



Biodiversity and Soil Property Variation Under Coffee-Enset-Based Agro forestry System And Land Affected By Gullies Along The Topo-Sequence In Southern Ethiopia

Haile Ketema; Mulugeta Sisay* & Mesfin Boja,

* Corresponding author <mamuler@gmail.com>

Dilla University, College of Agriculture and Natural Resources, P.O.Box 419

ABSTRACT

With the objectives of investigating and quantifying farmer's attitude and gully development in relation with biodiversity and soil property variation along topo-sequence in coffee-Enset based agroforestry system, two land units: Land with agro-forestry system (LWAGS) and Land with Gully Erosion (LWGE) under three slope categories (Upper, Middle and Lower slope) were selected in Southern Ethiopia. A household survey was conducted, supplemented with focus group discussions (FGDs), key informant interview and field observations. Concerning the soil, a total of 48 composite soil samples (4 replication _ 2 land units _ 3 slope categories _ 2 soil depth layers: 0– 15 cm and 15–30 cm) were collected to analyze soil physic-chemical characteristics. In addition, 48 undisturbed core samples were also collected to determine soil bulk density ($g\ cm^{-3}$). To determine species richness and evenness Shannon-Wiener's index and Simpson's index were used. Simple counts of naked eye soil macro-fauna (NMF) was also collected just to infer about the biological properties of the soil. The results showed that farmer's attitude was the major contributor for the expansion and developments of gully erosion in the study area. Tree cutting from the agro-forestry system was the main pressing causes of gully development in the agro-forestry system. Concerning the soil, the study revealed that Higher values of SMC (%), P_t (%), V_e (%), SOC (%), EC (μs), pH and naked eye macro-fauna were observed on land units with Coffee-Enset based agroforestry system. However, soil bulk density was higher on land units with gully erosion. SMC (%), B_d ($g\ cm^{-3}$), P_t (%) and V_e (%) were significantly varied with slope percent ($P < 0.001$), Land Units ($P = 0.001$, $P < 0.001$) and Soil Depth ($P < 0.001$), respectively. The soil pH was significantly ($p = 0.04$) affected by land unit. Soil Electrical Conductivity (EC μs) significantly varied with slope percent ($P = 0.045$) and land units ($P < 0.001$). SOC (%) significantly varied with land units ($p < 0.001$), slope percent ($P < 0.001$) and soil depth ($p < 0.001$). Naked eye macro-fauna was varied significantly ($P < 0.001$) with respect to land units and soil depth. On the other hand, in terms of species richness and diversity, LWGE has got the highest value than LWAGS. Soil bulk density and soil moisture content (SMC) increased while total porosity (P_t), Void ratio (V_e), number of macro-fauna and soil organic carbon (SOC) decreased with soil depth in both land units. However, the close management system of coffee-Enset based agroforestry system has contributed for minimum values of species richness and diversity. Thus, reducing the pressure as a result of anthropogenic effect and rehabilitating gullies through either physical or biological measures would help to improve the soil quality as well as the biological diversity.

KEY WORDS: Coffee-Enset based agroforestry; Farmer's Attitude; Gully Erosion; Soil Macro-fauna; Biodiversity.



39 1. Introduction

40 Global concern has increased over soil degradation as a result of soil erosion and their potential impact on
 41 climate change over the past decade (Valentin *et al.*, 2005; Fantaw *et al.*, 2006). As a result, each country
 42 has designed and launched a mitigation strategy through implementing appropriate land use planning and
 43 increasing the awareness of the people about tree planting in the form of agro-forestry system. As it is
 44 stated by different authors (for instance; Wasson *et al.*, 2002; Krause *et al.*, 2003; de Vente *et al.*, 2005;
 45 Huon *et al.*, 2005; Kumar *et al.*, 2012; ENSAP, 2013), soil degradation affects soil properties (physical,
 46 chemical and biological), biological diversities, food and fiber production, local climate and lastly the
 47 human being as a whole. Among the different cause soil degradation, soil erosion as a result of human
 48 impact takes the line share (Belay, 2000). According to ENSAP (2013), among soil erosion types; gully
 49 erosion has been recognized as an important environmental threat throughout the world affecting several
 50 soil and land functions. In connection with the above idea, Wood (1990) and Poesen (2011) have stated
 51 that, there are ample physical evidences of intense gully erosion occurrences spatially as well as
 52 temporally in different part of the world.

53 Ethiopia is one of the most environmentally troubled countries in the sub-Saharan belt. Gully erosion
 54 phenomena and its effects are very common in the country. It affect large areas with different
 55 morphological, pedological and climatic characteristics (Billia and Dramis, 2003). Land degradation in the
 56 form of soil erosion, gully formation, soil fertility loss and severe soil erosion are the principal
 57 environmental problems in Ethiopia (Wagayehu, 2003). Large parts of the countries highland areas are
 58 severely eroded. On the other hand, however, majority of Ethiopian population derives its livelihood from
 59 agriculture sectors. This is to mean that under subsistence agriculture in both densely populated highlands
 60 and sparsely populated lowland areas of the country, survival is solely linked to the exploitation of land
 61 (World Bank, 2003). Agricultural land subjected to poor land use management and lack of appropriate soil
 62 and water conservation leads to loss of agricultural soil which the country highland areas are well known
 63 off. In Ethiopia many contributing factors have been observed for gully erosion occurrence (Valentin *et al.*
 64 *et al.*, 2005). Farmer's attitude has played a vital role and takes the line share as being part of gully erosion
 65 contributors (Govers *et al.*, 2004). Farmers have been incurring cost as a result of not taking measures at
 66 the infant stage of gully erosion. On the other hand, being ignorant about what has been occurring on their
 67 farm (this is a typical scenario of the study area) has also contributed for the occurrence of gully erosion.
 68 In addition, as stated by Valentin *et al.* (2005), farming system, topography (Bale *et al.*, 1998), local
 69 hydrology and land use system of the area becomes the main factors that either limit or exacerbate gully
 70 erosion (Kakembo and Rowntree, 2003; Rajot *et al.*, 2003).

71 In spite of the great deal of soil and water management schemes undertaken aggressively by Ethiopian
 72 government in the last two decades to reduce soil erosion and their by maintain the productivity of
 73 biological diversity, gully erosion is still recognized to be a serious threat to the biological life's and to
 74 national economy in larger scenario (Ananda and Herath, 2003; Tamane, 2005). Currently, it is possible
 75 to see some patches of gullies even in an area where one has not expected it before in the agroforestry
 76 system. Here, anthropogenic causes are the main contributing factors for gully formation in the study area.



According to SLUF (2006), *Gedeo Zone* land use assessment has shown that there are three basic agroforestry systems (Enset based, Coffee-Enset based and Coffee-Fruit crops based) being continuously practiced by the farmers. Farmers have been practicing these basic agroforestry systems for long years as a cultural manifestation in the study area (Tadesse, 2002). Although farmers have been practicing these basic agroforestry systems, the focus of this research was only on Coffee-Enset based agroforestry system. The farmer had strong relationship and attachment with their agroforestry system. However, in recent years the tie between the people (specially the youth) and agroforestry practice becomes weak and non-responsive as a result of change in social, economic, and cultural phenomena of the area (Abiyot *et al.*, 2013). As a result, land use/land cover change becomes a common phenomenon as it was associated with population growth and remarkable depletion of forest cover. Human population density is very high in the study area. This high population was become a serious problem in the study area as it seriously affect the vegetation cover of the area. Based on the current rate of tree cutting in the agroforestry system, it is possible to speculate the fate of biological diversity and the fertility status of the soil. The cover change has triggered the newly emerging gully channels and landslides in coffee-enset based agroforestry system of the study area. Though the study area is well known in its regenerative capacity (Abiyot *et al.*, 2013), the intervention of human being through tree cutting in the agroforestry system has triggered the formation of gully channel and landslides in the study area (physical observation and farmer's response). The problem is becoming more serious in recent years demanding immediate responses of concerned body.

Toposequence and the associated management of land unit and biodiversity can influence soil properties in localized area, though the amount of influence and changes could be varied depending upon the extent of human management and geomorphic influence. Therefore, understanding such inclusive and versatile interaction on the soil would have a meaningful concern on the soil properties of the area. On top of this, more importantly, the outcome of understanding and evaluation of the overall situation of the biodiversity and soil properties as influenced by coffee-enset based agroforestry system and gully under localized anthropogenic and geomorphic variables would help for designing sustainable agricultural and landscape management in the area. Previous studies conducted in the area (Tadesse, 2002; Wendemeneh, 2010) were less adequate and didn't consider the topo-sequential interaction of coffee-enset based agroforestry system and gully on biodiversity and soil properties. In line with this, the magnitude and pattern of biodiversity and soil properties variation within the two land units is still unanswered. Moreover quantitative evidences are very important for determining the type and extent of future land management in the area. So therefore, this study was intended to investigate the plant biodiversity and soil properties variations under coffee-enset based agroforestry and land with gully erosion along the toposequence in southern Ethiopia.

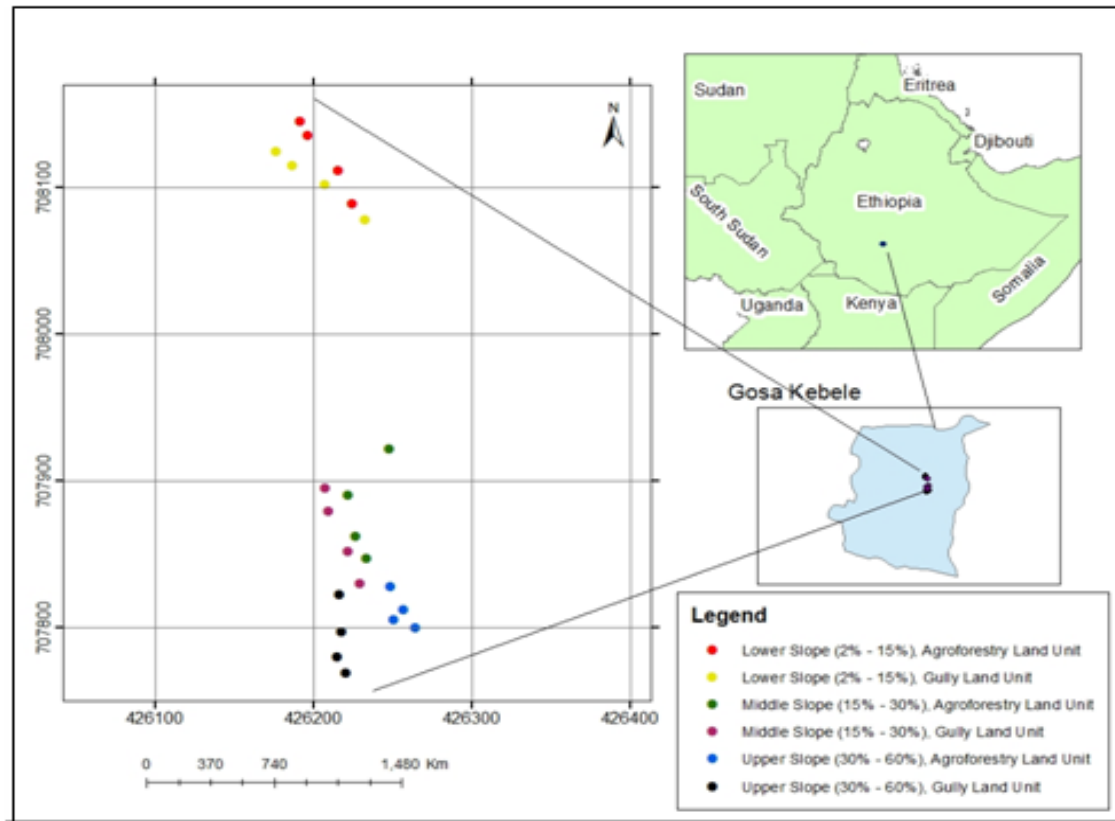
2. Materials and methods

2.1 Description of the study area

The study was undertaken in Gola *kebele*, Dilla Zuria District, *Gedeo Zone*, Southern Ethiopia (Figure 1). It is about 365 km south of Addis Ababa and about 90 km south of Hawassa; capital city of SNNPRS.

114 Astronomically, it extends from $68^{\circ} 18' 11''$ to $68^{\circ} 25' 32''$ N latitude and from $38^{\circ} 17' 40''$ to $38^{\circ} 23' 43''$
115 E longitude. The altitude ranges from 1450 m to 1800 m above sea level (Haile and Fantaw, 2014).

116



117

118 Figure 1: Location Map of the Study area

119 The study area is characterized by a bimodal rainfall distribution with a maximum between March to June
120 (main rainy season), and a relatively minimum rainfall between August and October (Figure 2). The mean
121 annual temperature was 20.7°C , while the mean monthly temperature ranges from 20.1 to 21.9°C .

122

123

124

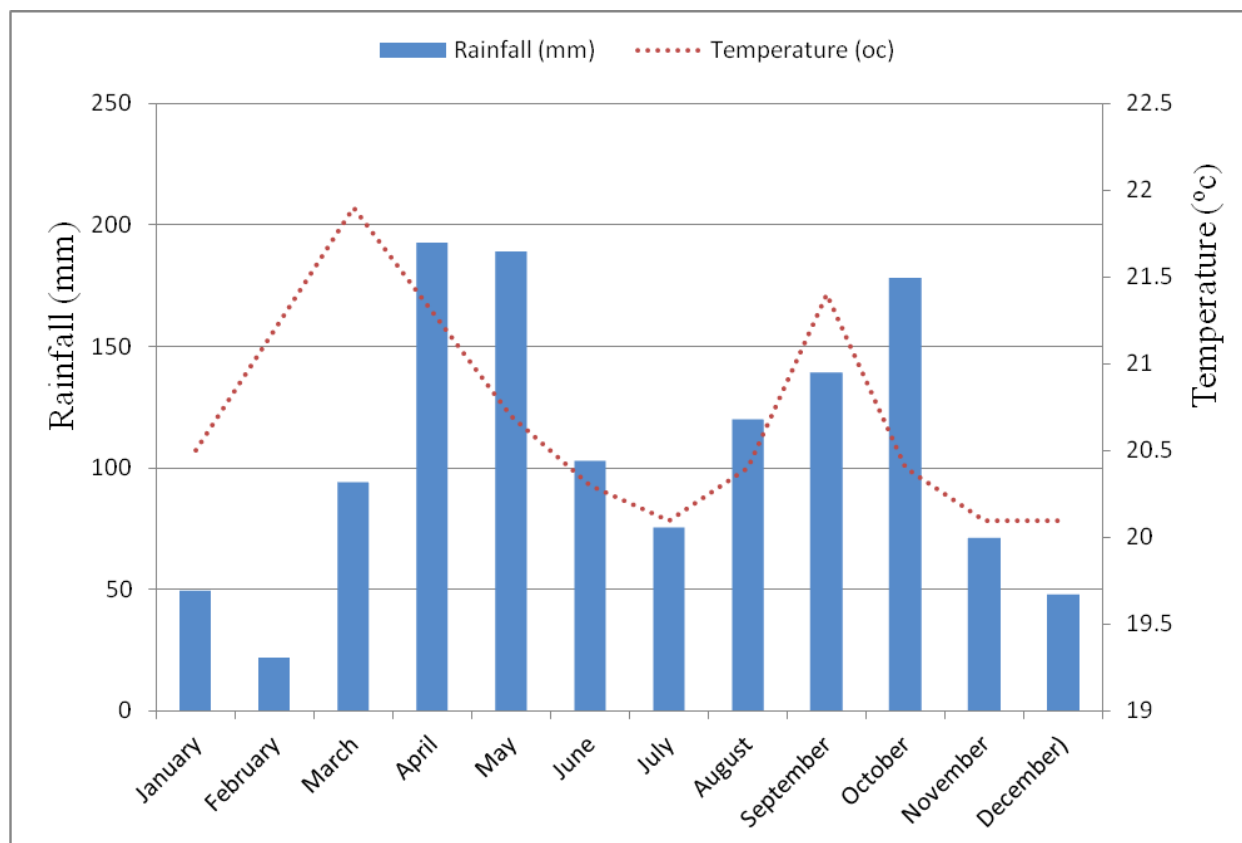


Figure 2: Mean monthly rainfall and temperature of the study area.

The dominant soil type in the study is chromic Luvisol (Wendemenneh, 2010), with dusky red (2.5 YR 3/2, moist) to dark brown (7.5 YR 3/2, moist) surface horizon; and dark reddish brown (2.5 YR 3/4, moist) to reddish brown (5 YR 4/4, moist) subsurface horizon. Its surface horizon is also characterized by a granular to crumb structure, porous and well aerated with good internal drainage potentials that can be suitable for a wide range of agricultural uses. It has an argillic B (B_t) horizon due to higher accumulation of clay compared to the overlying surface horizon.

The land use system in the study area is a mixture of agroforestry, forestry, grazing land, crop farming and others (Table 1). Agroforestry system is the common type (which cover around 90% of the total land area) of land management practice in the study area. The study area has a long history of traditional land use management and hence it is assumed that their indigenous knowledge has a long history (Tadesse, 2002; Abiyot *et al.*, 2013).

Table 1: Land use of the study area

N ^o	Types of land use	Area Coverage (ha)	Percentage (%)
1	Agro-forestry land	758.5	90
2	Forest land	5	0.594



142	3	Grazing land	5	0.594
143	4	Others	72.5	8.62
144		Total	841	100

145 Source: Dilla Zuria Woreda Agricultural Office, 2014

146 Among the many manifestation of their IK, the traditional agroforestry practices are the prominent. The
147 traditional agroforestry system has been known to be an exemplary land-use system in the study area
148 (Tadesse, 2002; SLUF 2006). However; currently, the culture of managing the agro-forestry system by the
149 local people becomes weak year after year. One reason for weak appearance of managing the agro-
150 forestry system in the study area is due to weak IK transmission from older generation to young people
151 (Abiyot *et al.*, 2013). It is becoming a common phenomena to see that most young people who travel to
152 towns on a daily basis to attend school, look for work, or sell farm products are no longer interested in
153 traditional values and norms or do not have the opportunity to learn about them. Consequently, it is
154 becoming harder for older generations to transmit their knowledge to young people (Grenier, 1998). As a
155 result of the above concepts, currently, tree cutting from the agro-forestry system for the purpose of timber
156 and fuel wood by the young generation is one of the manifestations of weak IK transmission by old people
157 in the study area.

158 The study area is dominated by undulating topography which could play a role for gully and landslide
159 formation. The problem of gully formation could further been exacerbated when the undulating
160 topography is combined with high population density (Tadesse, 2002) in the area. Therefore, as a
161 consequence of tree cutting and undulating topography in the agro-forestry system, gullies and landslides
162 were observed in the study area. Among the many areas affected by gullies and landslides in Gedeo Zone,
163 Golla *kebele* is one of the most severely affected areas.

164 The gully was formed in the study area 15 years before (own survey, 2014). It has an average width and
165 depth of 5.1m and 3.65m, respectively. Off course, the gully that was already formed is considered as an
166 active gully which contributes for the loss of large soil masses and depletion of basic natural resources in
167 the area (own observation).

168 Concerning the population of the study area, there were 1200 households in the *kebele* out of which 900
169 and 300 were male and female headed respectively. Agricultural activities in the *kebele* include both crop
170 production and animal fattening (mixed farming system). Cofee and enset are the dominant perennial
171 crops. Apart from this trees (*Carissa edulis* Forssek, *Citrus aurantifolia* Christm, *Cordia Africana* Lam,
172 *Syzygium guineense* Willd, *Ficus sur*) are dominantly grown in the area. Annual and seasonal crops such
173 as maize (*Zea mays*) and sweet potato, Banana (*Musa X paradisiaca* L.), and *Rhamnus prinoides* L Herit
174 are among the dominant. Traditional agro-forestry based conservation tillage is also the most common
175 farming practice in the study area.

176 2.2. Household, Soil sampling and laboratory analyses



Two land units [Land with agro-forestry system (LWAGS) and Land with Gully Erosion (LWGE)], hereafter referred to as “land units” both under upper, middle and lower slope category were selected along the topo-sequence. The upper slope ranges from 30-60 percent, the middle ranges from 8-30 percent while the lower slope ranges between 2-8 percent. Soil sampling points were allocated based on the principles of Anderson and Ingram (1993). Based on this method, long transect line was laid along the slope direction for the sake of minimizing experimental errors or reducing biasness in taking soil sample. The two land units were contiguous and have similar environmental conditions except their differences in the land feature and practices.

A total of 48 soil samples (2 treatments _4 replications _3 slope categories _2 soil depth layers 0-15 cm, 15-30cm) were collected using randomized complete block design (RCBD) with factorial design for laboratory analysis. Prior to laboratory analysis, the soil samples were air-dried at room temperature, crashed, and passed through a 2 mm diameter sieve. Undisturbed soil samples were also collected separately using core samplers from each soil depth for the determination of soil bulk density.

Total porosity (P_t %) and void ratio (V_e %) were determined according to Oguike and Mbagwu, (2009) assuming a particle density (P_d) of 2.65 g cm^{-3} . Soil bulk density was determined after an oven drying at 105°C for at least for 24 hr. The gravimeter soil moisture content (SMC, %) was calculated following the method described by Cuenca (1989). Soil pH was determined following the methods employed by Meclean (1982). Soil electrical conductivity (EC) was also determined following the standard of soil water suspension as described by Nelson and Sommer (1982). Soil organic carbon was determined following the method employed by Walkley and black method (Schnitzler, 1982).

The number of observable or naked eye soil macro-fauna was determined and sampled using the standard Method of Tropical Soil Biology and Fertility Programme (TSBF) handbook of methods (Anderson and Ingram, 1993). The soil macro-fauna were collected from $25 \times 25 \text{ cm}$ area of square soil monolith following the topo-sequence and the soil depth from both land units.

A total sample size of 60 (5 %) out of 1200 households were selected using simple random sampling techniques. General meeting (discussion) was made with the surrounding community members for understanding of the overall situation of the gully problem in the area. Focus group discussions (FGD) were also conducted with ten members (selected on the basis of their experiences on gully management in the area) of the local community. Moreover, 6 (six) key informants were also selected based on the length of time they had spent living in the local area (two key informants from each slope category). The selection of these key informants was carried out using snowball method.

The qualitative and quantitative data collected were organized and summarized using case summery and descriptive statistics. The result was described and depicted by using tables. Laboratory results were analyzed using General Linear Model (GLM) procedure of SPSS version 16.0 for windows (SPSS Inc., Chicago, USA). Analysis of variance (ANOVA) was employed to test the degree of variations. Tukey's Honest Significance Difference (HSD) test was used when the mean separation showed statistically significant differences ($p < 0.05$).

2.3. Vegetation survey

In each landscape position (upstream, midstream and downstream) woody plant data were collected by laying 400m² (20m x 20m) plots following transect lines, which were laid 300 m apart along the toposequence. The vegetation data were collected following the International Forestry Resource and Institutions Research (IFRI) methodology (Ostrom 2007). During data collection tree diameter at breast height (DBH) were measured using caliper and diameter tape. The later was used for tree diameter above 100 cm and tree heights were measured using clinometers. Individuals with DBH ≤ 2 cm and height ≤ 2 m were counted as follows: seedlings, height ≤ 1 m and saplings, height > 1 m and DBH ≤ 2 cm (Abayneh *et al.*, 2003). Saplings and seedlings were counted by laying 10mX10m plots within each plot. Plant specimens were prepared and brought to Dilla University, where the identification was made.

2.4 Species diversity analysis

Species diversity is the combination of species richness and evenness. Shannon-Wiener's index and Simpson's index are the two most commonly used diversity measure indices.

Shannon-Weiner Index (H')

Shannon-Weiner Index used to characterize species diversity in a community. The Shannon-Weiner Index (H) and Shannon evenness (E) indices are calculated as a measure to incorporate both species richness and species evenness (Magurran, 2004). The value of Shannon-Weiner Index usually falls between 1.5 and 3.5 and rarely surpasses 4.5 (Magurran, 1988). A rich ecosystem with high species diversity has a large value for the Shannon Diversity Index (H'), while an ecosystem with little diversity has a low H'. The Shannon-Weiner index (H') was calculated from the equation:

$$H' = - \sum_{i=1}^S p_i \ln p_i \dots\dots\dots 1$$

Where, H' = the Shannon Diversity Index

P_i = is the proportion of individuals found in the i^{th} species

S = total number of species (1,2,3.....n)

Shannon evenness (E)

Evenness compares the observed distribution with the maximum possible even distribution of the number of species in the studied area (Pielou, 1975) or it is the distribution of individuals among the species in a studied area. Evenness is maximum when all the species have same or nearly equal number of individuals. The Shannon evenness index (E) was calculated from the ratio of observed diversity to maximum diversity using the equation.

$$E = \frac{H'}{H'_{\max}} = \frac{\sum_{i=1}^S p_i \ln p_i}{\ln S} \dots\dots\dots 2$$



Where, E= Equitability (evenness) index which has values between 0 (a situation in which the abundance of all species are completely disproportional) and 1 (all species are equally abundant).

H' = the Shannon Diversity Index

H'_{max}= is the maximum level of diversity possible within a given population

P_i = is the proportion of individuals found in the ith species

S = total number of species (1, 2, 3.....s)

Simpson's Index (D)

Another group of diversity indices are weighted by abundances of evenness of the commonest species and are usually referred to as either dominance of evenness measures (evenness and dominance are two sides of the same coin) (Magurran, 2004). Simpson's index reflects the dominance because it is more sensitive to the most abundant species than the rare species. Simpson's index was calculated as:

$$D = \sum_{i=1}^s \frac{n_i(n_i-1)}{N(N-1)} \dots\dots\dots 3$$

Where n_i= the number of individuals in the ith species; and N= the total number of individuals. D ranges between 0 (represents infinite diversity) and 1(no diversity) i.e as D increase diversity decreases. This is neither intuitive nor logical, so Simpson's index is therefore usually expressed as 1- D or 1/D (Magurran, 2004). Therefore, Simpson's index was calculated as follow:

$$D = 1 - \sum_{i=1}^s \frac{n_i(n_i-1)}{N(N-1)} \dots\dots\dots 4$$

Here high D value suggests a stable and ancient site, while a low D value could suggest a polluted site, recent colonization or agricultural management (<http://www.countrysideinfo.co.uk/simpsons.htm>) or a forest with low diversity.

Sorensen's similarity Index (Ss)

The degree of similarity between any two sites (in this case agro-forestry and areas affected by gully within the system) was compared using similarity index that depends on species common to both stands. Sorensen's index is the common similarity measurement index, which ranges from zero (no species in common) to 1 (identical set of species) i.e the higher the value of the index the more similar will be the stand to each other. It was calculated with the following formula (Magurran, 1988):

$$S_s = \frac{2C}{(2C + A + B)} \dots\dots\dots 5$$

Where, Ss = Sorensen's similarity index)

A = number of species in coffee-based agro-forestry system,

B = number of species in areas affected by gully erosion within the system,

C = number of species common to both.



3. Result and discussion

3.1 Socio economic characteristics of the study area

The interviewed respondents were nearly all males (85%) with ages ranging from 18 to 45 years (75%) old with an education status that ranges from illiterate (65%) to grade 8 and more. In addition, 75% of the respondents were fully engaged or depend on the agro forestry system for their livelihood. Moreover, 45% of the respondents had family size of 6-8 people with land size of 0.25-0.5 ha per household in the study area. It is observed that female respondents were less in number in the study. In the study area, majority of field works were carried out by males and as a result, females became less familiar with the day-to-day agricultural activities in the study area. Instead of working in the agroforestry system, females could prefer to support their family with income from off-farm activities such as Merchants. Female participation on protection and conservation of soil in the study area was very small. Less participation of females could be mainly due to a lot of household activities and responsibilities (child care, food preparation, marketing and collection of firewood). Moreover, Gully erosion protection and conservation works usually require construction of check dams, different terrace and other types of heavy duty works that women are less likely to perform in the study area. Less participation of females in different land management activities were also reported by Mulugeta (2014) in the study made in Central Ethiopia. Another reason is that, women are less mobile due to cultural influences, and this could affect them to access information on different land management activities. Similar finding were also reported by Daniel (2002), Tilashwork, (2009) and Mulugeta and Kindu, (2013) where involvement of women in soil and water conservation activities has in general been low in the majority of Ethiopia. However, this finding was in contrary with the findings of Solomon *et al.* (2014) where majority of women in the plateau state of Nigeria were involved in farming and contributed significantly to land/soil conservation.

3.2 Attitude of the Farmers towards development of gullies in agro-forestry system

All respondents of the study area regarded the agro-forestry system as the main source of their livelihood needs such as fuel wood, fodder, medicinal plants, non-timber forest products, timber and complimentary food. Besides meeting biomass needs, a sizeable proportion of the respondents also admitted to their economic dependence on the system. However, currently, the function and service that has been delivered so far by the agro-forestry system becomes less and less in the study area. Significantly, a large proportion of the respondents (70%) stressed that the formation and development of gully is because of decrease in potential capacity of agro-forestry system in the area (Table 2). On the other hand, currently, the local farmers have become reluctant to maintain the gully using conservation measures in the agro forestry system.

Table 2: Farmer's Attitude for activities in the study area

N ^o	Farmer's attitude	SA		A		D		SD	
		N ^o	%	N ^o	%	N ^o	%	N ^o	%



311	1	The habit of tree planting in	13	21.6	45	75	2	3.3	-	-	AFS is
312		decreasing from year									year in the study
313		area									
314	2	Tree cutting without replacing in	15	25	40	66.7	5	8.33	-	-	the AFS
315		is more common in the									study area recently
316											
317	3	Gully erosion is one of the main	10	16.6	42	70	7	11.6	1	1.66	problems
318		of the AFS in the area									
319	4	IK transmission from father	50	83.33	10	16.67	-	-	-	-	to child is
320		decreasing in the									study area.
321											

322 SA = Strongly Agree, A = Agree, D = Disagree, SD = Strongly Disagree

323 Farmers were unwilling to take responsibility for making check-dam and other conservation works for
 324 restoring gullies, unless they are told to do so and even sometimes want to be paid for the maintenance of
 325 gullies which is a serious problem that should be tackled. Waiting for external body (government and
 326 NGOs) for maintaining and restoring gullies has made the gully to continuously expand both in depth and
 327 width in the study area. Most local farmers believe that the maintenance and restoration of gully should be
 328 carried out by government or safety net program. As a result, they couldn't undertake satisfactory action so
 329 far on maintaining the gully. This finding is in agreement with the findings of Daniel (2002). In addition
 330 to their attitudes (farmers), tree cutting for different purpose from the agro forestry system could have
 331 positively contributed for gully development in the study area. As it was depicted in table 3, 66.7% of the
 332 respondents have strongly agreed that tree cutting is the cause of gully development in the area. For this,
 333 the species richness illustrated under section 4.2.4 in the area showed evidence of a gradual decline of
 334 trees from the agro-forestry system.

335 On the other hand, the habit of tree planting in the agroforestry system is decreasing from year to year in
 336 the study area. Around 75 (%) of the respondents have agreed with the assertion that there was a decreased
 337 habit of tree planting in the study area. Moreover, weak transmission of indigenous agro-forestry
 338 management knowledge (Abiyot *et al.*, 2013) among the successive generational groups intensifies the
 339 problem of gully development. Additionally, high population density in the study area resulting from
 340 continuous land relocation by elders for their children were also hastens the development of gullies with
 341 different dimension following the topo-sequence (upper, middle and lower slope).

342 3.3 Cause and rate of Gully Erosion in the study area

343 The sampled respondents identified seven major causes for gully development in the agroforestry system
 344 and were ranked according to their contribution in the study area (Table 3).

345 Table 3: Causes of Gully erosion in the study area.

346	N ^o	Causes				Frequency Rank					Sum of the three			
347											top ranks	Rank order		
348	1	2	3	4	5	6	7							
349	1	Tree cutting				5	4	4	3	3	1	2	13	1
350	2	Population											pressure	5
351	5	-	3		4	1	1		10		3			
352	3	Road												
353		construction				4	4	1	-	-	3	2	9	4
354	4	Steepness of												the slope
355		4	6	2	1	2	-		1		12	2		
356	5	Nature of												the soil
357		2	-	1	4	-	2		1		8	5		
358	6	Improper												land use
359		2	-	1	4	-	2		1		3	7		
360	7	Rainfall				5	1	1	4	2	-	-	5	6
361	Total				60									

Among the seven major causes of gully erosion mentioned in the table, sampled respondents strongly agreed that tree cutting or deforestation is the principal cause of soil erosion in the study area. This is due to cutting of trees for different purposes like for fire wood, construction of house and for commercial (timber) purpose. This is in agreement with the findings of Daniel *et al.* (1994). According to the result from our trend analysis the gully is starting its development before the last 15 years. It's typical nature has a variable width along the topo-sequence in the study area (Table 4). The width of the gullies becomes very wide at the upper slope category while it becomes very narrow at the lower slope in the study area. Generally, based on the dimension of the gully, 6.31t ha⁻¹ year⁻¹ soil was removed from the study area.

Table 4: The dimension of gully measured beginning and end of one rainy season.

Evaluation Period (2014)	Gully Description	Measurement
Beginning of rainy season	Length (m)	500
	Average Depth (m)	3.65
	Average Width (m)	5.1
	Volume (m ³)	9,307.50



376	End of rainy season	Length (m)	500
377		Average Depth (m)	4.2
378		Average Width (m)	5.5
379		Volume (m ³)	11,550
380	Volume change in %		24.1%

381 **3.4 Soil physical and chemical properties along the topo-sequence**

382 **3.4.1 Soil physical properties**

383 **3.4.1.1 Soil moisture content (SMC %), bulk density (Bd g cm⁻³), total porosity (P_t %) and void ratio** 384 **(V_e %)**

385 The study revealed that SMC (%), Bd (g cm⁻³), P_t (%) and V_e (%) were significantly varied with slope
386 percent (P<0.001, Table 5), land Units (P = 0.001, P<0.001, Table 5) and Soil Depth (P<0.001, Table 5)
387 respectively. The combined effect of slope percent (SP %) and Land Unit (LU) were significant on Soil
388 moisture content (P= 0.006, Table 5) and all the rest had statistically insignificant effect on the soil
389 physical properties of the study area. The overall mean of SMC (%) was higher in Land with agro-forestry
390 system (LWAGS, Table 6) than in Land with Gully erosion (LWGE, Table 6). Higher SMC (%) was seen
391 on land unit with agroforestry system.

Table 5: Summary of ANOVA for SMC (%), BD (g/cm³), SOC (%), V_e (%), NMO (simple count), pH (H₂O), P_t (%) and EC (μs) of the soil.

Source of Variation	df	SMC		BD		SOC		V _e		NMF		pH		Pt		EC	
		MS	P	MS	P	MS	P	MS	P	MS	P	MS	P	MS	P	MS	P
SP	2	41.16	<0.001	0.13	<0.001	0.67	<0.001	5847.3	<0.001	93.34	0.41	0.053	0.44	187.74	<0.001	295.96	0.045
LU	1	62.82	0.001	0.15	0.001	11.51	<0.001	5836.2	<0.001	3870.02	<0.001	0.28	0.04	208.46	0.001	1872.5	<0.001
SD	1	251.13	<0.001	0.28	<0.001	1.81	<0.001	12025.7	<0.001	1485.19	<0.001	0.001	0.91	399.1	<0.001	39.97	0.504
SP*LU	2	25.75	0.001	0.02	0.24	0.25	0.004	332.15	0.39	63.15	0.53	0.46	0.002	24.99	0.24	171.26	0.16
SP*SD	2	2.08	0.62	0.003	0.804	0.084	0.114	363.89	0.35	30.06	0.74	0.09	0.241	3.44	0.81	91.5	0.36
LU*SD	1	0.006	0.97	0.05	0.87	0.264	0.04	83.48	0.62	927.52	0.004	0.031	0.49	0.41	0.88	92.1	0.076
SP*LU*SD	2	6.54	0.234	0.02	0.24	0.116	0.05	756.29	0.12	21.65	0.801	0.002	0.97	23.83	0.25	136.17	0.226
Error	36	4.32		0.012		0.04		340.76		97.20		0.062		16.61		87.79	
Total	48																

LU = Land unit, SD= Soil depth, SMC = Soil Moisture Content, BD = Bulk Density, SOC= Soil Organic Carbon, P_t = Total Porosity

Moreover, the SMC (%) was increased along the topo-sequence and soil depth. The higher soil moisture content was observed at the lower slope (2-8 slope percent) and at the bottom soil depth (15-30 cm) in both land units (Table 6). The higher soil moisture content in land with agro-forestry system (LWAGS) was resulted from the presence of higher SOC (%) content, less evaporation as a result of cover and due to less soil disturbance (Boffaa, 2000; Hailu *et al.*, 2000; Panday *et al.*, 2000 and Oguike and Mbagwu, 2009). Furthermore, the formation of stable soil aggregates in LWAGS has contributed for the presence of higher SMC in the soil (Mosaddeghi *et al.*, 2000; Romaneckas *et al.*, 2009; Tigist Oicha *et al.*, 2010). Previous studies (e.g. He *et al.*, 2009; Rajeswari *et al.*, 2009; Tripathi *et al.*, 2009) have also demonstrated that litter fall and crop residue that act as mulches can effectively reduce moisture evaporation from the soil, reduce surface runoff and further keep the soil moisture longer. The higher SMC (%) at the lower slope percent was attributed to the presence of soil deposition as a result of erosion effects coming from the middle as well as upper slope area especially on land with gully. It is obvious that soil erosion results in soil deposition at the lower slope so that the soil thickness automatically enriched and hence soil water holding capacity (WHC) also increased. The lower SMC at land with gully (LWGE) was due to the presence of less/no land cover and lateral subsurface flow associated with discontinuous permeability of the soil profile and hence there was higher evaporation from the soil. Moreover, the soil disturbance as a result of long year erosion (evidenced with respondents view) was also resulted in very thin soil with minimum SOC (%) in the study area. This result was in agreement with results of Haile and Fantaw (2014).

Table 6: Soil moisture content (SMC, %), bulk density (Bd g cm⁻³), Total Porosity (Pt %) and Void ratio (V_e %) in relation to soil depth (cm), land units and slope categories (Mean±SE).

Variables	Land Unit ^a	Soil Depth (cm)	Slope Categories			
			Upper	Middle	Lower	Overall
SMC	LWAGS	0-15	35.04(±0.99)	32.37(±0.66)	32.22(±22)	33.21(±0.77) ^a
		15-30	39.71(±1.63)	35.71(±0.35)	37.31(±0.88)	37.58(±0.75) ^b
		Overall	37.38(±1.25) ^a	34.04(±0.72) ^b	34.77(±1.34) ^a	
	LWGE	0-15	30.41(±1.16)	28.06(± 0.86)	34.23(±0.82)	30.90(±0.91) ^b
		15-30	35.98(±0.67)	33.47(±0.75)	36.49(±0.94)	35.31(±0.57) ^a
		Overall	33.19(±1.22) ^b	30.76(±1.15) ^a	35.35(±0.72) ^b	
Bd	LWAGS	0-15	1.04(±0.09)	1.05(±0.12)	0.89(±0.29)	0.99(±0.20) ^a
		15-30	1.21(±0.98)	1.1(±0.15)	1.12(±0.04)	1.14(±0.03) ^b
		Overall	1.12(±0.06) ^a	1.07(±0.01) ^a	1.00(±0.05) ^a	
	LWGE	0-15	1.19(±0.7)	1.12(±0.35)	0.99(±0.24)	1.1(±0.04) ^b

		15-30	1.37(±0.1)	1.32(±0.07)	1.09(±0.03)	1.25(±0.05) ^a
	Overall		1.27(±0.07) ^b	1.22(±0.52) ^b	1.04(±0.03) ^a	
P _t	LWAGS	0-15	60.72(±0.36)	60.44(±0.43)	66.16(±1.06)	62.4(±0.9) ^a
		15-30	54.4(±3.67)	58.37(±0.59)	57.8(±1.34)	56.8(±1.3) ^b
		Overall	57.56(±2.08) ^a	59.4(±0.52) ^a	61.99(±1.77) ^b	
	LWGE	0-15	55.09(±2.66)	57.64(±1.35)	62.65(±0.91)	58.46(±1.3) ^b
		15-30	48.49(±3.1)	50.28(±2.7)	58.76(±1.11)	52.5(±1.98) ^a
		Overall	51.79(±2.5) ^b	53.96(±1.97) ^b	60.7(±0.99) ^a	
V _e	LWAGS	0-15	1.55(±2.3)	1.53(±2.74)	1.96(±3.35)	1.68(±4.8) ^a
		15-30	1.23(±2.49)	1.4(±3.48)	1.38(±2.86)	1.30(±3.8) ^b
		Overall	1.38(±3.39) ^a	1.46(±3.13) ^a	1.67(±4.46) ^b	
	LWGE	0-15	1.25(±1.33)	1.37(±4.28)	1.68(± 2.36)	1.04(±3.40) ^b
		15-30	0.97(±1.35)	1.03(±3.45)	1.43(±2.69)	1.14(±2.65) ^b
		Overall	1.11(±1.49) ^b	1.19(±3.25) ^b	1.55(±3.01) ^a	

Overall means followed by the same letter(s) across columns and rows are not significantly different ($p > 0.05$) with respect to land units, soil depth and slope categories.

^a LWAGS- Land with agroforestry system, LWGE- Land with Gully erosion

The overall mean of soil bulk density (g cm^{-3}) was higher in LWGE than LWAGS. Higher soil bulk density was seen on land unit affected by gullies. Moreover, there was also higher soil bulk density (g cm^{-3}) in the lower soil depth in both land units. In addition, the overall mean of soil bulk density (g cm^{-3}) has shown decreasing trend along the topo-sequence in both land units. The higher bulk density in the LWGE was due to the presence of less SOC (%) contents, soil erosion and soil compaction as a result of rain droplets. With respect to soil depth, the presence of less soil aggregation as a result of lower SOC content and the pressure exerted by overlying soil layer have caused higher bulk density in the 15–30 cm soil depth (Arvidsson *et al.*, 2000; Mosaddeghi *et al.*, 2000; Mulugeta, 2004; Melesse, 2007). On the other hand, concerning total porosity and void ratio, higher overall mean values were observed in LWAGS than in LWGE along slope categories. Higher total porosity and void ratio were seen on land unit with agroforestry system. On both land units, P_t (%) was increased along the topo-sequence with respect to soil depth (Table 6). Considering the soil depth, on both land units, both P_t (%) and V_e (%) have shown minimum values as soil depth increase (Table 6). The increasing and decreasing of P_t (%) and V_e (%) along slope category and soil depth was directly connected with the distribution of soil organic carbon as well as soil bulk density of the study area.

3.4.2 Soil chemical properties

3.4.2.1 Soil reaction (pH, H₂O), EC (μs) and soil organic carbon (SOC %)

The soil pH value of the sampled soils was significantly ($p = 0.04$) affected by land unit but not significantly ($p > 0.05$) affected by both slope category and soil depths (Table 5). Considering combined effect, the interaction of slope percent and land units (SP*LU) have significantly ($P = 0.002$, Table 5) affected soil pH. The overall mean values of soil pH on LWAGS relatively higher than soil pH on LWGE (Table 7). So therefore, higher soil pH values were observed on land units with agroforestry system. Relatively low value of soil pH under the LWGE might be due to two major reasons. The first reason might be the depletion and removal of basic cations as a result of soil erosion. The result is in agreement with the finding of Ubuoh *et. al.*, (2013) who reported that low value of soil pH are recorded in erosion prone area. According to the local people in the study area, the gully was formed 15 years before. Therefore, there had been a continuous removal of basic cations in LWGE land unit. Secondly, it might be due to its highest microbial oxidation that produces organic acids, which provide H ions to the soil solution and thereby lowers the soil pH (Landon, 1991; Foth and Ellis, 1997). Gebeyaw (2007) also found lower pH values in area affected by erosion compared to area with agro-forestry and attributed this to a high rate of organic matter oxidation, which produces organic acids and provides H-ions to the soil solution and thereby reduces soil pH.

Soil Electrical Conductivity (EC μs) significantly varied with slope percent ($P = 0.045$, Table 6) and land units ($P < 0.001$, Table 5). Higher overall mean of EC was observed on LWAGS than LWGE. Along the soil depth, EC (μs) value was decreased on LWAGS and increased on LWG land units. Considering slope percentage, higher value of EC was observed at the middle slope (Table 7). The higher value of EC at the LWAGS was as a result of the presence of higher nutrient coming from accumulation of soil organic matter.

Table 7: Soil Reaction (pH, H₂O), Soil Electrical Conductivity (EC, μs) and Soil Organic carbon (SOC, %) in relation to land unit, soil depth (cm) and slope category (Mean±SE).

Variables	Land Unit ^b	Soil Depth (cm)	Slope Categories			Overall
			Upper	Middle	Lower	
pH	LWAGS	0-15	7.18(±0.16)	6.64(±0.31)	6.7(±0.09)	6.8(±0.13) ^a
		15-30	7.07(±0.08)	6.8(±0.01)	6.83(±0.63)	6.9(±0.47) ^a
		Overall	7.12(±0.09) ^a	6.72(±0.14) ^a	6.78(±0.05) ^a	
	LWGE	0-15	6.72(±0.10)	6.84(±0.01)	6.69(±0.02)	6.75(±0.36) ^b
		15-30	6.48(±0.19)	6.89(±0.02)	6.73(±0.04)	6.70(±0.07) ^b
		Overall	6.60(±0.11) ^b	6.68(±0.15) ^b	6.7(±0.02) ^b	
EC	LWAGS	0-15	70.1(±5.36)	79.92(±7.75)	64.15(±2.03)	71.39(±3.5) ^a
		15-30	66.88(±5.34)	61.73(±5.86)	65.3(±0.97)	64.63(±2.5) ^a

	Overall	68.48(±3.55) ^a	70.82(±5.66) ^b	64.72(±1.06) ^{ab}	
LWGE	0-15	45.37(±4.0)	60.65(±2.8)	55.88(±1.02)	53.9(±2.45) ^b
	15-30	51.53(±8.63)	64.23(±2.46)	55.47(±0.67)	57.07(±3.15) ^b
	Overall	48.45(±4.56) ^a	62.43(±1.85) ^a	55.67(±0.57) ^{ab}	
SOC LWAGS	0-15	2.19(±0.07)	2.27(±0.08)	2.2(±0.19)	2.29±0.07) ^a
	15-30	1.31(±0.5)	1.95(±0.12)	1.8(±0.16)	1.68(±0.1) ^b
	Overall	1.75(±0.17) ^a	2.11(±0.09) ^b	2.00(±0.14) ^b	
LWGE	0-15	0.84(±0.04)	1.01(±0.04)	1.44(±0.08)	1.1(±0.08) ^b
	15-30	0.64(±0.47)	0.81(±0.06)	1.13(±0.04)	0.85(±0.65) ^a
	Overall	0.74(±0.05) ^b	0.9(±0.05) ^a	1.28(±0.74) ^a	

Overall means followed by the same letter(s) across columns and rows are not significantly different ($p > 0.05$) with respect to land units, soil depth and slope categories.

^bLWAGS- Land with agroforestry system, LWGE- Land with Gully erosion

SOC (%) significantly varied with land units ($p < 0.001$), slope percent ($P < 0.001$) and soil depth ($p < 0.001$, Table 5). The interaction effect of slope percent and land units was also significant ($p = 0.004$, Table 5). Moreover, the combined effects of land units and soil depth were also significantly ($p = 0.011$, Table 5) affect SOC. The overall mean of SOC was higher in soil under LWAGS than in LWGE with respect to slope category (upper, middle and lower slope), respectively. So therefore, higher SOC (%) was recorded on land units with agroforestry system. Soil organic carbon was increased along the topo-sequence and decreased along the soil depth in both land units. The increment in SOC along the topo-sequence can be attributed to lower OM oxidation, lower losses of SOC due to soil erosion and higher deposition effects by slope position (Gregorich *et al.*, 1998). The higher SOC in LWAGS was due to the lower organic carbon turnover rate as a result of minimum soil disturbance, less water erosion occurrence (due to the presence of crop residue and perennial crops) and accumulation of higher amounts of organic matter in the soil (Post and Kwon, 2000; Worku Burayu *et al.*, 2006; Sithambaranathan, 2009). The lower SOC in LWGE (Table 7) in relation to LWAGS was due to oxidation of OM (high turnover and decomposition rate) due to frequent soil disturbance, breakdown and removal by water erosion (Solomon *et al.*, 2000; Fantaw *et al.*, 2006a, b; Liu *et al.*, 2006; Strudley *et al.*, 2008).

According to Fantaw *et al.* (2007), water erosion promotes SOC loss due to exposing micro-aggregate organic carbon to microbial decomposition by changing the moisture and temperature regimes. Furthermore, the insufficient input of organic materials in soil under the LWGE due to the presence of less crop residue (Solomon *et al.*, 2000; Igue, 2004; Mulugeta, 2004) also contributed to the lower level of SOC content. The vertical distribution of soil organic carbon appeared to differ with land units. Irrespective of land units, the top surface soils (0–15 cm depth) showed relatively higher SOC content compared to the 15–30 cm depth layer. The decrease in SOC with depth was more rapid under LWGE than in the LWAGS (Table 7). He *et al.* (2009), Hiederer (2009) and Mulugeta (2014) reported similar results of a decrease in SOC with soil depth, a result of corresponding decrease of organic matter storage

via root biomass and litter decomposition, which are the main pathways of organic carbon inputs (Saikh *et al.*, 1998; Zhong and Qiguo, 2001). On the other hand, household waste disposal and compost addition as well as dead weeds left in the farm plots might have increased the SOC at the top surface layer under the LWAGS.

4.2.3 Soil biological properties

4.2.3.1 Naked eye macro-fauna (NMF,%) in the soil

Naked eye soil Macro-fauna was significantly varied with land units ($P < 0.001$) and soil depth ($P < 0.001$, Table 5) but not with slope category. The combined effect of land units and soil depth were significant ($P = 0.004$) on NMF of the soil. The overall mean value of NMF was higher in the LWAGS than LWGE. The overall values of NMF (Table 8) were decreased along the soil depth in both land units while it is increasing along the slope categories. The increased in NMF in LWAGS was due to the presence of higher organic matter in the soil. On the other hand, the less number of soils NMF along soil depth was as a result of less amount soil organic matter and soil compaction as a result of weight of overlaying soil (Moges *et al.*, 2013). Biological activity in soils is largely concentrated in the topsoil (Anton, 2004). On both land units, the number of macro-fauna has increased along the topo-sequences. This was partly because of deposition at the lower slope especially on the LWGE land units.

Table 8: The number of Naked eye Macro Fauna (NMF) in the study area.

Variables	Land Unit *	Soil Depth (cm)	Slope categories			
			Upper	Middle	Lower	Overall
NMF	LWAGS	0-15	24.75(±6.48)	27.25(±3.66)	37.8(±4.14)	30(±5.10) ^a
		15-30	9.00(±4.00)	8.75(±1.25)	12.25(±4.09)	10(±1.80) ^b
		Overall	16.87(±4.64) ^a	18.0(±3.90) ^a	25.0(±8.34) ^b	
	LWGE	0-15	3.0(±4.00)	2.5(±0.65)	4.0(±4.08)	3.16(±0.2) ^b
		15-30	0.5(±0.28)	1.0(±0.41)	1.0(±0.41)	0.83(±0.2) ^a
		Overall	1.75(±0.53) ^b	1.75(±0.45) ^b	2.5(±0.63) ^a	

Overall means followed by the same letter(s) across columns and rows are not significantly different ($p > 0.05$) with respect to land units, soil depth and slope categories.

* LWAGS- Land with agroforestry system, LWGE- Land with Gully Erosion

4.2.4. Species diversity and species richness

A total 71 plant species (41 trees, 13 shrubs, and 17 herbs). These species belongs to 45 families (20 in Agro-forestry system and 25 in area affected by gully erosion (Table 9). Fabaceae was the most species-rich family comprising 9 (12.7%) of the total plant species identified in the study area, followed by

Euphorbiaceae with 8(11.3%) species. The next dominant families were Moraceae with 7 (9.9%) species. Rutaceae and Myrtaceae were each represented by 6 species and together accounted (16.9% of the total identified species). The remaining 25 families (49.2%) were rare and each represented by a single species. When considering the two areas separately, a total of 30 and 41 plant species were recorded in agro-forestry system and areas affected by gully erosion respectively. Fabaceae was the most species-rich family represented by 4 species (in the agro-forestry system) and 5 species (in the gully affected area) followed by Euphorbiaceae with 4 species in each areas. Out of the total 71 species, 19 plant species including *Acacia decurrens*, *Aframomum corrorima*, *Carica papaya*, *Catha edulis*, *Citrus medica*, *Citrus aurantium*, *Coffea arabica*, *Cupressus lusitanica*, *Eucalyptus camaldulensis*, *Grevillea robusta*, *Jacaranda mimosifolia*, *Mangifera indica*, *Myrtus communis*, *Persea Americana*, *Psidium guajava*, and *Rhamnus perinioides*, were all planted species.

Table 9: List of families with species number ≥ 2 within agro-forestry system and area affected by gully.

LWAGS ^e		LWGE		Study area in total	
Family names	No of species	Family names	No of specie	Family names	No of species
Fabaceae	5	Fabaceae	4	Fabaceae	9
Euphorbiaceae	4	Euphorbiaceae	4	Euphorbiaceae	8
Moraceae	4	Rutaceae	3	Moraceae	7
Myrtaceae	4	Rubiaceae	3	Rutaceae	6
Rhamnaceae	3	Moraceae	3	Myrtaceae	6
Rubiaceae	3	Asteraceae	3	Rubiaceae	4
Rutaceae	3	Anacardiaceae	2	Asteraceae	4
Asteraceae	3	Verbenaceae	2	Anacardiaceae	2
Boraginaceae	2	Myrtaceae	2	Rhamnaceae	3
Ebenaceae	2	Ebenaceae	2	Olacaceae	3
Ranunculaceae	2	Cappardaceae	2	Acanthaceae	3
Malvaceae	2			Asclepiadaceae	2
2				Bignonaceae	2
Olacaceae	2			Boraginaceae	2
				Cappardaceae	2
				Celasteraceae	2
				Cupressaceae	2
				Dracaenaceae	2
				Ebenaceae	2
Total	41		30		71

^eLWAGS, Land with agro-forestry system, LWGE, Land with Gully Erosion.

The woody species diversity indices of the study area recorded in the whole agro-forestry system is presented in Table 10. The area affected by gully had higher values of species richness, evenness and diversity than the agro-forestry system. The Sorensen's floristic similarity index ($S_s=28.7\%$) showed that the two areas share very few plant species. In addition, plant species identified in IUCN Red Data list as endangered: *Millettia ferruginea*, *Rhus glutinosa* and *Vepris dainellii*, and threatened endemic species: *Acanthus sennii* and *Clematis longicauda* were recorded in the study area.

Table 10: Comparison of richness, Shannon diversity (H') Simpson's diversity (D) and evenness (E) of woody species in coffee-based agro-forestry system and area affected by gully erosion.

Land Units ^f	Richness	Diversity		
		H	E	D
LWGE	60	2.96	0.43	0.94
LWAGS	48	2.21	0.23	0.75
The study area	74	2.6	0.64	0.66

The Sorensen's similarity index of the two patches =28.7%

^fLWAGS- Land with agroforestry system, LWGE- Land with Gully Erosion

The woody species diversity index of agro-forestry system ($H=2.21$) was lower than the gully affected area ($H=2.96$). The lower Shannon diversity index in agro-forestry system may be due cutting of trees/shrubs for different purposes like of fuel wood and timber, removing of trees/shrubs to give space for coffee plant. It is clear that species composition and agro-forestry system structures significantly affected by human activities. Anthropogenic disturbances create an environmental difference through favoring selected and suppressing the unwanted plant species. The finding in this study agrees with Tripathi and Singh (2009). Analysis of evenness index showed that the different species in the agro-forestry system were unevenly abundant/distributed ($E=0.23$) than those in gully affected areas ($E=0.43$). Despite the proximity of the two areas to each other, they shared only 32.4% of the species which indicates that each area was composed of different woody species. This might be the impact of anthropogenic influence (management), slop and altitude of the two areas. The overall woody species diversity of the study area was found to be $H= 2.6$. The number of species (71) recorded in the study area was found to be higher than the number of species recorded in other Ethiopian agro-forestry systems (Abebe *et al.*, 2010; Tesfaye, 2013; Ewketu *et al.*, 2014). However, the total species number in this study was lower than that reported by (Kitessa and Tsegaye, 2008; Teshome *et al.*, 2004). Fabaceae was the family represented by highest number of species in the study area.

Generally, factors like human and environmental influences have a strong impact on agro-forestry system structure, composition and species richness Espinosa and Cabrera (2011) though it depends on intensity

and persistency of influences (Kuffer and Senn-irlet, 2004). Possible reasons for these differences may be laid on landscape fragmentation or microclimatic factors.

CONCLUSION

The farmer's attitude has contributed for gully development in the coffee-enset based agro-forestry system and takes the lion share in the study area. Even if the area is characterized by self-regeneration capacity, it could not able to withstand the human interference (since majority of the household income is generated from the agroforestry system). According to the respondents, tree cutting, topography of the area and population pressure were become the main cause for gully development in the study area. Moreover, weak IK transmission (about agro-forestry system) from elders to youth has played a major role for gully development. So therefore, strong awareness creation campaign through training the local farmers on the overall situation of the agro-forestry system would have a positive impact on its future fate.

In relation to soil property, LWGE has shown a remarkable decline in soil quality indicators while LWAGS have shown a great potential in improving soil physico-chemical properties. Understanding the effect of these two land unit (LWAGS & LWGE) on soil property changes is quite important for the prediction of overall soil behaviors and its response to different management options. The investigated soil under LWAGS has shown improvements in Soil moisture contents, EC, Porosity, Void ratio, pH, SOC, NMF and low soil bulk density, favoring good soil structure, aeration and root penetration. These improvements were a direct result of high SOM and less soil disturbance in LWAGS. In relation species richness and diversity, LWAGS

has a minimum richness and diversity index as compared to LWGE land units as a result of continuous farm management. The soil under LWGE has shown poor physico-chemical as well as biological properties. Therefore, LWAGS is a good management option for rehabilitation and improvement of soil qualities. Thus, these soil properties should be maintained and restored through appropriate land as well as soil management practices and gully control measures.

Acknowledgements

We thank the Research and Dissemination Directorate of Dilla University/Ethiopia, for financing the research and supporting laboratory work. We also would like to thank the farmers in Gola area for their assistance during the fieldwork.

References

- [1] Abayneh Derero, Tamrat Bekele and Naslund, B.A., 2003. Population structure and regeneration of woody species in a broad- leaved Afromontane rain forest, south-west Ethiopia. *Ethiop. J. N. Res.* 5: 255-279.
- [2] Abebe, T. Wiersum, K.F., Bongers, F., Sterck, F., 2010. Diversity and dynamics in home gardens of southern Ethiopia. *Int. J. Agroforestry system*, 78:309-322.
- [3] Abiyot Legesse, Bogale Teferi and Axel Baudouin, 2013. Indigenous agroforestry knowledge transmission and young people's participation in agroforestry practices: The case of Wonago Woreda, Gedeo Zone, Southern Ethiopia. *Acta Geographica-Trondheim Serie A*, Nr. 26



- [4] Anderson, J.M., Ingram, J.S.I., 1993. Tropical Soil Biology and Fertility: A Handbook of Methods, 2nd ed. Oxford University Press, USA, pp. 240.
- [5] Anton, M. B., 2004. Soil biodiversity: measurements, indicators, threats and soil functions, International Conference soil and compost eco-biology, September 15th – 17th 2004, León - Spain.
- [6] Arvidsson, J., Rydberg, T., Feiza, V., 2000. Early sowing – a system for reduced seedbed preparation in Sweden. Soil Till. Res. 53, 145–155.
- [7] Bale, C.L., Williams, B.J., Charley, J.L., 1998. The impact of aspect on forest structure and floristics in some Eastern Australian Sites. For. Ecol. Manag. 110, 363–377.
- [8] Belay Tegene, 2000. Processes and causes of accelerated soil erosion on cultivated fields of South Welo, Ethiopia, EASSRR, Vol. XVI, No. 1 January 2000.
- [9] Billi, P. and Dramis, F., 2001. Geomorphologic investigation on gully erosion in the rift valley and northern highlands of Ethiopia. Catena Vol. 50: 353-368.
- [10] Boffa, J.M, 2000. Field scale influence of karate sorghum production in Burkinafaso. Int. J.Agroforestry system,6:19-35.
- [11] Cuenca, H.R., 1989. Irrigation System Design – An Engineering Approach. Prentice-Hall, Inc., EngleWood Cliffs, New Jersey, pp. 552.
- [12] Daniel, C.C., Mark, G. and Sally, W., 1994. Population and Land Degradation. Michigan State University, USA, pp:1-30.
- [13] De Vente, J., Poesen, J., Verstraeten, G., 2005. The application of semi-quantitative methods and reservoir sedimentation rates for the prediction of basin sediment yield in Spain. Jou. of Hydr. 305, 63–86.
- [14] ENSAP /Eastern Nile Subsidiary Action Program (2012). A Field Guide on Gully Prevention and Control Eastern Nile Technical Regional Office (ENTRO) Eastern Nile Watershed Management Project, Nile Basin Initiative.
- [15] Espinosa, C.I. and Cabrera, O., 2011. What factors affect diversity and species composition of endangered. Tumbesian Dry Forests in Southern Ecuador, *Biotropica* 43(1): 15–22.
- [16] Ewuketu Linger Mekonnen, Zebene Asfaw and Solomon Zewudie, 2014. Plant species diversity of homegarden agroforestry in Jabithenan District, North-Western Ethiopia. International Journal of Biodiversity and Conservation Vol. 6(4) PP 301-307
- [17] Fantaw Yimer, Ledin, S., Abdelkadir, A., 2007. Changes in soil organic carbon and total nitrogen contents in three adjacent land use types in the Bale Mountains, Southeastern highlands of Ethiopia. Forest Ecol. Manage. 242, 337–342.
- [18] Fantaw Yimer, Ledin, S., Abdu Abdelkadir, 2006a. Soil organic carbon and total nitrogen stocks as affected by topographic aspect and vegetation in the Bale Mountains, Ethiopia. Geoderma 135, 335–344.

- [19] Fantaw Yimer, Ledin, S., Abdu Abdelkadir, 2006b. Soil property variations in relation to topographic aspect and vegetation community in the south-eastern highlands of Ethiopia. *Forest Ecol. Manage.* 232, 90–99.
- [20] Gebeyaw Tilahun. 2007. Soil fertility status as influenced by different land uses in Maybar areas of Southern Wollo Zone, Northern Ethiopia. M.Sc. Thesis submitted to the faculty of Plant Science, Haramaya university, Ethiopia.
- [21] Govers, G., Poesen, J., Goossens, D., Christensen, B.T., 2004. Soil erosion—processes, damages and countermeasures. In: Schjonning, P., Elmholt, S. (Eds.), *Managing Soil Quality, Challenges in Modern Agriculture*. CABI Publishing, Wallingford, UK, pp. 199–217.
- [22] Grenier, L. (1998). *Working with Indigenous Knowledge: A Guide for Researchers*. International Development Research Centre, Ottawa, Canada, 82 p.
- [23] Haile Ketema and Fantahun Yimer, 2014. Soil property variation under agroforestry based conservation tillage and maize based conventional tillage in Southern Ethiopia. *Soil Till. Res* 141 (2014) 25–31.
- [24] Hailu, T., Negash, L. and Olsson, M., 2000. *Milletia ferruginea* from Southern Ethiopia. impacts of soil fertility and growth of maize. *Int. J. Agroforestry system*, 48:9-24.
- [25] He, J., Kuhn, N.J., Zhang, X.M., Zhang, X.R., Li, H.W., 2009. Effects of 10 years of conservation tillage on soil properties and productivity in the farming–pastoral ecotone of Inner Mongolia, China. *Soil Use Manage.* 25, 201–209.
- [26] Hiederer, R., 2009. Distribution of Organic Carbon in Soil Profile Data. EUR 23980 EN. Office for Official Publications of the European Communities, Luxembourg, pp. 126.
- [27] Huon, S., Bellanger, B., Bonté, Ph., Podwojewski, P., Valentin, C., Velasquez, F., Bricquet, J-P., de Rouw, A., Girardin, C., 2005. *Monitoring soil organic carbon erosion with isotopic tracers, two case studies on cultivated tropical catchments with steep slopes (Laos, Venezuela)*. *Advances in Soil Science*. CRC Press, Boca Raton, Florida, USA.
- [28] Igue, A.M., 2004. Impact of land use effects on chemical and physical soil characteristics in the Colline department of Benin (West Africa). In: *Proceedings on the International Conference on Land degradation (ICLD4) at Madrid, Spain*, pp. 1–10.
- [29] Kakembo, V., Rowntree, K.M., 2003. The relationship between land use and soil erosion in the communal lands near Peddie town, eastern Cape, South Africa. *Land Deg. and Dev.* 14 (1), 39–49.
- [30] Kitessa Hundera and Tsegaye Gadissa, 2008. Vegetation composition and structure of the Belete forest, Jimma Zone, South Western Ethiopia. *Ethio.J.Bio.Sci.*, 7(1): 1-15.
- [31] Krause, A.K., Franks, S.W., Kalma, J.D., Loughran, R.J., Rowan, J.S., 2003. Multi parameter fingerprinting of sediment deposition in a small gullied catchment in SE Australia. *Catena* 53 (4), 327–348.



- [32] Kuffer, N. and Senn-irlet, B., 2004. Influence of forest management on the species richness and composition of wood-inhabiting basidiomycetes in Swiss forests. *Biodiversity and Conservation* 14:2419–2435.
- [33] Kumar, R., Singh, K. R. and Yadav, B., 2012. Vertical Distribution of Physico-Chemical Properties under Different Topo-sequence in Soils of Jharkhand. *Journal of Agricultural Physics*, Vol. 12, No. 1, pp. 63-69 (2012), ISSN 0973-032X.
- [34] Liu, X., Herbert, S.J., Hashemi, A.M., Zhang, X., Ding, G., 2006. Effects of agricultural management on soil organic matter and carbon transformation – a review. *Plant Soil Environ.* 52, 531–543.
- [35] Magurran, A. E., 1988. Ecological diversity and its measurement. Chapman and Hall, London.
- [36] Magurran, A.E., 2004. Measuring Ecological Diversity. Blackwell Science Ltd., Malden.
- [37] Melesse Temesgen, 2007. Conservation Tillage Systems and Water Productivity Implications for Smallholder Farmers in Semi-arid Ethiopia. (Ph.D. thesis) Delft University of Technology, The Netherlands, pp. 132.
- [38] Moges, A., Dagnachew, M. and Yimer, F., 2013. Land Use Effects on Soil Quality Indicators: A Case Study of Abo-Wonsho Southern Ethiopia. Hindawi Publishing Corporation, Applied and Environmental Soil Science, Volume 2013, Article ID 784989, 9 pages <http://dx.doi.org/10.1155/2013/784989>.
- [39] Mosaddeghi, M.R., Hajabbasi, M.A., Hemmat, A., Afyuni, M., 2000. Soil compactibility as affected by soil moisture content and farmyard manure in central Iran. *Soil Till. Res.* 55, 87–97.
- [40] Mulugeta Lemenih, 2004. Effect of Land Use Changes on Soil Quality and Native Flora Degradation and Restoration in the Highlands of Ethiopia: Implications for Sustainable Land Management. (Ph.D. thesis) Swedish University of Agricultural Sciences, Uppsala, pp. 31–39.
- [41] Mulugeta Sisay 2014. Socioeconomic and Biophysical Issues Impacting Tree and Shrub Integration LAMBERT Academic Publishing. Saarbrücken, Germany.
- [42] Nelson, D. W. and L. E. Sommer. 1982. Total Carbon, organic Carbon and Organic matter. P. 539-577. In Page. A. L. M. H. Miller and D. R. Keeney, (eds) Method of Soil Anal. Part-2. 2nd Ed. chemical and microbiological properties. Am. Soc. Agron. Madison. WI. USA. PD: 539-580.
- [43] Obot, A.E., 1995. Psychological issues in environmental education ' In UK pong, E.M., UN., obot, A.E., and Ewa, N.U. (eds) community environmental education. Lagos ! Macmillan .65
- [44] Oguike, P.C., Mbagwu, S.C., 2009. Variations in some physical properties and organic matter content of soils of coastal plain sand under different land use types. *World J. Agric. Sci.* 5 (1), 63–69.
- [45] Pandey, C.B., Singh, A. K. and Sharma, D.k., 2000. Soil properties under Acacia nilotica Trees In a traditional Agroforestry System A Central India. *Agroforestry system.*, 49:53-61.



- [46] Pielou, E. C. (1975). Ecological diversity. John Wiley and Sons, INC, 165. <http://worldwidescience.org/topicpages/a/afromontane+tropical+forest.html>. Date access 12/09/2013
- [47] Poesen, J, 2011. Gully erosion: procedures to adopt when modeling soil erosion in land scapes affected by gulling. Black well publishing ltd, chichester, UK .chapter 19: p360-386.
- [48] Post, W.M., Kwon, K.C., 2000. Soil carbon sequestration and land use change: processes and potential. Global Change Biol. 6, 317–328.
- [49] Rajeswari, A.P.M., Seca, G., Osumanu, H.A., Nik, M., 2009. Effect of different ages of a rehabilitated forest on selected physico-chemical properties. Am. J. Appl. Sci. 6 (6), 1043–1046.
- [50] Rajot, J.L., Alfaro, S.C., Gomes, L., Gaudichet, A., 2003. Soil crusting on sandy soils and its influence on wind erosion. Catena 53 (1), 1 – 16.
- [51] Romaneckas, K., Romaneckien, R., Šarauskis, E., Pilipavius, V., Sakalauskas, A., 2009. The effect of conservation primary and zero tillage on soil bulk density, water content, sugar beet growth and weed infestation. Agron. Res. 7, 73–86.
- [52] Saikh, H., Varadachari, C., Ghosh, K., 1998. Changes in carbon, nitrogen and phosphorus levels due to deforestation and cultivation: a case study in Simlipal National Park, India. Plant Soil 198, 137–145.
- [53] Schnitzer, M., 1982. Total carbon, organic matter, and carbon, In: Page, A.L., Miller, R.H., Keeney, D.R. (Eds.), Methods of Soil Analysis. Part 2, 2nd Edition. American Society of Agronomy 9:539–577.
- [54] Sithambaranathan, P., 2009. Cause and Effects of Soil Structure Decline and Its Implication to Agricultural Practices. Bukisa, Culture and Society, [http:// www.bukisa.com/](http://www.bukisa.com/) (accessed 26.05.11).
- [55] Smart, K.C, 1998. An introduction to global environmental issues. London: rout ledge
- [56] Solomon, D., Lehmann, J., Zech, W., 2000. Land use effects on soil organic properties of chromic Luvisols in the semiarid tropics: carbon, nitrogen, lignin and carbohydrates. Agric. Ecosyst. Environ. 78, 203–213.
- [57] Strudley, M.W., Green, T.R., Ascough, I.I.J.C., 2008. Tillage effects on soil hydraulic properties in space and time. Soil Till. Res. 99, 4–48.
- [58] Sustainable Land Use Forum (SLUF), 2006. Indigenous agroforestry practices and their implications on sustainable land use and natural resources management: The Case of Wonago District, Research Report No 1. Addis Ababa, Ethiopia. pp 3-101.
- [59] Tadesse Kippie, 2002. Five Thousand Years of Sustainability. A case study on Gedeo Land Use (Southern Ethiopia) (Ph.D thesis) Treemail Publishers, Heelsum, The Netherland, pp. 295.
- [60] Tesfaye Abebe, 2013. Determinants of crop diversity and composition in Enset-coffee agroforestry homegardens of Southern Ethiopia. Journal of Agriculture and Rural Development in the Tropics and Subtropics, Vol. 114 No. 1 29–38.



- [61] Teshome Soromessa, Demel Teketay and Sebsebe demissew , 2004. Ecological study of the vegetation in Gamo Gofa zone, southern Ethiopia. *Tropical Ecology* 45(2): 209-221.
- [62] Tigist Oicha, Cornelis, W., Verplancke, H., Nyssen, J., Deckers, J., Mintesinot Behailu, Mitiku Haile, Govaerts, B., 2010. Short-term effects of conservation agriculture on Vertisols under teff (*Eragrostis tef* (Zucc.)) in the northern Ethiopian highlands. *Soil Till. Res.* 106 (2), 294–302.
- [63] Tilashwork chanie, 2009. The effect of eucalyptus on crop productivity, and soil in the koga watershed, western amhara region, ethiopia, MSc thesis, cornell university, USA, pp: 13-43
- [64] Tripathi, K.P. and Singh, B., 2009. Species diversity and vegetation structure across various strata in natural and plantation forests in Katarniaghat Wildlife Sanctuary, North India. *Tropical Ecology* 50(1): 191-200.
- [65] Tripathi, O.P., Pandey, H.N., Tripathi, R.S., 2009. Litter production, decomposition and physico-chemical properties of soil in 3 developed agroforestry systems of Meghalaya, Northeast India. *Afr. J. Plant Sci.* 3 (8), 160–167.
- [66] Valentin, C., Poesen, J. and Yong, L., 2005. Gully erosion: Impacts, factors and control. *Catena* 63 (2005) 132–153.
- [67] Wasson, R.J., Caitcheon, G., Murray, A.S., McCulloch, M., Quade, J., 2002. Sourcing sediment using multiple tracers in the catchment of Lake Argyle, northwestern Australia. *Environmental Management* 29 (5), 634– 646.
- [68] Wendemeneh, D., 2010. Characterization and Classification of the Soils of Upper Sala Watershed in Dilla Zuria District of Gedeo Zone, Southern Ethiopia. (M.Sc. thesis)Haramaya University, Natural Resource Management and Environmental Sciences, Ethiopia, pp. 88.
- [69] Wood, 1990. Natural Resource management and rural development in Ethiopia.PP:187-197.
- [70] Worku Burayu, Sombat, C., Rungsit, S., Thongchai, M., Sunanta, J., 2006. Conser- vation tillage and crop rotation: win-win option for sustainable maize production in the Dryland, Central Rift Valley of Ethiopia. *Kamphaengsaen Acad. J.* 4 (1), 48–60.
- [71] World bank, 2003. World development report Oxford university press, .New York
- [72] Zhong, J., Qiguo, Z., 2001. Organic carbon content and distribution in soils under different land uses in tropical and sub tropical China. *Plant Soil* 231, 175–185.
- [73] Solomon, Z. Wuyep, Vincent C. Dung, Arin H.Buhari, Daloeng H. Madaki, and Baminda A. Bitrus, “Women Participation in Environmental Protection and Management: Lessons from Plateau State, Nigeria.” *American Journal of Environmental Protection*, vol. 2, no. 2 (2014): 32-36. doi: 10.12691/env-2-2-1.