPTION
                     FMS             FINGER MILLET SALE
                     CPIWO           CHICK PEA PRODUCTION IRRIGATION NO FERTILIZE»
R
                     CPRWO           CHICK PEA PRODUCTION RAIN NO FERTILIZER
                     CPSB            CHICK PEA SUBSISTENCE
                     CPC             CHICK PEA CONSUMPTION
                     CPS             CHICK PEA SALE
                     ONIWO           ONION PRODUCTION IRRIGATION NO FERTILIZER
                     ONSB            ONION SUBSISTENCE
                     ONC             ONION CONSUMPTION
                     ONS             ONION SALE
                     ONSD            ONION SEED
                     DMP             DRY MATTER PRODUCTION
                     DMINTAKE        DRY MATTER INTAKE
```

```
          DMSB          DRY MATTER SUBSISTENCE
          DMS           DRY MATTER SALE
          CGPASTP       COMMUNAL GRAZING PASTURE PRODUCTION
          DUNP          DUNG PRODUCTION
          DUNSB         DUNG SUBSISTENCE
          DUNC          DUNG CONSUMPTION
          DUNS          DUNG SALE
          LCOWMP        LOCAL COW MILK PRODUCTION
          LCOW          LOCAL COW CALF KEEPING
          LBUTP         LOCAL COW BUTTER PRODUCTION
          MILKSB        MILK SUBSISTENCE
          MILKC         MILK CONSUMPTION
          BUTS          BUTTER SALE
          LOX           LOCALL OX KEEPING
          DONNK         PACK ANIMAL KEEPING
          LHEFR         LOCAL HEIFER REPLACEMENT
          LHEFS         LOCAL HEIFER SALE
          LCOWR         LOCAL COW REPLACEMENT
          LCOWS         LOCAL COW SALE
          LCUCOWS       LOCAL CULLED COW SALE
          LBULLR        LOCAL BULL REPLACEMENT
          LBULLS        LOCAL BULL SALE
          LOXR          LOCAL OX REPLACEMENT
          LOXS          LOCAL OX SALE
          CUOXS         CULLED OXEN SALE
          BOWR          BORROWING /

   C1(V) CROPS /TEFRWO,MAIZIWO,MAIZRWO,MAIZRW,
               RIRWO,CPIWO,CPRWO,BARLRWO,
               VEIWO,VERWO,FMRWO,FMRW,ONIWO/

C2(V)  COMMUNAL GRAZING PASTURE PRODUCTION /CGPASTP/
C3(V)  LOCAL COW CALF KEEPING             /LCOW/
C4(V)  PACK ANIMAL KEEPING                /DONNK/
C5(V)  LOCAL OX KEEPING                   /LOX/
C6(V)  MILK CONSUMPTION                   /MILKC/
C7(V)  TEFF CONSUMPTION                   /TEFC/
C8(V)  BARLEY CONSUMPTION                 /BARLC/
C9(V)  MAIZE CONSUMPTION                  /MAIZC/
C10(V) VETCH CONSUMPTION                  /VEC/
C11(V) RICE CONSUMPTION                   /RIC/
C12(V) CHIECK PEAS CONSUMPTION            /CPC/
C13(V) FINGER MILLET CONSUMPTION          /FMC/
C14(V) DUNG CONSUMPTION                   /DUNC/
C15(V) DRY MATTER INTAKE                  /DMINTAKE/;

ALIAS (I,IP);ALIAS (V,VP)


SCALARS

CLAND  TOTAL CROP LANDAREA      /1.3/
CPLAND COMMUNAL PASTURE         /0.7/
TEFSB  TEF SUBSISTENCE          /54/
BARLSB BARLEY SUBSISTENCE       /36/
MAIZSB MAIZE SUBSISTENCE        /210/
CPSB   CHICEKC PEAS SUBSISTENCE /33/
VESB   VETCH SUBSISTENCE        /30/
RISB   RICE SUBSISTENCE         /502/
FMSB   FINGER MILLET SUBSISTENCE /123/
MILKSB MILK SUBSISTENCE         /152.1/
DUNC   DUNG CONSUMPTION         /1034/
```

```
DMSB   DRY MATTER SUBSISTENCE  /8942/
DONKNO  PACK ANIMAL NUMBER             /1/
LCOWNO  LOCAL COW NUMBER               /2/
LOXNO   LOCAL OX NUMBER                /2/;
```

PARAMETERS

```
B1 (I) RESOURCE SUPPLY

/ LAB1    588
 LAB2    777
 LAB3    819
 LAB4    798
 LAB5    693
 LAB6    714
 OXD1     196
 OXD2     259
 OXD3     273
 WCAP    2405/


B2(V) TEFF PRODUCTION KG PER HA

/ TEFRWO   796
  TEFS     -1/

B3 (V) ONION YIELD (KG PER HA)
/ ONIWO  7080
  ONSD   +1
  ONS    -1 /


B4(V)  MIAZE GRAIN YIELD (KG PER HA)
/ MAIZIWO  2210
  MAIZRWO  1729
  MAIZRW   2292
  MAIZSD   +1
  MAIZS    -1/

B5(V) BARLEY GRAIN YIELD (KG PER HA)
/ BARLRWO 2061
  BARLS   -1 /


B6(V) VETCH GRAIN YIELD (KG PER HA)
/ VEIWO  1018
  VERWO  873
  VES     -1  /

B7(V) RICE GRAIN YIELD(KG PER HA)
 / RIRWO  3298
   RIS    -1/

B9(V) CHECK PEA GRAIN YIELD(KG PER HA)
/ CPIWO 914
  CPRWO 973
  CPS   -1/
B10(V) FINGER MILLET GRAIN YIELD (KG PER HA)
/ FMRWO 1531
  FMRW  1669
  FMS   -1/
```

```
B11(V) DRY MATTER PRODUCTION AND INTAKE  IN KG PER HA
/ TEFRWO  717
  CPIWO   813
  CPRWO   866
  MAIZIWO 1679
  MAIZRWO 1349
  MAIZRW  1738
  FMRWO   4179
  FMRW    4556
  BARLRWO 5569
  VEIWO    777
  VERWO    906
  RIIWO   5146
  RIRWO   4461
  CGPASTP 1014
  DMS       -1
  DMP      +1   /

B12(V) AVIABLE MILK PRODUCTION (LITTER)

/ LCOW 225
  LBUTP  -1 /

B13(V) LOCAL COW BUTTER PRODUCTION(KG PER LITTER)

/LBUTP 0.04
  BUTS  -1 /
B14(V) DUNG PRODUCTION (KG PER ANIMALS)

/ LCOW  440
  LOX   429
  DONNK  369
  DUNS  -1
  DUNP  +1/
B15(V)  LOCAL COW REPLACEMENT

/LCOW          -0.067
 LHEFR           1 /
B16(V) LOCAL HIEFER BALANCE (FEMALE OFFSPRING FOR REPLACMENT)
/ LCOW           0.067
  LHEFR          -1    /
B17(V)  AVILABLE  LOCAL HIEFER SURPLUS FOR SALE
/ LCOW           0.1205
  LHEFS        -1   /
B18(V) AVILABLE LOCAL COW CULLED SALE
/ LCOW           0.067
  LCUCOWS        -1  /
B19(V) LOCAL OX REPLACEMENT
/ LCOWR           0.125
  LBULLR           - 1/
B20(V) LOCAL BULL BALANCE (MALE OFFSPRING FOR REPLACMENT)
 /LCOW         - 0.125
 LBULLR           1  /

B21(V) AVILABLE SURPLUS LOCAL BULL SALE
/LCOW            0.0625
 LBULLS          -1/
B22(V) AVILABLE CULLED OXEN SALE
/ LOX    0.125
 CUOXS     -1/

D(V) ENTERPRISE COST AND RETURN

 / MAIZRW - 530,MAIZSD -170, FMRW -413,
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    TEFS 2.55,VES 1.55,CPS 2.00, BARLS 1.60,RIS 2.20,
    FMS 1.65,MAIZS 1.30,BUTS 24,CUOXS  600,
    LBULLS  800,LHEFS 600,LCUCOWS 600,BOWR -1.53,
    LCOW - 5,LOX - 15,DMS 0.50, DMP - 0.40/;

  PARAMETER


BUT(V)       BUTTER CONVERSION;


BUT(V)      = B12(V)*B13(V);


TABLE E(I,V) RESOURCE USE

        TEFRWO BARLRWO VERWO  VEIWO
LAB1     56     14      70     63
LAB2     28      3.5    14     14
LAB3     21      3.5     7      7
LAB4     26     35      42     35
LAB5     15     28      15     17
LAB6     64     21      56     16
OXD1     21     14       7      4
OXD2     35     25       0      0
OXD3     30     28       3      4
WCAP      0      0       0      0


+         MAIZIWO MAIZRWO MAIZRW  RIRWO BOWR
LAB1       120       72     68      79
LAB2        25       10     30      39
LAB3        27       26     38      40
LAB4       187      287    460     782
LAB5       123      117    184     228
LAB6       124      116    123     114
OXD1        25       20     20      25
OXD2        14       10     10      15
OXD3         7        4      4      10
WCAP         0        0    521       0      -1
CREDIT                                        +1

+      FMRWO  FMRW  CPIWO CPRWO  ONIWO
LAB1      11  108    32    46     193
LAB2       5   55    15    23      90
LAB3       5   50    16    20     100
LAB4      63  175    14    14     431
LAB5      35  182     9    91     479
LAB6      35   23    49    42       0
OXD1      11   54    16    23     100
OXD2       5          7    11       0
OXD3       5   25     8     7      50
WCAP       0  413     0     0       0 ;



VARIABLES

X(V) FARM ACTIVITIES

Z TOTAL INCOME IN BIRR;

POSITIVE VARIABLE X;
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EQUATIONS

INCOME DEFINE OBJECTIVE FUNCTION

SUPPLY(I)   OBSERVE RESTRICTION ON INPUTS
QCLAND      OBSERVE RESTRICTION ON CROP LAND
QCPASTL     OBSERVE RESTRICTION ON COMMUNAL PASTURE LAND
QLCOWNO     OBSERVE RESTRICTION ON LOCAL COW NUMBER
QLOXNO      OBSERVE RESTRICTION ON LOCAL OXEN NUMBER
QDONKNO     OBSREVE RESTRICTION ON PACK ANIMALS
QTEFP       OBSERVE RESTRICTION ON TEFF PRODUCTION
QMAIZP      OBSERVE RESTRICTION ON MAIZE PRODUCTION
QBARLP      OBSERVE RESTRICTION ON BARLEY PRODUCTION
QVEP        OBSERVE RESTRICTION ON VETCH PRODUCTION
QRIP        OBSERVE RESTRICTION ON RICE PRODUCTION
QFMP        OBSERVE RESTRICTION ON FINGER MILLET PRODUCTION
QCPP        OBSERVE RESTRICTION ON CHICEK PEA PRODUCTION
QONP        OBSERVE RESTRICTION ON ONION PRODUCTION
QDMP        OBSERVE RESTRICTION ON DRY MATTER PRODUCTION
QLCOWMP     OBSERVE RESTRICTION ON LOCAL COW MILK PRODUCTION
QLBUTP      OBSERVE RESTRICTION ON LOCAL COW BUTTER PRODUCTION
QDUNP       OBSERVE RESTRICTION ON DUNG PRODUCTION
QTEFC       OBSERVE RESTRICTION ON TEF CONSUMPTION
QFMC        OBSERVE RESTRICTION ON FINGER MILLET CONSUMPTION
QMAIZC      OBSERVE RESTRICTION ON MAIZE CONSUMPTION
QBARLC      OBSERVE RESTRICTION ON BARLEY CONSUMPTION
QVEC        OBSERVE RESTRICTION ON VETCH CONSUMPTION
QCPC        OBSERVE RESTRICTION ON CHICEK PEAS CONSUMPTION
QRIC        OBSERVE RESTRICTION ON RICE CONSUMPTION
QMILKC      OBSERVE RESTRICTION ON MILK CONSUMPTION
QDMC        OBSERVE RESTRICTION ON DRY MATTER CONSUMPTION
QDUNC       OBSERVE RESTRICTION ON DUNG CONSUMPTION
QLHEFR      OBSERVE RESTRICTION ON LOCAL HEIFER REPLACEMENT
QLHEFS      OBSERVE RESTRICTION ON LOCAL HEIFER SALE
QLCOWR      OBSERVE RESTRICTION ON LOCAL COW REPLACEMENT
QLCUCOWS    OBSERVE RESTRICTION ON CULLED COW SALE
QLBULLR     OBSERVE RESTRICTION ON LOCAL BULL REPLACEMENT
QLBULLS     OBSERVE RESTRICTION ON LOCAL BULL SALE
QLOXR       OBSERVE RESTRICTION ON LOCAL OXEN REPLACEMENT
QCUOX       OBSERVE RESTRICTION ON CULLED OXEN  ;


INCOME..SUM((V), D(V)*X(V))=E=Z;

SUPPLY(I)..SUM(V,E(I,V)*X(V))=L=B1(I);

QCLAND..SUM(V$C1(V), X(V))=L= CLAND;
QCPASTL..SUM(V$C2(V), X(V))=L=CPLAND;
QLCOWNO..SUM(V$C3(V), X(V)) =E=LCOWNO ;
QDONKNO..SUM(V$C4(V), X(V)) =E=DONKNO;
QLOXNO..SUM(V$C5(V), X(V)) =E=LOXNO;

QMILKC..SUM(V$C6(V), X(V)) =G= 0;
QTEFC..SUM(V$C7(V), X(V)) =G= 0;
QBARLC..SUM(V$C8(V), X(V)) =G= 0;
QMAIZC..SUM(V$C9(V), X(V)) =G= 0;
QVEC..SUM(V$C10(V), X(V)) =G= 0;
QRIC..SUM(V$C11(V), X(V)) =G= 0;
QCPC..SUM(V$C12(V), X(V)) =G= 0;
QFMC..SUM(V$C13(V), X(V)) =G= 0;
QDUNC..SUM(V$C14(V), X(V)) =G= 0;
QDMC..SUM(V$C15(V), X(V)) =G= 0;
```

```
QTEFP..SUM(V, B2(V)*X(V)) =G= TEFSB;
QONP..SUM(V, B3(V)*X(V)) =G= ONSB ;
QMAIZP..SUM(V,B4(V)*X(V)) =G= MAIZSB;
QBARLP..SUM(V, B5(V)*X(V)) =G= BARLSB;
QVEP..SUM(V, B6(V)*X(V)) =G= VESB;
QRIP..SUM(V,B7(V)*X(V)) =G= RISB;
QCPP..SUM(V,B9(V)*X(V)) =G= CPSB;
QFMP..SUM(V,B10(V)*X(V)) =G= FMSB;
QDMP..SUM(V, B11(V)*X(V)) =G=DMSB;
QLCOWMP..SUM(V,B12(V)*X(V))=G= MILKSB;
Q1BUTP..SUM(V, B13(V)*X(V)) =G= 0;
QDUNP..SUM(V, B14(V)*X(V)) =G= DUNC;
QLCOWR..SUM(V, B15(V)*X(V)) =G=0;
QLHEFR..SUM(V, B16(V)*X(V)) =G= 0;
QLHEFS..SUM(V, B17(V)*X(V)) =G=0;
QLCUCOWS..SUM(V, B18(V)*X(V)) =G=0;
QLOXR..SUM(V, B19(V)*X(V)) =G=0;
QCUOX..SUM(V, B22(V)*X(V)) =G=0;
QLBULLR..SUM(V, B20(V)*X(V)) =G=0;
QLBULLS..SUM(V, B21(V)*X(V)) =G=0;

MODEL cropping /ALL/;

SOLVE cropping USING LP MAXIMIZING Z;

DISPLAY X.L, X.M;
```

DECLARATION

I, the undersigned, declare that this thesis is my original work, has not been presented for a degree in any other university. All the resources of materials used for the thesis have been duly acknowledged.

Declared by:

Name: Yirgedu Miliket

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Date: 12-04-2007

Confirmed by Advisor:

Name: Dr. Berhanu Adenew

Signature: ____________

Date: 12.4.2007

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