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INTEGRATED SOIL AND WATER MANAGEMENT APPROACH AND ITS SOCIO-ECOLOGICAL IMPLICATIONS IN GONCHA-SISO-ENESE WOREDA, NORTH-WESTERN HIGHLANDS OF ETHIOPIA

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This is to certify that the dissertation was prepared by Ermias Debie Adane entitled: "Integrated Soil and Water Management Approach and its Socio-Ecological Implications in Goncha-Siso-Enese Woreda, North-Western Highlands of Ethiopia". It submitted in fulfilment of the requirements for the degree of doctor of philosophy in 'Environment and Natural Resources Management'. The dissertation meets the accepted standard with respect to originality and quality.

Approved by the Examining Board:

External Examiner	Signature	Date
Internal Examiner	Signature	Date
Advisor	Signature	Date
Chairman of Department or Graduate program Coordinate	Signature	Date

DECLARATIONS

I declare that this PhD dissertation is my original work which has not been presented and published for any degree in any other university and that all sources of materials used have been accordingly acknowledged.

Ermias Debie Adane Signature ___________ Date ______________

As the principal dissertation supervisor, I hereby certify that I have critically read and evaluated “Integrated Soil and Water Management Approach and its Socio-Ecological Implications in Goncha-Siso-Enese Woreda, North-western highlands of Ethiopia”. I advocate that this thesis submitted in fulfilment of the requirements for the degree of doctor of philosophy in ‘Environment and Natural Resources Management’.

_____________________________ ______________ ______________

Supervisor Signature Date

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Acronyms

CIFOR -Centre for International Forestry Research

CPRs- Common-Pool Resources

CSA: Central Statistic Agency

DA- Development Agent

ETB- Ethiopian Birr

FAO- Food and Agriculture Organization

FGDs- Focus Group Discussions

GDP- Growth Domestic Production

GIS- Geographical Information System

ISWM -Integrated Soil and Water Management

LCCR- Legume-Cereals Crops Rotation

LULC- Land Use/Land Cover

MERET- Managing Environmental Resources to Enable Transition

NDVI -Normalized Difference Vegetative Index

SWC- Soil and Water Conservation

SWM- Soil and Water Management

TOPSIS- Technique of Order Preference by Similarity to Ideal Solution

WFP- World Food Programme

Glossary of local terms

***Areki*-** traditional alcohol

Boda-infertile soil

***Enjera*-** flat bread

Fesus- traditional drainage ditch

Gesho- a leaf that use for brewing of traditional drinks like tella and areki

Goti-small village or sub-kebele

Kebele-small administration unit of Ethiopia

Tekebikeb- traditional cut-off drain

Tella-brewing traditional beer

Abstract

The study was aimed to investigate the practicing process, farmers' acceptance and adoption, and socio-ecological implications of Integrated Soil and Water Management (ISWM) approach in Northwestern highlands of Ethiopia. Data were generated using combination tools including observations and measurements, informal and formal interviews, focus group discussions, field and household surveys, and cloud-free satellite image products. The results of qualitative analysis reveal that stakeholders' participations and interactions are not grounded as expected in the principles of ISWM approach. Technical designing and implementing of terracing not fitted with particular cultivated field character due to unrecognizing of farmland holders experience and skills. Nevertheless, the integrated use of structural, vegetative and agronomic in both traditional and modern perspectives indicates substantial reflection the approach. According to the results of multi-criteria analysis (TOPSIS), against to a range of identified relative criteria, soil bunds stabilized with Sesbania sesban shrubs, followed by, *Fanya-juu* complemented with *Sesbania sesban* shrubs are the most preferred ones due to providing multi-benefits. After that, compost use can also give short-term benefits in enhancing soil fertility and in increasing crop yields and reducing cost of chemical fertilizer application perspectives. Hence, combine use of compost and structural measures complemented with growth of *Sesbania sesban* shrubs is the best alternative approach to sustainable cropland management in the humid mid-highland agroecosystem. Findings of logistic regression model indicate that farmers' crop preference, ownership status of farmlands, farmers' perceptions on plot distance from home and fertility status, technical fitness of constructed structural measures and holding any perceived suitable plot for legume crops production are major influential factors for farmers' decision to use ISWM on a specific field. Results of satellite image analysis reveal that the spatial extent of forests, shrubs and wetlands (largely where the accessibility of information system and market linkage is poor as well as the natural resources base is more fragile), and grasslands were radically declined at the chiefly expanding of cropland and settlements. Rampant population pressures and weak institutional structure and arrangement were further pushed instant severe effects of Common-Pool Resources (CPRs) changes including expansion of barren surfaces and gullies development, and consequently shortage of fodder and fuel wood, and loss of croplands. Findings of multi-criteria analysis (weighted score) further show that complete enclosure scheme of forests and shrubs mainly favours for ecological restoration with no pay attention to socio-economic outputs whereas grasslands management under periodic enclosure without rotation mainly focuses on fair distribution of short-term economic benefits. Natural forests and shrubs lands under semi-open access management and grasslands in open-access management perform between very weak and poor performance against to almost all locally identified criteria/indicators. Based on the findings of rill surveying at cultivated field scale in Beribere catchment, rill erosion in conserved fields was reduced by 53.51%, as compared to non-conserved control fields. In the conserved area, terraces damage is the most important contributing factor for soil loss due to rills. In the non-conserved fields, entering of concentrated runoff from up-slope areas and drainage ditch damaging were observed as the principal accelerating factors for initiation and development of rill erosion, whereas they had insignificant effect for rill erosion in the terraced fields. Rill erosion also demonstrated spatial differences in terms of crop patterns (between tef and wheat cropped fields) and relative topographic positions in the valley sides of the study area. Results of variance of analysis reveal that the use of ISWM on a specific field has largely contributed to increase tef and wheat grain yields in the short-run and then more in the long-run as comparatively seen croplands that treated with lesser activities. Findings of t-test analysis point out that size of irrigated croplands (in ha), and number of bee hives and total number of livestock positively and significantly (at $P<0.01$) associated with perceived increase of households' income. Total sizes of farmlands, and pasture and trees planted field (in ha) also positively and significantly (at $P<0.05$) related with perceived improvement of individual households income. Therefore, in proportion to the major findings of the study, the following suggestions provided. It suggests that balanced information and knowledge flows recommend being honourable when farmers interact with external actors. Recognition of local farmers' interest, knowledge and skills about particular croplands spatial characteristics should emphasize during designing and implementing of introduced conservation technologies. It can recommend that local social, economic and site specific ecological decision criteria should incorporate in decision making process of SWM alternatives to increase utility. To promote the dissemination of ISWM practices in the broad context, policy should recognize farmers' crop preference, ownership status of farmlands, farmers' perceptions on plot distance from home and fertility status, technical fitness of structural measures and holding suitable plot for legume crops production and their mutual interdependence influence on farmers' decision to use activities overtime. The existing management schemes of CPRs should reformulate to relevant holistic scheme that takes into account multiple functions, and diverse interest and preference of the local communities. There should be adequate criteria and skills by promoting hybrid knowledge and skills with effective communication between farmers and extension staffs for designing site specific erosion control activities in addressing the problem. Efforts should make to boost crop productivity while sustainable conserving soil fertility through scale up of ISWM strategy that accounts the interaction effect of vegetative stabilized structure measures along with combined use of organic and inorganic fertilizers under farming systems of legume-cereals crop rotation. In the lens of integrated approach, agricultural extension packages should intensively engage to empower smallholder farmers to enhance forage, livestock, trees and apiculture productions by planting of multipurpose exotic and indigenous plants on their outcropped and in cropped plots.

Key words: Integrated; Soil and Water Management; Common-Pool Resources; Rill Erosion; Crop Yield; Household Income; Ethiopia highlands

CHAPTER ONE

INTRODUCTION

1.1. Background of the study

Land degradation has been and continues to be one of the most severe problems as it threatens the livelihood of millions of subsistence farmers in developing countries (Stocking, 2003). This situation is more prevalent in sub-Saharan Africa where rapidly growing human populations are mainly dependent on natural resources like soil, water, vegetation and confronted by rain fed agriculture along with ineffective management practices (Pimentel, 2006).

Since thousands of years, the accelerated rate of land degradation has experienced in the highlands of Ethiopia (Hurni, 1998). In the highlands (cover over 50% of Ethiopia), continuously deteriorating of soil quality, available water and vegetation covers are widespread phenomena, where more than 80% of the human and 60% of livestock populations of the country are living and 90 % of the area suited for agriculture (Hurni *et al*., 2010). Moreover, in the highlands, soil erosion by water that is often accompanied by nutrient depletion from cultivated lands, which directly affects crop yields through damaging and washing away of young seedling and indirectly affecting by depletion of soil fertility, degrading of soil structure, and reducing in plant available water reserves and in effective rooting depth, has been a common problem. This has been emanating due to multiple interacting of high and ever increasing human and livestock populations pressure, land tenure insecurity, inappropriate land use system and improper land managements (Berry, 2003; Mahmud and Pender, 2005).

The average rate of soil loss from croplands of the Ethiopian highlands estimated at 42t $ha^{-1}yr^{-1}$ that will remove the total soil cropland within 100-150 years (Hurni, 1993). In terms of economic, as Bojo and Cassells (1995) estimated, there was a loss of Birr 637 million due to soil erosion by water and nutrient depletion, of which 1.6% due to loss of grain, 0.13% due to decreased feed availability of livestock and 98.3% due to depletion of nutrient. The extensive rate of land degradation negatively affects soil productivity, threatens food security and livelihoods options of subsistence farmers, and worsens poverty in Ethiopia (Pender *et al*., 2001). To avert the problem, efforts need to make on the improvement of land productivity through relevant management programmes that could go long way in sustainable use of natural resources and improving the livelihoods of smallholder farmers.

Following the famines of 1970s and 1980s, numerous modern Soil and Water Conservation (SWC) measures of varied magnitudes having been applied through different programs and strategies, which, of lie were undertaken through the food-for-work program by WFP with the donors support for short-term assistance and long-term development purpose (Berhanu, 2004). However, the implementations of conservation techniques have not been considering security of land tenure, farmers' full participation and livelihoods assets status, economic returns and ecological relevance of the introduced SWC technologies, and ever increasing population pressure (Gete *et al*., 2006; Woldeamlak, 2007). This implies that the SWC measures predominantly undertaken without considering biophysical and socio-economic diversities as well as spatial variation of soil degradation at site-specific level when entire catchments conserved through campaign along with weak extension interventions and institutional arrangements (Mitiku *et al*., 2006; Woldeamlak, 2012).

Moreover, in the past few decades, most proposed structural SWC measures have not been well integrated together with biological components (soil fertility management, agro-forestry and enclosure practice) (Hurni, 2000; Gete *et al*., 2006). The success of SWC programs depends on the integrated provision of ecological outputs with socio-economic outputs to the poor farmers since conservation measures are not an end by themselves (Reddy *et al.*, 2004). Integrated SWM approach is crucial to enhance equity in terms of local level organizational development (Reddy *et al.*, 2004), to address problems of severe ecological degradation (Boyd *et al*., 2000), and to enhance crop yield and household income (Merrey *et al.*, 2005).

Accordingly, the approach is relevant where over deteriorated natural resources (soil, water and vegetation) become the main cause for declining of subsistence agriculture productivity (fodder and crop yields) under the mixed-farming system and rapidly growing populations situations, in the North-western highland of Ethiopia in general (Woldeamlak, 2003a), in Goncha-Siso-Enese Woreda in particular. Goncha-Siso-Enese woreda is one of four chronically food insecure Woredas *(Enarj- Enawga, Enbise Sar-Midir, Sheble-Berenta*) in East Gojjam zone, Amhara National Region because of much of their farmland being extremely depleted, deforested and eroded (Rami, 2003). In attempting to tackle land degradation and secure smallholder farmers livelihoods, by local based participatory integrated SWM strategy, substantial conservation efforts of MERETs ("Managing Environmental Resources to Enable Transition for Better Livelihoods") project initiative through its food-for-work program were undertaken in the seven catchments of Goncha-Siso-Enese Woreda for a decade ago. Despite promoting integrated SWM approach through agricultural research and development project is fundamental (Place *et al*., 2003), farmer-centre studies on practising processes, acceptance, adoption and socio-ecological implications of integrated SWM activities have not been investigated in humid mid-highlands of North-western Ethiopia as far as to the knowledge of the author. In the hope of making modest contribution in the field, therefore, the rationales of this study justified as follow.

1.2. Justifications and rationales of the problem

Research efforts in SWM practices are now shifting towards improving decision makers' interaction with multi-criteria analysis models including better activities for farmers' preferences (Hajkowicz and Collins, 2007). Multi-criteria analysis is an effective method to evaluate non-monetary and less quantifiable effects of SWM activities, which is not possible with a cost-benefits analysis, through utilizing local farmers' knowledge, experience and preference (Aklilu et al.,2006; Prato and Herath, 2007; Akalu et al., 2014; Vulevic et al., 2015). It identifies and evaluates SWM alternatives that implemented in the most degraded areas in according to the landholders' preference (weights) for multiple-criteria and the values of those criteria. Nevertheless, in the lens of multi-criteria analysis method information on the influence of farmers' preference of SWM activities in ecological and socio-economic aspects on adoption decision to combine the use of multiple practices not well documented. Therefore, the central queries were, whether farmers' participation in the integrated SWM practices were based on recognition of their priority problems, skills and knowledge, and planned actions along with intermediate interventions of extension staffs or via imposition by the local administration units? Did the components of implemented SWM alternatives show acceptable performance in farmers' perspectives?

While promoting integrated soil and water management activities are thriving in agricultural development project, research that is more social needed on farmers' adoption and integration of individual component of SWM activities (Place et al., 2003). However, numerous studies conducted on the issue of adoption of introduced structural measures (Bekele and Holden, 1998; Woldeamlak and Sterk, 2002; Wagayehu and Drake, 2003; Aklilu and De Graaff, 2007; Anley et al., 2007; Bekele et al., 2008) and manure (Mehretie and Woldeamlak, 2013a) as a binary choice in the Ethiopian highlands. These studies overlooked the adoption potential of integrated SWM activities by considering a range of adoption possibilities including indigenous and introduced conservation measures. Therefore, the results of this study expected to provide insight on the existing adoption theories of SWM efforts by investigating factors influencing farmers' decision to use integrated SWM activities.

Decision making in CPRs management can be complex and seemingly intractable as the inherent trade-off between socio-economic, ecological and institutional factors. Since CPRs have been and continue to be a principal component of the base of subsistence farmers' livelihoods under mixed farming system, as well as the main indication of environmental preservation or severe degradation (Bereket, 2002), an adequate understanding of the linkage between local social system and ecological character of CPRs is fundamental. However, in the lens of holistic methodological approach that accommodates multiple criteria (ecological, economic, social and institutional), studies on the status and sustainability condition of management schemes and use of CPRs (valley floor and sloping communal grazing lands) in the humid highlands of Ethiopia is inadequate. In addressing this, therefore, the results of this study expected to produce more information concerning the characteristics, problems, relative importance of criteria, performance and alternatives scenarios of the existing management systems of CPRs by using multi-criteria analysis method.

There are limitation and advantages of different approaches of soil erosion measurement. On the one hand, while its spatially aggregated nature, measurements using macro-order modeling often do not provide critical information to significantly understand the spatial patterns of erosion and effectiveness of conservation practices(Stocking, 2001). On the other hand, micro-level measurements like experimental at plot level may not be relevant methods to draw conclusion at field or large spatial scales as it represents a particular confined area (Boix-Fayos et al.,2006). However, erosion shows large spatial variation due to influence of erosivity of rain, effect of relief on such erosion, soil profile, vegetative or plant residue cover and conservation practices. In accordance with, field assessment techniques like rill survey has a substantial advantage as it is more realistic, simple and practical methods of measurement of soil erosion by water and effectiveness of conservation practices at actual field level through integrated views of the ultimate clients for the work, the farmers (Stocking, 2001; Evans, 2002; Morgan, 2005). Participatory identification of soil erosion indicators and computing soil loss approaches are quite important to enhance awareness on type of soil erosion by water, magnitude of soil loss and conservation attention to key actors (farmers, development agents) (Evans, 2002; Okoba and De Graaff, 2005). Woldeamlak and Sterk (2003) suggested that rill survey approach is commendable for obtaining good semi-quantitative information on magnitudes of soil loss in the real situation of different land uses and conservation practices. Therefore, this study conducted with respect to the actual soil loss from cultivated fields, the principal units for evaluating the effectiveness of SWC practices by the farmers, using rill survey technique in high rainfall highlands of Ethiopia, wherein studies were few in number.

Moreover, since soils/water losses and nutrient depletion are major limiting factors for crop growth and yield, smallholder farmers in the highlands of Ethiopia need to invest on combined use of structural, vegetative and agronomic measures in an attempt to close the yield gap (Tilahun, 2003; Getachew et al.,2012). Nevertheless, household survey studies at field level on the integrated effects of SWM practices in improving crop yield and household income in the humid highlands of Ethiopia have not well documented. Yields obtained from experiment plots, perhaps, misleading as they are often overestimating or underestimating attainable yields under the farmers' conditions. Instead, farmers estimate of harvested yields attainable in their fields in a harvesting time recognizing heterogeneous farming systems and landscape of smallholder agriculture (Tittonell and Giller, 2013). Several techniques of estimating harvested yields of farmers' plots are available. These include farmer estimation, crop cutting, complete harvesting and others. Complete harvesting undertakes wherein entire farmer plots harvest under project staff supervision. Crop cutting technique' involves direct physical measurement by enumerator of crop taken from randomly selected sub-plots that may not represent the total area of the farm plot. 'Surveying Farmer Estimation Method' is more appropriate as it is simpler, less cost and permits greater sampling efficiency than complete harvesting method and 'Crop cutting technique' (Patrick, 1999), for this study. Therefore, this study expected to shed light more in the issue by using farmer estimation technique.

1.3. Research objectives

The main objective of the study was to investigate the practicing process, farmers' acceptance and adoption, and socio-ecological implications of integrated soil and water management approach in Goncha-Siso-Enese Woreda, North-western highlands of Ethiopia. The following specific objectives defined as follows:

1. Evaluate the performance of integrated SWM practices from farmers' perspective,

2. Explain factors influencing decision of smallholder farmers in practising ISWM,

3. Investigate the dynamics and management schemes of common-pool resources in the mixed-farming system,

4. Analyse the contribution of SWC practices to combat magnitude of soil loss and,

5. Evaluate the effects of ISWM practices on enhancing of crop yield and household income.

1.4. Research questions

To address the defined specific objectives, the following research questions identified:

1. To what extent do components of integrated SWM practices get acceptance by the farmers'?
2. Why factors do influencing on the decision of smallholder farmers to use ISWM practices?
3. To what proportion do common-pool resources make dynamic changes?
4. What do local people perceive about the performance of prevailing and alternative management schemes of common-pool resources in the mixed farming systems?
5. What proportion do SWC practices contribute to reduce magnitude of soil loss? And
6. To what extent do integrated SWM practices contribute to improve crop yield and household incomes?

1.5. Significance of the study

This study adds some views on the contribution of integrated SWM practices in combating erosion, and enhancing crop yield and household income. It important to provides highlights on constraints that influence stakeholders' participation at different levels, components of SWM practices, and goals of conservation practices and smallholder farmers' livelihoods to provide guidelines to planners and agencies for further relevant interventions. The study contributes to add knowledge about the relative performance of various SWM practices in farmers' perspective, in terms of social, economic and ecological criteria. It is quite important to explore and understand farmers' knowledge and experiences on the on-site effects of practised integrated SWM measures. Hence, it significantly contributes some highlight views concerning developments that can assist Development Agents (DAs) in assisting farmers in targeting specific areas, where to implement the best conservation practices. This possibly disseminate to neighbourly villages or communities through farmers and extension agents. In general, this study is important to provide guidelines for concerned planners and agencies for faster and appropriate preconditions to further implementing projects.

1.6. Scope of the study

The theme of the study presents practicing processes of ISWM activity and its acceptance, adoption, and impacts on rill erosion, crop yields and household income in *Goncha-Siso-Enese* Woreda. The capacity of the study includes communities from three catchment (*Beribere, Woyibila* and *Wochit-wuha*) sites out of the seven incorporated by MERET project for ten years. Moreover, the Woreda, and its four kebeles (*Buza-Yemerat, Gindewoin-Beza, Yebuchir-yewoya and Dequate-goshera*) respectively consider for satellite image analysis, and participatory evaluation study pertaining to dynamics and management system of common-pool resources. Assessment of integrated actions, where farmers as the main players and external actors' (extension staffs, MERET project and government agents from Woreda to kebele levels) as the facilitators,' was part of this study. Moreover, ISWM practices could be elaborated in terms of integration between introduced and indigenous conservation practices including physical (terracing and traditional drainage ditches), vegetative (*Sesbania sesban* shrub and grass) and agronomic(composting and legume-cereals crop rotation) for not only ecological outputs but also socio-economic. The performance and socio-ecological effects of practised ISWM activities were analysed at individual household level as well as the overall sustainability situations of the practised SWM practices at the community level.

1.7. Ethical issues in the study

Originality in the use of various methods in the form of applying the already established techniques, seeking cordial mutual cooperation of the participants, genuineness of the information, keeping of the confidentiality of the information and in adapting a compromising way out so as not to irritate varied components of the society and the nationalities given great consideration in this study.

1.8. Study outline

This thesis composed from themes including performance of different components of SWM practices, farmers' decision to practice integrated soil and water management, dynamics and management schemes of common-pool resources, and effects of soil and water management practices on combating soil loss, and enhancing crop yields and household income. For instance, practicing process of SWM activities and their socio-economic and technical performances in farmers' perspective were included in chapter four. Physical (plot level and technical), socio-economic and institutional factors influencing farmers' decision to adopt and use ISWM involving introduced (terracing, compost) and indigenous (legume-cereals crop rotation) measures was discussed in chapter five. The dynamics of common-pool resources (forests lands, shrubs lands, grasslands and wetlands) changes, and associated driving factors and socio-ecological implications, performance of prevailing management schemes, and the potential alternative scenario for the sustainable use of common-pool resources were included in chapter six. The effects of terraces complement with natural grasses or *Sesbania sesban* shrubs on reduction of soil loss using rill survey technique was discussed in chapter seven. Effects of ISWM practices on enhancing crops (tef and wheat) yields and household income presented in chapter eight. Lastly, chapter nine presented summary and recommendations of the study.

CHAPTER TWO

REVIEW OF RELATED LITRATURE

2.1. Evolution of soil and water management efforts in the Ethiopian highlands

Hurni *et al***.** (2015) reported that two-thirds of Ethiopia population is affected by land degradation that mainly begins when forests are converted into agricultural lands. In response to this, indigenous and institutionalized soil and water conservation efforts have been undertaken. For instance, indigenous soil and water conservation measures have been undertaken for centuries in the northern (Aksum area) (Ciampalinia et al., 2012), southern [Konso area] (Beshah, 2003), and northwestern (Monsieurs et al., 2015) highlands of Ethiopia.

Since 1970s, institutionalized soil and water conservation programs incorporating soil or stone bunds, trenches afforestation, exclosure and gullies treatment are undertaken (Osman and Sauerborn, 2001). From 1970s up to 1990s, the program was carried out through top-down approach of incentive based (Food-for-Work) that favoured to technical aspect with typical intention of reducing soil erosion (Gebregziabher *et al.,*2016). In 1970s, the Food-for-Work program started in the form of food aid (Osman and Sauerborn, 2001; Devereux et al., 2006). Later in 1980, the Ethiopian ministry of agriculture and World Food Program with technical support from Food and Agricultural Organization of United Nations (FAO) began implementing development oriented program, "project 2488", through engaging the community in the rehabilitation of degraded catchments and micro-watershed in drought-affected areas (Devereux *et al.*, 2006; Betru and Wickrema, 2010). Despite substantial conservation efforts have been done and some ecological benefits accrued from it, Food-for-Work approach encountered a number of limitations (Betru, 2002). There was a general lack of guidance concerning the most appropriate technologies and suitable approaches to the context of local socio-ecological environments (Erny, 2004).

In the early 2000s, promoting on the experience of "project 2488", MERET was adopted as community-based participatory integrated watershed development approach to achieve integrated objectives of natural resources management and livelihood improvements by extended to incorporate a wider range of productivity improvements and income-generating activities (Alemneh, 2003; Betru and Wickrema, 2010; Gebregziabher *et al*., 2016), which mostly focused on low potential areas (Alemneh, 2003; FDRE, 2012). Bezuayehu and Stroosnijder (2007) suggested that integrated watershed management is emerging as an alternative to the centrally planned and sectoral approaches that characterize the planning process for dam construction in Ethiopia. Integrated soil and water management has contributed to improve natural resources, crop-livestock productivity and livelihoods owing to biophysical, institutional and socioeconomic factors, supporting institutional structures and extent of community participation (Nigussie *et al.,* 2012; Gebregziabher *et al.,* 2016). Gebregziabher *et al.* (2016) indicate that integrated watershed management has improved farm incomes and food security by an average of 50% and 56%, respectively. However, as they further indicated, lack of technical advice and information, lack of coordination among the stakeholders, and uneven distribution of costs and benefits are factors that threaten the success of integrated watershed management.

In 2005, the Productive Safety Net Programme (PSNP) was launched by international donors and agricultural ministry of Ethiopian government. The programme is undertaken through predictable payments in cash or kind for six month ever or Food-for-work and Cash-for-Work approaches to reducing food insecurity in the short-term and to achieve sustainable livelihoods in the long-term (Nick and Tassew, 2012). Despite the programme shows significant improvement of land productivity on communal areas, lack of attention to private lands is undermining the sustainability conditions of the improved land management (FDRE, 2012).

In 2008 another decade long national programs, Sustainable Land Management Program (SLMP) was established through holistic framework under which mobilization of voluntary uncompensated labor at community level, government, civil society and development partners (EFDRE, 2012). SLMP is focused on reversing land degradation, promoting farmers’ incomes and food security, and protecting ecosystem integrity and functions through support small scale rain water harvest, micro-irrigation, agro-forestry and other income generating activities in targeting micro-watersheds but large watershed planning context with emphasizing on high potential areas (EFDRE, 2012). It is appropriate that current issues like food security and environmental quality related to sustainable land management are addressed within the context of watershed management (Lal, 2000). Despite land management in the relatively surplus crop producing areas of southwestern and northwestern parts of the Ethiopia given by policy attention of SLMP, the interventions are not significantly implemented as set out in the sustainable land management project objectives (Nigussie *et al.,* 2015).

2.2. Performance and acceptance of soil and water management alternatives

Accelerated rate of land degradation has resulted major ecological and socio-economic problems on agricultural lands of the Ethiopian highlands (Hurni, 1998). To avert these problems, substantial conservation efforts have been made with emphasizing on construction of introduced physical Soil and Water conservation (SWC) activities on cultivated fields and afforestation on hillsides since early1970s (Yeraswork, 2000). The efforts have been undertaken through top-down approach with limited participation of farmers by labour contribution that persuaded by food-for-work payments of international donor community (Wood, 1990; Berhanu, 2004). There are two controversial views on the acceptance of introduced SWC approaches and practices, have been carried out in the Ethiopian highlands in the last three decades.

On the one hand, some scholars argue that since the approach did not recognize site-specific knowledge and socio-economic conditions during planning and implementation stages, farmers failed to maintain and in some cases destructed structural measures (Bekele and Holden, 1998; Yeraswork, 2000; Tilahun, 2003; Berhanu, 2004; Gete *et al.*, 2006). Woldeamlak and Sterk (2002) noted that farmers participated in the SWC unwillingly since they discouraged by ineffectiveness of the structures under construction. To develop the willingness and ability of farmers, direct economic incentives based participation used in numerous structural and biological measures. However, this approach was a potential cause of low acceptance of SWC activities and even opened the door to the obliteration of constructed measures when incentives renounced while it applied for short-term labour cost with unrealized real participation of the beneficiaries (Berhanu, 2004). Instead, utilizing beneficiary household labour through incentive contract, under food-for-work programs, is likely to be effective when used to subsidize the smallholder until conservation provides positive net benefits over subsistence land use (Bekele and Holden, 2000).

On the other hand, various others argued that investment in SWC approach seem to have been positively beneficial in terms of ecological and social perspectives. For instance, Nyssen *et al*. (2004) mentioned that many introduced structural measures dating from the 1980s are still in place in the highlands of Ethiopia due to most farmers are accepted and maintained. Nyssen *et al*. (2007) concluded that the extensive use of stone bunds in the semi-arid environment, involving people participation, is a positive operation from technical, ecological and economic point of view. Woldeamlak (2007) also noted that despite sustainable adoption and widespread replication are more unlikely, the newly introduced SWC measures have generally obtained acceptance by the local farmers due to effectiveness in arresting soil erosion and as having the potential to improve land productivity. Getachew *et al*. (2011) added structural measures (*Fanya-juu*) complemented with vetiver and elephant grass accepted by all stakeholders as promising soil conservation techniques in reducing soil erosion and increasing crop yield in humid agro-climatic condition. In the eastern highlands of Ethiopia, Wagayehu (2003) also suggested that SWC is a dominant production strategy for subsistence farmers while realizing that its contribution to enhance yields and increase food crop availability is a major concern.

These controversial views on farmers' acceptance of introduced conservation measures call for further studies on the issues of local preferences and participation in designing relevant and acceptable integrated Soil and Water Management (SWM) alternatives. In the context of integrated SWM approach, the introduced soil and water conservation practices should be tailored and adapted with "site-specific" to varied farm situation, more commonly to less favoured environment and resource poor farmers (Altieri, 2002; Lal, 2001). Using locally available and affordable resources, and diversified information on ecology, socio-economic and institutional aspects are essential to make specific and straightforward application in SWM activities (Altieri, 2002; Bekele *et al*., 2008). Due to this fact, the inclusion of both local farmers' and scientific knowledge at all stages of projects planning is the fundamental element in agro-ecological production system accentuating rational use of natural resources (De Vries *et al*., 2008).

Considering benefits and inconveniences of indigenous SWC measures is one principal factor for the successful introduction of any introduce activities which must at least match and preferably improve the benefits to be obtained from the indigenous ones(Simpson,2010). This further provides launching pad for building new hybrid knowledge systems since farmers are well experienced with their farming conditions and able to give supportive sight for relevant strategies as problems arise or new opportunities develop to manage their farmland soil fertility (Hurni, 2000). Using shared views can be promoted new attitude to farming and the management of natural resources schemes according to farmers preferences that largely depend on low investment and maintenance costs, and short-term as well as long-term gains make acceptable(Hurni *et al*., 2008; Aklilu *et al*., 2006; De Vries *et al*., 2008). Therefore, the working speculation of this study was that farmers accepted the multi-advantageous SWM alternatives.

2.3. Nutrient depletion rates

Soil fertility decline through nutrient depletion is the widespread and growing severe problem as it directly leads to decline in yields and potential starvation in sub-Saharan African countries where subsistence farming system is the overwhelming economic sector (Scoones, 2001). For example, Stoorvogel *et al.* (1993) estimated the alarming annual average soil nutrient depletion rates for 38 Sub-Saharan Africa countries at 22kg N, 2.5kg P, and 15kg K from 1982 to 1984 and projected to 26kg N, 3kg P and 19kg K in 2000 due to high nutrient exported in the form of harvested products, crop residue and erosion. They further pointed out that the depletion rate was the most intense, N > 40kg $ha^{-1}yr^{-1}$ and K > 25kg $ha^{-1}yr^{-1}$ in the densely populated and erosion prone countries, particularly in Ethiopia, Kenya, Malawi and Rwanda.

Stoorvogel *et al.* (1993) also estimated the depletion rates of soil nutrient for Ethiopia as 41kg ha^{-1} N, 6kg ha^{-1} P and 26kg ha^{-1} K from 1982 to 1984 and projected to 47kg ha^{-1} N, 7kg ha^{-1} P, 32kg ha^{-1} K in 2000. In Ethiopia, improper land management activities including use of animal dung for cooking, use of crop residue for animal feed and cooking, continuous cropping, and minimal adoption of modern conservation measures are the major factors for the overwhelming deterioration of nutrient balance (Tilahun,2003). For instance, a study in southern Ethiopia by Alemayehu *et al.* (2001) showed consistently large negative N balances due to the outputs of harvested crops not being compensated by inputs. Based on their study in Central Ethiopia, Aklilu *et al.* (2006) indicated that on average, a farm household export about 43.5kg N, 9.0kg P and 41.4kg K yr^{-1} through selling dung-cakes made of cattle dung. Results of study by Amare *et al.* (2006) conducted in the central highlands of Ethiopia revealed that N and K fluxes were -28kg N $ha^{-1}yr^{-1}$ and -34kg K $ha^{-1}yr^{-1}$, and -6kg N $ha^{-1}yr^{-1}$ and -14kg K $ha^{-1}yr^{-1}$ in the tef- based and the Enset-based systems respectively while P fluxes were almost slightly positive.

Assefa (2005) also indicated quick reduction of nutrients stocks in the soil, especially on farms of rich farmers’ with annual depletion rates of 2.4% of total N, 1.3% of total P and 1.3% of total K due to removal in crop yields and animal feeds, in the Northern Ethiopia. Results of study conducted in Northern Ethiopia using nutrient monitoring model

(NUTMON)(Hengsdijka *et al*.,2005) indicated that larger depletion rates of 34kg $Nha^{-1}yr^{-1}$ on a plot basis without taking into account internal farm flows whereas the majority of redistributed N in crop residues was 6kg N ha^{-1} used for cattle feeding. In addition, despite being tenaciously encouraged by the government as a principal production boosting technologies, loss of nutrients did not compensated by low-scale application of inorganic fertilizers (Sonneveld, 2003; Minale *et al*., 2009). Regardless of efforts made through extension programs to scale up several conservation technologies of soil (like terracing, composting), the combined use of those practices under Legume-Cereals Crop Rotation (LCCR) system is more unlikely in the highlands of Ethiopia (Mitiku *et al*., 2006).

2.4. The need for integrated soil and water management activities

An integrated effort of indigenous soil conservation practices with introduced ones through extension program is imperative to scale up farmers' adoption (Anley *et al*., 2007), to reduce water, soil and nutrient losses to an acceptable level, and consequently boosting agricultural production in the predominant subsistence farming systems in the Ethiopian highlands (Scoones, 2001; Tilahun, 2003; Mitiku *et al*., 2006). In the context of site specific characteristics, relevant integrated SWM activities can be involved in nutrient saving (including controlling erosion, and recycling crop residues and other biomass) or adding nutrients such as applying compost and inorganic fertilizers (Smaling *et al.,* 1997), which aimed at maximizing the agronomic efficiency of applied nutrient inputs (Vanlauwe *et al.*, 2011). For instance, mechanical measures can influence reducing run-off concentration and erodibility of the soil as well as encouraging the infiltration capacity of the soil (Morgan, 2005). Vegetative measures can also influence the rate of erosion in the form of resistance and protection (Blanco and Lal, 2008). Furthermore, these principal roles of mechanical and vegetative measures should supplemented by agronomic measures like composting and LCCR (Morgan, 2005).

The most stable and suitable for incorporation into the soil form of organic matter is humus, which can be formed through composting a very wide range of organic waste which can accelerated by large numbers of micro-organisms in a moist, warm and aerated heap in order to lower the C: N ratio of the mix (White, 2006). Compost application enhances the organic matter content of the soil. Organic matter is the principal factor in soil fertility as it improves the soil structures and thus enables the soil to improve porosity and bulk density, resist erosion, to retain moisture for long time during dry spells and to hold a greater stock of nutrient that largely required by plants (Hatfield *et al.*, 2001; Evanylo *et al*., 2008).

In the cultivated fields, inputs of N-rich organic materials like legumes residues and animal composts are required to replenish insufficient Soil Organic Matter (SOM) and N supply at an adequate level where cereal crop residues are insufficient to maintain through recycled back into the soil (Giller *et al.*, 1997). For example, the results of experimental study on a plot in Japan by Zai *et al*. (2008) indicate that composting of pea crop residues with dried chicken manure maintained higher rate microbial activity in the soil and supplied sufficient nutrient to wheat crop and thus wheat harvested higher amount of N P K with efficient recovery rate. Ramos and Martı'nez-Casasnovas (2006) also reported that the concentration of N and P nearly doubled 1 year after the compost application. Based on the results of three year study conducted in Virginia, Evanylo *et al.* (2008) reported that soil organic C, total N and available P increased with 60%, 68% and 225% in the 144 Mg ha^{-1} compost (dry wt.) application plots than the controlled fields. Ouédraogo *et al.* (2001) reported that application of compost in the soil increased cation exchange capacity from 4 to 6 cmol kg^{-1} and soil PH.

Ramos and Martı'nez-Casasnovas (2006) indicate that application of compost to the soils demonstrated a positive effect like improving infiltration and reducing runoff volumes by up to 20%. Gilley and Risse (2000) also reported that in the fields at which compost is applied yearly, runoff decreased between 2 and 62% and soil loss reduced between 15 to 65% as compared to non- composted fields. Accordingly, compost application is preferred as a low cost soils recovery activity through improving physical, chemical and biochemical properties, and consequently highly contributes to improved yield components and yield (Zai *et al.,* 2008). For instance, Ouédraogo *et al*. (2001) also reported that yield of sorghum increased with 45% on 10 Mgh^{-1} compost plots as compared to no-compost plots.

In order to promote the capacity of nutrient input adding, using compost is more preferable if integrated with Legume-Cereals Crop Rotation (LCCR) practices. While the activity of nitrogen fixing bacteria (Rhizobium) in the root nodules of legume crops return nitrogen (N) to the soil, the legume crops have too high N: P ratio, which is required by cereals (Wild, 2006). This necessitates to properly alternation of cereals with legume crops under a particular condition through emerging soil ecological interactions and processes that happen year to year is vital to increase the quantity and quality of soil organic matters and hence enhance chemical and physical soil properties, and then productivity (Carter *et al*., 2003;

Vanlauwe and Giller, 2006). For instance, Liu *et al*. (2005) indicated that 11-year continuous corn, soybean, and wheat resulted in a 10%, 11% and 5.3% decline in SOC respectively, compared with a rotation of all crops in China. Li *et al.* (2002) also indicated that after a 3-year cycle, some rotations significantly increased soil water-stable aggregates compared with the initial measurement**.**

LCCR can lead to reducing soil born pests, diseases and troublesome weeds than repeated mono cropping with cereals (Fernandez *et al*., 1998; Sauerborn *et al*., 2000). Moreover, Sauerborn *et al.* (2000) indicated that alternating of cereals with non-cereals crop had a more favorable effect on the yield of maize and sorghum than mono cropping of cereals. Porter *et al.* (1997) also reported that in low yielding environments, the yield advantage of an annual rotation of corn and soybean compared with monoculture was frequently greater than 25%.

Agronomic activities should supplemented with legume and herbaceous plants stabilizing soil erosion control measures in order to keep the nutrient capital investment in place (Sanchez *et al*., 1997). Nutrient inputs and availability can be increased by planting hedgerow of legume shrubs through their rooting nodules nitrogen fixation systems as well as curbing soil erosion by water accompanied with nutrient loss from sloping cultivated fields (Schroth *et al*., 2003; Mapfumo *et al*., 2005). Snapp *et al.* (1998) noted that legumes with high quality residues and deep root systems are effective ways of improving nutrient cycling.

Overall, uptake of a set of conservation practices, in particular organic management practices like composting, LCCR, terraces stabilized with legume shrub hedgerows and supplementing with some inorganic fertilizers to intensify land use with sustainable, in particular in the less favoured environment under greater pressures with severely degraded land, should be promoted (Schwilch *et al*., 2007; Vanlauwe *et al*., 2010). This integrated approach in turn, results in enhancing crop, fuel woods and fodder productions, and then reduce financial risk of buying chemical fertilizers on credit and vulnerability of the household.

2.5. Factors influencing integrated soil and water management activities

Use of different SWM activities are intimately related with farmers' priority, objectives and contribution level of conservation technologies to achieve their objectives (Boyd *et al*., 2000). Awareness level of stakeholders on the types, extents, and cause and effects of soil erosion by water, as well as on the relative benefits of conservation technologies (Aklilu and De Graaff, 2007) can be required for problem priority and decision-making process.

Promoting awareness of farmers towards negative impact of soil erosion and the need of integrated use of soil and water management measures for productive uses of land resources may be because of individual farmers' willingness, relevant extension services and integrated actions (Woldeamlak, 2012). Overall, farmers' human capitals' status (labour size, educational level, farming experiences, awareness of soil erosion and fertility, the ability of crop preference and management, extension and technical assistance) are more likely influence farmers' decision to use integrated SWM activities.

Farmers' perception of uncertainty on land ownership status due to historical changing patterns of land ownership and government control is more likely an important constraint that encourages them to over-utilizing land for short-term gains in Ethiopia. Land endowment (farmland status and farmland size) may influence to practices of integrated use of long-term beneficial management activities. For instance, land renters are more likely to intend instant needs of augmenting their crop yield as compared to owners (Samuel, 2002). Moreover, farm size (Aklilu and De Graaff, 2007) may have influence on degree of integration of SWM practices.

Due to distance of farm land from home (Bekele and Holden, 1998) and limited availability of equipment and materials (manure, crop residue for fodder), farmers may not be interested to use more SWM measures consistently. Even, the degree of integrating different SWM technologies is more likely to influence by soil quality status and slope of the plot (Aklilu and De Graaff, 2007).

The relative beneficial measures that require less labour and cost with more short-terms and long-terms returns persuade to integrate the farming systems. Integrated use of conservation activities in any cultivated land will only be successful if the owners of the plots see them as the basis of their benefit (Steele, 1991). In progress, when communities are able to link their survival and day-to-day welfare to a particular conservation activity, they show commitment to the sustainable management. Moreover, the economic status of smallholder households could influence practical capacities of SWM measures. For example, household income, livestock size and variability in stock availability may influence farmers' objective to adopt various SWM practices on their farmlands (Asafu-Adjaye, 2008). Proportionate to this reviewed literature, this study emphasized on the relationship between socio-economic, institutional, and technical and plot level factors with integrated use of SWM activities (stabilized structural measures with vegetative growth, composting and LCCR) as a part of farmers' production and livelihood system.

2.6. Dynamics and management schemes of common-pool resources

In the recent decades, croplands and pastures have expanded globally accompanied with considerable loss of biodiversity of communal lands (Foley *et al*., 2005). For instance, the current grazing lands (cover more than 25 % of global land surface, the larger geographic extent than any other form of land use), which, under marginal bio climatic conditions results in the emergence of major components of global environmental change like desertification, woody encroachment and deforestation (Asner *et al*., 2004).

Despite Common-Pool Resources(CPRs) like forests, shrubs, grasslands and wetlands had been and continue to have valuable contributions to the subsistence livelihoods of millions of smallholder farmers, they are among the most neglected sectors that are threatened by expropriation, over-exploitation and under investment in the developing countries(Wade, 1987; Jodha, 1990). Undercutting of local institutions and obstructing of local communities initiative by the state policies are the principal reasons for the poor management of common property natural resources, particularly in the sub-Saharan Africa (Lawry, 1990; Ostrom *et al*., 1999). The triumph of the commons has been and continues to challenge wherein resources are being open-access accompanied with unsupportive institutional condition (Pretty, 2003). Because of a local societal failure to control individual access, contradicting interactions of open-access CPRs and social systems result in maximization of individual interest with potential destruction of those resources on village commons (Hardin, 1968). Hardin argued that individual decisions cumulative to a tragic overuse and the potential destruction of an open access commons until the expected benefits of his or her actions equal the expected cost. When a use rate of CPRs is greater than a rate of replenishment of those resources, tragedy is inevitable (Vandermeer, 1996).

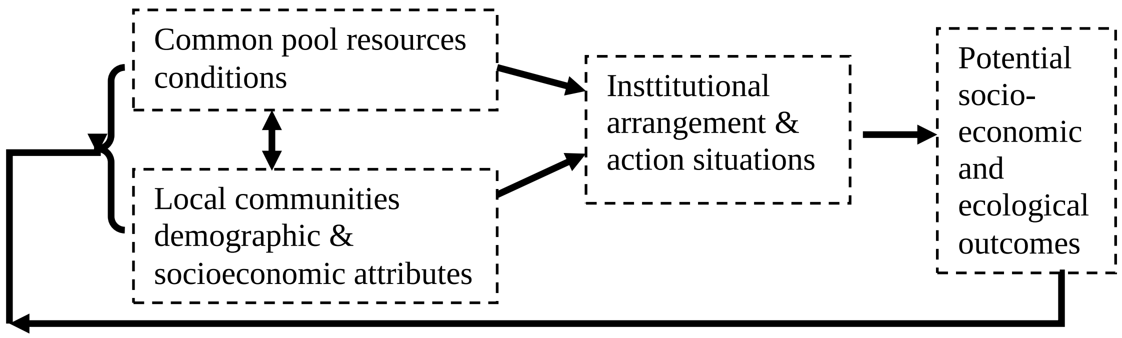
Findings of different studies conducted on issues of land degradation indicate that tragedies of the commons might have been symbolized and in existence in the Ethiopian highlands' context. For instance, uncontrolled deforestation and overusing of CPRs are the main factors to aggravate degradation of vegetation in the absence of institutional concern about measures to combat the problem (Tilahun, 2003; Hurni *et al.*, 2010). Rapidly growing population has highly contributed to expand cultivated lands at the cost of communal grazing lands (grasslands, shrubs and forests), consequently resulting in an exponential fall of per capital grazing lands (Gete and Hurni, 2001; Amare *et al*., 2011). Because of persistent overgrazing and rapidly growing pressure on open-access common grazing lands, the availability of traditional feed resources base has been and continues to be over deteriorated and then insufficient fodder to the dense and low quality livestock population (Jabbar *et al*., 2002; Mitiku *et al*., 2006). Moreover, overgrazing that has often occurred on the sloping common pasture lands, in particular during the rainy season, has substantially effected on the prevalence of severe surface runoff and soil erosion (Mwendera *et al.*, 1997). According to Hurni (1993), degraded soils and vegetation lead to increase runoff rates of up to 80% of the rainfall whereas well-covered soils (long grasses, trees) will retain more than 90 % of the waters. The triggering effects of over deterioration of vegetation, and inappropriate farming practices and road constructions have more likely contributed to the rapid development of gully systems on the highlands grazing areas (Nyssan *et al*., 2006; Lulseged *et al.*, 2014).

To resolve the dilemma of tragic use and, thus properly manage the common property, different alternative approaches have proposed. For instance, on the one hand, Hardin (1968) proposed that the solution was in tenure reform either socialistic or privatized free enterprise. The implication is that either free riding could circumvent through completely defined private property rights to the resources or imposing rules of use by an external agent, the government.

On the other hand, collective action theories (Wade, 1987; Ostrom, 1990; Ostrom *et al*., 1999) argue that both government and private owner ships are expensive to make substantial impacts, and hence will be associated with more degradation. Instead, from small to relatively large group property regime within a single community, which involve nested institution at varying scales, can sustain on locally based rules and avert the tragedy through restrained access to common property resources. Common-pool resources should be governed by the direct users or local communities with facilitating actions of external agents (non-users) through providing information and legitimize local communities right (Ostrom *et al*., 1999; Heltberg, 2001; Carney and Farrington, 2005). Clearly defined boundaries, optimal number of communities, identical action of individuals, collective choice arrangement, monitoring, graduated sanction, the benefits of cooperation exceed the costs, conflict resolution, trust relations, reciprocity and exchanges are important principles in the efficiently and sustainable use of CPRs(Ostrom, 2002; McCarthy, 2001; Pretty, 2003).

In the Ethiopian highlands, since early 1980s, area enclosure of the degraded lands within the delineated catchments has been one of the main strategies of soil and water conservation programs for sustainable use (Betru *et al*., 2005). Different studies indicate that collective action at local level community management with intermediate action of external agents is more preferable and effective option to combat severe degradation of CPRs and then to sustainable use of the resources than private and centralized management regimes (Berhanu *et al.,* 2000; Bereket, 2002; Mastewal *et al*., 2011; Tilaye *et al*., 2011). However, area enclosure efforts have adversely influenced the sense of ownership and the community's commitment for effective protection and sustainable management of the resources (Betru *et al*., 2005). Perhaps, the open and semi-open access management schemes are more likely the effective management problems (more likely revealed to open access for free riders) that commons faces.

The mutual interdependence of local socio-economic and demographic attributes with the management problem of CPRs further points to socio-institutional arrangements for the potential management of CPRs. For this study, the interactions of actors in the social space to solve tragic degradation of CPRs and their potential outcomes (cost and benefits, equality on efforts and benefits, accountability and sustainability) are essential indicators for the sustainable use of those resources. Accordingly, the following figure depicts the relationships of general variables in the framework of socio-ecological environment (Ostrom, 2011).



2.7. Effects of soil and water conservation practices in reducing magnitude of soil loss

Soil erosion is the critical environmental threat to sustainable production of agriculture. Pimentel *et al*.(2003) stated that during the last 40 years, close to one-third of world's arable land has been lost by erosion and continues to be lost at rate of more than 10 million ha yr^{-1}.

Most of this land has been losing its soil cover at rates ranging from 13t $ha^{-1}yr^{-1}$ to 40t $ha^{-1}yr^{-1}$ (Pimentel, 2006). In developing countries, accelerated soil erosion is a serious problem and will remain too during 21st century (Lal, 2001). Pimentel (2006) estimated that on an average the ratio of soil erosion is the highest (ranging between 30 and 40t $ha^{-1}yr^{-1}$) in Africa.

Accelerated soil erosion by water is a critical problem for Ethiopia, where population is rapidly growing and extensive farming system is the backbone of the country's economy (Hurni, 1998). Hurni (1993) estimated that soil loss due to erosion by water from slopes amounts about 1493 million tons per annual, out of which 45% is from cropland only. He further estimated mean soil loss from cultivated fields about 42t $ha^{-1}yr^{-1}$.

The highest soil loss rates measured in Gojjam (North-western highlands of Ethiopia) due to combination of factors of high rainfall and erosivity, and intensive cultivation along with non conservation-based land management and cropping system (Mitiku *et al.,* 2006; Amdihun *et al.,* 2014). For example, based on the field assessment of rill erosion, Woldeamlak and Sterk (2003) indicated that the rate of soil loss from cultivated fields ranges between 18 and 79t $ha^{-1}yr^{-1}$ due to rill and sheet erosion in Chemoga watershed. By using the same method, Woldeamlak (2003b) also estimated around 37t $ha^{-1}yr^{-1}$ of soil loss due to rills and inter-rills from croplands in Digil watershed. Getachew *et al.* (2011) measured two years amount of soil loss of 141.9t ha^{-1} from experimental cultivated plots of Debre-Mewi watershed.

Others studies have estimated the rates of soil loss from cultivated plots in semi-arid environment of Ethiopian highlands. For instance, Desta *et al*. (2005) estimated the mean annual soil loss rate of 57t $ha^{-1}yr^{-1}$ by sheet and rill erosion from 202 plots in 12 representative sites of *Dogu's Tembien* district, Northern Ethiopia. Based on eight years (1982-1989) Soil Conservation Research Project (SCRP, 1996) data, Belay (2000) estimated the average rate of soil erosion by water as 35t $ha^{-1}yr^{-1}$ on cultivated slopes of South Welo Zone, North-Eastern Ethiopia.

In general, all those studies of soil erosion conducted in varied agro-ecology of the Ethiopian highlands endorse that the magnitude of soil loss is high and revealed urgent need of intervention in Soil and Water Conservation (SWC) practices. The basic paradigm and approach to soil and water conservation has developed through time. The Ministry of Agriculture of Ethiopia and international development agencies like World Food Program(WFP) have been invested considerable resources in encouraging and scaling up of SWC practices for curbing severe soil erosion by water (Gete *et al.*,2006). The practising of effective SWC measures should consider using interdependence between biophysical factors (erosivity, erodibility and slope) and land use patterns (Belay, 2000).

Numerous studies at micro-watershed level were estimated and agreed upon the substantial role of conservation practices(in particular stone bunds) in reducing the magnitude of soil loss in the semi-arid environment of Ethiopian highlands (Nigussie *et al.,* 2012; Desta *et al.*,2005; Gebeyehu *et al.*,2013; Nyssen *et al*.,2007; Nyssen *et al*.,2009). Moreover, few plot level studies indicated contribution of conservation practices in reducing soil loss in the high rainfall areas of Ethiopia highlands (Herweg and Ludi, 1999; Getachew *et al.,* 2011; Tadel *et al.,* 2014) with regardless to emphasis on the actual soil loss from cultivated fields, the principal units for evaluating the effectiveness of SWC practices by the farmers.

2.5. Effects of integrated soil and water management activities on improvements of crop yield and household income

The ability of sustainable agricultural production has been and continues to be a big concern on the global policy agenda, where accelerated soil erosion continues, and rampant human population and its requirements for food and other resources expand geometrically (Wild, 2003; Pimentel, 2006). The livelihoods of immense majority of the world's population in particular small-scale farmers that hold over 2.5 billion people, over 70% of whom live below poverty line directly depends on land resources, particularly soil and water (Hurni *et al*., 2008). Crop yield reduction of small-scale farmers could directly influence through soil erosion involving loss of water, nutrient, organic matter, biota and depth of soil. For example, about 10 million ha of world croplands were lost by erosion and thus reducing the cropland availability for production (Pimentel, 2006). The annual reduction in total crop yield due to accelerated erosion in 1989 was estimated at 8.3 million Mg of cereals, 9.2 million Mg of roots and tubers, and 0.6 million Mg of pulses in Africa and 3.6 million Mg for cereals, 6.5 million Mg for roots and tubers, and 0.36 million Mg for pulses in Sub-Saharan Africa (Lal,1995). He further forecast that if accelerated soil erosion continues unabated, yield reduction by the year 2020 maybe 16.5% for the continent of Africa and 14.5% for Sub-Saharan Africa. By the year 2020, indeed soil erosion could be severe threat to food production in the continent, in particular in densely populated pockets of rural poverty (Scherr and Yadav, 1996), where crop yield gaps are among the largest in the world(Pretty *et al.,* 2011; Tittonell and Giller, 2013).

In Ethiopia, accelerated soil erosion by water accompanied with nutrient depletion has posed a series threat to reduction of potential agricultural yield and the area under cultivation due to potential drops below a threshold value, where crop/livestock production is the major source of smallholder household income (Sonneveld, 2003; Tilahun, 2003; Hurni *et al*., 2010). Sonneveld and Keyzer (2003) estimated that soil erosion by water reduces the potential production of the land by 10% in 2010 and by 30% in 2030. Thus, the value added per capital per annul in the agricultural sector drops from US$ 372 in 2000 to US$ 162 in 2030, which is below the poverty line as defined by the world bank (income of less than one US$ day^{-1}). As Hurni (1993) estimated, an average soil loss of 42t $ha^{-1}yr^{-1}$from cropland results annual production loss between 1 and 2%.

Before reaching beyond a certain threshold level of soil degradation thus to impede production, relevant agro-ecological based integrated SWM activity with combined use of improved crop seed varieties is quite indispensable (De Vries *et al*., 2008; Pretty *et al.*, 2011) in the Ethiopian highlands. The basic paradigm and approach to Soil and Water Conservation (SWC) has itself developed through time. The Ministry of Agriculture of Ethiopia and international development agencies like World Food Program (WFP) have been invested considerable resources in encouraging and scaling up of SWC practices as a part of efforts to ensure sustainable agricultural production through enhancing environmental condition (Tilahun *et al.*,2007). In relation to this issue, various studies have conducted in diverse agro-ecology of the Ethiopian highlands to assess whether the introduced physical SWC activities contribute to crop yield improvement or not. In the semi-arid environment of the Ethiopian highlands, numerous plot experiment studies found plots with structural measures are more productive than those without since availability of soil water is a principal limiting factor for crop yield (Menale *et al*., 2007; Kato *et al*., 2009; Hengsdijka *et al*., 2005; Vancampenhou *et al*., 2006; Pender *et al*., 2002; Nyssen *et al*., 2007).

In the high rainfall areas of the Ethiopian highlands, however, different studies found contradictory results. On the one hand, some social studies found that the value of crop production for fields with structural measures was lower than for fields without. Menale *et al.* (2008) stated older bunds (*Fanya-juu*) correlated with a decline in average crop value of $19.00 (ETB 160) and a new bund yielded a $21.00 (ETB171) decline. Bekele and Holden (2001) added investment costs did not improve the increasing gains from conservation as long as cropping land occupied by structures remains underused. Zenebe *et al.* (2012) also mentioned that soil bund do not increase crop yield instead even reduce by about 7% ha^{-1} since the reduction of the cropping area by 8-6% ha^{-1} attributable to construction of soil bunds.

On the other hand, long term maintenance of structural measures (like stone/soil bunds, *Fanya-juu*) is crucial to reap positive gains in value of crop yield and hence risk reduction (Kato *et al*., 2009; Gizaw and Hurni, 2011). If the household continues to maintain structural measures from 7 to 15 years, the expected value of production increases ranges from 2-13% (Schmidt and Fanaye, 2012). Getachew *et al*. (2011) reported that plots with *Fanya-juu* with elephant grass (315.9gm^{-2}) and *Fanya-juu* with vetiver grass (309.6g m^{-2}) were produced significantly higher yield than plots with not-conserved(207.9g/m^2). Yihenew *et al*. (2009) concluded that mean value of barley grain and straw yield were significantly ($p<0.05$) lower in non-conserved fields than all other 6 to 9 years old structurally or bio-physically conserved fields. These inconsistency findings in humid environment of the Ethiopian highlands call for further investigation.

2.6. Conceptual framework

Conservation efforts thoroughly weighted in favor of physical aspect of the watershed with seldom pay attention to institutional and socio-economic context are more likely resulted in persistence severe land degradation and accordingly threatening subsistence livelihoods of smallholder farmers (Pimentel and Kounang, 1998). The weak inter-linkage of strategies as well as inconsistency relationship of multi-actors further disgraced the institutional capacity and negotiation of farmers on soil and water management (SWM) program (Bryant and Bailey, 2005). To address these problems, SWM programme that should be inclusive of physical, institutional and socio-economic aspects of the catchment is fundamental (FAO, 2006). Integrated SWM approach is the process of formulating and implementing the course of action involving natural and human resources in the catchment to achieve specific environmental and socio-economic objectives (Stocking and Murnaghan, 2000; Sharma *et al*., 2005). It is vital for subsistence farming sustainability in terms of both production and environmental conservation that should rely on maximizing the ecological and socio-economic synergies, and minimizing the conflicts' among them (Stocking and Murnaghan, 2000; German *et al*., 2012).

Integrated SWM approach including intensification and diversification of subsistence crop-livestock mixed farming activities is fundamental in the highlands of Ethiopia in general (Woldeamlak, 2003a) and in the study area in particular, where the accelerating rate of land degradation under ever increasing populations' pressures (Sonneveld and Keyzer, 2003) is more likely results to have susceptible livings of subsistence farmers. Therefore, in such circumstances, this study assessed the practicing process, farmers' acceptance and adoption, and socio-ecological outputs of integrated SWM approach. To look at this, the schematic representation of conceptual framework outlined. The conceptual framework should sketch in an attempt to indicate the overall skeleton of the study that was encompasses different interrelated relevant issues. It sketched out through the intricate relationship between independent variables of varied pertinent issues and practicing integrated SWM activities, and then effects of the activities on combating soil erosion, and improving crop yield and household income.

The analysis of this study began to make sure whether farmers' priority problems, objectives and their knowledge and experience of land resources' management more likely consider in the identifying, designing and implementation of ISWM practices. In an attempt to create good atmosphere of integrated practicing processes, developing awareness, and agreement between farmers and extension staffs ought to give priority. This in turn opens track for best bet practices of relevant SWM technologies for effective achievement of goals of conservation and smallholder farmers. At the end of a particular phase of the process, farmers' decision to adopt and use integrated SWM activities may be influenced by physical (plot level and technical) and socio-economic attributes at individual household level and external influences (institutional factors). Addressing farmers' priorities and objectives may be the key to triggering further capacity of integrating SWM activities and consequently more likely effects on reducing soil loss, increase fodder, crops yields and then household income. The diagram representation of analytic framework sketched as follows.

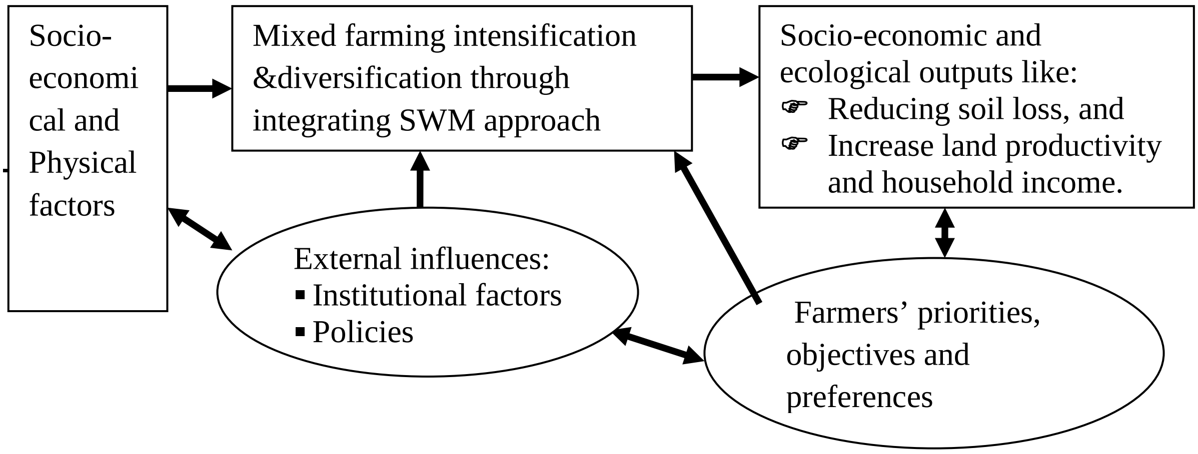


Figure-1: Conceptual Framework
Sources: Adapted from Ashley and Hussein (2000)

CHAPTER THREE

MATERIALS AND METHODS

3.1 Description of the study area

Goncha-Siso-Enese Woreda lies between $38^{0}\ 0^{'}12.2^{''}$ and $38^{0}\ 23^{'}46.2^{''}$ E longitudes, and $10^{0}\ 46^{'}11.6^{''}$ and $11^{0}\ 9^{'}31.9^{''}$ N Latitudes (figure-2a). In administrative terms, it is located in the East Gojjam Zone of Amhara National Regional State, lying in North-Western part of Ethiopia (figure-2b). It covers about 1038.81 square kilometers (sq km) of the surface area. The geological characteristic of the woreda is categorized by tarp series volcanic rock formed during Cenozoic era. The major land forms include flat, gently sloping to slightly dissect undulating plain, rugged and dissected plateau, high mountainous hills and gorges. Elevation in the Woreda ranges from 1400m to 3400 m above sea level with mean altitude 2400m. The mean annual rainfall amount (from 1994 to 2013) in the Woreda vary from 1326.5mm (at Gindewoin town) to 917.9mm (at Blue Nile canyon). Spatial distribution of mean annual rainfalls was estimated by interpolating a raster surface from point's discrete data (average value of monthly rainfall records from *Debrework, Gindewoin, Motta, Felege-birhan and Wegada stations* in proximity to the study area), using Arc GIS-version-10.2 software.

The total population of the Woreda is estimated about 159,735, of which 79,359 males and 80,376 females (CSA, 2013) implying that 49.68% are males and 50.32% are females. Population density is estimated 153.76 people per km^2. Sex ratio (females per 1000 males) is estimated about 1013, of which 1185 in urban (Gindewoin) and 1004 in rural. Moreover, in the Woreda, about 8,403 are urban inhabitants (3,846 males and 4,557 females) and 151,332 are rural inhabitants (75,513 males and 75,819 females).

Goncha- Siso-Enese Woreda is situated about three agro-ecological zones such as tepid moist mid-highland, cool moist highlands and warm moist lowland, which are equivalent to Ethiopian agro-ecological zones of *Woina-Dega*, *Dega* and *Kola*, respectively. In the *Woyina-Dega* agro-ecological zone, Tef, Wheat, Barley, Maize, and leguminous crops such as pea, horse bean, chickpea and others are growing. Tef and wheat are predominantly grown crops among the others.

In the *Dega* agro-ecological zone (above 2800m elevation of cool moist highlands) barley & potato are chiefly produced**.** However, degradation and soil acidity may be series problems in the hills. Moreover, poor market access likely increased household food insecurity.

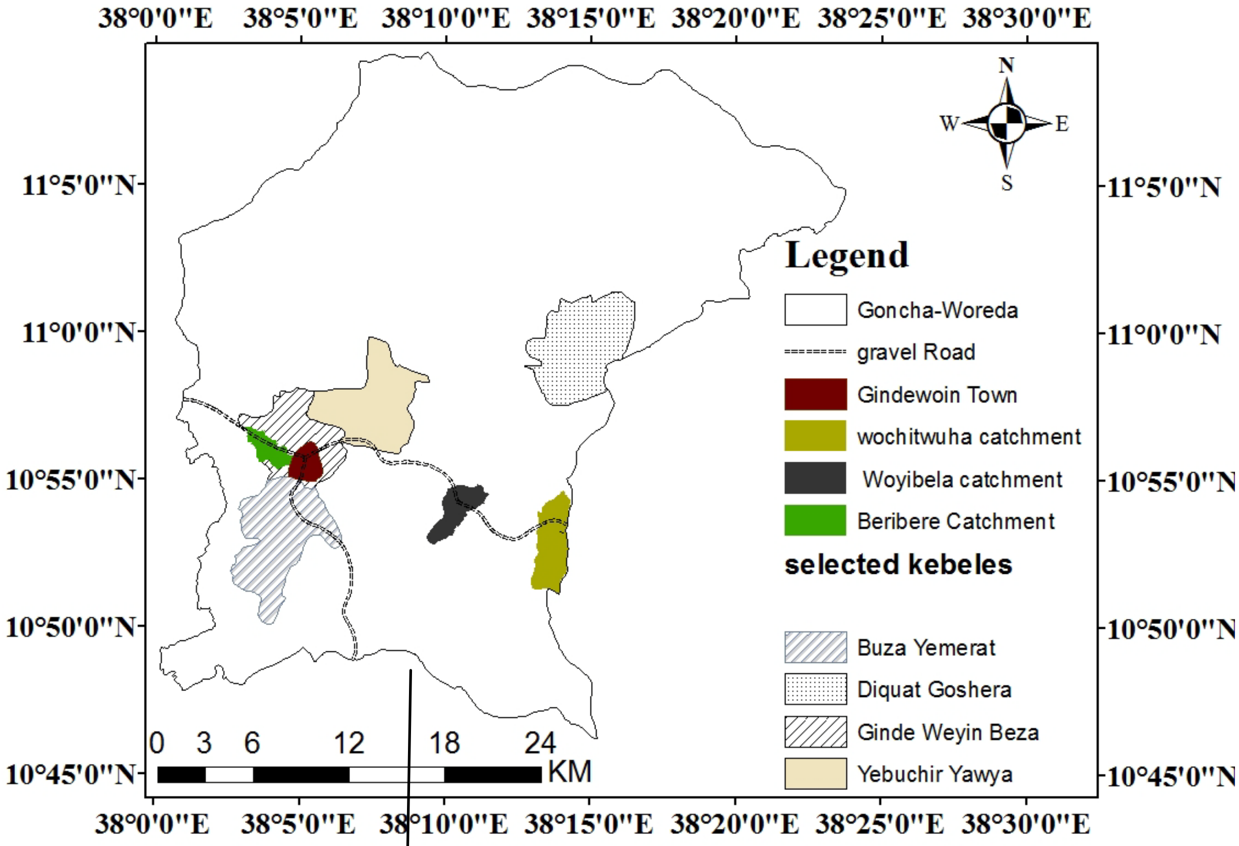


Figure-2a: Selected catchments and kebeles in the Goncha-Siso-Enese woreda

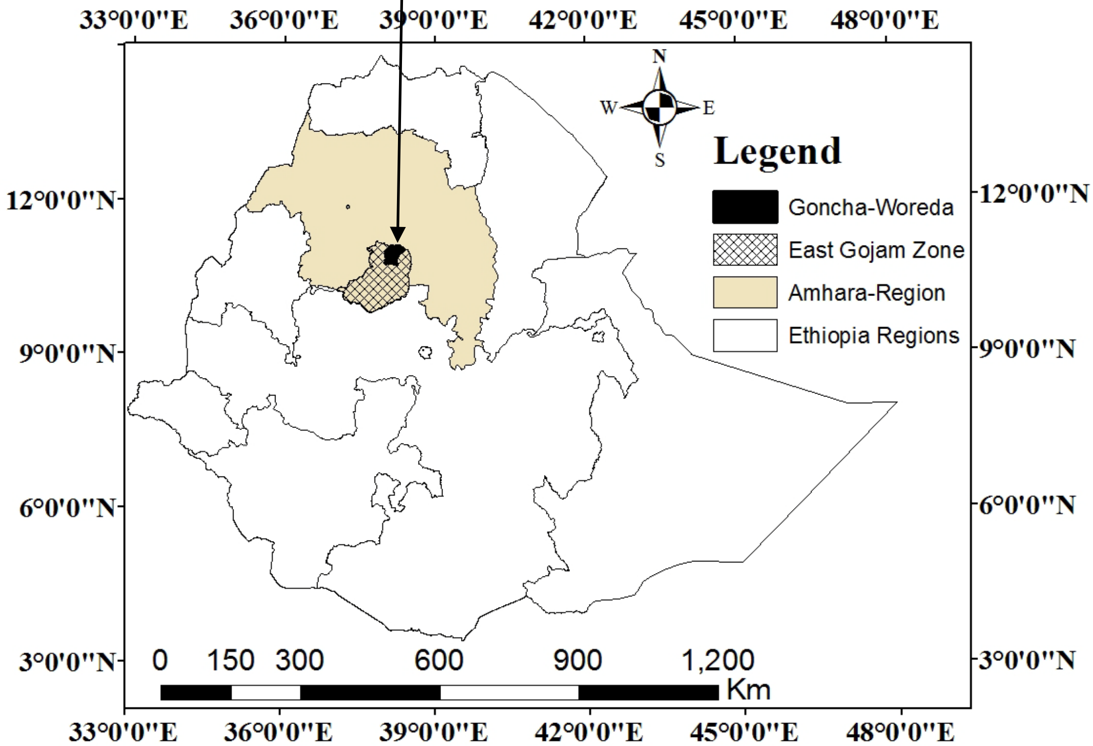


Figure-2b: Location of Goncha-Siso-Enese Woreda in the administration map of Ethiopia

In the *Kola* (warm moist lowland) agro-ecological zone, agricultural production is suffering (Rami, 2003) that perhaps from erratic rains, small landholdings, and severe ecological degradation. Local labour and firewood/charcoal/ sales are alternative means of the farmers to meet their food needs. Moreover, in the *Kola* agro-ecological, market accessibility is limited due to remoteness and inaccessible. Mixed farming activity is the prominent livelihoods' sector in all agro-ecological zones of the *Woreda*.

Under the study Woreda, for issues discussed in chapters' four, five and eight, three catchments i.e. *Woyibila*, *Beribere* and *Wochit-wuha*, purposely chosen out of the seven catchments, where there are the prevalence of conservation efforts since more than ten years. The identification of the study sites was mainly based on the existing situations i.e. the proximity of the catchment to market centre and residential areas, cropping pattern of particular catchment and practicing status of SWM activities in a catchment. For issue presented in chapter seven, Beribere catchment selected. In absolute location, Beribere catchment is located between from $38^{0}3^{'}4.3^{''}$ to $38^{0}4^{'}49.8^{''}$ E longitudes and from $10^{0}55^{'}19.1^{''}$ to $10^{0}56^{'}46.2^{''}$ N latitudes. Woyibila catchment situates between $10^{0}52^{'}48^{''}$ and $10^{0}54^{'}51.23^{''}$ N latitudes, and $38^{0}9^{'}21.6^{''}$ and $38^{0}11^{'}31.1^{''}$ E longitudes. Wochit-wuha found between from $10^{0}51^{'}8.52^{''}$ to $10^{0}54^{'}38.71^{''}$ N latitudes and from $38^{0}12^{'}57.2^{''}$ to 38^{0} $14^{'}19.7^{''}$ E longitudes (see figure-3).

The study sites mainly situate in the moist sub-tropics (locally named as *Woina-dega*) agro-ecological zone, where high annual rainfalls and moderate temperatures record. The mean elevations of the catchments are 2595.5 m a.s.l. in *Beribere*, 2677m a.s.l. in *Woyibila* and 2471m a.s.l. in *Wochit-wuha*. The estimated mean annual rainfall distributions in the catchments are ranging from 1326.2 mm to 1300.5mm in Beribere, 1164.6mm to 1208.1mm in *Woyibila*, and 1052.1mm to1117.3mm in *Wochit-wuha*. More than three-fourth percent of the total rainfall in all study sites occur in the summer season (June, July, August, and September). The soils colour that covers large area of the selected study sites is reddish soils. Moreover, greyish brown colour soils covered large area of Wochit-wuha catchment. *Woyibila* and *Wochit-wuha* catchments are largely composed more dense settlement than *Beriberi*. *Beriberi* catchment locates more close to market centre (*Gindewoin* town) than others. In all catchments, under the mixed farming systems of smallholder community, tef (Eragrostis tef) and wheat (Triticum vulgare) are predominantly grown. After that, Niger seed (*Guizotia abyssinica) in Beribere;* maize (*zea mays*), barely (*Hordeum vulgare*) and Niger seed (*Guizotia abyssinica) in Woyibila;* and legume crops like horse beans (*Vicia faba*) and pea (*pisum sativum*), barely (*Hordeum vulgare*), maize (*zea mays*) and Niger seed (*Guizotia abyssinica*) in *Wochit-wuha* are grown.

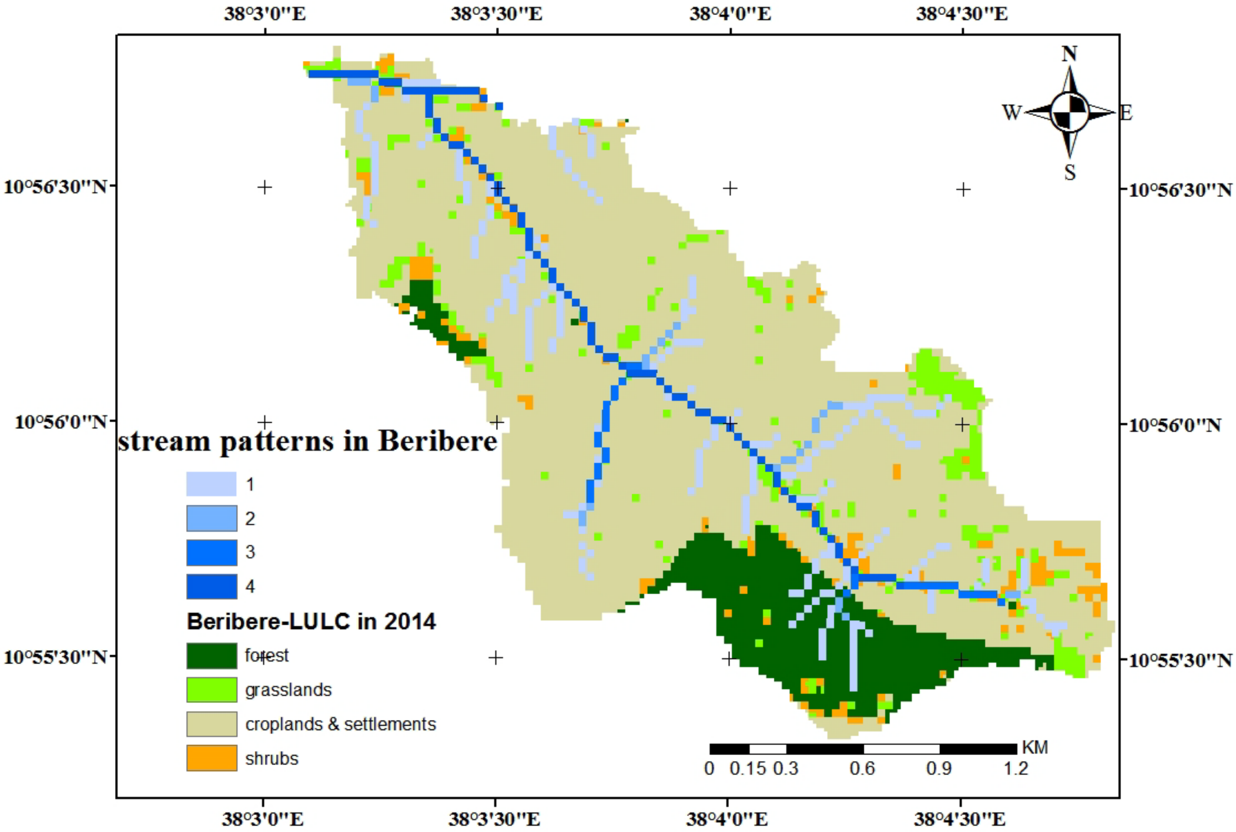


Figure-3a: Stream patterns and land use/covers' distributions in Beribere catchment

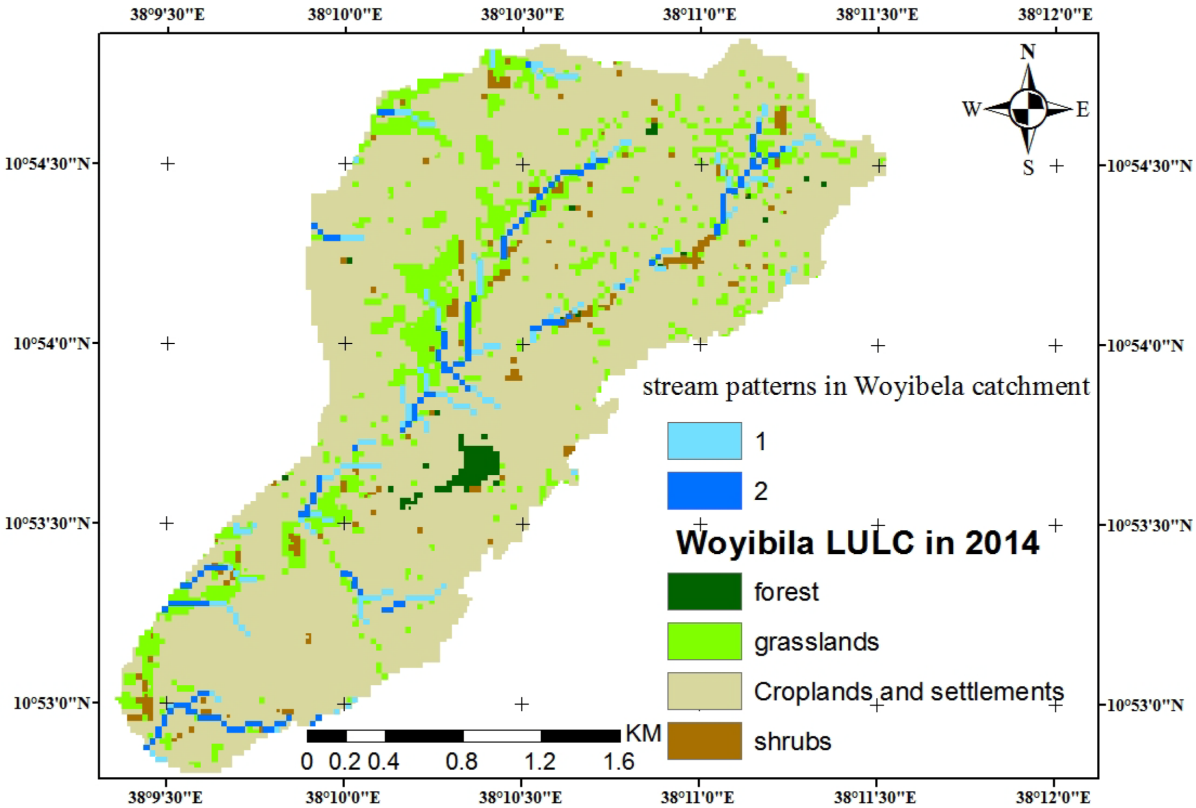


Figure-3b: Stream patterns and land use/covers' distributions in woyibela catchment

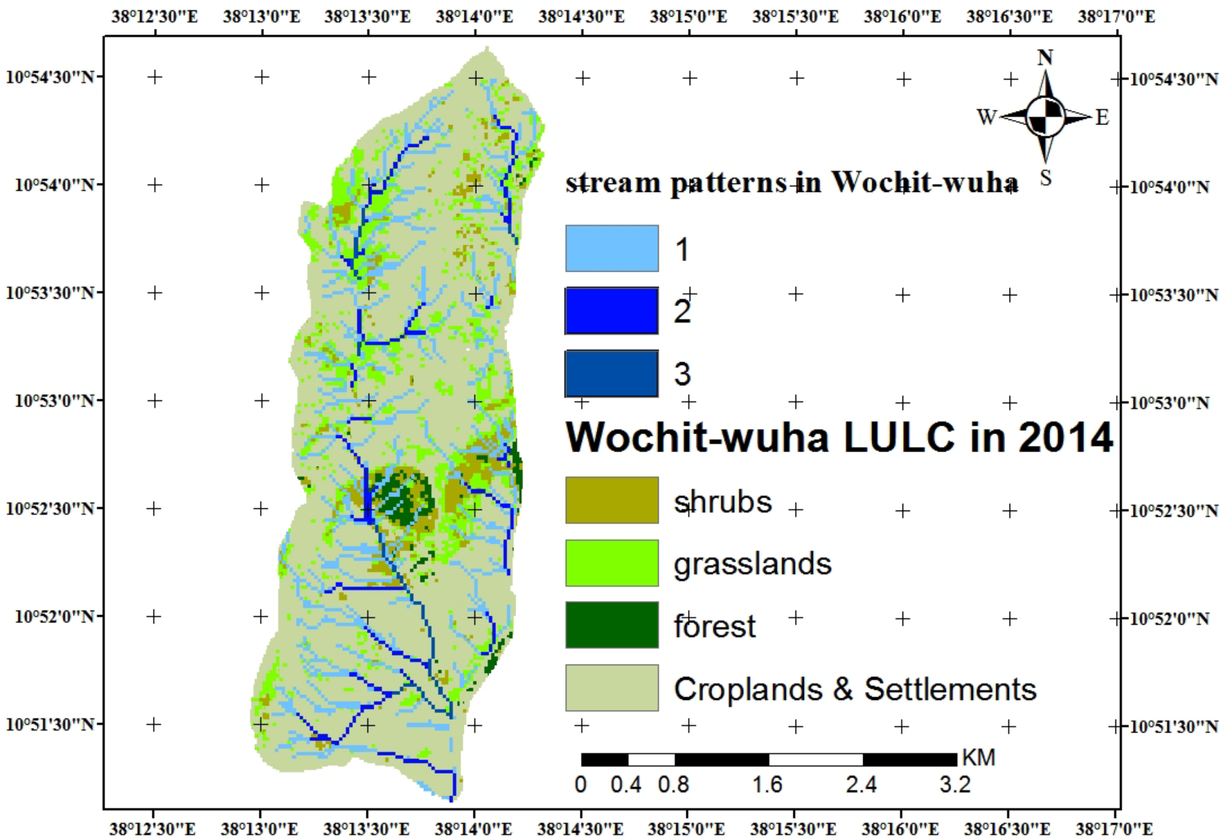


Figure-3c: Stream patterns and land use/covers' distributions in Wochitwuha catchmnet

The total areas of *Beriberi*, *Woyibila* and *Wochit-wuha* catchments estimated about 389.9ha, 650.5ha and 1068.7ha, respectively. In year 2014, the major land use/cover types in the study areas are croplands and settlements, grasslands, shrubs and forests (figure-3). The distribution of those major land use/cover types (in ha) by catchment are displayed in Table-1.

Table-1: Distribution of major land use/covers in ha(%) by catchments in 2014

Types of land use/covers in 2014	**Study Sites**		
	Beriberi	Woyibila	Wochit-wuha
Croplands & Settlements	302.95(77.7)	545.77(83.9)	622.9(58.3)
Grasslands	23.78(6.1)	83.26(12.8)	149.62(14)
Shrubs	14.43(3.7)	14.96(2.3)	73.74(6.9)
Forests	48.74(12.5)	6.51(1)	22.44(2.1)
Total	389.9(100)	650.5(100)	1068.7(100)

3.2. Methodology

3.2.1. Philosophical foundation of the study

Philosophical stance for this study upon critical realism that acknowledge the ontological independence of the biophysical world while at the sometime recognizing that people understanding of the natural world (knowledge) is partial, situational and contingent (Neumann,2005). In accordance with this, in attempt to add knowledge, this study was established ontological premise regarding the existence of integrated SWM approach and its socio-ecological implications are outside of people's perceptions and knowledge. Thus, the epistemological view of the study dealt with the way integrating of various SWM practices with smallholder farmers' livelihoods. Realizing this, the research designs based on pragmatic knowledge claim that come up with actions, situations and consequences (Crotty, 1998). This opens the door for employing mixed design that integrates both quantitative and qualitative approaches.

3.2.2. Research designs of the study

For this study, mixed design used as it opens the way to look at different quantitative and qualitative methods of data collection and analysis (Crotty, 1998). On the one hand, from deductive perspectives, through administering survey of the sample (Creswell, 2009), providing numerical description for socio-economic and household characteristics of the farmers and predicting of the influence of independent variables on dependent variables, as well as inspecting the effect of integrated SWM activities on socio-ecological outputs through comparative analysis of spatial difference were included. On the other hand, from inductive approach perspective, phenomenological design was employed to explore an in-depth information (Cloke *et al*., 2004) pertaining to farmers views and perceptions towards practicing and possible effects of integrated SWM activities within the local community setting and land-use system. In general, for this study, mixed design was depended upon appropriate integration of different methods on the same issue, problem, and query to conduct realist research (Yeung, 1997). Accordingly, triangulation method applied while realizing the soundness of the data collected and analysed. Moreover, quantitative data intended to substantiate with qualitative data. Mixed sampling design incorporating purposive and probability sampling techniques was employed. Methods of data collection and analysis described separately for each objective as follows.

3.2.3. Methods of data collection

a. *Observation and measurements*

Observations through transect walks across the study Woreda and catchments carry out. This was important to obtain background information on the farming system, and practicing and adoption patterns of SWM activities. Field observations and measurements (using meter or tape and clinometer) also conduct to identify attributes associated with the technical character of both indigenous and introduced conservation measures. These techniques use to assess land use types, soil properties (including soil colour, depth and texture), slope length and gradient of indigenous practices (drainage ditches), and status and function of various SWM activities (structural, agronomic and vegetative), erosion indicators (broken terraces and traditional ditches, rills, sheet wash, deposition occurrence, presence of surface run-off entering into the fields from up-slope areas). Recording of land use types and conversion techniques, and gully developments and their associated factors observed. Moreover, during the cropping seasons field observations made concerning crops growth and biomass variability within terraces, and practices of different income generating activities.

b. Informal interviews

Informal discussions with farmers conducted at working on their farm plots in the selected catchments. In the interviews open-ended questions used to gather information on practicing process and performance SWM activities; factors influencing CPRs dynamics and management schemes of CPRs; soil erosion indicators and magnitude on terraced and non-terraced fields; and the overall situation of the components of conservation efforts' contribution to enhance land productivity to crop variety and yields.

c. Satellite images acquiring

Frequent and accurate ascertaining of LULC by using remote sensing data is important to understand primarily the degree of interaction between social system and ecological characteristics of CPRs (Xie et al., 2008). The selection of satellite images, acquired by using adequate sensors, is mainly determined by mapping objectives, climate condition and technical issues for image interpretation. Landsat TM (Thematic Mapper) image of year 1986, ETM +(Enhanced Thematic Mapper Plus) image of year 2000 and Landsat-8 Operational Land Imager (OLI) image of year 2014 ranging from 15 to 30m spatial resolution were obtained from United State Geological Survey (USGS)-Earth Resources Observation Systems (EROS) (http://glovis.usgs.gov). Cloud-free satellite imagery data, January/1986, 2000 and 2014, Path 169 and Row 052 satellite images acquired to assess the patterns of dynamics of land use/covers in Goncha-Siso-Enese Woreda.

Moreover, secondary data on background information of each kebeles like livestock and human populations, and number of farmers who hold common resources for their private use obtained from the Woreda land use and administration offices.

c. Formal interviews

To generate data concerning practicing process, acceptance and adoption of components of integrated SWM activities, formal interviews with Woreda and Kebele extension agents, and watershed committee carryout from September to October/ 2015. Open-ended questions prepared for respective stakeholders addressing the issues that pertinent to their mandate and status. The questions focused on the issues of participation and perceptions of stakeholders and implementation process of SWM practices (see Appendix-II). The relevant background data directly related with the issues gathered from unpublished reports available in Woreda agricultural bureau, Kebele’s administration and Developmental Agent (DAs) offices.

Considering analysis of satellite images as background information, four kebeles namely *Buza-Yemerate, Gindewoin-Beza, Dequate-goshera and Yebuchir-yewoya* (see figure-2a) selected to generate primary data. These selected study sites consider as typical representatives in terms of magnitude of dynamics and coverage of CPRs (natural and afforested forests, shrubs and grasslands) in the Woreda (see figures-7abc) for participatory evaluations of relative importance of criteria and performance of existing management schemes for the sustainable use of CPRs. To generate information, participatory key informant interviews also conducted from April to May /2015, with 24 farmers (6 farmers from each of the 4 kebeles) selected with respect to their age, wealth status and proximity of resident areas (very close and far) to the CPRs. The farmers (local CPR resources users) approached to participate in the open discussions on evaluation of CPRs management schemes. Additional interviews were conducted with 12 practitioners (including DAs, kebele leaders and heads of CPR regulating committee in each Kebele) and 3 Woreda experts (forester, SWC expert, and land administration expert). Almost all informants asked to discuss the issues of spatial characteristics of CPRs and associated driving factors, in generating and assigning the importance of criteria and indicators to evaluate the existing use and management schemes of CPRs, and in settings of alternative management scenarios for the sustainable use of those resources. The interviews conducted using open ended and semi-structured guiding tools (see appendix-VIII).

d. Focus group discussion

Three focus group discussions (members in Wochit-wuha [n=11], in Beribere [n=8] and in Woyibila [n=9]) held in February 2015. Participants in the discussions purposely selected through considering heterogeneous characteristics in socio-economic, plot and technical levels, and institutional factors. All participants in the discussions had implemented all identified SWM alternatives at their farmlands. Open-ended questions and prearranged structural questionnaires prepared to address the discussions. Focus group discussions conducted on the issues of participation of stakeholders, identifying criteria in accordance with the formulated objectives of the implemented SWM alternatives, relative importance of identified criteria and practised SWM alternatives, and constraint conditions of the sustainable use of these practices (see Appendix-II).

f. Household surveys

Household surveys undertaken to gather information on respective issues of farmers' decision to use ISWM activities and effects of integrated SWM activities on crop yields and household incomes. In the survey, from the selected catchments a systematic random sample of 189 farming household heads, proportionately 155 from adopter and 34 from non-adopter of terracing involved to generate information on decision to use ISWM activities (Table-2).

Table 2: Sample size allocations

Name of Catchments	Frequency of Household Heads			Allocated Sample Size (10%)		
	Adopter	Non-adopter	Total	Adopter	Non-adopter	Total
Beribere	271	71	342	27	7	34
Woyibila	381	41	422	38	4	42
Wochit-wuha	902	232	1134	90	23	113
Total	1554	344	1898	155	34	189

Source: Kebeles' DAs Offices, 2014

Cultivated fields with terraces age less than four years and greater than six years, 150 farm household heads who grow tef and wheat crops were selected by using a systematic random sampling to gather information concerning effects of ISWM activities on crop yields and household income. The sampling was done using a list obtained from kebeles' land use and administration, and DAs offices. Every eleventh household heads (fields' owners) on the list was incorporated in the sample. Sample allocation was listed in Table-3.

Table-3: Sample allocation mechanism

Catchments	Numbers of fields treated with ≤3 years age terraces		Numbers of fields treated with ≥7 years age terraces		Total
	Tef cropped	Wheat cropped	Tef cropped	Wheat cropped	
Beribere	38(3)	33(3)	117(11)	105(9)	293(26)
Woyibila	55(5)	47(4)	145(13)	132(12)	379(34)
W/t Wuha	140(13)	125(11)	381(34)	353(32)	999(90)
Total	233(21)	205(18)	643(58)	590(53)	1671(150)

Source: kebeles' land use and administration, and DAs Offices, 2014

Note*:*

- *For this study, cultivated fields treated with terrace age from four to six years were considered as intermediate stage for land productivity and hence not included in sampling,*
- *Values out and in parentheses represent population and sample sizes of fields' owners, respectively.*

To conduct formal household survey, three enumerators chosen. The researcher gave orientations to the enumerators regarding the administering of the questionnaires. Thus, the enumerators accompanied by close supervision of the researcher undertaken face to face interviews with all the sampled farmers using prearranged and semi-structured questions from December 2014 to February /2015. The persons interviewed at home, or where were farmlands, when available at church or assembly area.

In order to reduce response bias of under or over report crops (wheat and tef) grain yield due to perceiving of incentives or personal costs, respondents informed to recognize that their responses mainly required for academic purpose only.

Prearranged and structured questionnaire use to the household surveys. The instrument contain components of SWM practices and factors of socio-economic, institutional, and technical and plots characteristics, was prepared that put to pilot terms for essential modifications (see Appendix-III). Issues like area of crop land (in ha), perceived fertility status and slope categories of the fields, the type of crops sown in the successive years, types and degree of practised SWM activities, agronomic practices of tef and wheat crops growing, costs of inorganic fertilizers, and amount of harvested grain yields of a particular field in which Tef and wheat crops in pure stand grown also incorporated in the questionnaire (see Appendix -X). Moreover, perceived change of household income, total size of farmlands (in ha), holding size of productive trees and shrubs planted, and pastures fields (in ha), irrigated crop fields (in ha), number of productive labour, number of bee hive, off-farm income, financial credit access and total number of livestock included (see appendix-X).

g. Rill survey

Sample form of 24 representative cultivated fields (commonly identified as infertile and steeply sloping) under terraced and adjacent non-terraced zones selected in reference to relative topographic positions in the valley sides and fields covered with principal crops (Tef and Wheat) in the catchment (Table-4) for rill erosion (commonly recognized erosion indicator by the local farmers) survey.

Table-4: Distributions of surveyed fields by topographic position in the valley sides, conservation status and type of principal crops cultivated in the *Beriberi* catchment

Topographic positions in the valley sides	No. of cropped fields of terraced zone		No. of cropped fields of non-terraced zone		Total
	Tef	Wheat	Tef	Wheat	
Up-slope	3(9,200)	2(8800)	2(6600)	1(2600)	8(27,200)
Mid-slope	4(13,200)	3(10,000)	2(8000)	2(6100)	11(37,300)
Down-slope	2(5000)	1(2500)	1(2000)	1 (2500)	5(12000)
Total	9(27,400)	6(21,300)	5(16,600)	4(11,200)	24(76,500)

Source: Field survey, 2015

Note: Values in parentheses represent total surface area of the surveyed fields in m^2

The total area of the selected fields was 76,500m2, which is equivalent to 7.65ha (Table-4), about 1.96 % of the total area of Beriberi catchment [389.9ha] (Table-1).

From the selected fields, measuring and recording of the fields' area and rills in the fields undertaken in the presence of cropland owners and sometime DAs as well. Rill survey conducted in different period of the growing season to increase the reliability of the data. First, frequent visits undertaken to identify and measure the rills before planting by crops i.e. between mid-June and early July/ 2015. Second, during early growing season, between end of July and beginning of September/ 2015 frequent visits performed to identify the prevalence of rills following surface area covered with crops. Last, rapid and timely measurements of rills made between mid-November to end of December /2015, before disappearance of rills due to farming practices like free grazing and tillage following crop harvesting from the fields. Section of traditional ditches that washed run-off accompanied with uncovered crop seedling were also identified, numbered and measured as rill.

In field assessment of rill erosion, detailed measurements of length, and cross-section of rills using tape are considered (Stroosnijder, 2005; Casalı´ *et al*., 2006). Hence, for a study rills identified and numbered, and their depths, widths and lengths measured by using tape meter. To assure the precision and reducing potential error from total volume estimation, measurements of depth and width of each rill channel along its length (Herweg and Ostrowski, 1997) carried out. Measurements repeated and averaged with emphasis on keeping track of the actual shape of the rill (often a point of changing width and depth of rill) as widths and depths of rills are seldom constant throughout the length. Moreover, the widths and depths of rills measured up to 3 times and averaged at a point due to the occurrence of different values. The length of a rill taken between the origin area of rill formation on up-slope and on the lower slope where main rill disappeared due to occurrence of sedimentation and confluence with other rills.

3.2.4. Methods of data analysis

Descriptive statistic and discourse analysis methods employed to analyse data generated using qualitative methods.

Multi-criteria analysis method used to evaluate the identified criteria and decision options concerning SWM alternatives. Multi-criteria analysis method is useful to accommodate diverse views and interests reflected from multiple stakeholders who provide feedback concerning the consistency of judgment made on the relative importance of each criterion, and aggregated evaluations made by all participants arrive at a consensus (Mendoza *et al*., 1999). A set of SWM alternatives practised in the area, and their identified objectives and evaluative criteria identified through the FGDs in each catchments and interviews made with extension staffs (DAs) and watershed committee. Based on the framework of identified objectives, the nine evaluative criteria were refined and determined. Assigning criteria weight has been one of the most popular procedures in the multi-criteria analysis method for determining the relative weights of each criterion (Ananda and Herath, 2006). Hence, each participant in the discussions asked to assign a relative weight to each criterion depending upon the perceived importance of the decision element using predetermined point of scale. In this study, four point scales were used: 1= less important; 2=moderately important; 3= more important; and 4= extremely important. Based on these ranked values, the average weight of the criterion considered to accommodate the diverse views and opinions of the participants on the relative importance of the criteria. The normalized weight for j^{th} criterion calculated as the ratio of the total scores of individual criterion to the grand total for all criteria or average value of individual criterion to sum average of all criteria (Zanakis *et al*., 1998; Mendoza *et al*., 1999).

Suppose that ranking responses obtain from n-participants in the discussions, if the n-participants assign rj1, rj2 ..., rjn criterion can calculate as:

$$W_j = \frac{\sum_n r_{jn}}{\sum_j \sum_n r_{jn}} \text{ or } W_j = X_j / \Sigma X_j \quad ,\ldots\ldots (eq.1)$$

Where:

Wj is the normalized weight for j^{th} criterion,

$\sum_n r_{jn}$ is the sum of farmers valued for jth criterion

$\sum_j \sum_n r_{jn}$ is the farmers valued grand sum of criteria

or Xj is the average weight for the j^{th} criterion, ΣXj is the sum of the average weight for all criteria.

Sets of nine criteria employ to be the basis for the evaluation of commonly practised SWM alternatives. Thus, with respect to criteria of cost requirement to invest, and short-term and long-term returns in ecological and socio-economic aspects, the practised different SWM alternatives evaluated through giving ranking scores. As scoring is highly sited specific, farmers point of view on cost requirements and multifunctional character of each component of SWM practices is fundamental to identify which is /are categorized under the most beneficial and the least cost oriented in the short-run as well as in the long-run(positive ideal).

Hence, the participants evaluated the performance of component of integrated SWM alternatives through giving the values of 4= very favourable performance; 3= acceptable; 2= Poor performance; 1= very weak performance. Thus, a higher value (point score) indicates that the criterion has greater importance in a respective SWM alternative. This means that the scores represent the perceived level of importance of each SWM alternative with respect to the criteria defined. Technique of Order Preference by Similarity to Ideal Solution (TOPSIS) used as multi-criteria analysis method of farmers' preferences of different SWM activities with respect to economic, social and ecological criteria (Liu *et al*., 2006).

TOPSIS method is the best option to select the SWM alternative that is the closest to the ideal alternative (the one that has the best level for all considered criteria) and farthest from the negative ideal alternative (the one that has the least value for all considered criteria) (Jahanshahloo *et al*., 2006). According to Shiha *et al*. (2007) merits of using TOPSIS method includes a sound logic that represents the rationale of human choice, a scalar value that accounts for both the best (multiple functions) and worst (the least functions) alternatives, and for any two dimensions, the performance measures for all alternatives can be visualized on a polyhedron. Some authors used such method to evaluate soil and water management technologies (Ghanbarpour and Hipel, 2011). According to Chen and Hwang (1992), the procedures of TOPSIS express in a series of steps:

1. Let xij be the score of alternative i with respect to criterion j, we have a matrix X= (xij) m*n matrix. Let J be the set of benefits attributes or criteria (more is better), and J' be the set of negative attributes or criteria (less is better).
2. To transforms dimensions of various attributes into non-dimensional attributes which allows comparisons across criteria and to normalized average scores data:

   $$Nij=xij \Big/ \sqrt{\sum_{i=1}^{m} x^2 ij}, \quad i=1,......,m,\ j=1,........,n. \qquad \text{(eq.2)}$$

3. A set of weights for each criterion wj for j=1,......,n; to construct the weighted normalized decision matrix: vij= wj*nij ....(eq.3).
4. To determine the positive ideal and negative ideal attributes:

   Positive ideal: A*= {v1*,.......,vn*}, where vj*={max(vij)if $j\in$ J; min(vij)if $j\in$J'}

   Negative ideal: A'= {v1,.......,vn'}, where v'={min(vij) if $j\in$J; max(vij) if j $\in$J'}
5. To calculate the separation measures for each alternatives (practices):

   $Si^*=\sqrt{[\Sigma(vj^*-vij)^2]}$ = 1,......,m and $Si'=\sqrt{[\Sigma(vj'-vij)^2]}$ = 1,......,m .... (eq.4)
6. To calculate the relative closeness to the ideal contribution Ci*

   Ci*=Si'/ (Si*+Si'), 0<Ci*<1.. (eq.5)

Data concerning farmers' decision to use integrated SWM activities, which gathered through structured questionnaire survey organized in tabular and diagrammatic form. After that, it was analyzed using descriptive statistics (percentage, mean, cross tabulation, chi-square test, t-test). Correlation matrix also employed to check for high inter-correlations or multicollinearity among the predictor variables. Moreover, binary logistic regression model, using maximum likelihood estimation, employed to estimate the key influential factors on farmers' decision to adopt introduced activities (terracing, composting) and to use indigenous activity (LCCR), and then combine use of these practices in a cropland, by applying Statistical Package for Social Scientists (SPSS), Version 20. Binary logistic regression model was used when the dependent variables of only two categories (adopter/ non-adopter or user / non -user) are dichotomous/ categorical/ and independent variables are continuous [non-categorical] and dummy [categorical] (Pallant, 2005). Quantitatively analyzed data supplemented with qualitatively analyzed data that gathered from participatory field observations and informal discussions with farmers.

Since the high absorptive character of vegetation pigments (chlorophyll) in the red spectral region and high reflection in the near infrared spectral region (Reddy *et al*., 2014), and minimize the effect of illumination of features in an area, Normalized Difference Vegetative Index (NDVI) is important to estimate changes of vegetation covers over space variation. Therefore, the satellite imagery data was analysed by using NDVI change detection method to describe the magnitude of vegetation covers of CPRs in response to human activities. NDVI defines as the ratio of difference between the near infrared and red reflection to their sum. It is calculated by dividing the difference by the sum for each pixel in the image [NDVI= (NIR-RED) / (NIR+RED)], where: NIR is reflection of plant materials in near infrared bands 4; and RED is chlorophyll pigment absorption in the red bands 3.

The development of spatial database from remote sensing data can schematically represent as follows,

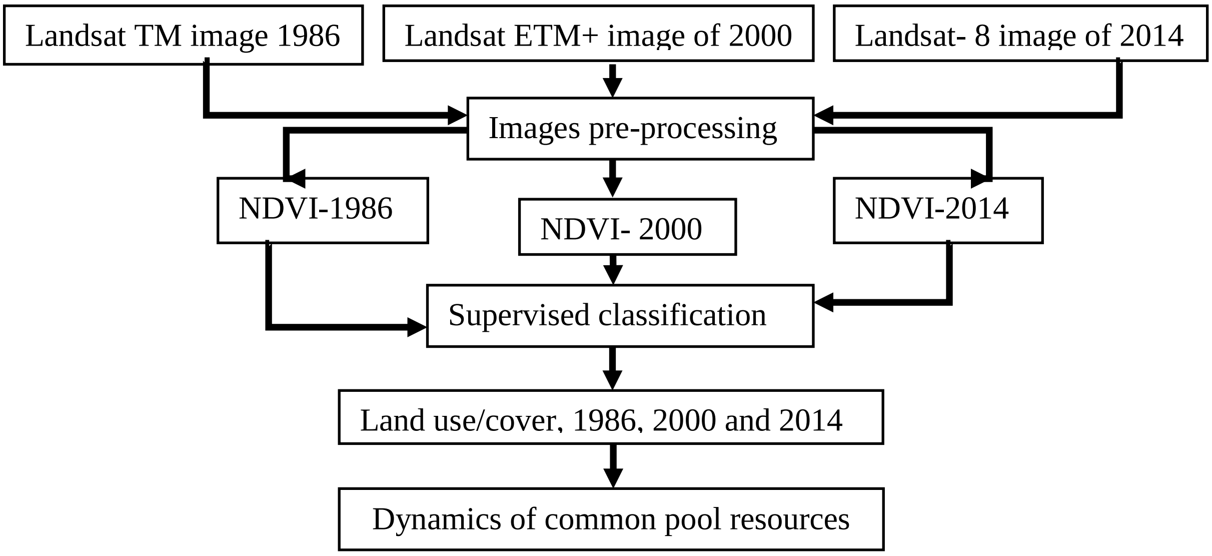


Figure-4: Analytic procedures of land use /covers in spatial perspective

The generated socioeconomic and institutional data were analyzed employing descriptive statistics and discourse analysis. In this study, six major classifications of land use /covers were identified with proper care to minimize errors due to aggregation (Table-5).

Table-5: Description of land use/ cover classes identified in *Goncha Siso Enese Woreda*, Ethiopia.

Land use/covers	Characterstics of identified classify
Forests	Areas that covered with dense growth of both deciduous and evergreen trees that included both natural and human made along with nearly closed canopies of trees and bushes charcterstics.
Shrubs	Areas covered with dense shrubs and bushes, and sparsely distributed small trees mixed with grass.
Grasslands	Areas dominantly covered with grasses used for communual grazing with no or with takecare of protection by the local community.
Cropland and Settlements	Areas used for rainfed and irrigated both annual and pernnial crop cultivation, scattered rural settlements with some tree plantation (eucalyptus, Juniperus procera, Acacia abyssinica and others) around homesteads, and barren fallow plots.
Wetlands	Areas with very wet ground or waterbody mixed with small trees,shrubs, grasses including swamps, marshes, rivers and ponds, as well as dried waterway
Lake	Area covered by lake

multi-criteria analysis method used to analyse data on existing problems and management schemes, the contextualized criteria/ indicators and potential alternatives for sustainable use of CPRs. Therefore, multi-criteria analysis (weighted score method) was used in order to determine the weight of each criterion and compute the weighted score for the performance of each prevailing management schemes and other perceived alternative scenarios.

By following the generic criteria and indicators framework of Centre for International Forestry Research (CIFOR, 1999); the initial sets of criteria and indicators were generated. Then informants asked to select the relevant criteria and indicators. A set of criteria and indicators were prioritized and proposed by the interviewers (farmers, *Kebele* leaders, CPRs regulating committee heads, DAs and *Woreda* experts) in according to the local prevailing socio-economic, institutional and environmental conditions. The informants asked to assign ranks for each decision element (indicator/criterion) based on its perceived importance by using the predetermined point of scales. Hence, ranks assigned according the following points: one=weakly important; three=less important; five=moderately important; seven=more important; and nine= extremely important, with two, four, six, and eight used as an intermediate level of assessments (Mendoza *et al*., 1999). Based on these ranked values, the average weight of the criterion (dividing the sum of all informants rank values by total number of informants) considered to accommodate the diverse views and opinions of the participants on the relative importance of the criteria. The relative weight of each indicator/criterion was calculated by dividing its average weight by the total of all average weights of the indicators under the criterion/criteria (Mendoza *et al*., 1999; Ananda and Herath, 2006). $W_j = X_j / \Sigma X_j * 100$.. (eqn.1)

Where: W_j is the relative weight of each indicator/criterion, X_j is average weight of each indicator/ criterion, and ΣX_j is the total of all average weights of the indicators in the criterion or criteria.

According to Mendoza *et al*. (1999), scoring system that adequately reflects the performance of CPRs management units is the key to multi-criteria analysis system. Informants also assigned the score to examine and judge the prevailing condition of each indicator relative to perceived desire condition (sustainable use) of the indicators under each criterion to assess the performance of CPRs management. The score provided to each indicator by comparing its status with sustainable condition. Therefore, the scoring was suggested as one= very weak performance; two= poor performance; three= acceptable or average; four= very favourable performance; and five= outstanding performance. The weighted score for each criterion was calculated by combining the average relative weights of each indicator (with reference to the desired condition of CPRs) with the average of actual scores assigned by ‘n’ informants to each indicator (with respect to performance prevailing management schemes of CPRs). The summation of these weighted scores is the final score of criterion. For instance, Mendoza and Prabhu (2000) weighted score method, the overall performance score of the j^{th} criterion (Sj) calculate as a weighted average as follows:

$$Sj=\sum_{m} w_{jm} x s_{jm} \quad \text{.......................... (eqn.2)}$$

Where under the criterion j, w_{jm} is the average relative weight of indicator 'm' estimated from in the previous ranking method (see eq.1); and s_{jm} is the average actual score of indicator 'm'.

Based on the measured depths, widths and lengths of rills, the quantitative data analysis on magnitude of rill erosion like the actual damage of surface area covered by rills, the rill density and volume of soil lost due to rills' were estimated (Herweg, 1996; Woldeamlak and Sterk, 2003). The distributions of the approximate values of actual damage, rills density and volume of soils loss of all identified rills across the surveyed fields used to analyze spatial variation between homogeneous segments in terms of status of conservation practices, topographic position in the valley sides, crop patterns and accelerating factors of rills initiation and development.

The actual damage of surface area covered by rills was calculated using equation:

$$ADSA= \frac{\sum (L_i W_i)^{Ni}}{A}$$

where ADSA- is Actual Damage of Surface Area covered with rills (in m^2ha^{-1}) in the study year; L_i is rill length in meter; W_i is the mean width of rill in meter; ^{Ni} is the number of rills of each homogeneous segment; and A is total area of homogeneous fields in hectare. Rill density (in mha^{-1}) in the study year was obtained by: dividing the total length of all rills (in meter) by the total area of all surveyed homogeneous fields (in hectare).

Moreover, to calculate the approximate volume ($m^3ha^{-1}yr^{-1}$) of soil removed by the rill channel:

$$V= \frac{\sum (W_i D_i L_i)^{Ni}}{A}$$

where:

V is total volume of soil loss due to formation of rills from homogeneous fields (in m^3ha^{-1}) in the study year; W_i is the mean width of rill in meter; D_i is the mean depth of rill in meter; L_i is the length of rill in meter; ^{Ni} is the number of rills of each homogeneous segment; and A is total area of homogeneous fields in hectare. The magnitude of soil loss is normally expressed either in units of mass or in volume per unit area per unit of time (Morgan, 2005). For this study, the rate of soil loss described in the unit of volume per hectare (m^3ha^{-1}) in the study year. Quantitative analysis was substantiated with qualitative data generated using observations and informal discussions. Nevertheless, as sheet (inter-rill) erosion is often so inconspicuous and should be measured using experimental method, its measurement excluded from this survey study. Moreover, analysis of temporal variation of soil erosion due to rills not incorporated in this study.

Data concerning effects of integrated SWM activities on crop yields and household income generated using semi-structured questionnaires analysed through employing descriptive statistics (percentage, range, mean, and t-test) and one-way ANOVA. Variance of analyze was used to analyze spatial variability in changes of application rate of chemical fertilizers, and harvested grain yield of tef and wheat crops between cultivated fields treated with different component of SWM practices. Independent T-test also employed to analyse the association between perceived changes of income with other socio-economic variables and yields changes from specific tef/wheat fields under different degrees of SWM practices in the particular catchment. The Statistical Package for Social Scientists (SPSS), Version-20 employed to analyse the quantitative data. Moreover, quantitatively analysed data complemented with qualitatively analysed ones (generated by observations and informal interviews).

CHAPTER-FOUR

PERFORMANCE OF INTEGRATED SOIL AND WATER MANAGEMENT ACTIVITIES: IN FARMERS PERSPECTIVE

4.1. Practices of soil and water management activities

Under the local based participatory integrated Soil and Water Management (SWM) strategy, there were substantial conservation efforts in the seven catchments of *Goncha-Siso-Enese* Woreda between 2003 and 2013. The conservation activities were performed by the local office of the ministry of agriculture (*Goncha-Siso-Enese Woreda* agricultural bureau) and MERET project initiative through its food-for-work program for ten years. The main objective of the intervention was in attempt to tackle land degradation and use it as a demonstration site to scale up surrounding areas.

4.1.1. Participation and interactions of stakeholders

In case study areas where MERETs' initiative integrated SWM efforts were undertaken, local administration units(Woreda agricultural bureau and *Kebele* administration), Development Agents (DAs) in a specific *Kebele*, cropland holders(owners) in a particular catchment (including watershed committee, farmers' terrace designer, farmers' development groups and leader of farmers' development group) are found to be the most important stakeholders. The participation of cropland owners and DAs of specific *Kebeles* are defined with reference to delineated catchments whereas the woreda officers are inclusive all areas are selected for intervention of conservation efforts.

According to the information of the Woreda agricultural office, the Woreda agricultural bureau collaborated with MERET's project selected seven catchments in seven kebeles out of thirty-eight *Kebeles* in the Woreda by identifying unproductive areas due to severe degradation, as well as areas with better accessibility of information system to use them as a demonstration sites. The woreda experts noted that the livelihood situation of cropland holders (farmers) in the selected sites had not been susceptible due to unproductiveness of catchment areas. Substantiating this, based on the background information of study sites, farmland holders within the catchments had not been food insecure before the intervention. Rather, the less favoured areas (seriously degraded along with densely populated with highly vulnerable living situation of smallholder farmers) are found in the inaccessible kebeles, *kola* (=lowlands with warm moist) agro-ecology. This depicts that the conservation intervention through MERET' project initiatives in the study area was probably grounded lacking the intention of less favoured and main concerned socio-ecological environments. However, the most important condition to select sites for the intervention of MERETs initiative, integrated SWM project, is uncertainty livelihoods of smallholder farmers due to severity degradation of natural resources with the intention of improving livelihoods through land rehabilitation efforts (Gete, 2006; Tilahun *et al*., 2007).

As the Woreda experts reported, after selecting intervention sites, they provided two to three hours orientations to total owners of cultivated lands in each catchment concerning the type of practices and their purposes, and ways of implementation. DAs reports noted that the orientation was in favour of convincing farmers to have a particular reaction to participate through project conservation intervention with intention of wheat and edible oil incentives. This indicates that from the beginning, empowerment of communities getting applicable directions of improving subsistence mixed-farming (crop and livestock outputs) through natural resources' management was not thoroughly impressed.

Woreda experts and DAs point out that at the time of orientation, watershed committees (who expect to represent the total landholders in a catchment) were selected by the direct participants (farmland owners in the particular catchment). In contrast to this view, as learned from informal discussions with large numbers of farmers, the selection and endorsement of committee members was unjust and biased due to anticipated nepotism. They also indicated that local administrators and extension staffs were not fully facilitated participatory election and then internalized inappropriate chosen of individuals for committee members. Farmers' further reported that committees did not represent the majority landholders' priorities, the interest, objectives and relevant alternative techniques. Rather, the Woreda experts in collaboration with DAs of a particular kebele provided training to the unfit representatives. The main tasks and responsibilities of these trained committees (in collaboration with DAs) like making of the catchment boundary, providing training for farmlands holders, preparing of action plan, and regulating and protecting the undertaken activities are included. However, farmers and DAs pointed out that the majority members of watershed committee are unqualified and uncommitted to perform their respective activities efficiently.

On the contrary, some watershed committees reported that the majority of farmland holders are reluctance to attend the training program, and proactively practice activities without gaining some daily and timely cash incentives. This indicates that mutual trust not likely builds among key stakeholders including farmers, watershed committees and DAs. This, perhaps, further implies that due to evidence of interest conflicts between DAs and watershed committees, awareness developing and capacity-building tasks on farmers' attitude change towards environmental stewardship habits was not effectively undertaken. "Farmers' terrace designers” are other groups of main stakeholders that particularly engage in designing and layout of introduced structural conservation measures (soil or stone bunds, *Fanya-juu*).

As was learned from views of DAs, farmers and watershed committees, DAs selected five “farmer terrace designers” using the main criteria of educational level, capability and community’s recognition. DAs provided general technical skills and capacity building training for “framers terrace designers” concerning technical installation of terraces on cultivated fields within two days. This indicates view sharing between watershed committee (who perceived to be represented farmland holders in the catchment) and DAs to select “framers terrace designers” not likely considered. According to “farmers’ terraces designers” and DAs views, during training time, a balance between farmers’ indigenous knowledge and scientific knowledge not well addressed. This implies that flow of information or knowledge undertaken in the conventional aspect of top-down approach.

In association with this, based on the informal discussions with farmers, however, most “farmers’ terrace designers” have inadequate technical skills and knowledge about where and how layout of terraces could be made on a particular cropland. This is due to inadequate training and lack of consideration knowledge of farmlands owners’ about spatial character of a particular cropland. This further entails that balanced sharing of knowledge between owners/ renters/ of specific farmlands and “farmers’ terrace designers” unlikely accentuated. The implication is that the involvement of farmlands owners/renters/ by being consulted them about the specific field character and its appropriate design of terracing was largely limited. “Farmers’ terrace designers” provided the designed results of technical pattern of terraces to other members of stakeholders, the development groups and their leaders.

According to the combined views of DAs and farmers, development group is often composed from 20 to 30 farmers of a particular small village or sub-kebele (*Goti*). The total member of farmers who hold croplands within a catchment can determine the sizes of development group members from specific *Goti*. Group members selected their leader. The main task of the leader could be accepting designed land segment from “farmers’ terrace designers” to apportion each member of development group for constructing terraces (including soils /stone bunds or *Fanya-juu.* Moreover, collective action of members of development group also performed planting of Sesbania sesban and Grevillia seedling on constructed bunds and seriously degraded areas.

Leaders of development groups chiefly controlled and evaluated the quality and quantity of undertaken activities (constructed terraces, treated gullies and planted area) and then they reported feedback to DAs. Unfortunately, this indicates that designers were not evaluators. Development group leaders did not have equal opportunity with "farmers' terrace designers" to train and develop their capacity about technical skills. This further signifies that the intermediate and facilitating actions of DAs and watershed committee on the communication and assigning patterns are more likely weak. In relation to this, farmers perceived that accepting unfinished activities without effective implementation of keeping standard qualities and quantities contributed to ill-design and poor quality bunds construction. Perhaps, this further shows that the occurrence of weak interaction between DAs and leaders of development groups on timely regulation and approval of undertaken conservation measures.

Overall, in the study areas, the unbalanced and inadequate flow of information and knowledge, incapability of assigned actors and unsatisfactory interactions, unwillingness and lack of commitment are more likely the main characters of stakeholders' participation and interactions in practicing integrated soil and water management approach.

The participation of stakeholders like DAs and farmers (watershed committees, terrace designers, leader of development groups and members of development groups) has been based on wheat incentive. This makes the only difference of MERET's project approach from Ethiopian government led campaign participation (limited to labour contribution which often induced by coercion) of soil and water conservation practices. As farmers noted, wheat has been provided as labour cost as realizing that number of attended days along with undertaken works quantity. In the context of the point of views of majority farmers, the purpose and procedures of wheat incentive was unclear, to use daily consumption otherwise. Some farmers discussed that watershed committee and development agents (from 150 to 250 kg) favoured allocated wheat than farmers (from 50 kg to 150kg) that depends to quantity of work and number of labour days.

Moreover, during wheat subsidization, the size of croplands held by individual farmer in a particular catchment intending that recompense of lost croplands due to terraces construction was not addressed. In views of that, many farmers were discouraged to adopting introduced activities, given that farmers' participation wheat incentive focused rather environmentally friendly. This concurs with the argument of wheat incentive based participation paradoxically imparted "the sense of dependency syndrome" on the part of farmers rather than stimulating them for natural resources' management based agricultural production improvement (Mitiku *et al*., 2006). Nevertheless, it is likely to be effective when wheat subsidization uses to compensate the lost cropping area that used for bunds construction until conservation provides positive net benefits over traditional land use system (Bekele and Holden, 2000).

4.1.2. Component of integrated soil and water management activities

According to the information from Woreda expert, DAs and watershed committee, the most important problems requiring intervention in the catchments had been soil erosion by water, deteriorating of soil fertility due to soil nutrient depletion, and hence severely declining land productivity. In concurrence with this, the farmers informally pointed out the declining productivity of croplands due to soil erosion by water and depletion of soil fertility referring as their priority problems. Furthermore, farmers identified that dispute between neighbouring farmers on reaching consensus in the layout of run-off drainage on the boundary between their farmlands. To alleviate these problems, based on field observations, and information from DAs, watershed committee and farmers, soil and water management practices like structural, biophysical, composting and income generating activities (bee keeping, irrigated cropping through stream development and channel diversion, fruit and vegetable production) undertaken in the study sites mainly with the MERETs intervention.

Rehabilitation measures on seriously degraded areas, terrace construction on unproductive croplands, and planting seedling on constructed bunds and gullies are undertaken by wheat incentive based collective action, whereas soil fertility management (composting) and income generating activities are implemented at individual households' level without wheat incentives. Moreover, according to the field observations, indigenous conservation practices like drainage ditches, contour ploughing, crop rotation, and planting of trees like eucalyptus and *Grevillia* along watercourse and farm boundaries close to homestead are commonly practised in the typical case study sites and other areas.

Vegetative stabilized terracing

For this study, vegetative stabilized terracing is an activity which operationally defined as structural terraces or contour barriers including stone/soil bunds or *Fanya-juu* complemented with vegetative measures like planted *Sesbania sesban* shrubs and '*Grevillia* tree, and natural grass coverage. Farmers are well aware bout the objectives and functions of terracing stabilized with vegetative measures. Farmers in both formal and informal discussions indicated that the main objective of terracing activities is to save soils from water erosion through controlling the length, direction and intensity of run-off by reducing slope length and angles. Following this, they discussed that to enhance the productive potential of croplands through encouraging levelling of steep croplands segment behind them is other function of terraces practice.

Farmers in the discussions also indicated the main reason of vegetative measures like planting and growing of *Sesbania sesban* and grass on soil/stone bunds and Fanna-Yejuu. For instance, the majority of them stated that its use as fodder for their cattle through cut-and-carry system. As some other farmers noted, vegetative measures are more important to stabilize structural measures, as well as to protect soils from being transported through concentrated run-off. This indicates that farmers are well familiar about the multi-purpose uses of biophysical measures on their cultivated fields.

In association with this, DAs and watershed committee indicated that farmers are well aware concerning the objectives of the introduced activities since possible awareness developing activities were undertaken prior to, as well as through practicing. However, according to the discussions with farmers, the majority identified the functions of introduced activities after implementing on their farmlands through practical observations, whereas some others have yet to develop full awareness about functions and practicing technique through extension staff (in particular DAs) supportive advice, as well as ideas sharing with farmers and watershed committee.

Pertinent implementing approach and techniques are quite important to address the anticipated functions or output of particular activity (like terracing measures). From frequent field observations, however, large numbers of soil or stone bunds were ill designed and poorly constructed. There are often inconsistencies in layouts and designs of terraces in the same slope. For instance, the space between terraces not considers site-specific plot character. This implying that slope length and gradient of particular cultivated field are not often considered as important factors for effective decision of proper spacing. Unnecessary narrowness and wideness space between vertical distance of successive terraces in relatively gentle and steep areas respectively frequently observe in all case study sites. Sometimes vertical distance between success terraces in fields where slope steepness and length are relatively larger observes in a similar condition in fields with lower steepness and length. In relationship to this, some farmers informally noted that there was no visible function of narrow space between successive terraces in the low slope fields instead causes difficulties in ox-pull contour plough operations, as well as additionally contribute to loss of cropping area.

What is more, based on information from DAs and practical measurements on fields, the length of terrace between waterways sometimes estimates to reach about 300 meters often with maximum of 5 degrees gradient. Some long terraces were broken due to their inability to drain concentrated surface run-off. Long terraces also breached due to practicing of traditional grassed waterways that bounded different farmers' own cultivated fields. This may be a lesson about farmers adapting conditions of inappropriate long practicing of introduced conservation measures. Thus, some of this technical inaptness of practised structural activities may be attributable to unrecognising of plot level or site-specific and socio-economic context.

According to the informal discussions at transect walk, for instance, farmers mentioned real causes of ineffectiveness of terraces. Firstly, inadequate regulation by the development group leaders or DAs when they accepted constructed terraces from development group members, in particular in the ending time of working day. Under this condition, unfinished terraces i.e. the width, depth and length of terrace channel were remained to be causes for forming concentrated surface water and damaging cropping areas. Secondly, recognition owners' knowledge about field/ plot / character and how to excess water (run-off) had been safely drained without considerably eroding soil and damage crop was not often considered during designing and construction of terraces. Accordingly, some extent incongruity technical character of undertaken structural activities with spatial character of specific crop land perhaps reveal that curbing of soil loss, as well as improving of land productivity at acceptable level are unlikely.

Traditional drainage ditches

To reduce soil erosion by water effectively and then improving croplands productivity, pertinently implemented introduced activities are supposed to be complemented with indigenous physical conservation measures like drainage ditches. Traditional drainage ditches commonly practise in the sub-humid/humid parts of the Ethiopian highlands in general, *Goncha-Siso-Enese* Woreda in particular. In the study sites, almost all farmers in the areas inherently and commonly practise two types of traditional drainage ditches, locally named as *feses* and *tekebikeb*.

Feses traditional ditch is usually constructed by one pressing ox-pulling tillage. Farmers note that the main purposes of constructing *feses* traditional drainage ditch across the slope is to protect lower loose soil or cropping area from concentrated surface water during heavy rain showers, as well as to properly sow crop seeds in narrow spaces. Ditches construct during seedbed preparing and seed sowing with irregular spacing. Based on the field observations, the density and spacing of traditional ditches often base on cropping pattern, soil texture, topographic variability and presence of introduced structural conservation measures.

For instance, based on many times' measurement using meter on croplands at time between after harvesting and before beginning of ploughing, space between *feses* drainage ditches are varied from one meters to three meters wide for *tef* (*Eragrostis tef*) cropping, and between five meters and twenty meters wide for other cereals cropping (including wheat (*triticum*), barley (*Hordeum vulgare*), maize (*zea mays*), nigerseed (*Guizotia abyssinica*), bean (*Vicia faba*)). The mean wide space between ditches estimates about 2 meters for tef (*Eragrostis tef*) and 12.5 meters for other cereal crop. Moreover, the numbers of ditches on *tef* (*Eragrostis tef*) cultivated fields are larger than other cereal crop fields. Thus, the larger quantity and narrower spacing ditches on tef cropping fields perhaps indicates *tef* cropping fields are more likely vulnerable for water erosion than other cereals cropping fields.

Furthermore, farmers noted that since tef seeds are very small, it is difficult to spread by hand throw on wide space seedbeds like other cereals crops. In the cultivated areas, where surface water percolation and slope length and steepness are low, the space between drainage ditches is estimated to vary from 1 to 1.5 meter wide for tef (*Eragrostis tef*) fields, whereas between 5 and 8 meters for other cereal and legume crops. As farmers noted, the main purpose of reducing spacing of ditches is to remove excess soil water for improving crop seedling conditions. However, where slope length and steepness is low along with no excess soil water, spacing between traditional ditches is becoming wider. Numbers and spacing of drainage ditches increase with increasing slope length and gradient, and decreasing water percolation capacity of soils. The gradient of drainage ditches often considers based on slope steepness and length of cultivated fields.

In most cases, according to the repetitive measurements using clinometer (often with farmland owners and DAs), ditches are practised with estimated about below 30 degree slope along with not often cause to bed erosion of loose soils, as well as significantly contribute to seed trapping and seedling on the margin and channel of parts of ditches. Accordingly, practical observations and measurement results reveal that practicing condition of traditional drainage ditches more likely contextualize with specific spatial character attributes. However, some farmers' occasionally practised traditional drainage ditches through inappropriate up and down slope tillage that directly exposed to bed erosion of loose soil and crop seed. This, perhaps, calls for technical advising from external actors like extension staffs and other scientific experts to improve practicing of traditional drainage ditches.

Feses drainage ditches join to diagonally constructed cut-off drains in crop fields, locally named as *tekebikeb*, and waterway stabilized with grass or planted shrubs at boundary between adjacent croplands. *Tekebikeb* drainage ditches are the cut-off drains, which construct through from 2 to 3 times deep ploughing by hand pressed ox-pulled ploughs across slope and *feses* drainage ditches. After deep ploughing, tilled soils on the ditch channel are excavated and thrown by hand on lower margin of the channel to enlarge its carrying capacity of concentrated run-off. Farmers report that the main purpose of *tekebikeb (*cut-off drains) is to reduce the length of concentrated surface run-off, which flow through *feses* ditches, and then to protect the damage of lower part of cropping areas. The spacing between *tekebikeb* ditches estimates to vary from 15 meters to 30 meters.

Combine use of terracing and traditional drainage ditches

The ability to compatible practice between traditional and modern soil and water conservation practices observes and measures. On the one hand, the number and the length of drainage ditches considerably decrease on terraced cultivated fields than non-terraced cultivated fields. Within terraced cultivated fields, the quantity and the length of drainage ditches increase with increasing of width of cropping space lies between terraces and width of individual owned croplands.

On the other hand, space between drainage ditches on terraced croplands is usually wider than non-terraced cultivated fields. Within terraced croplands, despite increasing width of cropping space lies between terraces and width of individual owned cultivated fields, space width between drainage ditches often remained to be unchanged. This indicates that indigenous conservation measures (drainage ditches) are more probably integrated with the introduced soil or stone bunds in order to curb soils and water losses, and reducing cropping space loss. This, perhaps, implies that the loss of cropping area due to construction of terraces could be compensated by practicing lesser number of wide spaced and short length drainage ditches on terraced croplands than non-terraced ones. In accordance with this, based on the field observations, gradient enough drainage ditches are more likely susceptible to bed erosion, and then water, soil and crop seed loses. Even, on the channel and margin of ditches, in which their gradients not often cause to bed erosion of loose soil, the biomass of crop seedling considerably decreases that perhaps because of loss of soil nutrients, when compared to cropping segment. However, as farmers informally reported, farmers did not often realize the loss of cropping area due to the practice of large number of drainage ditches on small plot despite that of the introduced (modern) ones.

Sheet erosion generated on cropping space contributes to the formation of concentrated run-off in the drainage ditches (*feses*). It learns that drainage ditches play a significant role to halt the growing of sheets into rills on cropping segment. However, concentrated run-off discharge from drainage ditches is silted up at the outlet of ditches (terraces channels) and then breaching of terraces as well as formation of rills and gullies in the downwards terraces. This condition typically happens wherein farmers had not excavated the silted up deposition from terrace channels.

Tekebikeb traditional ditches (cut-off drains) are not often observed in the terraced cultivated fields, whereas highly distribute in the non-terraced cultivated fields. Soil and stone bunds substitute *tekebikeb* traditional ditches. Perhaps, this indicates that due to its simplicity for implementation, farmers use *tekebikeb* drainage ditch instead of soil or stone bunds construction. Nevertheless, gradient of *tekebikeb* ditch is larger than introduced soil and stone bunds. Moreover, depth, width and length of *tekebikeb* are larger than *feses* traditional ditches. Hence, *tekebikeb* traditional ditches directly and substantially cause bed erosion of loose soil and sown parts of channel due to concentrated run-off.

Contour ploughing

It is one of indigenous soil and water conservation measure that is inherently and largely practised by the farmers in the study area. Farmers mentioned that contour ploughing practise to minimize ox pulling tillage operation difficulties, as well as to retain tilled soil from water erosion.

Soil fertility management activities

From soil fertility management, compost preparing, crop rotation and application of inorganic fertilizers are highly practised in *Goncha-Siso-Enese* Woreda in general and in the case study sites in particular.

a. Compost making and using

It is an introduced practice of soil fertility management. Farmers noted that the primary objective of preparing and using compost on croplands is to enhance crop yields and to reduce cost evolved in use of inorganic fertilizers. As they added, use of compost intends to improve long-term soil fertility potentials in the cultivated fields. This indicates that the prime objective of majority farmers' in making and using compost on croplands is in favour of economic gain than ecological advantage. This does not necessarily mean that the intention of majority farmers is entirely to disregard the ecological benefits of using compost.

From farmers discussions point of views, the majority of farmers obtained technical advice and skills, and purpose of compost practice from extension staff in particular DAs, whereas some other farmers often began compost making and using following observing and sharing of knowledge and skills about the procedures of preparation and merit of the practice from their neighbouring settlers. In corroboration to this, as farmers (at informal discussions) and DAs indicated, extension personnel like DAs develop awareness on farmers' technical skills through using *Goti* assembly before preparation period, in June of each year. Compost could be prepared from end of July to mid of October when materials like weeding, green flowering/ herbaceous plants and leguminous straws are available, as well as moisture content of these ingredients is sufficient. During the preparation time, sometimes, development agents' (DAs) monitor each household in various *Goti* of a particular kebele.

However, DAs and farmers noted that technical skills of the majority of farmers are inadequate to prepare compost consistent with scientific procedures. Instead, farmers are mostly preparing low quality compost due to unscientific procedures along with in favour of high proportion animal manure whereas small proportion from other ingredient materials. As most of the farmers pointed out, indigenous practice like fresh animal manure carrying and dispersing at homestead is gradually substituted by compost. In the period between mid-summers to mid-Autumn seasons, animal dung mainly uses for compost preparation whereas in remaining period animal dung mostly uses for fuel. Farmers viewed mixing prearranged compost by hand is not easy rather it required high labour potentials. Thus, number of mixing activities is more likely depends on the labour potential at household level. In relation to this, as farmers and DAs indicated, because of trouble of high labour potential requirement, intentionally and regularly prepare and use of compost at large individual household is not at acceptable level.

b. Crop rotation

It is the inherently and widespread accepted indigenous soil conservation practices in the study sites. As almost all farmers reported, their primary intent of crop rotation practice is to enhance crop yield through replenishing soil fertility and reducing diversity and intensity of spread of weeds. Farmers reported that cereal-to-cereal rotation i.e. rotating tef and wheat, wheat and maize, and tef and maize are well practised by the majority local farmers.

Based on field observations and farmers' views, legume crops often exclude from crop rotation patterns, in particular in *Woyibila* and *Beribere* catchments. Farmers enforce to cultivating cereal crops like *Tef,* wheat and maize in the successive years as they use them a lot for basic types of local food including brewing traditional bear (*Tella*), flat bread (*Enjera*) and bread. These crops also preferable by farmers in terms of yield, as they are better than legume crops.

Soil profile of crop fields is another constraint factor for legumes-cereal crop rotation practices in the areas. For instance, on the one hand, farmers suggested that reddish clay soils and moisture retention cultivated fields particularly in Woyibila and Beribere catchments not recommend for cultivation of legume crops (like pea and horse bean). Despite the majority of farmers are aware the negative consequences like deteriorating soil fertility and declining crop yield, alternating tef and wheat predominantly practise in those catchments. This gives lesson for practicing other alternative like nitrogen fixing shrubs or crops suitable to local soil properties or adequate amount of nitrogen fertilizer is essential. On the other hand, as most of the farmers mentioned, the fields covered by greyish brown and stone composite sandy soils and moisture released soils, in particular the large part of *Wochit-wuha* catchment and some upper part of *Beribere* catchments are appropriate for cultivation of legume crops(like pea and horse bean).

4.2. Farmers' preference of Soil and Water Management (SWM) practices

4.2.1. Evaluative criteria and their weights

Based on the combined views of farmers, watershed committees and DAs, the major objectives of integrated SWM practices were to increase crop yield through reducing soil loss and crop damage, increasing soil fertility and retaining rainwater in the soils. Based on the framework of these identified objectives, the modified and agreeable upon evaluative criteria such as economic (like man power requirement, inorganic fertilizers cost reduction, crop yield improvement and fodder production enhancement), social (decreasing farmer land owners disputes) and ecological (decreasing soil loss and damage of crop seedling, decreasing run-off, enhancing rainwater retaining in the soils and improving soil fertility) were incorporated. Table-6 presents the mean (X), mode (M) and sum (Σ) values of participants assigning on the relative weight (Wj) of each identified criterion.

Table-6: The Mean (X), Mode (M) and Sum (Σ) values of participants assigning on the Relative Weight (Wj) of each identified criterion (n=28)

	Identified criteria/ criterion									
		Economic				Ecological			social	Total
	MPR	IFRR	*CYE*	FPE	MR	RR	SFI	SLCDR	CR	
X	2.41	3.68	4	3.64	1.45	3.09	1.91	3.73	2.73	26.6
M	2	4	4	4	1	3	2	4	3	
Σ	53	81	88	80	32	68	42	82	60	586
Wj	0.09	0.138	0.15	0.137	0.06	0.116	0.072	0.14	0.102	1

Note: See the abbreviation definition of the identified criterion in figure-3.

Using the equation (1) from issue one in chapter three, the relative importance of each criterion estimated. Participants in the formal discussions gave higher value for crop yield enhancing followed by reducing soil loss/ damage of crop seedling and application rate of inorganic fertilizers, and improving fodder production in order of importance (Table-6). Whilst as participants ranked that moisture retaining and then soil fertility improvement are relatively the least important. This indicates that farmers are more likely favoured economic effect criteria than ecological ones. In agreement with this, Zenebe *et al*. (2013) reported that farmers assigned the highest relative weights to economic (0.58) related criteria than technical (0.29) and stability (0.13) criteria.

4.2.2. Soil and water management alternatives and their average values

For this study, the spider diagram (figure-5) represents the most important widely and commonly practised SWM measures on the cultivated fields that including the recommended (stone bunds, soil bunds, soil bunds stabilized with *Sesbania sesban* shrubs, *Fanya-juu*, *Fanya-juu* complemented with *Sesbania sesban* shrubs and composting) and the indigenous (drainage ditches, contour ploughing and crops rotation). Alternative of "none of any activity" not considered in the analysis acceptance since there was no cultivated field without amendment of any previously mentioned practices. Besides, alternative of 'a combination of the activities' that undertaken on any croplands not considered because of measures competed among each other.

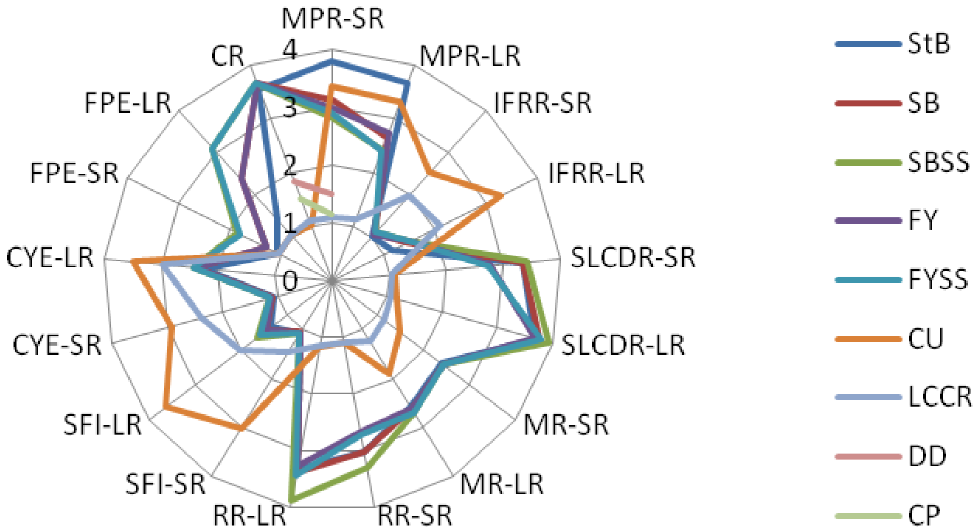


Figure-5: Mean value ranking of components of SWM Practices in terms of cost and benefits in temporal perspective using Spider diagram (n=28)

Practices:	***StB_*** *Stone Bund;* ***SB_*** *Soil Bund;* ***SBSS_*** *Soil Bunds Stabilized with Sesbania sesban;* ***FY_*** *Fanya-juu; FY****SS_*** *Fanya-juu stabilized with Sesbania sesban;* ***CU_*** *Compost Use; and* ***LCCR_*** *Legumes-Cereals Crop Rotation;* ***DD****-drainage ditches; and CP- contour ploughing.*
Cost Requirement	***MPR_*** *Man Power Requirement; and* ***IFRR_*** *Inorganic Fertilizer Rate Reduction*
Ecological Benefits	***SLCDR****-Soil Loss and crops damage Reduction;* ***MR_*** *Moisture Retention;* ***RR_*** *Runoff Reduction; and* ***SFI_*** *Soil Fertility Improvement*
Economical Benefits	***CYE_*** *crop yield Enhancement; and* ***FPE_*** *Fodder Production Enhancement*
Social benefits	***CR_*** *conflict reduction*
Time	***ST_*** *short-term and* ***LT_*** *long-term*

The spider diagram (figure-5) visualized the farmers' average valuation of the performances of different components of SWM practices in terms of economic, technical and social benefits in temporal perspective. The substance of all practised activities in terms of decreasing cost and increasing returns is higher in the long-term than short-term. This implies that farmers recognized the increase in temporal worth of the activities although they possibly require short-term benefits to contribute to their household income.

Farmers valued difference merit points among the undertaken SWM alternatives in respect of ecological and socio-economic aspects within a short-term horizon (figure-5). For instance, farmers considered that structural measures stabilized with *Sesbania sesban* shrubs represent the highest rank in reducing run-off, soil loss and conflicts a rising between adjacent farmlands owners, and enhancing fodder production. Following to this, soil bunds and *Fanya-juu* stabilized with natural grass, drainage ditches, and stone bunds in order of importance.

Farmers also gave high values for compost use and Legume-Cereals Crop Rotation (LCCR) in maximizing crop yields and minimizing costs of chemical fertilizers' application in the short-term horizon. Hence, this indicates to combine the use of agronomic measures (composting, LCCR) and terraces complemented with *Sesbania sesban* shrubs is perceived to have contributed to multi-benefits in mixed farming activities of smallholder farmers in the short-run horizon.

The average values (of both short-term and long-term performance) presented in Table-7 reveal the perceived degree of the importance of each practised SWM alternatives based on each predetermined criterion. For instance, stone bunds require the highest labour cost than all other practiced activities. This implies that stone bunds are the less preferred in man power requirement criterion aspect. According to formal discussions, stone bunds require intensive labour for continuous maintenance than other structural measures like soil bunds and *Fanya-juu*.

Table-7: Farmers average scores of different SWM alternatives in according to evaluation criteria (n=28)

SWM activities	Identified Criteria								
	Economic			Social		Ecological			
	MPR	IFRR	CYE	FPE	CR	SLCDR	MR	RR	SFI
StB	3.75	1.1	1.65	1.25	3.6	3.4	2.5	3.15	1.2
SB	2.86	1.25	1.75	1.85	3.7	3.5	2.5	3.2	1.25
SBSS	2.61	1.3	1.77	2.46	3.7	3.67	2.55	3.6	1.37
FY	2.87	1.3	1.75	1.95	3.6	3.22	3.2	2.98	1.25
FYSS	2.65	1.3	1.75	2.45	3.7	3.28	3.25	3.1	1.35
CU	3.35	2.9	3.2	1.05	1.01	1.15	1.15	1.15	3.3
LCCR	1.1	2.1	2.7	1.07	1.11	1.05	2.04	1.21	1.75
TDD	1.5	1.07	1.23	1.34	1.83	3.45	1.3	3.59	1.05
CP	1.14	1.06	1.3	1.03	1.52	3.18	3.6	3.2	1.1

Note: See the abbreviation definition in figure-5

Stone bunds can be easily destructed by free grazing or turning points of 'ox-ploughing' operation because they could not be well stabilized by growing grass and planting shrubs like *Sesbania sesban*. They are often causes to crop yield loss due to their side effect as mice protection or harbour in the available wide hallow spaces between stones, in particular in early age of the bunds than other structural measures. In agreement with this, Akalu *et al*. (2014) indicated that farmers did not prefer stone bunds due to largely high labour demands for establishing, ploughing inconvenience and risks of pest harbouring effects. Nevertheless, from field observations, it finds that stone bunds are lesser prone to destruction than soil bunds and Fanya-juu that stabilize with natural grass. This is perhaps also because of destroying stone bunds more likely required more labour than the expected benefits from bunds occupied land segment.

Making and using compost stands next to stone bunds in labour requirement. Contrary to this, legume-cereals crop rotation and then contour ploughing, traditional drainage ditches require lesser labour than others. This possibly shows that local SWM practices are highly preferred by the farmers due to their less labour requirement character.

In the case of enhancing soil fertility and crop yield, and reducing cost of inorganic fertilizer, compost followed by LCCR are more preferred by the farmers than other alternatives (Table-7). In agreement with this, Belay (1998) reported that crop rotation and composting are more acceptable by the farmers due to their lower cost requirement and provide multiple benefits like enhancing soil fertility and productivity. Farmers accepted that in short period, terraces are not able to compensate crop yields reduction due to loss of cropping area for terrace construction along with high input costs (chemical fertilizer cost).

Farmers' gave the highest average value for soil bunds and *Fanya-juu* stabilized with *Sesbania sesban* shrubs in contributing to fodder production improvement. They also perceived that improved structural measures (bunds and *Fanya-juu* stabilized with vegetation) largely contributed to reduce disputes between adjacent farmland owners or tillers that had occurred due to lack of agreement on the direction of drainage ditches to safely drain excess concentrated runoff.

In reducing run-off, soil loss and damage of crop seedling, soil bunds stabilized with saspaniya are the best preferred followed by soil bunds stabilized with natural grass for soil loss and damage of crop seedling, as well as traditional drainage ditches for reducing run-off. From formal discussion point of views, farmers perceived that terraces have significantly contributed to retain transported sediments within field lower slope terrace position. This is attributable to reducing run-off velocity on the relatively lower slope gradient part close to terrace structure. In the case of retaining rainwater in the soil, farmers assigned the highest value to traditional conservation practice like contour ploughing, and then for the introduce ones' like *Fanya-juu* stabilized with *Sesbania sesban*. In association with these, Akalu *et al*.(2014) reported that farmers evaluated the structural conservation measures (stone bunds, soil bunds, and *Fanya-juu*) by giving the highest scores to ecological impacts in steep sloping areas and stronger positive economic impacts in moderate and gentle sloping areas. They further indicate that farmers' rankings of these alternatives (soil bunds and stone bunds) for maximizing crop yields were highly correlated with the degree of erosion control of the measures. Aklilu *et al.* (2006) also reported that stone terraces (on the steep slope category), soil bunds (in the moderate slope category) and drainage ditches (on the gentle slope plots) were best preferred soil and water conservation measures in respect of technical effectiveness and cost associated farmers preference.

Based on the discussions, farmers have also different stances between contribution values of soil bunds and *Fanya-juu*. As they pointed out, in the young age, *Fanya-juu* terrace had higher destruction opportunity due to ox-pulled ploughing operations and lesser capacity to curb excess concentrated run-off than soil bunds. The supplementing function of grass to trap residues and retain excess surface water on raised part of *Fanya-juu* terrace is lesser than soil bunds. In the maintenance time, throwing of excavated soil from *Fanya-juu* channel area towards its raised part has required more labour and significantly contributed to unnecessary rising of height of terraces, whereas soil bunds require lesser labour cost during maintenance by excavating silted soil from channels and throwing to downhill. However, on channel of *Fanya-juu* terrace, silted-up capacity is lesser than soil bunds.

4.2.3. **Multi-functional activities of SWM alternatives**

Results of TOPSIS model presented in Table-8 reveal that the relative closeness of each SWM alternative to the ideal solution (multi-functional activities) with respect to economic, social ecological and aggregated criteria. For example, in economic efficiency perspective, compost use is the most valued followed by legume-cereals crop rotation (local practice), and soil bunds and/or *Fanya-juu* stabilized with *Sesbania sesban* in order of importance, whereas stone bunds is the least preferred. In terms of social criterion like reducing frequency of disputes between neighbours' plots tillers/owners, improved activities like SB, SBSS and FYSS are the most accepted alternatives.

Moreover, in respect to ecological criteria or technical effectiveness, soil bunds stabilized with *Sesbania sesban* shrubs are the most chosen and after that, *Fanya-juu* stabilized with *Sesbania sesban* shrubs, whereas legume-cereals crop rotation activity is the least preferred one. In agreement with this, Woldeamlak (2007) reported that a large majority of the farmers acknowledge introduced soil and water conservation practices (physical stabilized with vegetative measures) were effective in controlling soil erosion and improving land productivity.

Table-8: The relative closeness of each alternatives to the ideal solution (Ci*) based on the distance to the positive ideal solution (Si*) and negative ideal solution (Si')

SWM practices	Criteria											
	Economic			Social			Ecological			Aggregated		
	Si'	Si*	Ci*	Si'	Si*	Ci*	Si'	Si*	Ci*	Si*	Si'	Ci*
StB	.012	.078	.13	.03	.002	.94	.046	.033	.582	.085	.056	.397
SB	.028	.068	.29	.032	0	**1**	.048	.032	.6	.073	.064	.467
SBSS	.042	.063	**.40**	.032	0	**1**	.052	.029	**.642**	.070	.074	**.514**
FY	.030	.066	.31	.03	.002	.94	.044	.032	.579	.073	.061	.455
FYSS	.042	.064	**.40**	.032	0	**1**	.046	.030	**.605**	.070	.070	**.50**
CU	.073	.046	**.61**	0	.032	0	.032	.053	.376	.077	.080	**.510**
LCCR	.056	.046	**.55**	.001	.031	.03	.011	.057	.162	.079	.057	.419
TDD	.027	.078	.26	.01	.022	.31	.049	.037	.57	.089	.057	.39
CP	.030	.081	.27	.006	.026	.19	.047	.033	.588	.091	.056	.38

Note:
- ✓ *Ci* = Si' / (Si** + Si')
- ✓ *See the full procedures and steps of calculation in* Appendix-I *of this chapter, in the end section of the thesis*

The aggregate results of TOPSIS analysis in Table-8 present that farmers provided the highest score to soil bunds stabilized with *Sesbania sesban* shrubs. It is closely followed by compost use and *Fanya-juu* stabilized with *Sesbania sesban* were preferred as their relative multi-functional activities, whereas contour ploughing and traditional ditches were farthest from the ideal of the multi-benefits or the least preferred (Table-8). This, perhaps, implies that farmers intended to maximize their multiple short-term and long-term benefits by using raise segment of soil bunds or *Fanya-juu* for assorted utilities or purposes. In agreement with this, Zenebe *et al*. (2013) indicated that farmers assigned the highest total scores to soil bunds with elephant grass (SB+Eg) followed by soil bunds with *Sesbania sesban* (SB+Ss), implying that soil bunds stabilized with vegetative measures become more technically effective and economically viable than soil bunds only. Moreover, the area occupied with terrace should be stabilized by multi-purpose grasses and shrubs for animal fodder or fuel wood is more preferable to offset the yield reduction that mainly explained by the reduction of the cropping area, as well as to reduce labour cost during maintaining time (Nkonya *et al*., 2008; Zenebe *et* *al*., 2013). This further provides good opportunities for promoting and scale up the adoption of the technologies.

Farmers further discussed about the multi-benefits of terraces (soil bunds, *Fanya-juu*) complemented with *Sesbania sesban* shrubs in the short-term and long-term than other SWM alternatives. For instance, they mentioned that *Sesbania sesban* shrubs on terraces can provide checking erosion of terraces through stabilizing the structures and trapping eroded soil and other composted materials that are transported from upper-slopes. Since the shrub enables to support the carrying capacity of the channels through retaining excess concentrated run-off and its transported sediment on raised margin of the channels, bunds stabilized with *Sesbania sesban* shrub are more likely to require lesser labour in maintenance. Whilst as farmers noted, excavating accumulated sediments from channels of young age terraces (soil bunds and *Fanya-juu*) is required higher man power but lesser than stone bunds.

According to the farmers' standpoint, *Sesbania sesban* stabilized soil bunds or *Fanya-juu* terraces have considerably contributed to increase the productivity of cultivated land through retaining moistures, loosed soils and decomposed residues in the long-term. In agreement with this, Yihenew *et al*. (2009) also concluded that soil bunds stabilized with vegetative measures like tree *Lucerne* and *Vetiver*, can better hold the soil *in-situ* and enhance soils physical and chemical properties in the inter-terraces soils compared to non-conserved croplands.

Besides, these activities are capable to compensate for the lost cropping area (due to construction place) by producing fodder for cattle. Terrace stabilizers like *Sesbania sesban* and natural grass often use for feeding cattle through cut or prune-and-carry grazing system during winter and spring seasons (first rank for the majority). Most farmers preferred prune-and-carry activity for *Sesbania sesban*, at its flowering stage, for their livestock feeding while realizing that it is three times productive than free grazing system of grass. Based on farmers and DAs suggestions, pruning of leguminous shrubs like *Sesbania sesban*, at above one meter height, is quite important to entangle the residues and soils that transported by run-off, and to enhance biomass production of the shrub.

In addition to fodder and fuel wood uses, legume shrubs like *Sesbania sesban* strips on the terraced contour has the principal role in improving soil fertility through fixing nitrogen in their root nodules (Giller, 2003). In agreement with this, astonishingly, some farmers also pointed out that nitrogen benefits from *Sesbania sesban* shrub through its root nodules are important to substitute UREA as well as to improve soil fertility on the farmland. Based on the field observations, soil bunds or *Fanya-juu* stabilized with *Sesbania sesban* are the least destroyed as compared to any other grass stabilized structural measures of introduced activities. This may be due to the visible fodder profits for farmland holders.

Moreover, from formal and informal discussions it was generated that the use of compost is highly preferred by the smallholder farmers, in particular, perhaps, those who have more productive labour in the household, as it can be prepared from easily available materials but provided short-term multi-benefits including ecological and economical attributes.

Accordingly, as the results of sensitivity analysis illustrate, combining use of compost and soil bunds or *Fanya-juu* terrace complemented with *Sesbania sesban* shrubs suggests the best cropland management practices that involve the most beneficial and accepted introduced conservation measures in mid-highland of humid environment of the study areas. This goes in agreement with the argument that complementary and multi-purpose SWM activities are more likely accepted and then adopted by the farmers as compared to non-complementary or single purpose practices (Nkonya *et al*., 2008). Some studies also concluded that unless the on-farm yield reduction effect (due to losing of crop lands to terraces construction) is offset by improving fodder production on bunds or *Fanya-juu*, the structural measures could not be characterized as a "win-win" measure to land productivity in the humid area of Ethiopian highlands(Bekele and Holden,2001; Menale *et al*.,2008).

4.3.Constraints on the sustainability of implemented SWM measures

Based on field observations and farmers views, perhaps due to their degree of acceptance in terms of cost requirement, and technical and socio-economic benefits, farmers decisions on introduced soil and water conservation technologies can categorize into three groups. The group decided to destruct completely, some other the group that decided to adapt through modifying the gradient, and the remaining others (majority) who decided to adopt.

For instance, based on frequent field observations, it estimates that a number of terraces destructed, in particular where bunds or *Fanya-juu* had not complemented with vegetative measures (*Sesbania sesban* shrubs). According to conversations with farmers, conversion of cropping fields into tree (*eucalyptus*) production, land renting, weak regulation and controlling, difficulties to contour ploughing operation and loss of large cropping areas due to unnecessary narrow space between terraces, cause to harvest large excess run-off and damage for loose soil and cropped area due to fragmented construction and lack of safe drainage design, problem of labour difficulties to excavate silt deposits from terrace channels and inadequate control of free grazing are factors for destruction of terraces. The destruction rate is larger in *Beriberi* catchment, where conversion of croplands into tree production fields and cash or share land renting activities are largely observed, as comparatively observed with others. Value of cultivated fields for eucalyptus tree plantation is higher in *Beriberi* catchment as it situates very close to market centre (Gindewoin town).

Farmers mentioned that destructed terraces on some cultivated fields (which mainly caused to damaging other adjacent terraced areas) initiated the remaining adjacent farmland owners that bordered on right, left, top and bottom sides to destruct terraces on their farmlands and then outspread in the catchment. Cropland renters and owners of tree producing fields are often responsible for obliteration of terraces (see figure-6b). Farmers discussed that renters of cultivated field have removed the old terraces owing to need of relatively rich soil nutrient and soil water content of sediment accumulation area for more crop yields. This happened due to weak monitoring of renter by cropland owners and lack of instant local institutional measurement on first terraces' destroyer for the care of sustainability of conservation on croplands.

Moreover, as farmers noted, stealing of grass or a shrub for animal grazing not sees as forbidden by the local society and culture. Because of their higher values in the integrated livestock-crop production system, robbery of productive *Sesbania sesban* shrubs and grasses from terraced area during hushed/night and absence of catchment guard, is the ferocious constrain for the majority of farmers to sustainable use.

Figure-6a: Uncontrolled grazing in the conserved catchment in post harvesting period

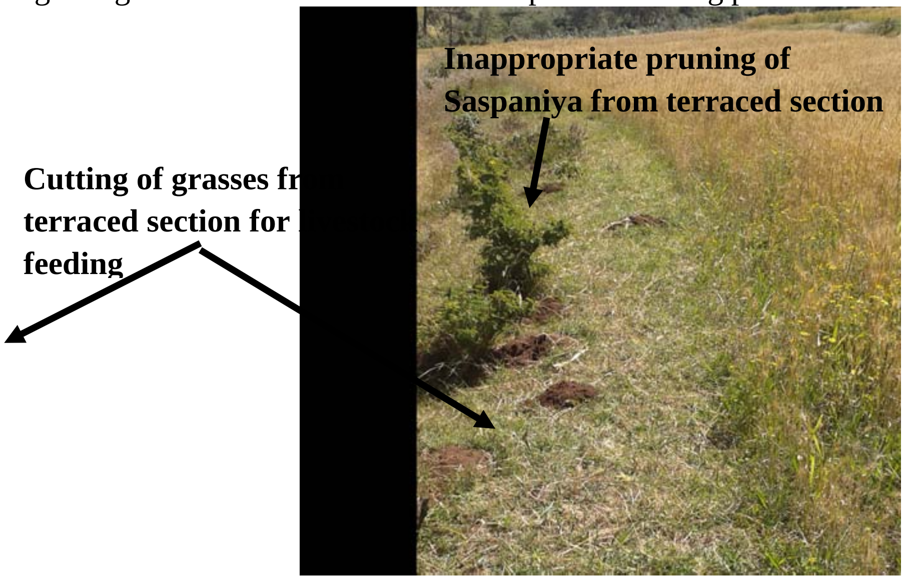


Figure-6b: Cut-and-carry grazing system of fodder from terraced section of croplands

Figure-6c: Terrace destruction for cropping and eucalyptus tree plantation

For instance, based on the field observations, in some cultivated fields' *Sesbania sesban* shrubs dried-up due to improper pruning (see figure-6b) and in some other fields complete removal of *Sesbania sesban* shrubs perhaps due to robbery action otherwise by some farmland owners since they have not benefited. Farmers indicated that to compete with free rider and thief, some landholders decided to free grazing of their livestock on conserved croplands.

Somewhat unlimited grazing in particular following to crop harvesting time to use productive fodder for cattle feed has been additional problems for the productive and sustainable use of shrub on terraced cultivated fields(see figure-6a). Policy that restricts post harvest open grazing is required at local level to enhance the sustainability and productivity soil bunds (Zenebe *et al*., 2013). In each study site (catchment), to manage free grazing from biophysically conserved cultivated fields, cash punishment has been the main controlling mechanism of free grazing. The watershed committee and DAs decided the amount of cash penalty. For instance, in *Beriberi* catchment it is 10 Birrs per cattle and 5 Birrs per sheep or goat, and in Woyibila and Wochit-wuha 10 Birrs per sheep/ goat and 50 Birrs per cattle although it not successfully implements. According to the institutional principle of the catchment community, the collected cash through punishing free grazers should service for developmental activities like buying seedlings of *Sesbania sesban* shrubs, paying catchment guard salary and others.

Nevertheless, as farmers indicated, despite shortage of available seeds/seedlings another serious problem to spread out *Sesbania sesban* planting on large parts of terraced croplands, collected cash is often used to drink alcohol by the watershed committee and kebele administrators. Instead, natural grass stabilizes constructed bunds in all catchments. This, perhaps, deter farmers to act consistently for maintaining the undertaken activities due to lesser beneficial contributions as compared to other adjacent farmers of holding croplands that terraced with *Sesbania sesban* shrub stabilizer.

Based on the field observations, appropriate maintenance combined with traditional cut-off drains in base part of bunds is usually undertaken in particular on first bund of upper part of crop lands while realizing that its substantial contribution to surface run-off diversion towards waterway or boundary of different owned cultivated fields. However, in all catchments, large number of channels of grass stabilized soil bunds fill with siltation due to lack of excavation. Instead, in most cultivated fields, farmers use drainage ditches on the bottom part of bunds to drain excess water from silted up channels of bunds. This leads to further constrains of sustaining situation like unnecessary rising of terraces particularly on steep cultivated fields.

Frequent tillage of foot terraces, soil movement through tillage translocation between bottom of upper terraces and top of lower terraces, and accumulation of sediment in the lower area of terrace in response to washing away of surface of tilled soil by rill and sheet erosion contribute to unnecessary rising up of height of terraces. Based on frequent field measurements, rising of old terraces is sometimes reaches up to 3 meter height. In response to this problem, some field owners till the sites of old terrace for cropping and construct other alternative terraces up or down slope of previous terraces by ox-pulled and hand dug techniques. Moreover, as some farmers suggested, excavating silt soil from terrace channel and throwing downs slope to the terraces is a preferable practice to compensate soil displacement during tillage, to balance soil productivity between terraces, to control unnecessary height of terraces and then to continue to use the terraces for longer time.

Nevertheless, due to lack of recognition of knowledge of owners' of farmland during designing of cross-section and gradient of bunds at specific cropping fields, as well as inadequate control of quality and quantity of practised bunds by extension staffs and well skilled technicians, considerable number of bunds on cultivated fields are ill-designed. During field observations, it was found that the gradient and cross-sectional character of ill-designed bunds do not match with the topographic characters (slope length and steepness) of the field. Under such condition, some farmers also technically adapted poor quality of constructed terraces by integrating with indigenous drainage ditches practices. Farmers adapted the previously constructed bunds by their context of practicing drainage ditches, using ox-pulled ploughing, on either side of earlier bunds. As farmers noted, bunds, modified by landowners, are appropriate to safely drains excess concentrated run-off towards waterway. Modified bunds not usually complement with *Sesbania sesban* shrubs instead; they stabilize with natural grass.

In response to these prevalent constrains, farmers and DAs were asked to identify factors that need to be considered to make enabling conditions for the sustainable use of practised soil and water conservation activities. For instance, according to the refined and combined information, building of mutual trusts interaction and balanced sharing of knowledge between extension agents and farmers, recognition of farmers full participation, technical suitability of the implemented technology to specific plots attributes, and strong institutional arrangement (including clearly defined land renting rules[formal or informal], effective monitoring and controlling, sanctions and enforcement systems, responsibility of concerned stakeholders and adequate access to *Sesbania sesban* seedling) were included. This implies that building strong institutional arrangement and measurement system is essential for the sustainable use of practised recommended soil and water conservation activities.

4.4. Conclusions

The major results of this study that obtained using different technique of data collection and analysis in the lens of triangulation approach conclude as follow. In the study sites, under MERET's project integrated Soil and Water Management (SWM) intervention context, stakeholders' participation and their collaborative actions are not sufficient as expected in the assumption of integrated SWM approach. The coordination between catchment communities, their representatives (watershed committees) and DAs are not likely based on mutual trusted situation. The flow of knowledge and communication is mainly reflected top-down approach.

Recognition of farmers' indigenous knowledge, preference and priorities in planning and implementing stage of integrated SWM activities at specific farmland character not successfully addressed. This implies that technical support to develop farmers' skill and knowledge about relevant conservation measures with recognition of their experience not effectively done. This probably results somehow ineffective in technical designing and implementing of introduced and local conservation activities. In association with Woldeamlak (2007) concluded that intervention of soil and water conservation was failed to address the priority and preference of local people proves that the project was not truly farmer-participatory and contributing factor to non-adoption.

Nevertheless, the integrated use of different components of SWM activities (including structural, vegetative and agronomic in both traditional and modern perspectives) indicate substantial reflection of integrated SWM approach. For instance, indigenous physical measures like drainage ditches (including locally named as *fuses* and *tekebikeb* [cut off drains]) are practically integrated with the modern (introduced) ones (terraces including stone/soil bunds, *Fanya-juu*). The modern structural practices were somewhat complemented with vegetative measures (like *Sesbania sesban* shrubs). Moreover, the combine use of some agronomic measures like legume-cereals alternating practices (local practices), and compost making and using (introduced ones) are undertaken by substantial numbers of farmers.

Farmers gave higher value for crop yield enhancing, followed by reducing soil loss/ damaging of crop seedling and reducing costs of inorganic fertilizers, and improving fodder production, in order of importance. In association with this, as farmers indicate soil bunds stabilized with *Sesbania sesban* shrubs followed by *Fanya-juu* stabilized with *Sesbania sesban* shrubs are the most preferred one due to providing multi-benefits in ecological aspect (reducing of concentrated run-off, soil loss and then damaging of crop seedling), economical aspect (enhancing fodder availability, moderately contribute to crop yield improvement) and social aspect (resolving disputes between adjacent cultivated field owners due to lack of consensuses of drains direction of excess run-off). Moreover, compost use can give short-term benefits in the ecological aspect (enhancing soil fertility) and in the economical perspective (increasing crop yields and reducing cost of chemical fertilizer application). Accordingly, from farmers' standpoint, it is possible to conclude that in the humid mid-highland agro-ecosystem, integrated use of structural measures stabilized by growth of vegetation like *Sesbania sesban* shrubs, and compost is the best alternative approach to sustainable cropland management.

However, the landholders (farmers) discussed different constraint factors that probably make bottleneck for the spreading out of terraces stabilized with *Sesbania sesban* shrubs towards other adjacent neighbouring croplands, as well as the sustainability of implemented activities in the study sites. Among these, inappropriately designed and installed structural measures due to lack of recognition of particular 'crop land- holders' knowledge, inaccessible and unavailability of *Sesbania sesban* seedling, and weak institutional regulation and facilitating intervention.

In line with the major findings of the study, it is argued that the prospect relevant practicing that intended to intensify primitive and subsistence mixed farming production through sustainable natural resources (soil, water and vegetation) management shall be emphasized the following points. It suggests that balanced information and knowledge flows are recommended to be honourable when farmers interact with facilitators or external actors (like Woreda experts, DAs) and watershed committee.

Recognition of local farmers' interest, knowledge and skills about particular croplands spatial characteristics should provide emphasize during designing and implementing of modern conservation measures. It argues that institutional strengthen activities (relevant extension supportive action, accountable and responsible formulation and implementation of by-law) to empower individual households is anticipated to be focused by the concerned stakeholders. It concludes that local social, economic and site-specific ecological decision criteria shall incorporate in decision-making process of SWM alternatives to increase utility. Moreover, identification and evaluation of the performance of different SWM alternatives by using multi-criteria approach is an issue needs further research in the future.

CHAPTER-FIVE

SMALLHOLDER FARMERS' DECISIONS ON PRACTICING INTEGRATED SOIL AND WATER MANAGEMENT ACTIVITIES

5.1. Definitions and measurements of variables

For this study, adopters included farmers who adopted and adapted earlier designed terraces. Adopting implies that adopted previously designed bunds without any modification of their gradients accompanied by maintaining activity. Adapting implies that adopted previously designed terraces with some modification of their gradient by practicing alternative drain ditches along with maintenance practice. In addition, non-adopter farmers are who completely destroyed previous terraces from cropping field with or without substituted them by alternative drain ditches in the context of particular farming system. Based on information generated from the sampled household heads (including terraces adopters and non-adopters), further categorical dependent variables (including users/non-users of compost, legume-cereals crops rotation and the combination of all three practices on specific field) were identified.

In context of this study, explanatory variables categorize into socio-economic, institutional, and field level and technical aspects since there is no standardized classification. These variables selected based on pilot survey and literature. For instance, variables including gender, age, owned farm size, family size, education, livestock size, off-farm income, extension contact, use of animal dung as fuel, perceived farmland distance to home, perceived fertility status and slope categories of a particular cultivated fields, adequate awareness on the benefits of introduced conservation measures, and technical fitness of structural measures were adopted from relevant literature (Bekele and Holden**,** 1998; Samuel, 2002; Wagayehu and Drake, 2003; Aklilu and De Graaff, 2007;Anley *et al*.,2007; Woldeamlak, 2007; Asafu-Adjaye, 2008). Moreover, farmland ownership status, crop preference, and farmers' perception on suitability of farmland for legume crops production derived from pilot survey. Therefore, such variables are generally influenced farmers' decision whether to adopt or not the introduced conservation measures (vegetative stabilized terracing and composting) and use or not use LCCR, as well as combination of all three practices on specific field.

Table 9:- Definition, mean, measurement and hypothesis of dependent and independent variables used in empirical model.

Acronym	***Mean***	***Definition and Measurement of Dependent Variables***	
TERRAC	0.82	Terracing measures adoption: 1 if farmers adopt terracing stabilized with vegetation measures, 0 otherwise	
COMP	0.87	Compost use: 1 if farmers regularly use compost at any plot,0 otherwise	
LCCR	0.5	Legume-Cereals Crop Rotation practice: 1 if farmers often use legume-cereals crop rotation in any plot, 0 otherwise	
ISWM	0.35	Integrated Soil and Water Management: 1 if there is frequent combine use of vegetative stabilized terracing, compost, and LCCR at particular plot, 0 otherwise	
Acronym	***Mean***	***Definition and measurement of socioeconomic variables***	***Hypothesis***
SEX*	0.83	Gender of household head: 1 if male, 0 otherwise	Sex is not likely influenced farmers decision to adopt and practice SWM measures
AGE*	46.4	Age of household head: age in years	Increasing farmers age often associated with farming experience is not necessarily influenced farmers' decision to adopt and practice SWM activities
PROLABSIZ*	3.62	Productive labour size: number of productive labour	More productive labour size is significantly contributed to adoption of introduced SWM practices
FAMSIZ*	5	Family size: number of family size	Family size is not likely influenced farmers' decision to adopt and practice SWM measures
EDU*	0.61	Education level of household members: 1 if half and above of them are literate, 0 otherwise	The likelihood of education level of household members does significantly influence farmers' decision to practice SWM measures
FARMSIZE*	1.77	Farmland holding size: Total farm size held by household in ha	Farm size is expected to have positive and significant effects on adoption of SWM activities
PERSUIT	0.51	Holding any suitable farmland for legume crop production: 1 if yes, 0 otherwise	Holding of perceived suitable cultivated fields for legume crop production is supposed to be positive significance influence on adoption of ISWM practices
LIVHOLD*	10.2	Livestock hold: in numbers	Size of livestock holding has more likelihood to adopt compost than others
CPREFER*	0.44	Crop preference for staple food, expected outcome and market price: 0 if farmers select cereals only, 1 otherwise	Preferring cereal crops only is more likely negatively influencing on farmers decision to use LCCR and ISWM than others activities
USEDUNG	0.9	Use of animal dung for fuel in compost making time: 0 if yes, 1 otherwise	Using animal dung for cooking fuel in compost preparing time is more likely negatively affecting on the uses of compost and ISWM practice
OFFFARM*	0.97	Off-farm income for fertilizer cost: 1 if no, 0 otherwise	The presence of off-farm income has no likelihood influence on adoption of any practices
BENAWAR*	0.94	Adequate awareness of benefits of SWM measures:1 if yes, 0 otherwise	Adequate awareness of benefits of SWM measures has more positive likelihood to influence on adoption of SWM measures

Acronym	*Mean*	*Definition and measurement of institutional variables*	*Hypothesis*
EXTN*	0.77	Considerable extension contact of farmers with DAs: 1 if yes, 0 No	Extension contact is suggested to be positive significant effect on adoption of introduced practices than local ones
FLOWNS	0.84	Ownership of field treated with biophysical:1 if owns, 0 otherwise	Farmlands owners have more likelihoods to use ISWM on specific plot than renters
	.99	Ownership of field treated with compost: 1 if owns, 0 otherwise	
	.96	Ownership of field treated with LCCR: 1 if owns, 0 otherwise	
Technical & plot level factors			
PERDIST	0.58	Perceived distance to home of field treated with biophysical:1if nearby, 0 otherwise	Homestead and croplands that sited very close to residential area have more probability to treated by individual SWM practice or ISWM practices than cultivated fields located relatively far away from home
	0.34	Perceived distance to home of cropland often treated with compost: 1if nearby, 0 otherwise	
	0.14	Perceived cropland distance to home that often treated with LCCR: 1 if nearby, 0 otherwise	
PERFERT	0.84	Perceived fertility status of cropland treated with biophysical: 1 if infertile, 0 otherwise	Perceived infertile status of cropland is more likely associated with farmers decision to adopt individual SWM practice or ISWM practices
	0.61	Perceived fertility status of cropland treated with compost:1if infertile, 0 otherwise	
	0.76	Perceived fertility status of cropland treated with LCCR: 1 if infertile, 0 otherwise	
PERSLOP	0.87	Perceived slope categories of cropland treated with biophysical: 0 if gentle, 1 otherwise	Perceived gentle slope of particular croplands is supposed to be negatively influenced on adoption of vegetative stabilized terracing practices
TECHFIT	0.79	Technically fitness of constructed terraces in terms of effectiveness in arresting soil erosion by water, and appropriateness to local plough operation and crop efficiency: 1 if yes, 0 otherwise	Technically fitted structural measures in terms of effectiveness in arresting soil erosion by water, and appropriateness to local plough operation and crop efficiency is more likely affected adoption decision of terracing and ISWM

Note: *For this study, FLOWNS, PERSLOP, PERFERT, PERDIST and TECHFIT are common factors for decision to adopt terracing and to use ISWM. PERSUIT is also common explanatory variable for farmers' decisions to practice LCCR and to use ISWM. USEDUNG was also common factor for decision to use compost and ISWM. Moreover, * is stand for common predictor variables for all dependent variables (biophysical, composting, LCCR and ISWM).*

5.2. Characteristics of explanatory variables

Table-10 shows that the average values of non-categorical socio-economic variables including age, family size, size of productive labour, size of farmland holding and size of livestock holding. For instance, the average age of sample household heads was 46.4 years. The mean size of family members of the sample households was 5 persons. Where subsistence mixed-farming is the predominant livelihood activity and high population pressure is observed, size of productive labour, farm size and numbers of livestock are more likely considered to be the most important socio-economic factors for smallholder farmers' decision on farming intensification by undertaking integrated soil management activities. For example, surveyed results indicate that the mean number of active persons comprising both sexes, who are able to provide work force for different kind of farming activities was 3.6 persons. The mean number of holding livestock was 10 per head. Moreover, the average holding size of farmlands was 1.77 ha per head.

Table 10: Mean values of non-categorical socio-economic variables (n=189)

Socio-economic variables	Mean	S. D
Farmland size per head (ha)	1.77	0.89
Productive labour number per head(number)	3.6	1.3
Age of household heads(years)	46.4	12.1
Family size per heads (number)	5	1.3
Size of livestock holding per head (number)	10.2	3.9

Table-11 reveals percentage distributions of categorical socio-economic variables like sex, education, awareness level to the benefits of conservation measures, dung use for cooking fuel during compost preparing time, holding of any perceived suitable plot for legume crop production, crop preference and off-farm income. For instance, sex of 85.2 % household heads was male whereas14.8% was female. Of the total respondents, about 61.4% of them reported that half and above of their household members are literate. Farmers informally noted that adequate awareness regarding the short-run and long run benefits of conservation activities (biophysical measures, compost and LCCR) in the specific land use is more likely imperative factors for their degree of adoption. Corresponding to this, about 94.2 % of farmers reported to have adequate awareness concerning the returns of each component of conservation practices, whereas the remaining 5.8% have no sufficient information.

Table-11: Proportion distributions of socio-economic, institutional, and plot level and technical categorical variables (n=189)

Socio-economic variables	***Categories***	***Response in %***
Sex	Male	85.2
	Female	14.8
Number of literate family members	$\geq$ Persons/hhs	61.4
	Otherwise	38.6
Adequate awareness on benefits of SWM measures	Yes	94.2
	No	5.8
Off-farm income for fertilizers cost	Yes	2.6
	No	97.4
Crop preference for staple food, expected outcome and market price	Cereals only	56.1
	Otherwise	43.9
Use animal dung as cooking fuel during compost making time	Yes	10. 1
	No	89.9
Hold any suitable farmland for legume crop production	Yes	50.8
	No	49.2
Institutional variables		
Considerable contact of farmers' with extension staff	Yes	77.3
	No	22.7
Ownerships of croplands conserved with terraces	Owned	83.6
	Rented	16.4
Ownerships of croplands treated with compost	Owned	98.9
	Rented	1.1
Ownerships of croplands treated with LCCR	Owned	96.3
	Rented	3.7
Plot Level and technical variables		
Perceived fertility status of croplands treated with terraces	Infertile	84.1
	Otherwise	15.9
Perceived fertility status of croplands treated with compost	Infertile	60.8
	Otherwise	39.2
Perceived fertility status of croplands treated with LCCR	Infertile	76.2
	Otherwise	23.8
Distance from home of croplands conserved with terraces	Nearby to home	58.2
	Otherwise	41.8
Distance from home of croplands often treated with compost	Nearby to home	33.9
	Otherwise	66.1
Distance from home of croplands often amended with LCCR	Nearby to home	14.3
	Otherwise	85.7
Perceived slope categories of croplands treated with terraces	Gentle	13.2
	Otherwise	86.8
Technical fitness of constructed terraces with particular cropland character	Yes	79.4
	No	20.6

Farmers' decision to use cattle dung in the form of composting is the decisive element for soil fertility improvement. Of the total respondents, 89.9 % of them reported, as they do not use cattle dung cake as cooking fuel during rainy season. This shows that the majority of farmers use cattle dung for compost making in the rainy months (in particular in summer season) when the climatic condition is inappropriate to make dung cake for cooking fuel. From the total surveyed respondents, 50.8% of them reported that they hold farmlands that perceived to be suitable for legume crop production. In the case of farmers' crop preferences in terms of staple food, expected output and market price; about 56.1% preferred cereals only, whereas 43.9% preferred both cereals and legume crops. Besides, almost all farmers (97.4%) reported that they could not obtain off-farm income incentive for fertilizers cost regularly.

Extension contact and farmlands ownership status considered as institutional variables for this study (Table-11). For instance, about 77.3% of them reported that they had considerable contact with DAs in terms of technical and advisory services, whereas the remaining 22.7% lacked contacts with them. In the case of ownership status, out of the total surveyed respondents, about 83.6%, 98.9% and 96.3% of farmers were owners of cultivated fields treated with terraces, compost and LCCR, respectively.

Table-11 also reveals proportion distributions of categorical plot level and technical variables including plot distances from farmers' residence area, perceived plot fertility status, perceived plot slope categories and technical fitness of constructed terraces. For example, out of the total household heads, 58.2%, 33.9% and 14.3% noted that they practice terraces, compost and LCCR, in that order, on cultivated fields that often found nearby to the residences. Out of the total surveyed farmers, about 84.1%, 60.8%, and 76.2% of them perceived that their cultivated plots treated with terraces, compost and LCCR, respectively, often classified in infertile category. About 86.8% and 13.2% of farmers reported that slope categories of their plot treated with terraces perceived to classify in steep and gentle categories, correspondingly. Surveyed farmers also noted the technical feasibility of constructed terraces on their specific situation of cultivated field. For instance, out of the total respondents, 79.4% of them reported that constructed terraces on their plots are technically fitted implying that effective in arresting soil loss, not cause difficulty of ploughing operation and not cause cropping lose.

5.3. Use of integrated soil and water management activities

Vanlauwe *et al*. (2010) defined Integrated Soil Fertility Management **(**ISFM) as "a set of soil fertility management practices that necessarily incorporate use of fertilizer, organic inputs, and improved germplasm aiming at maximizing agronomic use efficiency of the applied nutrients and improved crop productivity". In the context of this study, ISWM represents the combine use of activities incorporating terraces stabilized by vegetative measures (natural grass or *Sesbania sesban* shrubs), composting and LCCR on a particular plot. The assumption was that the adoption or use of such components of SWM activities are supposed to be varied between the selected sites that perhaps due to accessibility to farmers' resident area and market centre, and perceived suitable area for legume crop production. From the total surveyed respondents, about 79.4%, 90.5%, and 79.6% of farmers adopted terracing in *Beribere, Woyibila* and Wochit-wuha catchments, respectively (Table-12). This indicates that proportionately, more adopters found in *Woyibila* than other catchments.

Table-12: Percentage distribution and statistical difference of practicing of SWM components

Activities	Categories of Respondents	Selected catchments Beribere% (n=34)	 Woyibila% (n=42)	 Wochit-wuha% (n=113)	X^2
Terrace	Adopters	79.4	90.5	79.6	2.62
	Non-adopters	20.6	9.5	20.4	
Compost	Adopters	82.4	91.5	85.8	1.1
	Non-adopters	17.6	8.5	14.2	
LCCR	Users	14.7	14.3	73.5	63.23 [a]
	Non-users	85.3	85.7	26.5	
ISWM	Users	5.9	9.5	54	42.3 [a]
	Non-users	94.1	90.5	46	

*Note: [a] indicates significance at p<0.01and **ISWM**-represents Integrated Soil and Water Management that incorporating vegetative stabilized terracing, composting and LCCR at specific field*

In addition, Table-12 shows that out of the total surveyed farmers, 82.4%, 91.5% and 85.8 % of them were used compost on any cultivated fields regularly in *Beribere*, *Woyibila* and *Wochit-wuha* catchments, in that order. This entails that similar to terraces, more percentage of compost adopters found in Woyibila catchment than other catchment. However, the chi-square-test results reveal that there was insignificance difference in farmers' decision to adopt introduced conservation measures like composting and terracing in three catchments. Hence, unexpectedly, the assumption of influence of accessibility of plots from farmers' residences and market centre on different adoption of such mentioned practices between the catchments was insignificant.

Table-12 further indicate that of the total surveyed respondents, 73.5%, 14.7% and 14.3% of farmers practice LCCR in *Wochit-wuha*, *Beribere* and *Woyibila*, respectively. Besides, from the total surveyed farmers, about 54%, 9.5% and 5.9% of them found to have often used integrated soil management on a specific plot in *Wochit-wuha*, *Woyibila* and *Beribere*, correspondingly (Table-12). In substantiating with this, results of chi-square test in Table-12 further reveal significance differences in farmers' decision to use LCCR (at X^2 value of 63.23 and $p < 0.01$) and ISFM at particular plot (at X^2 value of 42.3 and $p<0.01$) in three catchments. This may be attributable to the presence of perceived suitable cultivated fields for legume crop production in both homestead and far-away areas of Wochit-wuha catchment. In association with this, according to frequent informal discussions with farmers at transect walks, larger coverage of Wochit-wuha catchment perceived to be suitable to legume crop production. As expected, therefore, the results suggested that there is a relationship between catchment characteristics (suitability for legume crop growing), and practices of LCCR and ISFM.

5.4. Influencing factors on practicing of integrated soil and water management

Results of T-test (inTable-13) and chi-square test (inTable-14) reveal that there are significance differences in categories of respondents (adopters/users and non-adopters /non-users) pertaining to socio-economic factors like farm size holding [FARMSIZE] (for terracing, composting and LCCR), holding of any perceived suitable plot for legume crop production [PERSUIT] and crop preference [CPREFER] (to LCCR and ISWM) and productive labour size [PROLABSIZ] (to terracing and composting).

Table 13: T-test analysis of response categories with non-categorical variables

Type of Practices	Categories of Respondents	Explanatory Factors FARMSIZE (in ha) t-test	 PROLABSIZ (in No.) t-test
Terraces	Adopters (n=155) Non-adopters (n=34)	4.5 [a]	5.8 [a]
Compost	Adopters (n=164) Non-adopters (n=25)	-1.97 [b]	5.3 [a]
LCCR	users (n=95) Non- users (n=94)	7.5 [a]	-
ISWM	users (n=68) Non-users (n=121)	3.7 [a]	-

Note: [b] and [a] indicates significance at $p<0.1$ and $p<0.01$, respectively

Results of chi-square test inTable-14 show significance differences in categories of respondents in respect to institutional factors like extension contacts [EXTN] (for terracing and composting) and ownership status of cultivated fields [FLOWNS] (for terracing and ISWM). Table-14 also show significance difference between categories of respondents with reference to plot level and technical factors including technical fitness of constructed terraces [TECHFIT] (for terracing and ISWM), perceived plot distance from farmers residence area [PERDIST] (for all practices), perceived fertility status of plot [PERFERT] (for composting, LCCR and ISWM) and perceived slope categories of plot [PERSLOP] (for terracing). Accordingly, these variables incorporated in further binary logistic regression modelling.

Table 14: Chi-square test (χ^2) values of categorical variables (only statistically significance difference between categories of respondents (adopters/users and non-adopters/non-users)) of SWM practices

Factors	Categories	Terraces adopter &non-adopter(χ^2)	Compost Adopter &non-adopter(χ^2)	LCCR users& Non-users(χ^2)	ISWM Users& Non-users(χ^2)
PERSLOP	Gentle Otherwise	17.6[a]	-	-	-
FLOWNS	owned rented	40.4[a]	-	-	13.63[a]
EXTN	yes No	10.1 [a]	85.7[a]	-	-
PERDIST	nearby otherwise	24.1[a]	12.13[a]	23.14[a]	7.71[a]
PERFERT	infertile otherwise	-	4.35[b]	6.4[a]	3.72[b]
TECHFIT	yes No	10.7 [a]	-	-	10.99[a]
PERSUIT	yes No	-	-	117.5[a]	62.4[a]
CPREFER	Cereals otherwise	-	-	44.4 [a]	24.3 [a]

Note: [a], and [b] significant at p< 0.01 and 0.05 levels, respectively

Nevertheless, the difference between response categories were not significantly observed in other socio-economic variables like age, sex, family size, livestock holding size, number of literate family members, adequate awareness of benefits of SWM activities, off-farm income for fertilizer cost, and use of dung for cooking fuel during compost making time. Hence, these variables excluded from further analysis of binary logistic regression model.

Results of goodness of fit test presented in Table-15 reveal that the set of variables used as predictors in the binary logistic regression model fits. For instance, the omnibus tests of model coefficients of terraces (χ^2=77.6, at df = 8 and Sig. p<0.000), compost (χ^2= 97.54, at df= 5 and Sig. p<0.000), LCCR (χ^2=194, at df=5 and Sig. p<0.000) and ISWM (114.67, at df=7 and Sig. p<0.000) indicate goodness of fit. This further interpret that resulting of highly significance value ($p < 0.05$) gives an overall indication of how well data fit to the model. The overall correctly classification schemes in the model were also 90.5% (98.1% for adopters and 55.9% for non-adopters of terracing), 95.2% (96.9% for adopters and 84.6% non-adopters of composting), 92.1% (93.6% for users and 90.5% for non-users of LCCR) and 91% (80.6% for users and 89.3% for non-users of ISWM). Moreover, according to the results of correlation matrixes multicollinearity between the explanatory variables not found to be a problem for this study.

Results of binary logistic regression modelling in Table-15 verify a priori expectation that the interaction of several factors influence farmers' decision on practice of ISWM (including introduced and indigenous).

Socio-economic factors

Findings in Table-15 show that among the 12 hypothesised socio-economic variables, only productive labour size, total farmland holding size, holding of any perceived suitable plot for legume crop producing and farmers' crop preference are found to significantly influence adoption or using of components of ISWM activities.

For instance, more productive labour size (PROLABSIZ) per household level has positive significant effect on farmers' decision to adopt terracing (at $p<0.05$) and composting (at $p<0.01$). This perhaps implies that larger potential of productive labour size has more likelihood effect to maintain terraces and to prepare compost than lesser productive labour size. In agreement with this, the results of the study by Wagayehu and Drake (2003) conducted in the Eastern highlands of Ethiopia indicated that family size per economically active household members is found negatively and significantly influence the farmers' decision of conservation effort. Woldeamlak (2007) also reported that a household's labour supply determines its ability to continuously maintain already established physical conservation measures as they characterize as too labour intensive.

The effect of total farmland holding size (FARMSIZE) per head is found to have negative significant (at $P<0.1$) on adoption of composting and positive significant (at $P<0.01$) in using of LCCR, regularly. This implies that lesser farmland holders are the ones who more likely invested substantial amount of labour in improving soil fertility through preparing compost instead of practicing LCCR, and consequently productivity on their relatively smaller croplands. In association with this, poorer farmers prepared and used more compost from easily available organic sources to complement their limited access to inorganic fertilizers and animal dung (Alemayehu *et al*., 2001). Mehretie and Woldeamlak (2013a) also reported that farmers with less land holding were more likely to use manure compared to larger landholder farmers. In contrary, farmers those who hold small farmland size are less likely alternated legume-cereals crops and its overturn on the same cultivated fields frequently. In agreement with this, Belay (1998) reported that the main concern of farmers, who hold small farmland size, is to produce major staple food crops like cereals on small owns fields for their survival rather than afford to alternated with legume crops repeatedly. Moreover, despite the coefficients of size of farmland is positive on adoption of terraces and negative on using of ISWM, its effect was not statistically significant.

Holding of any perceived suitable farmland for legume crop production (PERSUIT) is found to have positive significant effects (at $P<0.01$) on the likelihood of farmers' decision to use LCCRs and ISWM. In association with this, based on the informal discussions, farmers are usually preferred to use compost only for legume crops like beans and pea productions in the perceived suitable fields that also conserved with terraces stabilized by growth of *Sesbania sesban* shrubs. Farmers also noted that intermixing of legume crop like purple hull pea (*Vigna unguiculata*) in maize continue grown, and tef to legume and its overturn crop often practice at croplands close to residences than far-away farmlands. Because of this, as farmers further indicated, straws of maize (for cattle feeding and cooking fuel) and tef crops (for cattle feeding and home construction) are quite imperative from nearby fields with the intention of lesser labour for carrying.

Crop preference in terms of staple food, expected output and market price (CPREFER) has positive significance effect (at $P<0.05$) on the likelihood of using LCCR and ISWM on specific plot. This implies that farmers, those who have included legume crop as part their favourite crops, have more likelihood to use LCCR and ISWM at particular fields, frequently.

Table 15: Influential factors on farmers' decision to practice ISWM activities

Explanatory Variables	Terraces Coefficient (B)	Compost Coefficient (B)	LCCR Coefficient (B)	ISWM Coefficient (B)
PROLABSIZ	.625(.252) [b]	1.1 (.39) [a]	-	-
FARMSIZE	.219(.374)	-.838(.46) [c]	2.145(.604) [a]	-.389 (.317)
PERSUIT (1)	-	-	6.158(1.156) [a]	3.45 (.55) [a]
CPREFER(1)	-	-	1.53(.68) [b]	1.32 (.52) [b]
EXTN (1)	.995(.559) [c]	4.893 (.91) [a]	-	-
FLOWNS (1)	1.84(.66) [a]	-	-	2.64 (.92) [a]
PERDIST(1)	2.33(.594) [a]	3.1 (1.34) [b]	3.217(1.16) [a]	.983 (.477) [b]
PERFERT(1)	-	-089(.75)	1.547(.990)	1.624(.65) [b]
PERSLOP(1)	1.206(.671) [c]	-	-	-
TECHFIT(1)	.732(.59)	-	-	2.1 (.68) [a]
Constant	-5.483(1.22) [a]	-2.71 (1.3) [b]	-9.489(2.234) [a]	-8.795 (1.44) [a]
-2 Log likelihood	100.536	53.86	67.963	131.1
Omnibus Tests of Model Coefficients	model – χ2 (77.6) at df= 8 and Sig.(p<0.000)	model – χ2 (97.54) at df= 5 and Sig.(p<0.000)	model – χ2 (194) at df=5 and Sig.(p<0.000)	model – χ2 (114.67) at df=7 and Sig.(p<0.000)
Correctly predicted [a]	90.5	95.2	92.1	91
Sensitivity [b]	98.1	96.9	93.6	80.6
Specificity [c]	55.9	84.6	90.5	89.3

Note:
- *values of standard error (S.E.) are presented in bracket*
- *[c], [b], and [a] denote statistical significance at the 10 % (p<0.1), 5 %(p<0.05), and 1 %(p<0.01), respectively*
- *[a] based on a 50-50 probability classification scheme*
- *[b] correctly predicted adopters based on 50-50 probability classification scheme*
- *[c] correctly predicted non-adopters based on 50-50 probability classification scheme*
- *ISWM means Integrated Soil and Water Management including vegetative stabilized terraces, compost and Legume-Cereals Crop Rotation (LCCR)on specific plot*

Acronym of predictor variables define in the text

Institutional Factors

As expected, results in Table-15 reveal that both institutional factors including extension contact and ownership status of farmers on particular croplands have more likelihood effects on farmers' adoption decision of introduced SWM activities (compost and terraces). For example, extension contact (EXTN) is positively and statistically significant in influencing farmers' decision to adopt compost (at P<0.01) and terraces (at P<0.1) in cultivated fields, indicating that the importance of extension as a sources information and capacity building on smallholder farmers. This further implying that farmers those who had substantial extension contacts are more likely prepared and used compost, as well as maintained terraces than farmers that had less extension contacts, perhaps, due to practicing of composting and stabilized terraces with growth of vegetation are comparatively management skill-intensive. This made in agreement with results of studies (Asafu-Adjaye, 2008; Anley *et al*., 2007; and Minale *et al.*, 2009) which revealed that better access to extension services could influence on the level of improved soil conservation efforts. Moreover, project assistance and access to information have demonstrated significant positive effect on farmers' decision for conservation efforts (Wagayehu and Drake, 2003).

Ownership status of cultivated fields (FLOWNS) is also positively and significantly (at P<0.01) influenced on farmers' decision to adopt terracing, as well as to use ISFM on specific plot. This implies that owners are more likely adopt terracing and use ISFM since realizing long horizon planning than cash and share renters. In agreement with this, Minale *et al.* (2009) reported that ownership of plot has positive effect on farmers decision to use compost and to combine composting and conservation tillage, suggesting that ownership status could be increased the assurance of future access to the returns of investments. Renters or farmers that do not own the cultivated fields may well be hesitant to maintain in soil loss curbing and nutrient stock replenish measures as the pay-off is not always directly visible, as well as they are not often considered long term ecological benefits to farmland productivity rather than short-term gains.

Plot level and technical factors

Sustainable agricultural productions systems are instinctively site-specific with in particular inclusive of plot level and technical perspective attributes (Lee, 2005). Results appear in Table-15 reveal that out of the six hypothesised field level and technical predictor variables, only perceived cropland distance from home, perceived fertility status of croplands, perceived slope categories of farmlands and technical fitness of constructed structural measures are found to have significant effects on farmers' decision to adopt/use components of SWM practices.

For example, farmers' perceived plot distance from residences (PERDIST) is found to have positive and significant effects on farmers decision to adopt terracing (at P<0.01) and composting (at P<0.05), to use LCCR (at P<0.01) and ISWM on a particular plot (at P<0.05). This further notifies that more husbandry intensifications make with decrease of plot distance from farmers' residences. This implies that the probabilities of integrated use of different components of SWM practices are increasing with decreasing farmland distance from home (farmers' residential areas). Farmers could be managed their farmland according to their perceived closeness. Hence, perhaps, farmers those who hold farmland nearby their residences are more likely dedicated their labour and time to invest intense management efforts with less devote costs and resources than those who hold farmland sited far distance from home. This may be attributable to farmers' perception on uncertainty of farmland security, labour difficulty to carry and transport prepared compost, and inaccessibility to regulate stabilized terraces with growth of saspaniya shrub. In agreement with this study result, Amare *et al.* (2006) reported that organic matter related parameters like N and P contents were higher in soils wherein situate close to homestead and involves higher inputs of organic management than other soils. Anley *et al*. (2007) noted that distance of plot from residential area had negative significant effect on the use of improved soil bunds, improved cut-off drain and fanna-yejuu. Mehretie and Woldeamlak (2013a) also indicated that the likelihood of manure use tend to be lesser with increased plot distance from home. Besides, Chibudu *et al.* (2001) also found highly positive N and P balances in home fields since farmers considerable invested on farm fertility management in homestead fields. Moreover, study results in western Kenya, Tittonell *et al.* (2005) indicate that the distance from the homestead influence the distribution of macronutrients added through organic inputs implying that the inputs rates of C and N were much higher in the home gardens, where pattern of organic resources allocation is higher.

Perceived fertility status of croplands (PERFERT) also has positive significant effect on using ISWM ($p<0.05$) at particular plot. This implies that the practicing likelihood of ISWM is more likely increasing when farm plots perceived to be infertile. In association with this, Aklilu and De Graaf (2007) indicated that plots with infertile soils found positive and statistically significant effects on farmers' adoption and continued use of stone terraces, suggesting that not realizing of short-run negative effect of erosion. However, despite the coefficients of perceived infertile status of plots were negative on adoption of compost and positive on practice of LCCR, their effects were not statistically significant.

Perceived slope categories of farmlands (PERSLOP) had weak positive and statistically significant effects (at $P<0.1$) on adoption of terracing. This implies that the adoption probability of structural measures is likely increasing with steepness slope of farm plots that perhaps due to magnitude of soil erosion by water is likely to increase. In agreement with this, studies conducted in the highlands of Ethiopia (Wagayehu and Drake, 2003; Anley *et* *al*., 2007; Aklilu and De Graaff, 2007) indicated that a significant and positive association between slope of farm plots and the adoption or practice of improved structural measures (soil bunds, stone bunds, and fanna-yejuu). Minale *et al*. (2009) also found that the plot slope influence the decision to combine the use of compost and conservation tillage.

Moreover, farmers' perception on technical fitness of constructed structural measures (TECHFIT) has positive significant effect (at $P<0.01$) on the practicing likelihood of ISWM on a specific plot. The implication is that the adoption likelihood of stabilize terraces with growth of vegetation and then their integration with some other agronomic activities like composting and LCCR on specific plot more likely increases when the constructed terraces perceive to technically fits within a particular farmland context. In association with this, Bekele and Holden (1998) reported that farmers' decisions to retain structural conservation measures are positively and significantly associated with positive attitude or perception towards new technologies expected attributes. The result also agrees with the argument of technical fitness of introduced conservation technologies to farmers' requirements and farming system circumstance is one main encouraging factor to the sustainable adoption and widespread replication of the practices (Woldeamlak, 2007).

5.5. Conclusions

The smallholder farmers' decision to adopt/use Soil and Water Management (SWM) measures bases upon normal considerations of benefits and costs. One of the lessons learnt from this study results is that smallholder farmers decision to adopt/use individual components (stabilized terraces with vegetation (natural grass or *Sesbania sesban* shrubs), composting, Legume-Cereals Crop Rotation[LCCR]), as well as combine use of all mentioned practices on particular plot were influenced by a host factors. For instance, household-specific factor (productive labour size), institutional factors (farmland ownership status and extension contacts) and plot-specific factor (like perceived farmland distance and perceived plot slope categories) influence farmers' adoption of stabilized terraces with growth of vegetation. Decision at farm household level to use compost in any farmland regularly is positively and significantly influenced by productive labour size and degree of extension contact, whereas negatively and significantly influenced by total farmland holding size (in ha). Farmers' decision to practice LCCR is positively and significantly explained by holding any perceived suitable plot for legume crops production, farmland holding size (in ha), farmers crop preference in terms staple foods and market prices, perceived farmland distance from home and perceived soil fertility status of particular plot. And eventually, farmers' crop preference, ownership status of farmlands, farmers' perceptions on plot distance from home and fertility status, technical fitness of constructed structural measures and holding any perceived suitable plot for legume crops production are major influential factors for farmers' decision to use Integrated Soil and Water Management (ISWM) incorporating biophysical, compost and LCCR on a specific plot.

Therefore, based on the major findings of this study, to promote the dissemination of ISWM activities in the broad context, policy should recognize these key variables and their mutual interdependence influence on farmers' decision to adopt activities overtime. The most appropriate soil fertility management should be integrated both the modern and indigenous ones (Belay, 1998). The importance of extension as sources of information and capacity building on smallholder farmers should be paid attention to promote willingness and ability to combine the use of local and improved SWM activities in an attempt to scale up the replenishing of soil fertility and then productivity as well. The tremendous efforts of agricultural extension system to scale up multifunctional ISWM activity, which is relevant to provide both short-term and long-term returns, need to develop to contribute to sustainable agricultural production of smallholder farmers.

CHAPTER SIX

DYNAMICS AND MANAGEMENT SCHEMES OF COMMON-POOL RESOURCES IN THE MIXED FARMING SYSTEM

6.1. Dynamics of land use/covers in Goncha-Siso-Enese Woreda

In the context of this study, common-pool resources include forests, grasslands, shrub lands, wetlands, boundaries between cultivated fields owned by adjacent farmers, and animal tracking roads. These areas are more likely vulnerable to severe degradation including gullies expansion, deterioration of biomass and accelerated soil erosion by water that, perhaps, due to the assumption of tragedy of the commons in the form of overgrazing, de-vegetation, and encroachment of croplands and settlements towards commons.

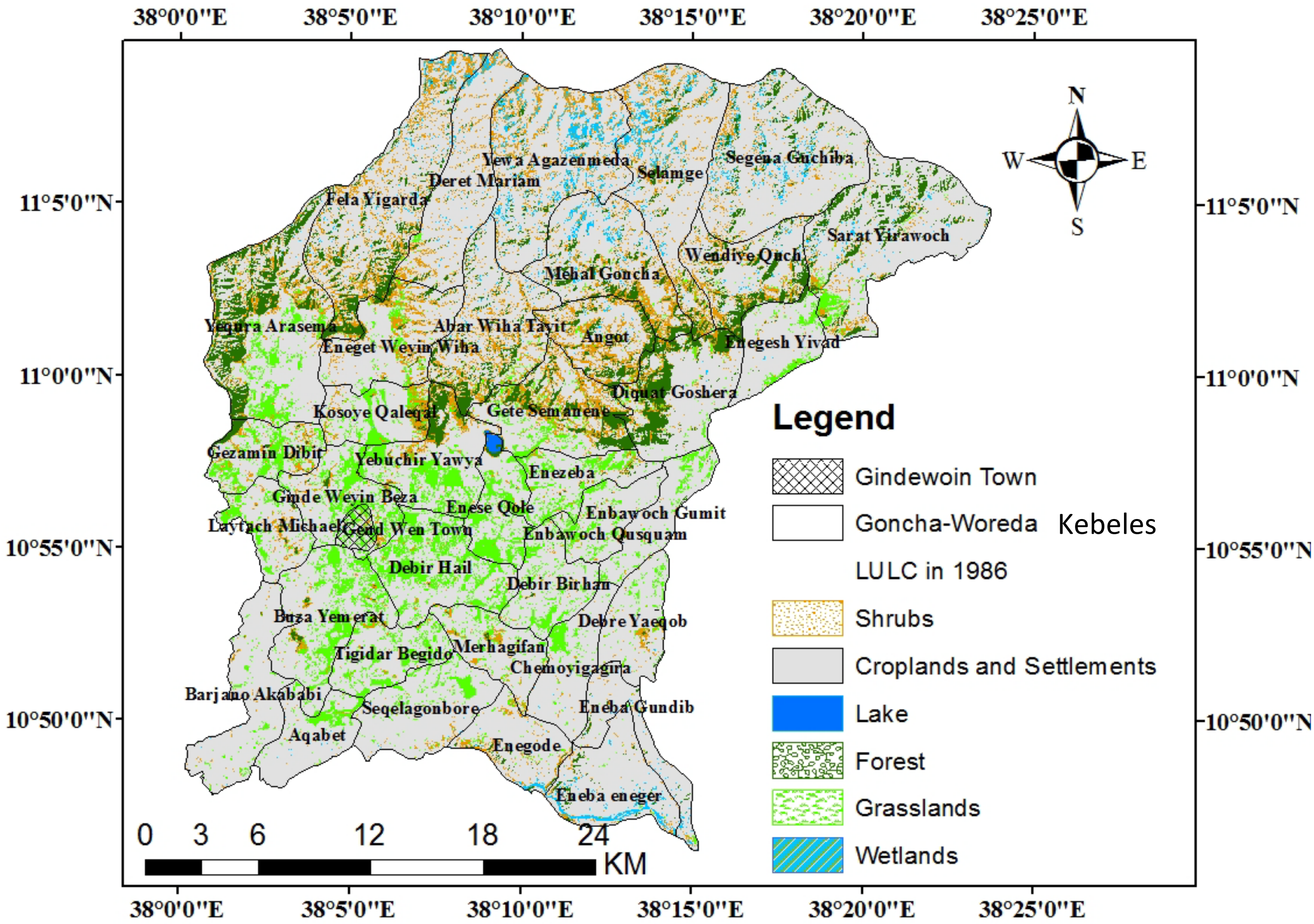


Figure-7a: Land use/covers of Goncha-Siso-Enese Woreda, 1986 G.C

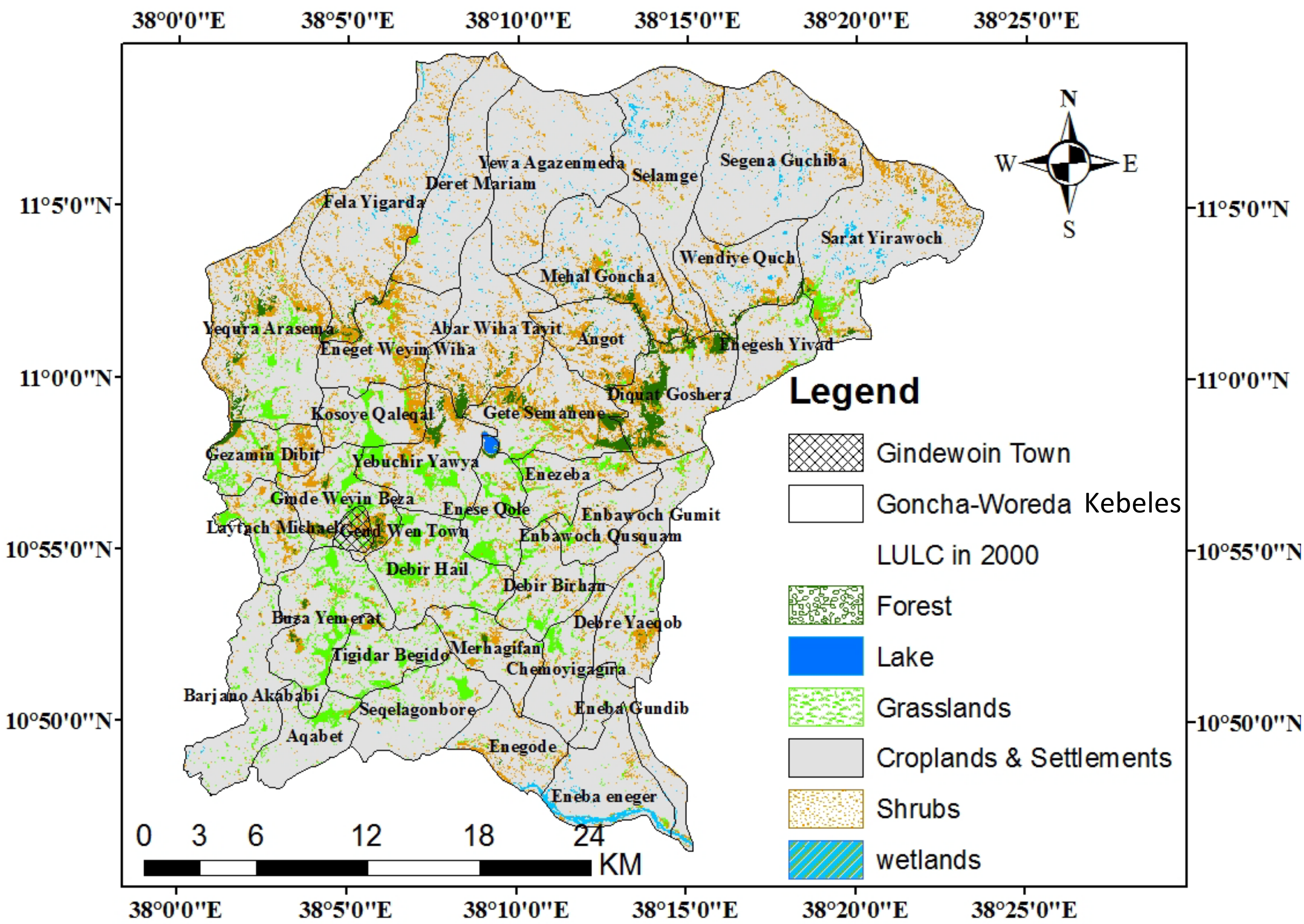


Figure-7b: Land Use/Covers of Goncha-Siso-Enese Woreda, 2000 G.C

Table-16: Dynamics in areal coverages in time perspectives.

LU/LC types	Areal coverage in ha (%)			% Change		
	1986	2000	2014	1986_ 2000	2000_ 2014	1986_ 2014
Forest	7,336.2(7.1)	2,122.3(2)	2,052.4(2)	- 71.1	-3.3	-72
Shrubs	8,394(8.1)	10,168(9.8)	2,282.3(2.2)	+21.1	-77.6	-72.8
Grasslands	9,361(9)	5,905.5(5.7)	9,422.2 (9.1)	-36.9	+59.5	+0.6
Cropland & settlements	76,910.8(74)	84,721.9(81.5)	89,660.5 (86.3)	+10.2	+5.8	+16.6
Wetlands	1809.9(1.7)	893.3(0.9)	394.4 (0.4)	-50.6	-55.9	-78.3
Lake	68.7(0.1)	69.6(0.1)	68.8 (0.07)	+1.3	-1.15	+0.15
Total	103,880.6(100)	103,880.6(100)	103,880.6(100)			

Sources: *Path 169 and Row052: Landsat TM January/1986, ETM+ January /2000 and Landsat 8 operational land imager (OLI), January/2014.*

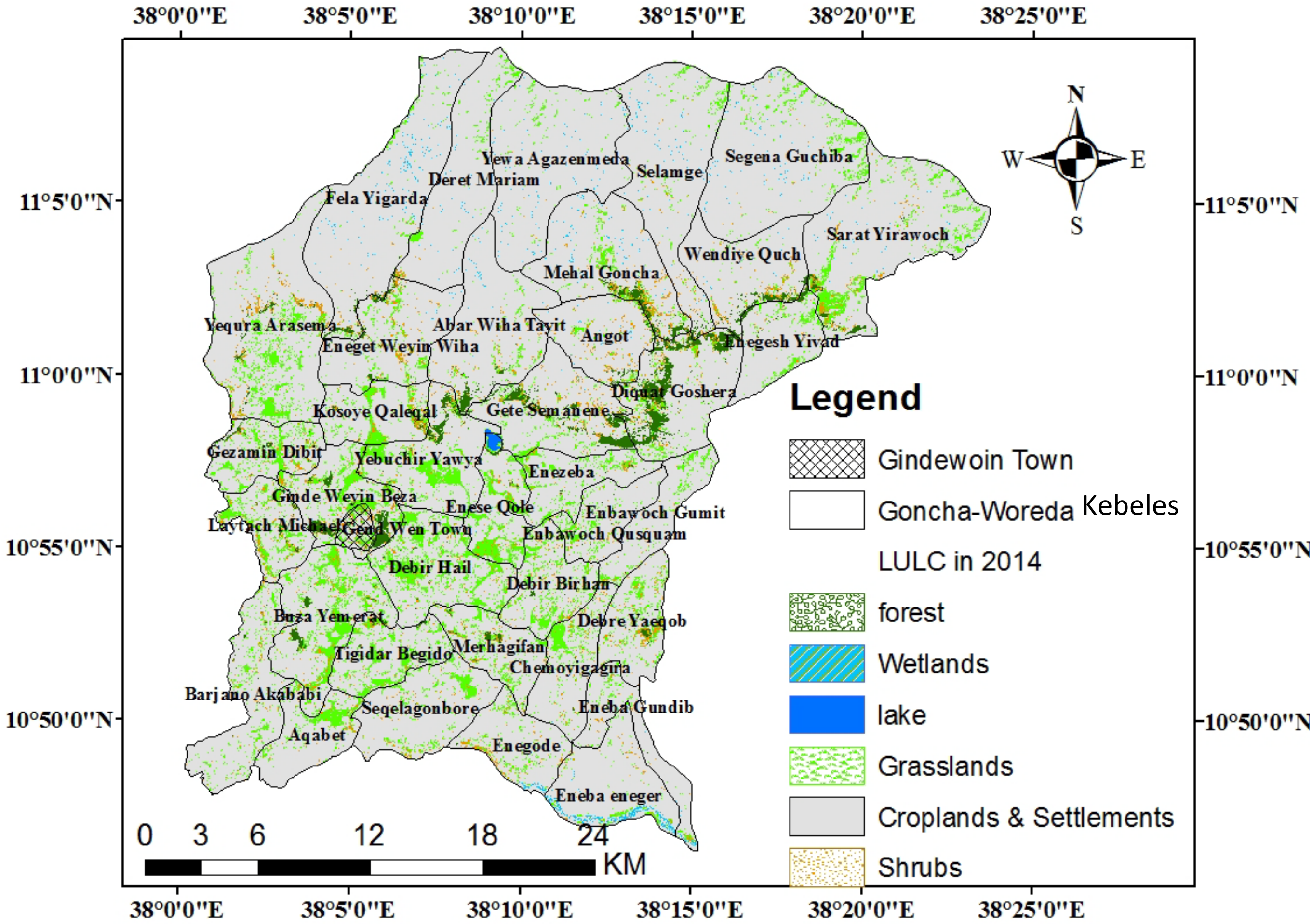


Figure-7c: Land Use/Covers map of Goncha-Siso-Enese Woreda in 2014 year G.C

Forest cover

Table-16 indicates proportion and dynamics of forest coverage in time perspectives. For instance, at the three different points of time i.e. 1986, 2000 and 2014, forest cover accounted, respectively, for 7.1%, 2% and 2% of the total area of the woreda. The reduction in areal coverage was by 71.1% in 2000 and 3.3% in 2014, when compared with its coverages in 1986 and 2000, respectively. In the first period (from 1986 to 2000), and second period (from 2000 to 2014) of the study, on an average of 384.3ha and 57.4ha of the forest covers, respectively, were converted into others land use/covers per annum.

Results in Table-17 revealed that dynamics of forests coverage between LU/LC classes in time perspectives. For example, from the total forest cover in 1986, about 73.31% was lost to the gains of other land use/cover classes like 58.7% to croplands and settlements and 14.4% to shrubs in 2000. Moreover, of the total forest cover in 2000, about 37.9% was lost to the gains of other LU/LC types such as 33.7% to croplands and settlements, and 3.4% to shrubs over the second period. The results indicate that forest covers were largely converted to cropland and settlements and then shrub lands than others classes. The magnitude of forest clearing in the first period was largely higher as compared with the second period.

Table-17: Dynamics of LU/LC between LU/LC classes in time perspectives in Goncha-Siso-Enese Woreda

Changed		Change (%)		
From	To	From1986 to 2000	From 2000 to 2014	From1986 to 2014
Forests	Shrubs	14.4	3.4	3.4
	Grasslands	0.01	0.8	0.9
	Croplands& settlements	58.7	33.7	74.6
	Wetlands	0.2	-	-
	Lake	-	-	-
Shrubs	Forests	0.6	5.7	2.9
	Grasslands	1.8	15.2	7.5
	Croplands & Settlements	55.8	65	78.9
	Wetlands	0.5	-	0.4
	Lake	-	-	-
Grasslands	Forests	0.2	-	0.6
	Shrubs	12.1	5	4.9
	Croplands & Settlements	41.7	25.9	47.2
	Wetlands	-	0.1	-
	Lake	-	-	-
Cropland & settlements	Forests	0.1	0.2	0.3
	Shrubs	5.9	0.6	0.9
	Grasslands	1.9	4.4	5.6
	Wetlands	0.7	0.3	0.3
	Lake	-	-	-
Wetlands	Forests	-	-	-
	Shrubs	0.4	0.6	0.1
	Grasslands	-	4	1.1
	Croplands & settlements	83.5	78.7	93.1
	Lake	-	0.1	-
Lake	Forest	-	-	-
	Shrubs	-	-	-
	Grasslands	-	4.9	4.4
	Croplands & settlements	-	-	-
	Wetlands	-	-	-

Sources: Path 169 and Row052: Landsat TM January/1986, ETM + January /2000, and Landsat-8 Operational Land Imager (OLI), January/2014.
Note*: See detail distributions of frequency and percentage values in Appendices-IV, V &VI of chapter six*

From the field observations and farmers viewpoints, trees, which cannot be easily accessible to livestock for graze and difficult to steal through cut-and-carry process due to fear of law and high financial punishment (up to 300 birr and a 5 years jail sentence), are seen very sparsely in hills open shrub and croplands. These scattered ruminants can take as the indicators of conversions of forest into cultivated fields and shrub lands. Excessive declining of forest covers over nearly three decades is largely observed in the *kola* and *Dega* agro-ecological environments of the woreda, where uncontrolled burning and cutting of trees and bushes on hills might have been practised for charcoal and crop production due to remoteness from the woreda administration centre (Gindewoin town)(see figures-7abc).

Shrubs

Table-16 indicates that from the total area of Goncha woreda, shrub covers were 8.1%, 9.8% and 2.2% in 1986, 2000 and 2014, respectively. Shrub covers increased by 21.1% in 2000 but decreased by 77.6% in 2014 as compared with its total area in 1986 and 2000, correspondingly (Table-16). Between 1986 and 2000, mean of 352.9ha of the shrub covers converted into other land use/covers per annum. Over this first period, from the total area of shrubs in 1986, about 58.8% was lost to the gains of other land use/cover classes (Table-17). Of the total lost area, for instance, 55.8% was added to croplands and settlements and 1.8% to grasslands. The figure indicates that shrub covers were highly changed in response to rampant expansion of croplands and settlements.

Moreover, between 2000 and 2014, on an average 623.9ha of the shrub covers converted into other land use/covers per year. Over this second period, of the total area of shrubs in 2000, 65%, 15.2% and 5.7% converted into croplands and settlements, grasslands and forests, in that order (Table-17). This reveals that at the expense of shrubs, large proportion of cropland and settlements, and then grasslands continuously expanded over nearly three decades. This incidence was mainly observed in *Derit-Mariam, Eneba-Eneger, Sarat-Yerawoch, Segena-Guchiba, Selameda, Wondiye* and *Yewa-Agazenmeda kebeles*, where the agroecology is locally categorized as *Kola*, as well as accessibility of information and market function are relatively difficult (see figures-7abc). In the areas of undulating topography, encroaching of croplands towards steep hills' shrub covers largely observes. Because of unsuitability for ox-pulled ploughing operations, farmers use hand-digging mechanism to prepare seedbeds and make soils loose for seed germination. Charcoal production by clearing common shrubs and bushes is one of the supplementary sources of cash incomes for livelihoods of large numbers of farmers' in the concerned agro-ecological environments.

From field observations, under the open grazing system, overgrazing of browsers (in particular goat) is caused to modification of shrub covers into poor quality grasslands and then highly susceptible barren surfaces for water erosion and new gully development, particularly in hilltops and their surrounding areas. Where the goat population is higher, the conversions of forests to shrubs and then from shrub lands into grasslands were radical. As farmers noted, modification of shrub covers into grasslands through direct intervention of farmers sometimes observes to the sake of cash income by selling grass for roofs of houses. Even some farmers use the steeply sloping croplands for grass production for cash income as is proved more beneficial than crop (particular sorghum) production. Farmers added that stealing of bushes for fencing of croplands area and home gardens appear to have contributed more to over deterioration of shrubs and consequently converted into grasslands.

Gains in forest covers at the expense of shrubs mainly observed in *Gindewoin-Beza, Gindewoin,* and *Debr-Hail Kebeles* of *Woina-Dega* agro-ecological zone of the Woreda (see figures-7abc). This is due to the prolonged protection of planted eucalyptus, Juniperus procera, Acacia abyssinica and other trees on degraded areas closed to woreda town, during Derge government afforestation program. Moreover, some shrub covers converted into forests particularly at churchyards and other natural forest in *Tigdar-Begido, Barijano, Debrebirhan, Debreyakob, Buza-Yemerat* and *Chemo-Giyorgis Kebeles* of *Woina-Dega* agro-ecology of the Woreda (see figures-7abc). This may be due to effective protection by the local communities.

Grasslands

Table-16 shows that percentage and dynamics of grasslands coverage in time perspectives. For example, grassland coverage described with 9%, 5.7% and 9.1% of the total area of the Woreda in the respective years of 1986, 2000 and 2014. The areal coverage of grasslands decreased by 36.9% in the first period (from 1986 to 2000) but increased by 59.5% in the second period (between 2000 and 2014) of the study. In the first period, on an average 361.63ha of the grasslands' coverage was converted into others land use/covers per year. From the total area in 1986, about 41.7% and 12.1% of grasslands converted into croplands and settlements, and shrub lands, respectively by 2000 (Table-17). In the second period, on an average 130.7ha of the grassland covers converted into others land use/covers per annum. Table-17 shows that of the total area of grasslands in 2000, about 25.9% and 5% were lost to crop lands and settlements, and shrubs, respectively by 2014. These results indicate that despite the conversion of more grassland covers into croplands and settlements, and then shrubs being consistent, its magnitude declined. In association with this, from field observations and informal discussions with farmers, expansion of croplands over open grasslands of valley floor usually occurs. Because of rapid population growth but confined cultivated lands, substantial amount of valley floor open grasslands allocated for young landless farmers in some number of the *Kebeles* of *Woina-Dega* agro-ecological zone of the Woreda. Moreover, farmers, who owned croplands bordering with open grasslands, generally expand their cultivated fields by illegal encroachments on the grasslands from year to year (see figure 8ab).

Figure-8a: Using common pool resources for personal services like fencing for cut-and–carry grazing system and heaping of tef straw

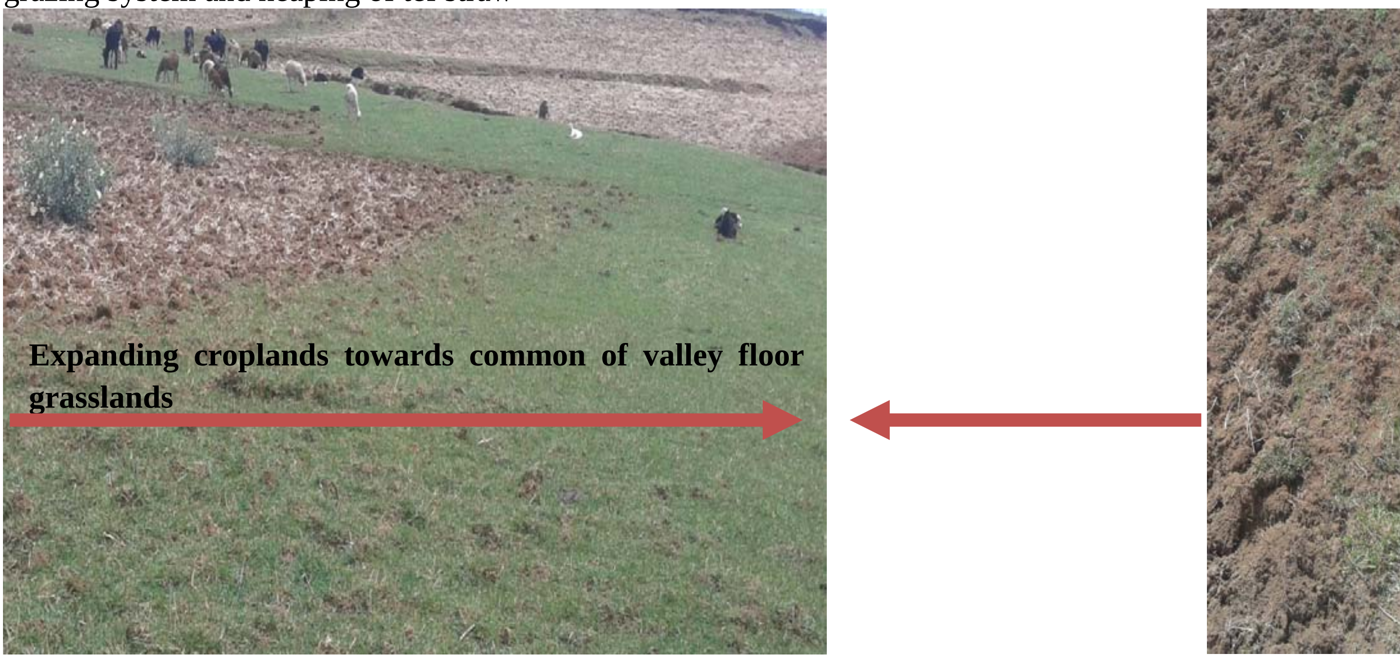


Figure-8b: Expanding of privately owned croplands towards common valley floor grasslands in February/2015

The degree of expansion of private croplands is usually higher on open-grasslands of vertisols, in particular on valley floors of large size coverage, located far away from settlement areas as compared with hilltops (less productive) and surrounded with settlements. This may be attributable to the productiveness of such soils to crop. As farmers reported, in the productive grasslands of vertisols, cash punishment is more possibly lesser than returns from encroached cultivated fields. Based on the frequent observations, twisting limits between private croplands and common grazing areas, and well productiveness of croplands portion on the side of common are indicators of progressive expansion of private croplands towards communal grasslands(see figure-8b).

Project or government initiative or at individual household plantations of shrubs and bushes on grasslands of hills in some kebeles of Goncha Woreda might have been also the cause to the gain of shrubs at the expense of degraded open grasslands.

Wetlands

Wetlands covered 1.7%, 0.9% and 0.4% of the total area of the Woreda in respective years of 1986, 2000 and 2014, showing a reduction of 50.6% in first period (from 1986 to 2000) and 55.9% in the second period (from 2000 to 2014) of the study (Table-16). In the first and second periods of the study, on an average 108.5ha and 53.2ha of the wetland covers, respectively, changed to others land use/covers per year. Moreover, wetland covers were lost to the gains of croplands and settlements by 83.5% in the first period and by 78.7% in the second period of the study (Table-17). This conversion circumstance often observed in the *kola* agro-ecological environment (see figure-7abc) that perhaps, due to the expansion of traditional irrigated farmlands. In the second period of the study, 5% of wetland covers also converted into grasslands (Table-17). This was probably due to the expansion of dryness of ponds and marshlands.

Crop land and settlements

Coverage of croplands and settlements has been accounted for 74%, 81.6% and 86.3% of the total area of the Woreda in 1986, 2000 and 2014, in that order (Table-16). It has continuously expanded respectively by 10.2% and 5.8% in the first and second periods of the study. Results of satellite image analysis revealed that common-pool resources including forests, shrubs, grasslands and wetlands have substantially contributed to the progressive expansion of croplands and settlements. Accordingly, areas used for both annual and perennials crops productions with dispersed rural settlement and plantation of some trees around the homesteads increased rapidly and consistently. Alternatively, of the total area in 1986, 5.9% were lost to shrubs in 2000 (Table-17). It prominently observed in *Chemo-Giyorgis* and *Debre-Birhan Kebeles* of *Woina-Dega* agro-ecological zone of the woreda (see figure-7abc). This may be due to plantations of shrubs or young stage of growth either of Grevillia trees, which planted on barren fallow fields and gullies individually or by the collective action.

Privately owned croplands also contributed respectively1.9 % and 4.4% to grasslands in the first and second periods under the study. The conversion of croplands and settlements into grasslands has mainly happened in *Akabit, Barijano, Buza-Yemerat, Chemo-Giyorgis, Debreyakob, Meragof, and Genbore Kebeles* administrations of *Woina-Dega* agro-ecological zone of the Woreda (Figure-7abc). Grasslands gained from abandoned unproductive croplands (fallow practices). Based on the field observations, such management activity mainly practises in unproductive croplands that are mainly located close to residences of the farmers. According to the informal discussions, fallow along with effective protection from free-grazing is mainly performed by rich farm households (those having relatively more livestock and larger farmlands) in order to cope with needs of livestock by using cut-and-carry grazing systems in the short-run, as well as to recover the previous productive potential of fields in the long-run. Moreover, common grasslands could regain from private cultivated and settlements area by taking institutional measures from kebele administrators.

6.2. Factors of dynamics of Common-Pool Resources (CPRs)

The overall results of LU/LC analysis indicate that the rivalry of CPRs increases with declining of the resource potentials. The driving factors of changes in common resources (forests shrubs, grasslands and wetlands) categorize into proximate and underlying causes. Encroachment of croplands and fragmented settlements towards CPRs was one of main factor that mainly caused the changes. In association with this, according to field observations and the information of local elder residents, after the failure of villagization policy of Derg regime, encroachment of settlements on CPRs escalated for multi-purpose uses from year to year.

For instance, farmers discuss that the main reasons of farmers proximity to the resources are using day to day grazing, to expand cultivated land bit by bit towards grazing areas, to heap crop straw on common graze area for private cattle feed, to get easy access fuel wood collection, to plant trees (like eucalyptus and *Grevillia* for cash income, fuel energy and home construction), and to easily steal bushes and tree during calm time for fence and house construction(see figure-8a).

Informants indicated that farmers, which settled nearby common grazing areas, often freely grazed their livestock for at least 15 hours per day. They added that sometimes some farmers acted to monopolize some part of common grazing areas. Within some years, regularly fencing some portion of common graze areas (adjacent to privately owned croplands) often practice to protect crop damage from free-rider, as well as to use protected grass for private cut-and-carry grazing systems(see figure-8a). Following this, the regularly fenced grazing area could convert into croplands unless an effective institutional measure instantly takes. In relation to this, farmers discussed that relatively wealthy farmers (who hold more livestock and farmlands, and gained household income) are more encouraged to expand cropping fields as they are capable to pay the expected cash penalty as well as less cost required for them to plough productive areas covered with intense grass than poor (less oxen holders).

Overall, farmers who settled very close to CPRs, benefited more than others who settled far away. This indicates that residents' relatively proximate to commons and better off households are more likely characterized as free rider to over-deterioration of the common resources.

Rampant population pressures on limited resources, and insufficient rules and laws unable to restrict free expansion of settlement and open grazing were further resulted in instant severe effects of CPRs dynamics like expansion of barren surfaces and gullies development (see figures 9 &10). Farmers indicated that reluctance of individual farmers, weak institutional structure, irresponsibility of kebele extension staffs, and weak intervention of kebele and woreda executive agents to take legal measures have substantially contributed to tragic degradation of CPRs. When one farmer begins to expand his private croplands towards commons, others neighbours follow him, instead decide to against. The relationship between kebele executive agents and villagers is not trusted due to the occurrences of favouritism to kinship and political supporters, and acting corrupt behaviours.

6.3. Socio-ecological implications of dynamics of Common-Pool Resources (CPRs)

Biodiversity deterioration, expansion of erosion prone areas and gully developments, and consequent uncertainties on the status of some attributes like shortage of fodder, fuel wood, and loss of croplands, are some major socio-ecological implications of CPRs degradation in the Woreda.

Based on the informal discussions with elders and residents close to forest covers, it learns that because of accelerated rate of de-vegetation of natural forest, different flora and fauna diversities deteriorated and then important wild animals were gradually lost. In the inaccessible areas from administration centre and road as well as where the goat population is higher and topography is undulated, there was radical decline of biomass of CPRs, in particular forest, shrubs and wetlands due to the rapid expansion of barren surfaces and cultivated fields. This perhaps led to erratic variability of microclimate and resulting in harshness of livelihoods, particularly where charcoal production is one main supplementary source of income of larger smallholders in the *Kola* agro-ecological zone of the Woreda.

In the humid environment of the Woreda, hill areas of CPRs intensively graze throughout the year. Particularly, during summer and autumn seasons, overgrazing and cattle stocking highly increase, as more than half of the open grasslands of valley floor are restricted to cut-and-carry grazing management. Especially, the numbers of small ruminants like goat and sheep, which are very dangerous to seriously deteriorated shrubs and grass, are highly increased. Goats and sheep are coming from far distances to stock on dry grazing areas of hills due to water logging of valley floor grazing area, which perceived to be unsuitable for small ruminant grazing. Field observations also confirmed that overstocking of animals on the uncovered grazing area of hills especially during summer loosen the soil to be removed by run-off processes. Thus, overgrazing in areas with steep slopes lead severe environmental damage including increasing dimension of gullies, expanding stony and barren area, and consequently severe shortage of available grass and leafs for livestock graze(see figure-9)

Pictures present the socio-ecological implications of overgrazing on common-pool resources (including forests, shrubs and grasslands in the hilltop and surrounding areas)

Figure-9: Photos from persistently overgrazed sites of common-pool resources (forests, shrubs and grasslands) in September/2015

Pictures present the expansion of gullies towards principal physical assets (croplands and grazing lands) of subsistence mixed farming system

Figure-10a: Photo presents gully expansion towards privately owned croplands in November/2015

Figure-10b:Picture indicates gully expansion towards privately owned croplands and communual grazing area in November/2015

The field observations revealed that gullies are concentrated on areas around ill-constructed roads, mass livestock tracking roads, overstocked open-grazing area, and boundaries between private farmlands and open grazing areas. Gullies /rills are also concentrated on junction of diverse slopes due to over-concentrated run-off coming from different aspect of numerous drainage ditches of cultivated fields. Lack of treatment to new developing gullies at appropriate time due to cost disagreement between adjacent owners of either side croplands is often the cause of further expansion of the gullies towards cropping areas. Gullies are also prevalent on mass livestock tracking and stocking areas. This is attributable to highly concentrated run-off, flowing from drainage ditches on both sides and terraced channels of cropping areas. Gullies development and CPRs closely link that more likely symbolize as tragedy of the commons. Accordingly, the dimension of gullies could be progressively expanded towards either private croplands or communal grazing areas (see figures-10a &b) unless they are curbed by relevant conservation measurements. This implies that, with the large expenses of fodder and croplands, which are the principal physical assets for subsistence mixed-farming systems, the progressive expansions of gullies are strongly larger, particularly in climatic condition with higher erosivity.

To sum up, despite an increasing population and associated demands continues to exert an increasing pressures on CPRs in the whole *Kebeles* of the Woreda, forests, shrubs and wetlands (largely in the *Kola* agro-ecology) and grasslands (mostly in the *Woina-Dega* agro-ecology) are radically declining due to expanding cropland and settlements. Overexploitation of CPRs leads not only to ecological catastrophic effects but also to adversely effects the livelihoods of subsistence farmers where mixed farming is the predominant activity. Thus, proper understanding and clear perception of protagonists on those self-evident problems are crucial for effective dialogue and management of CPRs.

6.4. Evaluation of management schemes of Common-Pool Resources (CPRs)

According to Salim *et al*. (1999), sustainable CPRs management defined as "a set of objectives, activities and outcomes consistent with maintaining or improving the resources ecological integrity and contribute to people well–being both now and in the future". Thus, the focal issue for this study was as how to maintain the functional dimensions of CPRs in sustainable way.

6.4.1. Identification of local criteria / indicators and their relative weights

Through taking into account the contextual factors of local management schemes, the hierarchically structured generic template of criteria and indicators developed by CIFOR (1999) was adapted and the initial set of criteria and indicators identified. Informants asked to describe the current wide thinking of peoples on uncertainty of existing management schemes and their perceived desired conditions, and to identify and score the relative performance of proposed alternative scenarios. Hence, from divers' views of stakeholders (farmers, CPRs regulating committee, DAs, kebele administrators and Woreda experts) in interviews, contextualized attributes, criteria, indicators and potential alternatives were accommodated.

Refined elements of criteria and indicators agreed upon and revised by the informants were employed in the participatory evaluation of existing management schemes and formulated the best management scenarios of multiple-uses by employing multi-criteria analysis method. Based on the framework of principal objectives, 4 criteria and 21 indicators identified. Informants' assigned ranks to the criteria/indicators (Table-18).

The calculated results in Table-18 indicate that an arrangement of enabling institutional conditions at local level (criterion-3) deems relatively the most important for sustainable use of CPRs than others. This criterion was also voted with least inconsistency by all the interviewers (S.D=1.1). This suggests that ineffective institutional arrangement may be the most important constraint for the sustainability of CPRs. Under institutional arrangement criterion, indicators like planning and regulating of settlements expansions towards CPRs (indicator-3.9), successful monitoring and controlling mechanisms of free riders (indicator-3.5) and effective sanctions and enforcement mechanisms (indicator-3.6) were relatively the most perceived importance than others. After that, indicator-3.4 that represents clearly defined rules of management, product access and benefits sharing was highly preferred in the consideration of decision making in the institutional criteria for sustainable use of CPRs. This may be attributable to the happening of ineffective functioning rules and mechanisms of monitoring or enforcing local regulations appears to be in operation in the existing management schemes of CPRs. The other indicators (3.1, 3.2, and 3.8) assigned as moderately importance with slight difference in their relative weights. However, indicator-3.7 (appropriate way of conflict resolving) and indicator-3.3(well-defined property right of CPRs to local communities) ranked as the less important for sustainable use of CPRs as comparatively seen from others under the criterion. This, perhaps, due to in some manner acceptable legalisation of communal ownerships and use rights to local resources, as well as occurred rare conflicts are satisfactorily resolved.

Next to criterion-3, adequate awareness and knowledge of local stakeholders, and their effective and mutually valued interactions (crierion-4) ranks as the second perceived importance for sustainable management and use of CPRs (Table-18). Under this criterion, indicator-4 (existing of effective and mutually respected interaction between local stakeholders for CPRs management) is the most percieved importance than other.

Table-18: Ranking method basis of relative weights/ importance / of criteria (n=39)

Criteria/ indicators of sustainable management of CPR	**X(S.D)**	R. W
C-1: *Ecological conditions should be Improved(ECOLRESTOR)*	4.78(1.1)	16.24
1.1.Plants biodiversity has increased(PLABIODIVINC)	2. 72(1.26)	14.23
1.2.Afforesting of multi-benefits plants on degraded hills has increased(AFFORESTMP)	5.21(0.89)	27.26
1.3.Gullies expansion and other erosions should be curbed (EGULLEC)	7.54(1.19)	39.46
1.4.Springs development, available & quality water are improved(SPRINGDEV)	3.64(1.1)	19.05
C-2: *Management scheme of CPRs should contribute to economic fits to the local users* **(***ECONBENEFITS)*	5.34(1.2)	13.62
2.1.Fodder and timber sharing mechanisms are perceived as fair by the local people(PROSHARE)	7.1(1.2)	44.32
2.2.People have access to harvest dead forest product (DFP)	4.38(1.25)	27.34
2.3. Good opportunities of harvesting apiaries should be existed in forest to local people employment (APIARIES)	4.54(1.2)	28.34
C-3: *Arranged local institutional situations enabling sustained use of CPRs (INSTITUTARRANG)*	5.84(1.1)	44.71
3.1. Boundaries of CPRs should be marked in the field by agreed upon adjacent peoples(BAUNDERIES)	5.23(1.1)	9.94
3.2.Full participation of communities in management of CPRs(PARTCIN)	4.77(1.29)	9.1
3.3.Well defined property right CPRs to local communities (PRORIGHT)	3.85(1)	7.32
3.4.Clearly defined rules of management, product access and benefits sharing (CDRULES)	6.56(1.25)	12.47
3.5.Successful monitoring and controlling mechanisms of free-riders(SMON_CON)	8.1(.88)	15.4
3.6.Effective sanctions and enforcement mechanisms (SAN_ENFORC)	8.1 (1.2)	15.4
3.7.Appropriate way of conflict resolving (CONFLICTRES)	3.1(1)	5.89
3.8.Periodic revision of management plan(PLANREV)	4.6(1.2)	8.75
3.9.Planning&regulating of settlement expansion towards CPRs (SETTLEM_EXC)	8.28(1.1)	15.74
C-4: *Adequate awareness and knowledge of local stakeholders, and their effective and mutually valued interaction for sustained use of CPRs (ADQAWAR MUTINTER)*	5.98(1.3)	25.43
4.1.People have adequate knowledge on socioeconomic and environmental benefits of sustained use CPRs(PKNOWLEFGE)	5.15(.99)	17.22
4.2.All people obey the rules(OBEYRULES)	6.51(1.45)	21.76
4.3.People recognize easing pressures of commons through planting woodlot and intensifying animal productivity (RECEASPRES)	4.87(1.5)	16.28
4.4. Local people maintain emotional links to the CPRs (EMOTIONLINK)	5.64(1.7)	18.86
4.5.Effective and mutually respected interaction should be existed between local stakeholders for CPR management (RESPINTERAC)	7.74(1)	25.88

Note: C, X, S.D, and R.W represent Criterion, Mean, Standard Deviation and Relative Weight values, respectively

Indicator-2 (all people obey the rules), indicator-1 (adequate knowledge on socio-economic and environmental benefits of sustainable use of CPRs) and indicator-3 (people recognize easing pressures of commons through planting woodlot and intensifying animal productivity) received the second, third and fourth ranks in relative importance for sustainable management of CPRs. This entails that inadequate empowering of local community by clearly defining laws and rules, developing adequate awareness and forming mutually valued interaction between stakeholders, may be the second serious problems for the sustainability of existing management and use of CPRs.

According to the accommodated views of different stakeholders, criterion-1 (improvement of ecological conditions**)** assigned the third position for the sustainability of CPRs (Table-18). Under this criterion, curbing of gullies expansion and erosion (indicator-1.3) was represented the most important decision element for ecological maintaining condition. Following to this, increasing of multi-benefits plants afforestation on degraded hills (indicator-1.2), indicator - 1.4(improving development of springs, and available & quality of water) and indicator-1.1(enhancing of plants biodiversity) were assigned in the second, third and fourth positions, respectively. This entails that development of gullies and other related erosion features on de-vegetated and over-exploited commons is the serious problems for sustainability.

Moreover, criterion-2(management scheme of CPRs should contribute to economic benefits to the local users) was ranked in the fourthly importance aspect for the CPRs sustainable conditions (Table-18). This implies that despite economic benefits (fodder, timber, fuel wood) contribution is more likely the principal short-run expected outcome to the local community, it may not be the main concern for the sustainability problems CPRs management. Fodder and timber sharing mechanisms are perceived as fair by the local people (indicator-2.1) was assigned as the most important decision element under the economic criteria of sustainable CPRs management.

6.4.2. Performance of existing use and management schemes of Common-Pool Resources (CPRs)

Permanent enclosure, periodic enclosure, semi-open access and open access are major mechanisms of the prevailing management schemes of CPRs in the study area. Using equation (2) (for issue three, in chapter three) the weighted performance scores of each of the four criteria were calculated (Table-19 and Table-20).

Forests and Shrubs

In the existing condition, forests and shrubs manage through two management schemes like complete enclosure and semi-open access.

Complete enclosures are usually undertaken on plantation and church forests, and some degraded sites (locally named *Borebor-Madan*). Complete enclosures on plantation forests often include afforested areas (implemented by Derge regime), and fragmentary rehabilitated degraded sites like hills and highly expanded gullies (undertaken either by incentive-based participations under NGOs [MERETs project and Safety-Net programme] initiative and or by local [kebele] community participations under government initiative).

The replica potentials of sparsely distributed enclosure areas (demonstration sites) in some kebeles towards other adjacent seriously degraded sites within a kebele or across the kebeles of the Woreda are remained unlikely. The enclosure sites are often protected through guard employing mechanism. Free grazing, periodic harvesting of cut-and-carry grazing system and harvesting of dead branches of trees and shrubs are very restricted. According to divers' discussion point of views, the principal purpose of permanent enclosure is mainly favoured to ecological restoration.

The results of the weighted performance scores presented in Table-19 indicate that under prevailing complete enclosure management scheme, criteria like improving ecological restoration (criterion-1: ECOLRESTOR) and arrangement of enabling local institutions for sustainable use (criterion-3: INSTITUTARRANG) gained acceptable performance. In accordance with the scoring guide (Mendoza *et al*., 1999) on section 3.3.2, score of 3 is acceptable implying that at or above the norm for good operations in the local area.

With weighted performance score of 3.55, improving ecological restoration (criteria-1: ECOLRESTOR) performed well above the acceptable operational standard. This, perhaps, portrays that maintaining function of ecological systems reasonably appeared with satisfactory improvement in biodiversity of multi-purpose plants on degraded sites. Under such criterion, the actual average scores of two indicators like plants biodiversity improvement (indicator-1.1) and curbing of gullies expansion and other erosion (indicator-1.3) represented above expected or average score whereas the rest of the indicators are below the standard condition for forests and shrub lands sustainability. This indicates that indicators 1.1 (PLABIODIVINC) and 1.3(EGULLEC) have considerably contributed to maintaining ecological performance of the current complete enclosure forests and shrub lands management.

Table-19: The actual average and the weighted scores of criteria/indicators in the prevailing forests and shrubs management schemes and other alternative scenario (n=39)

Criteria /indicators	Semi-open access(A1)		Complete Closing(A2)		A2+ A3	
	X(S.D)	W.S	X(S.D)	W.S	X(S.D)	W.S
C-1: ECOLRESTOR	1.2(.37)	1.2	3.58	3.55	3.9(0.55)	3.99
1.1. PLABIODIVINC	1.1(.27)	0.157	4.8(.41)	0.683	4.8(.41)	0.683
1.2. AFFORESTMP	1.3(.46)	0.354	2.6(.72)	0.708	4.1(.72)	1.118
1.3 .EGULLEC	1.2(.39)	0.474	4.4(.58)	1.736	4.4(.5)	1.736
1.4. SPRINGDEV	1.1(.34)	0.21	2.2(.57)	0.419	2.4(.55)	0.457
C-2: ECONBENEFITS	1.97(.52)	1.812	1.8(.55)	1.9	3.7(0.69	4.04
2.1. PROSHARE	1.1(.22)	0.488	2.6(.6)	1.152	4.6(.5)	2.04
2.2. DFP	3.6(.85)	0.984	1.4(.48)	0.355	3.6(.85)	0.984
2.3. APIARIES	1.2(.49)	0.34	1.4(.55)	0.397	3.6(.49)	1.02
C-3: INSTITUTARRANG	2.12(.71)	2.03	2.9(.64)	3.16	4(0.55)	4.12
3.1. BAUNDERIES	2.9(.69)	0.288	4.6(.55)	0.457	4.6(.55)	0.457
3.2. PARTCIN	1.9(.89)	0.173	3.1(.65)	0.282	4.1(.45)	0.373
3.1. PRORIGHT	3.4(1)	0.249	3.2(.9)	0.234	4.7(.44)	0.344
3.2. CDRULES	2.2(.59)	0.274	3.5(.6)	0.436	4.6(.49)	0.574
3.5. SMON_CON	1.8(.73)	0.277	3.9(.62)	0.6	4.3(.62)	0.662
3.6. SAN_ENFORC	2.1(.68)	0.323	3.8(.67)	0.585	4.4(.5)	0.678
3.7. CONFLICTRES	2.2(.77)	0.13	2.3(.73)	0.135	3(.63)	0.177
3.8. PLANREV	1.4(.58)	0.123	2.2(.45)	0.193	2.9(.6)	0.254
3.9. SETTLEM_EXC	1.2(.47)	0.189	1.5(.55)	0.236	3.8(.69)	0.598
C-4:ADQAWAR MUTINTER	1.7 (.53)	1.683	2.2 (.58)	2.119	3.3(0.61	3.368
4.1. PKNOWLEFGE	2.2(.8)	0.379	2.4(.72)	0.289	3.6(.5)	0.62
4.2. OBEYRULES	2.6(.58)	0.566	3.3(.55)	0.718	3.5(.51)	0.762
4.3. RECEASPRES	1.2(.43)	0.195	1.6(.49)	0.260	2.9(.78)	0.472
4.4. EMOTIONLINK	1.1(.31)	0.207	1.5(.55)	0.283	3.2(.69)	0.604
4.5. RESPINTERAC	1.3(.51)	0.336	2.2(.57)	0.569	3.5(.56)	0.91

Note:

- ✓ *C, X, S.D, and W.S represent values of Criterion, Average, Standard Deviation and Weighted Scores, respectively*
- ✓ *A1 and A2(alternatives of existing management schemes), and A3(Controlled, cut& carry grazing system, wood harvesting, Enrichment plantation of multi-purpose exotic and indigenous species) -represent other alternative scenario for sustainable management and use of forests and shrubs*
- ✓ *Abbreviations are defined in Table-18*

After that, weighted performance index of 3.16 in Table-19 resents that an arrangement of enabling local institutions for sustainable use (criterion-3: INSTITUTARRANG) is undertaken slight above from acceptable operational standard. Under this criterion, average score demonstrates that indicator-3.1(BAUNDERIES) has performed above very favourable performance level. This indicates that the demarcation line of permanent enclosure site often clearly defines. Moreover, the average values of actual scores of indicators like 3.3(PRORIGHT), 3.4(CDRULES), 3.5(SMON_CON) and 3.6(SAN_ENFORC) have demonstrated largely above the acceptable performance level (see Table-19). This indicates that there are rules and regulations but with some functioning, monitoring and sanction mechanisms. In association with, as farmers, and guards of enclosure sites informally reported, decision makers like concerned extension staffs, *Kebele* and Woreda cabinets are not committed to collaborate and take penalty measures on free-riders that are not obeyed. This further encourages other farmers to react illegally since the management scheme had not considered socio-economic outputs for the local communities from the beginning**.**

Based on the participatory observations, cheating of live *Grevillia* trees from some rehabilitated gullies is often noticeable, in particular where the guards do not protect the planted sites. However, despite it received most relative importance for sustainable management (Table-18), indicator-3.9 (planning and regulating of settlement expansion towards forests and shrub lands) performs with least performance index (Table-19). This shows that perhaps there are no enforced rules and effective mechanisms for enforcing local regulations appear to be in operation to control settlement expansion towards forests and shrub lands.

Despite its relative importance assigned in the second position (Table-18), the weighted score of criterion-4(adequate awareness and knowledge of local stakeholders, and their effective and mutually valued interaction for sustained use of forests and shrub lands **[**ADQAWAR_MUTINTERC**])** presented a poor performance level of 2.12 (Table-19). This demonstrates that empowering local community through obeying local rules, developing adequate awareness and knowledge, and promoting emotional links may be undervalued, as well as local stakeholder's interactions on the rare occasions perhaps marked by mutual contempt, fear and distrust.

Nevertheless, in the complete enclosure scheme of church forests, under the local communities' beliefs, common principles of social sect including taking piece of plot, cutting of live trees or wood for construction and bushes for fencing, and harvesting of dead part of plants for fuel wood and fodder for cattle feeding from church environmental state is strongly believed to be forbidden. As such, church forests more protect than others due to mainly to strong ties and believe by the local community along with guarding. This indicates that effective building of social trust and common believes and purpose in the local community has principally contributed to sustainable use of common property. Sense of stewardships towards church forests developed as local people accepted it as a vital part of people's lives. Church forests biodiversity importantly uses for blanketing of human burial.

Moreover, the weighted score of complete enclosure to contribute to economic benefits for local users is found to show very weak to poor performance with score index of 1.9 (Table-19). In general, therefore, based on the results of multi-criteria analysis, the sustainable use and management scheme of permanent enclosure sites is unlikely.

Semi-open access is another prevailing management system of natural forests and shrub lands in the typical study areas. Under such management system, free grazing and harvesting of dead branches of trees and bushes from natural forests and shrub lands not often restrict for individual households, whereas kebele DAs and administrators' controls restrict cutting live green trees and bushes. The main purpose of this management scheme is to preserve biodiversity for largely ecological benefits followed by economic benefits (used as sources of fuel wood and graze).

The weighted scores of performance presented in Table-19 indicate that against all criteria, the semi-open access management mechanism undertakes at and below what considers poor. As relatively seen, enabling institutional arrangement criterion scores poor performance (with index of 2.03) that represents the maximum weighted score whereas ecological restoration criterion (with index of 1.2) represents the least or very weak performance. Under institutional arrangement criterion, with the average index of 3.4, only property right indicator is demonstrated above acceptable performance whereas planning and regulating of settlement expansion towards forests and shrub lands indicator is performed what is considered very weak, the least ones(average index of 1.2) from all indicators. This pointed out that in the semi-open access management mechanism, no effective institutional arrangement and enforcement procedures appeared to be in operation for controlling and halting overgrazing, and illegal action of free riders by cutting of live bushes or trees, as well as expanding their privately owned farmlands towards forests or shrubs. Accordingly, this, perhaps, further significantly contributes to the prevalence of serious ecological degradation.

In respect of criterion-2: economic benefits contribution, despite the presence of unidentifiable ways of equitable sharing of benefits, local poor people have access to harvest dead forest product (indicator-2.2: DFP) above acceptable level (average score of 3.6).

Informants note that dead trees from natural forests often sell for the benefits of *Kebele* developmental activities. Moreover, the weighted performance index of 1.683 in Table-19 reveals that the performance of adequate awareness and knowledge of local stakeholders, and their effective and mutually valued interaction for sustainable use of forests and shrub lands (criterion-4) finds between very weak and poor levels. This implies that under the reluctance interaction systems of stakeholders, local communities do not recognize any responsibility to halt destruction as serious.

Overall, despite the desired conditions of sustainability is not likely to be satisfied for both prevailing management schemes of forests and shrub lands, complete enclosure performed reasonably better in terms of ecological restoration, enabling institution arrangement and other criteria than what is shown by semi-open access.

Grasslands

In the study area, grasslands manage under periodic enclosure and open-access systems. **Periodic enclosure management** is widely practised through restricting and cut-and-carry grazing system in large number of kebeles of the woreda, where adequate areas of valley floor grasslands are available, between beginning of July and mid of January of each year (see figures-11b,c&d).

In 2008, extension programme introduced periodic enclosure. Under periodic enclosure and regulated access of harvesting fodder for livestock, more than half of the valley floor grasslands manage in each kebeles/sub-kebeles. Based on the participatory observations and integrative views of different stakeholders (farmers and DAs), the main objective of periodic enclosures was to improve fodder production per household for feeding of livestock.

In periodic enclosure management system, weighted index of 3.7 presented in Table-20 reveals that enabling institutional arrangement (INSTITUTARRANG) criterion carries out above acceptable performance. Under this criterion-3, the average values of indicators like 3.1-BAUNDERIES, 3.2-PARTCIN, 3.3-PRORIGHT, 3.4-CDRULES and 3.5-SMON_CON also find from very favourable to outstanding performance levels (Table-20). Kebeles (small administration units) have the clearly defined boundaries of available grassland area and user group memberships. In a particular kebele, the numbers of periodic restricted sites depend upon the size and spatial distribution of available valley-floor grasslands. This implies that the numbers and coverages of enclosure areas increase with increasing of total grassland coverages in a specific kebele.

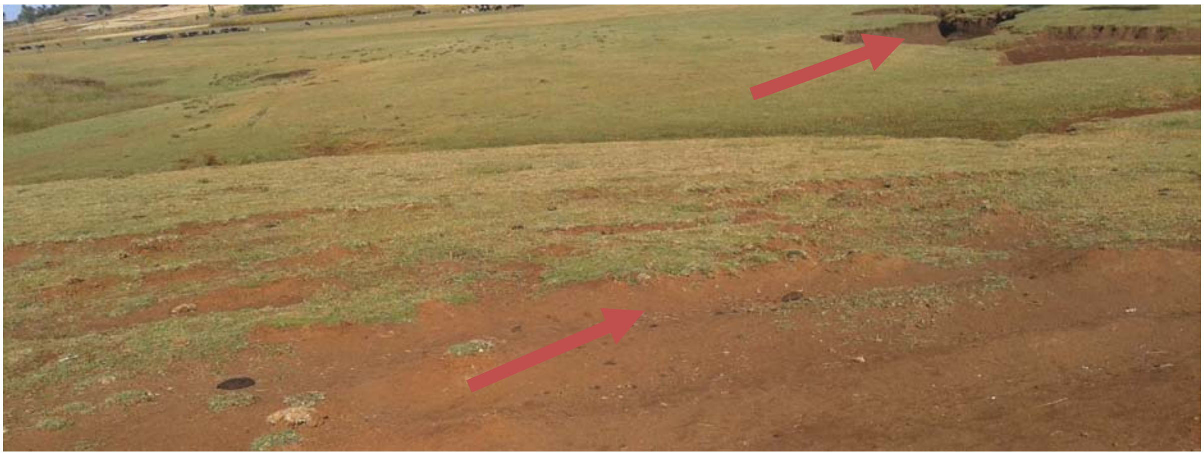


Figure-11a**:** Picture taken from permanently grazed grasslands in valley floor area in September/2015

Figure-11b: Photo from periodic enclosure grasslands in the valley floor area in September/2015

Figure-11c: Picture from unproductive fodder harvesting and sharing from periodic enclosure section of valley floor grasslands in February/2016

Figure-11d: Photo from productive fodder harvesting from periodic enclosure section of valley grasslands in December/2015

Table-20: The actual average and the weighted scores of criteria/indicators in the prevailing grasslands management schemes and other alternative scenario (n=39)

Criteria /indicators	Open access (reference)(A1)		Periodic enclosure, & cut &carry(A2)		A2+ A3	
	X(S.D)	W.S	X(S.D)	W.S	X(S.D)	W.S
C-1: ECOLRESTOR	1.23	1.19	2.8 (.55)	2.92	3.4(.6)	3.55
1.1. PLABIODIVINC	1.6(.55)	0.228	3.5(.51)	0.498	3.5(.51)	0.498
1.2 AFFORESTMP	1.1(.22)	0.3	1.2(.39)	0.327	4.1(.72)	1.118
1.3.EGULLEC	1.1(.34)	0.434	4.2(.71)	1.657	3.8(.63)	1.5
1.4. SPRINGDEV	1.2(.37)	0.229	2.3(.6)	0.438	2.3(.53	0.438
C-2: ECONBENEFITS	1.13(.34)	0.501	4.9(.31)	2.172	4.9(.31)	2.2
2.1. PROSHARE	1.13(.34)	0.501	4.9(.31)	2.172	4.9(.31)	2.2
C3: INSTITUTARRANG	2(18.4)	1.86	3.7(.54)	3.685	3.9(.59)	3.86
3.1. BAUNDERIES	4.2(.68)	0.415	4.2(.68)	0.417	4.2(.68)	0.417
3.2. PARTCIN	1.4(.5)	0.128	4.1(.45)	0.373	4.1(.45)	0.373
3.3. PRORIGHT	4.6(.49)	0.338	4.7(.44)	0.344	4.7(.44)	0.221
3.4. CDRULES	1.1(.34)	0.141	4.6(.49)	0.574	4.6(.49)	0.574
3.5. SMON_CON	1.3(.46)	0.197	4.3(.62)	0.662	4.3(.62)	0.662
3.6. SAN_ENFORC	1.26(.5)	0.194	3.8(.66)	0.585	3.8(.66)	0.585
3.7. CONFLICTRES	1.9(.49)	0.11	3(.65)	0.177	3(.65)	0.177
3.8. PLANREV	1.1(.34)	0.099	2(.4)	0.175	2.9(.6)	0.254
3.9. SETTLEM_EXC	1.5(.51)	0.238	2.4(.5)	0.378	3.8(.69)	0.598
C-4: ADQAWAR_MUTINTER	1.5 (7.3)	1.419	3.1(0.5)	3.12	3.5(.61)	3.6
4.1. PKNOWLEFGE	2.5(.51)	0.429	3.6 (.5)	0.62	3.6(.5)	0.62
4.2. OBEYRULES	1.3(.52)	0.285	3.1(.34)	0.675	3.5(.51)	0.762
4.3. RECEASPRES	1.2(.43)	0.200	2.4(.5)	0.391	2.9(.78)	0.472
4.4. EMOTIONLINK	1.1(.31)	0.207	2.8(.64)	0.528	3.2(.69)	0.604
4.5. RESPINTERAC	1.2(.37)	0.298	3.5(.56)	0.906	4.4(.5)	1.14

Note:

- ✓ *C, X, S.D, and W.S represent values of criterion, average, standard deviation and weighted scores, respectively*
- ✓ *A3-Controlled, Rotational, Enrichment plantation of multi-purpose exotic and indigenous species-represent other alternative scenario for sustainable management and use of grasslands*
- ✓ *Abbreviations are defined in Table-18*

In the *Kebele*, enclosure sections of grassland often bound and then allocate in according to their relative closeness to the communities of *sub-kebele* (*Goti).* The size of users depends upon the total households incorporated a particular *Goti*. Every member in a small-village (*Goti*), who is fully engaged in any developmental activity that practises either in a kebele or in a *Goti*, has equal access and participation opportunity in the management scheme. Accordingly, these insights, perhaps, point out that knowledge of resource boundaries and exclusion were not the more likely cause of mismanagement for desired sustainable use.

Restriction could put through two mechanisms i.e. by employing guards and by the community, particular by the *Goti* cabinets'. Where the local community decides keeping guard, his salary is from the contributions of households' cash income within the community of the *Goti*. Where community decides to restricted grazing on the lands by the people, the village cabinets, every individual household should has the responsibility to control restricted areas from free riders. Cash punishment under both the restricting mechanisms per cattle (in both night and daytime) ranging from 10 birr to 150 birr can be levied. Accordingly, monitoring, controlling and enforcement mechanisms not likely take as a bottleneck reason for desired sustainable use.

Under the economic criterion, with the mean index of 4.9 the performance of perception of fodder sharing mechanism (PROSHARE) is presented between very favourable and outstanding performance levels (Table-20). Fodder production sharing equally allocates for each user in a village community regardless of socio-economic (labour size, livestock holding size, farmland-holding size) and demographic (family size) difference between the households. Measuring total size of enclosure grazing area by using rope and then dividing it to total number of household heads incorporated in the kebele or sub-kebele (*Goti)* was the main mechanism of fodder distribution. The local community themselves decided fodder sharing mechanism. Farmers noted that restricting grazing land management is widely adopted by the local communities due to its higher contribution to fodder production with less cost requirement at individual household level. They pointed out that the harvested grass contributes to cover cattle feed in the morning and evening of each day mainly from February to June. Therefore, a benefit sharing is unlikely caused to mismanagement of periodic enclosure and regulated access harvesting scheme of valley-floor grassland management.

With weighted index of 3.1, criterion of adequate awareness and knowledge, and effective and mutually valued interaction of local stakeholders (C4-ADQAWAR_MUTINTER) carries out slightly above average performance for sustainable use of grasslands (Table-20). The arranged local institutions and rules at kebele and sub-kebele (*Goti*) levels have obtained legal recognition by the woreda authority. This intermediate action of recognizing local communities' preferences and rules is more likely sensitive to empowering end users (the farmers) for desired condition of sustainable management. However, as some farmers informally indicated, inability to harvesting and allocating of productive grass on the right time occasionally happens because of disagreement among the *Goti* cabinets with reluctance of kebeles' extension staffs and administrative agents (see figure-11c). This situation is often observed where the size of total population is larger, and grazing areas have been controlled by the kebele or *Goti* cabinet and the peoples themselves.

Results presented in Table-20 also reveal that criterion-1(ecological restoration) performed slight below acceptable level, with the weighted score of 2.92. Pocket sections of grasslands, which are out-of-the-way to surroundings open grazing sites, often consistently managed under periodic enclosure for easily protecting from free riders. Accordingly, the curbing performance of gullies expansion and other erosion problems (indicator: 1.3-EGULLEC) on these areas is found between very favourable to outstanding levels with average index of 4.2 (see Table-20 and figure-11b). However, the remaining adjacent portions of grasslands, which are easily accessible to free grazing, often use for regular livestock stocking (open-access grazing system). Such constantly overstocked sections are substantially resulting in mining of grass coverage and prevalence of gullies (see figure-11a). This more likely causes to undesired situation for environmental sustainability since conservation of ecological attributes by rotational enclosure not considers in the management scheme.

Open access is another existing management scheme of valley floor and hilly grasslands (see figures 9 and11a). When the net benefits of harvesting increase for the initial set of resource units withdrawn and decrease thereafter, each appropriator acting independently tends to make decisions that jointly yields a deficient equilibrium (Ostrom,2011). In association with this argument, in the study area, a large coverage of valley floor and hilly grasslands often characterize under open-access management scheme. As the weighted score results in Table-20 demonstrate, the performance of open access management of grasslands against all criteria/indicators, except property right (PRORIGHT) indicator, are undertaken between very weak and poor performance levels. The average score of indicator-3.3(PRORIGHT), under criterion-3, perhaps, indicates some acceptable legalization about communal ownerships and the open use rights to local grasslands. Nevertheless, according to the combined views of different stakeholders, the demarcation lines between those resources and privately owned farmlands were not clearly marked. There are no clearly defined operational rules that directly affect norms of resources use and the interest of maintaining an acceptable flow of resource units over time. Exclusion of users from other kebeles more likely seems difficult. The effect of increasing overgrazing pressure due to periodic enclosure of the adjacent and other grazing sites further aggravates accelerated degradation of these open access resources. Environmental restoration not intends to achieve. Accordingly, achieving desired results of sustainable management of open grasslands is more likely inconceivable.

6.4.3. Discussions on alternative management scenario

Not all existing management schemes are appropriate to achieve the desired goal of sustainable management and use of CPRs. Instead, the environmental services and the available resources at a given time and place determine the alternatives that may combine ecological, economic, institutional and social concerns in order to halt an ever-changing dynamic tension between ecological and human responses (Peterson, 2000). Despite scenarios have not used widely in conservation planning to date, they offer attractive and stimulating methods of engaging in a debate about what might happen in the future and how to deal with it, in particular potentially implemented at local scale (Newton, 2007).

For this study, based on the accommodated information and understanding points of relative importance of the criteria/indicators (decision elements), and the prevailing uncertainties and management schemes, information were organized. A particular integrated CPRs management scenario (A3) was compiled that was expected to represent the desires of all participants. The desirability and consistency of each scenario assessed and analysed using produced criteria and indicators representing diverse viewpoints.

In forests and shrub lands management, alternative-3(complete closing + controlled + cut-and-carry grazing system + dead wood harvesting + plantation enrichment of multi-purpose exotic and indigenous plant species) received the highest weighted score against all the sustainability criteria/indicators (Table-19). Moreover, in case of grassland management, alternative-3 (periodic enclosure + controlled + rotational + plantation of multi-purpose exotic and indigenous plant species enrichment) is the most preferred for desired conditions of sustainable grassland management (Table-20). These alternative scenarios are perceived to have performed with acceptable and above consideration of all sustainability criteria/ indicators.

For instance, since enabling institution(C-3) and empowering of local community(C-4) scored the highest relative weight for sustainability desire, they are proposed to be undertaken in a very careful and arranged way of obeyed with clearly defined laws and regulations in alternative-3 management scenario than others existing ones. In accordance with this, on the basis of clearly defined laws and rules, controlled management is mainly incorporated protection mechanism by guards, effective control, monitoring of free-riders as well as croplands and settlement encroachment, and effectual sanction and enforcement. Common property, by its nature requires common views and consensus of community members at manageable level to make accurate decision and enabling institutional arrangements for proper management at local level (Badege, 2001).

Intermediate actions (by the facilitators including government and non-government organization) are crucial to facilitate and coordinate effective management of common property by legally recognizing the local rules and regulations, as well as empowering local communities. In agreement with this**,** Bedru *et al*. (2010) reported that under socio-institutional criterion, empowering of local community with adequate knowledge and awareness about sustainable management of forests was the most important factor for sustainable use and management of communal resources like forests.

In alternative scenarios, environmental restoration was also perceived to have performance of above acceptable but which is weakly performed in semi-open access (for forests and shrub lands) and open-access (for grasslands) management schemes. This, perhaps, is attributable to, instead of free grazing both in semi-open and open-access managements; cutting of live fencing and construction materials; and free grazing system necessarily control under alternative-3 scenario. Cut-and-carry grazing system is also more preferred to halt ecological deterioration similar to complete enclosure and periodic enclosure schemes. This agrees with the argument that "badly overgrazed can be restored rapidly after restriction of free grazing or introduction of a rotational systems of grazing by setting up of social fence" (Hurni *et al*., 2008).

Moreover, enrichment of plantation by multi-functional exotic and indigenous plant species on dried stream/wetlands, barren/degraded hills and along gullies perceive to implement at high performance level under alternative-3 than other existing management schemes. This expects to have considerably contributed to ecological restoration (enhancing biodiversity, halting of erosion, and developing water-retaining capacity). In agreement with this, exclosures and planting of dense roots system plants (like eucalyptus) on steep slopes, poor quality sites and along gullies have proved to be effective for alleviating soil erosion and improvement of other ecological attributes (Badege, 2001; Valentine *et al*., 2005). Results of study conducted in the northern Ethiopia by Reubens *et al*. (2011) also indicate that *Cordial Africana* and *Dodonaea angustifolia, as well as Eucalyptus spp., Acacia abyssinica, Acacia* *salina*, *Olea europaea and Faidherbia albida* had the highest scores for household level economic and gully rehabilitation scenarios.

Economic benefits (fodder and timber sharing, as well as access to harvest dead forest product) are also expected to contribute fairly to local people in mechanisms under alternative-3 than the least performed in the prevailing complete closing management scheme. In association with this, Bedru *et al*. (2010) suggests that ecologically biased forest management regime needs to be substituted by relevant holistic scheme that also takes into account stakeholders socio-economical preferences and objectives.

Under alterantive-3, enrichment plantation of multi-functional exotic and indigenous plant species is intended to contribute to improve apiculture (by planting flowering plants), and fodder and timber productions sharing at household level. Through integrated approach premise, for instance, bee-keeping can be included into common-pool resources management strategies with planting of leguminous nitrogen–fixing trees like *Faidherbia albida*, *Leucaena leucocephala*, *Robinia pseudo-acacia* and *Gleditsia triacanthos* (Jacobs *et al*., 2006). Badege (2001) pointed out that planting of fodder shrubs with mixed configuration of grass and herbaceous legumes on unproductive pasture is important to supplement the low quantity and quality feed sources available during times of fodder shortage. Agroforestry and social forestry as land use systems have great potential to satisfy the rising demand of fuel wood, construction poles and timbers, as well as provide an alternative source of cash to smallholder farmers (Badege, 2001; Selamyihun *et al.*, 2005). Overall, therefore, the alternative scenarios indicated that in the Ethiopian highlands, policies on extension programmes should implement as an integrated premise of holistic approach for sustainable management and use of CPRs to improve smallholder livelihoods that mainly based upon crop-livestock mixed subsistence farming system.

6.5. Conclusions

Results from satellite images analysis demonstrate that the spatial extent of Common-Pool Resources (CPRs) including forests, shrubs, grasslands and wetlands substantially contribute to the progressive expansion of cropland and settlements. Accordingly, areas used for privately owned annual and perennials crop production accompanied with dispersed rural settlement and plantation of some trees around the homesteads increased rapidly and consistently. This implies that the rivalry of CPRs was increased with decreased the resources system size. This situation was highly seen in the less-favoured areas of *Goncha-Siso-Enese*

Woreda, where the accessibility of information system and market linkage is poor, as well as the natural resources base is more fragile compared to population (human and livestock) density.

Dynamics and over-deterioration of CPRs mainly caused by encroachment of croplands and fragmented settlements. Relatively proximate residents' to commons and better-off households are more likely characterized as free rider to over-deterioration the common resources. Rampant population pressures on limited resources, and insufficient rules and laws to restrict free expansion of settlement and open grazing were further resulted in immediate severe effect of CPRs dynamics like expansion of barren surfaces and gullies development. Reluctance of individual farmers, weak institutional structure, irresponsibility of *Kebele* extension staffs, and weak intervention of kebele and woreda executive agents to taken legal measurement substantially contribute to tragic degradation of CPRs. Over-exploitation of CPRs leads biodiversity deterioration, expansion of erosion prone area and developments of gullies, and consequently shortage of fodder and fuel wood, and loss of croplands.

Accordingly, the prevalence of tragedies of the commons calls for the holistic scheme of CPRs management. In relation to this, results of the study indicate that an arrangement of enabling local institutional conditions (criterion-3) followed by empowering of local community through forming mutually respected and valued interaction between stakeholders, developing awareness and knowledge, defining clear laws and rules deemed relatively the most important criteria for sustainable use of CPRs. By using local adapted and identified criteria/indicators, results of existing management schemes of CPRs are not on the paths of sustainable conditions since they are not holistic. For instance, on the one hands, complete enclosure scheme of forests and shrubs mainly favoured for ecological restoration with no pay attention to socio-economic outputs. Accordingly, this management scheme performed between very weak and poor performance in terms of achieving socio-economical outputs for the local communities.

On the other hand, grasslands management under periodic enclosure without rotation largely overlooked the target of ecological restorations. Instead, it mainly focused on fair distribution of short-term economic benefits like fodder for feeding of cattle to the local communities. Moreover, natural forests and shrubs lands under semi-open access management and grasslands in open-access management schemes performed between very weak and poor performance against almost all local identified criteria/indicators.

Based on this study results, the following policy and extension package implications for the sustainable management and use of CPRs give in the study area. The existing management schemes of CPRs should reformulate to relevant holistic scheme that takes into account multiple functions, and diverse interest and preference of local communities. An arrangement of enabling institutional principles followed by empowering local communities should give the most priority for desired conditions of sustainable use of CPRs. Lastly, conducting of further qualitative research on the existing characteristics and outputs of CPRs management schemes using multi-criteria analysis method recommends in addressing local constraints for sustainability condition in different parts of the Ethiopian highlands.

CHAPTER-SEVEN

EFFECTS OF SOIL AND WATER CONSERVATION PRACTICES ON COMBATING SOIL EROSION BY WATER

7.1. Effects of conservation practices on magnitude of rill erosion

Conservation activities like vegetative stabilized contour barriers/ structures such as terracing and drainage ditches generally seen as how practices control the amount of concentrated surface water (run-off) through changes the volume, speed and the direction in order to combat soil loss at acceptable level. In proportion to this, run-off often results shallow drainage line (rill erosion with commonly less than 30cm deep) on bare or tilled surface soils. Rill erosion is often described as the intermediate stage between sheet erosion (commonly measured by micro-modelling) and gully erosion (often measured by macro-modelling) and measured by employing intermediate technique like surveying at field level. Accordingly, results in Table–21 reveal that total numbers and lengths of rills, and damaged area and volume of eroded soils by rills under different conditions of conservation statuses and crop patterns of 24 surveyed fields in Beribere catchment in the study year of 2015. For instance, the total numbers of rills was 172 in conserved/ terraced/ fields (4.87ha) and 126 in non-conserved/ terraced/ fields (2.78ha). The total length of rills was 406.5mh^{-1} in terraced fields and 710.4mha^{-1} in non-terraced fields. This indicates rill densities in terraced fields were reduced by 42.8%, when compared with non-terraced fields. The total actual surface area damaged was 133.41m^{2}ha^{-1} in conserved fields and 302.7m^{2}ha^{-1} in non- conserved fields, implying that terracing contributed to reduce damaged area by 55.93% as relatively seen with non- terraced fields. What is more, damaged area as percent of total in non- conserved field was 2.31 times that of conserved fields. This shows that the direct effect of conservation practices on reducing the damage of productive cropping area in the field.

The total volume of all rills was 22.8m^{3}ha^{-1} in non-terraced fields and 10.6m^{3}ha^{-1} in terraced fields. This entails that rill erosion in conserved fields was reduced by 53.51%, when compared with non- conserved control fields. In agreement with this, different experimental studies have reported significant reduction in soil loss due to implementation of conservation practices in the high rainfall areas of North-western highlands Ethiopia. For instance, Herweg and Ludi (1999) reported that the majority of soil and water conservation treatments showed a significant effect on reduction of soil loss. Results of the study conducted by Tadel *et al*. (2014) in Debre-Mewi watershed indicate that soil loss was reduced by 63% due to combined effect of soil bunds with elephant grass, compared to the non-conserved plots in similar setting. In the same study site, Getachew *et al.* (2011) also reported that rill erosion due to the *Fanya-juu* with elephant grass, *Fanya-juu* with *Vetiver* grass and sole *Fanya-juu* were reduced by75.1, 80.3 and 63.6% respectively, when compared with non-conserved plots in similar setting.

Table-21: Numbers and lengths of rills, and damaged area and volume of eroded soils by rills in 24 surveyed fields of Beribere catchment, North-western highlands of Ethiopia in 2015 G.C.

Parameter of rill erosion	**Surveyed cultivated fields(7.65ha or 76,500m^2)**			
	Terraced (4.87ha)	Non-terraced (2.78ha)	Tef cropped (4.4 ha)	Wheat cropped (3.25ha)
Total number rills	172	126	149	149
Total length (mha^{-1})	406.5	710.4	441	619.6
Total damaged area (m^{2}ha^{-1})	133.41	302.73	193.61	215.3
Damaged area as % of total	1.3	3	1.94	2.2
Eroded soil volume (m^{3}ha^{-1})	10.64	22.84	15.34	16.9

Note:

- ✓ *10,000m^2=1ha*
- ✓ *Minimum mean depth of rill was 2cm (influenced by ill- ditch practice) in the terraced and wheat cropped field, situated in down-slope of valley side of the catchment*

Nevertheless, for this study, the measured magnitudes of rill erosion underestimated the actual rates of soil loss since inter-rill/sheet/ erosion was not included. Sheet wash is the most effective sediment transport agent, in particular when the tilled cultivated field is uncovered before and early after crop sowing time (Morgan, 2005). Gover and Poesen (1988) found that the relative importance of inter-rill erosion ranges between 22 and 46% whereas soil materials transported in rill erosion accounted for from 54% to 78% of the total erosion. In contrast to this estimates, Vandaele and Poesen (1995) found that rill erosion in the hill slopes accounted for 33% of the erosion coverage for the three years period in the hammerveld-1 catchment, central Belgium. In the rill survey methodology, it is probably to underestimate rill erosion by 10 to 30% since it ignores the contribution of inter-rill erosion to the sediment carried in the rills, as well as depends upon being able to identify conspicuously the edge of the rills (Morgan, 2005). Accordingly, for this study by assuming the contribution of inter-rill/sheet/ erosion as 28% in conserved fields and 30% in non-conserved fields, the annual actual soil loss due to rills and sheet erosion estimated about 32.6m^{3}ha^{-1} in non-conserved fields and 14.8m^{3}ha^{-1} in conserved fields. This, perhaps, indicates that the magnitude of soil loss in the conserved fields was not likely an acceptable level, when compared with the mean soil loss of 11t ha^{-1}y^{-1}, which generally considers as tolerance level (Hudson, 1981; cited in Morgan, 2005).

7.2. Crop type and rill erosion

When the root and shoot densities of crops increase on the topsoil, the concentrated flow of water erosion rates exponentially decrease, particularly for sheet and rill erosion in the early plant growth stage (Gyssels and Poesen, 2003). Table-21 shows the density of rill, affected area and volume of soil removed due to rill in the tef and wheat cropped fields in Beribere catchment in 2015. Based on the results of this rill survey study, total rill density, proportion of damaged area out of the total area and total volume of soil removed slightly increased in the wheat-cropped fields when compared with tef-cropped fields. For instance, the total length of rills was 619.6mha^{-1} in wheat fields and 441m ha^{-1} in tef cropped fields, implying that rill densities in wheat fields was 1.4 times that of tef fields. Out of the total area, the proportion of the actual damaged cropping area due to rill in wheat fields was also 1.34 times that of tef fields.

Moreover, the annual total soil loss due to rills was 16.9m^{3}ha^{-1} in wheat fields and 15.34 m^{3}ha^{-1}in tef fields, indicating that soil loss due to rills in wheat-cropped fields was 1.1 times that of tef-cropped fields. This is probably, due to more culmination of sheet flow into rills on cropping horizons because of constructing wide spaced ditches and inappropriate gradient of row crop sowing in wheat fields than tef. There was initiation of more rills due to poorly designed ditches and cut-off drains in wheat fields than those of tef fields. Even the dimensions of rills of wheat fields were larger than those of tef ones that might be due to tearing of tilled surface by highly concentrated run-off generated from widely spaced drainage ditches. In contrast to this study results, some studies indicated that soil loss rate in tef-cropped fields was larger than wheat fields. For example Bezuayehu and Sterk (2010) reported that the highest rill densities were observed in tef fields compared to others due to the fields are compacted by animal trampling which reduce infiltration rates and stimulates surface run-off. In association with this, according to the field observations, trampling of tilled surface by animals for tef bed preparation is often practised, probably results for the potential prevalence of splash and sheet erosions during heavy rain storms when the field is uncovered before and early crop sowing time.

7.3. Topographic positions of the fields and rill erosion

Figur-12 demonstrates that surface area damaged by the rill and volume of soils eroded due to rill by valley sides topographic positions of both conserved and non-conserved fields in Beribere catchment. In both terraced and non-terraced areas, fields in mid-slope topographic position were more susceptible to rill erosion than other topographic positions in the valley sides. For instance, under the conserved area, the surface area of actual damaged from the mid-slope fields was 1.47 times that of the up-slope and 1.79 times that of down-slop fields. Likewise, the volume of soil eroded from mid-slope fields 1.47 times that of the up-slope and 1.53 times that of down-slope fields. In the non-conserved area, the surface area actually damaged the mid-slope fields were 1.72 times that of the up-slope and 1.16 times that of down-slop fields. As well, the volumes of soil removed from mid-slope fields were also 1.47 times that of the up-slope and 1.4 times that of the down-slope fields. This is, perhaps, due to increasing of the potential of concentrated run-off that entering from up-slope fields. In agreement with this, Woldeamlak and Sterk (2003) reported that mid-slope position in non-conserved fields were more vulnerable to rill erosion.

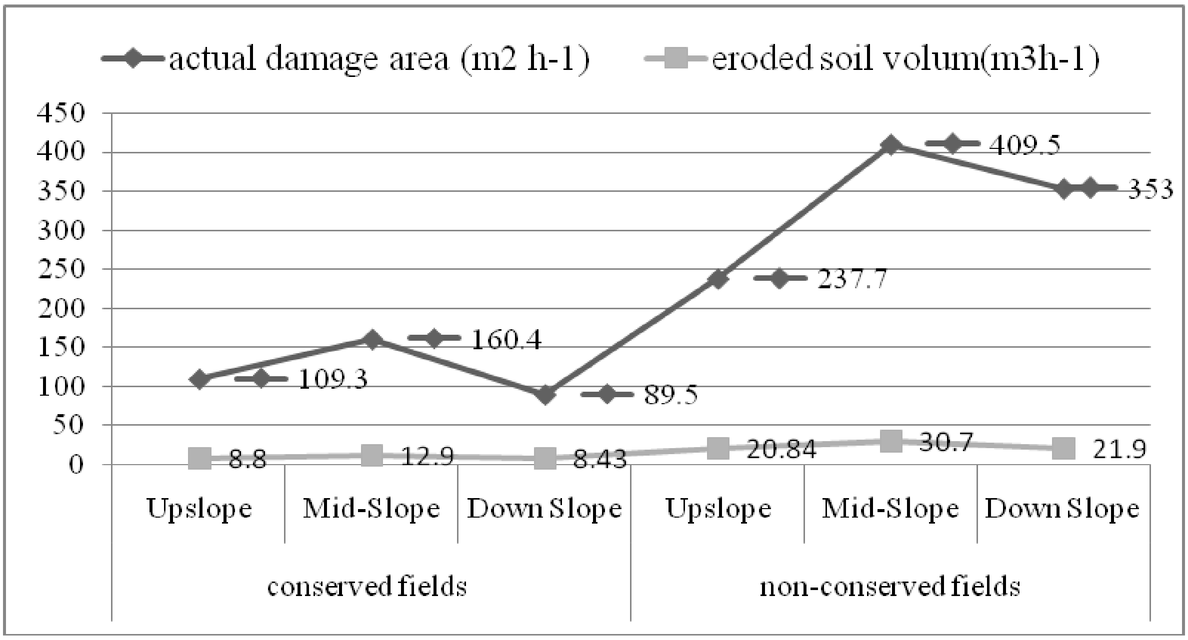


Figure-12: Rill erosion distribution in terraced and non-terraced fields by topographic position in the valley sides of Beribere catchment

Next to fields from mid-slope, fields from up-slope in the conserved area and fields from down-slope in the non-conserved area found to be vulnerable for rill erosion. This may be attributable to the contribution of terraces to reduce hydrological connectivity (the processes of surface run-off concentration) by reducing surface gradient and diverting course on up-slope and mid-slope positions in the valley sides of the catchment.

7.4. Factors accelerating rill erosion

Based on fields observations and measurements, concentrated run-off that entering from areas of up-slope direction, damaging of terraces and ditches, poorly designed ditches (which easily expose for bed erosion of tilled soils of channel of ditches), growing of sheet flow *in-situ* found to be the major factors accelerating rill erosion in the study site.

Table-22 reveals that out of the total volume of soils removed by rills in the terraced fields, almost three-fourth proportion occurred as the result of damaged terraces. Therefore, in the conserved areas, terrace damage is the most important contributing factor for soil loss due to rills in both tef and wheat cropped fields (see figure 13b).

Based on field observations and farmers' views, lack of proper maintenances of bunds and diversion ditches before the prevalence of rills at the first rainstorms in particular, when the soils become loose and bare due to repeated tillage, are the most important factors for damages of terraces resulting in rills formations in the down-slope section of cropped fields. For instance, when the first terrace of upper section of cultivated fields well maintains and stabilized, the lengths of rills on the middle and lower part of specific cultivated fields largely decrease that perhaps owing to substantial diversion of the velocity and strength of concentrated run-off by the first stabilized bunds. This implies that when terraces on cropping areas timely and properly maintain and stabilize, the probability of rills prevalence on that cropping field is minimal. Unfortunately, large numbers of farmers are often prepared to mitigate erosion which is often more vigorous on bare lands due to concentrated run-off. This probably happens due to inadequate knowledge about the source of initiation of rills along with topographic character of cropping area or inadequate labour to excavate soils from terraces and diversion ditches. Moreover, bunds destruction by farmers, lack of adapting ill-designed terraces (unable to drain surface water) and improper drainage ditches are important factors for damaging of terraces and then rills occurrence in the conserved cultivated fields. Because of these interactive factors, upper section of cropping areas between terraces is more vulnerable to rill erosion than middle and lower parts.

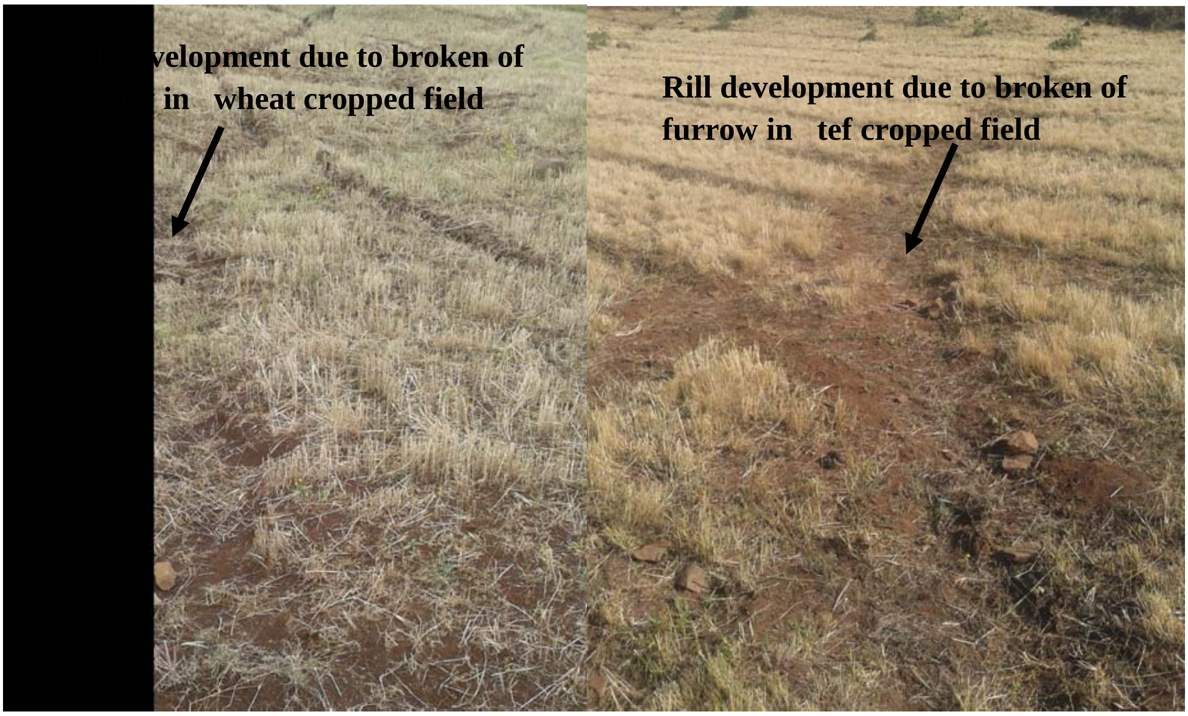


Figure-13a: Rill development due to entering of concentrated runoff from up-fields

Figure-13b: Rill formation due to insufficient maintenance of terraces

Rills numbers become decreasing when moving from upper to lower part of cropping area between terraces due to the contribution of indigenous drainage ditches or furrows. Even rills usually disappear from middle part of terraced area towards lower part. Drainage ditches or furrows play important role to interrupt sheet diagonal growing at their early stage.

Furthermore, in the fields where terraces are well designed, stabilized with vegetative measures (like *Fanya-juu* shrubs), properly maintained, and complemented with proper practice of indigenous drainage ditches, occurrence of rills in the conserved cultivated fields disappear. This implies that combined use of technically fitted indigenous (drainage ditches) and introduced (terraces stabilized with *Fanya-juu* shrubs) conservation activities is more acceptable to curb soil loss than a single soil and water conservation practice.

In the non-conserved fields, entering of concentrated run-off from up-slope areas and damage of ditches were observed as the principal factors accelerating for formation and development of rill erosion (see figure-13a), whereas they had insignificant effect on rill erosion in the terraced fields. For example, of the total soil lost due to rill in the non-conserved area, about 43.2% was because of entering of concentrated run-off from up-slope fields (Table-22). This indicates that terracing has substantial contributions to control concentrated surface run-off entering from up-slope areas.

Table-22: Factors accelerating rills erosion in terraced, non-terraced, tef cropped and wheat cropped fields

Factors accelerating rill erosion (in m^3) in the fields	Field types			
	Terraced	Non-terraced	Tef cropped	Wheat cropped
Up-field entering	1(1.9)	27.4(43.2)	15.1(22.4)	13.3(24.2)
Terraces damaging	38.7(74.7)	-	23.3(34.5)	15.4(28.1)
Ditches damaging	2.8(5.4)	27.3(43)	22.3(33)	7.8(14.2)
Ill- constructed ditches	8.1(15.6)	6.8(10.7)	5.8(8.6)	9.14(16.6)
Sheet grown *in-situ*	1.24(2.4)	2(3.1)	1(1.5)	9.3(16.9)
Total	51.84(100)	63.5(100)	67.5(100)	54.9(100)

Note: m^3 represented volume of soil lost due to rills, and values in the parenthesis-represented percentage.

From the total volume soil eroded by rills, damaging of traditional ditch also influenced 43% (Table-22). Based on frequent observations, absence of accompanied control measures (like terraces), long length of ditches along with shallow depth, concentrated run-off and unsafe gradient (gentle slope) of ditches are contributing factors to break the traditional drainage ditches ,and then prevalence of rills on down-slope cropped fields**.** Sometimes, rills are also occurring due to the damaged cut-off drains (locally named as *Tekebikeb*) because of inadequate excavation of tilled soils from channels in constructing and maintaining time.

The degrees of influence of the factors on rill erosion also differ in tef and wheat cropped fields. On the one hand, out of the total eroded volume of soil due to rill, 89.9% in tef and 66.5% in wheat-cropped fields were influenced by the combined effects of entering run-off from up-slope fields, and damaging of terraces and ditches. This implies that because of the combined effect of these accelerating factors, the proportion of soil loss due to rills in tef fields was 1.35 times that of wheat fields. This further pointed out that tef crop fields are highly vulnerable to erosive power of concentrated run-off that often enter from up-slope areas, as well as occur because of damaging of terraces and ditches.

Figure-14: Rills formation in tef and wheat cropped fields due to ill-designed drainage ditches

On the other hand, out of the total soil volume removed by rills in the wheat cropped fields, 16.6% and 16.9% were accounted for ill-designed traditional ditches and strength of overland flow, respectively. However, of the total volume of soil eroded by rill in tef-cropped fields, 8.6% and 1.5% find to account for ill-designed traditional ditches and overland flow strengthen, correspondingly. This indicates that the influence of sheet grown and ill-designed ditches on rill erosion in tef fields was lower than wheat ones. Based on observations, when row-direction of wheat seed sowing designed to cause for excessive erosion, rills often generated in tillage paths as the result of strengthen of sheet erosion *in-situ*. So, under the conventional tillage, growing of sheet wash into rills within cropping horizon (lies between traditional ditches or terraces) often observed. Alternatively, when seed sowing was in contour row, growing of sheets wash into rills was disappeared. Because of considerable proportion of bare tilled surface, particularly in the early stage of crop growth, row crops on slopes fields give rise to more rill and inter-rill erosion problems (Morgan, 2005; Arnhold *et al*., 2014).

Similarly, poorly designed traditional ditches with significantly gradient enough by themselves often accelerated rill erosion through bed erosion on channels of ditches and cut-off drain (see figure-14). The volume of removed parts that are not covered by crop seedling could be an indication of soil loss from bed surface of drainage ditches. This occurrence largely observed in the wheat-cropped fields that probably due to the flow of high concentration run-off (which generates from relatively wider affected cropping horizon) on the channels of ditches and cut-off drains. However, according to the views of owners of surveyed cultivated fields, a large number of farmers do not recognize negative effect of poorly designed ditches and cut-off drains for causing soil loss due to rills.

7.5. Conclusions

Based on the results of this rill survey study, the total volumes of soils removed by rills were about $22.8m^3ha^{-1}$ in non-conserved fields and $10.6m^3ha^{-1}$ in conserved fields, Beribere catchment by the year of 2015 G.C. This indicates that rill erosion in conserved fields was reduced by 53.51%, as compared to non-conserved fields. Nevertheless, for this study, the measured magnitudes of rill erosion would be underestimated the actual soil loss since sheet/ inter-rill erosion was excluded. Accordingly, suppose sheet/ inter-rill erosion contribution of 28% in conserved fields and 30% in non-conserved fields, the actual soil loss due to rills and inter-rill erosion estimated about $32.6m^3ha^{-1}$ in non-conserved fields and $14.8m^3ha^{-1}$ in conserved fields. This indicates the absolute soil loss in the conserved fields was still high (not at acceptable level). In the conserved area, terraces damage is the most important contributing factor for soil loss due to rills. In the non-conserved fields, entering of concentrated run-off from up-slope areas and ditch damaging observed as the principal accelerating factors for formation and development of rill erosion, whereas they had insignificant effect for rill erosion in the conserved fields.

Moreover, soil erosion demonstrated spatial differences in terms of crop covers and relative topographic positions in the valley sides of Beribere catchment. For instance, tef cropped fields were lesser vulnerable for rill erosion as compared to the wheat cropped fields. This is probably attributable to the higher contribution of sheet erosion and erosion on beds of ditches to the magnitude of rill erosion in wheat fields than tef. Sheet flow grown and ditches bed erosion were mainly occurred as a result of inappropriate gradient of row crop sowing, and widely spaced and ill-designed ditches, respectively. All surveyed fields from mid-slope of the valley sides were the most susceptible to rill erosion than other relative topographic positions.

It concludes that in spite of their advantages on considerable soil loss reduction, conservation activities are inadequate to curb soil erosion by water effectively. Erosion control activities (especially terracing and traditional ditches) often cause rill formation unless they properly design, maintain and stabilize. This aspect makes them site specific erosion control activities for addressing the problem. Promoting hybrid knowledge and skills through effective communication between farmers and extension staffs to improve farmers' skills of designing and practicing indigenous and introduced conservation activities should accentuate. Furthermore, it is suggested that since erosion control practices can do little to prevent detachment of soil particles, they need to be complemented with considerable practicing of agronomic SWM measures (like composting and legume-cereals crop rotation) to reduce soil, water and nutrient loss at acceptable level and thus enable the cultivated fields to sustainable crop yields. Eventually, the study corroborates that rill surveying method provides significant semi-quantitative information on the magnitude of soil erosion and important for pragmatic assessment of the effectiveness of conservation measures.

CHAPTER EIGHT

EFFECTS OF INTEGRATED SOIL AND WATER MANAGEMENT ON IMPROVEMENTS OF CROP YIELD AND HOUSEHOLD INCOME

8.1. Agronomic activities for growing of tef and wheat crops

Tef (*Eragrostis Tef*) and wheat (*Triticum durum*) are the major cereals staple crops grown in the highlands of Ethiopia. Tef has relative merit of versatile character to diverse types of environmental agro-ecological stresses like drought and water logging that ranging elevations from 800 to 3200m a.s.l. than wheat altitude ranges from 1500 to 2800m a.s.l. primarily under the rain fed condition.

8.1.1. Croplands characters and antecedent husbandry activities

In the study sites, results in Table-24 indicate that tef and wheat principally produce on fields that mainly categorized under perceived steep slope and infertile status. For example, out of the total, 97.5% of tef-cropped fields and 98.6% of wheat-cropped fields perceived to characterize under steep slope. Besides, of the total respondents, about 86.1% and 88.7% of farmers perceived that their tef cropped and wheat cropped fields, respectively, classified by infertile soil status.

These croplands, largely perceived with steep slope and infertile soils characters, treated with different types of SWM practices in the antecedent time (Table-24). For instance, out of the total respondents, 73.4% and 74.6% of farmers reported that they grown tef and wheat crops, in that order, on cultivated fields conserved with seven years and above age of terraces. Of the total respondents, about 34.2% and 18.3% of them also pointed out that they grown tef and wheat, respectively, on precursor legume crop grown fields. This indicates that larger proportion of farmers prefer to alternate legume crops with tef crop than legume to wheat. Pertaining to fertilizers type used, from the total respondents, about 30.4%, 35.4% and 34.2% of farmers noted that they were grown tef on fields that were amended with inorganic fertilizers only, combination of inorganic and compost, and compost only, in that order in the preceding year. About 74.6%, 5.7% and 19.7% of farmers also pointed out that they were produced wheat from fields that were treated with inorganic fertilizers only, combination of inorganic and compost, and compost only in the prior year, correspondingly. Moreover, of the total, about 20.3% of tef growers and 12.7% of wheat growers reported that they were used the combination of all three SWC practices ($\geq$7 years old terraces, compost, Legume-Cereals Crops Rotation [LCCR]) on a specific plot. This signifies that larger numbers of tef-cropped fields had treated with organic fertilizers than wheat-cropped fields. This perhaps due to tef is more likely required productive soils for its potential output seeing that the more favourite crop in terms of staple foods and market condition than wheat.

8.1.2. Croplands management activities in the growing year of tef and wheat crops

Conventional tilling through hand press with ox-pulling traditional technique is the common one to all farmers for tef, wheat and other crops production in the study areas. Many times ploughs are commonly undertaken starting from mid-September to end of July month for seedbed preparation and then sowing. As tef seed is too small and required very loose soil for seedling, fine seed bed preparation for sowing is required intensive labour costs than wheat. For instance, Table-23 indicate that the average numbers of conventional tillage for seed bed preparations of tef and wheat throughout a year were estimated about 6.8 or around 7 times with ranging from 3 to 9 times and 4 times with varying from 2 to 6 times, respectively. This represents high intensity of conventional tillage that perhaps due to the existence of more numbers of productive labours with holding of less cultivable fields, which results overutilization of labour cost. In association with this, through frequent informal discussions, farmers argued that more tillage has contributed to more yield than less ones. Nevertheless, this argument disagrees with some scientific investigations conducted in the highlands of Ethiopia. For example, Balesh *et al.* (2008) reported that tef yield enhanced with from 20 to 25% when tillage frequency reduced. Rockstroma *et al*. (2009) also noted that tef yield significantly higher ($p<0.05$) for "best bet "conservation farming plus fertilizers treatments, gains nearly doubled from 0.5 to 1.1ha^{-1} over conventional treatment.

Table-23: Descriptive statistics of some agronomic activities in tef and wheat crops production

Frequency of agronomic practices	Wheat			Tef		
	Min	Max	Mean	Min	Max	Mean
No. of weed removal in growing stage	1	2	1.2	1	3	1.6
No. of tillage in a year	2	6	4	3	9	6.8
Applied compost rate in quintal	0	3.5	1.3	0	3	0.2

Both wheat and tef mainly sow in the summer season. Wheat sow commonly practises when the rainfall fairly distributes in particular from last June to early July. Based on the frequent field observations, on sow day of tef, intense animal tracks usually tramples one time-tilled surface to make seedbed for favourable condition of too small seed germination. As farmers informally report, sowing dates of tef can be ranging from end of June to end of August because of specific field soils properties. Sowing date in the red colour soils fields often precedes than black colour soils fields. For instance, poor fertility status of red colour soils often undertakes before mid-July, whereas tef sowing of high water retention capacity of black colour soils (vertisols, fertile status) usually practises in August month. In relation to this, based on the results of their one year plot experimental study at Alem-Tena, Central Ethiopia, Abdulshukor *et al*. (2009) reported that biomass and grain yields were reduced by 35% and from 60 to 80%, respectively, when sowing dates delayed with one and two weeks.

Table-24: Distributions of croplands character and management activities for tef and wheat crops production

Croplands characters and management activities	Response categories	Tef growers %(n=79)	Wheat growers %(n=71)
Perceived soil fertility statuses	Infertile	86.1	88.7
	Moderate	13.9	11.3
Perceived slope categories	Steep	97.5	98.6
	Gentle	2.5	1.4
Age of terracing on cultivated fields	< 4 years	26.6	25.4
	> 6 years	73.4	74.6
Precursor grown crop on fields	Cereals	65.8	81.7
	Legume	34.2	18.3
Forerunner fertilizers types applied on fields	Inorganic only	30.4	74.6
	compost only	34.2	19.7
	compost& inorganic	35.4	5.7
Fertilizers types used in the Prevailing growing time	inorganic only	92.4	35.2
	compost& inorganic	7.6	64.8
Use of ISWM practices	No	79.7	87.3
	Yes	20.3	12.7
Seed variety	Not improved	63.3	23.9
	Improved	36.7	76.1
Crops sowing techniques	In dispersing	97.5	16.9
	In row	2.5	83.1

Note: *ISWM represents the combine use ≥7 years old terraces, compost, Legume-Cereals Crops Rotation [LCCR]) on a specific plot*

As shown in Table-24, of the total tef producers, about 97.5% of them reported that they were sown tef through local based hand throw spread on prepared broad seedbed and furrow. However, out of the total wheat growers, about 83.1% of them indicated that they were adopted wheat sow by row that introduced by agricultural extension package. This implies that wheat sow by row mechanism is more adopted than tef. In terms of seed variety, on the one hand, out of the total wheat growers, about 76.1% of them indicated that they were sown improved wheat seed. On the other hand, of the total tef producers, pertaining to 63.3% farmers reported that they were grown not improved tef seed (Table-24). This indicates that the majority farmers adopted introduced (recommended) wheat seed variety through extension package than tef crop.

Table-24 shows that farmers were used both organic and inorganic types of fertilizers in the growing year of wheat and tef crops in the study sites. For example, wheat crop was sown using inorganic fertilizers only (by 35.2% of farmers), and combination of inorganic fertilizers and compost (by 64.8% of farmers). This denotes that large numbers of farmers were adopted combine use of compost and inorganic fertilizers for wheat crop production. However, the farmers not largely used compost for tef growing. For instance, of the total, about 92.4% of farmers reported that they were not used compost for tef growing in the prevailing year instead inorganic fertilizers only. In agreement with this, farmers informally pointed out that growing tef crop on the forerunner compost amended accompanied with legume-cropped fields often practises for potential output of tef growing in the next year.

Wheat and tef crops grow during the main growing season between July and October. Following crop emergence in the growing stag, weed removal is (in particular by using manual hand weeding technique) one component of agronomic practices. Weed removal often practises beginning from end-July to end-August for wheat crop and from last August to last September for tef crop growing. Results in Table-23 reveal that the average numbers of manual hand weeding were about 1.2 times with varying from 1 to 2 times for wheat and 1.6 (around 2) times with ranging from 1 to 3 times for tef crop. This indicates that the frequency of manual hand weeding for wheat growing is lesser than tef, implying that tef is more susceptible to weed biomass competition than wheat. Farmers informally reported that three times hand weeding is often performed when suppressing weed biomass is observed in the tef cropped fields, whereas one times hand weeding is sometimes supplemented with spraying of herbicides (2, 4-D).

Farmers perceive that more numbers of conventional tillage and trampling of tilled soils by repeated tracks of mass livestock on the sowing day are important activities to reduce competition of weed biomass for tef growing. In agreement with this view, Alemayehu *et al*.(2008) reported that the weed biomass was substantially high in the conservation tillage with single ploughing than in seven times tilled plot in Adet, North-western highlands of Ethiopia. Balesh *et al. (*2008) note that lesser tef yield gained from zero tillage mainly due to high grass weed infestation as these were not controlled by pre-planting spray of non-selective herbicide. In association with this, Kassahun and Tebkew (2013) suggested that combine use of hand weeding and herbicides (2,4-D) application at critical period of weed competition for tef, three to four and six to seven weeks after crop emergence, is substantially contributed to improve tef yield.

8.2. Integrated effects of soil and water management practices on application rates of inorganic fertilizers

Results present in Table-25 reveal that the applied rate of inorganic fertilizers to grow tef and wheat crops was differed in proportion to the ability of management activities of cropping fields. For example, on an average of 163.4k.gha^{-1} and 158.7k.gha^{-1} inorganic fertilizers applied on fields conserved with below 4 years old terraces and above 6 years old terraces, correspondingly. This demonstrates that applied rate of inorganic fertilizers on fields treated with 7 and above years old terraces was decreased by 2.9% as comparatively seen with ≤3 years age terraced fields but not significantly differed. This indicates that biophysical conservation measures may not be considerably contributed to reduce input costs of farmers like application rate of inorganic fertilizers for tef and wheat crops growing, in particularly under the conditions of perceived infertile land and steep slope characters.

Table-25: Mean values and analysis of variance in differences of applied rate of inorganic fertilizer as a result of integrated SWM practices on both tef and wheat cropped fields (n=150)

SWM Practices on Tef and wheat cropped fields	Mean(k.g.h^{-1})	F
Below 4 years old terraces	163.4	
Above 6 years old terraces	158.7	0.13
Forerunner cereals crops	165.7	
“ legume crops	144.1	2.8^{c}
Precursor inorganic fertilizers only	171.6	
“ combination of compost and inorganic fertilizers	165.3	
“ compost only	133.7	4.2^{b}
Existing year applied compost (0 quintal)	172	
“ “ “ “ (0.5 quintal)	165.7	
“ “ “ “ (0.75 quintal)	160	
“ “ “ “ (1quintal)	142.1	
“ “ “ “ (1.25 quintal)	126.7	
“ “ “ “ (1.5quintal)	101.5	
“ “ “ “ (1.75 quintal)	113.3	2.5^{b}
Practicing ISWM activities on specific plot	100	
Otherwise	171.8	24.8^{a}
Total	159.9	

Note: *^{a}, ^{b} and ^{c} represent significant level of P< 0.01, P<0.05 and P<0.1, respectively;*
One quintal compost is equivalent to100 kg; and
ISWM- Integrated Soil and Water Management (combine use of more than six years maintained terraces, compost and legume-cereals crop rotation [LCCR] on a specific field).

Results in Table-25 show that farmers were also used different rate of chemical fertilizers on tef and wheat cropped fields that amended by different types of fertilizers in the former time. For example, on an average of 171.6k.gha$^{-1,}$ 165.3k.gha^{-1} and 133.7k.gha^{-1} inorganic fertilizers used, in that order, on fields that treated by inorganic fertilizers only, combine use of inorganic and compost, and compost only. This signifies that the mean applied rates decreased by 22.1% and 3.7% on forerunner compost only and its combination with inorganic fertilizers treated fields, respectively, as compared with precursor chemical fertilizers only. In substantiate with this, application rate of chemical fertilizers between croplands treated with inorganic fertilizers only, combination of compost and chemical fertilizers, and compost only in the prior year were varied at f=4.2 and $P< 0.05$ significant level (Table-25). This implies that compost followed by combination of inorganic and compost had applied for cereal or legume crops production in past year might have considerable contributions to enhance soil fertility and, consequently reduce costs of inorganic fertilizers in the next year than precursor inorganic fertilizers only.

The application rate of chemical fertilizers was also differed (at f=2.5, $P<0.05$) in compost using for prevailing crops (largely for wheat) growing (Table-25). Accordingly, likewise precursor amendment, using compost in existing crops growing was substantially important to reduce inputs cost (chemical fertilizers) with more likely accompanied by replenishing soil fertility in the sustainable condition.

Table-25 also reveals that farmers applied on an average of 165.7k.gha^{-1} and 144.1k.gha^{-1} rates of inorganic fertilizers on precursor cereals and legume cropped fields, respectively. This indicates that the mean applied rate was reduced by13% on forerunner legume grown fields (both tef and wheat cropped), and was significantly varied (at f=2.8, $P<0.1$), when compared to precursor cereals. This possibly suggests that amending of cultivated fields by precursor legume grown is found to have significant contributions to soil nutrient retain capacity and thus to reduce input costs like application rate of inorganic fertilizers for the coming year.

Moreover, the mean rates of inorganic fertilizers use on tef and wheat cropped fields that treated by ISWM activities and lesser practices estimated about 100k.gha^{-1} and171.8k.gha^{-1} respectively (Table-25). This illustrates that the mean application rate of chemical fertilizers was reduced by 41.8% on fields treated by ISWM and, significantly differed (at f=24.8 and $p<0.01$), when compared other fields treated with lesser activities. This perhaps suggests that contribution of ISWM activities to specific field is significantly higher to replenish soil fertility accompanied with reducing costs of inorganic fertilizers for growing of tef and wheat crops than other lesser treated fields.

8.3. Effects of integrated soil and water management practices on tef and wheat yields

In the study areas, wheat and tef are often harvested from early November to mid-December and from mid- December to last-January, respectively. Tef production is usually required for multitude functions including food security to the majority peoples by making flat cake (*Enjera*), and an important cash crop for smallholder farmers. Its straw is also the most preferred to bind mud that uses for house construction and to utilize as animal fodder than all other crops. Tef straw contains the highest nutritive value and provides the basis of the roughage supply to livestock in particular in the Ethiopian highlands wherein mixed crop-livestock production systems mainly practised (Alemu, 2013). Nevertheless, results in Table-26 show that expected output of tef crop was lesser than wheat. For instance, the mean tef and wheat grain yields, respectively, estimated about 1248.8k.gha^{-1} and 1800.2k.gha^{-1}. This demonstrates that the mean grain yield of wheat crop was larger by 44.2% when relatively seen with tef crop.

Results presented in Table-26 reveal that the significant effects of different SWM activities on improving tef and wheat grain yields. For example, the mean grain yields in fields treated by > 6 years old terraces were about 1326.2 k.g ha^{-1} for tef and 1903.4k.g ha^{-1} for wheat, and fields amended with < 4 years age terraces were about 1034.9 k.g ha^{-1} for tef and 1496.3k.g ha^{-1} for wheat crops. This implies that there is an average increase of grain yields by 28.15 % for tef and by 27.21% for wheat and considerably higher (at f=22.54, $P<0.01$) from cultivated fields that conserved with above 6 years old terraces, when compared to fields conserved by <4 years age terraces. This possibly suggests that terraces stabilized with grass or *Sesbania sesban* shrubs have significant contributions to enhance soil productivity, and then tef and wheat yields improvement in the long-run if they properly maintained by the farmers.

Results of this study made in agreement with other survey and trial findings conducted in the highlands of Ethiopia. For instance, social study by Enyew *et al*. (2013) indicates that 25 yrs old terraced farm were more productive that show an average yield increment of 94 % of tef as compared to the adjacent fields without terraces. Wagayehu (2003) also noted that crop yields from conserved fields significantly higher than cultivated fields without conservation.

Based on the results of their survey study, Schmidt and Fanaye (2012) suggested that adopters that maintain conservation measures for at least 7 years and continues to maintain for 15 years, the value of the production would increased with 2% by the end of 7th year and with 13% by the end of the 15th years respectively than adopters did not maintain their structural conservation measures for at least 7 years. Furthermore, the findings of this study concur with results of other experimental studies. For instance, Yihenew *et al*. (2009) found that barley grain yield was significantly ($P<0.05$) higher in >5 years old conserved fields than non-conserved ones. Getachew *et al.* (2011) also reported that grain yield increment due to *Fanya-juu* with elephant grass; *Fanya-juu* with vetiver grass and sole *Fanya-juu* were 51.5, 48.9 and 37.7 % respectively as compared to non-conserved plot.

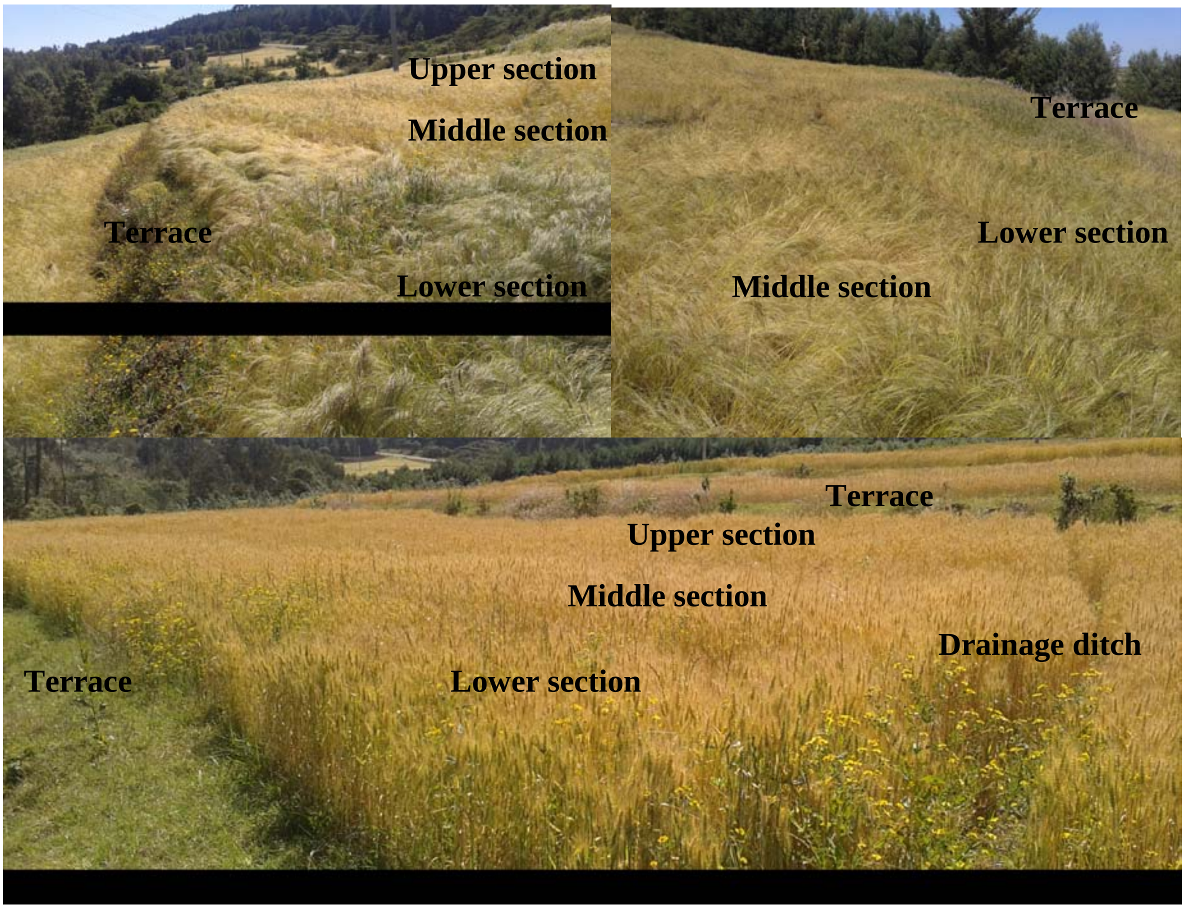


Figure-15: Variability in biomass productivity of tef and wheat crops within terraces

Based on the field observations conducted during cropping season, crop biomass productivity increases when moving from upper sections of terraces towards lower sections (see figure-15). Leafs of crops upper part of cropping area between terraces is yellow and less growth, as compared to middle and lower part (most improved section) of cropping area attributable to soils in accumulation zone of terraces are relatively hold higher nutrient and moistures. In association with this, according to the repetitive informal discussions with farmers, the amount of grain and straw yields gained from accumulation zone (lower part of fields between terraces) is higher by half than upper section of fields between terraces regardless of considerable reduction in application rate of inorganic fertilizers. As observed in all cropping areas on the steep slope fields, when the number of terraces increase, the proportion of improved land section in the particular field also increase. In agreement with this, Tadel *et al*. (2013) found that higher significant variation ($p \leq 0.01$) average value of grain (wheat) yield on accumulation zone than that of middle and loss zone of the terraces with mean value of 1077.23, 759.93 and 656.19 $kgha^{-1}$, respectively. Yihenew *et al*. (2009) also reported that the mean grain yield of barley from accumulation zone of terraces was higher with 29.8% than the mean yield from the loss zones of terraces. Moreover, Nyssen *et al*. (2007) found that grain yield from lower part of terraced plot higher by 53% as compared to the middle and upper parts.

Table-26: Mean values, and one- way ANOVA in differences of grain yields of Tef and Wheat crops due to components of SWM practices including terracing, composting and legume-cereal crop rotation, as well as their combination use on a specific plot (n=150)

	Tef grain yield		Wheat grain yield	
Soil and water management activities	Mean($k.gh^{-1}$)	F	Mean($k.gh^{-1}$)	F
Age of terracing on cultivated fields				
< 4 yrs terraces	1034.9	22.5 [a]	1496.3	10.5 [a]
> 6 yrs terraces	1326.2		1903.4	
Type of precursor fertilizers applied on the fields				
Inorganic only	1065.2		1647.2	
Combination of compost and inorganic	1232.7	15.7 [a]	1686.5	21.5 [a]
Compost only	1428.5		2411.9	
Type of forerunner crop grown on the fields				
Cereals	1140.7	34.2 [a]	1752.3	2.83 [b]
legume	1456.8		1995.2	
Combine use of > 6 yrs terraces age, compost and LCCR (ISWM)on specific plot				
Yes	1618.8	69.8 [a]	2544.4	35.3 [a]
No	1154.8		1692.1	
Grand mean	1248.8		1800.2	

Note: [a] and [b] are represent P<0.01and P<0.1 significant levels.

The mean yields from cultivated fields that previously amended with inorganic fertilizers only, combination of inorganic fertilizers and compost, and compost only, in that order, were about 1065.2$k.gha^{-1}$ for tef and 1647.2$k.gha^{-1}$ for wheat, 1232.7$k.gha^{-1}$ for tef and 1686.5$k.gha^{-1}$ for wheat, and 1428.5$k.gha^{-1}$ for tef and 2411.9$k.gha^{-1}$ for wheat (Table-26). This shows that the mean grain yields from cultivated fields that formerly treated with compost were higher by 34.11% for tef and 46.42% for wheat, and combine use of compost and chemical fertilizers were larger by 15.72% for tef and 2.4% for wheat when compared with fields previously treated with inorganic fertilizers only. In corroboration to this, results of analysis of variance in Table-26 indicate that grain yields were significantly differed (at f =15.7, $P<0.01$ for tef and at f =21.5, $P<0.01$ for wheat) between fields formerly treated with organic fertilizers and fields treated by inorganic fertilizers. This implies that forerunner use of compost followed by combine use of inorganic and compost for cereal or legume crop growing in past year have significant effects on improving soil productivity and, consequently tef and wheat crops yields in the next year than inorganic fertilizers only. This finding made in agreement with results of different experimental studies, which conducted in central highlands of Ethiopia. For example, Agegnehu *et al*. (2014) found that the use 30/10kg $NPha^{-1}$ with 50% of compost as N equivalence increased mean grain yield of wheat by 129% and tef by 122% compared to control ones. Moreover, Getachew *et al*. (2012) concluded that an application of half the recommended rate of inorganic fertilizers with 50% of the recommended dose of 3t ha^{-1} compost can be an alternative best integrated soil fertility management measures for sustainable grain (in particular cereals) production than sole application of inorganic NP fertilizers.

Table-26 also shown that the mean grain output from cultivated fields with precursor legume crop grown were 1456.8k.gha^{-1} for tef and 1995.2k.gha^{-1} for wheat, and forerunner cereal crop were about 1140.7k.gha^{-1} for tef and 1752.3k.gha^{-1} for wheat. This signifies that the mean grain yield from cultivated fields of forerunner legume crop grown added by 27.7% for tef and 13.86% for wheat and significantly higher at f=34.2 & $P<0.01$ for tef and at f=2.83 & $P<0.097$ for wheat crop, when compared with fields grown by precursor cereals in the former year. In relation to this, large number of farmers informally reported that use compost only for legume crops growing is their prominent preference. In the cultivated fields wherein legume crop grown in the former year might have more significant contributions to soil nutrient retain capacity, and thus to increase crops yield in the coming year in particular for tef crop output than wheat. In agreement with this finding, based on results of their trail study Getachew *et al*.(2014)found that the highest grain yields for malting barley grown after Faba beans followed by rapeseed and field pea than continuous barely cropping fields. Teklu and Hailemariam (2009) also reported that the interaction effects of farmyard manure and nitrogen application under cereal-pulse-cereal rotation system was significantly influenced biomass, grain and straw of wheat (*Triticum durum*) and tef (*Eragrostis tef*). What is more, according to their three years trial study conducted in farmers fields in Ghana, Sauerborn *et al*. (2000) indicated after growing legumes and sunflower for one year, the grain and straw yields of maize and sorghum were significantly higher in the two consecutive years than after cereals(maize-sorghum monoculture).

Moreover, according to the farmers' estimation results in Table-26, the mean grain yields of fields conserved with ISWM were about 1618.8k.gha^{-1} for tef and 2544.4k.gha^{-1} for wheat, whereas grain yields from fields that treated by lesser SWM activities were about 1154.8k.gha^{-1} to tef and 1692.1k.gha^{-1} to wheat. This demonstrates that the mean grain yields from fields treated with ISWM increased by 40.18% to tef and by 50.37% to wheat crop and significantly higher (at f=69.8, P<0.01 to tef and f=35.3, P<0.01 to wheat), as compared with croplands treated by lesser practices. This suggests that combine use of terraces stabilized with vegetative measures and agronomic (bio-chemical treatment of soils through promoting organic fertilizers) components of SWM practices, perhaps, greatly contributed to soil quality and then crop yield improvement as compared with croplands that treated with only agronomic or physical activity, as well as non-conserved fields.

8.4. Farmers' perceptions on the improvement of household income

The integrated SWM practices need to directly contribute to improve crops yield and indirectly contribute to diversify income-generating activities for significantly increasing household incomes (Ashley and Hussein, 2000). In addition to crop and livestock productions, other income generating farm activities like bee-keeping and tree production are usually practised in the highlands of Ethiopia in general in the study area in particular. In the study sites, many farmers informally report that the main purpose of practicing these activities was to contribute to household income betterment. Since getting accurate information about change of income in the form of monetary is more unlikely memorable for the majority farmers, using unforgettable dichotomous term like 'increased' and otherwise (including no change and decreased) was preferred in the context of this study. Farmers asked to perceive the existing change status of their household income over time, in particular after the intervention of integrated SWM program. Table-27 shows that about 14% of farmers reported that their household income increased, whereas others majority (86%) respond no change and decreased.

Results presented in Table-27 reveal that different socio-economic factors were significantly associated with perceived improvement of individual household income. For example, holding of irrigated croplands (in ha), and beehives and total livestock (in number) were significantly associated (at $P<0.01$) with perceived enhancement of household income. Total holding farmlands, and pasture and trees planted field sizes (in ha) also significantly related (at $P<0.05$) with perceived improvement of household income. In agreement with this, Assan and Fikirte (2013) indicated that household mean income has increased in the post intervention of 'Tree Gudifecha' project with an associated rise in diversifying of farm income activities including tree plantation, sheep fattening, bee keeping, and vegetable and fruit productions.

The mean irrigated croplands holding per head (hh^{-1}) were about 0.28ha for farmers who improved income, whereas about 0.025ha for farmers who respond otherwise. In consistent with this, farmers' perception on improvement of household income was significantly differed (at $t=13.2$, $P<0.000$) in holding size of irrigated croplands in hectare per head. This suggesting that diversifying farm income through traditional irrigation is more likely contributed to household income betterment. In agreement with this, Mehretie and Woldeamlak (2013b) indicate that access to traditional irrigation contributes to increased household income and closely link to improved rural households. Based on repetitive field observations, water productivity of high market price crops like fruits (apple, garlic, onion, potato) and vegetables (cabbage) often produce by some farmers in particular at homestead by using hand well irrigation, as well as in streams valley area through channel diversion irrigation. As farmers informally discussed, digging wells and diversion channels through using collective action of some number of villagers usually practice in order to simplify the intensive labour requirement. This often occurred through making an agreement between owner of irrigated cropland and other co-workers to provide some section of irrigated croplands for each from one to two years long.

The mean numbers of beehives were larger for farmers who perceived to increase their income (4.4) than who respond otherwise (no change or decrease) (0.5) and significantly varied (at $t=11.8$, $P<0.000$). This implies that diversifying farming income through bee-keeping activity more likely contribute to improve household income. In association with this, based on the field observations, some bee-keeping activities mainly practice in the homestead area for honey production, in particular where farmers' home often sites close to stream valley areas. Farmers informally discussed that when the windbreak trees surround production site and close to flowering plants and streams, bee keeping is productive. Windblown area is not suitable for apiculture production. Hence, farmers planted some introduced and pertinent flowering plants like *Sesbania sesban* and *Grevillia* in surrounding to homestead by seeing that their flower part for bee keeping and leaf part for fodder production of cattle, sheep and goat grazing. As farmers further noted, honey production can get twice (during spring and autumn seasons) in a year.

Table-27: The association between perceived changes of household income (increased [n=21] and otherwise [n=129]) and socioeconomic factors

Socioeconomic factors	Perceived changes of household income over time (increased[14%] and otherwise[86 %])		t-value
	Increased (**X**)	Otherwise (**X**)	
Irrigated croplands(ha)	0.28	0.025	13.2[a]
Pasture & trees planted fields(ha)	0.07	0.038	2.1[b]
Total farmlands size (ha)	2.24	1.76	2.5[b]
Number of bee hives	4.4	0.5	11.8[a]
Total number of livestock	11.9	9.2	3.1[a]
Number of productive labour	3.7	3.7	0.03
Tef & Wheat mean grain yields from conserved fields (in $K.gh^{-1}$)	1461.8	1517.6	-.49

Note: [a] and [b] represent significance values at P<0.01 and P<0.05, respectively.
***X**- Represents mean of different socioeconomic factors in respect to increased and otherwise response categories of farmers.*

The average size of pasture and trees or shrubs planted area were 0.07ha (to farmers who perceived to increase their household income) and 0.038ha to farmers who respond 'no change and decrease' (Table-27). In verifying with this, perceived betterment of household income was significantly varied (at t=2.14, P<0.034) in terms of holding sizes of pasture and trees/ shrubs planted area in ha per head. From field observations, *Eucalyptus and Grevillia* trees usually plant at household level to cover costs of fuel woods consumption and home construction materials and cash income-gaining purposes. These trees often distribute in the farm boundary, and in the margin of stream channels, gullies and waterways. Moreover, cropping lands sometimes convert into eucalyptus tree production in particular where the areas are proximate to market and easily accessible for transportation. As farmers informally indicated, when cultivated field is unproductive for crops production, farmers are often preferred to convert into Eucalyptus tree production because of highly rising of price per tree for construction materials. A large numbers of farmers are also produced shrub plant like locally named as *Gesho (Rhamnus prinoides)* in their homestead area for traditional drinks or beers (*Tella and Areki*) productions and cash income purposes. Under trees or shrubs coverage areas, productive fodders (like grasses and herbaceous plants, saspaniya shrubs) were usually planted /mixed in free spaces for cattle feeding through cut-and-carry grazing system.

Table-27 also indicated that total holding size of farmlands (in ha) and livestock (in number) significantly and positively associated with perceived improvement of household income (at $t=2.48$, $P<0.014$) and (at $t=3.1$, $P<0.002$), respectively. However, access to financial credit service, off-farm income activity, productive labour size (in number), and crops (tef and wheat) grain yields improvement from conserved fields of a particular catchments are insignificantly related with perceived enhancement of household income.

Despite boosting of crop yields is one principal objective of integrated SWM approach, results of t-test analysis in Table-27 depicts that estimated crops (tef and wheat) grain yield improvement from some conserved plots in a particular catchment by itself has more likely insignificant effect to improve household income. This, perhaps, due to unlikely replication of conserved fields (including diversification and sustainable intensification of pertinent farming activities, weighted on site specific attributes and farmers' preference) towards other fields by empowering of individual household. In agreement with this study result, results of the study by Reddy *et al*. (2004) conducted in India indicated that despite land productivity (crop yields) has considerably increased in all watershed, it may not results in improved household income rather than linked to other diverse activities sources like availability of fodder in the sustained basis for productive livestock rearing, wage employment, access to water for irrigation and fuel wood production.

Based on the frequent informal discussions, farmers identified major factors that seriously limiting income betterment of smallholder farmers. These include poor management in post harvesting, inappropriate market situation (unpredictable) of crop yields in the early post harvesting time and buying time of inorganic fertilizers, and skyrocketing price of inorganic fertilizers, which is not permitted to buy/afford/ the required amount.

8.5. Conclusions

The findings of this study, using farmers estimation technique, were confirmed that long-term ($\geq$7 years age) maintained terraces stabilized with vegetative measures have significantly contributed to improve tef and wheat grain yields when compared with fields conserved with $\leq$3 years age terraces. Practicing of organic farming activities (composting and Legume-Cereals Crops Rotation [LCCR]) also considerably contributed to short-term returns like reduction of chemical fertilizer costs as well as improvements of tef and wheat grain yield. Moreover, the combine use of long-term maintained terraces stabilized with vegetative measures and agronomic (composting, LCCR) on a specific plot has largely contributed to reduce inorganic fertilizer cost, and increase tef and wheat grain yields in the short-run and then more in the long-run as comparatively seen croplands that treated with only agronomic or biophysical activity, as well as non-conserved fields.

Despite boosting of crop yields is one principal objectives of integrated SWM approach, results of t-test analysis depict that estimated improvement of tef and wheat grain yields from some conserved field in a particular catchment by itself is insignificantly associated with perceived enhancement of household income. Nevertheless, different assets were significantly associated with perceived improvement of household income. For instance, holding size of irrigated croplands (in ha), and number of beehives and total livestock were positively and significantly (at $P<0.01$) associated with perceived increase of households' income. Holding sizes of total farmlands, and pasture and trees planted field (in ha) were also positively and significantly (at $P<0.05$) related with perceived improvement of individual households income.

Based on the major findings of this study, the following suggestions give. Efforts should make to boost crop productivity while sustainably conserving soil fertility through scale up of integrated soil and water management strategy that accounts the interaction effect of vegetative stabilized structure measures along with the combined use of organic and inorganic fertilizers under farming systems of legume-cereals crop rotation. In the lens of integrated approach, agricultural extension packages should be intensively fully engaged to empower smallholder farmers to enhance forage, livestock, trees and apiculture productions by planting of multipurpose exotic and indigenous plants on their outcropped and in cropped plots. The integration of multipurpose trees, shrubs and grasses between and within croplands should scale out and internalized by individual households with considering as part of sustainable livelihoods condition. The sampled locally applicable and recognized indigenous and improved SWM practices should willingly invest and then scale up towards other croplands. Moreover, developing adequate awareness about efficient management in post harvesting, creating of good market condition for crop yields at relevant time and subsidization of fertilizers costs shall incorporate in the integrated SWM approach to enhance households' income. Better market condition for local production and subsidization of inputs like chemical fertilizers makes a strong positive contribution to raising the returns to land and labour in smallholder agriculture of Ethiopian highlands (Bekele *at al.*, 2008).

CHAPTER NINE

SUMMARY AND RECOMMENDATIONS

9.1. Summary

Despite substantial conservation efforts, thoroughly weighted in favour of physical aspect with seldom pay attention to institutional and socio-economic context of the watershed, have made since early1970s, accelerated rate of land degradation was unabated. Integrated SWM approach incorporating intensification and diversification of crop-livestock mixed farming activities is fundamental in the highlands of Ethiopia, where the accelerating rate of land degradation under ever-increasing populations' pressures is more likely results to have susceptible livings of subsistence farmers. Therefore, in such circumstances this study was assessed the practicing process, farmers' acceptance and adoption, and socio-ecological outputs of integrated SWM approach in *Goncha-Siso-Enese* Woreda, North-western highlands of Ethiopia. The major findings of these multi-perspective and multi-scale investigations present as follow.

For instance, one section of the study undertaken to investigate the practicing process of integrated SWM approach, and acceptable performance of SWM practices in farmers' perspectives using multi-criteria analysis method. The results of the study shown that integrated SWM intervention was not addressed recognition of farmers' local experience, skills, and preference in planning and implementing stage of conservation activities at specific farmland level. This implies that the promotion effort through technical support to develop farmers' skill and knowledge about relevant conservation measures with recognition of their experience not done efficiently. This probably results somehow ineffective in technical designing and implementing of introduced and local SWC activities. However, the integrated use of different components of SWM activities (including structural, vegetative and agronomic in both traditional and modern perspectives) indicate substantial reflection of integrated SWM approach. As farmers show, soil bunds stabilized with *Sesbania sesban* shrubs followed by *Fanya juu* stabilized with *Sesbania sesban* shrubs are the most preferred one due to providing multi-benefits against to a range of identified relative criteria. Compost use can give short-term benefits in the ecological aspect (enhancing soil fertility) and in the economical perspective (increasing crop yields and reducing cost of chemical fertilizer application). Accordingly, from farmers' perspective, it is possible to conclude that in the humid mid-highland agro-ecosystem, integrated use of terraces complemented with growth *Sesbania sesban* shrubs and compost is the best alternative approach to sustainable cropland management.

The study pointed out results on factors influencing the farmers' decision to use integrated soil and water management practices. Productive labour size, farmland ownership status, extension contacts, perceived farmland distance and perceived plot slope categories positively and significantly influence farmers' adoption of terraces stabilized by vegetation measures. Decision at farm household level to use compost in any farmland regularly is positively and significantly influenced by productive labour size and degree of extension contact, whereas negatively and significantly influenced by total farmland holding size (in ha). Farmers' decision to practice Legume-Cereals Crop Rotation (LCCR) is positively and significantly explained by holding any perceived suitable plot for legume crops production, farmland holding size (in ha), farmers crop preference in terms staple foods and market prices, perceived farmland distance from home and perceived soil fertility status of particular plot. And finally, farmers' crop preference, ownership status of farmlands, farmers' perceptions on plot distance from home and fertility status, technical fitness of constructed structural measures, and holding any perceived suitable plot for legume crops production are major influential factors for farmers' decision to use Integrated Soil and Water Management (ISWM) incorporating biophysical, compost and LCCR on a specific plot. It concluded that policy should recognize these key variables and their mutual interdependence influence on farmers' decision to adopt activities overtime.

This study was carried out to evaluate the characteristics, relative importance of criteria and performance of the management systems of Common-Pool Resources [CPRs](including forests, shrub lands and grasslands) by using satellite image and multi-criteria analyses. Results from satellite images analysis reveal that the spatial extent of forests, shrubs and wetlands (largely in the *kola* agro-ecology where the accessibility of information system and market linkage is poor, and the natural resources base is more fragile compared to populations (human and livestock) pressure), and grasslands (mostly in the *Woina-dega* agro-ecology) radically declined at the chiefly expanding of cropland and settlements. These proximately caused by encroachment of croplands and fragmented settlements towards CPRs. Rampant population pressures, and weak institutional structure and arrangement further pushed instant severe effects of CPRs change including expansion of barren surfaces and gullies development, and consequently shortage of fodder and fuel wood, and loss of croplands. Participatory evaluation results indicate that an arrangement of enabling local institutional conditions followed by empowering of local community through forming mutually respected and valued interactions between stakeholders, developing awareness and knowledge, defining clear laws and rules were deemed relatively the most important criteria for sustainable use of CPRs than others(ecological and economical ones). Existing management schemes of CPRs are not on the sustainable paths since they are not holistic. For instance, on the one hands, complete enclosure scheme of forests and shrubs is mainly favoured for ecological restoration with no pay attention to socio-economic outputs. On the other hand, grasslands management under periodic enclosure without rotation mainly focuses on fair distribution of short-term economic benefits as fodder for cattle feeding with overlooked the target of ecological restorations. Moreover, natural forests and shrubs lands under semi-open access management and grasslands in open-access management scheme are performed between very weak to poor performance against to almost all local indentified criteria/indicators.

The study also presented on the results of effects of SWC practices on reducing the magnitude of soil loss by using rill survey technique at cultivated field scale. The results indicate that the total volumes of soils removed by rills were about $22.8m^3ha^{-1}$ in non-conserved fields and $10.6m^3ha^{-1}$ in conserved fields, Beribere catchment by the year of 2015. This indicates that rill erosion in conserved fields reduced with 53.51%, when compared with non-conserved control fields. Nevertheless, for this study, the measured magnitudes of rill erosion underestimated of the total soil loss for Beribere catchment since inter-rill/sheet erosion excluded. By assuming sheet erosion contribution of 28% in conserved fields and 30% in non-conserved fields, the actual soil loss due to rills and sheet erosion estimated about $32.6m^3ha^{-1}$ in non-conserved fields and $14.8m^3ha^{-1}$ in conserved fields. This indicates that the absolute soil loss in the conserved fields was still high (not at acceptable level). In the conserved area, terraces damage is the most important contributing factor for soil loss due to rills. In the non-conserved fields, entering of concentrated run-off from up-slope areas and ditch damaging observed as the principal accelerating factors for initiation and development of rill erosion, whereas they had insignificant effect for rill erosion in the terraced fields. Moreover, soil erosion demonstrated spatial differences in terms of crop covers and relative topographic positions in the valley sides of the study site. For instance, wheat cropped fields were slightly vulnerable for rill erosion when compared with tef cropped fields. This probably attributable to the higher contributing proportions of sheet flow grown and ditches bed erosion to the magnitude of rill erosion in wheat fields than tef. Sheet flow grown and ditches bed erosion were mainly occurred as a result of inappropriate gradient of row crop sowing, and wide spacing and ill-designing of ditches, respectively. All surveyed fields from mid-slope topographic position were the most susceptible to rill erosion than other topographic positions. It concluded that despite there was considerable soil loss reduction, conservation activities are inadequate to curb soil erosion by water effectively.

Moreover, the household survey study at field level conducted to assess the effects of integrated SWM practices in improving crop yield and household income. In this section, results reveal that long term ($\geq$7 years age) maintained terraces stabilized with vegetative measures have significantly contributed to improve tef and wheat grain yields as compared to fields conserved with $\leq$3 years age terraces. Practicing agronomic activities (like composting and LCCR) also considerably contributed to short-term returns like reduction of chemical fertilizer costs, as well as improvements of tef and wheat grain yield. Moreover, the combine use of long-term maintained terraces stabilized by vegetative measures and agronomic (composting and LCCR) on a specific plot has largely contributed to reduce inorganic fertilizer cost, and increase tef and wheat grain yields in the short-run and then more in the long-run when compared to croplands that treated with only agronomic or physical activity, as well as non-conserved fields. Holding size of irrigated croplands (in ha), and number of bee holding hives and total livestock were positively and significantly (at $P<0.01$) associated with perceived increase of households' income. Holding sizes of total farmlands, and pasture and trees planted field (in ha) were also positively and significantly (at $P<0.05$) related with perceived improvement of individual households' income.

9.2. Recommendations

It suggests that recognition of local farmers' knowledge and skills about particular croplands spatial characteristics should emphasize during designing and implementing of modern conservation measures. It is argued that institutional strengthen activities (relevant extension supportive action, accountable and responsible formulation and implementation of by-law) to empowering individual households is anticipated to be focused by the concerned stakeholders. It can conclude that local social, economic and site-specific ecological decision criteria should incorporate in decision-making process of SWM alternatives to increase utility.

The tremendous efforts of agricultural extension system to scale up multi-functional integrated soil and water management activity, which is relevant to provide both short-term and long-term returns, need to develop to contribute to sustainable agricultural production of subsistence farmers.

It suggests that an arrangement of enabling institutional principles and then empowering local communities should provide the most priority for desired condition of sustainable use of Common-Pool Resources (CPRs). Moreover, the existing management schemes of CPRs should be reformulated to relevant holistic scheme that takes into account multiple functions, and diverse interest and preference of local communities

Erosion control activities (especially terracing and traditional ditches) often cause for rill formation unless they fittingly design, maintain and stabilize. Hence, there should be adequate criteria and skills for designing of site-specific erosion control activities for addressing site-specific nature of concentrated flow of run-off. Moreover, erosion control practices need to be complemented with considerable practicing of agronomic SWM measures (like organic fertilizers [composting] and legume-cereals crop rotation) to reduce soil, water and nutrient loss at acceptable level and thus enable the cultivated fields to sustainable crop yields.

It recommends that efforts should make to boost crop productivity while sustainably conserving soil fertility through scale up of integrated soil and water management strategy that accounts the interaction effect of vegetative stabilized structure measures along with the combined use of organic and inorganic fertilizers under farming systems of legume-cereals crop rotation. In the lens of integrated approach, agricultural extension packages should be intensively fully engaged to empower smallholder farmers to enhance forage, livestock, trees and apiculture productions by planting of multi-purpose exotic and indigenous plants on their out-cropped and in-cropped fields.

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APPENDICES

Appendices for chapter-four

Appendix-I:

Farmers AVERAGE SCRORE of different activities

	Economic				Social	Ecological			
	MPR	IFRR	CYE	FPE	CR	SLCDR	MR	RR	SFI
StB	3.75	1.1	1.65	1.25	3.6	3.4	2.5	3.15	1.2
SB	2.86	1.25	1.75	1.85	3.7	3.5	2.5	3.2	1.25
SBSS	2.61	1.3	1.77	2.46	3.7	3.67	2.55	3.6	1.37
FY	2.87	1.3	1.75	1.95	3.6	3.22	3.2	2.98	1.25
FYSS	2.65	1.3	1.75	2.45	3.7	3.28	3.25	3.1	1.35
CU	3.35	2.9	3.2	1.05	1.01	1.15	1.15	1.15	3.3
LCCR	1.1	2.1	2.7	1.07	1.11	1.05	2.04	1.21	1.75
TDD	1.5	1.07	1.23	1.34	1.83	3.45	1.3	3.59	1.05
CP	1.14	1.06	1.3	1.03	1.52	3.18	3.6	3.2	1.1
Total	21.8	13.4	17.1	14.5	23.8	25.9	22.1	25.2	13.6
Asu.wj	0.123	0.073	0.096	0.082	0.134	0.146	0.125	0.142	0.08

Squaring

	Economic					Social	Ecological		
	MPR	IFRR	CYE	FPE	CR	SLCDR	MR	RR	SFI
StB	14.1	1.21	2.723	1.563	12.96	11.56	6.25	9.92	1.44
SB	8.18	1.563	3.063	3.423	13.69	12.25	6.25	10.24	1.563
SBSS	6.812	1.69	3.133	6.052	13.69	13.47	6.5	12.96	1.877
FY	8.237	1.69	3.063	3.803	12.96	10.4	10.24	8.88	1.563
FYSS	7.023	1.69	3.063	6.003	13.69	10.73	10.6	9.61	1.823
CU	11.22	8.41	10.24	1.103	1.02	1.323	1.323	1.323	10.89
LCCR	1.21	4.41	7.29	1.145	1.232	1.103	4.162	1.464	3.1
TDD	2.25	1.145	1.513	1.796	3.349	11.903	1.69	12.89	1.103
CP	1.3	1.124	1.69	1.061	2.31	10.112	12.96	10.24	1.21
$(\Sigma x^2ij$	60.3	22.93	35.77	25.95	74.9	82.92	60.05	77.53	24.56
$(\Sigma x^2ij)^{1/2}$	7.77	4.79	5.98	5.1	8.65	9.12	7.75	8.81	4.96

Step 1 (b): divide each column (average score) by $(\Sigma x^2ij)^{1/2}$ to get **rij**

$Xij / (\Sigma x^2ij)^{1/2} = rij$

	Economic				Social	Ecological			
rij	MPR	IFRR	CYE	FPE	CR	SLCDR	MR	RR	SFI
StB	0.483	0.23	0.276	0.245	0.416	0.373	0.322	0.358	0.242
SB	0.368	0.261	0.293	0.363	0.428	0.384	0.323	0.363	0.252
SBSS	0.336	0.271	0.276	0.482	0.428	0.402	0.329	0.409	0.276
FY	0.369	0.271	0.293	0.382	0.416	0.353	0.413	0.338	0.252
FYSS	0.341	0.271	0.293	0.480	0.428	0.360	0.419	0.352	0.272
CU	0.431	0.610	0.535	0.206	0.117	0.126	0.148	0.131	0.665
LCCR	0.142	0.438	0.452	0.210	0.128	0.115	0.263	0.137	0.353
TDD	0.193	0.223	0.206	0.263	0.212	0.378	0.168	0.407	0.217
CP	0.147	0.221	0.217	0.202	0.176	0.349	0.465	0.363	0.222

Table-3: Average and sum of Group Discussant Ratings on the Relative Weight of Each Identified Criteria (n=28)

	Identified Criteria									
	Economic				Ecological				social	Total
	MPR	IFRR	CYE	FPE	MR	RR	SFI	SLCDR	CR	
Mean	2.41	3.68	4	3.64	1.45	3.09	1.91	3.73	2.73	26.6
Mode	2	4	4	4	1	3	2	4	3	
Sum	53	81	88	80	32	68	42	82	60	586
Wj	0.090	0.138	0.15	0.137	0.055	0.116	0.072	0.14	0.102	1

Multiply each column (rij value) by wj to get vij.

	Economic				Social	Ecological			
vij	MPR	IFRR	CYE	FPE	CR	SLCDR	MR	RR	SFI
StB	0.043	0.032	0.041	0.034	0.042	0.052	0.018	0.042	0.017
SB	0.033	0.036	0.044	0.050	0.044	0.054	0.018	0.042	0.018
SBSS	0.030	0.037	0.041	0.066	0.044	0.056	0.018	0.047	0.020
FY	0.033	0.037	0.044	0.052	0.042	0.049	0.023	0.039	0.018
FYSS	0.031	0.037	0.044	0.066	0.044	0.050	0.023	0.041	0.020
CU	0.039	0.084	0.080	0.028	0.012	0.018	0.008	0.015	0.048
LCCR	0.013	0.060	0.068	0.029	0.013	0.016	0.014	0.016	0.025
TDD	0.017	0.031	0.031	0.036	0.022	0.053	0.009	0.047	0.016
CP	0.013	0.030	0.033	0.028	0.018	0.049	0.027	0.042	0.016

Step 3 (a): determine ideal solution A* and find negative ideal solution A'.

	Economic				Social	Ecological			
vij	MPR	IFRR	CYE	FPE	CR	SLCDR	MR	RR	SFI
StB	0.043 '	0.032	0.041	0.034	0.042	0.052	0.018	0.042	0.017
SB	0.033	0.036	0.044	0.050	0.044*	0.054	0.018	0.042	0.018
SBSS	0.030	0.037	0.041	0.066*	0.044*	0.056*	0.018	0.047*	0.020
FY	0.033	0.037	0.044	0.052	0.042	0.049	0.023	0.039	0.018
FYSS	0.031	0.037	0.044	0.066*	0.044*	0.050	0.023	0.041	0.020
CU	0.039	0.084*	0.080*	0.028 '	0.012 '	0.018	0.008'	0.015 '	0.048*
LCCR	0.013*	0.060	0.068	0.029	0.013	0.016 '	0.014	0.016	0.025
TDD	0.017	0.031	0.031 '	0.036	0.022	0.053	0.009	0.047*	0.016 '
CP	0.013*	0.030 '	0.033	0.028 '	0.018	0.049	0.027 *	0.042	0.016 '

Step 4 (a): determine separation from ideal solution A*=vj*= {0.013, 0.084, 0.080, 0.066, 0.044 , 0.056, 0.027, 0.047, 0.048} Si* = [Σ(vj*– vij) ^{2}] ½ to respective SWM alternative in the row, and determine separation from ideal solution Si*.

Note: (vj*– vij) ^{2} should be calculated within a respective criterion /under each column /

	Economical				Social	Ecological			
vij	MPR	IFRR	CYE	FPE	CR	SLCDR	MR	RR	SFI
StB	0.0009	0.002704	0.001521	0.001024	0.000004	0.000016	0.000081	0.000025	0.000961
SB	0.0004	0.002304	0.001296	0.000256	0	0.000004	0.000081	0.000025	0.0009
SBSS	0.000289	0.002209	0.001521	0	0	0	0.000081	0	0.000784
FY	0.0004	0.002209	0.001521	0.000196	0.000004	0.000049	0.000016	0.000064	0.0009
FYSS	0.000324	0.002209	0.001521	0	0	0.000036	0.000016	0.000036	0.000784
CU	0.000676	0	0	0.001444	0.001024	0.001444	0.000361	0.001024	0
LCCR	0	0.000576	0.000144	0.001369	0.000961	0.0016	0.000169	0.000961	0.000529
TDD	0.000016	0.002809	0.002401	0.0009	0.000484	0.000009	0.000324	0	0.001024
CP	0	0.002916	0.002209	0.001444	0.000676	0.000049	0	0.000025	0.001024

	Economical				[Σ(vj*– vij)2	Si*= √[Σ(vj* – vij)^2]	Social	Si*= √[Σ(vj *– vij)^2]
vij	MPR	IFRR	CYE	FPE			CR	
StB	0.0009	0.002704	0.001521	0.001024	0.006149	0.078	0.000004	0.002
SB	0.0004	0.002304	0.001296	0.000256	0.004256	0.068	0	0
SBSS	0.000289	0.002209	0.001521	0	0.004019	0.063	0	0
FY	0.0004	0.002209	0.001521	0.000196	0.004326	0.066	0.000004	0.002
FYSS	0.000324	0.002209	0.001521	0	0.004054	0.064	0	0
CU	0.000676	0	0	0.001444	0.00212	0.046	0.001024	0.032
LCCR	0	0.000576	0.000144	0.001369	0.002089	0.046	0.000961	0.031
TDD	0.000016	0.002809	0.002401	0.0009	0.006126	0.078	0.000484	0.022
CP	0	0.002916	0.002209	0.001444	0.006569	0.081	0.000676	0.026

	Ecological				[Σ(vj*– vij)2	Si*= √[Σ(vj*–
	SLCDR	MR	RR	SFI		
StB	0.000016	0.000081	0.000025	0.000961	0.001083	0.033
SB	0.000004	0.000081	0.000025	0.0009	0.00101	0.032
SBSS	0	0.000081	0	0.000784	0.000865	0.029
FY	0.000049	0.000016	0.000064	0.0009	0.001029	0.032
FYSS	0.000036	0.000016	0.000036	0.000784	0.000872	0.030
CU	0.001444	0.000361	0.001024	0	0.002829	0.053
LCCR	0.0016	0.000169	0.000961	0.000529	0.003259	0.057
TDD	0.000009	0.000324	0	0.001024	0.001357	0.037
CP	0.000049	0	0.000025	0.001024	0.001098	0.033

Activities	Criteria				
	Si*			Aggregated	
	Economical	Social	Ecological	[S(vj*– vij)^2	Si*
StB	0.078	0.002	0.033	0.007236	0.085
SB	0.068	0	0.032	0.005266	0.073
SBSS	0.063	0	0.029	0.004884	0.070
FY	0.066	0.002	0.032	0.005359	0.073
FYSS	0.064	0	0.030	0.004926	0.070
CU	0.046	0.032	0.053	0.005973	0.077
LCCR	0.046	0.031	0.057	0.006309	0.079
TDD	0.078	0.022	0.037	0.007967	0.089
CP	0.081	0.026	0.033	0.008343	0.091

Step 4 (b): find separation from negative ideal solution A' = vj’= {0.043, 0.030, 0.031, 0.028, 0.012, 0.016, 0.008, 0.015, 0.016} Si’ = [Σ(vj'– vij) ^{2}] ½ to the respective SWM alternative in the row, and determine separation from negative ideal solution Si'.

Note: (vj*– vij) 2 should be calculated within a respective criterion /under each column /

	Economic				Social	Ecological			
vij	MPR	IFRR	CYE	FPE	CR	SLCDR	MR	RR	SFI
StB	0	0.000004	0.0001	0.000036	0.0009	0.001296	0.0001	0.000729	0.000001
SB	0.0001	0.000036	0.000169	0.000484	0.001024	0.001444	0.0001	0.000729	0.000004
SBSS	0.000169	0.000049	0.0001	0.001444	0.001024	0.0016	0.0001	0.001024	0.000016
FY	0.0001	0.000049	0.000169	0.000576	0.0009	0.001089	0.000225	0.000576	0.000004
FYSS	0.000144	0.000049	0.000169	0.001444	0.001024	0.001156	0.000225	0.000676	0.000016
CU	0.000016	0.002916	0.002401	0	0	0.000004	0	0	0.001024
LCCR	0.0009	0.0009	0.001369	0.000001	0.000001	0	0.000036	0.000001	0.000081
TDD	0.000676	0.000001	0	0.000064	0.0001	0.001369	0.000001	0.001024	0
CP	0.0009	0	0.000004	0	0.000036	0.001089	0.000361	0.000729	0
	0.003005								
	0.055								

	Economic				[Σ(vj'– vij)^2	Si'= √[Σ(vj'– vij)^2]	Social	Si'= √[Σ(vj'– vij)^2]
vij	MPR	IFRR	CYE	FPE			CR	
StB	0	0.000004	0.0001	0.000036	0.00014	0.012	0.0009	0.03
SB	0.0001	0.000036	0.000169	0.000484	0.000789	0.028	0.001024	0.032
SBSS	0.000169	0.000049	0.0001	0.001444	0.001762	0.042	0.001024	0.032
FY	0.0001	0.000049	0.000169	0.000576	0.000894	0.030	0.0009	0.03
FYSS	0.000144	0.000049	0.000169	0.001444	0.001806	0.042	0.001024	0.032
CU	0.000016	0.002916	0.002401	0	0.005333	0.073	0	0
LCCR	0.0009	0.0009	0.001369	0.000001	0.00317	0.056	0.000001	0.001
TDD	0.000676	0.000001	0	0.000064	0.000741	0.027	0.0001	0.01
CP	0.0009	0	0.000004	0	0.000904	0.030	0.000036	0.006

	Ecological				[Σ(vj'– vij)^2	Si'=√[Σ(vj'– vij)^2]
	SLCDR	MR	RR	SFI		
StB	0.001296	0.0001	0.000729	0.000001	0.002126	0.046
SB	0.001444	0.0001	0.000729	0.000004	0.002277	0.048
SBSS	0.0016	0.0001	0.001024	0.000016	0.00274	0.052
FY	0.001089	0.000225	0.000576	0.000004	0.001894	0.044
FYSS	0.001156	0.000225	0.000676	0.000016	0.002073	0.046
CU	0.000004	0	0	0.001024	0.001028	0.032
LCCR	0	0.000036	0.000001	0.000081	0.000118	0.011
TDD	0.001369	0.000001	0.001024	0	0.002394	0.049
CP	0.001089	0.000361	0.000729	0	0.002179	0.047

	Criteria				
	Si'			Aggregated	
	Economic	Social	Ecological	[S(vj*– vij)^2	Si'
StB	0.012	0.03	0.046	0.003166	0.056
SB	0.028	0.032	0.048	0.00409	0.064
SBSS	0.042	0.032	0.052	0.005526	0.074
FY	0.030	0.03	0.044	0.003688	0.061
FYSS	0.042	0.032	0.046	0.004903	0.070
CU	0.073	0	0.032	0.006361	0.080
LCCR	0.056	0.001	0.011	0.003289	0.057
TDD	0.027	0.01	0.049	0.003235	0.057
CP	0.030	0.006	0.047	0.003119	0.056

	Economic			Social			Ecological			Aggregated		
	Si’	Si*	Ci	Si’	Si*	Ci	Si	Si*	Ci	Si*	Si’	Ci
StB	0.012	0.078	.133	0.03	0.002	.94 [b]	0.046	0.033	.582	0.085	0.056	.397
SB	0.028	0.068	.292	0.032	0	1 [a]	0.048	0.032	.6	0.073	0.064	.467
SBSS	0.042	0.063	.4	0.032	0	1 [a]	0.052	0.029	.642 [a]	0.070	0.074	.514 [a]
FY	0.030	0.066	.313	0.03	0.002	.94 [b]	0.044	0.032	.579	0.073	0.061	.455
FYSS	0.042	0.064	.396	0.032	0	1 [a]	0.046	0.030	.605 [b]	0.070	0.070	.5
CU	0.073	0.046	.613[a]	0	0.032	0	0.032	0.053	.376	0.077	0.080	.510 [b]
LCCR	0.056	0.046	.549[b]	0.001	0.031	.03	0.011	0.057	.162	0.079	0.057	.419
TDD	0.027	0.078	.257	0.01	0.022	.31	0.049	0.037	.57	0.089	0.057	.39
CP	0.030	0.081	.270	0.006	0.026	.19	0.047	0.033	.588	0.091	0.056	.38

Note:

- ✓ Ci* = Si' / (Si* +Si')
- ✓ [a] and [b] represents the first and second farmers rated soil and water management practices

Appendix-II: Open-ended questions and pre-arranged structural questionnaires

1. Tell me how the sampled catchments have been selected (what were the main criteria and who have been highly engaged in the selection of the catchments) (for woreda agricultural officers/experts)
2. Who have been the most important stakeholders in full participation of integrated SWC practices? (for woreda agricultural officers, farmers, DAs)
3. Discuss about the characteristics of information/knowledge flow pattern and interaction between stakeholders during implementation of SWC activities in the selected catchments(for woreda expert, DAs, watershed committee, farmers[including farmers terraces designers and developmental group members])
4. Tell me the roles, accountability, responsibility and capability of each stakeholder during implementation process(for woreda expert, DAs, watershed committee, farmers[including farmers terraces designers and developmental group members])
5. What were the most important problems of requiring intervention in the catchments(woreda expert, DAs, watershed committee, famers)
6. What are the major activities that have been practiced in the study sites mainly with the MERETs initiative SWC intervention (woreda expert, DAs, watershed committee, famers)?
7. Discuss about the purpose/objectives/functions and practicing character of the major activities that have been practiced in the study sites mainly with the MERETs initiative SWC intervention (woreda expert, DAs, watershed committee, famers)?
8. What are the common and agreed upon criteria that use to evaluate the performance of component of integrated SWM practices(for DAs, watershed committee, formal discussants)

9. Please assign the perceived importance the decision element using the following predetermined four point of scale: 1= less important; 2=moderately important; 3= more important; and 4= extremely important (for formal discussants).

S.No.	Criteria	Assigned value
1	Man Power Requirement(**MPR**)	
2	Inorganic Fertilizer Rate Reduction(**IFRR**)	
3	crop yield Enhancement **(CYE)**	
4	Fodder Production Enhancement(FPE)	
5	Soil Loss and crops damage Reduction(SLCDR)	
6	Moisture Retention(**MR**)	
7	Runoff Reduction(**RR**)	
8	Soil Fertility Improvement(**SFI**)	
9	reducing conflict(RC)	

10. Based on the nine sets of perceived relative importance criteria (decision elements), please evaluate the performance of major components of SWC activities by giving the values of 4= very favourable performance; 3= acceptable; 2= Poor performance; 1= very weak performance (for formal discussants).

S.No.	Criteria in the **short-term**	Major Components of SWC Activities								
		Stone Bunds (**StB**)	Soil Bunds (SB)	Soil Bunds Stabilized by Saspaniya (SBSS)	Fanna Yejuu (FY)	Fanna-Yejuu stabilized with saspaniya (FYSS)	Compost use (CU)	Legumes-Cereals Crop Rotation (LCCR)	drainage ditches (DD)	contour plowing (CP)
1	MPR									
2	IFRR									
3	CYE									
4	FPE									
5	SLCDR									
6	MR									
7	RR									
8	SFI									
9	RC									

S.No.	Criteria in the **long-term**	Major Components of SWC Activities								
		Stone Bunds (**StB**)	Soil Bunds (SB)	Soil Bunds Stabilized by Saspaniya (SBSS)	Fanna Yejuu (FY)	Fanna-Yejuu stabilized with saspaniya (FYSS)	Compost use (CU)	Legumes-Cereals Crop Rotation (LCCR)	drainage ditches (DD)	contour plowing (CP)
1	MPR									
2	IFRR									
3	CYE									
4	FPE									
5	SLCDR									
6	MR									
7	RR									
8	SFI									
9	RC									

11. Please discuss about the constraining factors on sustaining situation of the major components of SWC activities (DAs, watershed committees, farmers in both formal and informal discussions)

Appendix to chapter-five

Appendix-III

Dear respondent, I am asking your cordial coordination for giving your genuine information for academic purpose only. Up keeping, the confidentiality of your provided information should be given great consideration. Therefore, please read carefully and fill/write / the relevant response by your context for each question.

1. Gender A. Male B. female
2. Age____
3. Size of your family members____
4. Productive labour size in your family members____
5. Total livestock numbers per household head ___
6. Total holding owned farmland size per household head (in ha)-----
7. Education status of your family members in number
   A. Half and above of them are literate B. More of them are illiterate
8. To what extent do you have contacted with the extension staffs?
   A. substantial B. insignificant
9. Do you have any off-farm activities that you have engaged regularly for fertilizer cost incentive A. yes B. No
10. Do you practiced legume-cereals crop rotation activity at any particular croplands regularly A. Yes B. No
11. Do you practiced composting at any particular croplands regularly A. Yes B. No
12. Do you combine use of biophysical, composting and legume-cereals crop rotation practices at any particular croplands regularly A. Yes B. No
13. Please fill the following number on the appropriate spaces of the corresponding SWC activity

Specific plot level attributes	Biophysical	Composting	Legume-cereals crop rotation	combine use of all three practices
Ownership (owned [1]) and rented [0] of fields treated with				
Perceived fertility status(infertile[1] and otherwise[0]) of specific plot treated with				
Perceived slope categories(Gentle[0] steep[1] specific plot treated with				
Perceived distance from home (homestead only[1]) and otherwise or faraway[0] of field treated with				

14. Do you think that constructed terraces are technically fitted with your particular cultivated field in terms of effectiveness in arresting soil erosion by water, and appropriateness to local plough operation and crop efficiency? A. Yes B. No
15. Do you have an adequate awareness about the benefits of SWC practices?
    A. Yes B. No
16. Have you ever used animal dung for cooking fuel during compost preparing time?
    A. No B. yes
17. Do you have any perceived suitable farmland for legume-cereals crop rotation practices?
    A. Yes B. No
18. What is/ are your family preference /favourite /crop for household staple food
    A. Cereals (tef, wheat, maize) B. Otherwise

Appendices- to chapter-six

Appendix-IV: Dynamics of LU/LC between LU/LC from 1986 to 2000

Class Type 1986		Class Type in 2000 Forest ha	Shrubs ha	Grasslands ha	Cropland& settlements ha	Wetlands ha	Lake ha	Total 1986
Forests	ha	1955.4	1056	3.8	4305.9	14	1.1	7,336.2
	%	26.6	14.4	0.01	58.7	0.2	1.6	100
Shrubs	ha	55	3454.2	152.1	4688.2	44.8	0	8394
	%	0.6	41.2	1.8	55.8	0.5	-	100
Grasslands	ha	19.7	1133.2	4298.13	3906.9	3	0	9361
	%	0.2	12.1	46	41.7	-	-	100
Cropland &Settlement	ha	91.9	4516.7	1450.8	70311.5	539.9	0	76910.8
	%	0.1	5.9	1.9	91.4	0.7	-	100
Wetlands	ha	0.3	8.1	0.63	1509.2	291.5	0.2	1809.9
	%	-	0.4	-	83.5	16.1	-	100
Lake	ha	0	0	0.09	0.2	0.09	68.3	68.7
	%	-	-	-	-		99.4	100
Total of 2000		2122.3	10,168	5905.5	84,721.9	893.3	69.6	103,880.6

Appendix-V: Dynamics of LU/LC between LU/LC from 2000 to 2014

Class Type 2000		Class Type in 2014 Forests ha	Shrubs ha	Grasslands Ha	Cropland& settlements ha	Wetlands ha	Lake ha	Total 2000
Forests	ha	1318.3	73.3	16.2	714.5	0	0	2122.3
	%	62.1	3.4	0.8	33.7	-	-	100
Shrubs	ha	584.6	1433.	1539.5	6605.1	5.1	0.2	10,168
	%	5.7	14.1	15.2	65	-	-	
Grasslands	ha	2.7	295.1	4076	1528.7	2.9	0.1	5905.5
	%	-	5	69	25.9	0.1	-	100
Cropland &Settlements	ha	146	474.3	3750.3	80108.7	242.3	0.3	84,721.9
	%	0.2	0.6	4.4	94.5	0.3	-	100
Wetlands	ha	0	5.3	36	702.7	148.2	1.1	893.3
	%	-	0.6	4	78.7	16.6	0.1	100
Lake	ha	0	0	3.4	0	0	66.2	69.6
	%	-	-	4.9	-	-	95.1	100
Total of 2014		2051.6	2281.5	9421.4	89659.7	398.5	67.9	103,880.6

Appendix-VI**: Dynamics of LU/LC between LU/LC from 1986 to 2014**

Class Type 1986		Class Type in 2014 Forest ha	Shrubs ha	Grasslands ha	Cropland& settlements ha	Wetlands ha	Lake ha	Total 1986
Forests	ha	1544.1	248.6	63.7	5476.2	2.3	1.3	7336.2
	%	21	3.4	0.9	74.6	-	-	100
Shrubs	ha	247.4	868.1	629.3	6619	29.9	0.3	8394
	%	2.9	10.3	7.5	78.9	0.4	-	
Grasslands	ha	53.1	454.6	4429.9	4421.1	2.3	0	9361
	%	0.6	4.9	47.3	47.2	-	-	100
Cropland &Settlements	ha	207	707.9	4275.9	71458.2	261.7	0.1	76,910.8
	%	0.3	0.9	5.6	92.9	0.3	-	100
Wetlands	ha	0	2.3	19.6	1685.2	102.3	0.5	1809.9
	%	-	0.1	1.1	93.1	5.7	-	100
Lake	ha	0	0	3	0	0	65.7	68.7
	%			4.4				100
Total of 2014		2051.6	2281.5	9421.4	89659.7	398.5	67.9	103,880.6

Appendix-VII: Interdependence between accessibility and goat population, and dynamics of common pool resources between 1986 and 2014 by using non-parametric correlation test

Spearman's rho Correlations		forest change -/+	shrub change -/+	grassland change -/+	C&S change -/+	wetlands change -/+	goat popn	accessibility
DFC 1986-2014	r	1						
	Sig.	.						
	N	38						
DSC 1986-2014	r	.595**	1 **					
	Sig.	.000	.					
	N	38	38					
DGC 1986-2014	r	-.122	-.043	1				
	Sig.	.465	.796	.				
	N	38	38	38				
DCSC 1986-2014	r	-.601**	-.463**	-.350**	1 **			
	Sig.	.000	.003	.031	.			
	N	38	38	38	38			
DWC 1986-2014	r	-.009	.147	-.705	.223	1		
	Sig.	.965	.463	.000	.264	.		
	N	27	27	27	27	27		
goat popn	r	-.621**	-.565**	.529**	.198**	-.249**	1 **	
	Sig.	.000	.000	.001	.241	.220	.	
	N	37	37	37	37	26	37	
accessibility	r	.708**	.528**	-.511**	-.336**	.425**	-.696**	1 **
	Sig.	.000	.001	.001	.039	.027	.000	.
	N	38	38	38	38	27	37	38

* and **. Represent correlation is significant at the 0.01 and 0.05 levels respectively.

Note: DFC-direction of forests cover change; **DSC**- direction of shrubs cover change; **DGC**-direction of grasslands change; **DCSC**-direction of croplands and settlement changes; and **DWC**-direction of wetlands change. Direction of land use/covers changes represent variables like increase(1) and decrease(0), as well as accessibility (3=close to; 2= intermediate ; and 1= remote)

Appendix-VIII: Questions

1. Please discuss about changing character of CPR covers and associated driving factors, and socioe-cological implications
2. Please select your familiar from the listed indicators under each four criteria from generic, and assign the ranks for each decision element (indicator/criteria) based on its perceived importance by using the predetermined point of scales. Hence, ranks are expected to be assigned according the following nine points: 1=weakly important; 3=less important; 5=moderately important; 7=more important; and 9= extremely important

Criteria/ indicators of sustainable management of CPR	Criteria value
C-1: Ecological conditions should be Improved(ECOLRESTOR)	
1.1.Plants biodiversity has increased(PLABIODIVINC)	
1.2.Afforesting of multi-benefits plants on degraded hills has increased(AFFORESTMP)	
1.3.Gullies expansion and other erosions should be curbed (EGULLEC)	
1.4.Springs development, available & quality water are improved(SPRINGDEV)	
C-2: management scheme of CPR should contribute to economic fits to the local users **(**ECONBENEFITS)	
2.1.fodder and timber sharing mechanisms are perceived as fair by the local people(PROSHARE)	
2.2.people have access to harvest dead forest product (DFP)	
2.3. good opportunities of harvesting apiaries should be existed in forest to local people employment (APIARIES)	
C-3: arranged local institutional situations enabling sustained use of CPR (INSTITUTARRANG)	
3.1. boundaries of CPR should be marked in the field by agreed upon by adjacent peoples(BAUNDERIES)	
3.2.full participation of communities in management of CPR(PARTCIN)	
3.3.Well defined property right CPR to local communities (PRORIGHT)	
3.4.Clearly defined rules of management, product access and benefits sharing (CDRULES)	
3.5.successful monitoring and controlling mechanisms of free-riders(SMON_CON)	
3.6.effective sanctions and enforcement mechanisms(SAN_ENFORC)	
3.7.appropriate way of conflict resolving (CONFLICTRES)	
3.8.periodic revision of management plan(PLANREV)	
3.9.planning&regulating of settlement expansion towards CPR (SETTLEM_EXC)	
C-4: adequate awareness and knowledge of local stakeholders, and their effective and mutual valued interaction for sustained use of CPR **(**ADQAWAR MUTINTER**)**	
4.1.people have adequate knowledge on socioeconomic and environmental benefits of sustained use CPR(PKNOWLEFGE)	
4.2.all people obey the rules(OBEYRULES)	
4.3.people recognize easing pressures of commons through planting woodlot and intensifying animal productivity (RECEASPRES)	
4.4. local people maintain emotional links to the CPR(EMOTIONLINK)	
4.5.effective and mutually respected interaction should be existed between local stakeholders for CPR management (RESPINTERAC)	

3. Please examine and judge the prevailing condition of each indicator/criteria relative to perceived desire condition (the sustainable use) of the indicators under each criterion and set alternative management scenarios on the sustainable use of those common pool resources by assigning the following provided scores. The score was provided to each indicator by comparing its current status with the desired condition. Therefore, the scoring is suggested as: 1= very weak performance; 2= poor performance; 3= acceptable or average; 4= very favourable performance; and 5= outstanding performance.

Criteria /indicators	Forests and shrubs			Grasslands		
	Semi-open access(A1)	Complete Closing (A2)	A2+ A3	Open access (reference)(A1)	Periodic enclosure, & cut &carry(A2)	A2+ A3
C-1: ECOLRESTOR						
1.2. PLABIODIVINC						
1.2. AFFORESTMP						
1.4 .EGULLEC						
1.4. SPRINGDEV						
C-2: ECONBENEFITS						
2.1. PROSHARE						
2.2. DFP						
2.3. APIARIES						
C-3: INSTITUTARRANG						
3.1. BAUNDERIES						
3.2. PARTCIN						
3.3. PRORIGHT						
3.4. CDRULES						
3.5. SMON_CON						
3.6. SAN_ENFORC						
3.7. CONFLICTRES						
3.8. PLANREV						
3.9. SETTLEM_EXC						
C-:ADQAWAR_MUTINTER						
4.1. PKNOWLEFGE						
4.2. OBEYRULES						
4.3. RECEASPRES						
4.4. EMOTIONLINK						
4.5. RESPINTERAC						

Appendices: for chapter seven

Appendices-VIIII : Data collection form as the sample

PLOT-category: ------------------ (field size in ha---------)/

No. of measurements	R1		R2		R3		R4		Ri	
	W(cm)	D (cm)	W(cm)	D (cm)	W(cm)	D (cm)	W(cm)	D (cm)	W(cm)	D (cm)
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
14										
15										
16										
17										
18										
19										
20										
-										
-										
mi										
Sum										
mean										
Length of rill										
Width*Length										
Volume of rill										

Non- terraced zone

Non-terraced upslope-tef		**0.66ha**		
Causes of Rills Formation	No. of Rills	Sum of Length (m)	Sum of Damaged Area(m2)	Volume Sum(m^3)
Entering From Up-Fields	5	108.4(164.2ha-1)	54.12(82ha-1)	5.56(8.4ha-1)
Ditches Broken	9	148.3(224.7ha-1)	80.4(121.81ha-1)	7.4(11.2ha-1)
Ill-Designed Ditches	6	62.4(94.5ha-1)	13.3(20.2ha-1)	0.79(1.2ha-1)
Sheet Grown In-Situ	2	16.7(25.4ha-1)	3.6(5.52ha-1)	0.23(0.35ha-1)
Total	22/33ha-1/	335.8(508.8ha-1)	151.42(229.5ha-1	13.98(21.2ha-10
NON-Terraced-TEF-MID-SLOPE(0.80ha)				
Causes of Rills Formation	No. of Rills	Length (m)	Damaged Area(m2)	Volume (m3)
Entering from up-fields	6	140.5(175.6)	96.5(120.6)	9.43(11.8)
Ditches Broken	14	275.5(344.4)	178(222.5)	10.4(13)
Ill-Designed Ditches	3	37(46.3)	6.6(8.3)	0.43(0.54)
Sheet grown in-situ	3	25.9(32.4)	6.204(7.8)	0.48(0.6)
Total	26	478.6(598.7)	287.3(359.2)	70.74(25.94)
NON-Terraced-TEF-DOWN-SLOPE				
Causes of Rills Formation	No. of Rills	Sum of Length (m)	Sum of Damaged Area(m2)	Volume Sum(m3)
Ditches Broken	10	127(635ha-1)	41.1(205.4ha-1)	2.76(13.81ha-1)
Ill-Designed Ditches	1	4(20ha-1)	0.852m2	0.081(0.41ha-1)

Total	11	131(655ha-1)	41.95(209.76ha-1)	2.84(14.2ha-1)
NON-Terraced-WHEAT-UPSLOPE				
Causes of Rills Formation	No.	Sum of Length (m)	Sum of Damaged Area(m2)	Volume Sum(m3)
Entering From Up-Fields	2	70.8/272.3ha-1/	17.53/67.4ha-1/	1.81/6.96ha-1/
Ditches Broken	5	50.4/193.8ha-1/	38.612/148.5ha-1/	2.66/10.23ha-1/
Ill-Designed Ditches	3	44/169.2ha-1/	8.6/32.91ha-1/	0.6/2.31ha-1/
Sheet Grown In-Situ	2	15/57.7ha-1/	2.53/9.73ha-1/	0.123/0.47ha-1
Total	12/46ha-1	213.2m/820mha-1/	67.231/258.6m2ha-1	19.97m3ha-1
NON-Terraced-WHEAT- MID-SLOPE				
Causes of Rills Formation	Frequency	Sum of Length (m)	Sum of Damaged Area(m2)	Volume Sum(m3)
Entering From Up-Fields	13	199/326ha-1/	66.28/108.7ha-1/	6.5/10.6ha-1/
Ditches Broken	7	70/114.8ha-1/	31.414/51.5ha-1/	1.58/2.6ha-1/
Ill-Designed Ditches	9	294/482ha-1/	58/95.1ha-1/	4.7/7.8ha-1/
Sheet Grown In-Situ	10	94.5/154.92ha-1/	21.21/34.8ha-1/	0.922/1.5ha-1/
Total	39/64ha^{-1}	1077.9mha^{-1}y^{-1}	290.1m2ha^{-1}y^{-1}	22.5m3ha^{-1}y^{-1}
NON-Terraced-WHEAT-DOWN-SLOPE				
Causes of Rills Formation	Frequency	Sum of Length (m)	Sum of Damaged Area(m2)	Volume Sum(m3)
Entering From Up-Fields	7	96/384ha^{-1}	74.9(299.6ha-1)	4.1(16.4ha-1)
Ditch (Fesus) Broken	3	46/184ha-1	33.3(133.2ha-1)	2.49(9.96ha-1)
Ill Design Ditch	3	34/136ha-1	3.96(15.84ha-1)	0.184(0.736ha-1)
Sheet Grown In-Situ	3	15.5/62ha-1	4.69(18.76ha-1)	0.26(1.04ha-1)
Total	16	746m ha-1y-1	467.4m2 ha-1y-1	28.1m3ha-1y-1

Terraced zone

TERRACED UPSLOPE TEF-0.92ha				
Causes of Rills Formation	No. of Rills	Sum of Length (m)	Sum of Damaged Area(m^2)	Volume Sum(m^3)
Entering From Up-Fields	-	-	-	-
Terraces broken	15	182.2/198ha-1/	85.3 (92.72ha^{-1})	7.35 (8ha-1)
Ditches Broken	1	6(6.5ha-1)	1.2(1.3ha-1)	0.04(0.043ha-1)
Ill-Designed Ditches	4	54(58.7ha-1)	11.4(12.4ha-1)	0.95(1ha-1)
Sheet Grown In-Situ	-	-	-	-
Total	20	242.2(263.3)	97.9(106.42)	8.34 (9.1)
TERRACED-MID-SLOPE- TEF-1.32HA				
Causes of Rills Formation	No. of Rills	Sum of Length (m)	Sum of Damaged Area(m2)	Volume Sum(m3)
Entering From Up-Fields	1	6m(4.5ha-1)	1.5(1.14ha-1)	0.104(0.08ha-1)
Terraces broken	27	324.5(245.8ha-1)	156.9(118.9ha-1)	14.3(10.82ha-1)
Ditches Broken	8	76(57.6ha-1)	22.3(16.9ha-1)	1.3(0.99ha-1)
Ill-Designed Ditches	14	129.5(98.11ha-1)	30.3(22.95ha-1)	1.63(1.23ha-1)
Sheet Grown In-Situ	-	-	-	-
Total	49	536/406.1ha-1/	ha-1	17.33(13.13ha-1
TERRACED DOWN SLOPE-TEF-0.5ha				
Causes of Rills Formation	No. of Rills	Sum of Length (m)	Sum of Damaged Area(m2)	Volume Sum(m3)
Entering From Up-Fields	0	-	-	-

Terraces broken	7	72.7 (145.4ha-1)	25.1 (50.2ha-1)	1.68 (3.36ha-1)
Ditches Broken	2	14(28ha-1)	6.2(12.4ha-1)	0.43(0.86ha-1)
Ill-Designed Ditches	10	119(238ha-1)	28.6(57.2ha-1)	1.91(3.82ha-1)
Sheet Grown In-Situ	1	11(22ha-1)	2.42(4.84)	0.3(0.6ha-1)
Total	17	172 (344ha-1)	48.73 (97.5ha-1)	4.32 (8.64ha-1)
TERRACED UPSLOPE-WHEAT-0.88ha				
Causes of Rills Formation	No. of Rills	Sum of Length (m)	Sum of Damaged Area(m2)	Volume Sum(m3)
Entering From Up-Fields	0	-	-	-
Terraces broken	14	191.2(217.3ha-1)	53.9(61.3ha-1)	4.2(4.8ha-1)
Ditches Broken	3	36(40.9ha-1)	9.04(10.3ha-1)	0.52(0.59ha-1)
Ill-Designed Ditches	12	144.5(164.2ha-1)	31.5(35.8ha-1)	2.323(2.64ha-1)
Sheet Grown In-Situ	1	10.8(12.3ha-1)	4.43(5.03ha-1)	0.4(0.45ha-1)
Total	30	382.5(434.7ha-1)	98.9(112.4ha-1)	7.44(8.5ha-1)
TERRACED MID-SLOPE-WHEAT(1ha)				
Causes of Rills Formation	No. of Rills	Sum of Length (m)	Sum of Damaged Area(m2)	Volume Sum(m3)
Entering From Up-Fields	0	-	-	-
Terraces broken	25	336.4	134.85	10.53
Ditches Broken	2	14	4.64	0.192
Ill-Designed Ditches	9	114.5	17.3	1.3
Sheet Grown In-Situ	5	29	4.41	0.474
Total	41	493.9 ha-1y-1	161.2 ha-1y-1	12.5 ha-1y-1
TERRACED DOWNSLOPE-WHEAT(0.25ha)				
Causes of Rills Formation	No. of Rills	Sum of Length (m)	Sum of Damaged Area(m2)	Volume Sum(m3)
Entering From Up-Fields	1	40(160ha-1)	6(24ha-1)	0.9(3.6ha-1)
Terraces broken	5	38(152ha-1)	7.1(28.4ha-1)	0.68(2.72ha-1)
Ditches Broken	1	14(56ha-1)	2.82(11.3ha-1)	0.32(1.3ha-1)
Ill-Designed Ditches	2	8.4(33.6ha-1)	0.94(3.8ha-1)	0.03(0.12ha-1)
Sheet Grown In-Situ	2	7.8(31.2ha-1)	1.5(6ha-1)	0.064(0.26ha-1)
Total	11	108.2(432.8ha-1)	18.4(73.6ha-1)	2(8ha-1)

Photo-a: Rill development befor sowing period

Photo-b: Rills formation due to ill-designed drainage ditches in the growing stage of tef and wheat productions.

Appendices for chapter eight

Appendix-X: Questions

1. Age of terraces that conserved cultivated fields
   a. below 4 years b. above 6 years
2. types of crop covered cultivated fields a. Tef b. wheat
3. size of specific tef cropped or wheat cropped field ------ (in ha)
4. perceived fertility status of cultivated fields
   a. fertile/moderate b. infertile
5. perceived slope categories of cultivated fields
   a. gentle b. steep
6. the type of crop grown on the cultivated fields in the previous years
   a. legume b. cereals
7. the types of fertilizers had applied in the previous years
   a. inorganic fertilizers only b. compost only c. combination of compost and chemical
8. Number of tillage throughout of a year------
9. Total size of productive labour ------(in number)
10. The type of sowing technique used in the present years
    a. In row b. disperse
11. Type of crop seed sown in the present year
    a. Improved b. Not-improved
12. Amount of fertilizers applied in the existing year _____ K.g. DAP and ____K.g. UREA and ____quintal compost
13. Number of weed removal during growing stage of particular crop plant--------
14. Fill the amount of harvested grain yields from pure stand tef cropped or wheat cropped fields ------------------ (in K.g by considering 1 quintal=100 K.g)
15. What do you perceived about the change of your households' gross income?
    A. increased B. otherwise (no change or decreased)
16. Did you get any credit services by cash income? A. Yes B. No
17. Do you have any off-farm activities A. yes B. No
18. Total size of holding livestock ------- (in No.) and size of bee holding hive------- (in No.)
19. Size of trees and shrubs planted, and private pasture area— (in ha), Size of irrigated croplands -------- (in ha), ------ Size of rainfed croplands ------- (in ha) and total size of farmlands holding per household level------- (in ha).

Appendix-XI: status of crops (tef and wheat) biomass in the growing time