ASSESSMENT OF RAINWATER MANAGEMENT PRACTICES FOR SUSTAINABLE DEVELOPMENT AND RURAL LIVELIHOOD IMPROVEMENT IN ANDODE/MEJA MICRO WATERSHED, JELDU DISTRICT, OROMIA REGION, ETHIOPIA

M.Sc. Thesis

BIRHANU AYANA TOLA

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Ambo University

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COLLEGE OF NATURAL AND COMPUTATIONAL SCIENCE, DEPARTMENT OF BIOLOGY

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In partial Fulfillment of the Requirements for the Degree of MASTER OF SCIENCE IN ENVIRONMENTAL SCIENCE

By

Birhanu Ayana Tola

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AMBO UNIVERSITY

SCHOOL OF GRADUATE STUDIES

As Thesis research advisor, I hereby certify that I have read and evaluated this Thesis entitled: ASSESSMENT OF RAINWATER MANAGEMENT PRACTICES FOR SUSTAINABLE DEVELOPMENT AND RURAL LIVELIHOOD IMPROVEMENT IN ANDODE/MEJA MICRO WATERSHED, JELDU DISTRICT, OROMIA REGION, ETHIOPIA prepared under my guidance by: Birhanu Ayana. I recommend that it be submitted as fulfilling the Thesis requirement.

____________________________	________________	___________
Major Advisor	Signature	Date
___________________________	__________________	___________
Co- Advisor	Signature	Date

As members of the Board of Examiners of the M.Sc Thesis Open Defense Examination, we certify that we have read and evaluated the Thesis prepared by Birhanu Ayana and examined the candidate. We recommended that the Thesis be accepted as fulfilling the Thesis requirement for the Degree of Master of Science in Environmental Science.

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Chairperson	Signature	Date
__________________________	____________________	___________
Internal Examiner	Signature	Date
__________________________	____________________	___________
External Examiner	Signature	Date
__________________________	___________________	___________
Name of PG Coordinator	Signature	Date

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ACRONYMS AND ABBREVIATIONS

ANOVA	Analysis of Variance
AVP	Available Phosphorous
BBF	Broad-Bed And Furrow
BD	Bulk Density
CA	Catchment Area
CEC	Cation Exchange Capacity
CA	Comprehensive Assessment
CB	Cropped Basin
DI	Deterioration Index
DAS	Development Agents
DAP	Diammonium Phosphate
EC	Electrical Conductivity
EPA	Environmental Protection Agency
FYM	Farm Yard Manure
FGD	Focused Group Discussion
FAO	Food And Agriculture Organization
GIS	Geographic Information System
GPS	Global Positioning System
GDP	Gross Domestic Product
HHs	Household Heads
IFAD	International Fund For Agricultural Development
IWMI	International Water Management Institute
LULC	Land Use Land Cover Change
MDGS	Millennium Development Goals
MOWR	Ministry of Water Resources
NEPAD	New Partnership For Africa's Development

NGO	Non-Government Organization
OC	Organic Carbon
OM	Organic Matter
ppm	Parts per million
PAS	Peasant Associations
RWH	Rain Water Harvesting
RWM	Rain Water Management
SOC	Soil Organic Carbon
SOM	Soil Organic Matter
SSSA	Soil Science Society of America
SAS	Statistical Analysis System
SPSS	Statistical Package For Social Science
SSA	Sub-Saharan Africa
TN	Total Nitrogen
UN	United Nations
UNEP	United Nations Environmental Protection
UNFPA	United Nations Population Fund Series
USD	United States Dollar
UTM	Universal Transfer Mercator
WWDSE	Water Works Design And Supervision Enterprise
WHO	World Health Organization

ABSTRACT

Poor rainwater management (RWM) and a resultant problems of land degradation, low agricultural productivity, food insecurity and poverty, are particularly severe in the rural highlands of Ethiopia. This study was undertaken at Andode/Meja micro watershed, which is located in the Jeldu district of west shoa zone in the Oromia region. The study was aimed to assess major problems and potentials for sustainable rainwater management for the improvement of rural livelihoods in the study area. Socio-economic conditions, biophysical and their management practices were assessed in the watershed under study. Using GPS and GIS techniques, the existing RWM interventions, the extent, and the nature of changes in LULC were also assessed and mapped for reflecting both the biophysical conditions and their management status in the study watershed. Furthermore, soil laboratory analysis was done for soil samples collected from the upper 0 - 20 cm depth from land utilized for crop cultivation, grazing and natural forest/ eucalyptus plantation in order to compare the relative soil degradation with some selected physico-chemical properties of soil. The results of the study indicated that, with few exceptions of RWM interventions potentially practiced, there was mainly poor and inefficient application of rainwater management in terms of both in-situ rainwater conservation methods and via RWM for storing water for later use in water storage structures such as ponds in the study watershed, which as a consequence resulted in inadequacy of water in the study watershed for household consumption, watering livestock and intensifying agricultural production via small scale irrigation systems. In the time of periods considered, for LULC analysis between 1990 and 2010, there was an increase in the extent of cultivated land followed by high expansion of eucalyptus plantation at the expense of natural forest and grazing lands in the study watershed. This gradual deforestation and poor resource management resulted in the soil degradation, reduction of hydrological regimes and water productivity in the watershed. As a result, major declines were observed for soil sand and silt content, pH, electrical conductivity (EC), organic matter (OM), total nitrogen (TN), cation exchange capacity *(CEC), exchangeable Na, exchangeable Ca, and exchangeable Mg more in soils of cultivated land than the other land use types. These variations of soil physico-chemical properties between land use types indicate the risk to the sustainable crop production in the area. Therefore, strategies to secure food among the expanding population in the study watershed will have to seek a sustainable solution that better addresses the integrated rainwater and soil managements.*

1. INTRODUCTION

1.1 Background

Water is one of the most useful natural resources for life and livelihood of the human beings. It is the most precious resource, of all other commodities, vital to the economy of the nation and indispensable to maintain the health of the environment (WHO, 2002).It is becoming a limiting factor for sustainable development in many parts of the world. Globally, the gap between demand and availability of water has become wide, necessitating immediate measures to be taken for its sustainable utilization and efficient management, especially in the developing world where economic crisis and population explosion are hazards in further development of water resources. It is estimated by International Water Management Institute (IWMI), that 33 per cent of population of the developing countries will be affected by severe water scarcity by 2025, including one billion of the world's poorest people living in semi-arid and arid tropical regions (Wani *et al.*, 2003). The solution to achieve sustainable development in the developing countries lies in the efficient management of water and other natural resources for increasing the productivity.

Rainwater is the main source of water and its current use efficiency for crop production ranges between 30 and 45 per cent, and annually 300 to 800 mm of seasonal rainfall is lost as surface runoff or deep drainage (Wani *et al*., 2003). Watershed is a logical unit for efficient rainwater management in the dry regions. Along with water, other natural resources such as soil, vegetation, and biota can also be managed efficiently by adopting integrated watershed management approach. In the integrated watershed approach, the emphasis is on *in-situ* conservation of rainwater at farm level, where by excess water is taken out from the fields safely through community drainage channels and stored in suitable low-cost structures. The stored water can be used for surface irrigation or for recharging groundwater. Following this, conservation of rainwater and its efficient use is achieved through appropriate crops, improved varieties, cropping systems, nutrient and pest management options for increasing the productivity and conserving the natural resources (Wani *et al.*, 2003). The major advantages of adopting IWM approaches are the involvement of those most affected by the decisions (i.e. the stakeholders) in all phases of the development of their watershed and

holistic planning that addresses issues which extend across subject matter disciplines (biophysical, social and economic) and administrative boundaries (village, woreda etc.) (UNEP, 2002). So, watershed development seeks to manage hydrological relationships to optimize the use of natural resources for conservation, productivity, and poverty alleviation. Achieving this requires the coordinated management of multiple resources within a watershed, including forests, pastures, agricultural land, surface water and groundwater, all linked through hydrology (World Bank, 2007).

Water harvesting involves on farm water harvesting and building small dams to capture runoff from upper watersheds after heavy rains. Reducing erosion minimizes silt in runoff water and in water harvesting ponds, thus lengthening their lifespan. Water harvesting in turn benefits farms further down the slope by providing irrigation, either via surface water or by recharging groundwater. These interventions are designed to eventually raise the productivity of all natural resources in the watershed. Soil becomes more productive for agriculture, water for irrigation, and pastures and forests for more biomass. All livelihood activities that depend on these resources may be enhanced, and employment may increase as agriculture becomes more productive and additional labor is needed for harvesting and other operations (Kerr, 2002).

In country like Ethiopia, where agriculture is the backbone of the economy, sever food insecurity and natural resource degradation have been challenging the livelihood of rural community. It has been estimated that 2 million ha of Ethiopia's highlands have been degraded beyond rehabilitation, and an additional 14 million ha are severely degraded. Removal of vegetation covers (through overgrazing and for charcoal production) exposes the soil to wind and water erosion. Soil compaction occurs in areas where there is excessive trampling by animals and, in cultivated areas; soil fertility is declining, as a result of the exhaustion of soils by mono-specific cropping and reduction of fallow periods. Soil degradation contributes to increasing rural poverty and food insecurity, because productivity is reduced, and subsistence farmers are less and less able to accumulate reserves of grain (UNEP, 2002). According to Hatibu (2003), poverty is mainly caused by inadequate availability of water for crop, livestock and other enterprises. He then argues that the

shortage of water is not caused by low rainfall as normally perceived, but rather by a lack of capacity for sustainable management and use of the available rainwater on these degraded soils. Thus, adoption of sustainable participatory integrated watershed management as the platform for integrated land and water management and improving the livelihood of community in Jeldu district is crucial. So the present study focuses to identify the major problems and potentials for better and sustainable rain water management through participatory integrated watershed management approach so as to improve the livelihood of the community.

1.2 Statement of the Problem

In the watershed under study there is an excess use of lands for cultivation (even in hilly areas) resulting in the reduction of grazing lands for animal production. The cultivated land in the study area is highly prone to sheet and rill erosion due to lack of soil and rainwater management practices. The reduction of forest coverage in the up lands and lack of conservation measures in the hillside areas have resulted in the formation of big and active gullies. The increase in human population in the study area has reduced land holding per household and created pressure on limited land for agricultural and livestock production. As a result, the community is exposed to seasonal food shortage and health problems. So, the present study focused to identify major problems and potentials for better and sustainable rainwater management through participatory integrated watershed management approach so as to improve the livelihood of the community.

1.3 Significance of the Study

The results of the study hopefully would contribute to the identification of major problems and potentials for sustainable rainwater management practices by the farmers in the watershed under study. It will also help developing community based integrated watershed management and to create awareness among the people to use their lands in a sustainable manner to sustain the water resources. The study will also enrich the existing literature for designing sound and sustainable rainwater management practices in the watershed under study. It will also contribute to propose appropriate conservation technologies as well as

proper intervention polices and strategies for sustainable rainwater management in the watershed for Government, Non-Government and development agencies for promoting future development strategies.

1. 4 Objectives of the Study

1.4.1 General objective

The objective of this study was to assess major problems and potentials for sustainable rainwater management through integrated watershed management approach to forward possible development interventions for the improvement of rural livelihoods in Andode/Meja micro watershed, Jeldu District, West shoa zone, Oromia Region, Ethiopia

1.4.2 Specific objectives

- To assess biophysical and socio-economic constraints and potentials in the watershed
- To assess, qualitatively evaluate and map the selected existing RWM interventions in the watershed
- To assess alternative livelihoods in the watershed
- To assess the nature and status of land use land covers in the watershed
- To evaluate land use impacts on selected physico-chemical properties of soil

2. LITERATURE REVIEW

2.1. Definition and Concept of Watershed

Watershed is defined as a geohydrological unit draining to a common point by a system of drains. All lands on earth are part of one watershed or other. Watershed is thus the land and water area, which contributes runoff to a common point. In other words, watershed is a topographically delineated area draining into a single channel. Watershed is considered as a biological, physical, economic and social system too. Viewed in another angle, watershed is a natural unit of land, which collects water and drains through a common point by a system of drains. Hence it comprises of a catchment area (recharge zone), a command area (transition zone) and a delta area (discharge zone). The topmost portion of the watershed is known as the “ridge” and a line joining the ridge portions along the boundary of the watershed is called a “ridgeline”. A watershed is thus a logical unit for planning optimal development of its soil, water and biomass resources (Kerala Calling, 2004).

2.1.1 Types of watershed

Watersheds could be classified into a number of groups depending upon the mode of classification. The common modes of categorization are the size, drainage, shape and land use pattern. The categorization could also be based on the size of the stream or river, the point of interception of the stream or the river and the drainage density and its distribution.

1) Macro watershed (> 50,000 Ha)

2) Sub-watershed (10,000 to 50,000 Ha)

3) Milli-watershed (1000 to10000 Ha)

4) Micro watershed (100 to 1000 Ha)

5) Mini watershed (1-100 Ha)

A watershed could be described as fan shaped (near circular) or fen shaped (elongated). Hydrologically the shape of the watershed is important because it controls the time taken for the runoff to concentrate at the outlet. Watersheds may also be categorized as hill or flat watersheds, humid or arid watersheds, red soil watershed or black soil watershed based on

criteria like soil, slope, climate etc. Depending on the land use pattern watershed could again be classified as highland watersheds, tribal settlements and watersheds in areas of settled cultivation (Kerala Calling, 2004).

2.1.2 Watershed management and its components

Watershed management has emerged as a new paradigm for planning, development and management of land, water and biomass resources with a focus on social and environmental aspects following a participatory approach. Watershed management is more a philosophy of comprehensive integrated approach to natural resources management. It aims at integration of social resources management with natural resource management. The approach is generally preventive, progressive, corrective and curative. Watershed management involves the judicious use of natural resource with active participation of institutions, organizations, in harmony with the ecosystem. The three main components in watershed management are land management, water management and biomass management (Kerala Calling, 2004).

Water management: Water characteristics like inflows (precipitation, surface water inflow, ground water inflow) water use (evaporation, evapotranspiration, irrigation, drinking water) outflows (surface water outflow, ground water out flow) storage (surface storage, ground water storage, root zone storage) are the principal factors to be taken care of in sustainable water management. The broad interventions for water management are: Rainwater harvesting, ground water recharge, maintenance of water balance, preventing water pollution, economic use of water. Rainwater harvesting forms the major component of water management (Kerala Calling, 2004).

Land management: Land characteristics like terrain, slope, and formation, depth, texture, moisture and infiltration rate and soil capability are the major determinants of land management activities in a watershed. The broad category of land management interventions can be as follows: structural measures, vegetative measures, production measures and protection measures (Kerala Calling, 2004).

Mechanical conservation measures may become necessary in watershed management in the initial stages. Structural measure includes interventions like contour bunds, stone bunds,

earthen bunds, graded bunds, compartmental bunds, contour terrace walls, contour trenches, bench terracing, broad based terraces, centripetal terraces, field bunds, channel walls, stream bank stabilization, check dams etc. Watersheds may contain natural ecosystems like grasslands, wetlands, mangroves, marshes, water bodies. All these ecosystems have a specific role in nature. Vegetative measures include vegetative cover, plant cover, mulching, vegetative hedges, grass land management, agro-forestry etc. The production measures include interventions aimed at increasing the productivity through mixed cropping, strip cropping, cover cropping, crop rotations, cultivation of shrubs and herbs, contour cultivation conservation tillage, land leveling, use of improved verity of seeds, horticulture, etc. Protective measures like landslide control, gully plugging, runoff collection, etc can also be adopted. Adoption of all the interventions mentioned above should be strictly in accordance with the characteristics of the land taken for management (Kerala Calling, 2004).

Biomass management: The major intervention areas for biomass management are: eco-preservation, biomass regeneration, forest management and conservation, plant protection and social forestry, increased productivity of animals, income and employment generation activities, coordination of health and sanitation programmes, better living standards for people, eco-friendly life style of people, formation of a learning community etc. (Kerala Calling, 2004).

2.1.3 Rainwater harvesting as the major component of water management

As water harvesting is an ancient tradition and has been used for millennia in most dry lands of the world, many different techniques have been developed. However, the same techniques sometimes have different names in different regions and others have similar names but, in practice, are completely different (Oweis, 2004). Consequently, there are a dozen of different definitions and classifications of water harvesting techniques and the terminology used at the regional and international levels has not yet been standardized (Nasr, 1999).

Kahinda *et al.* (2008) defined RWH as the collection, storage and use of rainwater for small-scale productive purposes. Critchley (1991) defined it as the collection of runoff for productive use. Oweis (2004) defined it as the concentration of rainwater through runoff into

smaller target areas for beneficial use. Mati *et al.* (2006) defined RWH as the deliberate collection of rainwater from a surface known as catchment and its storage in physical structures or within the soil profile.

Runoff may be harvested from roofs and ground surfaces as well as from intermittent or ephemeral watercourses and thus water harvesting falls into two broad categories: Water harvesting techniques, which harvest runoff from roofs or ground surfaces named RWH and all systems, which collect discharges from water courses named flood water harvesting (Critchley *et al.,* 1991). RWH technologies and systems can be classified in several ways, mostly based on the runoff generation process, size of the catchment and type of storage. Runoff generation criteria yields two types of systems i.e. runoff based systems (runoff concentrated from a catchment) and *in-situ* water conservation (rainfall conserved where it falls). The runoff storage criteria yield two categories, i.e., storage within the soil profile and storage structures. The size of catchment yields are of two categories, i.e., macro catchments and micro catchments (within field).

In general, RWH systems for crop production are divided into three different categories basically determined by the distance between catchment area (CA) and cropped basin (CB) (utilization area): *In-situ* RWH, internal (Micro) catchment RWH and External (Macro) catchment RWH (Hatibu and Mahoo, 1999). To give the general overview of the three categories, a short summary extracted from Hatibu and Mahoo (1999) for each is presented below.

In-situ RWH: The first step in any RWH system involves methods to increase the amount of water stored in the soil profile by trapping or holding the rain where it falls. This may involve small movements of rainwater as surface runoff in order to concentrate the water where it is wanted most. *In-situ* RWH is sometimes called water conservation and is basically the prevention of net runoff from a given cropped area by holding rainwater and prolonging the time for infiltration. This system works better where the soil water holding capacity is large enough and the rainfall is equal or more than the crop water requirement. Essentially, it includes all conventional approaches to soil and water conservation designed to enhance rainwater infiltration. Examples of *in-situ* RWH techniques include deep tillage, dry seeding,

mixed cropping, ridges and borders, terraces and trash lines (Mbilinyi *et al.*, 2005), vegetative / stone contour barriers, contour trenching, contour farming and tie ridging methods (Sivanappan, 2006).

Internal (Micro) catchment RWH: This is a system where there is a distinct division of CA and CB but the areas are adjacent to each other. This system is mainly used for growing medium water demanding crops such as maize, sorghum, groundnuts and millet. The major characteristics of the system include small semi-circular pits, strip catchment tillage, contour bunds, semi-circular bunds, meskat-type system and land conservation aspects.

External (Macro) catchment RWH: This is a system that involves the collection of runoff from large areas, which are at an appreciable distance from where it is being used. This method is sometimes applied with intermediate storage of water outside the CB for later use as supplementary irrigation. This system involves harvesting of water from catchments ranging from 0.1 hectare to thousands of hectares either located near the cropped basin or far away. The catchment areas usually have slopes ranging from 5-50%, while the harvested water is used either on cropped areas, which are terraced, or on flat lands. When the catchment is large and located at a significant distance from the cropped area, the runoff water is conveyed through structures of diversion and distribution networks. The most important systems included in this category are hillside sheet/rill runoff utilization, floodwater harvesting within the streambed and ephemeral stream diversion.

2.1.4 Watershed management and people’s participation

People’s participation and collective action are critical ingredients for watershed management. Sustainability, equity and participation are the three basic elements of participatory watershed management. Sustainability involves conservation and enhancement of the primary productivity of the ecosystem, the main components of which are land, water and biomass. Equity has to be seen in terms of creating an equitable access to livelihood resources for the watershed community. Participatory watershed management attempts at ensuring sustainability of the ecological, economic and social exchanges taking place in the watershed territory. This includes natural resource exchange, which is the conventional

watershed management, and participatory watershed management additionally considers the economic, political and cultural exchanges. At this juncture it may be advisable to understand the limitations of people's participation in any development project. Participation may lead to delayed start and slow progress in the initial stages of the programme. We may require more resources because in the participatory process we have to move along the path decided by the local people. Since participation is an empowering process where the people are empowered to make decisions, donors, governments, and other players have to relinquish power and control. Relinquishing power and control is not an easy task for the increased expectation due to involvement of the local people may not always be accomplished. However, the advantages of people's participation are many and sound. Participation can ensure effective utilization of available resources. In real terms community participation means voluntary sharing by the users group, their time, energy and money on the programme and adopts the recommended measures and practices on a sustained basis (Kerala Calling, 2004).

2.2 Water and Agricultural Development in Sub-Sahara Africa

Water is a critical input in agricultural growth and pivotal in agrarian livelihoods. However, most sub-Saharan African countries are facing with economic water scarcity, lacking the human, financial or institutional capital to adequately develop and use their water resources. Under-investment in water infrastructure, including provision for maintenance of existing facilities, is often compounded by poor governance and ineffective institutions, especially in poorer countries. The recently concluded study by the Comprehensive Assessment (CA) of Water Management in Agriculture (Molden, 2007) points out that improving land and water productivity is a critical contributing factor to achieving the Millennium Development Goals (MDGs) with regard to poverty, hunger and environmental sustainability. The need for integrated land and water resources management to reduce poverty and food insecurity especially in semi-arid Africa, where over 80% of rural livelihoods depend on land and water resources, cannot be overemphasized. The New Partnership for Africa's Development (NEPAD) has called for a 6% annual growth in agricultural output if the continent is to achieve food security by 2015. Furthermore, the World Bank and other development organizations recognize broad-based agricultural development as the engine of economic

growth (FAO, 2006a; IFAD, 2007; World Bank, 2008). Fortunately, renewed and vigorous responses to water scarcity, including investments to develop water infrastructure, intensifying agricultural production and improving its productivity together with the associated institutional reforms, are increasingly driving Africa's water agenda. Innovative ways of managing land and water are therefore called for in the face of growing economic and physical scarcity of water, compounded by rising costs of new developments, climate variability and climate change, increased prices of food and energy, and the imperatives to respect critical social considerations and ecological functions to sustain such developments.

2.2.1 Land, water and livelihood challenges in sub-Sahara Africa

Sub-Saharan Africa is the poorest region in the world (40-60% of SSA population is below $1/day) – and getting poorer (NEPAD, 2003), a consequence of population growth outstripping the growth of both overall and agricultural GDP (World Bank, 2007). Sub-Saharan Africa's population remains predominantly rural (70%), poverty is widespread and 33% of its people is undernourished with a constant low average calorie intake per person around 2000 kcal/p/d. Forty to fifty percent of the population has no access to safe drinking water and adequate sanitation.

Agriculture, providing 60% of all employment, constitutes the backbone of most African economies. In most countries, it is still the largest contributor to GDP; the biggest source of foreign exchange, accounting for about 40% of the continent's hard currency earnings; and the main generator of savings and tax revenues. Agriculture thus remains crucial for economic growth, poverty reduction and food security in most African countries (NEPAD, 2003). But agricultural productivity is low and stagnant in SSA. Sub-Saharan Africa is the only region where per capita food production has fallen over the past forty years. More than 90% of food crops in SSA are grown under rain fed conditions; this renders SSA agriculture vulnerable to rainfall variability and in turn affects the livelihoods of the poor and the national economy. At the same time, SSA also has a large untapped potential of irrigation. FAO (2006 b) has reported that only a small share of the potentially irrigable area of 39.4 million hectares has been developed in SSA. Overall, 183 million ha of area are under cultivation in Africa, of which 5% or about 9 million ha is under water management and 7

million ha are equipped for full or partial irrigation. Only about 70% (5 million hectares) of the equipped area is operational (World Bank, 2007).

Africa has very high spatial and temporal variability in rainfall as compared to other continents (FAO, 2003; UN Millennium Project, 2005; Walling, 1996; World Bank, 2002). The coefficient of variation in annual rainfall ranges from 200% in desert areas to 40% in semi-arid areas, and 5-31% even in humid areas (Africa Water Task Force, 2002). In several African countries, there is a strong correlation between GDP growth and the country's highly erratic rainfall. For example, the 2003 floods have cost Kenya about 2.4 billion USD (Grey and Sadoff, 2004), and recurrent drought and flood made millions of people in East African dependent on food aid.

The current phenomenon of rising food and energy prices should also lead us to rethink approaches to agricultural land and water management in SSA. While agricultural growth in SSA in the past has been mainly achieved through area expansion and provision of irrigation facilities (the use of "blue" water), there is growing realization that the reliability of agricultural water supply can also be assured by improving land and water management on rain fed areas (i.e. by harnessing more "green" water). Low-cost technologies such as rainwater harvesting, soil moisture conservation, etc. can help stabilize and increase crop yields and farmer incomes in rain fed agriculture by encouraging hitherto risk-averse farmers to invest in inputs (fertilizers, improved varieties,) and adopt improved management practices. Promoting awareness about and access to such technologies can also help unlock the potential of smallholder farming and uplift rural livelihoods. In this regard, it is worthwhile highlighting that in SSA, women are in charge of up to 80% of food production (FAO, 2003); more than elsewhere in the world, gender is central for equity and productivity in agriculture and agricultural water management. Hence, it is important to ensure that, both for productivity and equity reasons, all farm decision-makers, whether men or women, are included in programs of public support and investment. Irrigation development will also have to play a major role if the ambitious NEPAD targets for agricultural growth on the continent are to be met. Irrigation in SSA has suffered from declining investments over the past two decades due to results falling short of expectations and disappointing returns. The hydrology

and pedology are partly responsible for that but there was also a popular view that irrigation projects in SSA are more expensive than elsewhere. However, a recent analysis (Inocencio *et al.,* 2007) of over 300 irrigation projects world-wide showed that irrigation is not uniquely expensive in Africa.

Africa has 63 trans-boundary river basins – more than any other continent – implying very high water inter-dependence. Seventy-seven percent of the human population live in these basins which contain 93% of the total water, and cover 61% of the surface area. Integrated planning and management of international river basins has seldom proved straightforward in Africa. Developing these basins requires agreements, institutions, information sharing and human resources (Wright *et al*., 2003).

Ethiopia has a renewable surface and ground freshwater amounts to 123 and 2.6 billion cubic meters per annum respectively (CARE 1998; cited in Wagnew, 2004). Its distribution in terms of area and season and its contribution to the sustainable growth to the economy is not well documented. Floods and droughts, and lack of means to store water in times of plenty, place Ethiopia at risk of drought and chronic food shortages (CARE, 1998). Excess runoff is also responsible for the soil erosion in the highlands. Recent studies have shown that the sediment yields in different rivers range between 180 and 900 t/year per km^2 (Rodecco, 2002; cited in Wagnew, 2004). It is estimated that the Trans-boundary Rivers alone carry about 1.3 billion tones of sediment each year to neighboring countries (MOWR, 1993). Poor watershed management and farming practices have contributed to these rates.

Rapid population growth and the consequent encroachment of food crop farming on environmentally sensitive areas has created a vicious cycle of declining soil fertility, erosion, low crop yields, feed shortages, progressive land degradation, and reduction of areas under fallow and greater exploitation of marginal areas. The declining productivity in rain fed agriculture and the need to double food production over the next two decades, arises the needs for effective and efficient irrigation. However, there are important issues associated with land and water resources management like salinization, nutrient depletion, water pollution, loss of vegetation cover, soil erosion, over grazing, soil degradation and groundwater depletion. These processes could lead to long-term deterioration and reduction

of the potential and actual productivity of land, with adverse effects on agricultural productivity and serious food security implications at both the national and local levels (Kamara and McCornick, 2002*)*.

Water related policies, programs, strategies and laws, are in place to combat these trends (Gulilat, 2002; cited in Wagnew, 2004). But the current challenge is implementation; harmonization of the water sector with other sectors, capacity gaps and opportunities in linking existing research and capacity building activities (Gulilat, 2002).

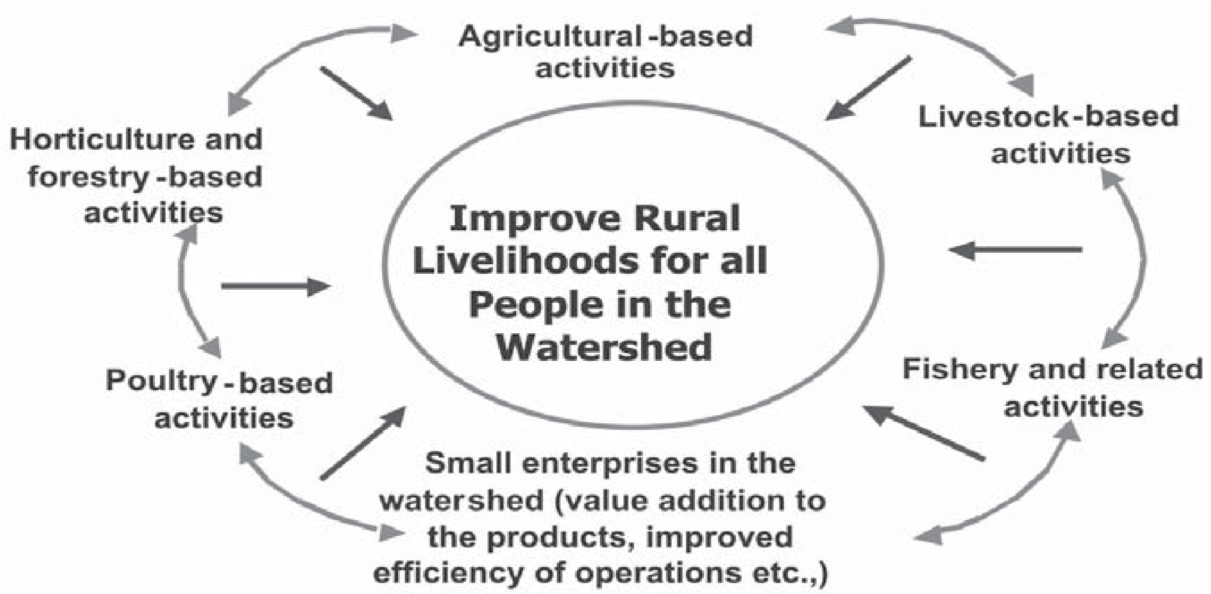
The country has an estimated irrigable land of about 1.5-3.5 million ha of which only about 5% ha developed to date, with about 55% of the developed area being traditional irrigation (MOWR, 2001a). At the end of the 1990s, the area under small-scale irrigation was estimated at around 65 thousand ha while that of medium and large-scale were appraised at 112 thousand ha, of which 22 thousand ha were new small-scale irrigation schemes implemented since 1992 (WWDSE, 2001). The country has a National Irrigation Development Strategy to use water and land potential to meet food self-sufficiency, generate export earnings, and provide raw materials for industry on sustainable basis (MOWR, 2001a) .The way water is developed and managed has social, economic and environmental consequences. Integrated approaches to the development, management and use of water resources will help foster a more balanced and inclusive approach to water decision-making that emphasize social equity, environmental sustainability along with economic efficiency.

2.2.2 Improved livelihoods through convergence

To achieve the goal of improving rural livelihoods and sustainable utilization of existing resources through convergence of activities in the watersheds, such as agriculture, horticulture, livestock, fisheries, poultry and small enterprises that bring value addition to rural produce.

Sustainable Management of Rainwater management model fits into the framework as a tool to assist in sustainable rural livelihoods. The convergence approach is to make watershed development to be explicitly linked with rural livelihoods and effective poverty reduction and in the process to identify policy interventions at micro, meso and macro levels.

In the new model, emphasis is on to encourage the convergence of people centric rural development programs at the watershed level. Any project design should encourage a more holistic understanding of the needs and priorities of the poor people in integration with policy and institution structures. An example of convergence for agriculture related activities in the watershed and its link with other micro-enterprises is shown in Fig. (Wani *et al*., 2003a).



Source: Sharma (2005)

Figure1: An example of convergence of various activities based on use of natural resources

Convergence can take place at different levels. Convergence at the village level requires facilitation of processes that bring about synergy in all the watershed related activities. An approach is needed to address the equity issues while addressing livelihood options through integrated watershed management. Scope for issues related to suitable processes for change in micro-practices, macro policies, convergence and knowledge management systems also form part of the program. Socio-economic institution and policy needs to increase adoption of improved options by the rural people are adapted in the convergence approach.

2.3 Concepts of Land Use and Land Cover Changes

Land cover refers to the vegetation (natural and planted), water, bare rock, sand and similar surface and man-made construction occur on the earth's surface. While Land use refers to a series of operations on land, carried out by humans, with the intention to obtain products and/or benefit through using land resources including soil resources and vegetation resources which is part of land cover (DeBie *et al.,* 1996: cited in Lemlem, 2007). Thus, land use often influences land cover. In the same source change defined as an alteration in the surface component of the landscape and is only considered occur if the surface has a different appearance when viewed on at least two successive occasions. Changes like clearing of forest for agriculture or plantation area for urban expansion can be detected using remotely sensed data. Moreover, according to Byrne (2001) the term land use describes the type of uses (forest, residential areas, mining and conservation areas) to which the land has been subjected, whereas land cover describes the appearance, features and characteristics of that land in more detail (Byrne, 2001; cited in Asnake, 2006). Land cover, therefore, refers to things that cover the land characteristics such as crops, wood, bush, grazing and settlements. Land cover influences erosivity of the soil eroding agents and erodibility of the eroding subjects (Morgan, 1995;cited in Asnake,2006).Since the late 1960's (Brandon and Bottomley 1998;cited in Lemlem,2007), the rapid development of the concept of vegetation mapping has lead to increased studies of land use and land cover change worldwide.

Since the beginning of domestication of crops about 10,000 years ago, the human population has increased from approximately 5 million to more than 6 billion people. The environmental consequences of uncontrolled population growth are obvious such as forest destruction, pressure on land and other natural resources, unsustainable pattern of land use for agriculture, degradation of land and depletion of resources (EPA, 1997a; cited in Lemlem,2007). These environmental consequences in turn lead to other problems. For instance, vegetation destruction increases surface runoff by doing that it affects the ground water recharge. Vegetation has a significant impact on infiltration both by providing canopy and litter cover to protect the soil surface from raindrop impacts and by producing organic matter, which binds soil particles and increases its porosity. Higher porosity increases

infiltration and percolation rates and the water-holding capacity of the soil. Infiltration rates are positively related to litter and grass basal cover, being up to 9 times faster with 100% litter cover than for bare soil (Maidment, 1993a). Therefore deforestation increases surface runoff and reduces recharge by affecting the above condition especially if the area is steeply sloped and recharge zone.

2.4 Soil and Soil Fertility

2.4.1 Definition and concepts

Soil is one of the natural capitals that provides long-term economic, production and environmental services (Sanchez *et al*., 1997), but constitutes a fragile living environment which teems with biological and physico-chemical processes (Solomon, 2008). It has been subjected and influenced by genetic and environmental factors of parent material, climate, macro- and microorganisms, and topography all acting over a period of time (Gardiner and Miller, 2004). In order to take advantage out of such long-term economic production, humans' activity can change soil (i.e. It can be improved or damaged) (Gardiner and Miller, 2004).

But the change that brings about the damage outweighs when compared to the improvement so that scientists are virtually unanimous about the fact that human activity is increasingly damaging soils all over the world (Solomon, 2008). Thus soil degradation becomes one of the consequences of this damage.

Soil degradation is defined differently by different scholars, but for the purpose of this study, the following two definitions are preferred. Thus according to Oldeman *et al*. (1991) soil degradation is fertility decline and reduced organic matter contents and loss of nutrients. And it is the decline in soil quality or reduction in its productivity and environmental regulatory capacity (Lal, 1997).

Major types of soil degradation includes water and wind erosion, chemical degradation processes such as depletion of organic matter and loss of nutrients, salinization**,** acidification and pollution and physical degradation processes like compaction, crusting and sealing, and water logging (Syers, 1997). Almost all of these processes have directly or indirectly linked

to soils chemical, physical and biological properties of soil (soil fertility). According to Solomon (1994) soil fertility (soil quality) is a measure of the amount and the availability of elements necessary for plant growth, and of how physically conducive the environment of the soil is. Soil fertility is defined as the quality of a soil that enables it to provide nutrients in adequate amount and in proper balance for the growth of specified plants or crops (SSSA, 1997). Soil with good fertility has beneficial effect on the environment because it supports more plant to be grown. The more trees, grasses crops the soil allows to grow on, the larger amount of CO_2 removed from the atmosphere as a result it contributes to climate change, reduce top soil loss due to minimized erosion (Gardiner and Miller, 2004) and fertility of soil controls the availability of water and nutrients which are essential for plants (Swift, *et al*., 1994) and modify the structure of the soil.

Thus, soil fertility decline is the key factor in soil degradation (Syers, 1997). According to Hartemink (2003) soil fertility decline is a decline in chemical soil fertility or a decrease in the levels of SOM, pH, CEC and plant nutrients. A decline in soil fertility implies a decline in the quality of the soil. Its decline (loss) or gain concerning its chemical properties can be expressed by the nutrient content or status which is defined by the ratio, expressed as a percentage, between the existing nutrient content of soil and its estimated under natural vegetation (Young,1976), on the other hand its degradation or improvement is indicated by the deterioration index (DI) (Mulgeta, 2004).Thus, it is very important to describe about the conditions , importance and contribution of soil fertility attributes to soil fertility.

2.4.2 Chemical degradation

Chemical degradation is mainly due to leaching and poor farming practices which results in the loss of nutrients and a concomitant increase in exchangeable Al, and sometimes Mn. Soil nutrient depletion results when the inflows of nutrients to the soil through manure, chemical fertilizers, biological nitrogen fixation, addition of wastes or plant materials from outside the system, atmospheric deposition, and sedimentation are less than outflows due to crop harvesting, removal of crop residues, erosion, leaching and gaseous losses (Stoorvogal and Smaling, 1990). Changes in chemical properties are largely a function of changes in chemical parameters such as soil reaction, nutrient composition and forms, ion exchange and rotation.

Chemical degradation processes includes depletion of organic matter and loss of nutrients, salinization**,** acidification and pollution (Syers, 1997).

2.4.2.1 Soil pH and electrical conductivity

The term pH is derived from the French pouvoir hydroge*n*, or hydrogen power and it is a numerical measure of the activity or hydrogen ion activity of a soil (Gardiner and Miller, 2004). It is also defined as the negative logarithm of hydrogen ion activity in solution and expressed in scale from 1 to 14, even though it doesn't have upper or lower limits. However, it is classified as acidic, neutral and alkaline with pH values below 7, equal to 7, and above 7, respectively (Table 3). Most soils under field conditions vary between about pH 4.0 and 10.0 (SSSA, 1996). Soil pH is easily determined and provides various clues about other soil properties because it greatly affects the solubility of minerals. For instance, in acidic soils the phosphate ions react with iron, aluminum, and manganese ions to form insoluble phosphates, since acidic soils have high amount of exchangeable aluminum, manganese, and iron. On the other hand, in alkaline soils soluble phosphate ions adsorb on solid calcium carbonate surface so phosphorous is most available at about pH 6.5 for mineral soils and pH 5.5 for organic soil (Gardiner and Miller, 2004). Moreover, it influences plant growth by its effects on the activities of beneficial microorganisms. Therefore, according to the aforementioned author most plants are best suited to a pH of 5.5 on organic soils and a pH of 6.5 on mineral soils. Therefore, Tan (1996) cited in Abiy (2008) indicated that soil pH is the most important determinant of soil chemical properties.

Electrical conductivity (EC) is a measure of salinity. In addition to overcoming some of the ambiguities of total dissolved salt measurements, the EC measurement is quicker and sufficiently accurate for most purposes. Excessive accumulation of soluble salts convert soils to salt affected soils and the process leading to accumulation of salts are common in arid and semi arid regions where rainfall amount is insufficient to leach soluble salts (Bohn *et al*., 2001).

Table 1: Soil pH with associated soil reaction

PH value	Acidity	PH value	Acidity
4.0-4.5	Extremely acidity	6.5-7.4	Neutral
4.5-5.0	V.strongly acidic	7.4-7.8	Slightly alkaline
5-5.5	Strongly acidic	7.8-8.4	Moderately alkaline
5.5-6.0	Moderately acidic	8.4-9.0	Strongly alkaline
6.0-6.5	Slightly acidic	9.0-10.0	V.strongly alkaline

Source: SSSA (1996)

2.4.2.2 Soil organic matter

Soil organic matter (SOM) is plant and animal residue in the soil in various stage of decomposition (Gardiner and Miller, 2004). It has a number of positive effects such as it is a source of 90 to 95 percent of the nitrogen in unfertilized soil, is the major source of both available phosphorous and available sulfur, contributes to the Cation exchange capacity (CEC); often furnishing 30 to 70 percent, increases water content and air and water flow rate, supply carbon for many microbes that perform other beneficial functions in soil, when it is left on top of soil as mulch, OM reduces soil erosion; shades the soil, preventing moisture loss; and moderate soil temperature and it buffers the soil against rapid changes in acidity or toxicity (Gardiner and Miller, 2004). So it helps to sustain soil fertility by improving retention of mineral nutrients, increasing the water-holding capacity of soils and increasing the amount of soil flora and fauna (Woomer *et al*., 1994). It is also a key factor associated with improvement or decline of soil fertility (Brown *et al*., 1994) which plays an important part in establishing the intrinsic property of soils (Peter, *et al*., 2000). However, it is affected by the kind of farming and soil fertility management practices for instance; Lewandowski (2002) in his study reported that continuous cultivation becomes the major causes of most OM losses, but farmers can increase the amount of active OM by reducing tillage and increasing organic inputs.

Continuous cropping can also reduce SOM or SOC (Dalal and Mayer, 1986a; Peter *et al*., 2000, Igue‘, 2004). Thus, assessment of SOM is a valuable step towards identifying the overall quality of soil (Gregorich, *et al*., 1994). Therefore it is customary to determine SOM quantitatively from the organic carbon content using conversion factor of 1.724 adopted from Young (1976) and Buruah (1998) and rate so as to judge or determine its status in different land use type in comparative study so that it is rated as from very high to very low.

Table 2: Rating of total organic matter (%) and its categories

Rating	Total Organic Mater (%)
Very high	>6
High	4.3-6.0
Medium	2.1-4.2
Low	1.0-2.0
Very low	< 1.0

Source: Tan (1996)

2.4.2.3 Total nitrogen

Nitrogen is the nutrient most frequently deficient and is often the controlling factor in plant growth. Thus lack of nitrogen is the greatest single cause of low crop yield (Young, 1976). It is a major competent of SOM which contains an average of about 5 percent nitrogen (Gardiner and Miller, 2004). Nitrogen in organic forms is not available to plants but must be converted to available forms, either the cationic form ammonium ion ($NH4^{+}$), or the anionic from nitrate ($NO3^{-}$). Even though total nitrogen (TN) is not a measure of available nitrogen to plants, but it is an important indicator of the soil potential for the element. Nitrogen contents of soils are also needed for the evaluation of C.N ratios of soils, which indicates the quality of organic materials (Myers, *et al*., 1994) which give an indication of the process of transformations of organic N to available N like ammonium and nitrate ion (Abiy,2008)). It is very important to classify soil total nitrogen and accordingly Barber (1984) classified soil from very low to very high in total nitrogen as illustrated in (Table 2).

Table 3: Classification of soil based on total nitrogen content (%)

Total Nitrogen	Class
>0.4	Very high
0.4-0.3	High
0.3-0.2	Medium
0.2-0.1	Low
< 0.1	Very low

Source: Barber (1984)

2.4.2.4 Available phosphorous

Phosphorous is the second key plant nutrient and is also the second most often deficient. It is mostly present in soil in the form of the phosphate anion $H2PO4^-$ as available forms for plant absorption. It is most available at about PH 6.5 for mineral soils and at pH 5.5 for organic soils (Gardiner and Miller, 2004). Soil pH, because of its influence on the presence and solubility of calcium, iron, and aluminum, and because of effect on bacterial growth, influenced available phosphorous (AvP). Furthermore, the conversion of natural vegetation to cropland (Mekuria, 2005), continuous mining of nutrients in smallholder farms in 55 countries (Henoa and Baanante, 2006) are important causes of the lowering of available phosphorous. Through very small and infinitesimal small part of soil total phosphorous of, it is relevant in assessing phosphorous fertility level in the soil. Tisdale *et al.* (1997) calibrated available phosphorous by Olsen method as very low (<3.00ppm), low (4.00 to 8.00ppm), medium (8.00-11.00ppm) and rich (>12.00ppm).

2.4.2.5 Cation exchange capacity

The other crucial attributes of soil, given due consideration in this paper is, the cation exchange capacity (CEC); which is defined as the quantity of exchangeable cation sites per unit weight of dry soil being an important phenomenon in soil fertility and contributes the following indispensable functions to the soil (Gardiner and Miller, 2004): Imparts the buffering capacity which enables the soil to resist a change in pH, retain cations on the

surface of the soil and slowly releases calcium, magnesium and potassium ions to plants and slows their loss by leaching and filters the percolating water by retaining water pollutants such as Lead (Pb^{2+}), Mercury (Hg^{2+}), Cadmium (cd^{2+}). But as the pH, humus and clay content of soil change, the CEC changes (Gardiner and Miller, 2004). For instance, a decrease in SOM substantially lowers the amount of CEC to the soil (Gardiner and Miller, 2004) besides an increases in soil acidity, a decrease in pH causes a decrease in CEC this is due to the higher concentration of H^+ ion in the soil solution which hinders the ionization of hydrogen from R-OH or forced hydrogen to remain on the exchange site that is R-O- (Gardiner and Miller, 2004) and proton transfer on the surface of the clay (Young, 1976).

2.4.2.6 The exchangeable cations

Exchangeable cation is any cation held through electrical attraction to a charged surface of a soil and can be displaced by other ions from the surrounding soil solution. The cations most numerous on exchange sites in soils are Ca^{2+}, Mg^{2+}, Na^+, K^+, H^+ and various forms of aluminum (Gardiner and Miller, 2004). Exchangeable cations are not affected by continuous burning of vegetation on farm fields but it may strengthen leaching, principal cause of its lowering. They are highly soluble, readily lost under moderate leaching intensity (Young, 1976). And their proportion in the soil can be changed from loses by plant uptake or by leaching, or by the addition of ions from dissolving minerals. For stance potassium in soil is mobile in solution and therefore susceptible to leaching (Tisdale *et al*., 1993).

Crop residues often contain considerable quantities of potassium specifically as exchangeable ion on humus exchange (Gardiner and Miller, 2004 and Wijinhaud, 2007). Therefore crop residues and harvest removal reduce large quantities of these cations. Moreover, deforestation, intensive cultivation and generally land use changes decreases chemical soil properties from soil under natural vegetation to cultivate lands (Lumbanraja *et al*., 1998 and Igue, 2004). However, the declining of exchangeable Ca and Mg may not imply the deficiencies of both exchangeable cations because they equally occupy more cation exchange sites than any other cations unless aluminum ion exceeds in strongly acidic soils (Gardiner and Miller, 2004).

2.4.3 Physical degradation

An adverse change in properties such as porosity, permeability, bulk density and structural stability; often related to a decrease in infiltration capacity and plant water deficiency (Stocking, 2000). Physical degradation basically includes a negative impact on physical soil properties, such as structure, texture, aggregate stability, porosity, permeability (compaction) and crusting. Soil compaction is an increase in bulk density due to external load leading to the degradation of physical soil properties such as root penetration, hydraulic conductivity and aeration (Mitiku *et al,.* 2006). Physical degradation includes those processes such as poor cultivation practices, which adversely affect soil physical properties such as infiltration rate, structural stability, root penetrability and permeability.

2.4.3.1 Bulk density

Bulk density (BD) is a measure of the amount of solid phase soil particles per unit volume (Swift and Bignell, 2001). The same author suggests that it is the principal physical attributes of relevance for faunal biodiversity and plant growth. Thus, soils with smaller weight per unit volume may have favorable environment for plant root penetration and proliferation (dense rooting), imparts good filtration rate which reduces run-off and minimizes erosion and facilitate gas exchange. But an increased bulk density reduces the nutrient availability for crops because rooting is restricted which limits the volume of soil from which nutrients can be extracted (Peter *et al*., 2000 and Hartemink, 2003), but they do not mean that nutrient availability is necessarily reduced. In normal soils bulk density ranges from 1-1.65 mg/m3 (Shawab *et al*., 2002). It is affected by heavy farm equipment, soil erosion, and loss of organic matter can lead to increase in bulk density (Peter *et al*., 2000).

Table 4: Management factors influencing bulk density

Increases bulk density	Decreases bulk density
• Continuous tillage • Removing or burning residue	• Continuous cropping • Adding organic amendments • Trafficking on wet soils

Source: Arshad *et al.* (1996)

The bulk density of any one soil varies according to its degree of compaction. Organic matter decreases bulk density in two ways. First, organic matter is much lighter in weight than a corresponding volume of mineral matter; second, organic matter gives increased aggregate stability to a soil (Troeh and Thompson, 1993). When soil particles are pushed close together, it can increase the mass per unit volume, the soil is compacted.

2.4.3.2 Texture

Soil texture is a term that refers to the size of the mineral particulars in the soil. It also refers to the relative proportion of stone, gravel, sand, silt and clay in specified quantity of soil. Sand particles are 2.00 -0.05 mm in diameter, silt 0.050-0.002mm and clay < 0.002mm .Soil texture is the most permanent and most fundamental soil property, it has considerable influence on soil structure, consistence, degree of compaction and stability, soil drainage, soil aeration and root penetration. It determines the ability of the soil to hold and exchange nutrients and it is a crucial factor in determining soil response to liming and fertilizer applications on agricultural lands (Gachene and Kimaru, 2003).

2.4.4 Biological Degradation

Biological degradation includes reduction in total biomass and decline in biodiversity. The process of land degradation usually starts with a decrease in organic matter content of the top layer of the soil. This results in a rapid decline of biological activity in the soil. When the topsoil is washed or blown away, sub-soil material with low fertility and high acidity will be exposed to the surface. More rocks, stones and hard structures make more difficult the workability of the soil and reduce the biomass production and thus Yields (Eswaran *et al.,* 2001).

3. MATERIALS AND METHODS

3.1 Description of the Study Area

3.1.1 Location

West Shoa is one of the zones found in Oromiya Regional State. It consists of 18 woredas. The study was conducted at Jeldu district, West Shewa zone, Central Ethiopia (9° 02' 47" to 9° 15' 00" N and 38° 05' 00" to 38° 12' 16" E which is delineated by Meta Robi, Dendi and Ejere woredas in East, Gindeberet Woreda in West, Abuna Gindeberet Woreda in North and Eliphata Woreda in South. It has an area of 139, 389 hectares. It is located 114 kms and 70kms away from Addis Ababa and Ambo respectively. It has 38 rural and 3 urban kebele.

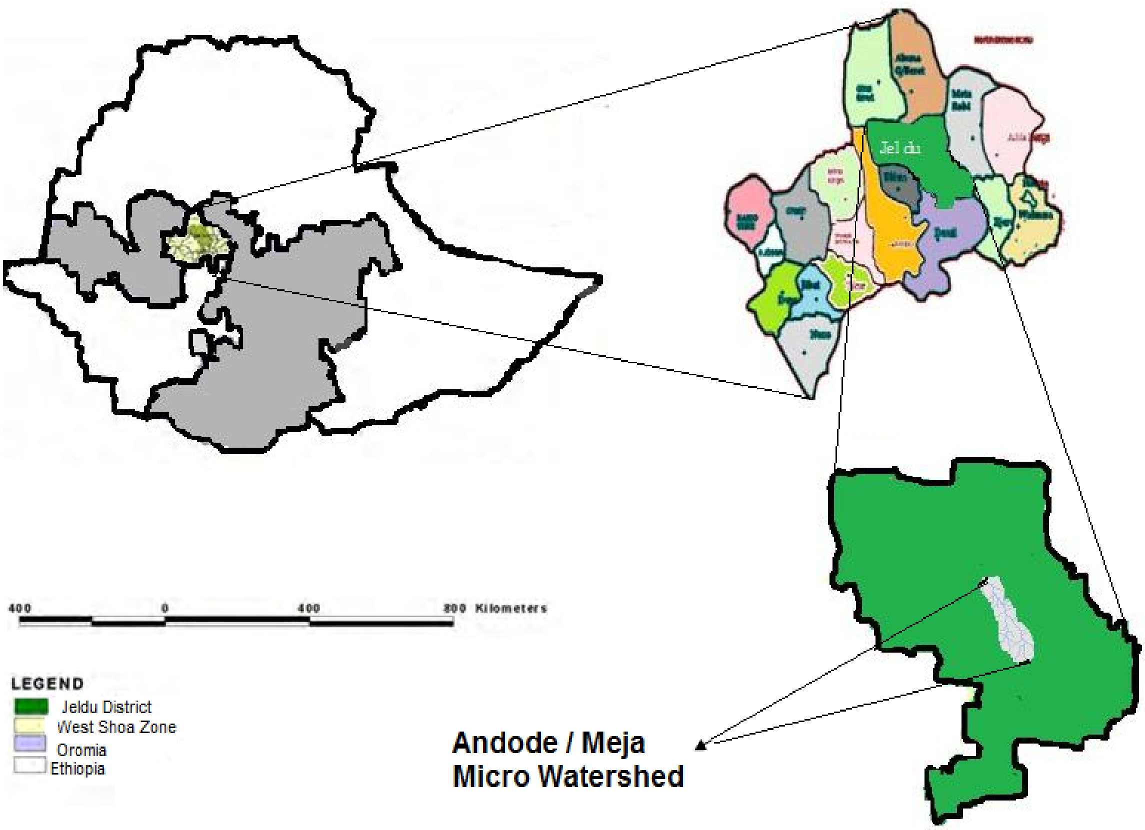


Figure 2: Location of Map of study area

3.1.2 Topography, geology and soil

The geology of central high land of the country is characterized by late tertiary that covers the Pre- Cambrian rocks that underlie all other rocks in Ethiopia (Mohr, 1971). Throughout the Blue Nile basin in Ethiopia the soils are generally vertisols or latosols. The Upper basin is mainly formed from clay and clay-loam soil type, but the riverbed has a loam and sandy-loam type of soil (Hurst *et al*., 1959 cited in Dereje, 2010). The woreda has an undulating terrain nature and with altitude ranging from 2900-3200 meters above sea level. (District's Agriculture and rural development office annual Report of 2009, unpublished).

3.1.3 Climate

Rainfall pattern is bimodal with the main rainy season from June to September and short rainy season from February to March. Mean annual rainfall is ranging from 1800 to 2200mm. The maximum and minimum temperature ranges from 17 to 22 0C (District's Agriculture and rural development office annual Report of 2009, unpublished).

3.1.4 Vegetation

Trees and shrub species are mainly concentrated around homestead for better management and protection. According to Seyoum and Zinash (1989), Fodder tree and shrub species are mostly required as supplement to low quality feeds. Fodder tree and shrub species are considered important contributors to grazing animal nutrition in the highlands of Galessa-Jeldu areas. During the dry and crop-fallow season, farmers traditionally feed indigenous fodder species to meet nutritional requirements of the grazing animals. *Hagenia abyssinica*, *Dombeya torrida*, *Buddleja polystachya* and *Chamaecytisus palmensis* (tree Lucerne) are the main fodder tree species. They were included in the nutritional evaluation process of the fodder species as they are priority species of the farmers. *Chamaecytisus palmensis* (tree lucerne) was recently introduced an exotic N-fixing woody species. *Eucalyptus globules* is the main tree planted in the area for construction and income generation purposes.

3.1.5 Population

According to national population census of 2008, the population of the woreda is 202,655 of which 99,859 and102, 796 is male and female respectively (District's Agriculture and rural development office annual Report of 2009, unpublished).

3.1.6 Farming / Cultivation system

The most common land-use systems in the study areas are mixed crop– livestock systems. Barley (Hordeum vulgar) is the dominant crop, followed by wheat (*Triticum vulgare*), potato (*Solanum tuberosum*) and enset (*Ensete ventricosum*). Cattle, Sheep, and Horses are the dominant livestock species. The major income sources of farmers in the area are selling barely, wheat, livestock products and Potato. (District's Agriculture and rural development office annual Report of 2009, unpublished).

3.2 Study Design

3.2.1 Reconnaissance survey

A reconnaissance survey was carried out in order to understand the site conditions and to identify sampling sites. The study was conducted in micro-watershed that has significant problems of land degradation, unsustainable water management, low crop and livestock productivity in the woreda.

3.2.2 Socio-economic survey

Socio economic study was conducted to assess biophysical, socio-economic constraints and potentials, resource use and management practice in the watershed for sustainable management of rain water to improve agricultural productivity and livelihoods in the selected micro-watershed through both quantitative and qualitative questionnaires. Structured and semi-structured interview questionnaires, group discussion with men and women representatives and key informant interview were employed to gather relevant information. Moreover, discussion was held with, government administrators at various levels and natural resource officers to get the necessary information on history of the area, population

dynamics, socioeconomic activities, and participation of the local people in conservation efforts.

Total number of households of the micro- catchment was registered from available secondary sources. The number of sample household farmers selected for the interviews was determined by using the formula developed by Kothari (2004).

$$n = \frac{z^2 \cdot p \cdot q \cdot N}{e^2 (N-1) + z^2 \cdot p \cdot q}$$

Where: n= sample size

Z = 95% confidence limit (interval) under normal curve that is 1.96

P = 0.1 (proportion of the population to be included in the sample that is 10%)

q = None occurrence of event =1-0.1 that is (0.9)

N = Size of population.

e = Margin of error or degree of accuracy (acceptable error term) (0.05)

In the catchment, sample households were selected using simple random sampling techniques from the list of households.

3.2.3 Identifying, assessing and mapping of existing RWM interventions

An inventory of past and recent RWM interventions in the study area was conducted through a review of the literature, interviews with key stakeholders and a field survey of RWM practices. During the field survey data was collected through observations and interviews with farmers using a semi-structured questionnaire. The field survey was focused on the type of RWM practiced, year of construction, farmers' experiences and constraints, duration of water storage, water uses and application methods. This helped to understand the bottlenecks and successes of RWM interventions in the watershed under study. To map the existing RWM interventions in the watershed under study, by transect walk through the catchment the readings of positions of RWM interventions in terms of UTM was taken from the watershed under study by an instrument Atlas Global Positioning System (GPS) and recorded in a

recording sheet. After the collected readings were listed in access or excel and saved as dbf file, the data was then processed by software ERDAS imagine 9.1 and Arc GIS to produce the map of the RWM interventions in the delineated watershed under study.

3.2.4 Data base for land use land covers change

To assess the changes in land use and land cover (LULC) for reflecting both the biophysical conditions and the history of the socio-economic setting of the watershed under study, multi temporal satellite images of 1990, 2000 and 2010 of the study area were used. Household survey was conducted to acquire data relating to the socio-economic conditions of rural households which would help to explain the changes observed in the LULC. To evaluate changes in the LULC, the satellite images were systematically processed, involving georeferencing, mosaicing, interpretation, classification (supervised), digitization, and mapping (Daniel, 2008). Global Positioning System (GPS) readings of the boarder of the watershed under study were collected for delineating the watershed. Ground control points were also collected from different land use types in the micro-catchment with GPS that was used for geo-referencing the satellite images of the area. An automatic classification method was applied to identify and delineate the different LULC units for the satellite image. Then, satellite images were mosaiced and geo-referenced to UTM coordinate system. Supervised classification was employed by using training sites (samples) on the image which were representative of each desired land cover category. Based on the predefined areas representing specific signatures the software classified the remaining pixels using classification decision rule. The interpretation and classification based on the satellite images was checked against ground truth. Then, the maximum likelihood classification method was applied for identifying land use and land cover types for the study area as a whole. Finally, the land use and land covers map of each year was produced and the land use and land covers change was summarized in tabular form.

3.2.5 Soil sampling and data collection

Soil sample was taken from three representative land use systems; cultivated land, grazing land and forest/plantation land in the micro-watershed to assess the status of soil degradation through the analysis of some selected physical and chemical soil properties. Soil samples

were collected in four replicates of composite samples of top soil from depth of 0-20cm in a zigzag method from each land use using an Auger. Litters and residue materials were manually removed from the surface before sampling. A separate undisturbed soil sample for bulk density determination (BD) was collected by a core sampler (cylindrical metal sampler). The disturbed soil samples were air-dried, finely ground using mortar and pestle, and sieved to pass through 2mm mesh. Samples were collected in plastic bags, labeled and taken to laboratory test.

The finely ground soil samples less than 2mm were tested for selected soil chemical properties, such as soil PH, electrical conductivity (EC), soil organic matter content (OM), total nitrogen (TN), available phosphorous (AvP), cation exchange capacity (CEC) and basic exchangeable cations by following standard laboratory procedures. PH and electrical conductivity of soil samples were determined by potentiometric method at soil to water ratio of 1:2.5 (soil: water suspension ration of 1:2.5) using pH meter and portable conductivity meter respectively (Black, 1965). The Walkley and Black (1934) wet digestion method was used to determine soil carbon content and percent soil OM was obtained by multiplying percent soil OC by a factor of 1.724 following the assumptions that OM is composed of 58% carbon. This method involved a wet oxidation of the organic carbon with a mixture of potassium dichromate, sulfuric acid and titrated by ferrous sulphate. Total nitrogen was analyzed using the Kjeldahl digestion, distillation and titration method as described by Black (1965) by oxidizing the OM in concentrated sulfuric acid solution (0.1N $H2SO_4$). Available soil P was analyzed according to the standard procedure of Olsen *et al.* (1954) extraction method (extraction from the soil using sodium carbonate ($NaHCO_3$) at PH equals 8.5). Cation exchange capacity (CEC) and exchangeable bases (Ca, Mg, K and Na) were determined after extracting the soil samples by ammonium acetate (1N NH4OAc) at pH 7.0. Exchangeable Ca and Mg in the extracts were analyzed using atomic absorption spectrophotometer, while Na and K were analyzed by flame photometer (Chapman, 1965; Rowell, 1994). Cation exchange capacity was thereafter estimated titrimetrically by distillation of ammonium that was displaced by sodium from NaCl solution (Chapman, 1965).

Physical degradation was assessed using bulk density and texture. Soil texture was measured by the standard Bouyoucos Hydrometer method after destroying OM using hydrogen peroxide (H2O2) and dispersing the soils with sodium hexameta phosphate ($NaPo_3$) (Bouyoucos, 1951).Bulk density of undisturbed soil sample was determined using core sampler (cylindrical metal sampler) (Blake, 1965) and determining the mass of solids and the water content of the core, by weighing the wet core, drying it to constant weight in an oven at 105^0C for 24 hours and reweighing after cooling. Bulk density was then calculated from the measurement of the bulk volume, using the core length and the diameter of the cutting edge of the sampler.

$$BD = \frac{\text{Weight of sample (gm)}}{(\text{Volume of sample (cm}^3))}$$

Volume of sample=∏ r^2h

Where: ∏=3.14, r= radius of internal diameter of the core sampling tube, h= height of core sampler tube.

3.3. Data Analysis

3.3.1 Socio-economic data analysis

Data obtained from household questionnaire survey was analyzed using statistical package for social sciences (SPSS) version 15.0 and the results are presented with descriptive statistics; tables, graphs and percentages. The qualitative data generated by the informal discussions was used to substantiate results from the questionnaires.

3.3.2 Soil laboratory data analysis

The laboratory data obtained from the soil sample was subjected to one-way analysis of variance (ANOVA) using SAS packages of 9.0 version software to detect whether there was significant effect in soil attributes between the land use types. Minimum significance difference by Tukey test was used for mean comparison for those properties that was found to be significantly different. The level of significance used was 0.05.

3.3.3 Computation of the relative soil fertility degradation

According to Islam and Weil (2000) cited in Mulugeta (2004), soil degradation under different land use systems were evaluated by applying the degradation (also called deterioration) index (DI) which was used to estimate the extent of soil properties that would be deteriorated/improved for the land uses when compared to the same soil properties under a pre-existing steady-state base line, ideally the native vegetation. The calculated percentage changes were summed across all soil properties for each land use system, which was then used as an index of soil degradation or improvement.

$$DI = F\text{-}I / I \times 100\%$$

Where DI = Degradation index

F= Mean value of soil property under different land uses

I = Mean value of the same soil property for soil under natural vegetation.

4. RESULTS AND DISCUSSION

4.1. Socio-Economic Survey

4.1.1 Characteristics of sampled households

The study revealed that 98% of the total household heads (HHs) surveyed were male headed. The age of the sampled household heads ranged from 24 to 70. From the total respondents, 98% were married and their average family size was 6.2. Fifty three percent (53%) of the total family members of the sampled households were adults (> 17 Yr.) and the rest (47%) were children. Even though there was at least one primary school in each kebele this time, the educational level of the respondents was low (Table 5). Most respondents complained about the poor accessibility of education in the past especially before 10 years. Results of the household survey indicated that all respondents were engaged in agricultural activities with 16.9 % of the households being additionally involved in non-farm activities. Even if 94.4% of total respondents had their own farm land, the farm land owned was not sufficient (2.12 ha per household on average) .Those farmers who didn't have their own farm land, did the farming either through share cropping or through rent (contract) arrangements.

Table 5: Educational level of the HH respondents

HH Educational Status	Illiterate	Grade 1-4	Grade 5-8	Grade 9-12	Above 12
%	54	21.8	20.2	4	0

Source: Field survey, 2010

4.1.2 Water scarcity issues

In the study area there were about 16 springs of which 14 were seasonal and 2 were perennial. Out of 88 streams, 55 were seasonal and 33 were perennial. There was only one perennial river in the watershed (District's Agriculture and rural development office annual Report of 2009, unpublished). These water sources were not sufficient to meet every needs (i.e. for drinking and cooking, washing clothes, watering livestock and growing crops by irrigation) of the societies in the watershed as reported by all respondents. Out of 132

households interviewed, 32% HHs reported that they were not accessible to water every day for household purposes. The result of interview showed that the main reason for this water scarcity was due to poor and inefficient application of rainwater management (RWM) to empower the water sources (66.9%) in the watershed under study. Even if the area is with high rain water potential, there were poor rain water management practices for increasing the time for infiltration of water in to the soil profile by *in-situ* water conservation methods to raise ground water table and for storing water for later use in water storage structures in the watershed under study. For instance, farmers destroyed natural trees from the course of streams and rivers for the sake of cultivation and grazing purposes due to shortage of lands. Furthermore, the existing RWM interventions were poorly practiced and less attention was given to them by farmers for protection.

Forty two percent (42%) of respondents indicated that insufficient amount of water in water sources was also another reason for why they were not accessed to sufficient water in the watershed under study. According to the focused group discussion of women, there were very thin stream discharges (locally called "Chororsa") at every stream for fetching (Figure 3). Some of these streams even dry during dry season (27.4%) and hence they had to go a long distance for fetching. Therefore, the availability of water sources at distant (33%) was another reason raised by respondents in the survey for describing water scarcity issues. On average it takes 45 munities for one way and another 45 munities for waiting the turn and until the water fills fetching material in dry seasons and this affected their production and productivity as reported by most respondents. Similarly, Degefa and Tesfaye (2008) reported that the problem of time and labor spent for fetching water affected not only household productivity but also had affected the physical wellbeing of women fetching water from a distant.

Figure 3: People waiting to fetch water in the watershed under study

In general, lack of access to sufficient water had brought illness to family members and livestock, time wastage and labor spent in fetching water, decreased livestock production and had led to problems of irrigating farms and intensifying agriculture (Table 6).

Table 6: Water scarcity problems faced by households in the watershed under study

	Health problems of household members and food utilization	Decreased livestock production	Taking too much time and energy in fetching water	Inability to intensify agricultural production via small scale irrigation systems	Induced conflict over water use
% of total HHs with specified water problem	42.5	99.2	87.9	67.7	56.3

Source: Field survey, 2010

4.1.3 RWM practiced

The field study revealed that different types of RWM practices exist in the study watershed. Many of them were aimed to increase the amount of water stored in the soil profile by trapping or holding the rain where it falls to improve the land and underground water table. These includes: earthen/soil bunds, gully plugging, deep tillage, vegetative barriers, contour farming, crop rotations, use of farm yard manure (FYM) and use of composts. Likewise, Alem (1999) cited in Girma (2009) reported that soil bunds, stone bunds and grass strips were the major conservation structures meant for erosion control commonly practiced in Ethiopia also conserve water *in-situ.* There were also few RWM systems which were designed to store water for later use as supplementary irrigation and as a source of drinking water for human beings and livestock. In this regard the observed structures during field survey includes: ponds (3.2%), roof rainwater harvesting (35.5% during wet seasons only), open wells which locally called “Ella” (3%), and check dams for stream stabilization and diversion (43.5%). Most of these rainwater management and land improvement structures (interventions) were constructed individually by farmers where farmers contributed labor during the construction. Concerning roof rain water harvesting, the respondents with corrugated sheet of house were commonly used this RWM system for water storage during wet season. They used the harvested water for household consumption purposes. The other existing RWM and land improvement structures (interventions) were as given in figure 4.

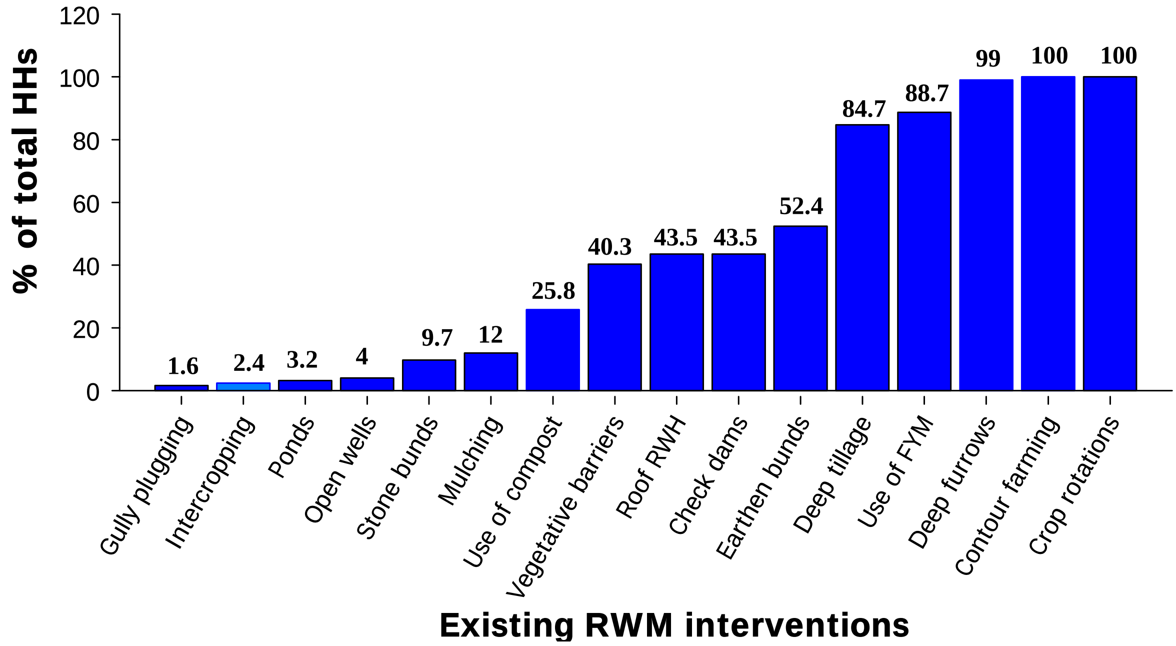


Figure 4: Existing RWM structures (interventions) in the watershed under study
Source: Field survey, 2010

4.1.3.1 Ponds

There were four ponds, used to store water for later use in the study area, of which three were constructed by community during the Derge regime (about 28 years ago) and one pond constructed privately in the recent time (3 years ago) in Tullu Gurra kebele. The private pond had a circular shape and was 3 meters wide and 2 meters deep while the community ponds were found in Sariti and Tulu Gura kebele and were circular in shape and about 6-9 meters wide and 2-3 meters deep. Now a days the community ponds were neglected without maintenance; grasses being grown in it, felt with sediment, broken down (Figure 5 B) and even some without water in it. The privately constructed pond was also not properly protected as it was filled with broken woods, leaves and grasses. Even though the functioning ponds were not properly protected, they were still mainly used as a source of drinking water for livestock and for small scale irrigation to grow potatoes, onion and seedlings of pepper and eucalyptus tree especially privately constructed pond in Tullu Gurra kebele (Figure 5 A). A success story with this privately constructed pond is that; the owner prevented the pond from drying off by diverting the stream which was about 180 m far away from the pond and

he was able to produce cabbage, onion, potatoes and seedling of eucalyptus tree on his farm in the dry season and was able to secure food at his household level. The report of Alem (1999), cited in Girma (2009), indicated that ponds were the main RWH structures in the Ethiopian Rift Valley where groundwater was deep and other sources of water were not available and they were used to collect water for growing vegetables and fruits around homesteads for markets and home consumption.

According to the surveyed farmers, all of the observed ponds were not performing as intended in terms of storing/retaining harvested runoff. The owners argued that the poor performance was caused by high water losses mainly through seepage, evaporation, siltation problem and also due to less attention given to the value and maintenance of the ponds. The same problems were reported by Girma (2009) in his study on identification of potential rain water harvesting areas in the central Rift Valley of Ethiopia using a GIS based approach. In general, the ponds were left unprotected allowing livestock to drink directly from the pond and silt, leaves, grasses and woods were being accumulated in it (Figure 5 A and B). For well functioning of such ponds, there had to be full participation of the entire community for properly handling of the ponds. Thus strong community organization was required to mobilize labor for operation and maintenance.

A) B)

Figure 5: Privately constructed pond in Tulu Gura kebele (A) and unprotected community pond in Sariti kebele (B) of the watershed under study

4.1.3.2 Check dams for perennial stream (river) diversion

About 43.5% of respondents in the study area were practicing perennial stream or river diversion by locally constructed check dams from locally available materials such as soil, stone, wood and leaves. Most of these structures were constructed privately in the upper parts of the watershed on nearby spring or streams for the sake of household consumption and drinking of livestock purposes. One locally constructed check dam by own labor in Chillanko kebele from Laga shasi stream was among a productive check dams observed in the study watershed during field survey. The check dam was locally constructed from locally available eucalyptus tree in a systematic way for taking water in a desired direction for potato cultivation in this upper part of the watershed (Figure 6). It took them two days in order to construct the check dam and irrigation furrow leading to the potato land which was approximately 300 m^2 in area coverage. The owner of the potato responded that he used to use the same stream from the upper course for potato, onion and cabbage cultivation on his piece of land for about 16 years. However, he was no more able to use now because of the reduction of the power of water of the stream. This forced him to irrigate the current potato land by share arrangements with the owner of the land and would produce about 30q from the land. The respondent complained about the scarcity of water in the stream and short durability of the locally constructed check dam.

Figure 6: Privately constructed local check dam in Chillanko kebele

On the other hand, it was never tried to divert the big Andode/Meja River in the upper part of the watershed by constructing local check dams because of its being flowing in the deep gorge. This hindered the farmers to take water from Andode/Meja River for irrigation system. To solve these problems two respondents were using water pumping motor purchased ($9000) by themselves in group of two to cultivate potato and onion in the upper part of the watershed (Figure 7). They had used the instrument for two years and were able to cultivate on average about 1 ha of crop land. By doing this they maximized their yield and were able to secure food at their household level. According to the perception of the owners of the water pumping motor, buying the fuel, spare parts and maintenance of the pumping motor were among the challenging problems in using this method for which up to know they spent 500 birr for maintenance and buying the spare parts.

Figure 7: Water pumping motor being used in the watershed under study

In lower part of the watershed check dams were largely practiced in order to divert perennial streams and Andode/ Meja River. The terrain nature is also suitable for wide range of small scale irrigation system for production of potato, maize, barley, onion and cabbages in this lower part of the watershed. According to the field survey observation and perception of most local people, there were an irrigation systems for maize, potato or onion in the pieces of land (that was not more than 0.5ha per household) by most households (Figure 8A).The limitation of land for irrigation system (<0.5ha/HH) was due to the scarcity of water to cover the wide range of land they have as needed by the households. The most widely used water sources for small scale irrigation system in this lower part of the watershed were Andode/Meja River, laga kile and laga Jeba streams. With the help of these water sources the beneficiary households were able to produce yield twice a year from their farm land. Lega Jeba stream was originated from kollu Galan kebele and diverted from the upper part of the stream to serve as source of water for production of maize, potato and onion for about 200 households down the stream. The power of the flow of the water from diverted stream decreases as it moves away from the diverting point. For instance, at the diverting point the discharging rate, measured by volumetric method (Majumdar, 2002), of the water was 33 seconds with 44 micro seconds while it was3 minutes with 32 seconds on average at the farm land site. This difference in discharging rate at both sites probably indicated water loss or existence of seepages along the course of the irrigation line. This showed that the required amount of water did not reach and used in the farm field. So, this insufficient amount of

water on the field site was the main problem for not to expand the land for irrigation system and then intensify agricultural production. To solve this problem people in the area were organized in groups to use the water. The day for each group (totally 3 groups) was identified and the fixed time (about 2-3 hrs per day) for individual person in the group was also limited. This system of using the water was guided by water committee in the village so as to reduce conflict over the water use.

Meja River which is the largest and only river in the study area is originated from Galessa aera. It passes the watershed under study from top (around Sariti and Hinto Dale kebele) to bottom (Chobi Sirba and Kollu Galan kebele up to bridge on Chobi road).There were four check dams locally constructed mainly from stones, soil and woods at Bicho (one check dam), Tullu Gurji (two check dams) and Kollu Galan (one check dam) kebele at intervals along the course of Meja river every year during the dry seasons. The check dam in Tullu Gurji was constructed for small scale irrigation purposes so as to serve about 400 households which were organized in to 5 zones from two kebele partly found in the watershed. These 5 zones were about 5 gasha (200 hectares) in area as reported by the respondents in the study watershed. The length of the check dam was approximately 12m (Figure 8B) and constructed for about two days by the communities from the 5 zones. According to the perception of the surveyed farmers, maize, potato and onion were the main crops cultivated by irrigation system by diverting the river. As in the case of Laga Jaba, here there was also water committees which were even further organized in hierarchical manner for wise use of Meja water for irrigation system among the 5 zones. As most respondents forwarded the main problems in using the Andode/Meja River were the problem of not to construct the dam easily, maintenance problem and scarcity of water at the distant zones. There was also the problem of breaking down of the check dams by water force every year during summer season; that was why local farmers were complained about the lack of standardized check dam on the river.

A) B)

Figure 8: An example of irrigated maize and onion land in Kolu Galan kebele (A) and locally constructed Meja check dam in Tulu Gurji kebele (B) in the watershed under study

4.1.3.3 Open wells

The survey data showed that 4% of the sampled households had private open wells in their garden constructed by the expert paid by the owner themselves. The open wells, which the people call "*Ella"*, were circular in shape and in average about 1m wide and 9m deep (Figure 9). As most owners responded, open wells were full of water during rainy season and with very little water in the dry season. They used rope for lifting mechanisms without pulley system. All of the surveyed households with the open wells were used water in the structures for washing and cooking purposes and to irrigate tiny plots in the garden to produce vegetables for home consumption and to raise pepper seedlings. One of the respondents in the Sariti kebele complained about the insufficient amount of water in the well during dry season even for household consumption purpose and the problem of cleaning it without the expert. The other respondent in Hinto Dale kebele raised the problem associated with lifting mechanism in that the rope sometimes cut and fetching materials left in the well.

Figure 9: Privately constructed open well in Hinto Dale kebele in the watershed under study

4.1.3.4 Bunds (Earthen and Stone) and Gully plugging

Fifty two point four (52.4%) and 9.7% of the respondents in the study watershed used earthen bunds and stone bunds on their farm land respectively. Most of the earthen bunds were constructed during the Derge regime (about 28 years ago) by the community. The earthen bunds varied in length and height (on average about 50 m in length and 50-75cm in height) and were constructed horizontally on the land which usually prone to soil erosion by runoff water. High labor and time demanding nature of constructing the structure was the reason for not constructing the structure at the household level according to 11.3% of the respondents. Eight percent (8%) of the respondents, however, reasoned lack of information and training about the structure for not being constructed at household level. The earthen bunds were mainly constructed for increasing the time for water infiltration into the soil and for runoff protection purposes. Besides this most respondents used the structure as boundary for separation of pieces of plots from one another (wheat plots from Barley ones) and also for separation of land of one owner from another. In some places of the study watershed some of these structures were broken down by excessive runoff water and by livestock trampling (Figure 10A). The stone bunds observed in the study watershed were constructed horizontally (in average 20m in length and 1.25m in height) (Figure 10B) and used for similar function as that of earthen bunds. They were constructed in the current time privately.

Earthen bund (A) Stone bund (B)

Figure 10: Earthen (A) and stone (B) bunds used in the watershed under study

The undulating terrain nature and the high potential of rainfall in the study area were responsible for the formation of runoff following heavy rain. Following roads, furrows and rill erosion, there were a number of gullies being formed in the study watershed. According to the surveyed households there were only 1.6% gully plugging structures constructed privately in Tullu Gurra and Bicho kebele from locally available structures such as wood, leaves, soil, and stone in the past summer (Figure 11A). Even these existing structures, observed by walking through the catchment, were not fully constructed and hence runoff water may easily break them down. This implied that such type of gully erosion management by gully plugging needs community participation so as to fully construct and easily control the erosion problem in the area.

A) B)

Figure 11: Gully plugging (A) and deep tillage (B) used in the study watershed

4.1.3.5 Deep tillage and furrows

The most RWM interventions used in the study area next to contour farming, crop rotations and use of farm yard manure (FYM) were deep tillage (84.7%) and deep furrows (99%).As most respondents raised, they practiced deep tillage (about 15-20cm deep by local ploughs) on their farm land on which they would go to grow crops starting from the October every year. This practice was common and used by the farmers mainly for preparing the land for crop production and for increasing the time for infiltration of rainwater into soil profile (Figure 11B above). Deep furrows were on average 25 cm deep and constructed mostly by farmers themselves for diverting runoff to reduce the washing out of their farm land. This practice was also very common and adopted from parents and neighbors. The main problems in using deep furrows were that most farmers did not take care of the runoff water once it passed on their farm land and they did not give attention to the direction of the furrows as downward directed once were further responsible for gully erosion formation.

4.1.3.6 Vegetative barriers and Mulching

Respondents of 40.3% and 12% in the study watershed have used vegetative barriers and mulching respectively as options for RWM methods. Mulching method was commonly practiced during growing seedling of pepper and eucalyptus tree around springs, streams and

homestead areas. It protected the soil from raindrop impact and reduced the velocity of runoff. Maintaining crop residues or mulches on the farm controls effectively soil erosion and has considerable potential for the restoration and maintenance of soil fertility and moisture (Ministry of Agriculture, 2005).Most farmers planted eucalyptus tree on steep area around streams and rivers for runoff and land sliding protection while others simply planted on their crop land in order to sell the tree when it was matured. So eucalyptus tree plantation by the farmers was very common in the study area not only for run off protection but also for "Hatena" purpose to attain food security situation at their household level by selling.

4.1.3.7 Contour farming and Crop rotations

With regard to household perceptions of contour farming and crop rotations in the watershed under study, all of the respondents were using these methods for managing rainwater in order to increase their soil moisture and productivity. According to all respondents, the use of these methods was adopted from their parents and neighbors. Even if wheat and barley were commonly cultivated from year to year alternatively by farmers, crop rotation between cereals and pulses was more productive according to farmers' perceptions. Furthermore, those farmers who had small scale irrigation (32.3%) on their farm land especially on the lower part of the study watershed were able to cultivate twice a year by rotating potato and onion between cereal crops. On the other hand, farming on the contour reduces soil erosion and conserves soil moisture by minimizing the rate of runoff. There was also intercropping cultivation system observed during field survey in Bicho kebele where maize and potatoes were cultivated on the same farm land. According to the owner of the farm, the method was practiced on a piece of irrigable land for about three years and a great change in both product and improvement of soil fertility were observed.

4.1.3.8 Use of farm yard manure (FYM) and compost

Use of farm yard manure (FYM) and compost as the RWM and land improvement structures (interventions) methods were account for 88.7% and 25.8% respectively of the perception of the total households surveyed. Traditionally farmers add cattle dung and other manure on their garden to improve soil quality. According to the perception of the interviewed farmers, the farmers were also trained by developmental agents to make compost and add it to their

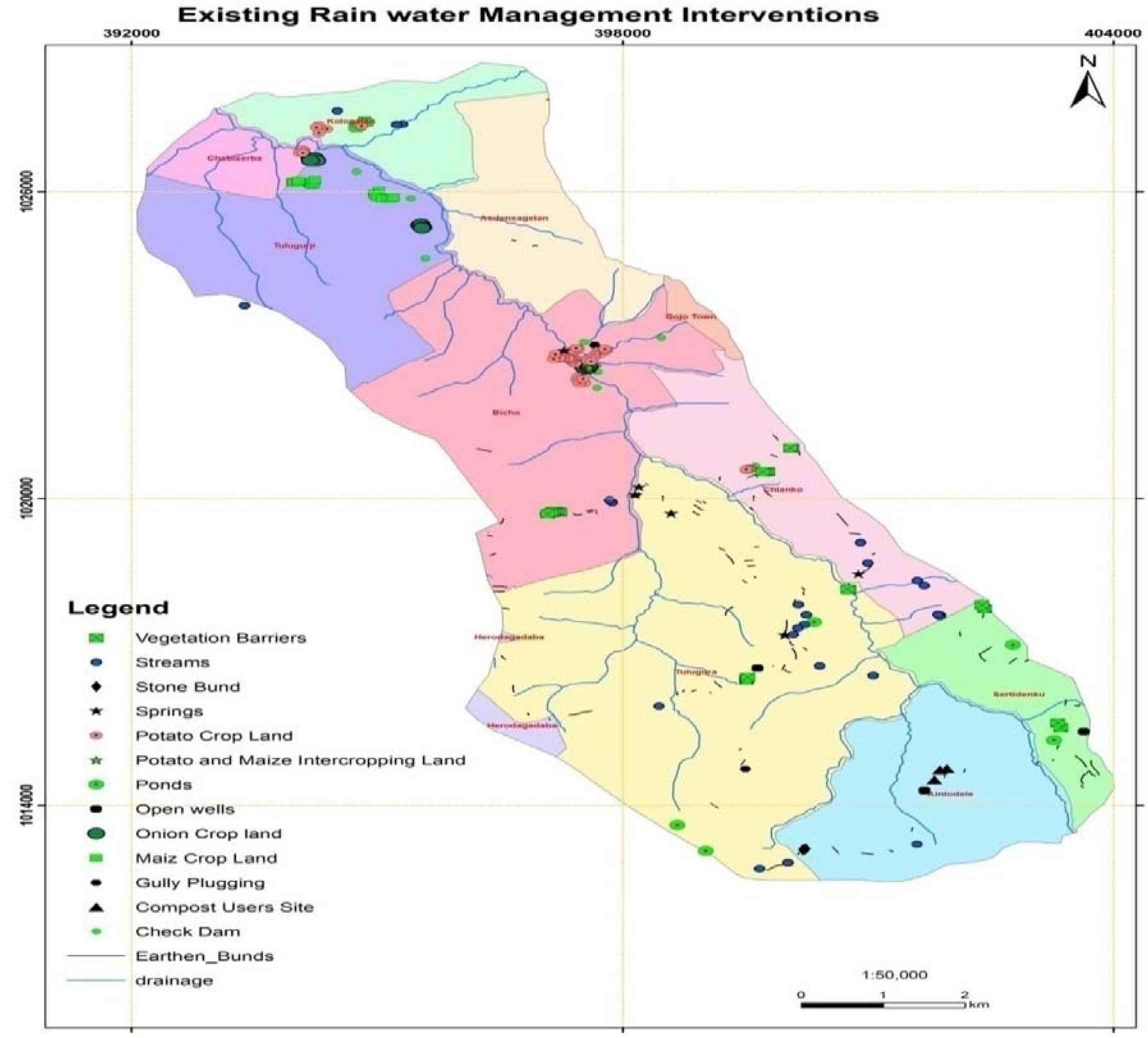
farm land to improve both soil moisture and quality. According to both FGD of men and women in the study watershed, addition of FYM (Figure 12A) and compost (Figure 12A) were commonly restricted to homestead areas because carrying and taking them to a distant field was time consuming and tiresome. But around homestead areas they were commonly used and were able to increase the product of their crops such as wheat, barley, potatoes and occasionally that of inset in the study area.

Farm yard manure (A) Compost (B)

Figure 12: Farm yard manure (A) and compost (B) used in the watershed under study

4.1.3.9 Map of selected RWM interventions practiced

Next to the most and widely used RWM interventions such as contour farming (100%), crop rotations (100%), use of farm yard manure (FYM), deep furrows (99%) and deep tillage (84.7%), the other existing ones in their order of prevalence in the study watershed were earthen bunds (52.4%), check dams (43.5%), roof rain water harvesting (43.5%), vegetative barriers (40.3%), mulching (12%), stone bunds (9.7%), open wells (4%), ponds (3.2%), intercropping (2.4%) and gully plugging (1.6%).The map of some of the selected RWM interventions and other information were given in the figure(13) below.



Source: Field survey, 2010.

Figure 13: Map of existing rain water management interventions practiced in the study watershed

4.1.4 Soil degradation and management status

The survey on soil degradation and management issues was designed to include most soil problems and management issues in the watershed, i.e. soil erosion, sedimentation, fertility problems and regarding soil management, its type of protection measures, method of implementation, year of construction and any improvement seen after taking measures were assessed.

4.1.4.1 Soil erosion/sedimentation problems

Results from the socio-economic survey revealed that 100% of the respondents reported that there were soil erosion/sedimentation problems in their farm lands. As the study revealed, the existence of sheet erosion (97.6%), sediments in ditches and furrows (94.4%), rills in the farm (94.4%) and gullies in the farm (25.8%) were helped the respondents whether there was soil erosion/sedimentation problems or not on their farmlands. According to most respondents the problems of soil erosion/sedimentation were seen on their farm land since 10 years ago. The problem was very serious and productivity would be decreased as a result of top soil erosion (96.7%) and portion of their farm land would be lost by erosion (96.7%), as reported by the surveyed respondents, if protection measures would not take place. The major causes of soil erosion/sedimentation and indicators of the problem as perceived by the respondents were given in Table 7.

Table 7: Causes of soil erosion/sedimentation problems and its indicators as perceived by the respondents

Causes of soil erosion/sedimentation problems	* Percentage (%)	Indicators of soil erosion/sedimentation problems	* Percentage (%)
Deforestation	99.2	Sediments in ditches and furrows	94.4
Improper tillage	90.3	Existence of Sheet erosion	97.6
Slope/terrain	100	Rills in the farm	94.4
High rainfall and absence of its management measures	91.9	Gullies in the farm	25.8

*The percentages do not add up to 100 due to the multi response of the respondents

Source: Field survey, 2010

4.1.4.2 Soil fertility problems

All surveyed farmers (100%) pointed out that there was soil fertility problem on their farm land. The farmers were able to know the existence of such problems in their farm land via different indicators such as reduction of crop yield (100%) from year to year and increased input demand (92%). According to one respondent in the watershed, plot of land which was about half hectare was used to demand 50kg inorganic fertilizer only to produce 15 quintal wheat; however, by adding manure as supplementary to inorganic fertilizer in the current, the yield showed reduction from year to year. According to the perception of respondents, soil structure and color change (91%) was also another indicator for soil fertility decline where red colored and rough soil (commonly called “borki”) was less fertile soil type. Similarly, stunted crop growth (85%) as they reported indicates poor soil in fertility. As most of them responded that such soil fertility problems were seen in their crop farms on average since 8 years ago. The causes of soil fertility problem in the study watershed include high rain fall followed by leaching and erosion (97.6%), continuous cultivation and removal of crop residues (96.8%), absence of the addition of manure (73.3 %) especially to a distant farm land and absence or inappropriate application of inorganic fertilizer (63.4%). The sloppy nature and cultivation on this steep slope in the study watershed were also accelerated the rate of erosion. Furthermore, the degree and length of the slope was also an important factor influencing soil erosion.

4.1.4.3 Soil problem management practiced

According to the result of surveyed HH data, none of the respondents were made discussion on soil erosion problems with their neighbors, local authorities, extension agents or any other community members. Accordingly none of them were involved in participation of soil conservation work initiated by the above mentioned agents. But the existing soil erosion/sedimentation protection, soil fertility management and other land improvement interventions were practiced privately on their farm land without discussion with any other agents but as adopted/learned from their neighbors (67.7%) and parents (80%).

The findings of the present study showed that 100% of the total HHs surveyed had taken directly or indirectly the protection measures for soil erosion/sedimentation problems

privately on their farm land. The common protection measures that most farmers had been exercising were ditches/trenches which the people commonly called deep furrows (99%), soil/earthen bunds (52.4%) and check dams (43.5%). Contour planting (40.3%) and stone bunds (9.7%) were also among the other protection measures that few people in the study watershed were using for similar purposes. When 34% of the total respondents taking protection measures had seen improvement after taking the measures, the rest (66%) did not .This was because of the fact that, as seen during field observation and according to the perception of most respondents, the farmers didn't apply and protect the protection measures correctly, for instance ditches/trenches were dug vertically which were even more responsible for gully formation and then for land form damages. Similarly, soil/earthen bunds were not protected as well in that livestock breakdown them for grazing purposes.

As far as land use was considered, any land type available to the people was used for all purposes in need regardless of its natural suitability. Land use classification was done according to the distance of the respective plot from the residential location of the owner. Whatever the proper utility of the land may be, homestead area was reserved for enset, maize, potato and other vegetables and relatively distant plots are meant for other cereal crop dominated by wheat and barley. Differences in farming systems and land uses can alter nutrient input and output fluxes in soil and vegetation. This can change soil fertility, which in turn affects biomass production and human decisions on land management (Priess *et al.,* 2001). In addition to inherent soil fertility gradients, diverse and long-term anthropogenic interventions are important sources of soil fertility. They create zones of fertility within and between different farming systems (Brady and Weil, 2002).The table below (Figure 14) shows the major soil fertility management practices of farmers in the study watershed. For most of the farmers, there was no single method of soil nutrient management. They use the combination of two or more of different methods.

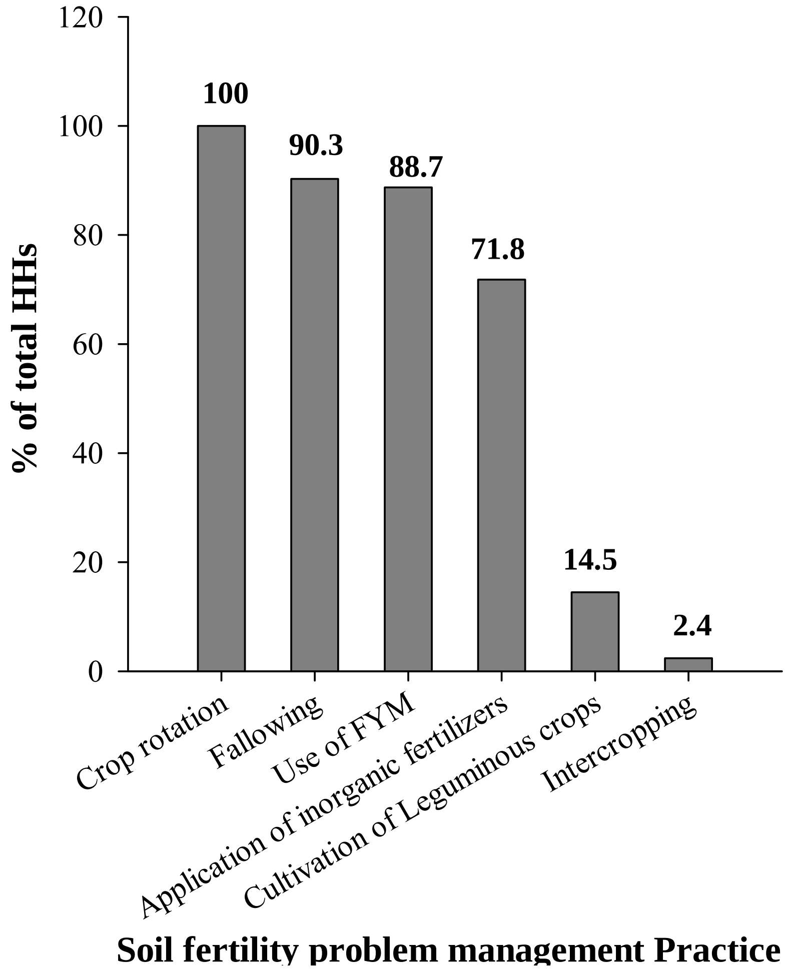


Figure 14: Major soil fertility management practices adopted in the study watershed
Source: Field survey, 2010.

Crop rotation was the most commonly practiced (100%) as soil fertility management in the watershed under study. As the study revealed that the respondents put their land commonly under the rotation of barley and wheat especially at the upper part of the watershed. At the lower part of the watershed there was also the rotation of potato and onion with cereal crops after small scale irrigation. According to the perception of respondents (14.5%), when the farm land was considered to be poor in soil fertility, the farmers also rotated the other cereal crops with leguminous crops in the study watershed.

Next to crop rotation fallowing was the common soil management practice in the study watershed. Half of the total farmland of a household was put under annual crops, and the rest

half was under fallow being rotated after every year for the purpose of restoring land fertility. But, it seems that this type of cultivation would not be continued because of the rapid population growth and the resultant shortage of land. From the total respondents, 90.3% used fallow method of soil nutrient management.

Application of farm yard manure was also another means of soil fertility management practiced in the watershed. But it was restricted to around homestead areas and as a result farm plots at distant from the residential area had less chance of being treated with manure. 88.7% of the respondents used manure, the remaining do not use because of lack of livestock and distance of farmland from the residential areas.

Application of inorganic fertilizer in the form of DAP and UREA was another alternative means of soil fertility management system in the watershed. However, the amount of fertilizer applied per hectare by most of the farmers (60.6%) was significantly less than (<100kg of DAP/ha) the officially recommended dose of 100 kg DAP/ha and 50 kg Urea/ha (Eyasu, 2002). The major constraint on the use of fertilizer was its relatively high price and existence of large number of poor family in the study watershed. As a result, some farmers have stopped using it. From the surveyed respondents, only 71.8% of them were found to use fertilizers.

According to surveyed HHs only 2.4% of respondents pointed out that they were using intercropping methods as treatment to the soil fertility of their farm land. Through field survey such types of management practices were observed in the irrigable lands of study watershed.

4.1. 5 Land use and land holding status

Even if 94.4% of total respondents in the study watershed had their own farm land, the household survey results indicated that the farm land owned by all farmers was not sufficient (92.7%).All the landless farmers were young household headed mostly with age group ranging from 22 to 35 ages. Those landless farmers had got land for production via share cropping (4%) and rent (contract) (1.6%) arrangements. So, it was very difficult to newly married HHs' member to get land this time in the watershed as there was no free farm land in

the kebele of the watershed that could be allocated for the landless. According to the surveyed households, 100% respondents raised that when a member of the household gets married he/she gets land from their own parent. As family size is increasing from time to time, the same land of the household would be shared by their own newly married offspring. This situation finally resulted in shortage of land in the area as a result of which farmers were forced to cultivate on very steep slope land. This would aggravate the study watershed susceptibility to soil and fertility loss by force of erosion. Rapid population growth requires additional farm land for increasing production leading to deforestation and converting of pasture land into crop land which in turn reduces soil productivity due to increased erosion, decline in soil fertility, change in aeration and moisture content, salinization or change in soil flora or fauna (Bossuyt *et al*., 1999). In short scarcity of land was the main problem in the watershed under study and on average survey results revealed that 32.3% of the resident having 1ha, 28.2% with two hectare, 23.4% with three hectare, 15.3% with four hectare and 0.8% with more than four hectare respondents were living in the watershed. According to the perception of the respondents, the major land use types in the study watershed were cultivated cropland (94.4%), grazing land (65.3%), natural forest (0.8 %/) and plantation (66.7%) (Table 8).Moreover, fallow land (90.3%) which the farmers reserved for crop production on the following year was also there. Hence, fallow land was considered as part of crop land but currently without crops on it. Similarly, 87.9% respondents had backyard garden around homestead areas on which potatoes, onion, and other vegetables were growing on it in the watershed. Backyard garden was also part of cropland that was restricted for garden vegetables and occasionally for maize cultivation especially in the lower part of the watershed. Generally, one can say that cropland, grazing land and forest/plantation land were the major land use land cover types in the study watershed that were essential to the livelihood welfare of the residents.

The terrain nature of the study watershed is undulating and is not favorable for crop cultivation. However, the widespread cultivation was being practiced on steep slope (86.3%), gorge land type (1.3%) and on the plain (6.8%) type of the study watershed (Table 8). On the other hand, 40.2% and 18.5% respondents had grazing land on steep and gorge type of lands, respectively in the study watershed. Such type of grazing land was affected not only by

grazing but also via trampling by livestock. Forest/plantation land use land cover types owned by farmers were mostly on the steep slope and gorge land types.

Cultivation on steep slope strongly exacerbated soil erosion and loss of soil fertility in the study watershed. According to the perception of the surveyed HHs, only 1.7% of respondents were with fertile cropland while the rest were with moderately fertile (60.2%) and less fertile (32.5%) type of cropland. Similarly, the soil fertility status of the grazing land of the study watershed was fertile (8.9%), moderately fertile (40.1%) and less fertile (16.3%) according to perception of the respondents; while it was fertile for forest (100 %) and plantation (42.7%) land. So, by any standard the results of the study indicated that the fertility of grazing land was higher than that of cropland but lower than that of forest/plantation land. Regarding the farm land management, even if the degree and efficiency varies from household to household, all the surveyed HHs had taken directly or indirectly the protection measures privately on their farm land (see section 4.1.4.3).

Table 8: Current land use types, its slope and soil fertility status in the watershed under study

Current land use types	Average plot size in hectare per HH with specified land use type	% total HHs with specified land use type	Slope of the specified land use			Fertility of the specified land use		
			%HHs with plain land type	%HHs with steep slope land type	%HHs with gorge type of land	%HHs fertile type	%HHs with moderatly fertile land type	%HHs with less fertile land type
Cultivated crop land	1	94.4	6.8	86.3	1.3	1.7	60.2	32.5
Backyard garden	0.06	87.9	70.3	17.6	0	61.2	26.7	0
Grazing land	0.25	65.3	6.6	40.2	18.5	8.9	40.1	16.3
Forest	0.06	0.8	0	0	0.8	0.8	0	0
Plantation	0.25	66.7	7	38.6	21.1	32.7	26.2	7.8
Fallow	0.5	90.3	7	80.5	2.8	1.3	56	33

Source: Field survey, 2010

4.1.6 Crop production status

In the study area crop production was the main farmers' activity primarily for subsistence and also as a source of income. The cropping pattern was mono cropping system especially at the upper part of the study watershed where cultivation of barley (100%) followed by wheat (97.6%) was dominant. Beans (21.8%) and peas (16.9%) were among the legume crops that were rotated with cereals occasionally in the watershed. Teff (9.7%) and maize (24.2%) were also cultivated around the outlet of the watershed. Enset (10.4%), potato (81.5%), onion (31.5%) and other vegetables were also cultivated at the homesteads especially by using irrigation water in the lower part of the watershed. In this lower part of the watershed; crop production through the use of irrigation water was wide spread after the harvest of rainy season crop making the cropping pattern to be bimodal.

In the study watershed, as raised by respondents, farmers were using both Urea and DAP (71.8%) in order to treat their soil fertility problems. The amount of these commercial fertilizers applied appropriately by the farmers varies from person to person based up on their wealthy status. Those farmers with high economic level had been using recommended dose of 100 kg DAP/ha and 50 kg Urea/ha (Eyasu, 2002). But 9.7% of respondents reported that they were using less than unrecommended dose per hectare because of their low economic level. As supplementary to the commercial fertilizers, farmers in the area had been also using improved seed (51.6%), pesticides and herbicides (90.3%), compost (25.8%) and FYM (88.7%) on their farm to improve their soil quality. As almost all (100%) surveyed HHs pointed out, having applied all these treatments to their farm land, the yield decline from year to year. Significant percentages of surveyed households (99.2%)) believed that, the decline in the fertility of their cropland was one of the most important reasons for the reduction of yield. As management measures farmers were directly or indirectly adopting RWM to reduce erosion problems and also by increasing of farm inputs (84.7%). So, addition of large amount of farm inputs, as practiced in the area, was meaningless unless RWM technology was well practiced in order to reduce the washing out of nutrients even together with farm inputs.

4.1.7 Livestock production status

Livestock status in the study watershed comprises rearing of cattle, sheep, equines and chicks. Cattle are kept for meat, milk and milk products and as a store of wealth. Equines play beneficial roles for households as they are used to transport humans, farm products, farm inputs and other services. Similarly, sheep and chickens are reared for the sake of their meat and as a source of monetary income by selling.

From the total surveyed households, 94.4% had livestock but the others (5.6%) had not. Those respondents, who said yes for the question that they were asked (i.e. whether they have livestock or not) were further asked about the trend of their livestock size since the last 10 years. All respondents (100%) raised that the number and the productivity of their livestock had been decreased from year to year and on average the number of livestock possessed per HH in the watershed was given in the table below (Table. 9). In the study watershed the largest percentage of land use occupied by farmers was cropland as described under section

4.1.5. In addition to this large coverage of the area by cropland, the large proportion of grazing land's topography which as perceived by farmers 40.2% steep slope and 18.5% gorge type was not suitable for rearing livestock on it. Shortage of lands for grazing forced farmers to collect crop residues, which would have an impact on the soil properties and long term productivity of the area, for livestock as a feed. Since crop residues as source of fodder for livestock was also not enough (63.7%) the livestock were wandering the whole day along the course of streams and rivers searching for green leaves. The scarcity of water for drinking (98.4%) and the long distance to be traveled in the area plus the problems associated with water borne diseases typically "dullandula" as people locally called (93.5%) were also among other reasons for the reduction of the number and productivity of livestock in the study area.

Table 9: Average livestock possessed in the watershed under study

Livestock	Cattle	Sheep	Goat	Equines	Chickens
Average livestock/HH	4	2	0	2	2

Source: Field survey, 2010

4.1.8 Forest/plantation status

According to the perception of the surveyed HHs and visual observation, there were almost no (0.8%) natural forests which can be seen together in the watershed rather than remnants of very few scattered trees of forest occasionally seen in the cropland (Figure 15) and scattered vegetation around the steep slope and gorge of Andode/Meja River. However, as raised by respondents (100%), there was natural forest before 20-30 years in the watershed around Hinto Dale kebele and along the course of Andode/Meja River.

Figure 15: Remnants of natural forest in the cropland in the watershed under study

What was very common in the study watershed was that the plantation of eucalyptus tree (66.7%) for the sake of "Hatena" selling. Most of the farmers were planting the eucalyptus tree on steep slope land and around the streams and rivers but few others were converting their current cropland to eucalyptus plantation. According to the perception of surveyed HHs, there was a great change in the status of both natural forest and plantation in the current time in that natural forest has disappeared (75.8%) and has decreased (25.8%) while plantation forest has increased (100%) in the study watershed. Farmers of the study watershed had different perception for the causes of disappearance or reduction of natural forests in the watershed (Figure 16).

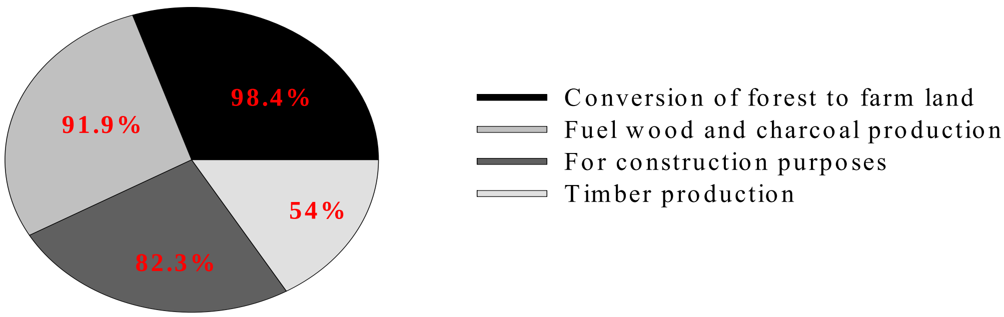


Figure 16: Farmers' perception for natural forest reduction or disappearance in the watershed under study

Source: Field survey, 2010

4.1.8 1: Effects of forest cover change

The presence of forest has many functions in that it protects soil from erosion problems by reducing surface runoff and increasing the infiltration of rain water into the soil profile. Forest cover also prevents soil erosion by wind. Beside these it also serves as sources of food and as dwelling home for different kinds of animals and birds. Despite these facts, almost all area of natural forest has been disappeared in the study watershed leading to the over flow of most of the rain water carrying soil particles and significant amount of minerals and nutrients. This has resulted in yield decline and more rills and gullies formation followed by land fragmentation. The other effect of forest cover change was the reduction of the water flowing in the form of springs and streams from the area leading to the reduction of drinking water to human and livestock. So stream flow reduction and drying was the main impact of reduction or absence of natural forest in the study area. The information from field survey, key informants and field observation also supported this idea.

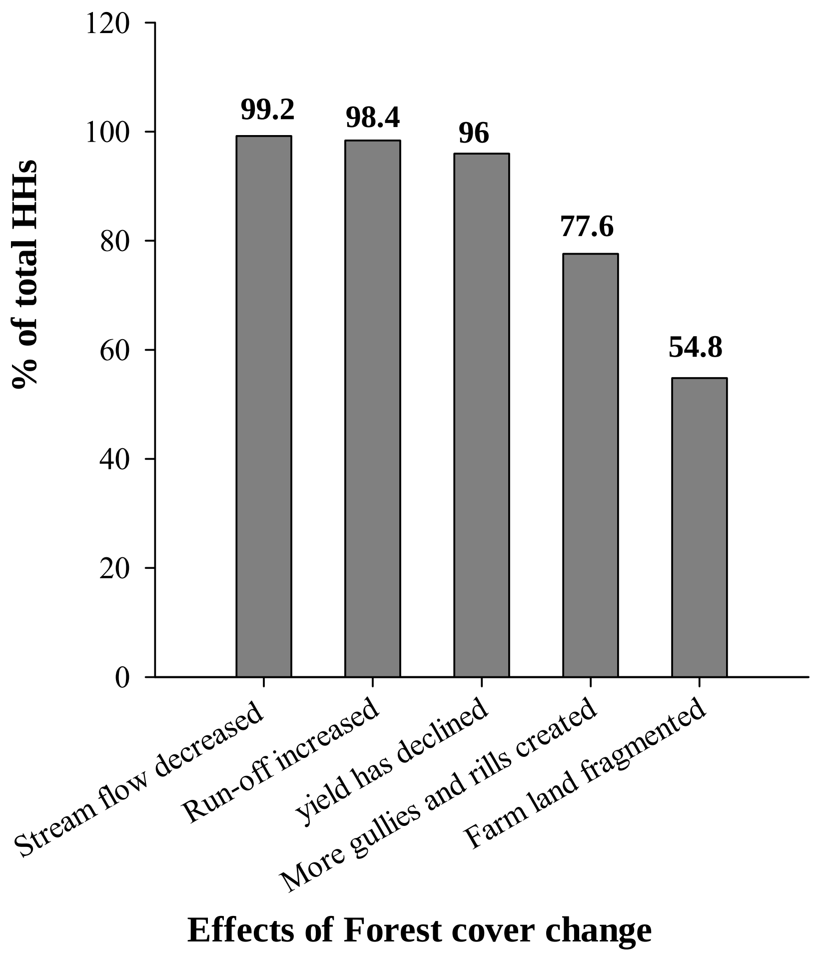


Figure 17: Summary of effects of forest cover change as perceived by respondents in the watershed under study

Source: Field survey, 2010

4.1.8.2 Protection measures of forest cover change practiced

Natural resource management is a very essential issue for the development of an area. As it was tried to gather information from different sources (questionnaire, focus group discussion, informal interview, and physical observation) there were no practical activities carried out by the government, local as well as international NGO, and the communities so far to conserve and rehabilitate the natural resource especially forest in the study watershed rather than farmers' eucalyptus plantation (66.7%) which was not mainly for the sake of protecting the effects of forest cover change but for income generation purposes. If it had not been for the

sake of income generation purposes, the plantation was not mono plantation type rather it would have been involving different kinds of exotic and indigenous tree plantations.

4.1.9. Food security status

Quantitative measurement of food security indicators at household level was not carried out under this study. Rather, the study relied on a self-reporting method for examining household food security. Households were asked whether they could meet food and other basic needs all year round from their own production and could afford to purchase from the market by deploying their own assets. Accordingly, the sampled households in watershed were asked to carry out self-reporting using the four categories as shown in Figure 18.

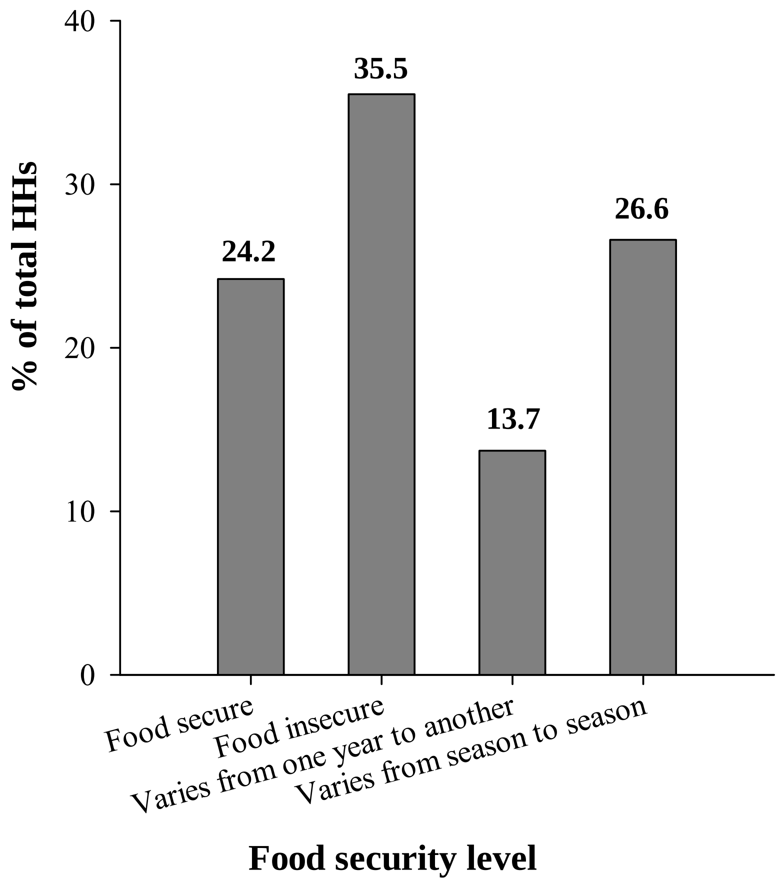


Figure 18: Categories of food security level in the watershed under study
Source: Field survey, 2010

According to the results of the surveyed HHs, the largest percentages (35.5%) of respondents felt that they were food insecure. This situation was more prevalent at the upper part of the watershed where there was less small scale irrigation system for crop production twice a year.24.2 % of the total HHs interviewed reported that they were food secured while 13.7% and 26.6% of respondents were claimed that food supply situation varies from one year to another and from season to season, respectively. According to one respondent in the upper part of watershed, it was possible to attain food security situation when the weathering system especially regular rain fall distribution in the year was very good but during frost (locally called "wagy") years it was impossible. Similarly, people always suffer from food scarcity during summer season when the past grain was finished and the new ones would not reach as reported by food insecurity household member. Farmers also relate food insecurity situation with shortages of land for crop production and livestock rearing and with reduction of water and soil fertility from time to time for father production.

4.1.9. 1 Causes of food insecurity

According to the result of surveyed HHs, the major factors for food insecurity at the household level were given in the table below (Table 10).

Table 10: Reasons for households becoming food insecure in the watershed under study

Reason	% of total households
Inability to produce sufficient grain due to poor RWM on crop farm and Inability to intensify production via small scale irrigation	67.7
Inability to rear sufficient number of livestock due to insufficient amount of water	52.4
Land scarcity for more grain and livestock production	72.6
Meager income from non-farm activities	7.3

Source: Field survey, 2010

In the study watershed land scarcity, due to high population growth, was the main problem for expansion of crop production and livestock rearing (72.6%).There was no free land to be allocated for landless farmers especially younger individuals in the study watershed for production. This issue which hinder both crop and livestock production clearly affected food security situation at household level of those respondents who had been complaining for land scarcity in the watershed.

Poor RWM to produce sufficient grain and inability to intensify production via small scale irrigation was also another reason for food insecurity at household level in the watershed (67.7%).Undulating terrain nature of the watershed which makes the land more susceptible to soil erosion and soil fertility loss by runoff and leaching and insufficient water and soil conservation measures practiced in the watershed under study ultimately decreased yield and then resulted in food insecurity in the study watershed. Furthermore, the terrain nature in the upper part of watershed was also hinders the farmers especially from using the Andode/Meja river for small scale irrigation purposes.

Poor RWM also resulted in surface water scarcity for livestock production (52.4%) and intensifying production via small scale irrigation by stream and rivers diversion. Similarly, insufficient amount of income derived from non-farm activities (7.3%) was another causal factor for food insecurity among household level of respondents who were struggling for generating income via alternative livelihood (discussed under section 4.1.9.2).

4.1.9. 2 Alternative livelihoods

Sixteen point nine percent (16.9%) of the surveyed HHs in the study watershed were engaged in certain non-farm activities. The type of these non-farm activities vary in kind, time of work and benefit derived from them as reported by the respondents. According to the survey made, the non-farm activities that exist in the study watershed were given in the figure below (Figure 19).

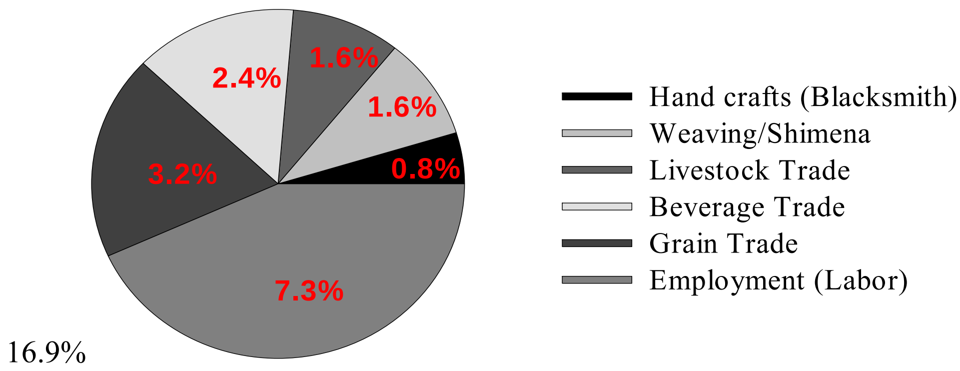


Figure 19: Type of non-farm activities in the watershed under study

Source: Field survey, 2010

The largest percentage (7.3%) of total households in the study watershed were involving in employment (Labor) type of non-farm activities where some member of the surveyed households engaged in wage labor in the nearby town, mainly in construction-related work (house construction).In some others the member (mainly children) of surveyed HHs was permanently employed in some other body's house in salary or in kind to drive income to their family in order to sustain food security at their household level.

Participants in grain and livestock trade accounted for 3.2% and 1.6% respectively in the study watershed. Grain trade especially for wheat, barley and potato was practiced by farmers dwelling near the Gojjo town. Even though the farmers were not legal trader for which their capital does not allow, they were trying to buy grains from other farmers and sell them within the town with their limited capital.

Similarly, livestock traders were buying and selling for sheep, chickens and occasionally for cattle from the nearby society and town. Both grain and livestock traders were not permanently involved in the activity throughout the week/year but during one or two market days in the week as they were doing this activity together with farm works.

Respondents of 2.4% in the study watershed indicated that their household member especially females were engaged in beverage trade (Tela, Katikala and "Tenaye"; local

name).Beside farm work female mothers were able to get income by selling these beverages in their home and others by seating on the main roads.

Weaving/shimena is a type of skilled work where the expert makes different threads and clothes from cotton. Only 1.6% respondents were engaged in such type of activity in the study watershed. According to the perception of one respondent in Hinto Dale kebele, he was able to know this activity by the training once given by the government for work less persons together in Derge regim .Beside farm work, by engaging in this activity the respondent was able to make “Kuta”, “Natela” and “Fota” (Figure 20) and was able to get income by selling them to secure food at his household level.

Figure 20: Weaving/Shimena practiced in the watershed under study

For making and shaping farm instruments very few surveyed households (0.8%) were engaged in hand crafts (blacksmith) non-farm type of local-skill work. This activity was seasonal in that it was mostly practiced during farming season and the income derived from it was also very limited which could not be sufficient to buy food to bridge the deficiency of food.

Out of 16.9% total surveyed HHs engaged in non-farm activities, few of them (7.3%) reported that the income drawn from such ventures was not sufficient to support households (Table 4.11).According to them (informants) the major reasons were shortage of start-up

capital to begin off-farm activities, the relatively low income that one can make from such work and lack of knowledge to conduct non-farm activities.

4.1.10 Linkages between rainwater management practice, agricultural productivity and household food security

Even though RWM practices were adopted by all respondents directly or indirectly, the real application of the RWM interventions was different from household to household. When few farmers (beneficiary ones) were practicing RWM interventions for solving water scarcity problems and improving soil erosion and fertility problems for increasing agricultural productivity (34%), the others 66% (non-beneficiaries) were adopting RWM interventions (especially the *in-situ* water conservation practices like deep tillage, addition of FYM, contour farming and crop rotation) without giving proper care for the interventions but only for why their parents and neighbors had been using.

Food insecurity was reported by the largest percentages (35.5%) of surveyed households, while only 24.2% claiming that they could fulfill their all-year round requirements from their own production (Figure 18). It should also be noted that the role of RWM in food security was subsumed in other activities, such as agricultural and livestock production and productivity. As shown earlier (section 4.1.9.1), these were the key factors in food security: 67.7% of sampled respondents believed that their food insecurity was related to their inability to produce sufficient grain, 52.4% related it to their inability to raise a sufficient amount of livestock.

According to the perception of non-beneficiaries of rainwater management interventions, all of them (100%) believed that rain water management problems (in proper and inefficient use of the interventions) were a factor in their low agricultural production and productivity, low livestock production and access to in sufficient amount of water in their village.

Conversely, about 94.7% of beneficiary households ascertained that their food security status and livelihoods had improved following RWM interventions, most particularly in terms of improved agricultural productivity. As raised on focused male group discussion it was possible to increase their crop yield by using appropriate RWM interventions through

reducing soil erosion, sedimentation and soil fertility loss thereby securing food at their household level. Moreover, 32.3 % of the respondents were able to intensify agricultural production through the use of irrigation water cultivating maize, potato, onion, cabbages and other vegetables by diverting streams and rivers in the watershed. Similarly, according to the FGD, the farmers were producing twice a year mainly at the lower part of the watershed but they complained about the insufficient amount of water in an irrigation line as it had to go a long distance for serving large population depending on it.

According to focused female group discussion, they were relieved from long distance journey to fetch water for household consumption, for washing and for watering vegetation around their house as few of them had open wells and stabilized stream near their house. The discussion made with DAs also revealed that few farmers were also able to diversified their sources of income by adopting RWM for water storage system in ponds and by stream or river diversion for more production and then to attain food security at their household level.

4.2 Land Use Land Covers' Data Analysis

4.2.1 Status of land use land covers distribution

The four major LULC types identified in the study watershed were riverine trees/vegetation, farm land, grazing land and tree plantation. The description for the LULC types was that riverine trees include trees grown along river and stream courses, including indigenous tree species and exotic trees such as eucalyptus and juniperus trees. Tree plantations mainly refer to eucalyptus trees that are not found near river courses. Lands that are used for growing annual crops such as wheat and barley including fallow land and homestead area (including settlement) were categorized under farm land in this study watershed. The proportions and distributions of LULC types in hectare and percent for 1990, 2000 and 2010 years are given in table below (Table 11).

Table 11: Land use land covers distribution (1990, 2000, and 2010)

Land use/land cover categories	1990		2000		2010	
	Area (ha.)	Area (%)	Area (ha.)	Area (%)	Area (ha.)	Area (%)
Farm land	5,147.55	61.87	5,697.36	68.48	5,854.54	70.37
Grazing land	1,206.99	14.5	301.41	3.62	285.13	3.43
Plantation	951.57	11.44	1,261.26	15.16	2,018.61	24.26
Riverine trees/ vegetation	1,013.76	12.19	1,059.84	12.74	161.59	1.94
Total	8,319.87	100	8,319.87	100	8,319.87	100

Source: Field survey, 2010

Land used for farm land covered the highest proportion in the three periods considered in the study watershed. It covered 61.87% of the total area in 1990, followed by grassland (14.5%), riverine trees/vegetation (12%) and eucalyptus plantation (11.44%).

In 2000, the coverage of farm land increased to 68.48% of the total area followed by Eucalyptus plantation which accounted for 15.86%. While riverine trees/vegetation and grazing land covered 12.04% and 3.62%, respectively.

In 2010, 70.37% of the total land use and land cover was covered by farm land and the remaining area of 24.26%, 3.43% and 1.94 % was covered by eucalyptus plantation, grazing land and by riverine/vegetation, respectively (Table 11).The highest percentage in area coverage of the farm land use type in the classification within the three periods considered indicated that the conversion of the grazing land and forest land into cultivated land, fallow and homestead areas was the long lasting problem in the study watershed. The same pattern of changes in area coverage of farm land was reported by Daniel (2008), in that land used for

growing annual crops was more important in the Upper Dijo River catchment and increased in area coverage from 1972 to 2004 periods.

4.2.2 Pattern (nature) of changes in land use and land cover

An important aspect of change detection was to determine what was actually changing to what i.e. which land use class was changing to the other. This information would also serve as a vital tool in management decisions. This process involved a pixel to pixel comparison of the study year images through overlay. The loss or gain by each class of LULC between 1990 and 2010 particularly in the change in hectares was given in table 12.

Table 12: Pattern of LULC changes between 1990and 2000 and between 2000 and 2010 in the study watershed.

Land use / land cover categories	Change b/n 1990 and 2000		Change b/n 2000 and 2010		Average rate of Change (1990-2000)		Average rate of Change (2000-2010)	
	(ha)	%	(ha)	%	ha/yr	%	ha/yr	%
Farm land	+549.81	+10.7	+157.18	+2.8	+49.98	+0.97	+14.29	+0.25
Grazing land	-905.58	-75.0	-16.28	-5.4	-82.33	-6.82	-1.48	-0.49
Plantation	+309.69	+32.5	+757.35	+60.5	+28.15	+2.95	+68.85	+5.46
Riverine trees/vegetation	-11.72	-1.6	-840.25	-83.9	-1.07	-0.10	-76.39	-7.62

Source: Field survey, 2010

It can be observed from the table (Table 12) that farmland increased by10.7% and 2.8% between 1990 and 2000 and between 2000 and 2010, respectively in the study watershed. This might be due to high population growth which demands more land for cultivation in the watershed under study. Eucalyptus plantation showed similar patterns of change, which increased with 32.5% and 60.5% between the 1990 and 2000 and between the 2000 and 2010 periods, respectively. Even if the area coverage of farm land was large from the beginning,

its rate of expansion was lesser (0.97%) between1990 and 2000 and 0.25% between 2000 and 2010 when compared to that of eucalyptus plantation (2.95% between1990 and 2000 and 5.46% between 2000 and 2010).

In contrast, grazing land and riverine tree/vegetation cover showed a reverse trend, reducing by 75% and 1.6% respectively between 1990 and 2000 and 5.4% and 83.9% respectively between 2000 and 2010.

In general, the pattern showed that more land being used for farmland followed by eucalyptus plantations at the expense of grazing land and riverine trees/vegetation. Likewise, Daniel (2008) indicated that the pattern of land use and land cover changes between 1972 and 2004 in the Upper Dijo River catchment showed a tendency towards more land being brought under annual crops, while at the same time tree plantations became more important at the expense of shrub-grassland and riverine trees.

LULC change detection results indicated that, over the past 20-30 years there was gradual reduction and even near to the year of the present study almost a total disappearance of natural forest (1.94%) in the study watershed (Table 12). The main reason for the disappearance of natural forest in the study watershed was due to the conversion of forest to farmland (98.4%) as discussed under 4.1.8 topic. As a result crop fields had taken the major areas even in hilly areas in the study watershed. Due to poor and inefficient utilization of RWM practices in the area, the expanded farmlands were highly prone to sheet and rill erosion as well as for the formation of big and active gullies in the study watershed. The change detection result also revealed that there was reduction of grazing land in the study watershed within the periods considered. The shortage of grazing land for livestock was the main cause for increased crop residue removal for livestock feed purpose from crop fields which in turn resulted in soil fertility problems (as discussed under topic 4.1.4.2) in the study watershed. Stream course deforestation for grazing purposes and other associated problems such as drying of streams and land sliding caused by livestock trampling were also consequences of grazing land reduction considered over the periods in the study watershed. Generally, variations in soil properties (discussed under section 4.3), livestock, agricultural

and water productivities in the watershed under study were attributed to the observed differences in the LULC.

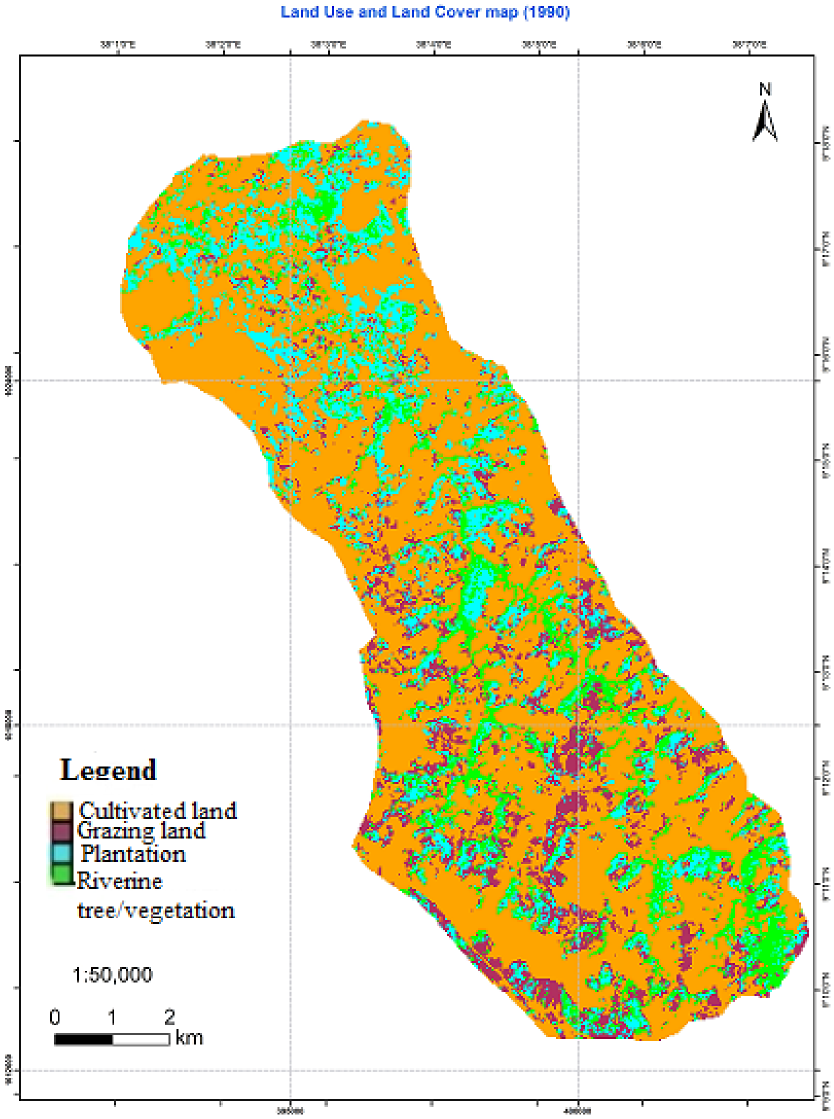


Figure 21: Map of LULC of the study watershed derived from landsat image of 1990

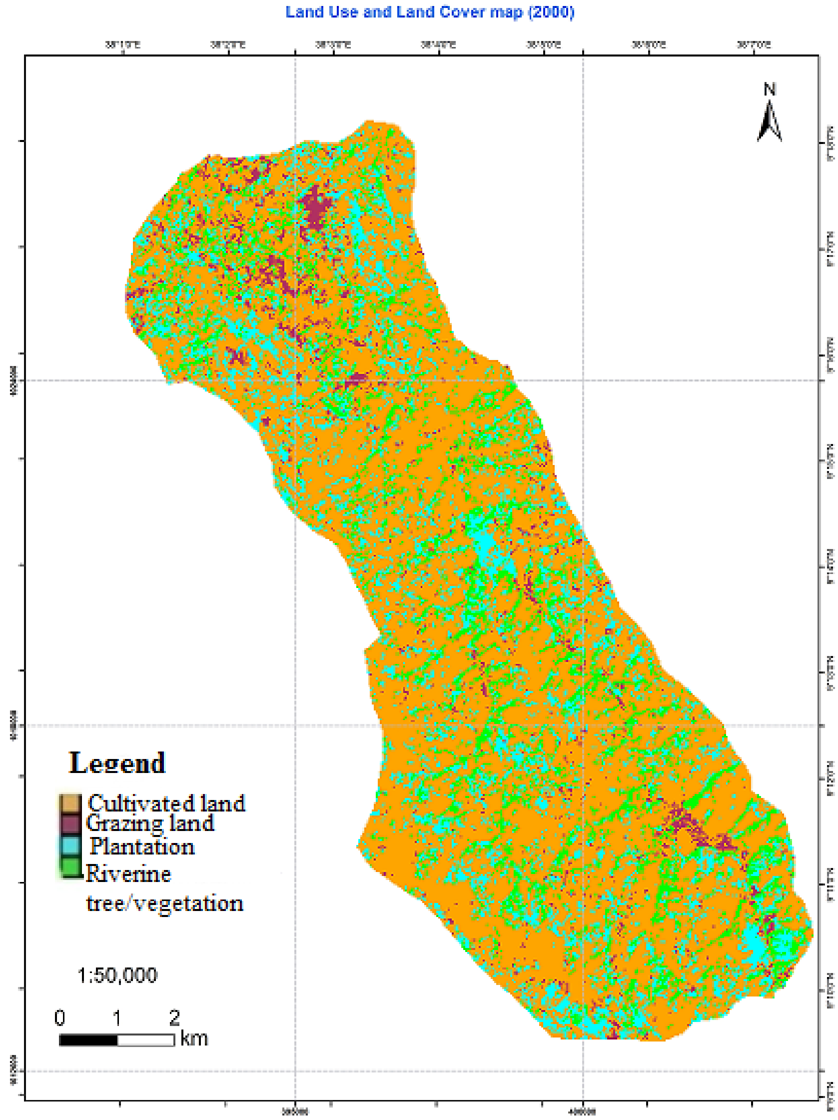


Figure 22: Map of LULC of the study watershed derived from landsat image of 2000

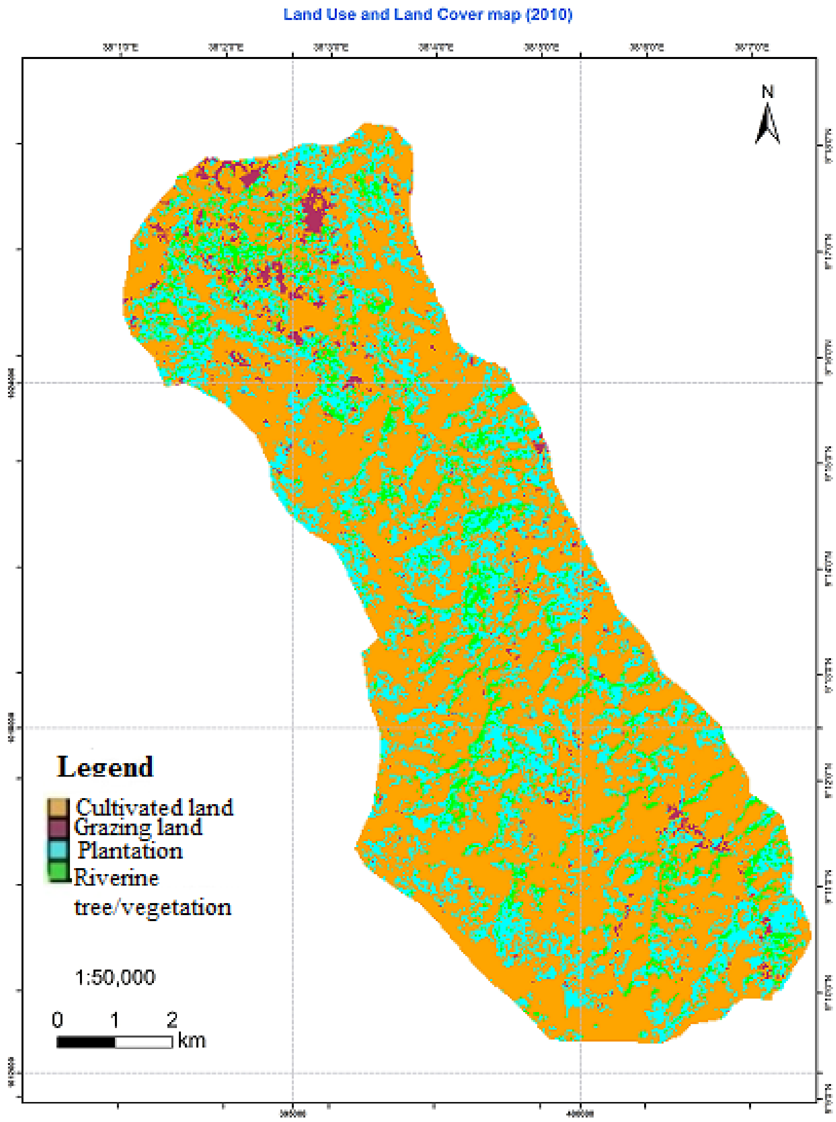


Figure 23: Map of LULC of the study watershed derived from landsat image of 2010

4.3 Results of Soil Laboratory Analysis

4.3.1 Soil texture

The result of soil texture (%) analysis of the soil samples taken from land use types indicated that the soil texture was significantly affected ($P<0.001$) by land use types (appendix 1a). A perusal of data presented in figure 24A showed that the proportion of sand fraction was low in soil samples taken from all land use types. The lowest sand fraction was recorded for

cultivated land (9.05%) while the highest was recorded for the forest/plantation land (18%). The proportion of silt fraction was intermediate between that of sand and clay proportion for the soils taken from cultivated and grazing lands with an average value of 33.45% and 34 %, respectively. However, the silt content was the highest in the soil of forest/plantation land (42%). On the other hand, proportion of clay fraction was the highest in soil obtained from cultivated land with an average value 54.75% followed by soil taken from grazing land (50%);while it was low (40%) in forest/plantation lands (Figure 24A). According to soil textural classification by Nyle (1990), the textural classes of cultivated land and grazing land were clay while that of forest/plantation soil was silty clay loam.

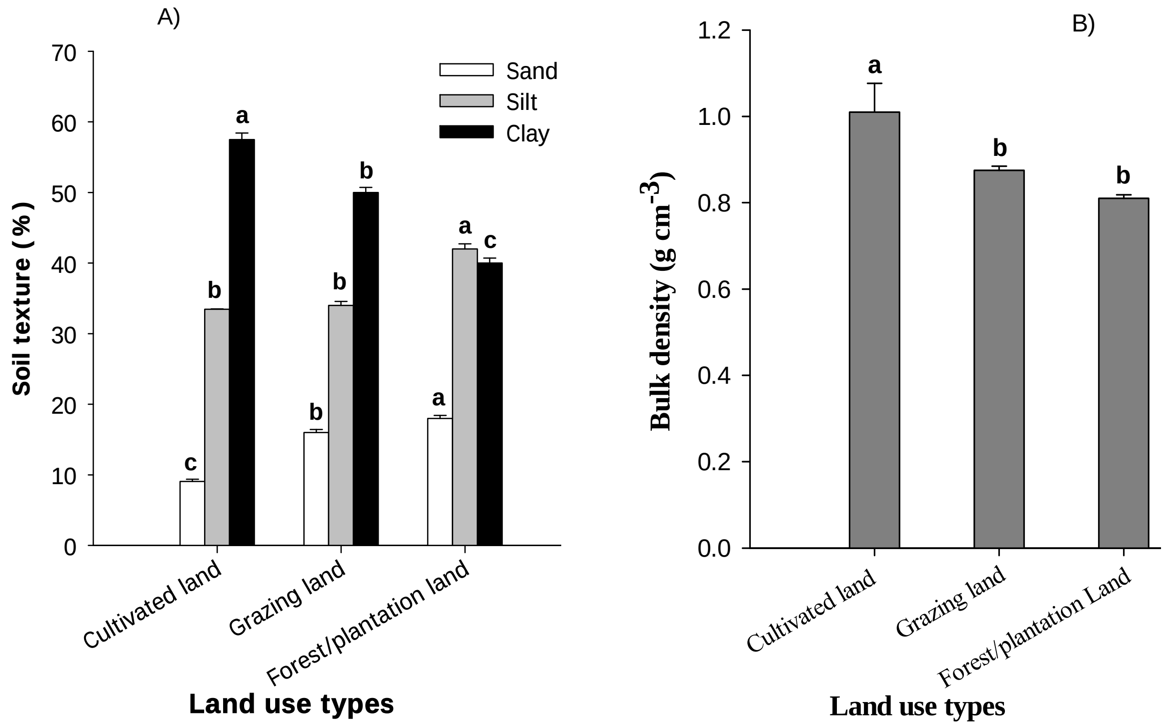


Figure 24: Soil texture (A) and bulk density (B) as affected by land use types *(Similar colored bars followed by the same letter are not significantly different at α= 0.05 probability level)*

The results indicated that there was significant difference in sand content between land use types. Sand content was significantly the highest for soil taken from forest/plantation land and was the lowest for soil taken from cultivated land. Likewise, the silt content was significantly higher for soil taken from forest/plantation land compared to that of cultivated

and grazing lands. However, there was no significant difference between the cultivated and grazing lands in terms of silt content. On the other hand, the clay content of soil obtained from forest/plantation land was significantly the lowest while it was significantly the highest for cultivated land. The present finding was in agreement with report of Hassan and Majumder (1990) who also found that cultivated soils were considerably lower in silt content and slightly lower in clay content than the adjacent soils under natural forest. The lower silt content of soil taken from cultivated land was most likely as a result of preferential removal of silt by accelerated water erosion during the monsoon months.

4.3.2 Bulk density

Bulk density (BD; g/cm^3) was significantly affected ($P<0.001$) by land use types (appendix 1a). The soil samples taken from cultivated land showed significantly higher bulk density ($1.01 g/cm^3$) as compared to the soil samples collected from both grazing and forest/plantation lands (Figure 24B). However, there was no significant difference in BD between soils drawn from grazing land and forest/plantation land. Likewise, Igwe (2001) reported that soils of the arable land have the highest mean value of BD ($1.83\ Mg\ m^{-3}$) and soils of native forest land showed the lowest mean value of BD ($1.58\ Mg\ m^{-3}$).

The compaction of the top soil of the cultivated land by livestock during grazing after harvest and during fallow period and intensive agricultural practices for croplands might be the reasons for the higher mean value of soil BD in the case of cultivated land. This was in line with the result obtained from the study in Iran (Lal, 1986). According to Lal (1986) the BD values of soils from pasture and crop land, at two sampling depths (at the 0-10 cm and 0-20 cm), were significantly different from forest land, the value being higher for crop and pasture land. Such differences might be ascribed to the compaction of topsoil due to overgrazing in the case of pasture land and use of heavy machinery or intensive agricultural practices in the case of croplands (Lal, 1986). The lowest BD in the current investigation in forest/plantation land was most probably ascribed to its higher soil organic matter content than the other land use types (Figure 26A) since organic matter and bulk density are negatively correlated. Likewise, Aweto and Dikinya (2003) reported that the lower bulk density under the canopy of trees in forest land was presumably due to the effect of litter addition to soil under the

canopies, which has resulted in organic matter build-up in soil under the canopies relative to levels in the soil outside the canopies.

4.3.3 Soil PH

Analysis of variance (ANOVA) revealed that there was significant soil pH effect ($p<0.001$) among the land use types (appendix 1a). The pH value of soil taken from forest/plantation land was the highest (6.23) and that of the cultivated land was the lowest (5.07) (Figure 25A). Soil taken from forest/plantation land showed significantly higher pH value than soil from other land use types (Figure 25A). Similar soil pH trend was reported by Gebeyaw (2007) for the different land use types under study in Maybar areas of south Wello zone of Ethiopia. According to him, the highest (6.82) and the lowest (5.83) soil pH values were recorded for forest and the cultivated lands, respectively.

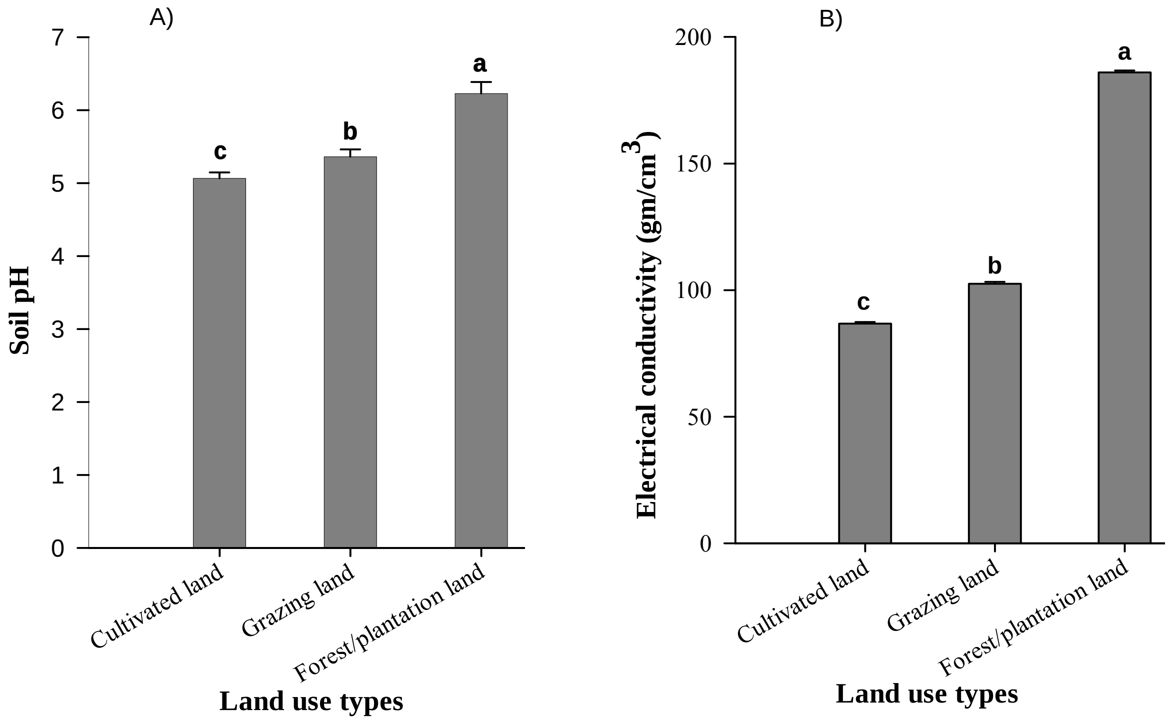


Figure 25: Soil pH (A) and electrical conductivity (B) as affected by land use types *(Bars followed by the different letter are significantly different at α= 0.05 probability level)*

The lowest pH value of the cultivated land in the present investigation might be due to the plant uptake of basic cations and its removal with crop harvest, intensive cultivation that

enhanced leaching of basic cations and drainage to streams in runoff generated from accelerated erosions. It may also be due to organic matter decomposition that leads to organic acids production, which ultimately acidifies the soil. Another reason for the lowering of the pH value of this soil might be the reduction of soil OM which lowered the buffering capacity of soil acidity. Likewise, Tesema (2008) stated that the low pH in cultivated field was probably due to continuous removal of basic cations by crops, intensive cultivation and washing away of exchangeable bases by rill and sheet erosion. The relatively higher pH value in forest/plantation soil was attributed to the presence of relatively higher total exchangeable bases and higher CEC (Figure 27B) than in the cultivated land and also due to the highest soil OM content (Figure 26A). Generally, the soils of cultivated land and grazing land were strongly acidic whereas that of forest/plantation land were slightly acidic according to the standard rating of SSSA (1997).

4.3.4 Soil electrical conductivity

Results showed that the electrical conductivity (EC, $\mu s.cm^{-1}$) of the soils was significantly influenced by land use types ($p<0.001$) (appendix 1a). Mean EC values of 86.75, 102.5 and 186 were recorded for cultivated land, grazing land and forest/plantation land, respectively (Figure 25B). Forest/plantation land showed significantly higher EC value as compared to both grazing and cultivated land use types whereas grazing land in turn showed significantly higher EC value than cultivated land (Figure 25B). The lowest EC value for cultivated land might be associated with the loss of base forming cations (Ca^{++} and Mg^{++}) following deforestation and intensive cultivation. According to Doerge (1999), the significant difference in EC of the soil taken from different land uses types have been attributed to different water contents, salinity levels, temperatures and cation exchange capacities of the soil.

4.3.5 Soil organic matter

Organic matter (OM) (%) content was significantly ($P<0.001$) affected by land use types (appendix 1a). The mean value of soil OM content was highest (7.76%) for soil drawn from the forest/plantation land and lowest (4.23%) for soil taken from the cultivated land (Figure 26A). The result indicated that there was significant difference in soil OM content between

the cultivated land and the grazing land as well as between the cultivated land and forest/plantation land. However, there was no significant difference between the grazing and forest/plantation lands (Figure 26A). According to Tan (1996) rating of organic matter, the soil OM content of both grazing land and forest/plantation land of the present study was very high while that of cultivated land was medium.

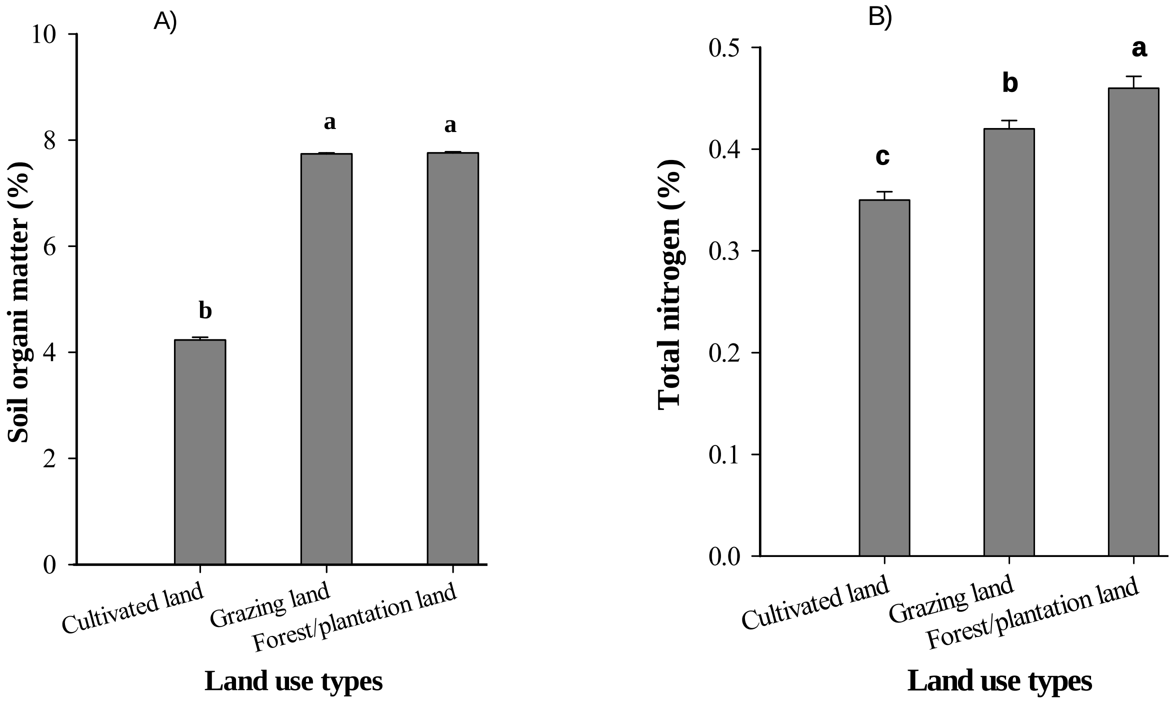


Figure 26: Soil organic matter (A) and total nitrogen (B) as affected by land use types *(Bars followed by the different letter are significantly different at α= 0.05 probability level)*

The lowest mean value of OM in the present finding for the cultivated land might be due to continuous withdrawal of nutrients from the soil as a result of recurrent crop production activities, inadequate fertilization especially lack of manuring of a distant cultivated lands, removal of soil nutrients by erosion process, removal and burning of crop residues. This present finding was in agreement with the report of Roose and Barthes (2001). They stated that periodic tillage operation with insufficient soil and water management in the cultivation land may be responsible for the significant low soil organic content. The report of Lewandowski cited in Solomon (2008) had also justified the results of the present study. In

his study, he reported that continuous cultivation becomes the major causes of most OM losses. The present study could also be confirmed by the report of Brown and Lugo (1990), Spaccini *et al*. (2001) and Wu and Tiessen (2002). In their investigation, there was a comparable loss of soil OC and TN due to cultivation of forest or pasture. Soil OM over the 0-20 cm depth of the cultivated soils was lower than corresponding values for the forest and pasture soils by 49.5% and 47.9%, respectively. Similarly, after 18 years of cultivation, TN decreased by 51% and 47.7%, respectively compared to the forest and pasture soils. The lower carbon content in cultivated soils could also be attributed to lower residue return to the soil, as a significant portion of dry matter production was removed in harvested material (Golchin et al., 1995).Likewise, Mulugeta (2004) reported that the decline in SOC and total N, although commonly expected following deforestation and conversion to farm fields, might have been exacerbated by the insufficient inputs of organic substrate from the farming system due to residue removal and burning on the farm fields**.** On the other hand, the greater OM in the forest/plantation soils was due to higher production, accumulation and decomposition of litters and low physical soil loss (Islam et al., 1999 and Descheemaeker et al., 2006).Similarly, forest/plantation soil had the highest soil OM because the soil was not tilled or exposed to erosion.

4.3.6 Total nitrogen

The ANOVA revealed the presence of significant effect ($P<0.001$) in the mean values of total nitrogen (TN) (%) of soils taken from the land use types (appendix 1a). The mean value of TN was 0.46%, 0.42%.and 0.35% for soils taken from forest/plantation land, grazing land and cultivated land, respectively (Figure 26B). Following the standard rating of TN of more than 0.4% as very high, 0.3 to 0.4% high, 0.3 to 0.2% medium, 0.2 to 0.1% low and less than 0.1% as very low N status as indicated by Barber (1984), the surface soils taken from the forest/plantation and the grazing land in the present study qualified for very high and that of the cultivated land qualified for high status of N. Soil taken from forest/plantation land showed significantly higher TN value than soil from other land use types (Figure 26B).

The lowering of TN in the current investigation for cultivated land might be explained by the fact that it was highly associated with the reduction in soil OM. This could be supported by

the findings of Yeshitela and Bekele (2002), who reported that the TN content of the soil in different communities vary with the amount of organic matter; it was higher in those soils with higher organic matter content and lower in those having lower organic matter content. Moreover, continuous cropping (or the removal of large quantities of nutrients from the soil) without applying additional organic matter such as manure and inorganic fertilizer, residue removal, and accelerated erosion might be the cause of soil TN content to decline. This could also in lined with the report of Mullar-Harvey et al. (1985) and Girma (1998).In their report, the lower levels of organic carbon and TN in cultivated soils may have resulted from a combination of lower C inputs because of less biomass C return on harvested land and greater C losses because of aggregate disruption, increased aeration by tillage, crop residue burning, accelerated water erosion and livestock grazing. The report of Mulugeta (2004) cited in Gebeyaw (2007) also revealed that the levels of soil OC and TN in the surface soil (0-10 cm) were significantly lower, and declined increasingly with cultivation time in the farm fields, compared to the soil under the natural forest. Su *et al*. (2004) found that even short-term cultivation had a significant influence on soil C, N and soil biological properties, with lower basal soil respiration and enzyme activities than the native grasslands soils.

4.3.7 Available phosphorus

The result of available phosphorus (AvP; ppm) of soils was significantly affected ($p<0.001$) by land use types (appendix 1a). The highest (5.81 ppm) and the lowest (2 ppm) AvP content of soil was observed in the soil taken from the forest/plantation and the grazing lands, respectively (Figure 27A). According to Tisdale *et al.* (1997) rating of AvP level of soil less than 3.00 ppm as very low, 4.00 to 8.00 ppm as low, 8.00-11.00 ppm as medium and >12.00 ppm as rich, the AvP of the soils of the land use types in the present study watershed was belonging to medium, low and very low range for forest/plantation land, cultivated land and grazing land, respectively. Soil taken from grazing land showed significantly lower AvP value than soil from other land use types (Figure 27A).

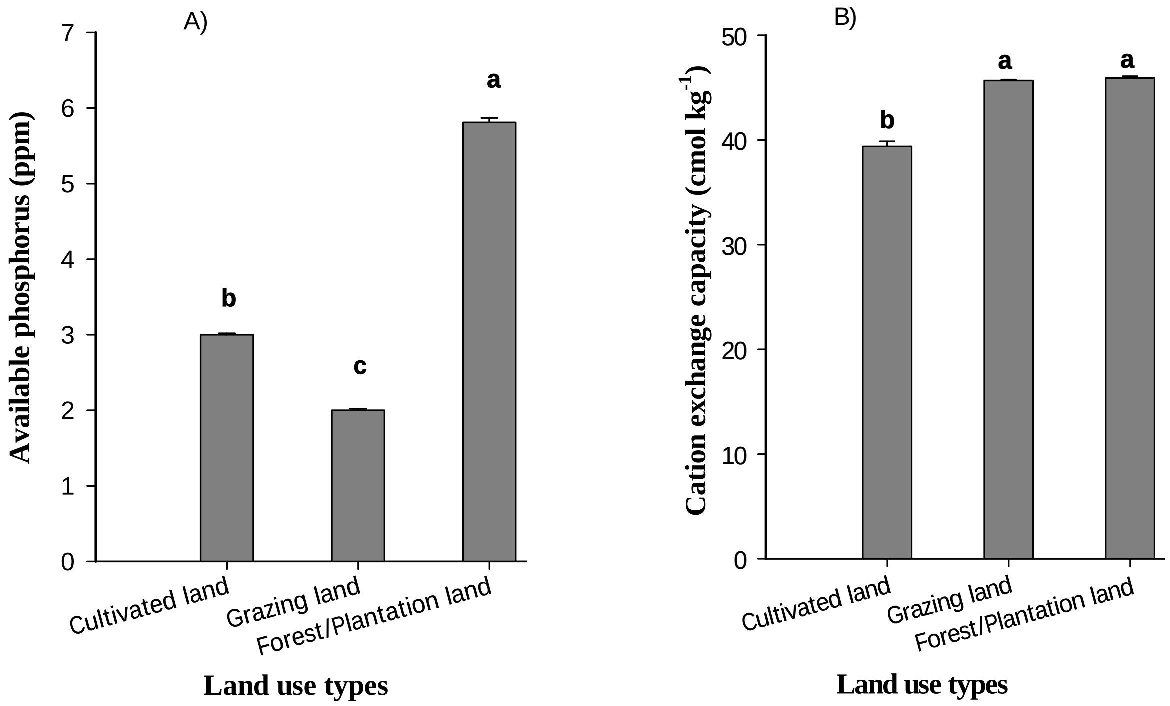


Figure 27: Available phosphorus (A) and cation exchange capacity (B) as affected by land use types *(Bars followed by the different letter are significantly different at α= 0.05 probability level)*

The relatively lower content of AvP in the soils taken from cultivated and grazing lands as compared to that of soils from forest/plantation land was probably due to up taken of AvP by crop harvest (for cultivated land) and losses by soil erosions. This present finding was in agreement with the results reported by Murphy (1968) and Eylachew (1987). They reported that the AvP under most soils of Ethiopia decline by the impacts of fixation, abundant crop harvest and erosion. Likewise, Mekuria (2005) reported that the conversion of natural vegetation to cropland is important cause of the lowering of available phosphorous. The significantly higher amount of AvP in the soil drawn from cultivated land as compared to that of soil from the grazing land was most probably due to the application of diammonium phosphate (DAP) fertilizer and manure to the cultivated land by farmers. Likewise, Gebeyaw (2007) reported that even though the OM content of the cultivated land was lowest compared to other land use types, its highest available P could be due to the application of diammonium phosphate (DAP) fertilizer on the cultivated land. The higher concentration of AvP under the

forest/plantation land as compared to the other land use types was probably attributed to accumulation of litter fall to forest soil. Similarly, Silver (1994) found a high correlation between litter fall and soil phosphorous.

4.3.8 Cation exchange capacity

Cation exchange capacity (CEC; cmol kg^{-1}) of soils was significantly affected ($p< 0.001$) by land use types (appendix 1a). The mean CEC values of the soils in the study watershed stand at 39.4, 45.7 and 45.9 for soil taken from cultivated land, grazing land and forest/plantation land, respectively (Figure 27B). The result also showed that there was higher significance difference (Figure 27B) in CEC of soil taken from forest/plantation and grazing land as compared to the soil taken from cultivated land. Likewise, Woldeamlak and Stroosnijder (2003) cited in Gebeyaw (2007), reported that CEC value was highest in soils under forest land and lowest under cultivated land.

The lowest mean CEC observed in the cultivated lands might be due to loss of basic cations (Mg and Ca) by crop harvest and soil erosion. This result was also in line with the finding of Tesfaye (2009) who reported the same reason. The relatively higher mean value of CEC according to the present study in soils taken from grazing land and forest/plantation land was probably due to their higher organic matter content than that of soil from cultivated land. It is a general truth that both clay and colloidal OM have the ability to absorb and hold positively charged ions. Thus, soils containing high clay and organic matter contents have high cation exchange capacity. So, the existence of higher OM under forest/plantation and grazing lands and their insignificance difference in their soil OM content made them relatively with higher CEC content in the present study. This was in agreement with the report of Unger (1997).According to him, the soils under various types of agricultural land uses contained less organic matter content, total nitrogen, exchangeable bases and cation exchange capacity (CEC) than similar soils under natural vegetation. Gardiner and Miller (2004) also indicated a decrease in soil OM substantially lowers the amount of CEC to the soil. Even if the mean CEC value of cultivated land in the present study was lower than that of grazing and forest/plantation lands due to its lower OM content, the figure (CEC value) was not as such bad because of its relatively higher percentage of clay content than the other land use types

(Figure 24A). A decrease in soil pH (Figure 25A) might be also the cause for the lowering of CEC of the soil under cultivated land. The same finding was reported by Gardiner and Miller (2004).

4.3.9. Basic exchangeable cations

4.3.9.1 Exchangeable potassium and sodium

Exchangeable potassium (K^+; cmol kg^{-1}) content in soils of study watershed was significantly affected ($P<0.001$) by land use types (appendix 1a). It had its minimum mean value in grazing land (0.31) and its maximum mean value in the forest/plantation land (1.51) (Figure 28A). The result of analysis also revealed that exchangeable K^+ of soil taken from forest/plantation was significantly greater than both of the cultivated and grazing land use types (Figure 28A).

The relatively lower exchangeable K^+ contents in the present investigation in soils taken from the cultivated and the grazing lands than in the soil taken from forest/ plantation land might be due to its continuous losses in the harvested and grazed parts of the plants from the cultivated and grazing lands, respectively. The application of acid forming fertilizers to the cultivated land might be also another major factor for reduction of exchangeable K^+ in the cultivated soil. This present finding was in agreement with the report of Baker *et al*. (1997) and Wakene (2001).According to them, the application of acid forming fertilizers was a major factor affecting the distribution of K^+ in soil systems mainly by enhancing its depletion especially in tropical soils. On the other hand, the relatively higher exchangeable K^+ content in soil taken from cultivated land when compared to that of soil taken from grazing land might be due to continuous cultivation which exposed the soil K content to further weathering. Likewise, Chadwick et al. (1999) reported that the effect of weathering over time, as favoured by frequent tillage, which exposes the fixed K of soil to further weathering made exchangeable K^+ remarkably higher in farm lands than other land use types. The highest exchangeable K^+ content in the soil drawn from forest/ plantation land might be related to its high pH value (Figure 25A) and this finding was also in agreement with study results reported by Mesfin (1996) that he reported high K was recorded under high pH tropical soils.

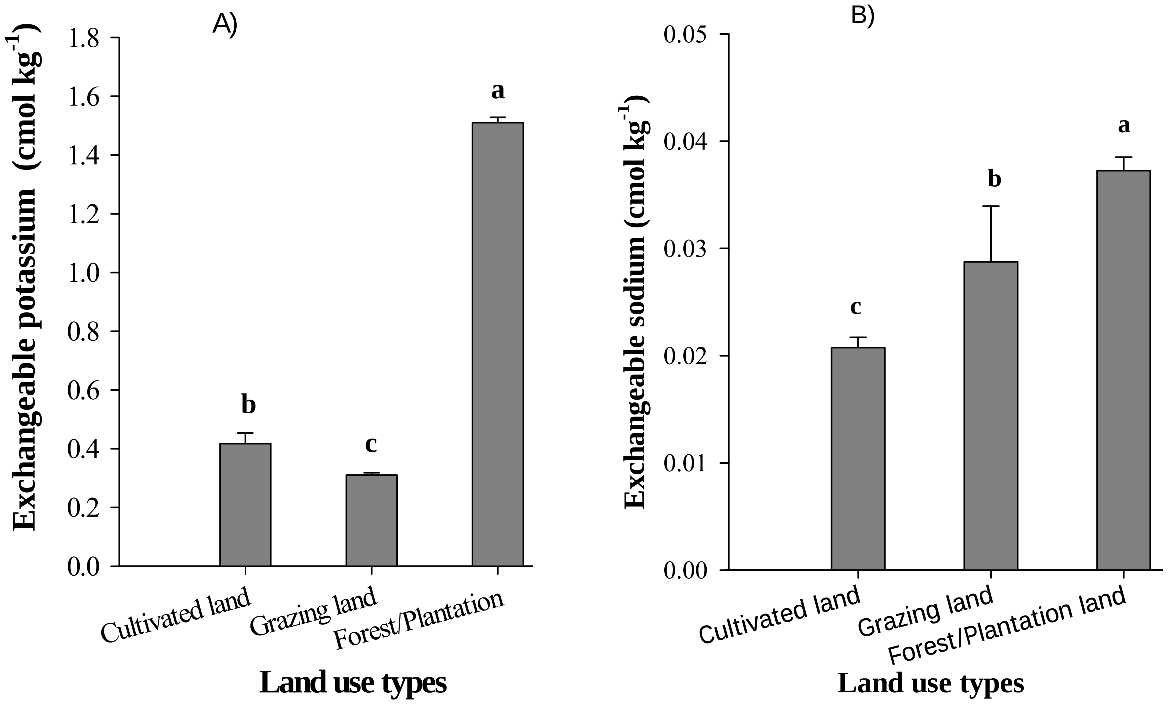


Figure 28: Soil exchangeable Potassium (A) and exchangeable Sodium (B) as affected by land use types *(Bars followed by the different letter are significantly different at α= 0.05 probability level)*

Similarly, the content of exchangeable sodium (Na^+; cmol kg^{-1}) was significantly affected by land use types ($P< 0.01$) (appendix 1a). The mean exchangeable sodium value was highest (0.037) under the forest/plantation land and lowest (0.021) on the cultivated land (Figure 28B). Soil taken from forest/plantation land showed significantly higher in exchangeable sodium value than soil from other land use types (Figure 28B). Even though, the land use types were significantly affected by exchangeable sodium, this value of exchangeable sodium is not expected to have any significant effect on soil degradation (i.e. on clay dispersion and reduction of aggregate stability) under the current climatic conditions (1800 – 2200 mm mean annual rainfall) of the watershed under study. As Lavee et al. (1991) and Imeson (1995) pointed out, below a rainfall of about 300 mm/year, soil degradation is related more to the dynamics of sodium than to organic matter content, while organic matter dynamics dominate over sodium effects where annual rainfall exceeds about 600 mm, which is the case of the watershed of the present study.

4.3.9.2 Exchangeable calcium and magnesium

The content of exchangeable calcium (Ca^{++}; cmol kg^{-1}) was significantly ($P<0.001$) affected by land use types (appendix 1a). The highest (28.02) and the lowest (18.01) exchangeable Ca^{++} contents were observed in the soils taken from forest/plantation and the cultivated lands, respectively (Figure 29A). The result also indicated that the forest/plantation land was significantly higher in exchangeable Ca^{++} content than the other land use types (Figure 29A).Likewise; Gebeyaw (2007) reported similar status of exchangeable Ca^{++} reduction in the land use conversion in to cultivated land. The lowering of exchangeable Ca^{++} in the present finding in the cultivated land might be attributed to the reduction of soil pH and excessive leaching because of continuous cultivation. This was in agreement with the findings of Dudal and Decaers (1993) who stated that soils under continuous cultivation, application of acid forming inorganic fertilizers, high exchangeable and extractable Al and low pH are characterized by low contents of Ca and Mg mineral nutrients resulting in Ca and Mg deficiency due to excessive leaching. Similarly, Saikhe *et al*. (1998) stated that continuous cultivation and use of acid forming inorganic fertilizers deplete exchangeable Ca and Mg.

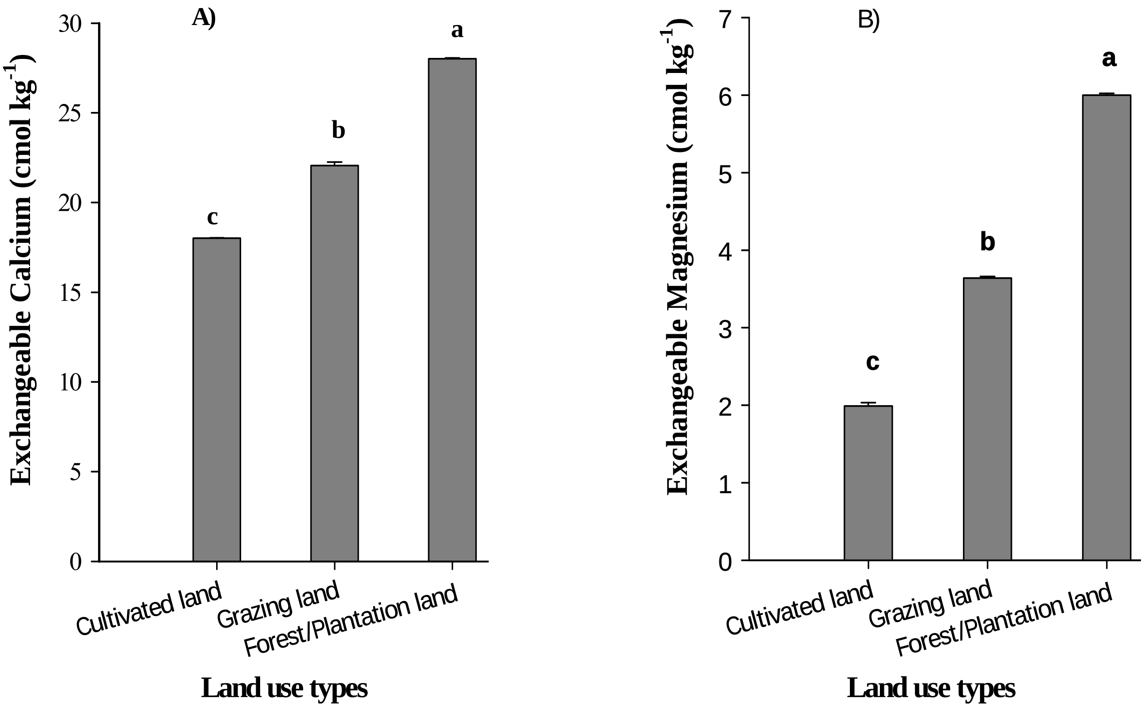


Figure 29: Soil exchangeable Calcium (A) and exchangeable Magnesium (B) as affected by land use types *(Bars followed by the different letter are significantly different at α= 0.05 probability level)*

Exchangeable magnesium (Mg^{++}; cmol kg^{-1}) content was also significantly ($P<0.001$) affected by land use types (appendix 1a). The mean exchangeable magnesium Mg^{++} value was highest (6) in the soil drawn from the forest/plantation land and lowest (1.99) in the soil taken from the cultivated land (Figure 29B).The result also indicated that the forest/plantation land was significantly different having higher exchangeable magnesium Mg^{++} content than the other land use types (Figure 29B).The cause of its decline in cultivated land was the same as that of exchangeable calcium. The lowest value obtained on the cultivated land could be also be related to influence of intensity of cultivation and abundant crop harvest with little or no use of input as reported by Singh *et al*.(1995) and He *et al*. (1999).

4.3.10 Soil degradation index

The degradation indices (DI) (%) computed in the present study for selected soil properties under different land use types were summarized in Table13 below.

Table 13: Selective soil properties degradation indices (DI) (%)

Soil Property	Mean values of soil attributes for the land use types			Degradation Indices (%)	
	Forest/plantation land	Grazing land	Cultivated land	Grazing land	Cultivated land
BD	0.81	0.88	1.01	8.64*	24.69*
pH	6.22	5.36	5.07	-13.83	-18.49
SOM	7.76	7.74	4.23	-0.26	-45.49
TN	0.46	0.42	0.35	-8.70	-23.91
AvP	5	2	3	-60	-40
CEC	45.92	45.68	39.38	-0.52	-14.24
Cumulative soil degradation indices				-91.95	-166.82

* *The value is taken as negative*

In the computation of degradation index (Table 13), the negative value indicated deterioration of soils in terms of the typical soil property considered. The results of computation of degradation index indicated that soil under both the cultivated and grazing lands showed deterioration in all the soil parameters studied. Except the deterioration of AvP, which was severely deteriorated in grazing land (-60%), the other parameters considered were deteriorated more in the soil under the cultivated land than the grazing land. It can be observed that soil OM, AvP, BD and TN were the four top most deteriorated soil parameters with values of -45.49%, -40% , -24.69% and -23.91%, respectively for cultivated land. However, soil CEC was the least deteriorated soil parameter for this study with values of -14.24% for cultivated land. Likewise, AvP and soil OM were the highest and the least deteriorated soil parameters with -60% and -0.26% values respectively for grazing land.

Generally, soil under the grazing land cumulatively deteriorated by -95% whereas it was deteriorated by-166.82% for cultivated land. The major reasons for the deterioration of soil attributes under the cultivated land were due to the subsequent removal of nutrients through continuous cropping and residue harvest, low levels of fertilizer application and poor and less soil and rainwater management practices. Furthermore, compaction effect on the soils due to livestock grazing has a role to play in physical soil degradation of the cultivated land and grazing land reducing the productivity of the soil. Likewise, Mulugeta (2004) stated that continuous deterioration of the physical soil attributes could affect the productivity of the soils by altering the hydrological regimes (e.g. infiltration and water-holding capacity), crop rooting depth and soil susceptibility to erosion in the long-term. Hence, unless proper RWM practices are adopted, the deterioration of soil in the study watershed will continue.

4.4 Challenges and Opportunities for Sustainable RWM in the Study Watershed

One of the challenging problem concerning the sustainability of RWM in the study watershed was the expansion of population (average family size per household was 6.2 as described under section 4.1) and the consequent shortage of farm land (described under section 4.1.9.1) in the study watershed. In the watershed under study there was no free farm land to accommodate the increasing population size; as a result farmers were cultivating on very steep slope land (86.3% of respondents reported that they were cultivating on steep slope land) which was not recommended (see section 4.1.5).Such kind of practices resulted in soil degradation problems ranging from sheet and rill erosion up to big and active gullies formation in the study watershed (Figure 17).These were the main reasons for low agricultural production and productivity, low livestock production and access to insufficient amount of water in their village particularly for non-beneficiary farmers (described under section 4.1.10).

Generally, problems associated with shortage of farm land were persisted for long periods of time not for less than 30 years as revealed by LULC change detection of the study watershed (see section 4.2.1).

Less expansion of alternative livelihoods in the study watershed was also another problem. To reduce burden on farm land that could be created by increased population growth and reduce rainwater erosion problems that could be happened, there had to be the existence of alternative livelihoods in the study watershed. Only 16.9 % of the households in the study watershed were engaged in certain non-farm activities (described under section 4.1.9.2) and out of which few of them (7.3%) reported that the income drawn from such ventures was not sufficient to support households (Table 10).

Less community initiatives and participation for sustainable RWM practices through integrated watershed management approach was also among other challenging problems in the watershed. It was possible to observe that except community participation in the lower part of the watershed in constructing and using local check dams on few streams and rivers (described under section 4.1.3.2), there were no other means of RWM practices adopted by community participation in this lower part of watershed. Similarly, apart from very few ponds and earthen bunds constructed by community participation during Derge regime in the upper part of the watershed, there were no other RWM practices presently adopted in the study watershed (4.1.3.1). Lastly, the inefficient existing irrigation system was another problem which needs introduction of best development interventions for improving the livelihood of the farmers in the watershed.

Among other things the existence of bimodal pattern and high rainfall potential (1800-2200 mm mean annual rainfall according to District's Agriculture and rural development office annual Report of 2009, unpublished) in the study watershed created the best condition for rainwater to be managed. Relatively high clay content, which has high water holding capacity, in the soil of expanded land use types (i.e. farm land, described under section 4.3.1) was also another opportunity for sustainable RWM for water storage purpose in water storing structures like ponds in the study watershed. Community cooperation on using stream and river water for small scale irrigation system especially in the lower part of the watershed was also among other opportunity to be encouraged for sustainable RWM in the study watershed. Generally, the watershed under study is suitable for production of potato, maize and vegetables twice a year through both rain fed and irrigation system.

5. CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Inefficient applications of rainwater management in terms of both in *in-situ* rainwater conservation methods and via RWM for storing water for later use in water storage structures such as ponds are the main causes for water scarcity and water productivity problems in the watershed under study. Most respondents (66%) are poorly implementing and protecting the RWM interventions. Although few RWM interventions such as check dams (43.5%, for diverting streams or rivers) and ponds (3.2%) were implemented privately and in groups with high effort, valuable agricultural products were obtained through them and enabled the owners of the interventions to sustain food at their household levels. However, still the insufficient amount of water in water sources (structures) and in diverted irrigation line are the main problems in effort of intensifying agricultural production via small scale irrigation systems in the watershed.

The food security situation for the study watershed is relatively better for RWM beneficiaries' households as compared to non beneficiaries'. Similarly, the more the households engaged in non-farm activities as alternative livelihoods, the more they diversified their source of income (9.6% out of 16.9% of total HHs engaged in non-farm activities) to sustain food security situation at their household level. Furthermore, engaging in non-farm activities as alternative livelihoods will reduce burden on farm land and as a result reduce rainwater related problems that could be happened. On the other hand, land shortage (as a result of high population growth) for further production is the main problem for not to produce more, and then for the increment of food insecurity situation in the study watershed.

Land conversion even steep slopes in to cultivated land and the expansion of the same land is a long time problem in the study watershed. The expansion, continuous and intensive cultivation of soils of cultivated land at the expense of forest and grazing lands was the main cause for the accelerated soil erosion, sedimentation, soil fertility loss and a resultant reduction in crop and livestock production in the watershed under study. The attributes of the soils under the cultivated lands showed overall change towards the direction of loss of their fertility compared to the soil attributes of the adjacent forest/vegetation and grazing land

soils. Hence, major declines were observed for soil sand and silt content, pH, electrical conductivity (EC), organic matter (OM), total nitrogen (TN), cation exchange capacity (CEC), exchangeable Na, exchangeable Ca, and exchangeable Mg in cultivated land. The average values of other selected soil physico-chemical properties under the cultivated, grazing and forest/plantation lands showed changes in bulk density (1.01,0.87,and 0.81g/cm), clay (57,50 and 40 %), AvP (3, 2 and 5.81 ppm) and exchangeable K (29.98, 25.7 and 60.73 ppm) respectively for the watershed. These variations of soil physicochemical properties between land use types indicate the risk to the sustainable crop production in the area.

Therefore, strategies to secure food among the expanding population in the study areas will have to seek a sustainable solution that better addresses integrated rainwater and soil managements.

5.2 Recommendations

- Sustainable RWM for storing water for later use structures such as ponds, check dams, etc. are needed to be more implemented and the other existing RWM interventions are suggested to be improved.
- Improving food security of households in the watershed calls for development interventions; especially in the area of introducing best rainwater management schemes in diverting streams and rivers for household consumption, sanitation, livestock watering and irrigation is needed in the study watershed.
- There is also a need to grow more indigenous trees mainly to conserve water and to reduce soil sedimentation/erosion and soil fertility loss problems. Introducing fodder tree species and shrub species are also needed to be grown to meet nutritional requirements of the grazing animals in the area.
- The farmers' practice like application of farmyard manure, compost, cow dung and other organic wastes in homestead areas should be mobilized to a distant cultivated land as well.
- Proper land use demarcation need to be implemented so as to use the land according to its natural suitability.

- People's participation in planning, developing and executing the watershed activities need to be implemented.
- There is also a need to expand and support traditional alternative livelihoods technologically in the study watershed to reduce the burden on farm land that could be created by increased population growth and then reduce rain water erosion problems that could be happened.

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APPENDICES

Appendix 1: Table of ANOVA for selected soil physical and chemical properties for land use types

Parameters	Source	df	Sum of Squares	Mean Square	F	P<
Sand	Between Groups	2	176.7416667	35.3483333	192.23	0.001
	Within Groups	9	1.1033333	0.1838889		
	Total	11	177.845			
Clay	Between Groups	2	618.8333333	123.766666	222.78	0.001
	Within Groups	9	3.3333333	0.5555556		
	Total	11	622.1666667			
Silt	Between Groups	2	184.7683333	36.9536667	240.13	0.001
	Within Groups	9	0.9233333	0.1538889		
	Total	11	185.6916667			
BD	Between Groups	2	0.08833242	0.01766648	12.11	0.001
	Within Groups	9	0.00875183	0.00145864		
	Total	11	0.09708425			
Soil PH	Between Groups	2	2.96240833	0.59248167	42.48	0.001
	Within Groups	9	0.08368333	0.01394722		
	Total	11	3.04609167			
Soil EC	Between Groups	2	22764.25	4552.85	23414.7	0.001
	Within Groups	9	1.16667	0.19444		
	Total	11	22765.41667			
Soil OM	Between Groups	2	32.99644167	6.59928833	4959.80	0.001
	Within Groups	9	0.00798333	0.00133056		
	Total	11	33.004425			
Total nitrogen	Between Groups	2	0.025	0.005	50	0.001
	Within Groups	9	0.0006	0.0001		
	Total	11	0.0256			
Available phosphorus	Between Groups	2	31.22293333	6.24458667	6535.03	0.001
	Within Groups	9	0.00573333	0.00095556		
	Total	11	31.22866667			
CEC	Between Groups	2	110.4646667	22.0929333	207.92	0.001
	Within Groups	9	0.6375333	0.1062556		
	Total	11	111.1022			
Ex. Ca^{++}	Between Groups	2	202.8849000	40.57698	2520.31	0.001
	Within Groups	9	0.0966	0.0161		
	Total	11	202.9815			
Ex. Mg^{++}	Between Groups	2	32.49973333	6.49994667	8239.37	0.001
	Within Groups	9	0.00473333	0.00078889		
	Total	11	32.50446667			

Ex. K^+	Between Groups	2	3.52784167	0.70556833	1045.29	0.001
	Within Groups	9	0.00405	0.000675		
	Total	11	3.53189167			
Ex. Na^+	Between Groups	2	0.00057492	0.00011498	11.89	0.01
	Within Groups	9	0.000058	0.00000967		
	Total	11	0.00063292			

Appendix 2: Figure of focused group discussion with male and female in the watershed under study

Appendix 3: Formula of volumetric method of flow measurement in the field developed by Majumdar (2002)

$$DR = \frac{V}{T}$$

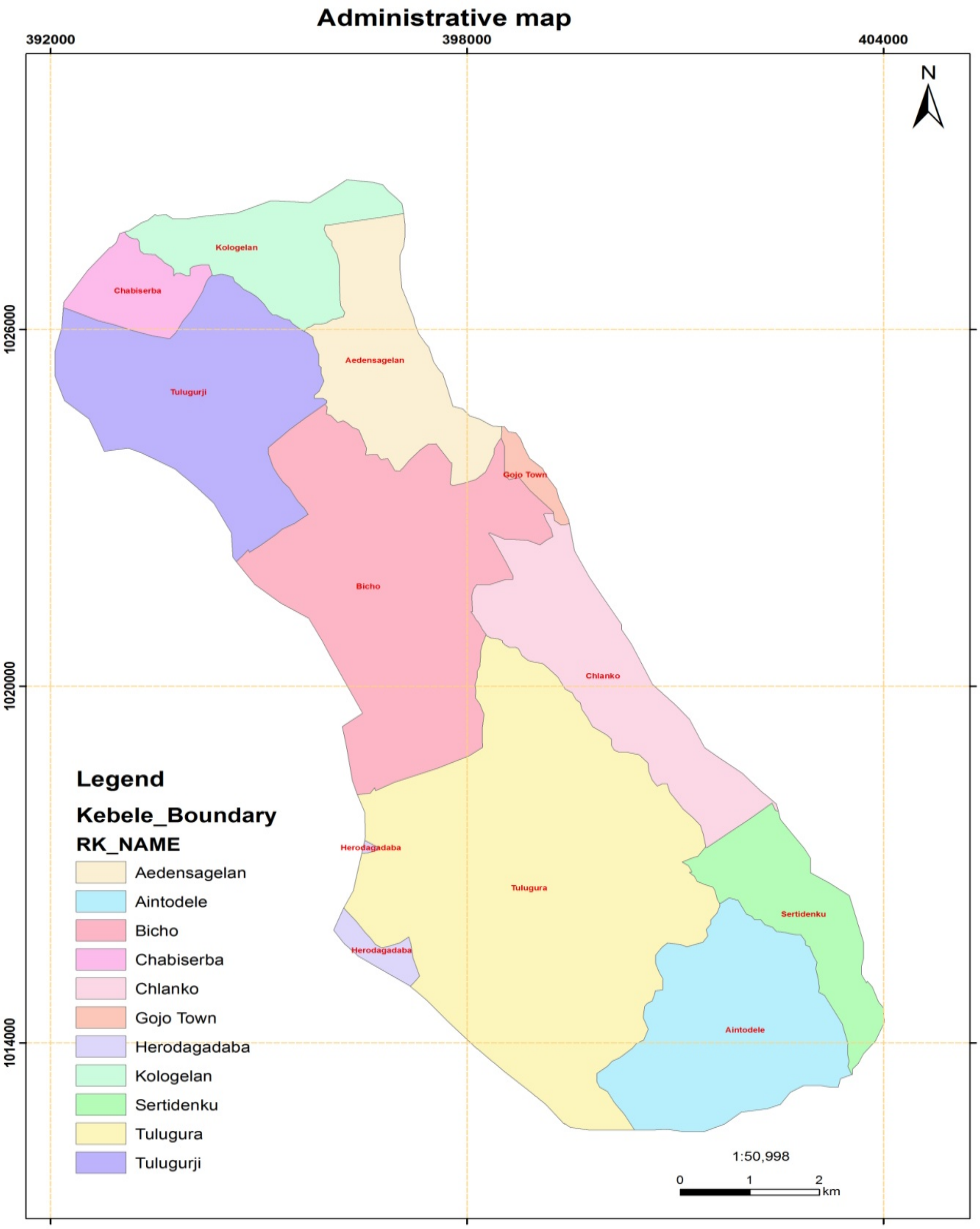
Where:

DR= Discharge rate in litre per second (l/s)

V= Volume of the container in litres

T = Average time in seconds taken to fill the container

Appendix 4: Figure of administrative Map of the watershed under study



Appendix 5: Map showing the slope (%) of the watershed under study

Appendix 6: Questionnaire-Semi-structured questions on assessments of Rain Water Management (RWM) in Andode/Meja watershed, Jeldu district.

Part one: General Information

1.1. Date of interview: _________________________ Name of interviewer: _______________

1.2. Name of head of Household: _______________________ Age: ________ Sex: _________

1.3. Respondent's Name (if different from the head): ____________________ Age: ___Sex: ___ 1.4. Survey Area: Region:_____________ Zone: _____________ Woreda: _____________ PA:_______________ Village: ______________ Altitude:______ UTM location of HH:_________

Part two: Household characteristics

For how long have you lived in this village?_________________

Marital status: a) Single b) Married C) Divorced d) Windowed

Family size________Number of adults (> 17 Yr.)_______ Children_________

4. Education a) Illiterate b) grade 1-4 c) grade 5-8 d) grade 9-12 e) above 12

5. Occupational status: a) Farm work b) Off-farm work (skilled & unskilled)

6. Total farm size: 1ha=1; 2ha=2; 3ha=3; 4ha=4 ;> 4ha=5

Part three: Household Survey Questionnaire on Assessments of Water constraints in the Study Area.

1. Is water supply available to your house? Yes=1; No=2

If yes, water availability is: Every day=1; Once three days=2; Weekly once=3

2. If No and availability is not every day for Q1, what are the reasons? The available water sources are at distant=1; The available water sources are seasonal=2; due to poor and inappropriate rain water management to empower the water sources =3; due to insufficient amount of water in water sources=4; others (specify) =5

3. For what purposes you need water? Drinking & cooking =1; Washing clothes=2; Watering livestock=3; Growing crops (irrigation) =4; Other (specify) =5

4. If yes for Q1, identify your sources of water for different purposes during dry and wet seasons, and the distance from your homestead in terms of walking time.

	Type of water use	A. Sources during wet season (Code*)	B. Walking distance one way (hour/minute = 00:00)	C. Sources during dry season (Code*)	D. Walking distance one way (hour/minute = 00:00)
2.1	Drinking & cooking				
2.2	Washing clothes				
2.3	Watering livestock				
2.4	Growing crops (irrigation)				
2.5	Other (specify) ______				
* 1. Tap water 2. Wells		3. Springs 4. Streams	5. Ponds 6. Rivers	7. Direct rain harvesting 8. Floods in gully	9. Other (specify)

3. What are the number, size and durability of water sources in your village (kebele)?

Water sources	Number	Size	Durability (Code*)
Springs			
Streams			
Ponds			
Rivers			
Lakes			
Other (specify)			
			* 1.Perennial 2.Seasonal

4. Do you think the water sources you have is sufficient to meet your needs? Yes=1; No=2

5. If No, What impacts do you think lack of access to sufficient water brought about on your household livelihood?

Livestock production decreased=1; Low agricultural productivity and production via small scale irrigation systems =2; Taking too much time and energy in fetching water=3; Induced conflict over water use =4; Affecting health of household members and food utilization =5; others (specify) =6

6. Is there any rainwater management structures (interventions) on your farm? Yes=1, =>Q7; No=2

If No why? I don't have the knowledge =1; I don't have any problem on my land= 2; Such type of works are very expensive =3; Others (specify) =4

7. What type of rainwater management structures (interventions) do you have?

	Rainwater management structures (interventions)	Yes(1)	No(2)
1			
2	Roof RWH		
3	Ponds		
4	Check dams		
5	Open wells		
6	Earthen bunds		
7	Stone bunds		
8	Gully plugging		
9	Deep tillage		
10	Deep furrows		
11	Vegetative barriers		
12	Mulching		
13	Contour farming		
14	Crop rotations		
15	Intercropping		
16	Use of FYM		
17	Use of compost		

8. By whom was it constructed? Government =1; NGO =2; Contribution from community=3; Other (specify) ____

9. When did you start to use the structure? _________________________________

10. For what purpose do you use the structures?

Crop production =1; Animal fattening=2; Drinking water =3; For supplementary irrigation=4

Others _______________________

11. Size of the structure (appx.)?____________________________

12. Have you experienced problem while you use it? Yes=1; No=2

If yes, what were the Problems ____

13. Do you have success story? Yes=1; No=2

If yes what are they? ____

If No____

14. What would you benefit in future from the interventions? __________________________

15. Is the harvested water sufficient for supplementary irrigation? Yes=1; No=2

If No why?____

16. Have you ever made maintenance work? Yes=1; No=2

If Yes how, what type and how often ______________________________________

If No why? ____

17. Any maintenance cost you incurred? ____

Part four: Household Survey Questionnaire on Assessments of Soil Degradation and Land Management

Section A: Soil Erosion/Sedimentation and Protection

We would like to know what problems you have on your farm and how you manage your farm. Please include all the land that you owe and you cultivate.

1. Is there any soil erosion or sedimentation problem in your farm? Yes =1, go to Ques. #2; No=2, go to Ques. #14

2.Farm land by croup type	3. What is the problem? Erosion=1 Sedimentation=2	4. What symptoms or indicators did you observe? *(Code a)*	5. When did you observe the problem? *(year)*	6. What do think are the causes? *(Code b)*	7. Did you take any protection measures? Yes=1, *Code c* No=2, to # 12	8. When did you start taking these measures? *(year)*	9. How did you learn these methods? *(Code d)*	10. Did you see any change or improvement after taking the measures?

Code a: Sheet erosion = 1; Sediments in ditches and furrows=2; Rills in the farm=3; Surface pans=4; Gullies in the farm=5; Others (specify) ____________________.

Code b: Improper tillage=1; Slope/terrain=2; Deforestation=3; High rainfall and Absence of its management measures=4; others (specify) =5; I don't know=6

Code c: Terraces=1; Ditches/trenches=2; Contour planting=3; Stone bunds=4; Check dams=5; soil/earthen bunds=6; Others (specify) =7

Code d: From parents (inherited) =1; From neighbors=2; From extension agents (training) =3; From NGOs=4; From school=5; Others (specify) =6

11. If No for Q10, why do you think you couldn't observe change? ____________________

12. Why didn't you take measures? ___________________.

It is costly=1; High labor & time demanding=2; I don't know how=3; Other (specify) =4

13. was there a similar problem 5 years ago? Yes =1, No =2; 10 years ago? Yes=1, No =2. 20 years ago? Yes=1, No=2; 30 years ago? Yes=1, No=2.

14. What do you think will happen to your farm in the next 5-10 years if you don't take protection measures?

I will loss portion of my land by erosion=1; Productivity will decrease as a result of top soil erosion=2; Nothing more will happen=3; I don't know=4; others (specify) =5

15. Do you discuss soil erosion problems with your neighbors, local authorities, extension agents or other community members? Yes =1, No =2.

16. Have you ever participated in any soil conservation work initiated by the above mentioned agents? Yes =1, No=2.

Section B: Soil fertility decline and Management

1. Is there any soil fertility problem in your farm? Yes =1, Ques. #2, No=2.

2. Farm land by croup type	3. When did you realize the problem? *(years)*	4. What indicators did you observe? *(Code a)*	5. What do you think the main causes *(code b)*	6. What management practices have you applied? *(Code c)*	7. How did you learn these methods? *(Code d)*	8. Did you see any improvement? Yes=1 No =2

Code a: Yield decline=1; Soil structure and color change=2; increased input demand=3; stunted crop growth =4; others (specify) =5

Code b: High rain fall followed by leaching and erosion=1; Continuous cultivation and removal of crop residues=2; Absence of the addition of manure =3; Absence or inappropriate application of inorganic fertilizer = 4; Others (specify) =5

Code c: Fallowing=1; Crop rotation=2; Intercropping=3; Manure=4; Fertilizer=5; Legume trees=6; others (specify) =7; Nothing=8

Code d: From parents (inherited) =1; From neighbors=2; From extension agents (training) =3; From NGOs=4; From school=5; Others (specify) =6

Part five: Household Survey Questionnaire on Assessments of Agricultural issues

Section A: Land holding, land use and Tenure

1. Do you posses your own farm land? Yes =1, No =2.
2. Is the land you have sufficient for the household? Yes =1, No =2.
3. When a member of the household gets married, where does she/he get her/his own land? From the household land=1; From local administration (kebele) = 2; By clearing the nearby forest=3; Others (specify) = 4
4. If No for Q1, how you get the cultivable land? Rent (contract) arrangement =1; Share cropping=2; Other (specify) =3
5. If yes for Q1, what is the size of your farm? Please list plot by plot.

Plot No.	Enumerator's identification note (crop type)	6. Plot size		7. What is the current use of the land? *(Code a)*	8. How is the fertility of the soil? *(Code b)*	9. What is the slope of the plot? *(Code c)*	10. Have you done any rain water management and soil improvement structures (interventions) on your land?
		Area	Unit*				
1							
2							
3							
4							

*Local units = Timad =1, Gasha = 2, Kert = 3, Gemed = 4, hectare = 5, Massa = 6

Code a: Cultivated crop land = 1, Grazing land = 2, Woodlot (forest) = 3, Backyard garden = 4, Unusable = 5, Fallow = 6, Others (specify) = 7

Code b: Lem=1, Lem-tef=2, tef=3

Code c: Meda=1, Dagtama=2, Gedelama=3

11. If No for Q10, what are your main reasons?________________.

I don't have any problem on my land= 1; such type of works are very expensive=2; The land may be taken away sometime in the future=3; I don't have the knowledge=4; Other (specify) =5

Section B: Crop production

1. Which type of crops did you mainly cultivate? Barely=1; Wheat=2; beans=3; Maiz=4; Sorghum=5; Teff=6; Other (specify) =7

2. What type and amount of commercial fertilizer did you apply? Urea=1; DAP=2; Both=3; Nothing=4

3. If yes for Q2, what is the estimated amount of urea or DAP do you apply? <50kg/ha=1;50-100kg/a=2; >100kg/ha=3

4. What types of other farm inputs did you use? Improved seed=1, Pesticides and herbicides=2, Compost=3; Fym =4; Others (specify) ________________

5. Having applied all these, have you observed yield decline from year to year? Yes =1, No =2.

6. If yes, what do you think are the major reasons?

Fertility decline=1; Lack of sufficient inputs=2; other reasons (specify) =4

7. What measures do you take when the productivity of your farmland decline? Rain water management to reduce water erosion =1; Look for additional farm land by deforestation=2; Increase amount of farm inputs=3; Oothers (specify)

Section C: Livestock production

1. Do you have livestock? Yes =1, No =2.

2. Mention the types and number of livestock you have

Cattle ___, Equines _______, Sheep_____, Goats ___, Chicks ____,Others (specify)_______

3. Do you think the number and productivity of your livestock decreased from year to year? Take into account the last 10 years to answer this question.

Yes =1=> Q4, No =2.

If yes for Q3, What is the reason? Shortage of feed=1; Shortage of grazing area=2; Shortage of drinking water=3; Pests and disease=4; Others (specify=5

Part Six: Household Survey Questionnaire on assessments of Forests/plantations

1. Is there a forest currently in this village? Yes=1, No =2.

2. If No, was there a forest 5 years ago? Yes=1, No=2; 10 years ago? Yes=1, No=2; 20 years ago? Yes=1, No=2; 30 years ago? Yes=1, No=2.

3. If yes, what type and how much? Natural _________ha, Plantation________ha. (Local units).

6. What changes have you observed in the forest cover since the last 5 years? 10 Years? 20 years? 30 years? Natural forest has disappeared=1; Natural forest has decreased=2; plantation forest has increased=3; plantation forest has decreased=4; Natural Forest has increased= 5

5. If decreased, what is the main cause for its reduction in order of importance? Conversion of forest to farmland=1; fuel wood and charcoal production=2; Construction of house=3; Timber production=4; Others (specify) =5

7. Is there anything that you used to get but now was lost due to the change in the forest cover? Yes=1, No=2.If yes, _______________________________________

8. Has the change negatively affected your land, adjacent land and the uplands in general? Yes =1, No =2.

9. If yes for Q8, can you mention some of the negative changes?

Stream flow decreased or dried=1; Run-off increased=2; More gullies and rills created= 3; Farm land fragmented=4; yield has declined=5; Others (specify) =6

10. If deforestation is a problem in your village, is there practice of community participation in forest conservation? Yes =1, No =2.

11. If yes, how do communities in the village contribute to the protection of forest? Participate in afforestation and reforestation programs=1; Reduce pressure on forest by planting multipurpose trees=2; Respect rules by laws and regulation of local governments and the community=3; Others (specify) =4

12. If no why? I don't have the knowledge =1; I don't have any problem on my land= 2; such type of works are very expensive and time consuming=3; others (specify) =4

Part seven: Assessments of Food security situation

1. Would you tell us the amount of grain and other foodstuff that covers the annual food requirements of your household members?

	Grain type	Amount (per year in kg)	Estimated value in cash (birr)
1.1	Cereals		
1.2	Pulses		
1.3	Oilseeds (Linseed, sesame…)		
1.4	Vegetables (cabbage, potato…)		
1.5	Fruits (papaya, banana, mango…)		
1.6	Livestock products (Meat, Milk and/or cheese etc.)		

2. Do you meet all-year round food requirements of your household members from own production? Yes=1; No=2, => Q5

3. According to your own self-assessment is your household: Food secured=1; Food insecured=2; Varies from one year to another=3; Varies from season to season=4; Do not know=5

4. If the response for Q9 is 'Food insecured', what do you think are the main reasons for being food insecured?

	Reason for food insecurity	Yes=1 No=2
4.1	Inability to produce sufficient grain due to poor RWM on my farm	
4.2	Inability to rear sufficient number of livestock and production via small scale irrigation due to insufficient amount of water	
4.3	Land scarcity for more grain & livestock production	
4.4	Meager income from non-farm activities	
4.5	others (specify)-------------------------	

5. If 'No' for Q4, do you or any member of your household engage in non-farm activities for income generation? Yes =1, => Q6; No =2.

6. If Yes for Q5, Which type of activity? Weaving/Shimena=1; Pottery/Shekla=2; Grain trade=3; Livestock trade=4; Beverage trade=5; Hand crafts (Blacksmith) =5; Employment (labor) =6; Others (specify) ____

7. If 'Yes' to Q5, does the income you earn from non-farm activities enable you to buy food to bridge the deficiency? Yes =1, No =2. If No why? _________________________________

Part eight: Household Survey Questionnaire on assessments of Linkages between rainwater management practice and agricultural productivity and then with household food security

I. Section for response by non-beneficiaries of Rainwater management interventions

1. Do you think lack of rainwater management practice adversely affects agricultural productivity and then household food security? Yes=1; No=2

2. If yes for Q1, in what ways?

	Response	Agree=1 Disagree=2
2.1	Vulnerability to water scarcity problems	
2.3	Low agricultural productivity and intensification through irrigation	
2.4	Low livestock productivity	

3. If no for Q1, what do you think are the determinant factors for your household food supply/security?____

II. Section for response by beneficiaries of Rainwater management interventions

1. How do you compare the livelihood in terms of agricultural productivity and food security of your household during pre- and post periods of Rainwater management interventions?

Improved following interventions =1, => Q2; Deteriorated since intervention =2,=> Q4;No changes recognized=3

2. If the response to Q1 is 'Improved since intervention', in what ways?

	Improvement in terms of	1. Yes=1 No=2
2.1	Diversified sources of income	
2.3	Allowed agricultural intensification through irrigation	
2.4	Improved livestock productivity	
2.5	Improved agricultural productivity with regular rainfall	
2.6	Other (specify) ________________________________	

3. If the Rainwater management interventions did not bring changes in livelihood and food security what do you think are the reasons? Severe problem of land scarcity=1; Lack of farm oxen =2; Inability to purchase other technological inputs=3; The environment is arid and harsh=4; Other (specify) =5

4. If the response to Q1 is 'Deteriorated', what are the explanations?