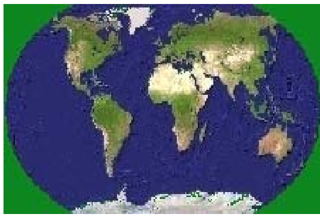

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Variation in Abundance and Diversity of Soil Invertebrate Macro-Fauna and Some Soil Quality Indicators under Agroforestry Based Conservation Tillage and *Maize Based* Conventional Tillage in Southern Ethiopia

Mulugeta Sisay, Haile Ketema

Abstract
This study was conducted in Wonago District of Gedeo Zone, Southern Etsiopia, with the objective of investigating the abundance, and diversity of soil invertebrate macro fauna and their effect on soil carbon stock under different land use types. A total of 18 monoliths from the two land uses i.e. indigenous agroforestry system and monoculture agriculture (9 from each) were sampled with the help of transect line for sampling point selection. Soil invertebrate macro fauna identification was sampled following Tropical Soils Biology and Fertility Institute methodology. A total of 9 families from indigenous agroforestry and 8 families from monoculture agriculture land use were identified. Among the three layers of the monoliths in the land use there is a significant ($P<0.05$) difference in abundance between the surface layer (0-10 cm) of monoculture agriculture and surface layer (0-10cm) of indigenous agroforestry, sub surface layer (20-30 cm) of indigenous agroforestry, and sub-surface layer (20-30 cm) of monoculture agriculture. The Shannon index value showed that the diversity of macro fauna in indigenous agroforestry (1.28) was higher than the monoculture agriculture (1.17). The soil carbon stock was significantly different among the land use type and between the three depths in the respective land uses. Indigenous agroforestry positively influenced both abundance and diversity of soil invertebrate macro fauna and this resulted in high level of carbon stock in the land use. As a recommendation, changing indigenous agroforestry land use to monoculture agriculture should be checked for its negative effects on both abundance and diversity of soil invertebrate macro fauna and soil carbon stock. The Gedeo indigenous agroforestry system should get special consideration as it may contribute a lot in carbon sequestration which is the global issue.

Keywords: Abundance, Diversity, indigenous agroforestry, monoculture agriculture, macro fauna, carbon stock

1. Introduction

One of the most dramatic consequences of contemporary global change is the rapid decline of biological diversity in many ecosystems [1]. This loss of biodiversity has generated concern over the consequences for ecosystem functioning and services [2, 3, 4] in particular those related to nutrient cycling which form vital agricultural provisioning services.

Diversity of soil fauna are known to affect soil function in a variety of ways, and could be used as indicators of nutrient status of soil in a given site [5, 6, 7]. Soil invertebrates are the major determinants of soil processes in tropical ecosystems. However, the potential for manipulating the beneficial soil animals has rarely been considered in designing management practices [8]. Practices that eliminate beneficial soil faunal communities are unlikely to contribute to the sustainable production in the long term, especially in low-input systems based on organic residues.

Several studies have been performed on the effect of various agricultural practices on the soil fauna. Practices generally considered as beneficial mostly involve the management of organic matter; particularly the control of the quality and quantity of the residues added or kept in the soil surface (litter) and the reduction or complete absence of soil disturbance (tillage). Crop rotation and diversification also play an important role in increasing the diversity of food resources and environmental condition for the soil biota. Other corrective practices such as fertilization and liming are also important and are generally considered to have positive effects on most organisms. Practices that have negative effect on soil fauna include the use of pesticides, particularly insecticide, nematicides and fungicides the use of frequent and/ or deep tillage, the lack of adequate organic matter management and protection of the soil from physical Degradation (erosion, compaction), contamination and pollution [9].

A number of studies have also given credence to positive trees' potential on soil microorganisms thereby enhance crop production when integrated with farming [10, 11]. In addition, results of a number of studies suggested particular significance of certain plant functional groups such as legumes, with the impact on soil microorganisms being primarily due to changes in plant productivity [12, 13, 14].

Despite the fact that soil invertebrate macro fauna has a big role in ecosystem functioning, little has been worked to assess the potentials of indigenous agroforestry practices in contributing towards soil invertebrate macro fauna conservation and rehabilitation. In general, studies that characterize the abundance and diversity of soil invertebrate macro fauna on indigenous agroforestry systems are scarce. Moreover, soil invertebrate macro fauna effect on soil carbon stock is also limited. Thus the present study is aimed at identifying abundance and diversity of soil invertebrate macro fauna and their effect on the soil carbon stock under agroforestry based conservation tillage and Maize based conventional tillage.

2. Materials and Methods

2.1 Description of the Study Area

The study was undertaken in Wonago District, Gedeo Zone, Southern Ethiopia (Fig 1). It is about 377 km south of Addis Ababa, Ethiopia. Geographically, it lies between 5-7° N latitude and 38-40° E longitude. The altitude ranges from 1270 to 2070 masl. The study area is characterized by a bimodal rainfall distribution with a maximum between March to June (main rainy season), and a relatively minimum rainfall between August and October. The mean annual rainfall ranges from 800 to 1600 mm with mean annual temperature ranging from 11-29 ^{0}C. The topographically, the area constitute mountainous (39%), flat land (9%) and undulating (52%). In extreme cases, the slope can extend up to 90% [15].

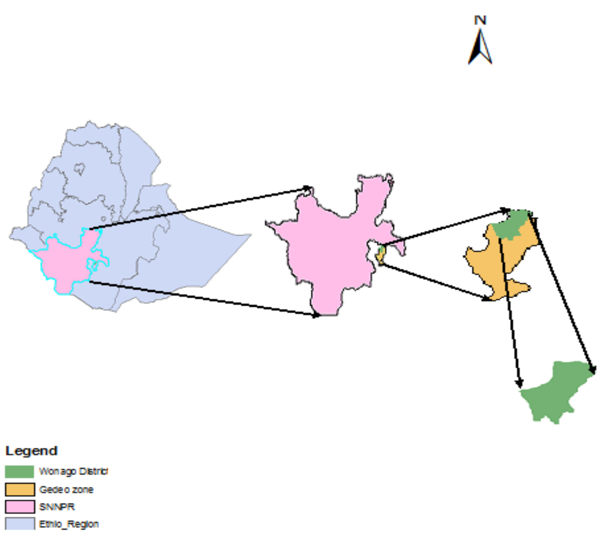

Fig 1: Map of the study area

The agroforestry based conservation tillage system of the study area represents one of the oldest traditionally intensified farming systems in Ethiopia. The land use system in the study area is not purely crop farming, purely cattle rearing or purely forestry but an integration of these components commonly known as agroforestry practice. The agroforestry based conservation tillage has different species on its vertical strata. Ficus sur Forssk, Erythrina abyssinica, Millettia ferruginea (Hochst.) Bak, Croton macrostachyus Del, Polyscias ferruginea, Cordia africana, species take the upper strata, Coffea arabica, Persea Americana, Manjifera indica, Citrus aurantifolia Christm, Musa X paradisiaca L, Zea mays, sugar beet, Dioscorea abyssinica take the middle and lower strata. Millettia ferruginea is being dominant tree species in the system that provides diverse benefits. The agroforestry system of the area includes enset- tree system, enset-coffee-tree system, and coffee-fruit crops-tree system. The dominant soil type of the study area is Nitisols having greater depth. The soil under agroforestry system usually replenishes itself with organic matter coming from the liter fall.

Currently, however, maize based conventional tillage is expanding at the expense of agroforestry based conservation tillage in the study area. Maize is the most common cereal crop produced for the sake of household consumption in the study area. The local farmers use the traditional *Maresha* (Fig.2) plow to prepare their farm plot. The plowing system is simple and shallow tilling up to soil depth of 15 cm on average.

The first plowing time for maize crop in the study area is done as soon as on the onset of the first rain season. Because of its V-shaped ploughing by *Maresha*, the local farmers have to do repeated tillage with any two consecutive tillage operations carried out perpendicular to each other [16]. As a result, the soil is pulverized resulting in weak soil structure and compact formation. Farmers plough 2-3 times before sowing maize in the study area. Because of repeated tillage at shallow depths, commonly 15 cm, plough pans may form below the plough layer. The V-shaped furrows also result in higher relative surface area exposure leading to an increased loss of moisture through evaporation. People often remove maize residues after harvest either for fuel wood or animal feed. Thus, no crop residue remains in the field each season for either mulching or organic amendment to the soil. However, the farmers have access to commercial fertilizers and sometimes use manure and compost in their farm plots near to their homesteads. Concerning the chemical fertilizers, Urea and DAP were the common inputs used in the study area for maize crop production on conventional tillage system. DAP (diammonium phosphate, (NH4)2HPO4) was used simultaneously at the time of sowing maize. On the other hand, Urea (with 46% of Nitrogen) was used after the crop develops 2-3 leaves. No chemical fertilizers have been used in agroforestry based conservation tillage system. In the agroforestry based conservation tillage system, animal plowing using traditional *Maresha* is difficult to apply. Thus, farmers use small hand equipments like hand hoe for land preparation. They also leave weedy herbaceous in the fields with the objectives of mulching and addition of organic matter in to the soil system. Therefore, nutrient cycling and soil protection from erosive forces and inducing rainwater to percolate in to the soil profile become the possible advantages derived from the system.

2.2. Study Site Selection Criteria

The criteria used to select the study site were by random selection of agricultural and indigenous agroforestry land which exists side by side and by taking the slope condition of the two land use in to consideration not to have a slope variation within the land use. After selection of land use, the sampling points for monolith extraction were located and marked using transect walk. In the assessment of soil macro fauna communities, the sampling is generally conducted along a transect 40 x 5 m; these are equally spaced along transect [17].

2.3. Experimental Design and Layout

Experimental design and layout were performed by using a transect line. 40m long transect line is laid across the slope and from that transect line at a distance of 5m monoliths were dug in 15 m interval. The shorter side of the transect (5m) failed along the slope gradient. The orientations of the two close land uses were kept uniform. The two land uses were monoculture agriculture (MA) and indigenous agroforestry (AF). A total of 18 sampling points were taken from the two systems by taking 9 representative monoliths from each land uses. The distance between each monolith in a land use was made to be greater than >10m along the transect [18].

2.4 Soil Invertebrate Macro Fauna Sample Collection and Soil Lab Analysis

Two land uses agroforestry based conservation (AFCST) and maize based conventional tillage (MCVT)], hereafter referred to as ''land use types'' both under 5, 10 and 15 years of cultivation, were selected. The land use types were contiguous and have similar environmental conditions (e.g. in soil conditions and slope) except their differences in the land management practices. Experimental design and layouts were performed by using a transect line. A total of 48 soil samples (2 treatments-4 replications-3 age categories-2 soil depth layers: 0-10 cm, 10-20 cm) were collected after crop harvest for laboratory analyses. 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 samples from each soil depth for the determination of soil bulk density. The soil textural fractions were determined following the hydrometer method after the soil was dispersed using sodium hexametaphosphate solution in the laboratory [19]. SOC was determined according to the Walkley and Black method [20]. Soil bulk density was determined after an oven drying at 105 8C for 24 h. Total porosity was determined according to [21] assuming a particle density (Pd) of 2.65 g cm——————————————3. The gravimetric soil moisture content (SMC, %) was calculated following the method described by [22]. Both the rate and cumulative water infiltrations for each land use type were determined using a set of Double Ring Infiltrometer [23]. It was carried out in triplicate on each land use type (3 age categories, 2 land uses types (treatments), 3 replications) separately. Laboratory results were analyzed using General Linear Model (GLM) procedure of SPSS version 16.0 for windows [24]. 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 ($p < 0.05$).

2.5 Soil Invertebrate Macro Fauna Sample Collection

The demonstration covers the preparations and material used to sample soil for the presence and abundance of soil macro fauna by performing the sampling methodology of the Tropical Soils Biology and Fertility Institute (TSBF method), which was the digging of soil blocks or monoliths of dimensions 25 cm long, 25 cm wide, and 30 cm deep. The steps followed were: sample area were selected and located and then sampling points for monolith extraction were marked then, litter within a 25-cm square were removed and faunas were hand-sorted then the monolith were isolated by cutting down with a spade a few centimeters outside the quadrant and then dug a 20-cm wide and 30-cm deep trench around it. Then delimited monolith blocks were divided into three layers: 0-10 cm, 10-20 cm and 20-30 cm. Each layer was hand-sorted separately and the soil from each layer was kept separately. For each layer, the hand-sorted soil macro invertebrates were conserved in different containers filled with alcohol of 75% and marked using a piece of paper with permanent marker the sample code noted on it.

2.6 Soil Invertebrate Macro Fauna Identification

It was proposed to identify soil invertebrate macro fauna to species level. But it was found very difficult and impossible to identify soil invertebrate macro fauna to species level due to lack of identification key to that level. Due to the above mentioned limitation fauna identification was raised to the family level. Family level identification of the fauna was conducted in consultation with the staff of Addis Ababa University Biology department. Samples of different soil invertebrate macro fauna preserved were brought for identification by making identification key. A group of different unidentified macro fauna were collected together by using a magnifying hand lens to use them as a key after identification. Then the key was used for identification to the family level.

2.6.1 Soil Invertebrate Macro Fauna Diversity and Abundance Determination

Soil invertebrate biodiversity and evenness were calculated using the Shannon index (*H′*), one of the most popular. Shannon's index measures both richness and evenness, or how evenly individuals were distributed among a group. High values of *H´* denote high biodiversity. Shannon's index was advantageous over simply counting the total number of different families, because the latter was greatly affected by sampling effort (plot size and total number of individuals sampled) [25].

Soil fauna family richness (S), Shannon diversity index (H') and equitability index (E) were ways of comparing the number and abundance of family. These indices do not account for differences in the number of families present, since assemblages differing in their family (group) composition may have the same values [26]. To determine faunal family richness of each system, species (family) index (S), the total number of fauna family on a land use was calculated. This index does not indicate the relative proportion or abundance of a particular family on a farm. Therefore, the Shannon index and Evenness measure (E) were used. Shannon's index takes into account the evenness or abundance of family [27]. Shannon's diversity index (H') was low when few species are more abundant than the others and high when the relative abundance of the different species in the sample was even. It was calculated using [Eq. 1].

$$\text{Diversity } H^1 = -\sum_{i=1}^{S} P_i \ln P_i \qquad \text{[Eq. 1]}$$

Where *S*= the number of families

P_i =the proportion of individuals or the abundance of the i^{th} family expressed as a proportion of total cover
ln = Log base$_n$

However, an additional measure of evenness (E), was calculated which compares the observed distribution for the maximum possible even distribution of the number of families in the sample. The measure of evenness (E) or equitability was the ratio of observed diversity to maximum possible diversity and it was calculated using [Eq. 2].

$$\text{Evenness (E)} = -\sum_{i=1}^{S} P_i \text{ Ln } P_i / \ln s \quad \text{..................[Eq. 2]}$$

Where s = the number of family

P_i = the proportion of individuals of the i^{th} family or the abundance of the i^{th} family expressed as proportion of total cover.

ln = Log base_n

E has values between 0 and 1.0 where 1.0 represents a situation in which all families were equally abundant. The above indices, which are generally referred to as alpha diversity, indicate the richness and evenness of species within a locality, but they do not indicate the identity of the family and where they occurred.

Hence, variation in the composition of the families within different land use system was determined by using Beta diversity (β) of Sorensen's community index of similarity. It was based on family numbers alone and does not take family abundance into account and it was calculated using Eq. [3].

I (Sorensen) = 2c/ (2c+a+b) …………………….. [Eq. 3]

where 'a' was the family number of assemblage A, 'b' the number of family in assemblage B, 'c' the number of family common to A and B.

2.6.2 Soil Sample Collection, Preparation and Analysis

Disturbed soil samples were collected from the three different layers (height) of a monolith for soil organic carbon and pH determination. Composite samples were collected from the top 30 cm of each of the 18 monolith (0-10, 10-20, 20-30 cm) and placed in plastic bag for soil carbon, and pH determination in soil laboratory. Then soil organic carbon was determined by [28] method and pH was measured by pH meter [29]. The bulk density was determined by using core method, where undisturbed soil samples were collected using core sampler of 100cm^3 volume [30].

2.7 Soil Carbon Stock Estimation

Soil carbon stock was estimated after determination of organic carbon, and mass of the soil (there was no coarse fragment in the soil samples) in the laboratory. Mass of the soil was determined by using bulk density and volume of core sampler. Soil organic carbon per unit area was calculated using Eq. [4]

Soil carbon stock (kg/ha) = mass of the soil*organic carbon (%)*coarse fragment (%).Eq. [4]

2.8 Statistical Analysis

One way analysis of variance (ANOVA) and mean comparison were made using the least significance difference (LSD) method at $P<0.05$ the effect of land use and soil depth on soil carbon stock. All Statistical analyses were conducted using the JMP 5 statistical software [31]. Shannon diversity index was also used to determine the diversity of soil invertebrate macro fauna in the two land uses.

3. Result and Discussion

3.1 Effect of Land Use Change on Abundance of Soil Invertebrate Macro Fauna

As shown in Table 1, the abundance of soil invertebrate macro fauna (SIMF) was various in the two land uses. Except for Formicidae family (136.48 and 233.6) and Blatidae (1.6 and 1.76), in indigenous agroforestry and monoculture agriculture, respectively the number of SIMF in indigenous agroforestry exceeds that of monoculture agriculture. In the system there is a significant difference between the abundance of SIMF at ($P< 0.05$) (Table 2).

Table 1: Abundance of soil invertebrate macro fauna

No	Vermicular name/common name	Family name	Total number of SIMF in indigenous agroforestry site per m^2		Total number of SIMF in monoculture agriculture m^2	
			No.	%	No	%
1	Earth worm	Lumbricidae	854.4	62.09	577.92	60.26
2	Centiped	Scutigeridae	76.48	5.56	37.12	3.87
3	Milliped	Trichopetem	5.76	0.42	0	0
4	Ants	Formicidae	136.8	9.92	233.6	24.36
5	Termite	Hodotemiae	90.24	6.56	48	5.00
6	Beetles	Gyrinidae	171.2	12.44	37.44	3.92
7	Spider	Linyphidae	24	1.74	14.24	1.48
8	Tree crickets	Grylidae	16	1.16	8.96	0.93
9	Cockroach	Blatidae	1.6	0.11	1.76	0.18
	Total		1376	100	959	100

A total of 1376/m^2 SIMF in indigenous agroforestry land use and 959/m^2 SIMF in monoculture agriculture were observed. The reasons for highest number of SIMF observed in indigenous agroforestry were the land management practice. On the other hand in monoculture agriculture such as frequent land clearing and burning, continuous tillage, monoculture practice, crop rotation, little organic residue inputs retention and use of agrochemicals have been shown to be among the causes of the alterations of soil fauna population structure, disappearance or reduction of key families and in some cases extremely low abundances or biomass in monoculture agriculture. Similar findings were reported by [32, 33, 34]. This result also indicates that there is a significant difference between the abundance of SIMF between the two land use types.

Earth worm was the most abundant in both indigenous agroforestry (62.02%) and monoculture agriculture (60.26%) system followed by, Beetles, Ants, Termite, Centiped in indigenous agroforestry land use and by Ants, Termite, Beetles, Centiped (Table 1). The result indicates unbalanced distribution of soil invertebrate macro fauna within the land uses. Their abundance in meter square (m^2) were also seen to be significantly different among all SIMF (Table 2).

Table 2: Significance level of soil invertebrate macro fauna in abundance between the land uses

SIMF	Mean±SE	
	AGL	CUL
Earth worm	854.4±0.01ª	577. ±0.04ᵇ
Beetles	171.2±0.05ª	37.44±0.6ᵇ
Centipeds	76.48±0.11ª	37.12±0.22ᵇ
Spider	24±1.3ª	14.24±0.57ᵇ
Milliped	5.76±0.01ª	1.3±0.09ᵇ
Treecriket	16±0.75ª	8.96±0.13ᵇ
Ants	136.48±0.01ᵇ	233.6±1.17ª
Cockroch	1.6±1.75ᵇ	1.76±2.23ª
Termites	90.24±1.5ª	48±0.08ᵇ

Similar letters across the row are not significantly variable at P<0.05

In vetical distribution (in depthwise distribution) the number of SIMF in indigenous agroforestry observed higher than the monoculture agriculture except in Ant and centipede (Table 3). Significant difference is also observed between the first layer of monoculture agriculture (0-10cm) and first layer of indigenous agroforestry (0-10cm), third layer of indigenous agroforestry (20-30cm), and third layer of monoculture agriculture (20-30cm). That means the first layer of monoculture agriculture is having less number of macrofauna than the first layer of indigenous agroforestry, third layer of indigenous agroforestry and third layer of monoculture agriculture. From this we can say that the abundance of SIMF in indigenous agroforestry system were higher than monoculture agriculture. Similar study report was found for high abundance of SIMF in agroforestry land use by [35, 36].

Table 3: Distribution of soil invertebrate macro fauna in land use type and depth of soil /monolith

Land use	Depth	Earth worm	Centipede	Millipede	Ant	Termite	Beetles	Spider	Tree crickets	Cockroach	Total
AF	10cm	16.4	1.78	0.00	2.2	2	7.3	1.1	1	0.1	31.88
AF	20cm	18.9	1.90	0.11	0.11	0.44	1.6	0.4	0	0	23.46
AF	30cm	18.1	1.10	0.25	6.22	3.2	1.8	0	0	0	30.67
MA	10cm	3.44	0.56	0.00	2.2	2	1.78	0.78	0.56	0	11.32
MA	20cm	4.78	0.56	0.00	12.4	0	0	0.11	0	0.11	17.96
MA	30cm	27.9	1.11	0.00	0	1	0.56	0	0	0	30.57

The number of SIMF in monoculture agriculture was directly proportional to the depth of the layer (Table 4). The number of SIMF in the third layer of monoculture agriculture is by much higer than the first and the second. This is because of the fact that the first 0-10 cm and 10-20 cm depth of monoculture agriculture is prone to different types of soil disturbance by fertilizer, pesticide appilication and exposure to sun light and moisture stress, which is having a negative effect on the availabilty of soil fauna in this layers. Similarly [37] reported that land management practice reduces the amount of SIMF in the soil. Student t-test showed that the abundance of SIMF in different depth was significantly different at (P< 0.05) for all SIMF in all depth and land use type.

Table 4: Relationship between land use, moisture content and number of soil invertebrate macro fauna

land use	Soil depth (cm)	Soilmoisturcontent %	Total no. SIMF/monolith/layer
AGL	0-10	34.8	31.88
	10-20	31.4	23.46
	20-30	34.7	30.67
CUL	0-10	22.7	11.32
	10-20	26	17.96
	20-30	33.7	30.57

AGL= Agroforestry land, CUL= Cultivated land

The abundance of SIMF revealed a direct (positive) relationship with soil moisture content (Table 4). The layer of the monolith in both land uses,which have larger number of SIMF (AF10, AF30, MA30) have a higher moisture content. Different studies showed that optimum level of moisture is important for better existence of SIMF. Specially earth worm appears to the surface when the upper soil is wet. Hence, the moisture content of the soil can be one of the factors for the higher abundance of SIMF in indigenous agroforestry land use and third layer of monoculture agriculture.

3.2 Effect of Land Use Change on Diversity of Soil Invertebrate Macro Fauna

The result indicated that the SIMF diversity of indigenous agroforestry is greater than monoculture agriculture as the diversity index (H' value) was higher (1.28) for indigenous agroforestry than that of monoculture agriculture (1.17) (Table 5 & 6). The wide array of highly diverse plant cover in indigenous agroforestry that facilitate the quality of organic matter produced and soil water and temperature regimes is the reason for higher SIMF diversity in this system. The positive effect of cover on SIMF activity and nutrient supply were also reported by [38].

Table 5: Shannon diversity index for indigenous agroforestry

Family name	No SIMF in AF	Pi	cumulative percentage	ln(Pi)	Pi*ln(Pi)	shannon index (H')
earth worm (Lumbricidae)	53.4	0.62	62.09	-0.48	-0.295	1.28
beetles (Gyrinidae)	10.7	0.12	12.44	-2.08	-0.259	
ants (Formicidae)	8.53	0.099	9.92	-2.31	-0.23	
termite (Hodotemitidae)	5.64	0.067	6.56	-2.72	-0.18	
centiped (Scutigeridae)	4.78	0.055	5.56	-2.89	-0.16	
spider (Linyphidae)	1.5	0.017	1.74	-4.05	-0.07	
tree crickets (Grylidae)	1	0.012	1.16	-4.45	-0.05	
milliped (Trichopetadem)	0.36	0.004	0.42	-5.48	-0.02	
cocroach (Blatidae)	0.1	0.0012	0.12	-6.76	-0.0078	
	86	1	100			

Analysis of evenness index showed that SIMF in monoculture agriculture unevenly abundant/distributed in both land uses (E=0.57) indigenous agroforestry (E= 0.58) (Table 7). Evenness was relatively higher in the indigenous agroforestry area indicating a higher number SIMF and better relative distribution. Due to the dominance (0.43) in the monoculture agriculture, domination of SIMF by few families is observed. This might be due to intensity and persistency of management activities in this land use.

Table 6: Shannon diversity index for monoculture agriculture site

Familyname	No SIMF in MA	Pi	cumulative percentage	ln(Pi)	Pi*ln(Pi)	shannon index (H')
Earth worm *(Lumbricidae)*	36.12	0.60	60.20	-0.51	-0.31	1.17
Ants *(Formicidae)*	14.6	0.24	24.33	-1.41	-0.34	
Termite *(Hodotemitidae)*	3	0.05	5.00	-3.00	-0.15	
Beetles *(Gyrinidae)*	2.34	0.04	3.90	-3.24	-0.13	
Centiped *(Scutigeridae)*	2.32	0.04	3.87	-3.25	-0.13	
Spider *(Linyphidae)*	0.89	0.01	1.48	-4.21	-0.06	
Tree crickets *(Grylidae)*	0.56	0.01	0.93	-4.67	-0.04	
Cockroach (Blatidae)	0.11	0.00	0.18	-6.30	-0.01	
Milliped *(Trichopetadem)*	0	0.00	0		0	
	60	1	100			

Variation in the composition of the families within different land use system was determined by using Beta diversity (β) of Sorensen's community index of similarity [39]. It is based on family numbers alone and does not take family abundance into account. The calculated result of Sorenson index of similarity was 0.48. Generally, factors like human influences have a strong impact on SIMF composition and species richness.

Table 7: Shannon-Weiner index of diversity, evenness, and dominance for the land uses

Indices	indigenous agroforestry	Monoculture agriculture
Diversity	1.28	1.17
Evenness	0.58	0.57
dominance	0.43	0.43

3.3 Effect of Land Use Change on Soil Carbon Stock

The soil carbon stock of the two land use types was found to be different. The analysis indicates significant difference in carbon stock level between the equivalent layers of both land uses. The difference in soil carbon stock in the upper layer of indigenous agroforestry land use system is statistically significant and by much higher than the other layers (Table 8). On the other hand the first and second layer of monoculture agriculture shows no significance difference but both have significant difference with the third layer. The two land use types showed no significant difference in carbon stock in their third layer. The difference in soil carbon stock between the two land uses might be attributed to difference in vegetation cover difference.

Table 8: Significance level of soil carbon stock in land use at different layers

Land use	Soil depth (cm)	Mean Carbon stock (kg/m^2)
AGL	0-10	41.18±0.02^a
	10-20	34.08±0.01^b
	20-30	25.59±0.32^c
CUL	0-10	32.30±0.5^b
	10-20	34.27±0.07^b
	20-30	25.92±0.11^c

Levels not connected by same letter are significantly different

The soil C stock is directly related to plant and SIMF diversity, and land use with higher, compared to those with lower number of plant as well as SIMF diversity had higher soil carbon stock, especially in the top soil layer. Hence, the interaction effect of land use type and SIMF has positive effect on the level of carbon stock (Table 9). As it is indicated clearly on Table 9 the total number of SIMF and the level carbon stock for indigenous agroforestry is higher than the monoculture agriculture.

Table 9: Relation between Carbon stock, Total SIMF and land use

land use	Total SIMF/m^2	carbon stock(kg/m2)	pH
AGL	1376	101	5.83
CUL	959	92	5.84

The level of soil carbon stock in the soil is dependent on the availability of soil organisms in the soil. Because the abundance of SIMF in the upper layer was high. The indigenous agroforestry land use system also has better diversity than the monoculture agriculture. This in turn resulted in high amount of carbon stock in indigenous agroforestry land use system. In this study pH level of the two land use showed no significant difference and was found closer to each other on the two land uses.

4. Conclusions and Recommendations

4.1 Conclusions

The abundance and diversity of soil invertebrate macro fauna depends on land use type. The indigenous agroforestry land use of the area favored the abundance and diversity of SIMF. The abundance of SIMF showed significant difference between the two land use types and it was clear that the macro fauna in indigenous agroforestry land use was abundant than the monoculture agriculture. Shannon-Weiner index value showed the diversity of SIMF was high in indigenous agroforestry land use. The indigenous agroforestry have shown more fauna (9 families) composition than the monoculture agriculture (8 families). A change in the land use type from indigenous agroforestry can alter the abundance and diversity of soil invertebrate macro fauna in the soil.

The level of carbon stock in the two land use system is significantly different with respect to soil depth. The interaction effect of SIMF and land use observed to have a significant effect on the level of soil carbon stock. Especially the interaction between SIMF and soil depth in land use has high effect on carbon stock. The indigenous agroforestry has a high level of carbon stock and this level is significantly different from monoculture agriculture at $P< 0.05$.

5. Recommendations

Based on the result of this study it is worth to recommend the following points.

- As soil fauna are always there in the soil any activity on the soil layer should consider the effect that it brings on the existence and survival of SIMF. To improve the availability of SIMF due attention should be given, because of their importance in maintaining life supporting system function.
- In addition to the other known ecological function of the indigenous agroforestry, the Gedeo indigenous agroforestry should be given special emphasis for their biodiversity as it may contribute a lot in sequestrating carbon which is the global issue.
- The consequence of altering indigenous agroforestry land use to monoculture agriculture should be checked for its negative effects

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