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Non-Market Measurement Techniques of Willingness to Pay, the Case of Environmental Resources: A Review

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Abstract: *The objective of this study is to review measurement techniques of willingness to pay (WTP), comparison of techniques and review of empirical evidences to support the theoretical concept of willingness to pay measurement methods. Particularly, the review mainly focuses on stated preference method. To address these objectives, intensive literature review was under taken. Finally, the result of the review was presented in narration, tabular and diagrammatic form. The review indicated that the concept of WTP has been applied in different field of study to assign monetary value using observed market behavior and hypothetical market scenarios for non-marketed goods and services. There are two commonly used methods for estimating WTP into revealed and stated preference methods. Depending on the type of goods or services in question, the time and research resources available, both methods can be useful though they have their own advantages and disadvantages. Revealed preference technique is used to estimate the use value only; on the other hand, stated preference technique is applicable to estimate both use and non-use value. This indicates that stated preference technique has broader scope than revealed preference.*

Keywords: Choice experiment, contingent valuation, non-use value, revealed preference, stated preference, use value

1. Introduction

Environmental resources provide material and non-material benefits to the society. These benefits play a great role for the day to day activities of human beings, plants and animals. According to Kasaye (2015)the benefits of environmental resources can be categorized into use value and non-use value. As discussed by Dlamini (2012) use value refers to the benefit a user derived from the actual use of the resource; whereas, non-use values do not involve any actual physical consumption of the resource. The value of environmental resources is very important to estimate their social benefit in monetary value. To do this, economists have employed different techniques which are called economic valuation of environmental resources. Economic valuation is a technique in which economists draw on to estimate the economic value of market and non-market goods.

According to Pearce and Özdemiroğlu (2002) non-market goods refers to those which may not be directly bought and sold in the market place. This implies that market has no price to estimate the monetary value of these goods and services. As a result, incorporating non-market values into the policy or decision-making process requires the adoption of a suitable valuation framework that captures all values (Philcox, 2007). For those resources for which markets exist, economists typically rely on directly observable behavior in the form of market transactions to reveal preferences or the value that individuals place on goods and services and their willingness to pay to avoid loss of such goods and services (Lipton *et al.*, 1995).

Economic value is a measure of what the maximum amount an individual is willing to give up in other goods and services in order to obtain some good, service, or state of the world. This measure of welfare is formally expressed in a concept called willingness to pay (WTP). According to Breidert (2007)willingness to pay is defined as the highest price an individual is willing to accept or pay for some goods or services. It is a survey method that presents the interviewees with hypothetical scenarios about a certain intervention or specific program which is intended to be evaluated (Mould Quevedo *et al.*, 2009). It is indispensable tool to develop optimal

pricing strategy to forecast market response to price changes and for modeling demand functions (Breidert *et al.*, 2006). The application of WTP in cost benefit assessments and decision-making processes has made this tool one of the most requested in the area of natural resource and health economics (Mould Quevedo *et al.*, 2009).

The approach of measuring willingness to pay has gained much more attention in the literature of environmental economics (Belete and Assefa, 2003; Alemayehu *et al.*, 2009; Amfo-Otu *et al.*, 2012; Hagos *et al.*, 2013), natural resources economics (Bogale and Urgessa, 2012; Angella *et al.*, 2014; Senayet, 2014),health economics and management sciences(Habtewold, 2009; Agago, 2014; Ahmed, 2016). So, methods that are used to estimate willingness t o pay support decision makers, researchers and experts to apply this concept practically in their day to day activities. Consequently, a number of methodological approaches exist to measure the value of non-market goods and services (Lee *et al.*, 2010).These methodological approaches are broadly categorized into two groups: revealed preference and stated preference method (Philcox, 2007; Stephens, 2010; Selam, 2013). According to Lee *et al.* (2010) and Stephens (2010) valuations based on revealed preferences are derived from prices paid for goods or services; whereas, stated preferences reflect a willingness to pay for a good or service (or a willingness to accept to forego it) expressed in terms of a stated choice in hypothetical scenarios presented to respondents. In light of the above explanation, this study aims to review non-market measurement techniques of willingness to pay and econometric models to estimate willingness to pay in the area of environmental resources, compare and contrast measurement techniques of willingness to pay and review empirical evidences to support the theoretical concept of WTP measurement and estimation.

2. Economic Values of Environmental Resources

According to Abdullah *et al.* (2011), economic valuation refers to the assignment of monetary values to non-marketed goods and services where the monetary values have a particular and precise meaning. Almost all environmental goods are non-market goods. From this concept, we can draw the definition of what does environmental valuation mean. Environmental valuation is an attempt to put monetary values to environmental goods and services or natural resources. It is a key exercise in economic analysis because it provides important information about values of environmental goods and services(Abila *et al.*, 2005). This implies that environmental valuation has an important role to play in environmental planning and management activities to answer questions like what is the value of conserving a certain environmental resource and to whom does the value accrue.

The Total Economic Value (TEV) that people attach to an environmental resource is the summation of use value and non-use value (Robinson, 2001; Abdullah *et al.*, 2011; Abebe and Geta, 2014). Use values relate to actual use of the good in question (e.g. a visit to a national park) while non-use values are non-instrumental values which are in the real nature of the thing but unassociated with actual use, or the option to use the thing(Dlamini, 2012; Kasaye, 2015).

According to Abila *et al.* (2005) and Jantzen (2006), use values are divided into direct and indirect use value. Direct use value of environmental resources refers to the active use of these resources in terms of the current values that people are deriving from their actual use (Abebe and Geta, 2014; Selam, 2013); whereas, indirect use value relates to indirect utilization through ecosystem function and regulation services (e.g. water purification, erosion protection or carbon sequestration) (Abila *et al.*, 2005).Option value is the value that people attach to environmental resources that they may use in the future though they do not use them currently (e.g. future visits to national parks, clean surface and ground water, avoiding of erosion to enable future use of pastures) (Jantzen, 2006; Dlamini, 2012; Selam, 2013).

The environment contributes to people's wellbeing in ways that do not directly involve markets (Baker and Ruting, 2014). Unlike market goods, the value of environmental goods goes largely unmeasured because markets do not provide these goods (Abdullah *et al.*, 2011). In addition to this, non-market values are often associated with market failures; as a result , markets do not adequately take into account the outcomes of both market and non-market value of environmental resources (Baker and

Ruting, 2014). This notion of an apparent failure of the market to account for non-use values of environmental services has led to a proliferation of studies to develop appropriate techniques to estimate a total economic value for environmental resources (Robinson, 2001). Specially, the stated preference technique is the only valuation method to capture use, non-use and option values of environmental resources (see Table 1 and Figure 1).

3. Methods of Measuring WTP

The total economic value comprises explicit use benefits as well as implicit non-use benefits (Kjær, 2005). There are different types of economic values, in which the sum of all the values (i.e. WTPs) defines the total economic value of any change in wellbeing due to an intervention. Several authors proposed different hierarchical classification frameworks to organize existing methods to WTP estimation (Kjær, 2005; Breidert *et al.*, 2006; Stephens, 2010). At the highest level, the literature classifies the different methods for estimating WTP into revealed and stated preference methods (Stephens, 2010). So, this paper clearly explains the advantages and disadvantages of these techniques (Table 1). Depending on the type of goods or services in question, the time and research resources available, both methods can be useful (Kjær, 2005; Stephens, 2010). But stated preference techniques can be used in more applications than revealed preference techniques because they are the only approaches that can be used to estimate non-use values (Morrison, 2009). Revealed preference is a generic term for market analysis and refers to the observation of preferences revealed by real market behavior; whereas, stated preference method uses a direct approach (survey method) to estimate willingness to pay (Freeman, 1992).

Table 1. Comparison of measurement techniques of WTP

Criteria	Revealed Preference	Stated preference
Approach	Consumers' preferences are revealed through their actions in real markets which are related to the value of interest	Consumers are asked to state their preferences for hypothetical alternatives that comprise a set of attributes and different levels of these attributes
Behavior	Observed	Hypothetical
Methods		
Direct	Market price	Directly asking individuals their WTP
Indirect	Travel cost method Hedonic pricing method	choice experiment (estimation of WTP by use of price variable)
Goods and services	Real	Real and hypothetical
Total economic value	Merely capture use value	Capable of capturing total economic value (use value, option value and non-use value)
Advantages	External validity is maximized because the choices observed are real market choices in which consumers have committed money, time and/or other resources Low-cost evaluation used for comparing the influence of policies on consumer behavior(Samuelson, 1938)	Provides preferences and information that are impossible to reveal when actual choice behavior is restricted in some way Applicable to estimate economic value of non-market goods and services (use value, option value and non-use value) Allows the researcher complete control over the choices offered and their attributes (no co linearity problem unlike revealed preference technique) Ensures sufficient variation in data Direct valuation method used to solicit value measured
Disadvantages	Limited to the supplying of information regarding values that have been experienced Limited number of cases where non-market values/goods exhibit a quantifiable relationship with market goods Choice sets, attributes of choice options and individual characteristics are not controlled i.e. co-linearity problem Not applicable to estimate economic value of non-market goods and services assumes that the preference scale remains constant over time; The inability to define or measure preferences independently;	Observed preferences may not reflect actual behavior Influenced by respondents to provide accurate responses Require large sample size Prone to strategic bias Costly evaluation

Adapted from Kjær(2005)

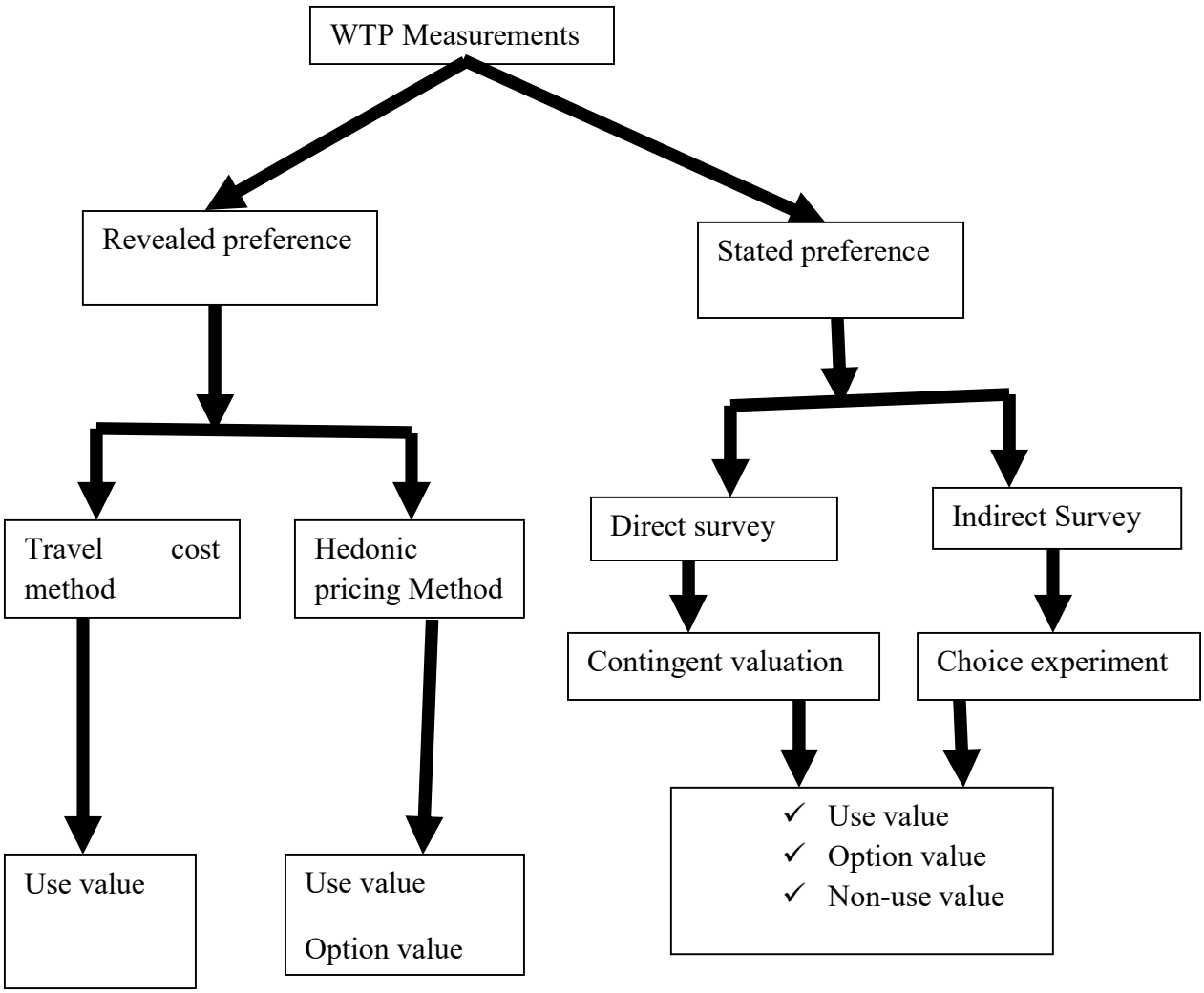

Figure 1. Summary of measurement techniques of WTP; Adapted from (Breidert et al., 2006)

3.1 Revealed preference techniques

3.1.1 Travel cost method

The travel cost method is the oldest and the first non-market valuation technique and was developed for use in environmental valuation (Kjær, 2005). The travel cost method is an indirect valuation technique mainly used for the valuation of environmental resources which has recreational sites (Dlamini, 2012). This method measures the benefit (WTP) for a recreational experience by examining household expenditures on the cost of travel to a desired recreational site i.e. parks (Stephens, 2010). The costs associated with travelling to the resource (fuel, mechanical maintenance of vehicle, time spent in travelling) become the variables to be used to determine the value of a resource (information on these costs reveals how much people are willing to pay for recreational services (Dlamini, 2012). Travel cost method uses survey data on direct costs and, in some cases, opportunity costs of time spent travelling to and from a site, evaluated at some fraction of the average wage rate (Bishop, 1999).

3.1.2 Hedonic pricing method

Hedonic pricing method is used mostly to estimate the willingness to pay for variations in property values due to the presence or absence of specific environmental attributes, amenity service of the environment and access to infrastructure (Ulibarri and Wellman, 1997). Similarly, the hedonic pricing approach is a method of ascertaining the value of or the pleasure felt from attributes of a good by comparing the market value of properties having different degree of a specific attribute and analysts

extract the implicit value of the attribute to property buyers and sellers (Ulibarri and Wellman, 1997). This indicates that the hedonic pricing method is used to estimate economic values for ecosystem or environmental services that directly affect market prices. It is most often applied to differences in housing prices that reflect the value of local environmental attributes. Use of data already available (selling prices of properties) and best applied to land and property but it needs high quality information (Kassahun, 2009).

3.2 Stated preference techniques

This technique includes choice experiment and contingent valuation(Robinson, 2001). Choice modeling does not ask questions directly whereas, CVM is used when markets do not exist for environmental resources by asking questions directly (Hausman, 1993). Likewise, choice experiments differ from contingent valuation in that respondents are presented with more alternatives involving different attributes and their levels, compared with contingent valuation (Haji, 2013). In a choice experiment, respondents are presented with a sequence of choice sets, each containing its own alternatives differentiated by its attributes and levels (Howley, 2011).

Moreover, choice experiment can do better in elicitation of preferences than CVM in measuring the marginal value of changes in the characteristics of environmental goods because it is easier to disaggregate values for environmental resources into the values of the characteristics that describe the resource (Woretaw *et al.*, 2017)

Table 2. Summary of stated preference techniques

Criteria	Contingent valuation	Choice experiment
Time scale	Shorter	Longer
Complexity of design	Less complex	Highly complex
Software and analysts	Less sophisticated	sophisticated
Complexity of task for respondents	Less complex	More complex
Valuations	Total package	individual attributes/choose between different alternatives/
Compliance bias	High/survey-based technique/	Low
WTP questions	Directly asking individuals their WTP/WTA	Estimate WTP by including price as one attribute/no direct questions about valuation/
WTP estimation	Total WTP for the good or service	Relative WTP values for different attributes of a good
	Used to measure use values , option values and intangible values (TEV)	Used to use values and option values but not use to measure none use values
Response efficiency	Respondents provide a single response	Each respondent may provide multiple responses for estimating WTP
Flexibility	Highly flexible and adaptable to many non-market valuation tasks	Less flexible and adaptable to many- none market valuation tasks.
Result interpretation	Result analysis interpretation is easy	Result analysis interpretation is difficult because of its complexity
First application	First application on recreation (1963) on existence values	First application to travel choice (1982)

Adapted from (Stephens, 2010)

3.1.1. Choice experiment

Choice experiment is a stated preference technique in which respondents choose their most preferred option from a number of alternatives (Haji, 2013). It is a recent innovation in stated preference method and its theoretical grounding were inspired by the Lancastrian microeconomic approach in which individuals derive utility from the characteristics of the goods rather than directly from the goods themselves (Woretaw *et al.*, 2017).It assumes that any good/service can be defined as a combination of levels of a given set of attributes and the utility that an individual derives from that product is determined by those attributes (Tinelli, 2016). Recently, choice experiment has been applied to value non-market goods in environmental and health economics (Tinelli, 2016; Woretaw *et al.*, 2017).

Ina choice experiment survey, the respondents are presented with several alternatives and are asked to choose their most preferred alternative (Haji, 2013; Howley, 2011). The alternatives consist of different combinations of attribute levels and each set of alternatives (choice set) (Ezebilo, 2010). Definition of attributes and attribute levels, experimental design, construction of choice sets, questionnaire development and sample and sampling strategy are the core steps involved in the design of a choice experiment (Clark, 2014).

Specially, definitions of attributes and their level is one of the most important stages when conducting a choice experiment study. The most efficient experimental design and advanced modeling of analysis cannot compensate if the attributes and levels are not appropriate. From this we can conclude that misspecification of the attributes and attribute levels has a negative implication for the construction of choice sets which leads to a risk of producing biased choice experiment results.

In choice experiment study, the construction of the choice set must be based on the main elements that influence the choice modeled. These elements can be divided into four stages: establishing attributes and their levels; creating a choice set and measuring design efficiency; constructing the survey instrument and collecting data and analyzing the data (Coast, 2012; Tinelli, 2016).

3.1.2. Contingent valuation method

According to Hoyos and Mariel (2010), the economic valuation of environmental resources using stated preference information has come to be known as contingent valuation method. Contingent valuation method is one of the most commonly used techniques for environmental resource valuation (Jantzen, 2006).

The contingent valuation technique has great flexibility, allowing valuation of a wider variety of non-market goods and services than is possible with any of the indirect techniques (Khalid, 2008). In the contingent valuation method, respondents are asked various questions directly on the basic issues such as the maximum amount they are willing to pay to access and enjoy any welfare gain due to an improvement in environmental quantities, qualities or both or the minimum amount they are willing to accept in compensation for welfare loss due to deterioration in environmental quantities or qualities or both (Kasaye, 2015). In environmental resources, contingent valuation studies generally derive values through the elicitation of respondents' willingness to pay to prevent injuries to environmental resources or to restore injured environmental resources (Khalid, 2008). Contingent valuation is one of the few methods used to assign dollar values to non-market and non-use values of the environmental goods and services (Philcox, 2007).

There are different elicitation methods to be used in a CVM application (Table 3). The choice of an elicitation technique however, depends on the type of resource being valued and the nature of the sample. CVM has four value elicitation formats: open ended, bidding game, payment card and dichotomous or discrete choice formats. Dichotomous choice contingent valuation questions have gained popularity over the last several years due to their purported advantages in avoiding many of the biases known to be inherent in other formats used in the contingent valuation method, but it comes at the cost of efficiency (Cameron and Quiggin, 1994). In the dichotomous or closed-ended format, respondents are asked for a yes–no answer to the WTP question (are you willing to pay X birr) (Hoyos and Mariel, 2010). If the answer is positive, a new question with a higher value for X is asked, and if the answer is negative, a new question with a lower value for X is asked

(Cameron and Quiggin, 1994; Hoyos and Mariel, 2010). Table 3 clearly shows the advantages and disadvantages of each elicitation formats and econometric models used to estimate the result.

Table 3. Contingent valuation formats

Format	Pros	Cons	Econometric models
Open ended	Straight forward No anchoring bias (avoiding starting point biases); Very informative since maximum WTP can be identified for each respondent; and, Highly statistically efficient	It leads to large non-response rates, Protest answers Zero answers and Outliers; Respondent' faces difficulty to pick a value out of the air without some form of assistance.	• Multiple linear regression • Tobit
Bidding game	This may facilitate respondents' thought processes and Encourage them to consider processes and encourage them to consider their preferences carefully.	Prone to starting point bias and succeeding bids used; It also leads to large number of outliers; and Bidding games cannot be used in mail surveys and other self-completed questionnaires.	• Multiple linear regression • Tobit • Bivariate probit/ Logit • Binary logit • Binary probit
Payment card	Provides a context to the bids, while avoiding starting point bias at the same time (starting point bias being a form of anchoring bias whereby bids are linked to the researcher's statement of the first amount); The number of outliers is also reduced in comparison to open ended format; and, some versions of the payment card show how the values in the card relate to actual payment; contain a large array of possible willingness to pay amounts	Prone to range and starting point bias; The location of the benchmarks; and requires the respondent to be literate, and little use in LDCs where illiterate rate is high and, it cannot be used in telephone interviews	• Multiple linear regression • Tobit
Single bounded	it is thought to simplify the cognitive task faced by the respondents Minimizes non-response and avoids outliers; and,	Starting point bias, i.e. answers are 'anchored' on the initial figure stated by the questioner Require larger sample size and Sophisticated design and Analysis techniques	• Binary logit • Binary probit
Double bounded	More efficient than single-bounded dichotomous choice and bidding game; More information is elicited about each respondent's WTP ("follow up" question in addition to the "yes-no" options of the single bounded dichotomous choice) Increase statistical efficiency	Starting point bias Require larger sample and Statistical assumptions	• Multiple linear regression • Tobit • Bivariate probit • Binary logit • Binary probit • Multivariate probit

Source: Own review (2018)

4. Empirical Studies

We reviewed different articles in relation to willingness to pay the case of environmental resources. Finally, we used narration and tabular form to summarize and present the results of the review. The study conducted by Han *et al.* (2011) estimated willingness to pay for forest conservation using contingent valuation method. The result indicated that 73% of the respondents were willing to pay for the conservation of the forest with average WTP of $8.03 but 27% of the respondents were not willing to pay anything at all. Similarly, Kalbali *et al.* (2014) analyzed factors affecting the willingness to pay of visitors and the amount they are willing to pay for Ghorogh Forest Park using contingent valuation and application of Tobit model. The report revealed that average willingness to pay per visitor for each visit of the Ghorogh Forest Park was estimated 2623 Rials and annual recreational value of the forest park was estimated to be around 4 billion Rials. Additionally, Cho *et al.* (2005) measured rural homeowners' willingness to pay for land conservation easements using contingent valuation method. The estimated result reported that household's WTP to participate in an easement program ranges from $10.97 to $21.79 per year per household.

Similarly, Mekdes (2014) analyzed visitors' willingness to pay for recreational use value of Menagesha Suba Forest Park using Tobit model. The result indicated that monthly income and quality of the recreational site had significant positive effect on visitors' willingness to pay; conversely, initial bid and employment status had negative effect on visitors' willingness to pay.

In the same way, Siew *et al.* (2015) estimated the visitors' willingness to pay for conservation of Pay Indah Wetlands using contingent valuation method. The result indicated that the mean willingness to pay of the respondents for the conservation of the wetland was 7.12 RM. Bogale and Urgessa (2012) used bivariate probit model to identify explanatory variables that influence households' WTP for improved rural water supply. Their result demonstrated that total household income, educational level, credit access and annual water expenditure were found to have statistically significant positive effect; in contrast, age of the household head and distance from water source had statistically significant negative effect (See Table 4 for detail information).

Table 4. Summary of studies conducted on household's willingness to pay

Study	Dependent variable	Independent variable	Model	Valuation technique
(Tilahun *et al.*, 2011)	Forest conservation	Gender, age, annual income, educational status, initial bid, access to radio, land size, dependency ratio, residence	Bivariate probit	CVM
(Han *et al.*, 2011)	Environment conservation	Gender, age, educational status, residence location, attitude	Binary logit	CVM
(Gatto *et al.*, 2014)	Forest ecosystem services	Recreation, carbon sequestration, biodiversity conservation, landscape, cost	Multinomial logit	CE
(Youe and Pabuayon, 2011)	Flooded forest conservation	Gender, age, educational status, household size, participation in training, income, distance	Multiple regression	CVM
(Amare *et al.*, 2016)	Church forest	Sex, age, formal education, household size, land size, livestock ownership, irrigation practice, credit access, extension service, church forest benefits	Heckman two stage	CVM
(Kasaye, 2015)	Soil	Sex, educational level, family size,	Bivariate	CVM

	conservation	dependency ratio, land size, total livestock, farm income, slope of land, distance to market, bid1, perception of soil conservation, credit access	probit	
(Nuva *et al.*, 2009)	Ecotourism Resources Conservation	age, gender, marital status, residential area, income level	Binary logit	CVM
(Mamat *et al.*, 2013)	Environmental environment	Age, education, income, visitors perception on recreational facilities & services provided, number of visit, dichotomous choice bid assigned, foreign visitors	Bivariate probit	CVM
(Gebremaria, 2012)	Soil conservation	age of the household head, sex, education level, family size, perception, land tenure, Total Livestock Units, initial bid	Bivariate probit	CVM
(Alemayehu *et al.*, 2009)	Environmental service restoration	Educational level, age, asset holdings, number of trees planted, number of livestock, training, assistance in land and water conservation techniques, distance to the office of agriculture	Interval regression	CVM
(Tilahun, 2009)	Soil and water conservation	Education, age expectations about yields in irrigated agriculture, wealth of the household, off-farm activities, distance to market, dependency ratio, randomly assigned bid working days	Binary logit	CVM
(Cho *et al.*, 2008)	Land Conservation	Household income, knowledge about land development issues, property used as a primary residence, property within city boundaries of highlands	Ordered probit	CVM
(Abebe and Geta, 2014)	Irrigation water	Sex, age, educational level, family size, farm experience, income, Livestock ownership, productivity, credit access, distance to market, initial bid, labor shortage	Tobit	CVM
(Abu *et al.*, 2011)	Soil conservation	Age, educational status, household size, farm size, farm experience, information access, occupation, source of capital, credit access, labor	Logit	CVM
(Angella *et al.*, 2014)	Irrigation water	Educational status, household size, land size, farm experience, market distance, training, credit access, off-farm income activity, irrigation water source	OLS	CVM
(Tang *et al.*, 2013)	Irrigation water	Age, gender, educational status, family size, income, land size, bid, satisfaction of water management	Binary logit	CVM

Source: Own review (2018)

5. Conclusion

Depending on the reviewed document and empirical results of selected articles regarding to environmental resources, this study concluded and recommended the following core ideas.

Even though several authors proposed different hierarchical classification frameworks to organize

existing methods to WTP estimation, literatures classify those techniques into two: revealed preference and stated preference techniques. Revealed preference is a generic term for market analysis and refers to the observation of preferences revealed by real market behavior; whereas, stated preference method uses survey method to estimate willingness to pay. In addition to this, each technique has its own approach, behavior (observed versus hypothetical), methods to elicit WTP (both direct and indirect), nature of goods and services (real versus hypothetical) and total economic value (use value versus non-use value). Those parameters are used to compare and contrast the two methods to apply in our field of study. Travel cost method and hedonic pricing are the two common revealed preference techniques used to estimate monetary value of resources which have recreational value and resources having different degree of a specific attributes, respectively. On the other hand, stated preference technique includes contingent valuation and choice experiment. Contingent valuation method is the direct method of estimating willingness to pay of individuals using survey questions; whereas, choice experiment is an indirect method of stated preference technique used to estimate WTP of each attribute using price variable of each attribute. Contingent valuation and choice experiment can be evaluated by cost of the survey, time scale, software and analysts, WTP estimation (total or individual attribute), accuracy of the result response task and efficiency. As a result, researchers take into account those criteria to use either of the two methods.

Dichotomous choice contingent valuation (single and double bounded) questions have gained popularity due to their advantages in avoiding many of the biases known to be inherent in other formats used in the contingent valuation method. Double bounded formats more efficient than single bounded dichotomous choice and bidding game. So, the application of double bounded yields better result as compared to other value elicitation formats of contingent valuation. The empirical result of mean willingness to pay is also better in double bounded than other formats.

Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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Status, Threats and Management of Wetlands in the Lake Tana Sub-basin: A Review

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Abstract: *Wetlands are one of the most productive ecosystems that play significant role in providing multiple ecosystem services. They are the heart of the landscape, which serve as natural filters for the world's wastewater with no cost and biological supermarkets that contain miscellaneous biodiversity. In the Lake Tana Sub-basin, majority of the wetlands distributed along the tributaries and around the lake shores and estimated to cover 2.14% of its total surface area. The wetlands in the Lake Tana Sub-basin support many endemic and globally threatened fish species as well as wintering site for world`s migratory birds. Regardless of their importance, the Lake Tana Sub-basin wetlands are under great pressure. The major anthropogenic threats are recession agriculture, unplanned urbanization, rapid population growth, indiscriminate industrial and development activities, disposal of domestic and industrial toxic wastes and free grazing. Many people in the lake sub-basin still now considered wetlands as unhealthy that are breeding places for disease vectors. Development activities in Lake Sub-basin very rarely consider the ecological and socio-economic values of wetlands and wetland destruction and conversion for the purpose of recession agriculture is still seen as advanced mode of development. Therefore, to halt these problems and to use the wetland resources sustainably, integrated problem solving approaches such as collaboration among the relevant stakeholders, public awareness creation, formulation and implementation of wetland policy, implementation of biosphere reserve and ratifying the Ramsar Convention are vital. Furthermore, in-depth research regarding the status and challenges of wetlands in the Lake Tana Sub-basin should be conducted.*

Keywords: Ecological status, Ecosystem services, Wetland distribution

1. Introduction

About 9% of the world`s population is undernourished which can be associated with the degradation and losses agricultural land along with the utilization of 70% of fresh surface and ground water for agriculture (WBCSD and IUCN, 2008). According to FAO (2015), sufficient food is therefore needed for additional 2 billion people by 2050. In this regard, minimizing challenges as well as promoting wetlands in the world may play significant role in the production of food crops. Because the ability of wetlands to store water during the wet season and release it in the dry season, its nutrient rich soil and year round soil moisture availability provide farmers with the opportunity to produce crops all year round thereby improving food security and income (Sakane *et al.,* 2011). Besides, wetlands support peoples livelihood by providing dry season livestock grazing and watering, domestic water supply, fishing and natural products (Mmopelwa, 2006).

The extent of world's wetlands is generally thought to range from 7 to 9 million Km^2, which is approximately 6% of the Earth's surface area (Mitsch and Gosselink, 2002). However, the U.S Department of Agriculture cited in Desta (2006) states that the world's wetlands cover about 18.8 million Km^2 (approximately 13.7% of the Earth's surface area).In Africa, it is estimated that 4% of the land surface is covered by wetlands (Lehner and Döll, 2004). In sub-Saharan Africa, wetlands constitute approximately 4.7% of the land surface (Rebelo *et al*., 2009). While, in Ethiopia, the total wetlands coverage is estimated to be about 2% of total country's surface area (EWNRA, 2008).

Although wetlands cover only small part of the Earth, they contribute 40% of the annual global ecosystem services (Zedler and Kercher, 2005). All over the world, wetlands are hot spots of biodiversity and provide various services such as water quality maintenance, carbon sequestration, shoreline protection, and recreational values (Dise, 2009). Wetlands, for example, remove up to 80% of

suspended solids, 60- 80% of organic matter, 20 - 60% of nitrogen, and 20 - 80% of phosphorus in treating wastewater (Ejigu, 2010). Additionally, wetlands have indispensable socio-economic importance. Ethiopian wetlands, for example, contribute billions of birr every year in the form of clean water, soil formation, provision of food and medicine, etc (Abunie, 2003). The importance of wetlands can be better understood by knowing the fact that two thirds of the world population live along the banks of wetlands, including rivers, lakes, and beaches (Nazaridoust, 2010).

Despite the fact that wetlands are among the most productive ecosystems, they are also the most threatened (Delelegn, 2003). More than 50% of the global wetlands were lost over the last centuries (Davidoson, 2014). For instance, in North America, Europe, and Australia more than 50% of the wetlands were lost over the last 20 years (MEA, 2005). Likewise, in Ethiopia, wetlands are ranked among the most threatened ecosystems (G/Silasie *et al.*, 2014). Decision makers, who are involved in wetlands conservation, are unaware of the biological, ecological and socio-economic importance of wetlands. Wetlands are considered as wastelands, which are obstacles to agricultural development (Taffa, 2007). Furthermore, many people in Ethiopian still consider wetlands solely as the breeding places for disease vectors like mosquito (Taffa, 2007). Due to this perception, wetlands in the Lake Tana Sub-basin are drastically degraded leading to habitats and biodiversity degradation (Gebremedhin *et al*., 2018). Among others damming, agriculture, grazing, and irrigation are the main anthropogenic impacts (Gebremedhin *et al.,* 2018). Additionally, untreated effluents and encroachment for different purposes are negatively affecting the wetlands water quality and biodiversity (Atnafu *et al*., 2011). Due to these threats, between 1986 and 2013, over 52% of the wetlands in the lake sub-basin were converted into other land use forms (BNWI, 2014 unpublished). Thus, for sustainable exploitation of the wetland resources, considerable attention should be given to their threats. Therefore, this review aimed at providing a comprehensive report on the existing situation, distribution, and threats of wetlands in the Lake Tana Sub-basin and suggests optimal management options.

2. Distribution of Wetlands in the Lake Tana Sub-basin

Wetlands in the lake sub-basin are distributed in 29 districts and three administrative zones (BoEPLAU, 2015) (Table 1). Most of the wetlands are found in the low lying plains adjacent to the lake and major rivers (Shimelis *et al*., 2008). They distributed from the headwaters of Guna and Gishe-Abay to the Fogera and Dembia floodplains mainly around the lake shores and along the tributaries of Gilgel Abay, Ribb, Gumara, and Megech River (Shimelis *et al*., 2008).

Table 1. Wetland types and distribution in the Lake Tana Sub-basin

Name of wetlands	Estimated area (ha)	Location		Type of wetland	Main source of water
		District	Zone		
Tana Dar	150	Bahir Dar Zuria	W/Gojjam	Palustrine	Gilgel Abay
Ambo Bahir	45	Bahir Dar Zuria	W/Gojjam	Palustrine	Lake Tana
Mesenta	300	Bahir Dar Zuria	W/Gojjam	Palustrine	Gilgel Abay
Lata Amba *	80	Bahir Dar Zuria	W/Gojjam	Palustrine	Gilgel Abay
Yiganda **	468	Bahir Dar Zuria	W/Gojjam	Lacustrine	Lake Tana and Mina stream
Infranz Springs	200	Bahir Dar Zuria	W/Gojjam	Palustrine	Springs
Infranz River Outlet**	1225	Bahir Dar Zuria	W/Gojjam	Riverine	Infranz River
Tekuma	88	Bahir Dar Zuria	W/Gojjam	Palustrine	Spring
Ambo Mesk *	275	Bahir Dar Zuria	W/Gojjam	--	--

Amluk	--	Bahir Dar Zuria		Lacustrine	Lake Tana
EngidoDengel	161	Bahir Dar Zuria	W/Gojjam	--	--
AmlkoMesk*	836	Bahir Dar Zuria	W/Gojjam	--	--
Abuach *	719	Bahir Dar Zuria	W/Gojjam	--	--
Chimba **	3230	North Achefer	W/Gojjam	Riverine	Gilgel Abay
Abay Dar	2048	North Achefer	W/Gojjam	Riverine	Gilgel Abay
Legidia	1445	North Achefer	W/Gojjam	Palustrine	Gilgel Abay
Shobela	1625	North Achefer	W/Gojjam	--	--
Dawnti	1419	North Achefer	W/Gojjam	--	--
Chomet	300	South Achefer	W/Gojjam	--	--
Kurt Bahir	45	Mecha	W/Gojjam	Palustrine	Koga River
Dengira Mender	70	Mecha	W/Gojjam	--	--
BeyMeda	200	Mecha	W/Gojjam	--	--
Cheqecheq*	150	Mecha	W/Gojjam	--	--
AbeyMesk	156	Mecha	W/Gojjam	--	--
Shesher	650	Fogera	S/Gondar	Palustrine	Rib river
Daga	100	Fogera	S/Gondar	Lacustrine	Lake Tana
Wolala	100	Fogera	S/Gondar	Palustrine	Rib river
Taqua	75	Fogera	S/Gondar	--	--
Dingzi	200	Fogera	S/Gondar	--	--
Daba	125	Fogera	S/Gondar	--	--
GirmoEwaka*	40	Libokemkem	S/Gondar	--	--
Aminda	40	Dera	S/Gondar	--	--
Atirko	38	Dera	S/Gondar	--	--
FetoMidir	44	Dera	S/Gondar	--	--
YetanaRegreg*	280	Dembia	N/Gondar	Palustrine	Lake Tana
Dirma**	--	Dembia	N/Gondar	Lacustrine	Lake Tana
Gibara	131	Dembia	N/Gondar	--	--

Likilik	127	Dembia	N/Gondar	--	--
Ketera	148	Dembia	N/Gondar	--	--
Abelay	181	Dembia	N/Gondar	--	--
AshiwaBahir	245	Dembia	N/Gondar	--	--
Teter	229	Dembia	N/Gondar	--	--
Bichign	246	Dembia	N/Gondar	--	--
Mehalge*	152	Dembia	N/Gondar	--	--
AmbaMesk*	221	Dembia	N/Gondar	--	--
Sheha Gomen*	200	Gondar Zuria	N/Gondar	--	--
Firiqua Dengure*	450	Gondar Zuria	N/Gondar	--	--
Mitriha *	321	Gondar Zuria	N/Gondar	--	--
Agid Kirigna	7	Gondar Zuria	N/Gondar	Palustrine	Lake Tana
Asratie Toka	30	Takusa	N/Gondar	--	--
Gohil Toka	30	Takusa	N/Gondar	--	--
Mate	80	Alefa	N/Gondar	--	--
Kudadie	41	Alefa	N/Gondar	--	--

Note: * Source: Hunegnaw *et al.* (2013)
** Source: Aynalem *et al*. (2017)
Without asterisk sourced: BoEPLAU (2015)

The plains around Lake Tana are often flooded during the rainy season and form extensive wetlands. Some of the main flood plains in the lake sub-basin are the Fogera plain in the east, the Dembia plain in the north, and the Kunzila plain in the southwest (Shimelis *et al*., 2008). Additionally, there are a number of small sized wetlands dispersed in the upper catchments (ANRSBA, 2013) (Figure 1).

In the Fogera district, wetlands are mainly located in Kidest Hana, Shaga, Nabega and Sheha villages (BoEPLAU, 2015). The two main wetlands are Shesher and Welala, characterized by seasonal inundation from Gumara and Rib rivers (IFAD, 2007). There are also delta types of wetland formed by Gumara River, which is located in low lying area around eastern shores of Lake Tana. Of the various wetlands in the Bahir Dar Zuria area, Tekuma (Wonjeta village), Mesenta (Deber Mesenta village), Infranz Minch Wuha (Wogelisa village), Ambo Bahirand Tana Dar (Debiranta village), Yiganda (Yiganda village), and Amilko Mesk (Lijimi village)are the major ones. The Dembia floodplain is also endowed with various types of wetlands. Of which, Gibara (JerJer Amba village), Tikur Bahir (Gurandi Wonbha village), AshiwaBahir (Achera village), and Ketera (Tana Weyna village) are the main wetlands in the area. Moreover Infranz spring (Wegelisa village) and Infranz river-outlet (behind Bahir Dar Airport) are some of the major wetlands in Infranz floodplains.

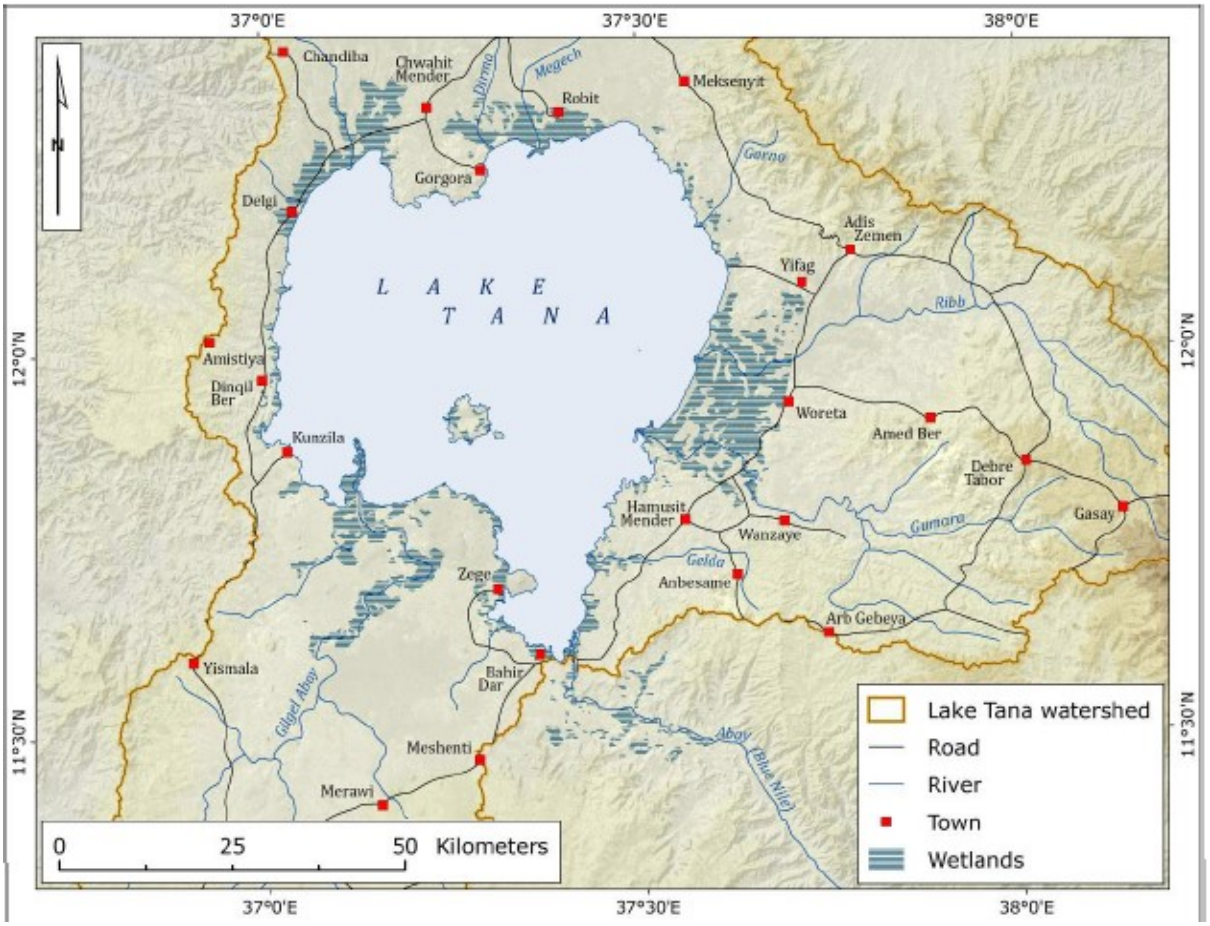

Figure 1. A map showing the Lake Tana Sub-basin and distribution of wetlands (ANRSBA, 2013)

3. Wetlands Ecosystem Services

Historically wetlands were designated as breeding places for disease vectors and as impediments to civilization (Day *et al.,* 2006). However, wetlands are now well recognized for their ecological functions and services they provide to human (Dixon and Wood, 2007). They are the heart of the landscape which serve as natural filters for the world's wastewater with no cost and biological supermarkets that contain miscellaneous biodiversity. The benefit people obtain from ecosystems is called ecosystem services (MEA, 2005). The Millennium Ecosystem Assessment (2005) categorized ecosystem services in to four main groups (Table 2). These are provisioning services: tangible products people obtain from wetlands; regulating services: the benefits obtained through the role of wetlands in the regulation of ecosystem processes; cultural services: non-material benefits people derive from wetlands through spiritual enrichment, cognitive development, and recreational, educational and aesthetic values; and supporting services: those services that are necessary for the production of all other ecosystem services such as soil formation, nutrient cycling, and biodiversity.

Ethiopia, with its varied geologic formations and climatic conditions, has considerable wetland ecosystems. Ethiopian wetlands provide various provisional, supporting, regulating and cultural services to the local people (G/Silasie *et al*., 2014). The Lake Tana Sub-basin embraces abundant wetlands (i.e. 24000 ha, 1.6% of its watershed) all-round its shores and tributary rivers (ZurHeide, 2012). Together these form the largest wetland complex in Ethiopia and are ecologically most important in the country (Wondie, 2010). The wetlands in the Lake Tana Sub-basin support many endemic globally threatened fish species and are also world recognized migratory birds wintering sites (Gebremedhin *et al.,* 2018). The wetlands, in the

Lake Tana Sub-basin, provided various goods and services to more than 500,000 people (Gordon *et al.,* 2007).

Since wetlands produce much plant biomass and invertebrate life, they serve as important nursery areas for fish and nesting sites of birds (Aynalem *et al.*, 2017). The Yganda and Dirma wetlands were known for feeding and breeding grounds of *Labeobarbus*, *Claris*, and *Oreochromis* fish species. Furthermore, most fish species in Lake Tana reproduce in the shallow shore areas and some migrate to adjacent wetlands (e.g. *C. gariepinus*) (Anteneh *et al*., 2012).

Wetlands also provide habitats for globally threatened wetland birds. For instance, wetland in Shesher provided a huge roosting site for 21,000 Common Cranes (Nowald *et al*., 2010). Yganda, Chimba, Debre Maryam, Dembia (near Gorgora) and wetlands close to Bahir Dar provided breeding sites for Black Crowned Cranes (Aynalem, 2011). Moreover, Aba Gerima (near Bahir Dar city), Infranz (behind Bahir Dar Airport), Abay Inflow Delta, Kunzila area, Delgi, and Dirma wetlands were known sites for both breeding and feeding of birds (Aynalem, 2017). In addition, wetlands provide habitat for wild life (Jacobs *et al.,* 2009). Amphibians, especially Anurans, reptiles, and mammals such as Hippos (*Hippopotamus amphibious*), reptiles like the Nile Monitor (*Varanusniloticus*) and African rock python (*Pythonsebae*), species were mainly present in the marshy shore-areas.

Table 2. Ecosystem services provided by wetlands (modified from Finlayson, 2005)

Services	Description of services	Examples
Provisioning services	Food	Production of fish, wild game, fruits and crops
	Water	For drinking, irrigation, cleaning
	Raw materials	Fiber, timber, firewood, fodder, fertilizer
	Genetic resources	For crop-improvement and medicinal purposes
	Medicinal resources	Biochemical products and test-organisms
	Ornamental resources	Artisan work, decorative plants, pet animals
Regulating services	Air quality regulation	Capturing (fine) dust, chemicals, particles
	Climate regulation	C-sequestration, vegetation influence on rainfall
	Moderation of extreme events	Storm protection and flood prevention
	Regulation of water flows	Natural drainage, irrigation & drought prevention
	Waste treatment	Water purification
	Erosion prevention	Retention of soil and or sediment
Supporting service	Maintain life cycles of migratory sp.	Nursery services
	Maintenance of genetic diversity and biodiversity	Provision of habitat for wild plant and animal
	Nutrient cycling	Store, recycle, process & acquisition of nutrients
Cultural services	Aesthetic information	Provision of attractive landscape features
	Opportunities for recreation	Provision of access for tourism
	Opportunities for tourism	Provision of access for recreation
	Spiritual experience	Religious heritage (sacred forests)
	Information to cognitive development	Provision of scientific & educational information

4. Major Threats to Wetland Ecosystems in the Lake Tana Sub-basin

Several reviews have identified a number of pressures facing tropical wetlands (Mitsch, 2010). Identifying the underlying causes is, therefore, necessary to prevent further loss and degradation. The main driving forces for wetland degradation in the lake sub-basin are rapid population growth and increasing economic transformation (Gebremedhin *et al*., 2018).

A recently observed threat is the expansion of the water hyacinths (*Eichhornia crassipes*) along several parts of the lake´s shorelines. According to Anteneh *et al*. (2015), infestation rate was increased alarmingly hence more than 50,000 ha of the lake shore was infested. It has threatened wetlands ecology by blocking sunlight from reaching native aquatic plants and hampers oxygen supply to the water body. And also by forming impenetrable thickets and destroying and replacing natural biodiversity. Furthermore, by increasing siltation and evapo-transpiration, it reduces water quality, fish stocks, and affects the biodiversity (Ayalew, 2003).

In the Lake Tana Sub-basin growing human population goes with livestock, whereas grazing area is limited and even shrinking due to extended agriculture (EPLAUA, 2007). Hence, there was continuous conversion of wetlands into crop and grazing land (IFAD, 2007). When grazing continuous livestock trample and compact the soil destroys natural vegetation, affect the infiltration capacity of the soil and erode drainage channels leading to gullies and water outflow (McKee, 2007).

Wetlands also threatened from sedimentation as a result of upstream agriculture and de-forestation (Wondie, 2010). Deforestation and recession agriculture coupled with erosion from the catchments resulted in high sediment deposition (Gebriye *et al*., 2009). Also riparian transport might add sediment to wetlands, which contributes to the deterioration (Heimann and Roell, 2000). Sediment accumulation finally might lead to the loss of wetlands. When wetlands are used for agriculture the soil may lose its fertility after drainage because of oxidation, acidification, and other processes that take place once the anaerobic conditions are removed (Wood, 2001). Thus, its ability to support biodiversity might be reduced.

Settlement, a growing problem of wetlands around Lake Tana (Ayenew, 2009), was another cause of wetland loss (Sisay, 2003). Due to the abundance of natural resources in wetlands, many urban centers are located near or in their vicinity. However, through time it becomes source of pollution (Mckee, 2007). If nutrient concentrations in the receiving waters becoming high, it might cause increase organic matter accumulation, decrease amount of oxygen and cause changes to water temperatures (Jackson, 2011). The pollutions might contribute to the degradation of wetlands particularly fishes, macrophytes, riparian vegetation, and other biodiversities found in the ecosystems. Besides, most of the wetland areas were lost by the settlement and associated demand of land for food, grazing, construction and agriculture.

Wetlands are also threatened by hydrologic alterations; any change in hydrology alters soil chemistry and plant and animal communities (EPA, 2001). Water extraction which is a common hydrologic alteration in wetlands affects the hydrologic and ecological functions by diminishing water availability and changing water levels, thus affecting the biodiversity composition. Water extraction could sometimes exacerbate the effects of other stressors on the ecosystem, resulting in effects that exceed those that would be expected from dewatering alone. For instance, dewatering in a wetland that receives water polluted by organic materials will result in increasing eutrophication due to a higher concentration of pollutants.

Apart from drainage, wetland hydrology has been modified by the construction of channels, dams, and ditches to achieve irrigation, transportation, and industrial activity. In the Lake Tana Sub-basins a number of irrigation and hydro-dams were under construction on the tributaries of the lake. In the watershed, the Koga, Rib, Gumara, Megech, Gilgel Abay and Jema Irrigation project have been initiated (Mulugeta, 2013). Also there was an effort to promote small scale irrigation in the sub-basin. Hence, if all the planned development occurs, the mean water level of the Lake Tana will drop by 0.44

m and the average surface area will decrease by 30 km^2 and up to 81 km^2 during some dry seasons. Such changes have affected estuarine and coastal ecology, and reduced the amount of water reaching flood plain wetlands (Kingsford, 2000). For instance, the hydrological modification due to the Rib Dam construction along Rib River was threatening the Shesher and Walala wetlands that depend on Rib River (Mekuriaw and Sewnet, 2014).

Additionally, different studies indicated that the abstraction of water from wetland for irrigation was a major factor for the loss of wetland (Ajibola *et al.,* 2012). Channelization increases the speed of water moving into and through wetlands. As a result, patterns of sedimentation and values that depend on the normal slow flow of water through a wetland could be affected.

In the Lake Tana Sub-basin, according to Ligdi *et al.* (2010), the Fogera floodplain wetlands have been among the most disturbed wetlands. More than 75% of the Fogera catchment was intensively cultivated (Asres and Seleshi, 2010). Due to conversion for agriculture and dam construction purposes and direct water extraction for irrigation or chat production, the wetlands in the Fogera floodplain are facing increasing pressures (Dejen *et al*., 2008). Besides, these wetlands are threatened by ecological degradation stemmed from invasion by alien species (ZurHeide, 2012). The intensive cultivation and free grazing activities in Shesher and Welala wetlands, for example, resulted in drastic shrinkage of their coverage (Atnafu *et al*., 2011; BoEPLAU, 2015). Similarly, Sisay (2013) reported the severe degradation of Shesher and Welala wetlands due to drainage and expansion of seasonal cultivation. In1987, the total area coverage of Shesher and Welala wetlands was 1,551 and 298 ha, respectively (Burnside and Taylor, 2009), while this was reduced to 134 and 159 ha in 2008, respectively. Thus, in the Fogera floodplain, only from the two major wetlands, a total of 1,560 ha were lost in a two decades time. Generally, in the Fogera floodplain, wetlands coverage was decreased from 0.66% in 1957 to 0.26% since 1985 and to 0.19 since 2005 (Anteneh *et al*., 2016). Similarly Ligdi *et al.* (2010) reported that, Gumara has producing high sediment load presumably due to degradation of riverine wetlands, buffer strips, and intensive farming.

The wetlands in the Bahir Dar Zuria area have been suffered by several threats such as free grazing, chat production, water abstraction, urbanization, encroachment, settlement, drainage for agriculture, and wetland distribution to landless youths (Table 2). Due to the lack of certified farming land, farmers mainly convert wetlands into farming land (Sewnet, 2015) and settlement led to intensification of the use of wetlands (personal communication). Above all, apart from the illegal expansion of farming land by farmers, the local government had officially distributed wetlands to youths for agricultural purpose (BoEPLAU, 2010). For examples, due to unwise utilization, wetlands in the Infranz watershed sharply declined, while settlement and farming land were rapidly increased (Figure 3).

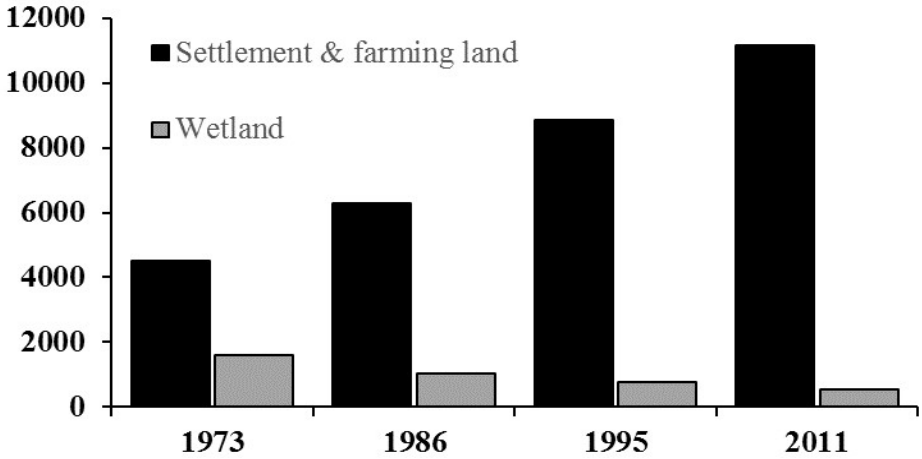

Figure 2. A bar graph that shows the change in wetland size, settlement area and farming land in the Infranz watershed from 1973-2011 (Sewnet, 2015)

Similar to the other areas, wetlands in the Dembia floodplain are also suffered by several threats including settlement, free grazing, farming, damming and water hyacinth invasion (Table 2). For examples, due to the Megech irrigation, the meadows which are important birds feeding site have been severely degraded (Ligdi *et al.*, 2010). Tewabe (2015) also reported that the occurrence of the highest water hyacinth infestation (80-100 ha) in the North and North-east parts have negatively affected the wetland resources in the area.

Regardless of their importance, wetlands in the Kunzila floodplain have been seriously threatened by increasing pressures such as free grazing, agriculture and overexploitation of the reeds. Free grazing is a common practice and the delta type wetlands are drastically degraded (Francis and Aynalem, 2007). Similarly, Sewnet and Kameswara (2011) reported that most of the wetlands in the catchment have been continuously declined, while the farming lands and settlement area have been increased.

Overall, the major threats to wetlands in the Lake Tana Sub-basin attributed to anthropogenic activities such as recession agriculture, unplanned urbanization, rapid population growth, indiscriminate industrial and development activities, disposal of domestic and industrial toxic wastes and free grazing (Gebremedhin, 2017; Gebremedhin *et al*., 2018)(Table 3). Many people in the lake sub-basin still now considered wetlands as unhealthy that are breeding places for disease vectors. Decision makers that are involved in natural resource conservation are unaware of the wetlands ecosystem services. Development activities in Lake Sub-basin very rarely consider the ecological and socio-economic values of wetlands. Wetland destruction and conversion for the purpose of recession agriculture is still seen as advanced mode of development. Above all a campaign is organized by development agents and undertaken every year to dry up clay soils, which are actually wetlands, for the purpose of agricultural activities. Additionally, *Cyprus papyrus*, one of the characteristic features of Lake Tana, has dramatically declined in its distribution with some local extinction due to overexploitation (ZurHeide, 2012). Therefore, the wetlands in Lake Tana watershed are not wisely utilized in the sense of the Ramsar Convention's definition, which emphasizes high yields and continuous benefits, while maintaining the wetlands' potential to meet the needs and aspirations of future generations (Ramsar Convention Manual, 2006).

Table 3. The major cause for the existing threats of wetlands in the Lake Tana Sub-basin

Major wetland threats	Wetlands in the Lake Tana Sub-basin			
	Fogera floodplain wetlands	Wetlands in Bahir Dar Zuria area	Dembia floodplain wetlands	Kunzla floodplain wetlands
Overgrazing	√	√	√	√
Recession agriculture	√	√	√	√
Settlement	√	√	√	√
Water abstraction	√	√	√	√
Irrigation	√	√	√	
Lack of awareness	√	√	√	√
Overexploitation		√		√
Dam construction	√		√	√
Water hyacinth	√		√	

5. Management Options

Due to the complexity and multifaceted nature of the factors that threatened wetlands, there is no quick and one-off solution to remedy the threats. However, there are options recommended to manage wetlands. In this regard, we have comprehensively reviewed different wetland management options and a detail explanation about each of the optimal management options for sustainable use of the wetlands in the

Lake Tana Sub-basin is given in the following sections.

5.1. Awareness creation about wetlands

Lack of awareness about the functions and values of wetlands have often led to their drastic degradation. Public awareness creation is one of the most important ways to conserve wetlands and enable the public to be more environmentally conscientious. Through public awareness campaigns, the importance of conserving wetland ecosystem would reach the public. However, awareness creation about the importance of wetlands in the Lake Tana Sub-basin is virtually lacking (Woube, 2008).Consequently, many people in the Lake Tana Sub-basin still consider wetlands solely as the breeding places for disease vectors like mosquitoes. This perception makes the wetlands susceptible to degradation. Therefore, this knowledge gap needs to be bridged through dissemination of information to the public. This can be achieved through: a) distribution of awareness raising materials (posters, fact sheets, booklets), b) use of mass media to put out features on wetlands, c) awareness raising workshops on identified knowledge gaps, d) promotion of environmental education and f) establishment of wetland clubs/support groups (Dejen, 2008).

5.2. Independent wetland policy development

Sustainable use of wetland resources is hardly possible if effective rules are not in place. Lack of independent wetland policy is the primer challenge to successful wetland management in Ethiopia. Even though various policies such as environmental, land, and water resources management have been issued to address the different aspects of environmental problems including wetlands, there is no specific national policy that deals with wetland issue (Bezabih, 2008). The implementation of wetland management in the context of the above policies is compounded by a more pressing wetland task force, extension package and food security policies that seek to convert wetlands for agricultural purposes (Aragaw, 2001). Thus, preparation and proper implementation of independent wetland policy is fundamental. Besides, ratifying the Ramsar Convention on wetlands could be helpful for sustainable conservation of the Ethiopian wetland resources.

Development of a unique or standalone wetland policy statement and/or strategy could be an important step in recognition of wetland problems and targeted action to deal with them. A unique wetland policy provides a clear opportunity to recognize wetlands as ecosystems requiring different approaches to their management and conservation, and not being masked under other sectorial management objectives (Ramsar Convention Secretariat, 2007).

In many cases, however, wetland policies or strategies are made a component of national sustainable development, water or other sectorial environmental policies. The wetland messages can therefore become diffused and remain dominated by the broader objectives of other Government policy objectives. The implication is that in many countries, institutions having a stake in natural resources management will not be motivated to assign adequate staff and even the available staff will be overloaded and pressurized to deal with the broader issues and tend to overlook wetland conservation and management (Ntambirweki, 1998). This seems an all pervading challenge observed in many areas of Ethiopia where wetlands are located. In view of these challenges, initiating a standalone wetland policy has the potential to draw the attention of legislators and the public to consider better and strong management interventions on wetlands.

5.3. Biosphere reserve

Biosphere reservation has great importance for ecosystem conservation and sustainable development. In the Lake Tana watershed three biosphere reserve zones (potential core zones, buffer areas and transition zones) were already identified (BoEPLAU, 2015). These zones are very important and can be the solution to minimize the risk of wetlands and the lake ecosystem as a whole (ZurHeide, 2012). Therefore, implementation of biosphere reservation could be one of the solutions.

5.4. Impact assessments and continuous monitoring of wetlands

Implementing detailed environmental impact assessments before any form of development (e.g. draining, damming, and diversion) is needed to ensure that the new modification will not bring

hazardous consequences on the ecology of a wetland area (Woube, 2008). It also involves implementing integrated management plans covering every aspect of wetlands and their relationships with catchments.

Besides the impact assessment, the other problem is proper implementation of the assessment study. This might be due to poor understanding of the economic value of the ecosystem services in terms of monetary unit (Lambert, 2003). So, in order to properly implement the impact assessment studies the government should first understand its countless value and change his attitude from 'waste land' to 'wealth land'. Since when the value of wetlands is known because of their incalculable value they are regarded as 'wealth lands' (Lee, 1999). Then formulate enacted legal frameworks, directives, and regulations that serve as an enforcement mechanism for the proper implementation. In addition, defining pertinent stakeholders having vested interest in wetlands and involving and consulting them in the whole process of wetland management issues are essential to achieve effective results. Additionally, ratifying the Ramsar Convention indirectly support and enforce the implementation process as well as the wetland management.

Besides to assessing the impacts of development, wetland monitoring is vital. It addresses both the issue of wetland integrity, *i.e.* change in wetland area, and change in wetland quality. This includes assessment of changes in biodiversity, physical and chemical properties of wetlands, water quality, and social activities around wetlands and considers if there are any new development plans that will potentially affect the wetlands. It is only through monitoring programs that the extent and causes of loss and degradation of wetlands can be determined, and the success of conservation actions be measured. It can be carried out at different levels of intensity, depending on available funding and/or technology (Woube, 2008). Monitoring methods include simple field observations, remote sensing, and quantitative sampling techniques. This activity is envisaged to take place at least at selected priority wetlands. In the sub-basin besides to field observation and quantitative sampling techniques using the remote sensing is beneficial. Since knowledge of the spatial distribution of wetlands and land cover maps assist in targeting and prioritizing risk mitigation activities.

5.5. Institutional nexus

In the Lake Tana Sub-basin, resources such as wetlands shared with public goods and there is no institution clearly responsible for management of the resources. This makes it difficult to sustainably exploit these natural resources. The problem of shared or lack of ownership is clearly reflected when it comes to the management wetland resources. Despite the fact that solving wetland problems in the Lake Tana Sub-basin appears to be very much dependent on institutional collaboration, the current cooperation among the institutions with a similar scope is weak. These institutions do not communicate very well about conservation of the wetland resources. Being a common ground they are suffering from the 'tragedy of the commons'. For example, although Ministry of Agriculture, Ministry of Water Resources, Environmental Protection Authority and Biodiversity Institute are the responsible organizations to wetland management, there is no organized system, in which these institutions co-operate and share their knowledge. Therefore, the organizations having similar scope should strengthen their co-operation and this is vital to have robust and holistic wetland management (EWNRA, 2008).

6. Conclusion and Recommendation

The Lake Tana Sub-basin is endowed with large number of wetlands, which are ecologically and socio-economically most important. The wetlands are distributed all over the sub-basin but most of them found around the lake shores and the tributaries. Despite the fact that wetlands in the Lake Tana Sub-basin provide wide range of social, economic, and environmental benefits, most of them are either severely degraded or are at the verge of extinction. Therefore, urgent action is required to combat the existing problems and successfully manage the wetlands. Among others, public awareness creation, independent wetlands policy development, strengthening the cooperation among organizations, buffer zone development and continuous monitoring are the optimal management options. Furthermore, ratifying the Ramsar convention is of crucial to sustainable conserve wetlands.

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Assessment of the Effect of Consumption of Lake Rice on Food Security of Households in Lagos State, Nigeria

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Abstract: *In Nigeria, food insecurity is still a critical challenge among rural and urban households. To enhance the country's food security status, a novelty was introduced to the nation's drive towards self-sufficiency in food production in 2016 when Lagos and Kebbi States launched the much-awaited Lagos-Kebbi Rice, christened LAKE RICE. Thus, this study assessed the effect of the consumption of Lake Rice on food security of households in Lagos state, Nigeria. Random sampling technique was used to pick 200 farming households for this study. The analytical tools include: descriptive statistics, likert scale, food security index and logistic regression. The result implied that majority of the sampled respondents were male with an average household size of 6 persons. The food insecure and secure households' were 26% and 74% respectively when Lake Rice was consumed. On the other hand, the percentage of food insecure and secure households was 29.5% and 70.5% respectively when other rice was consumed. The result indicated that the introduction of Lake Rice has to certain extent reduced the food insecurity of households. This is probably because Lake Rice is readily accessible, available and highly consumed than other rice. The logistic regression suggested that age of the respondents, family size, income and amount of Lake Rice consumed were the critical determinants of food security among households. The most effective coping strategies adopted by the respondents are reduction in daily/monthly spending. The government should encourage the production of Lake Rice by given soft loans to farmers. Policies and strategies that reduce household size should be enthusiastically pursued to reduce food insecurity.*

Keywords: Agriculture, coping strategies, food security and logistic regression

1. Introduction

Food is fundamental to life. It is considered as the basic means of nourishment, and a recommended food intake in terms of quantity and quality, is critical for healthy and productive life (FAO, 2005). Food occupies a large part of a typical Nigerian household budget. The need for food is topmost in the hierarchy of needs. Thus, the achievement of food security is crucial to any given country. Food security is when people at all times have social and economic access to sufficient, safe and nutritious food to meet their dietary needs and health (FAO, 2006). Food insecure households are households whose food intake drops below their minimum calorie (energy) requirements, and those who exhibit physical symptoms caused by energy and nutrient deficiencies resulting from inadequate diets. In Nigeria, food insecurity is still a critical challenge among rural and urban households (Ifeoma and Agwu 2014). The cost of food insecurity is substantially high. The country's food security situation was deepens by the poor performance of the agricultural sector. This creates food availability and accessibility challenges at the local and national levels (Aliu, 2018). Consequently, it becomes more pertinent to increase the productivity of the sector.

To enhance the performance of the agricultural sector, a novelty was introduced to the nation's drive towards self-sufficiency in food production in 2016 when Lagos and Kebbi States launched the much-awaited Lagos-Kebbi Rice, christened Lake Rice. The initiative is not only to ensure food security but to showcase Nigeria's potentials in rice production. Both Lagos and Kebbi State governments signed a Memorandum of Understanding (MoU) in March 2016, to produce Nigerian rice to ensure food security and also to showcase the ability of Nigeria to become a producing nation. The partnership is expected to expand the rice production for Lagos that has the largest consumption market to absorb it. A 50kg bag of the rice sells for ₦12,000. Unlike imported rice that has five to six years storage life span, Lake Rice is fresh (Vanguard Newspaper,

2016). The addition of Lake Rice to the local varieties like Abakaliki and Ofada rice is a major leap towards self- sufficiency in food production. The idea is to prevent Nigeria from being a dumping ground for expired imported rice. The partnership would in the nearest future lead to an expansion of production of the rice. Kebbi State has comparative advantage in area of rice production, Lagos boasts of the largest consumption market, as the Lake Rice can stand any integrity test in Nigeria. Many studies (Omonona *et al.,* 2007; Babatunde *et al.,* 2007; Amaza *et al*., 2008; Ahmed *et al*., 2015) have been carried out on factors influencing food security of households. However, none of these studies have assessed the effect of the consumption of Lake Rice on food security of respondents. Thus, this study determines the food security status of the respondents assesses the effect of consumption of Lake Rice on food security and identifies the effective coping strategies adopted by the respondents in reducing the effects of food insecurity.

2. Materials and Methods

2.1. Area of study

Lagos state was chosen for this study because it is the second populous state in Nigeria next to Kano state with a population of over 21 million people (NPC, 2016). The state was created on 27th May 1967. Lagos state is arguably the most economically important state of the country (Nigerian Congress, 2005).

Figure 1. Map of Lagos showing the various communities

Lagos state is situated in the South Western Nigeria within latitude 602'N to 604'N and longitude 2045' E to 4020'E (Figure 1). The state is bounded from the North and East by Ogun State, in the West by the Republic of Benin and the South by the Atlantic Ocean. The total land mass of the state stretches over 3,345 kilometers with an estimated population of about 15 million. About 40% of the total land area in the state is covered by water and wetlands. There are Lagoon, and creeks, wetlands, barrier islands, beaches and estuaries in the state. It has 20 Local Governments Areas (LGAs) namely: Agege, Alimosho, Ifako-jaye, Ikeja, Kosofe, Mushin, Oshodi-isolo, Somolu, Apapa, Eti-Osa, Lagos Island, Lagos mainland, Surulere, Ajeromifelodun, Amuwoodofin, Ojo, Badagry, Ikorodu, IbejuLekki, and Epe. The urban areas include: Lagos mainland, Ikeja, Surulere, Lekki, Lagos island etc. while the rural areas include; Epe, Ojo, Badagry, Ijede, Eputu, Ikorodu etc.

2.2. Methods of data collection and sampling

Essentially, structured interview schedule was employed to gather the primary data. A two- stage random sampling procedure was adopted for this

study. Five out of the 20 LGAs were randomly selected in the first stage. The chosen 5 LGAs are: Lagos Island, Badagry, Ikorodu, Surulere, Epe and Ijede. Forty households were selected randomly from each LGA in the second stage to make up a sample size of 200 households. Information were collected from the respondents on socio-economic characteristics, food consumed, consumption expenditure, monthly income, perceived effects of food insecurity and coping strategies adopted in reducing the effects of food insecurity.

2.3. Analytical methods

Descriptive statistics, food security index and logistic regression were the analytical tools used to achieve the objectives of this study. Descriptive analysis was used to describe the socio-economic characteristics and the coping strategies employed by households to minimize food insecurity. Using food security index, the households were classified into food secure and food in secure households.

The index is given as:

Fi = Per capita food expenditure for the $_i^{th}$ household/ 2/3 mean per capita food expenditure of all households

Where Fi = Food security index

When Fi > 1= Food secure ith household

Fi < 1= Food insecure ith household.

A given household is said to be food secure, if the per capita monthly food expenditure is higher or is equal to two third of the mean per capita food expenditure. While, a food insecure household is that whose per capita food expenditure is lower than two-third of the mean monthly per capita food expenditure (Omonona *et al.,* 2007).

Based on the result of food security index (Fi), a binary logistic regression model was estimated to identify determinants of food security.

Binary logistic regression model is given as:

$Z = m_o + m_1X_1 + m_2X_2 + \ldots + m_kX_k + u$

Where Z = Logit for food security = Logit (p)

mo= Constant

$m_1, m_2,\ldots,m_k$ = the regression coefficients which interpret the effect of Xon Z

X = independent variables

K = number of independent variables

P = probability of presence of characteristic of interest

u = error term

The independent variables are:

X_1 = Age of the respondent (years)

X_2 = Sex of household head (D=1 for male; D=0 for female)

X_3 = Number of years of schooling (years)

X_4 = Family size (number)

X_5 = Total amount of lake rice consumed (kg)

X_6 = Household per capita income (₦)

Multi co-linearity test conducted between X_5 $_{and}X_6$indicated that there was 3.1% correlation between the two variables and are statistically not significant as shown in the Table 1.

Table 1. Correlation between the amounts of Lake Rice consumed and average monthly income

		Average monthly income	Amount of Lake Rice consumed
Average monthly income	Pearson correlation	1	0.031
Sig (2 tailed)			0.663
N		200	200
Amount of Lake Rice consumed	Pearson correlation	0.031	1
Sig (2 tailed)		0.663	
N		200	200

Field analysis, 2018

3. Results and Discussion

3.1. Socio-economic characteristics of respondents

Of the sampled respondents80.5% were males and 19.5% were females with an average age of 48 years (Table 2).

Table 2. Socio-economic characteristics of the sampled respondents

Variables	Frequency	Percentage	Mean	STD
Gender				
Male	161	80.5		
Female	39	19.5		
Age			48.14	5.832
20-30	1	0.5		
31-40	18	9		
41-50	106	53		
51-60	71	35.5		
61 and above	4	2		
Marital Status				
Single	9	4.5		
Married	151	75.5		
Divorced	11	5.5		
Widow	22	11.0		
Widower	7	3.5		
Household Size			5.925	2.447
1-5	90	45.0		
6-10	99	49.5		
11-15	11	5.5		
Educational Level				
No formal education	15	7.5		
Primary education	11	5.5		
Secondary education	55	27.5		
Tertiary education	119	59.5		
Religion				
Islam	104	52		
Christianity	96	48		
Occupation				
Civil servant	99	49.5		
Trader	91	45.5		
Artisan	10	5.0		
Access to credit facility				
Yes	163	81.5		
No	37	18.5		

Source: field survey, 2018

This suggests that males are mostly the household head (breadwinner) of a family, only certain circumstances such as death of the husband or other reasons makes female the head of the household. The average household size is 6 persons. The average age of the respondent is 45 years. Age is a critical variable which can affect the ability and agility with which the head provides the food needs of the household. An old household head is more likely to have larger family size and may lack the energy required to work for the upkeep and sustenance of the households. About 50% of the household heads were civil servants, 45.5% were traders and 5% were artisans. This implies that, for maximum food

security to be attained in a society there is need for sufficient stable jobs and employment opportunity. Majority (81.5%) of the household heads had access to credit facilities. Access to credit facilities, to a very large extent determine the type of food consumed and consumption expenditure of households. A large (59.5%) proportion of the household heads had tertiary education. It is believed that respondents are able to take good decisions which will likely enhance their food security status, given this literacy level (Babatunde *et al.,* 2007).

3.2. 3.2 Food security status of households

The estimated 2/3 PCMFE was ₦4417.797.Therefore, households whose MPCFE is lower and higher than₦4219.787 were said to be food insecure and food secure respectively. Hence, 26% and 74% of the households were food insecure and food secure respectively when Lake Rice was consumed (Table 3). On the other hand, the percentage of food insecure and secure households was 29.5% and 70.5% respectively when other rice was consumed (Table 4). This suggests that the introduction of Lake Rice has reduced the food insecurity of households.

Table 3. Food security status of households when Lake Rice was consumed

		Frequency	Percent
Valid	food insecure	52	26.0
	food secure	148	74.0
	Total	200	100.0

Table 4. Food security status of households when other rice was consumed

		Frequency	Percent
Valid	food insecure	59	29.5
	food secured	141	70.5
	Total	200	100.0

As indicated in Table 5 and 6, there was significant difference (0.000) between the mean consumption of Lake Rice (0.7600) and other rice (0.7000). The mean increase (0.0600) at 95% level of confidence interval, stressing from lower boundary (0.02680) to upper boundary (0.09320).

Table 5. Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	food security status for consumption of lake rice	0.7600	200	0.42815	0.03028
	food security status for consumption of other rice	0.7000	200	0.45941	0.03249

Table 6. Paired Sample Test

Food security status for consumption of Lake Rice - food security status for consumption of other rice	t-statistics	3.564
	Df	199
	Sig. (2-tailed)	0.000
	Mean Difference	0.06000
	Std. Error Difference	0.01683
	95% Confidence Interval Lower of Difference	0.02680
	Upper	0.09320

Field analysis, 2018

3.3. Effect of Lake Rice on food security

The drivers of food security among the sampled respondents are shown in Table 7. The Nagelkerke R Square value of 83.6% suggested that the total variation in the explained variable was accounted for by the explanatory variables.

Table 7. Determinant of food security among the respondents

Variable	Coefficient	Standard Error	Sig.
Gender	0.630	0.983	0.522
Age	0.253	0.090	0.005**
Family size	-1.211	0.268	0.003**
Education	0.140	0.553	0.800
Income	0.000	0.000	0.000*
Lake Rice consumption	1.512	0.392	0.000*
Constant	0.858	2.705	0.751

Source: Field survey, 2018. * ****significant at 1% and 5% levels respectively; Nagelkerke R^2 = 83.6%*

The result indicated that age, family size, income and amount of Lake Rice consumed were the significant determinants of food security among the respondents. The age of the household head is positive and significant at 5% level of probability. This result suggests that younger household head would be more food secure than older ones. Positive relationship was also observed between income of the household and food security. This connotes that the higher the income the more a particular household is food secured. Furthermore, the coefficient of the amount Lake Rice consumed is positively related with food security at 1% level of probability. Households who consumed Lake Rice is more likely to be food secure than those who consume other rice. On the contrary, the coefficient of family size is negative and is critical at 1% level of probability. This suggests that household with larger family size are more likely to be food insecure. Surprisingly, education and gender of the household heads were not important in determining food security of households. These findings are not in consonance with that of Omonona *et al*. (2007), Babatunde *et al*. (2007) and Amaza *et al*. (2008) who found out that sex and education are important factors driving food security of households. This could probably because most of the respondents are in their active age and about 60% of them had tertiary education.

3.4 Coping strategies adopted by the respondents

The most important coping strategies adopted by the respondents are presented in Table 8.

Table 8. Coping strategies adopted by the respondents

Coping strategies	Frequency	Percentage
Reduction in daily/monthly expenditure	30	15
Eating less expensive foods	15	7.5
Reduced quality and quantity of food chewed	25	12.5
Eat whatever is available	23	11.5
Minimize food variations	10	5
Doing other jobs to raise money	20	10
Engage in borrowing	10	5
Using money budgeted for other things to purchase food	20	10
Obtain food from relations	12	12.5
Foregoing one or two meals per day	11	5.5
Consuming less preferred foods	14	7
Purchasing food on credit	10	5

Source: field survey, 2018.

Most (15%) of the respondents were engaged in the reduction in daily/monthly expenditure to reduce the effects of food insecurity on the households. This could probably because a large (50%) proportion of

the respondents were civil servant. About 13%, 12.5% and 11.5 of the respondents employed reduction in quality and quantity of food consumed, obtain food from relations and eat whatever is available to curb food insecurity respectively.

4. Conclusion and Recommendations

This study assessed the effect of consumption of Lake Rice on food security of households in Lagos state, Nigeria. The findings showed that 26% and 74% of the households were food insecure and food secure respectively when Lake Rice was consumed. On the other hand, the proportions of food insecure and secure households were 29.5% and 70.5% respectively when other rice was consumed. This connotes that consumption of Lake Rice has lessen food insecurity in the area. Furthermore, age of the respondents, family size, income and amount of Lake Rice consumed were the significant factors influencing food security among the respondents. The most critical coping strategies adopted by the respondents to curb the effects of food insecurity are reduction in daily/monthly expenditure. The government should encourage the production of Lake Rice by given necessary incentives to farmers. Policies and strategies that raises household income as well as lowers family size should be vigorously pursued to reduce food insecurity in the country.

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Effects of Soil and Water Conservation Practices on Selected Bio-physical, and Livelihood Attributes and Farmer`s Perception at Akusti Micro Watershed, Northwest Ethiopia

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Abstract: *Soil and Water conservation practices are widely practiced in Akusti Micro Watershed (AMW).The main purpose of this study was to assess the effects of soil and water conservation practices (SWCP) on selected biophysical, livelihood attributes and farmer`s perception at AMW, Northwestern Ethiopia. Field survey using questioner was conducted to assess the perceptions of farmers about SWCP. Data was also collected through key informant interviews, focus group discussions, field observations and field measurements and using Google Earth with 30 meter resolution. Data was analyzed using qualitative and quantitative analytical methods using SPSS software. Yield increments were evaluated by using the quadrant measurement 1m×1m (1m²) method. Yields before construction of SWCP were assessed using questioners. The results indicated that about 168.5 hectares of land were covered by vegetation and crop yields were increased, although the increments differed from farmer to farmer as the soil management practices differed. According to the respondents, the productivities of teff, wheat, maize and potato before construction of SWCP were 460 kg/ha, 240 kg/ha, 400kg/ha and 500kg/ha, respectively. After construction of soil and water conservation measures, yields of teff, wheat, maize and potato increased up to 6800, 3500, 12000 and 16000 kg/ha, respectively. According to survey results, 84.2% of the respondents practiced land restoration activities while the remaining 15.8% were not. Farmers who perceived SWCP more effective in controlling soil erosion and ensuring sustainability of crop yields adopted modern conservation methods. In Akusti micro watershed, lands are sloppy and thus soil erosion is very high that removes all the top fertile soils, applied fertilizers and sown seeds. Cultivating these vulnerable lands without proper management may result no or very low harvest. Therefore, it is recommended to integrate the use of agricultural inputs with Swept increase crop yields.*

Keywords: Bio-physical, Crop yield, Livelihood, Perception, Soil erosion, SWCP

1. Introduction

Barley (*Hordeum vulgare* L.) is one of the most

Soil erosion and nutrient depletion considered as one of the major problems constraining the development of the agricultural sector in Ethiopia (Berhane *et al*., 2011). The problem is particularly severe on cultivated marginal and sloping lands because such area generally susceptible to soil erosion (Kassa *et al*., 2004).

As to international journal of environmental monitoring and analysis IJEMA's (2013) national level studies estimation, more than 2 million hectares of Ethiopia's highlands have been degraded beyond rehabilitation. Additional 14 million hectares of land have been severally degraded which is reflected by the reduction of cereal yields (< 1.2 t/ha) in most of the highlands. Avoiding such problem is badly needed to achieve food security.

To alleviate this problem, a number of policy measures have been taken by the government, although their success is highly questioned i.e. a limited success in addressing the problem. A range of conservation practices, which include stone-faced soil bund, soil bunds and area closures, have been introduced into individual and communal lands at massive scales. Understanding farmers' perception of soil erosion and its impact is important in promoting soil and water conservation technologies (Chizana *et al*., 2006).

Different SWCP implemented like bunds stabilized with grasses such as vetiver (*V. zizanioides*), *C. palmensis*, other leguminous plants and etc. brought changes on the nature of landscape. This signifies that, the integrated implementation of physical

structures with biological/vegetative measures especially grasses are more effective in slope transformation and stabilization of the micro-ecosystem as compared to other soil and stone bund stabilization techniques (Demelash *et al.*, 2010).

The traditional agricultural land use and the absence of appropriate resource management often result in the degradation of natural soil fertility. Such activities haven egative implications on soil productivity, household food insecurity as well as on poverty of the people in different parts of the country (Teklewold *et al*., 2011). To mitigate soil degradation that is occurred due to soil erosion, deforestation and overgrazing and to enhance the productive potential of the farmlands some SWCP were practiced and promoted by Bureau of Agriculture (BoA) and other concerned non-governmental organization in the study area. However, the effects of these interventions on biophysical and livelihood attributes were not evaluated and documented. Therefore, the objective of this paper was to evaluate the effects of SWCP on biophysical, and livelihood attributes in the study area.

2. Materials and Methods

2.1. Description of the study area

Akusiti watershed is located in Fagita Lekoma district of Awi Zone, Amhara Region. The watershed is geographically located at 10º59′30′′N to 11º1′30′′N Latitude and 36º53′0′′ to 36 º 55′0′′E Longitude. The total area of the watershed is 410.7 ha and the altitude ranges from1887 to 2902 masl. It is situated about 460 km Northwest of Addis Ababa and 105kmSouthwest of Bahir Dar, the capital city of Amhara National Regional State (ANRS).

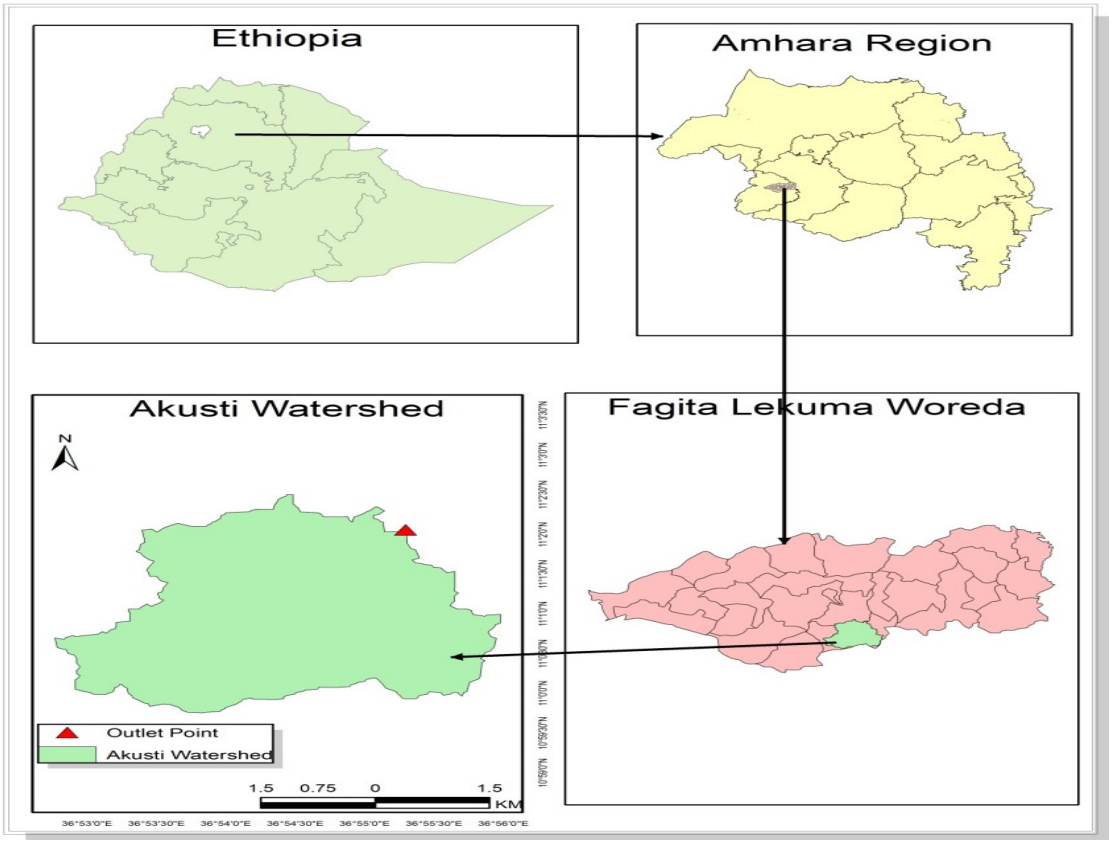

Figure 1. Location map of Akusiti watershed

2.1.1. Climate

The study area mean annual maximum and minimum temperatures are 25°C and 11°C, respectively. The study area has annual rainfall of 2379 mm which is characterized by one long summer and one short spring rainy season (Alemayehu, 2015). The long summer rainfall is mostly started mid-June and ended

mid-October which is the main rainy season for crop production while the short rainy season which called '*Belg*' is occurred between March and April.

2.1.2. Topography and soil type

The topography of the Akusiti watershed consists of 62% plain, 23% mountains, and 15% others (Alemayehu, 2015). According to the same author, Nitosols with stony phase is the predominant soil type of the study area.

2.1.3. Vegetation

Many indigenous tree species with very limited abundance are found in the area. They are found on some farmer's farmlands, around churches homesteads and the community woodlot. Major indigenous tree species found in the study area are Abalo (*Brucianti discentrica*), Yeabesha Girar (*Acacia abyssinica*), Weyra (*Olea africana*), Bisana (*Croton macrostachyus*) and Gesho (*Rahmnu sprinoides*). Exotics species Nech Bahir Zaf (*Eucalyptus globules*), Deccurence (*Acacia deccurence*) and Sesbania (*Sesbania sesban*) are also found in the study area.

2.1.4. Major agricultural practices

Rain-fed crop production during summer season is mostly practiced in the catchment area where intensive cultivation, sowing, weeding and other activities are performed. The livelihood of the community is mainly based on mixed farming system (Alemayehu, 2015). The dominant crops produced in the area are barley (*Hordeum vulgare*), wheat (*Triticum spp.)*, teff (*Eragrostis teff*), potato (*Solanum tuberosum*), maize (*Zea mays*) and others.

Moreover, livestock production plays a significant role in the livelihoods of the people in the study area. Livestock is also a source of foods and cash as well as the major source of draft power, fuel and fertilizer for crop production. The common types of livestock in the area include cattle, sheep, and poultry.

2.2. Methods of data collection

The sampling technique employed in this study was random sampling technique. Informal interview of the farmers was carried out using a combination of Participatory Rural Appraisal (PRA) techniques such as semi- structured interviews and group discussions. The interview and focus group discussions were supplemented with personal observation, secondary data and information from knowledgeable people in the Bureau of Agriculture. Since the target population is less than10, 000 (Cochran, 1977), the required representative sample sizes have been determined by the proportion sample size formula. The total number of household in the watershed were 250 and 152 sample household were selected for structured questioner interviews.

Formula for sample size determination

$$n=\frac{no}{1+\frac{no-1}{N}} \text{ and } no= z^2 p\, q/d^2$$

Where:

No = the desired sample size

Z= standard deviate at require confidence level (1.96).

P= the proportion in the target population estimated to have a particular Characteristic (0.5)

N=target population (the total number of household in the watershed, 250)

q=1-p, (0.5)

d= Statistical significance (0.05)

Accordingly:

$no=1.96^2*.5*.5/.05^2 =385$

n=no/1+ (no-1)/N

n=385/1+ (385-1)/250 =152

To collect the existed SWCPs in the watershed, observations through transect walk from East to West and from North to South direction in the study area were carried out as well as questionnaires were used. Observation checklist related to the stated objectives was used in order to strengthen the reliability and validity of the data gathered. The existing vegetation in the study area was observed and their area was measured using GPS. Interviews and literature reviews/ secondary data have been used to collect data of the area before the intervention of SWCP.

To collect data on the effects of soil and water conservation practices on the livelihoods of the community; crop yields were estimated from eight households using the quadrant measurement (1m×1m) method. On the other hand, crop yields before SWCP interventions were assessed from three group discussions where each group has consisted

four households. Moreover, secondary data were also used.

2.3. Methods of data analysis

Questionnaire data of the existing SWCPs as well as vegetation cover before the intervention of SWCPs were analyzed by SPSS version 20. The existing vegetation cover was analyzed using Google Earth 30 meter resolution 2015 / 16 as well as using GIS techniques.

3. Results and Discussion

3.1. Major soil conservation practice implemented by farmers in the study area

The survey result indicated the agreement of the respondents where soil conservation practices are important to minimize the rate of soil erosion on farm plots and communal grazing lands. In this regard, various physical soil conservation practices have been applied by the community farmers on their own farm plots and grazing lands. Based on the results of the field survey (Figure 2), about 8.6 %, 15%, 51.8% 12.5% and 11.8%of the household heads have been constructed stone and stone faced terracing, fanyajuu, soil bund, cutoff drains and waterway, respectively.

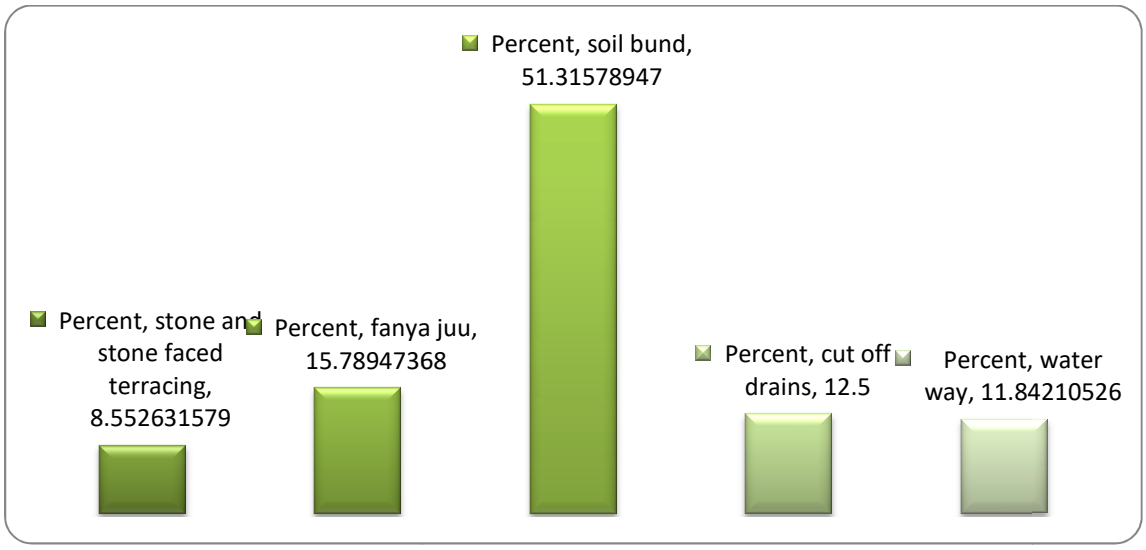

Figure 2. Major physical soil and water conservation structures practiced in study area

The respondents during the focus group discussion (Figure 3)revealed that soil and water conservation practices improved soil fertility of their farmland, increased water holding capacity of the soils, reduced runoff and erosion and increased land productivity. Soil and water conservation practices employed in the responsive settlement areas were fences of forage plants, agro-forestry and vegetable, and fruit production in at the garden.

Figure 3. Focus group discussion with farmers in the study area

The results of focus group discussion also indicated the positive effects of soil and water conservation practices on communal lands used for grazing which improved forage biomass quantity and increased rates of water percolation.

3.2. Effect of soil and water conservation practices on vegetation cover

Based on the results of Google Earth pro 2015/16, the study area which is covered by vegetation covers was about 168.5ha (Figure 4) which is about 22% of the watershed area. The majority of vegetation that covered the watershed is *Acacia decurrens.* According to the respondents, the vegetation cover of the watershed before implementation of SWCPs was about 87 ha.

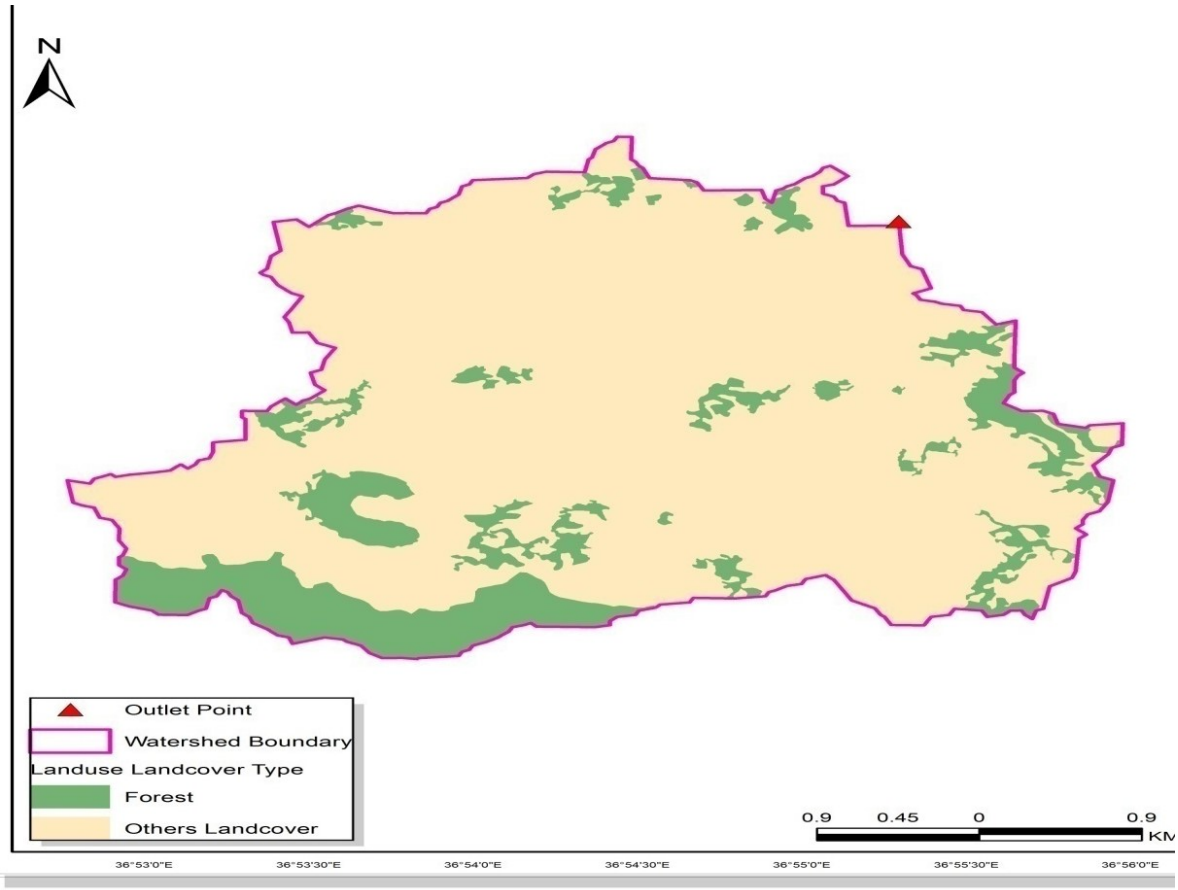

Figure 4. Akusti watershed vegetation cover map (2015/16)

The results of the present study is generally in agreement with the findings of Alemayehu (2015) who found the increase of *Acacia decurrens* plantation in Fagita Lekoma district from time to time. This is because of the fact that the growth rate of the tree in degraded and infertile soil is high. Moreover, the tree is used for charcoal production in the district which improves the cash income of the farmers and thus their livelihoods. The fact that the tree is leguminous, it may help to improve the fertility of the soil and the yield of crops produced after cutting of the trees.

3.3. Effect of soil and water conservation practices on livelihood condition

According to the survey results, 10.5, 25 and 64.5% of the respondents perceived that the intervention of soil and water conservation practices increased the crop yield very high, high and moderately, respectively, as indicated in Figure 5. In this regard, Tesfaye (2008) indicated that the introduced soil and water conservation measures, fanya-juu and soil bunds are widely acknowledged as being effective measures in protecting soil erosion and as having the potential to improve land productivity.

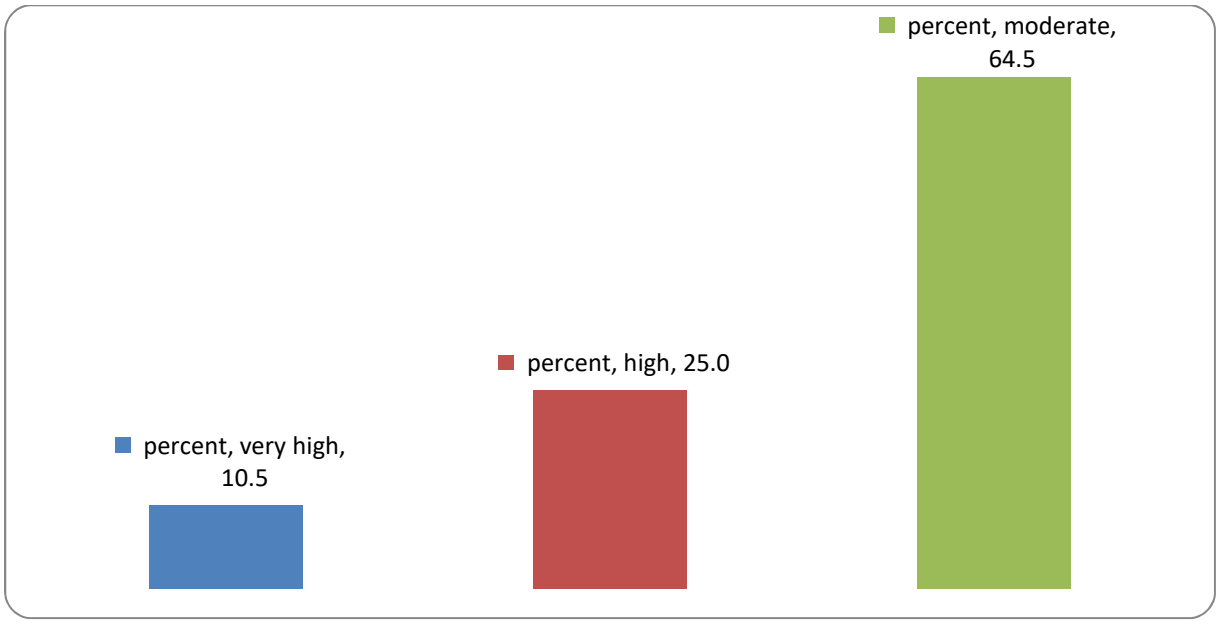

Figure 5. Proportion of respondents that preserve the increment of crop yields after SWCPs

As per the respondents, the living conditions and purchasing power of the farmers was increased after the implementation of soil and water conservation practices. Before SWCP, the farmers ought to work in off-farm activities to buy clothes and get other services since their harvest was very small. After SWCP however, they could able to maintain seeds and reduce removal of top soil, seeds and fertilizer by erosion that in turn increased their crop harvest and able to buy the necessary materials by selling of the farm out puts. .

As shown in Table 1, crops yields were increased after construction of soil conservation structures, although the yield increment differed from farmers to farmers which is probably due to the differences in soil management activities of the farmers. According to the response of the farmers, the yields of teff, wheat, maize and potato were about 460 kg/ha, 2400 kg/ha, 4000 kg/ha and 5000kg/ha, respectively before construction of soil conservation measures. After construction of soil and water conservation measures however, the yields of *teff,* wheat, maize and potato increased up to 6800 kg/ha, 3500 kg/ha, 12000 kg/ha and 16000 kg/ha, respectively.

The findings of the present study were supported by Ayalew (2011) who observed low yields of crops in Gununo area before construction of soil conservation structures, even with application of fertilizers. According to him, the yield of teff in different farms increased from 300 kg/ha to 800 kg/ha after construction of soil conservation structures and that of haricot bean increased from 180 kg/ha to 400 kg/ha in different farms. Similarly, the yield of wheat was increased from 200 kg/ha to 800 kg/ha. Moreover, maize yield was increased four folds, from 400 kg/ha to 1600 kg/ha and that of potato was increased from <400 kg/ha to 1600 kg/ha.

Table 1. Crop yield before and after construction of soil conservation measure

Crop	Estimated crop yields before SWCP (kg/ha)	Estimated crop yields after SWCP (kg/ha)
Teff(local seed)	460	6800
Wheat (danifei)	240	3500
Maize	400	12000
Potato	500	16000

3.4. Farmers' perceptions about soil and water conservation practices

Table 2 shows the distribution of sample household heads by age group. The age of respondents was categorized in to different age groups. Accordingly , the average age of rural households of Akusti micro watershed was between the ranges of 20-30, 31-45, 46-55 ,56-65 and >65 which is 11.2 %, 34.2%, 23.7% 21.1% and9.9%, respectively. Age is one of the demographic characteristics that influence the perception of farmers to soil and water conservation practices. Most of the HHH were in the age ranges of 31-64 and 46-55 years. Farmers in these age groups are assumed to have a good understanding towards soil erosion problems due to their access to information about soil and water conservations practices. The proportion of elderly farmers above the age of 65 years was lower in percentage, as old age affects their participation in soil and water conservation practices due to their inability in terms of labor. However, these farmers especially the elderly age groups usually implement and accept soil and water conservation practices because of their access to money for rented oxen as well as hired labor compared to the young age group.

Table 2. Distribution of sample household heads by age group

Age	Frequency	Percent
20-30	17	11.2
31-45	52	34.2
46-55	36	23.7
56-65	32	21.1
>65	15	9.9
Total	152	100

The findings of the present study are in agreement with that of Assefa (2009) who found that most of the farmers between ages of 20-64 years participated in soil and water conservation practices. This group of people seems to have better understanding for soil and water conservation practices. Moreover, this group of people is effective labor forces to implement soil and water conservation practices. Few elder people implement soil and water conservation practices through hiring laborers of young age group.

3.5. Sex, marital, and educational status of household heads

The sex distribution of sample household heads was about 17.8% female and 82.8% male (Table 3). The great difference in male and female household heads in the present study clearly shows gender difference in the implementation of SWC measures. As indicated in the survey results, most of the female household heads managed their land through share cropping or renting their land male headed households and contracting for ploughing of the land for which they paid.

Table 3. Family size of sample household heads

Characteristics of HHH	Respondents	
	Frequency	Percent
Sex		
Female	27	17.8
Male	125	82.2
Marital Status		
Single	26	17.1
Married	126	82.9
Education Status		
Illiterate	109	71.7
Literate	43	28.3

The results of the present study are similar with that of Kibemo (2011) where the majority of the people who participated in SWCP were male headed. According to him, marital status of household head determines the access to information and resource that intern to soil and water conservation measures. Getting the household head married is adventitious to share information among members about the SWCP which is in line with the findings of Tesfaye (2015) who found the majority of the respondents participated in SWCP measures.

With regard to the educational back ground of the respondents, as can be seen in (Table 3), about 71.7 % household heads cannot read and write (illiterate) and 28.3% of household heads can read and write (literate). The majority of the household heads participated in the survey were illiterate which is difficult to create awareness on the importance of SWCP. To bring a positive perception as well as to implement soil and water conservation measures, it is necessary increase the educational background of the people as indicated by Ermias (2014).

3.6. Family size of household heads

As illustrated in Table 4about 19.7%, 62.5% and 17.8% of the household heads had 1-3, 4-7 and 8-10 family members, respectively. Accordingly, the majority of household heads participated in the survey had 4-7 family members. Generally, household heads with large number of family members have positive influence on the implementation of SWC practices. This is because household heads with large number of family members may help to effectively adopted several SWC measures in their farm land.

These findings are generally supported by Ayalew (2014) and Kibemo (2011) who found that household heads with large family member have positive influences on practicing soil and water conservation measures. This means household heads with high working capacity may positively correlate with soil and water conservation practices. Therefore, it is possible to conclude that family size has significant role in the construction of physical conservation measures.

Table 4. Family size of sample household heads

Family size	Frequency	Percent
1-3	30	19.7
4-7	95	62.5
8-10	27	17.8
Total	152	100

3.7. Households` perception on maintenance of SWCP

Soil and water conservation measures have to be regularly maintained for their sustainable benefits. The effort of the farmers to maintain soil and water conservation structures indicate their acceptance. As shown in Table 5, about 56.57% of the respondents maintained soil and water conservation structures while 43.42% did not maintain the conservation structures. Regarding to the reasons not to maintain the conservation structure, about 18.18% of the respondents said that the work is very tedious work while 51.51% of the respondents claimed loss of land due to the bund. Moreover, about 30.3% of the respondents did not maintain the structures due to inadequate labor for maintenance.

The results indicated that although different soil and water conservation measures have been practiced, the structures were not maintained my most of the respondents in the study area. This was mainly because of the tediousness of the work and lack of labor of the respondents. According to development agents (DA) and model farmers, soil and water conservation practice were done especially by public participation with help of government and non-governmental organization to control soil erosion as well as to enhance agricultural productivity. However, their maintenance is not done in the study area. The results of the present study are in agreement with the observation of Tesfay (2015) where soil and water conservation measures practiced in the study area were not maintained mainly because of shortage of farm land and lack of awareness.

Table 5. Distribution of issues related to the maintenance of SWC structures

Description	Response	Frequency	%
Doing maintenance on SWC structures	No	66	43.42
	Yes	86	56.57
Total		152	100
Reasons for no Maintenance	Work is very tedious	12	18.18
	Because of loss of land to the bund	34	51.51
	Labor shortage	20	30.30
Total		66	100

3.8. Access of information and training on soil erosion and conservation practices

According to the survey results, about 74.3% of the respondents got training on the importance and implementation of soil and water conservation practices while the remaining 25.7% did not had any types of trainings. Frequent training and appraisal on the importance of soil and water conservation practices, land use and soil fertility management is paramount important to maximize crop production. Moreover, accessing of information about SWCP from different sources is also important for their implementation. Accordingly, about 73.7% of the respondent household heads accessed information through trainings by DAs and non-governmental organizations while 19.7% and 6.6% got information from media and traditional information exchanges (neighbor) as indicated in Figure 6.

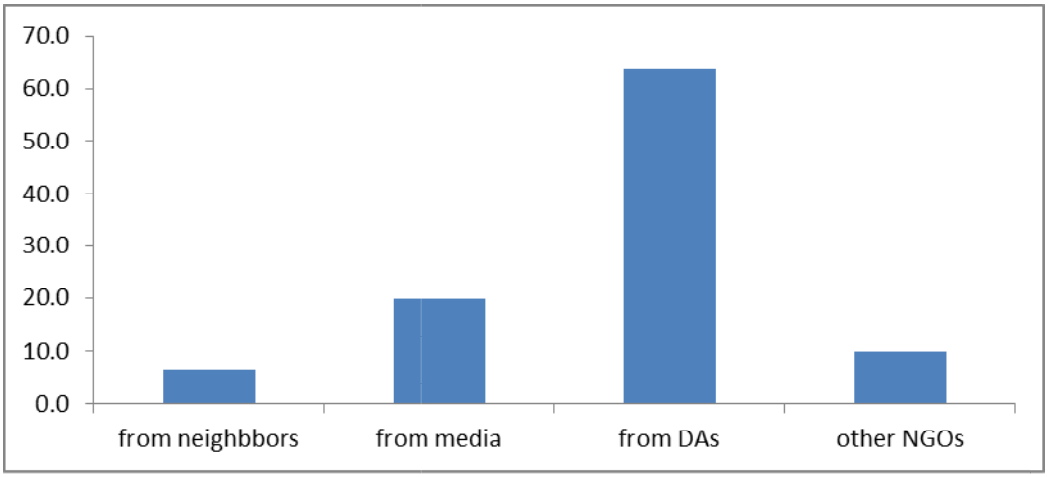

Figure 6. Source of information about soil and water conservation practices

3.9. Soil fertility improvement practices

Farmers at individual level practice different land management activities mainly to increase agricultural yields and conserve the farming plot. Based on the results of the present study, about 44.7% of the respondents used chemical fertilizer while 33.6 % used crop rotation to improve soil fertility and conserve soils of soils of cultivated fields. On the other hand about 19.7% of the respondents applied manure and only 2% practiced fallowing to improve the fertility of soils as indicated in Figure 7. Application of chemical fertilizer is the common and important soil fertility management practice to improve land productivity as indicated by Berhe (2004).

Crop rotation is one of the most important soil fertility managements. This method becomes more important when leguminous crops are part of the

rotation system to improve the nitrate content of the soil. According to the information of agricultural office of the district, the rotation system mostly consists of cereals, legumes (haricot bean) and root crops like potatoes in the farm land in different seasons and years of cultivation.

Manure is also used for promoting the fertility status of the soil. Its application to farmland raises the nutrient level of the soil, increases water infiltration and reduces soil erosion (Ermias, 2014). Currently, application of manure on farm lands has decreased from time to time as the number of livestock per household significantly declined for various reasons. Participants of focus group discussions indicated that manure is used only for homestead area because of shortage of manure. In addition, the use of cattle dung as source of fuel rather than as organic fertilizer is another contributing factor for low application of manure for soil fertility improvement practice in the study area.

The contribution of fallowing as soil improvement strategy is very small. This is because of the fact that cultivation of the farmland year after year is necessary to satisfy food requirements of the ever increasing population density.

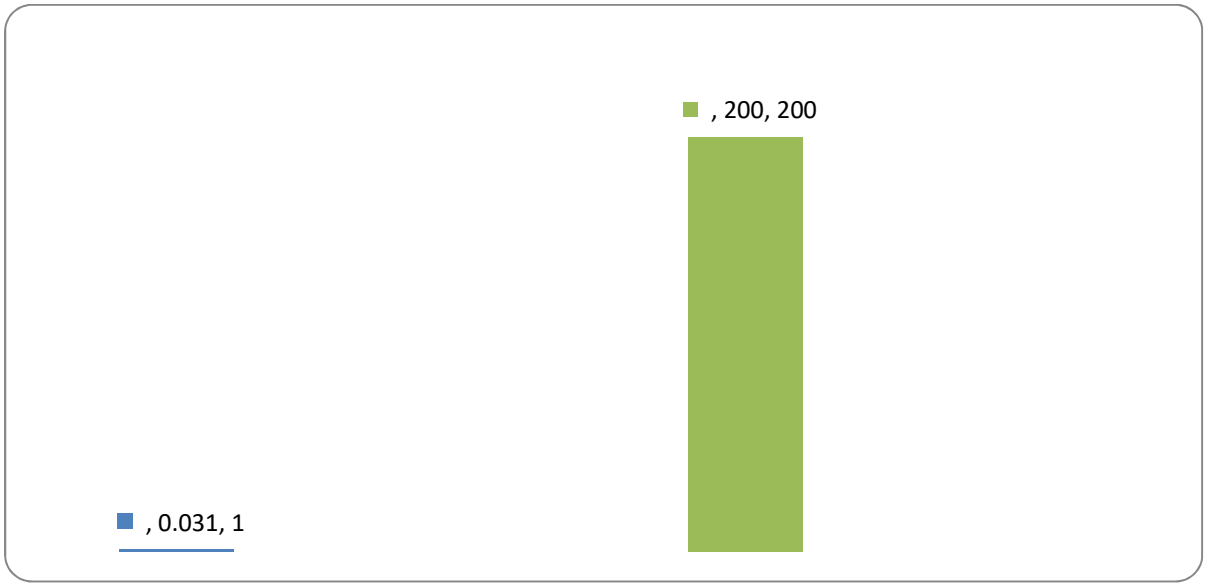

Figure 7. Soil fertility management strategies followed by the respondents

3.10. Measures of the respondents for declining of land productivity

Land productivity is essential to increase agricultural production on a given plot of land. Therefore, appropriate measures for improvement of land productivity should be taken if the fertility of the soil is declining. Accordingly, about 80.3% of the respondents will try to use appropriate measures to improve the soil fertility if its status declined while the remaining 11.2% shifting to other fertile plot (Figure 8). From the field observation, it was noticed that varieties of fruits and vegetables including tomato, cabbage, carrot, banana, apple etc. are growing along the farm land using ground water and boring water holes which are mostly produced for self-consumption and local markets.

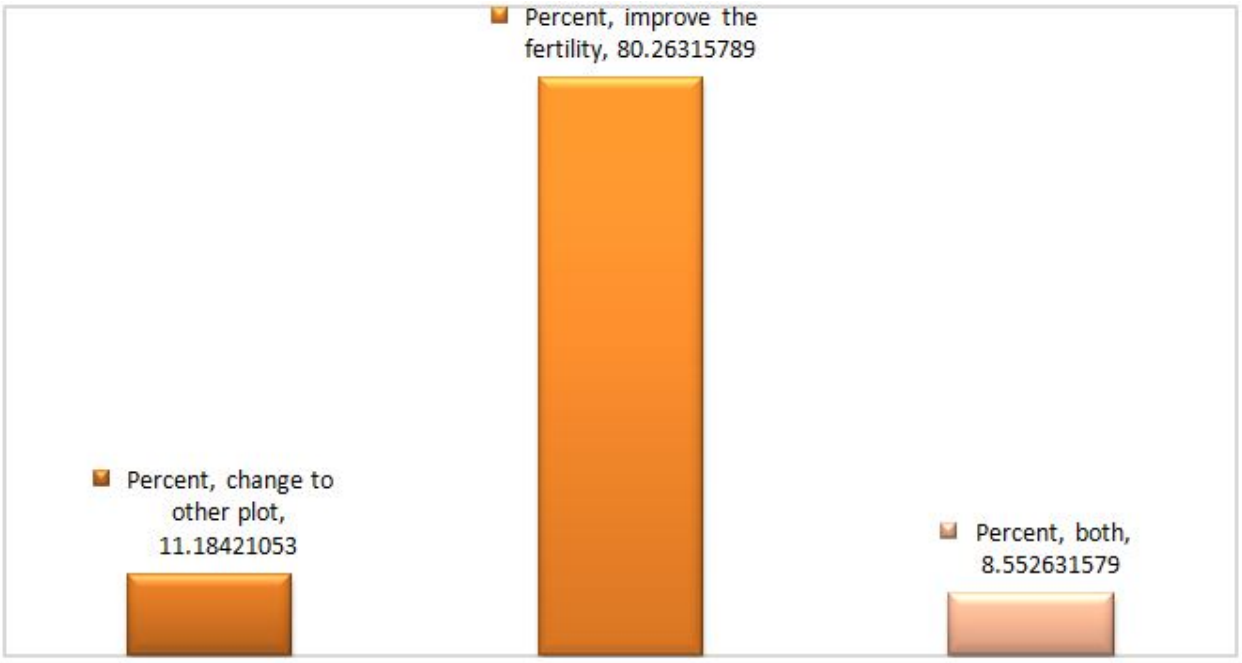

Figure 8. Measures under taken when the productivity of plot declines

3.11. Efforts of projects in the restoration of degraded land in the study area

Sustainable land management (SLM) is widely involved in environmental restoration works. The main activities of SLM are establishment of nursery and production of seedlings, plantation and distribution among the societies. In addition distribution of fruits and tree seedlings in order to introduce agro forestry practice is part of the activities. Moreover, soil and water conservation structures are practiced on individual lands to minimize soil loss and to increase productivity of farm land. With the involvement of the society and government cooperation extremely degraded areas around hill side are enclosed to protect from encroachment of livestock. In the study area, sustainable land management is working on alternative energy sources to minimize pressure exerted on natural vegetation. Among these activities, trainings on construction and distribution of biogas and fuel saving stove are the main ones. To restore gully lands, they are working different types of check –dam practicing plantation of degraded lands, establishing nursery and selling trees to increase the incomes of the respondents. These findings are supported by Ermias (2014) who found that NGOs are involved in the restoration of land sensitization and mobilization of the society through panel discussion, workshops and trainings for establishment of nursery, seedling production, and plantation on degraded land.

4. Conclusion

This study was conducted to evaluate the effects of SWC on selected biophysical, livelihood attributes and farmer`s perception at Akusti Micro Watershed (AMW), Northwestern Ethiopia. The results indicated that about 168.5 hectares of land were covered by vegetation and crop yields were increased, although the increments differed from farmer to farmer as the soil management practices differed. According to the respondents, the productivities of *teff,* wheat, maize and potato before construction of SWCP were 460 kg/ha, 240 kg/ha, 400kg/ha and 500kg/ha, respectively. After construction of soil and water conservation measures, yields of *teff,* wheat, maize and potato increased up to 6800,3500, 12000 and 16000 kg/ha, respectively. According to survey results, 84.2% of the respondents practiced land restoration activities while the remaining 15.8% were not. Farmers who perceived SWCP more effective in controlling soil erosion and ensuring

sustainability of crop yields adopted modern conservation methods.

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Ecological and Socio-Economic Implications of Free Grazing in Ethiopia: A Review

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Abstract: *Livestock production in the tropics (including Ethiopia) is mainly sustained on free grazing as a major feed source. It is a known fact that the practice of livestock grazing is important for the growth of green biomass and composition of plant communities on grazing-lands. Moreover, grazing has the beneficial impact on biodiversity as extensive grazing contributes to the aesthetic and leisure importance of pastures. The practice can also contribute to the production of healthy feed of high quality. Grazing by livestock can also be used as a tool to limit the expansion of weeds and shrubs in open landscapes, but in most cases cannot stop or reverse natural succession. The conservation and protection of pastures requires the careful selection of razing management and appropriate number of grazing animals. Grazing species differ in their preference of habitat and plant species, which can enable the effective use of mixed grazing systems with different animal species. Thus, for purposes of biodiversity conservation, grazing should be combined with other practices, such as mowing, cutting or burning. Improper use of pasture such as both overgrazing and under grazing creates a threat for its biodiversity. Thus, both abandonment and overly intensive management of pastured grassland are harmful for biodiversity and should be avoided. Optimum grazing can be a tool to maintain or enhance biodiversity of grazed areas. The question, of which method or combination of methods is most suitable and most feasible in a particular area, depends on local biological and socio-economic factors. Research findings suggest that existing agro-environment schemes based only on blanket stocking rates are too crude to increase plant diversity and that site conditions must also be taken into consideration. In Ethiopia, the increase in number of livestock coupled with increase in human population has resulted in shrinkage of grazing lands and animals are limited to graze on overgrazed communal lands, road side and aftermath grazing and limited supplementation of straw. Besides, soil erosion and deforestation has worsened the situation. In line with this, one of the contributing factors to poor soil fertility, land degradation and erosion is the free grazing of animals. Free grazing is common practice in Ethiopia except in areas where grazing lands are limited in size and where the farming system favors growth of perennial cash crops. Strategic research is required into methods of achieving compliance with environmental protection and sustainable agricultural practice in developing countries including Ethiopia. In order to increase outputs from livestock, conserve soil and moisture and reforest degraded and over grazed communal grazing lands, controlling animals from freely grazing can be taken as alternative option of the negative effect of free grazing. This paper reviews ecological and economic benefits of free grazing, the effect of over grazing on natural resources and techniques to reduce the negative effect free grazing in Ethiopia.*

Keywords: Abiotic, Biotic, Ethiopia, Environment, Grazing, Livestock

1. Introduction

In developing countries, livestock play an important role in most small-scale farming systems. They provide traction to cultivate fields, manure to maintain crop productivity, and nutritious food products for human consumption and income-generation (Sere *et al.*, 2008). Irrespective of population of livestock in the country, however, the productivity per head is usually low mainly because of inadequate year round nutrition, unimproved genetic resources and prevalence of diseases and parasites. For example, the average milk yield is only 207.6 kg per cow per lactation which is lower than the average for East Africa and Africa which is 364.4 kg and 446 kg per animal, respectively (ILRI, 2000).

Beef production per animal per year is 8.6 kg, while that for sub-Saharan Africa is 13.7 kg (Richardson and Smith, 2006). For instance, average carcass weight for Ethiopian sheep is 10 kg (FAO, 2001) which is lower than the values for neighboring countries such as Sudan, Somalia, Djibouti and Kenya which have sheep carcass yields of 13, 13, 12, and 13 kg/head, respectively (FAO, 2001). Among constraints of livestock production, inadequate livestock nutrition is a major factor affecting the development of viable livestock industries in many developing countries (Sere *et al.,* 2008). Like many developing countries, insufficient and poor quality feed, particularly during the dry season, is one of the most important constraints to Ethiopian livestock feeding system (Anderson, 1987). The most important livestock feed resources in the highland of Ethiopia are natural pasture, crop residues and stubble grazing (Alemayehu, 2004) the major feed source is grazing (CSA, 2015).

Grazing lands are important sources of livestock feed in developing countries (ILRI, 1999), although unrestricted access to such resources can result in overexploitation and land degradation. CSA (2015) indicated that grazing is the major type of feed (56.23 %) followed by crops residue (30.06 %), where the remaining portion of feed supply is covered by agro-industrial byproducts and improved fodder. Although grazing has such importance to the ecology and economy of grazers, casual free grazing system has contributed significantly to the land degradation problem in many parts of Ethiopia. The free grazing system has a negative effect on the conservation efforts, as trampling animals often damage physical conservation structures such as stone terraces and soil bunds. Thus, the free grazing system results in significant negative externalities, especially for farmers who do not own livestock, as they are forced to bear the additional cost of maintaining their plots. However, these same farmers may benefit from increased soil fertility arising from the manure left by the grazing animals.

Table 1. Animal feed resources in Ethiopia

S. No	Feed Type	Percentage
1	Grazing	56.23
2	Crop residue	30.6
3	Hay	7.44
4	Agro-industrial byproducts	1.21
4	Others feed/concentrate feeds	4.76
5	Improved fodder	0.3

Source: CSA (2015)

2. Benefits of Grazing

2.1. Feed source for domestic and wild animals

Grazing land is vital for health and welfare of farm animal production (Smit *et al*., 2008)). Plant species diversity influences both the performance of livestock grazing on pastures, and the quality of the raw animal products. The positive influence of sward diversity on the performance of grazing animals was confirmed by Soder *et al*. (2007). The presence of herbs and specific plant species in the sward positively influences the fatty acid composition of milk and meat, with a particular influence on health promoting substances, such as polyunsaturated fatty acids. The greatest advantage of pasture-based milk and meat production is obtaining a product with higher content of unsaturated fatty acids and vitamins, known to be beneficial for human health (Martin *et al*., 2004; Couvreur *et al*., 2006). In addition, Pastushenko *et al*. (2000) have shown that pasture feeding in organic beef and veal production improved the quantity and composition of polyunsaturated fatty acids of meat. Wood *et al*. (2003) reviewed the information about fatty acid composition of pork, beef and lamb and concluded that feeding grass elevates the content of polyunsaturated fatty acids and vitamin E. Dillon *et al*. (2005) studied the feasibility of pasture-based milk production systems in temperate regions. They indicated that such systems were characterized by lower unit production costs, through lower feed and labor expenses, as well as reduced capital investment. The production of green forage from permanent grassland consumes less energy than crop cultivation,

with relatively high energy and protein yields. As a result, low-input pasture provides cheap green forage (Soder *et al*., 2007). Kasperczyk (2008) emphasizes, that economical rationalization of pro-ecological use of meadows and pastures is possible only under sustained management and should be supported by further, reliable scientific investigations.

2.2. Grazing as biodiversity protection

Due to its influence on the environment, animal grazing is used as a tool for protection and restoration biological and cultural value. According to Dolek and Geyer (2002), grazing is considered to be an important practice for the survival of many threatened plant and animal species. The most important function of animals grazed on threatened grazing area is to control plant species richness. This is a serious matter in the conservation and management of plant communities and biodiversity. In order to attain the expected results, the species of grazing animal and method of pasture management must be chosen carefully whilst taking into account the local natural conditions and the conservation goals of that particular area.

Numerous field experiments on plant communities have shown that herbivores often, although not always, increase plant diversity. In most cases, grazing was introduced as a prevention measure against the proliferation of shrubs. Van Braeckel and Bokdam (2002b) studied Biebrzanski National Park (Poland) in order to evaluate the effectiveness of cattle and horse grazing as a tool to prevent the succession of undesirable plants. Their results show that grazing animals prevented and limited the invasion of reeds, but did not restore desirable agglomerations of sedges and mosses. This indicates that a major role of extensive grazing is to preserve, not to restore desirable sward composition. Hoffmann (2002) described the successful use of cattle, horses and sheep to halt the expansion and succession of shrub species. Many authors have described the use of sheep grazing for nature conservation, both in the uplands and in the mountains (Nowakowski *et al*., 2000) as well as in the lowlands (Groberek, 2005). Sheep grazing inhibited the succession of undesirable plants and had a positive effect on the enrichment and diversity of floristic communities (Gutman *et al*., 1997; Niznikowski, 2003). Sheep were also successfully used for grassland conservation in France (Debayle, 2004). Harris (2002) reported that use of sheep was successful in the conservation of habitats for endemic plants, such as the Scottish primrose (*Primulascotica*) on the Orkney Islands.

In order to maintain and preserve biodiversity of open landscapes, a combination of practices including grazing, mowing, and reed and wood cutting were suggested by van Braeckel and Bokdam (2002b). Groberek (2005) reported that sheep of the native Polish breed Wrzosowka (Hether Sheep) were successfully used to prevent undesirable plant succession in lowland areas. Opinions about the use of mixed grazing for environmental protection are not consistent. Some authors claim that mixed grazing can lead to restoration of plants diversity, while others believe that it reduces the biodiversity of a sword. Generally, many published results suggest that the introduction of large herbivores into natural grasslands may help to maintain and enhance its botanical diversity. However, in the examples published, grazing was not always the correct method for vegetation management, as demonstrated by Kohyani *et al*. (2008) in coastal dune habitats. Thus, the existing scientific evidence indicates that scale and environmental site conditions are both to be considered when grazing animals are introduced. The successful use of grazing for environmental protection and biodiversity enhancement requires careful planning. In all cases, the choice of breed, animal density and pasture management should be suited to local conditions and conservation goals in order to achieve the desired results. There is no universal solution, and grazing programs should be tailored to local conditions.

The biodiversity of grazing-land is important not only as a tool to protect plant and animal communities, but also in sustaining their agricultural productivity. Studies show that increase in grassland productivity results in a decline in number of plant species in many habitats (Marty, 2006). Sustainable farming systems such as extensive or organic farming, with the use of farm animal grazing, are seen as a potential solution to continued biodiversity loss. According to some workers (Hansen *et al*., 2001; Bohner, 2007), organic and low-input production systems support greater genetic and biotic diversity of agricultural

ecosystems). In regions with rich soils, the number of species on organic fields has been found to be up to 10 times higher compared to conventional fields (Heineken, 1990).

2.3. The role of grazing animals on general ecosystem

Grazing animals can affect an ecosystem through defoliation, treading and leaving excreta (Duncan, 2005; Wasilewski, 2006). The transport of seeds is another significant way in which grazers can influence plant diversity (Olff and Ritchie, 1998). Natural fertilization and transport of nutrients in animals' excreta is also important for grassland and adjacent biocenoses which may be used by herbivores for feeding and resting. It may be assumed that wild plants are adapted to herbivores since they have evolved together. However, the intensity of defoliation, treading and natural fertilization in farming landscapes may exceed the levels occurring in natural systems, thus adversely affecting grazing land ecosystems. Defoliation is the main way in which herbivores affect plant communities. Periodic defoliation is vital for controlling succession of plants (Rook *et al*., 2004).Intensive defoliation, on the other hand, inhibits the development of trees and shrub seedlings and supports mass growth of grasses (van Braeckel and Bokdam, 2002a). Rook *et al*. (2004) concluded that the main mechanism through which grazing animals influence pastures is their dietary selection, which in consequence creates and maintains the structural heterogeneity of pasture swards Treading or trampling creates gaps in the sward and has a positive effect on the establishment of annual and bi-annual species (Van Braeckel and Bokdam, 2002a). Treading of the soil surface creates gaps thus allowing seeds to sprout, which in effect speeds up the growth of grasses, and eventually prevents soil erosion (Warda and Rogalski, 2004). The extent of that impact depends largely on the size of grazing animals and the number of individuals per surface area. For example, Bartoszuk *et al*. (2001) suggest that size is an advantage of using cattle for pasture conservation, as heavy animals prevent the growth of weeds by trampling and disturbing the soil with their hoofs. According to Vavra (2005), grazing animals can protect specific plant seeds by churning the soil and creating mulches which cover them. On the other hand, trampling may reduce stream bank stability and increase soil erosion (Vavra, 2005). The risk of erosion increases when a soil is wet, when animals cut the canopy very short (less than 20 mm) or when stocking rate is too high (Russell *et al*., 2001).

Moreover, the presence of grazing cattle reduced the pressure of small predators on nests and nestlings. The positive effects far exceeded nest losses caused by the cattle themselves (Mazurek 2003). Animal manure plays an important role in creating and preserving biological diversity. The excreta produced by herbivores during grazing act as a natural fertilizer and influence seed distribution. Manure is a rich source of nutritive substances essential for green biomass growth. The dispersal of faces results in species and structural diversity of flora (Peco *et al*., 2006). However, intensive grazing can also cause over-fertilization of pastures, disturbing organic matter and the nutrient circulation balance, thus negatively influencing the biodiversity of a whole ecosystem. For example, a decrease in wader populations on mown and grazed peat grassland is observed when the farmland is drained and heavily manured (Kleijn *et al*., 2001). Possible positive effects of grazing include the removal of dead growth, the opening of the canopy to allow earlier soil warming in the spring, the decreased moisture losses from the plant, the removal of some older leaves that may be infected and the intercept of significant amounts of rainfall (PAI, 2004).

2.4. Importance of grazing for plant species diversity

Grazing disturbance has different effects on native and exotic plants, and on various plant functional groups. Grazing also often favors exotic annual grasses, which have higher growth rates and seed dispersal rates than perennials (Holmes & Rice, 1996). Annuals therefore sustain populations by rapidly dispersing and colonizing open patches, while perennial recruitment is more severely limited by defoliation and trampling (Seabloom *et al*., 2003). Grazing is almost always detrimental to perennial grasses (Milchunas and Lauenroth, 1993). Many exotic perennial species have been shown to be superior competitors than natives, and this competitive advantage may be amplified under grazing pressure (Thomsen *et al*., 2006; Corbin and

D'Antonio, 2009). Exotic perennials have also been shown to be able to colonize more rapidly after disturbance than native perennials. Additionally, grazing is often detrimental to native for species (Hayes and Holl, 2003). Livestock may be effectively used to control exotic invasive perennial grasses, but it may also have a detrimental effect on native species.

3. Cons of Overgrazing

3.1. Effects of overgrazing on vegetation

Botanical composition of the pasture is influenced by the joint effect of several environmental factors. In an experiment, Jones and Bunch (1995) found that the spread of a specific plant species was more affected by the annual precipitation than by the presence of animals. Grazing animals also have an effect on the botanical composition by trampling and selective grazing. Furthermore, animal faces and urine change the element content of soil and plants. Species composition is also influenced by the time of the year that a pasture is grazed. Hyder *et al.* (1975) pointed out that repeated heavy grazing during any particular month in the growing season had approximately three times higher effect on key species as did grazing during the months when plants were senescent.

The way that a plant community responds to a specific grazing pressure depends on the season effect. The area covered by Desmodium spp. decreased as the stocking rate increased; however, the same conditions did not have the same effect in the next year (Aiken, 1990). Moreover, high grazing pressure decreases plant density. However, this may not decrease the total plant production of a given community, because the roots of other plants may simply occupy that space in the soil. These other plant species are often less productive and less palatable, often weedy forbs and brush, which would result in decreased animal productivity (PAI, 2004). According to Pratt (2002), it is important to notice that weeds do not make the land unhealthy; they appear because the land is unhealthy.

High grazing pressure changes the botanical composition of the pasture (Jávor, 1999). Török and West (1996) studied the influence of marked population growth of mouflon on the vegetation composition of 7 rock grassland communities by re-sampling after 30-50 years. The results showed environmental degradation of the communities: the presence of protected plant species decreased and that of degradation indicators increased. The rate of degradation depended on the type of the substrate. Brizuela and Cid (1993) stated that the first signs of overgrazing were a decrease in legumes and an increase in forbs and in bare soil. Similarly to overgrazing, the lack of grazing also has negative impacts on pastures of continental climate, for instance it entails the spread of weed and shrub species (Jávor *et al*., 1999). In an experiment of Longhi *et al*. (1999) species number was higher within ungrazed, fenced areas or areas where topography provided protection from grazing. Moreover, species number was correlated with herbage height, which is an indicator of grazing intensity. On the other hand, Paulsamy *et al*. (1987) found that both protected and grazed sites had equal numbers of species with different floristic composition.

Fuls (1992) claimed that long-term patch-overgrazing induced substantial vegetation retrogression with reductions in basal cover up to 90%. According to Arianoutsou *et al.* (1985), in the absence of grazing pressure the plant cover were 30% trees, 10% tall shrubs and 25% sub-shrubs. Under high grazing pressure the plant cover was mainly low woody shrubs. The grazing of a cattle herd was investigated in our experiment on the pasture of Hortobágy. Bare soil was found at over utilized areas, such as camps for rest, water and salt sources. As a result of the fact that the camps were not moved approximately for one decade the area covered with no vegetation extended to 0.1 hectares. Plant species at the bank of over utilized areas were grazing tolerant, not native and not typical of the land, such as Loliumperenne, Polygonumaviculare and Chenopodium album.

3.2. Effects of overgrazing on soil properties

Increased livestock numbers in arid regions cause overgrazing which results in reduced infiltration and accelerated runoff and soil erosion. Results of several studies indicate that at the macro- and mesoscales soil erosion can increase dramatically due to overgrazing, causing increases of 5 to 41 times over the control at the mesoscale and 3 to 18 times at the

macroscale (Sharma, 1997). Villamil *et al*. (1997) pointed out those inappropriate cattle grazing practices, such as overgrazing harm the quality of natural pastures and soil properties. The soil structural degradation in the upper horizons are approved by high bulk density values, high dry mechanical resistance and low structural stability in comparison with the climax situation. Soil and sward are in close connection, which determines the changes in soil physical, chemical and microbiological properties. This fact is especially true in areas where animals are grazed for a long time (Kátai, 2003). Grassland soils usually have extreme physical and chemical properties as well. Soil microorganisms play a significant role in developing soil fertility. The dominant characteristics influencing the existence and activity of soil microbes are soil water content and storing capacity, texture, size and rate of pores (Kátai, 1994). However, treading may decrease habitable pore space and increase soil bulk density, which negatively affect soil microbes (Kátai, 1998).

Zhang *et al.* (2001) stated that heavy grazing can cause grassland deterioration because of heavy defoliation and treading, and is often used for weed control. Sheep Night Penning, a form of heavy grazing, has developed into a successful method of removing the native vegetation and establishing a new pasture. Results show that high sheep density for a short duration removes almost all of the above-ground natural vegetation, but does not significantly affect the soil bulk density, the penetration resistance, and the air permeability. Jiang *et al.* (1996) also found that sheep nigh penning combined with grazing has eliminated the natural vegetation containing shrubs. The removal of natural vegetation is caused by the fact that the concentrations of ammonium-N and nitrate-N in the soil were high enough to be toxic to plant roots during and after sheep night penning (Zhang *et al*., 2001).

Abril and Bucher (1999) measured the changes in soil characteristics, nutrient availability and microbial activity on sites utilized by different grazing intensities in Argentina. Three sites were selected for comparison: a highly restored (no grazing for 20 years); a moderately restored (8 years of restoration); and a highly degraded (extremely overgrazed). The following parameters decreased as the grazing intensity increased: the soil moisture (4.5 to 2.25%), the organic matter (4.68 to 1.45%), and the nitrogen content (0.28 to 0.14%). Microbial activity ranged from 0.89 at the restored sites to 0.22 mg CO_2/g/week at the highly degraded site. According to Ling Hao *et al*. (1997) an average of 12.4% of the total carbon initially stored in soils (0-20 cm soil layer) has been lost due to overgrazing over the 40-year period. Most carbon loss was from the active and the slow soil carbon pools which had a residence time of decades. Villamil *et al*. (2001) claim that topsoil horizons show a reduction in depth in grazed sites, mainly as a consequence of soil compression caused by animal hooves. They found that total porosity values in the top few centimeters are lower in grazed sites, primarily due to the collapse of macro-pores (>50 μm) and larger meso-pores (50-9 μm). Evans (1996) observed that degradation occurred mostly along fences where often more than half the soil was exposed to trampling and weathering. Similarly, Moles (1992) described that bare soil is commonly found along tracks, for example around gateways or farm buildings where animals concentrate. Most bare soil, sometimes referred to as 'sheet erosion' (Whitlow, 1988) is created by sheep at small breaks of slope where they initiate scars by rubbing against the vegetation (Evans, 1977). Scars have been extended by the constant disruption of the soil surface by hooves, being used not only as scratching posts but also for shelter, so that vegetation cannot colonize and stabilize the surface (Evans, 1977). Tallis and Yalden (1983) also noted in their study that in case the soil surface is continually disturbed by animals during the growing season, the seedling germination and the invasion by plants is inhibited.

Overgrazing means grazing land with livestock in such numbers as to adversely affect the growth, quality or species composition of vegetation on that land to a significant degree (Statutory Instrument, 1996). Overgrazing can mean different things to the glazier and the range manager. For the glazier, it implies that the pasture can no longer carry as many animals as before, or that its productivity has declined so that the performance of the animal either in terms of live-weight gain or offspring reproduction

has worsened. To the range manager therefore: the carrying capacity of a pasture or range is the number of animals of a specified type that can subsist on a unit area and produce at a required rate over a specified period, usually a season, a year, or longer. Overgrazing is believed to be the most important cause of soil degradation worldwide (Oldemann *et al*., 1991), sharing about 35.8% of all forms of land degradation. However, degradation caused by overgrazing is especially widespread in Australia and Africa, where it accounts for 80.6% and 49.2% respectively of all soil degradation, and least extensive in Europe (22.7%) (Warren and Khogali, 1992).

An optimum stocking rate allows grazing animals to produce at the most economical rate (Cowlishaw, 1969). The fact that overgrazing is not a function of animal numbers, but rather a function of time, has to be emphasized. Overgrazing occurs when animals are kept in a paddock too long or brought back too soon, the latter means that a plant is grazed before it has recovered from a previous grazing (Pratt, 2002).

Plant communities are disturbed when animals graze them. Farm animals can make easy the establishment of invasive plants by trampling and defoliating established species, thereby reducing their competitive ability and creating bare patches, and by disrupting nutrient cycles (Dorrough *et al.*, 2004). However, grazing removal also represents a disturbance (Hayes &Holl, 2003). Moderate grazing has been shown to promote community diversity (Fujita *et al*., 2009), and livestock exclusion can result in diversity loss by allowing certain species out-compete other species and establish dominance (Schultz *et al*., 2011).

4. Optimizing Livestock Production and Free Grazing

4.1. Awareness creation

Creating of awareness creation to livestock farmers and experts at different levels through provision of intensive training, experience sharing and visits to successful zero grazing practices, strengthening farmers training centers and development of pilot learning sites as demonstration plots in potential areas is a key for the successful implementation of zero grazing.

4.2. Practice zero grazing and land rehabilitation

Zero grazing is a grazing system that prevents livestock from grazing freely in open pasture. In this system, livestock is confined to a stall and fed with cut and carried fodder (harvested forage plant material) and other types of feed (concentrate, wheat bran etc.). Zero grazing systems help address issues of lack and degradation of grazing land, low productivity of dairy cows, low quality fodder and disease spread between free grazing cattle. It is also the ideal way to maintain improved breeds. Interventions focusing on improving water and soil conversation techniques and reforestation must be implemented on a large scale to revitalize degraded lands. Abatu *et al*. (2009) state with the current condition of the communal grazing lands; the sustainable utilization of the rangeland ecosystems is not possible. Practices like reforestation, soil conservation and water management are also crucial to sustain existing agricultural land.

4.3. Management of grazing animals

Grazing is a key disturbance that shapes the structure and function of grassland communities (McNaughton 1983a, 1985). Structurally, grazing modifies the species composition, richness, vertical profiles, plant traits, and a number of other attributes of grasslands (McIntyre and Lavorel 2001; Rodrıguez *et al*., 2003). Functionally, grazing alters the flow of energy and the cycling of materials, both directly, through defoliation, trampling, and dung and urine depositions, and indirectly, through modification of species composition and species interactions (Hobbs *et al*., 1996). The relationships between a structural trait, species diversity, and a functional trait, primary productivity, is at the core of a current debate within the more general, but also current discussion on the relationship between biodiversity and ecosystem function (Naeem and Wright, 2003). As stated above, grasslands and their grazers provide one of the strongest and widespread cases for studying the relationship among diversity, productivity, and disturbance. Grazing drastically alters plant species composition, particularly in mesic grasslands, and it

also affects above-ground net primary production (Oesterheld *et al*., 1999).

Grazing intensity is a key management variable that influences the structure and composition of pastures. A decrease in grazing intensity is assumed to favor biodiversity as a result of the increased heterogeneity of pastures (Grime, 1979). This has been confirmed by surveys of the changes in the composition of plant (Marriott *et al*., 2004) and animal species (Van Wieren, 1998) in grasslands. Additionally, while there are clear differences between herbivore species of livestock in their grazing behavior and impact on grazed communities (Dumont *et al*., 1995; Loucougaray *et al*., 2004), the breed, sex and age of the animals allowed to graze are often based on anecdotal evidences or at best on empirical studies with limited applicability (Rook *et al*., 2004), with the result that the expected biodiversity benefits are not reaped (Kleijn *et al*., 2001). Traditional livestock breeds are often recommended for grazing management to meet conservation objectives (Tolhurst and Oates, 2001) as, in addition to their adaptation to harsh environmental conditions (D'hour *et al*., 1998).

The degradation of the landscape may be a short-term phenomenon and recovery is possible after grazing pressures have been greatly reduced. This occurs because animal population crash as the vegetation cover is grazed out. This phenomenon can also be found in cold climates where, for example, reindeer have been introduced and thrived until their preferred forage has become grazed out (Leader and Williams, 1988). BCMF (2002) categorized the tools for managing over utilized grasslands. Several studies were carried out about bio-indicators of overgrazing. Read (2002) suggests reptiles as bio-indicators of the initial effects of heavy cattle grazing in a South Australian chenopod shrub land. Paton *et al.* (1997) conducted a regression for usage of grasslands by cattle for Spanish environmental conditions in which a plant species (Plant ago major) was used as a bio-indicator.

4.4. Livelihood diversification

Livelihood diversification can also aid in decreasing pressure on grazing lands. Industries such as tourism and non-agricultural livestock related businesses can alleviate pressure on Ethiopia's grazing land and natural resources.The cultural mindset throughout Ethiopia equates livestock with wealth, and prioritizes quantity vs. quality. As households continue to engage in diversified industries and are able to improve their income and quality of life, livestock's association with wealth will gradually decrease.

5. Conclusion

Livestock grazing in Ethiopia is mainly based on extensive grazing of communal grazing lands and arable lands. Animals grazing communal lands are believed to perform poorly which is a reflection of nutrition, health and breeding related problems. Animal grazing is a natural process of forage utilization, because herbivores produce in the environment where evolution formed them. This is the most appropriate, low cost tool for meat production. A significant portion of world grasslands are over utilized by livestock. Although a parcel of land is not overgrazed there are some parts where signs of degradation can be found. These special areas are attractive for ungulates because there is water, supplement and salt sources, camps or shelters. Overgrazing has detrimental effects on soil and vegetation but changes are reversible. High grazing pressure decreases plant density, changes botanical composition, and often accelerates the invasion of unpalatable species. Moreover, overgrazing increases area covered by no vegetation, reduces infiltration, soil moisture and fertility, accelerates runoff and soil erosion, increases soil bulk density, penetration resistance, soil ammonia and nitrate content and changes soil microbial activity. Nevertheless, all these negative impacts can be prevented and/or reversed by proper grassland management practices. Strategies of grazing land management such as grazing management, treatment of crop residues and livelihood diversification are the methods to reduce the negative impact of free grazing and use the grazing land properly in Ethiopia.

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