Uttar Pradesh Journal of Zoology

Volume 44, Issue 22, Page 145-153, 2023; Article no.UPJOZ.2811
ISSN: 0256-971X (P)

Macro Invertebrate Diversity in Different Land Use System and Soil Fertility Status in Relation to Macro Invertebrate Distribution in Shashogo District, Hadiya Zone, Southern Ethiopia

Tsegaye Dobamo Misebo [a*], Denebo Sebaro Wanore [a] and Abera Fikre Gemeda [a]

[a] *Biology Department, College of Natural and Computational Sciences, Wachemo University, Ethiopia.*

Authors' contributions

This work was carried out in collaboration among three authors. Author TDM designed study, performed analysis, wrote the first draft of the manuscript. Authors DSW and AFG follow up the research, managed the analysis of the study and searched all possible literatures. All authors read and approved the final manuscript.

Article Information

DOI: 10.56557/UPJOZ/2023/v44i223728

Editor(s):
(1) Dr. P. Veera Muthumari, V. V. Vanniaperumal College for Women, India.
Reviewers:
(1) M. G. Sanal Kumar, Pandalam Affiliated to University of Kerala, India.
(2) Imran Arshad, United Arab Emirates.

Original Research Article

Received: 23/07/2023
Accepted: 28/09/2023
Published: 31/10/2023

ABSTRACT

Invertebrate species are predominant in the food webs and among the ecosystem engineers associated with agriculture. They have a major influence on productivity and therefore play a key role in food security. The objective of the present study is to evaluate the ecological role of soil

**Corresponding author: Email: denesmicro2021@yahoo.com;*
Email: denebosebro@gmail.com;

macro invertebrate diversity for maintenance of soil fertility in Shashogo District, Hadiya zone, Southern Ethiopia. Both field and laboratory work were applied during investigation of the study. Invertebrate's diversity was identified and Soil samples were collected from different sites and evaluated for soil fertility status. The physico-chemical analysis; organic carbon content, total nitrogen, available phosphorous, available K, soil pH, soil texture, sodium etc… was analyzed. The main soil macro invertebrates identified were Termites (order Isoptera), Beetles (order Coleoptera), Wasps (Hymenoptera), Millipedes (order diplopoid), Centipedes (chilopoda), Ants (Hymenoptera) and Earthworm (order Opisthopora). The average selected chemical properties of the soil were Soil PH (5.60), Total Nitrogen (0.23), and Organic carbon (2.44), Phosphorus (2.63), Calcium (22.73), Potassium (0.376) and Sodium (0.096). There is significant association between soil macro invertebrate groups and selected soil physical and chemical properties. To conserve soil resources, it needs highest attention of policy makers as well as land use planners to concentrate their efforts on land management strategies based on land use system.

Keywords: Soil; macro invertebrate; diversity; soil fertility.

1. INTRODUCTION

"Agriculture in many developing countries is leading the economics activities for many years and serves as back bone for livelihoods of people. This is also true in our country Ethiopia when more than 85%of total populations are depending on agriculture. The majority of population of Ethiopia consists of farmers and there where reside in rural areas and whole life are almost entirely depends on agriculture and agricultural products. Agriculture is the main stay of major proportion of human population of the country, even though it is threatened by human induced degradation and climate factors" [1].

"Ethiopia is reported to have the highest rates of soil nutrient depletion in sub-Saharan Africa, with soil erosion estimated to average 42 tons per hectare per year on cultivated land and past studies have shown that the frequency and spatial coverage of droughts have increased over the past few decades. In addition to this, the combined effects of deforestation, overgrazing, expansion of cropland and unsustainable use of natural resources has contributed to land degradation" [2].

"Integrated management of soil fertility and plant nutrients is an important prerequisite for boosting up crop production and sustaining higher yield over a period of time. Future strategies for increasing agricultural production will have to focus on using available natural resources more efficiently, effectively and sustainably than in the past" [3]. "Since there is no scope to increase the net cultivable land, intensive cropping through integrated soil fertility and nutrient management could be one of the important means to further increase of crop production in Bangladesh. This system helps farmers to make a decision regarding proper way of farm management which enhances high crop yields and improves the soil fertility in the long run" [4].

"Soil biodiversity has been widely studied since the soil itself is the base for farming" [5]. "The conservation of biodiversity is necessary to maintain the sustainable functioning of soil. Soil invertebrates are important components of tropical ecosystems. Soil invertebrates perform important functions related to the growth conditions of plants. For example, ecosystem engineers such as termites and earthworms increase soil porosity and average pore size by tunnelling through the soil. These invertebrates ingest considerable amounts of soil and dead plant material, thereby contributing to the mixing of organic matter and mineral soil. This improves aggregate stability and increases the surface of organic material so that it is more readily colonised and decomposed by soil bacteria and fungi" [6]. "Examples have shown that soil fauna enhance nitrogen mineralization markedly by up to 25%. Soil invertebrates are the dominant animal group in many terrestrial ecosystems and may have higher biomass on an area basis than above-ground her-bivorous insects or vertebrates" [6].

In 1881, Darwin was one of the first scientists who noted that the topsoil consisted mostly of earthworm castings, thus highlighting the importance of earthworms in pedogenesis processes (soil organo-mineral complex). For example, the earthworm population builds galleries and ingests large quantities of organic and mineral matter, thus modifying the porosity and aggregation of the soil. This earthworm bioturbation may subsequently be reflected in soil profiles [7], for example: soil profile disturbance, soil structure modification, and vertical and horizontal redistribution of soil and organic matter (OM). “This redistribution of OM depends on the earthworm ecological groups. Endogeic earthworms keep moving inside the soil to feed on soil organic matter (SOM) while anecic ones feed on plant litter and organic residues at the soil surface and tend to stay in the same burrow” [6]. “Epigeic species, which consume considerable amounts of raw OM have a broad range of enzymatic capacities, probably mainly originating from ingested microflora” [8]. As discussed by Lavelle et al. [6], the soil biogenic structure (mixture of casts, burrows, OM, etc.) created by earthworms is commonly termed the “drilosphere” [9]. There is limited information in Ethiopia towards soil biodiversity for soil fertility and integrated soil management for improved crop production. Therefore, the present study fulfill gap by studying ecological role of soil macro invertebrate diversity for maintenance of soil fertility in Shashogo District, Hadiya zone, Southern Ethiopia.

2. METHODOLOGY

2.1 Description of the Study Area

The study was conducted in Hadiya Zone, Shashogo District, which is 224 km far from the capital of Addis,117 km from Hawassa capital of Southern Nations, Nationalities and Peoples Region (SNNPR), 52 km from zonal capital Hossana at an elevation ranging from 1800 to 2000 m above sea level. “The district contains 36 kebeles (smallest administrative unit in Ethiopia) (34 rural and two urban) within an area of 32,310 $km^2$and it has a total population of 12, 7281,. Shashogo district has predominantlydry kola (hot low land) agro-ecology. The rainfall has a bimodal nature in which the months from March to May and June to September are marked by relatively higher rainfall records; while months from November to February are dry. The long rainy season in the area is between June and September, during which crop cultivation takes place in the area. The total annual rainfall reaches 1005.1 mm. The mean maximum temperature is 21.6 °C, occurred during February; while the mean minimum temperature is 18.5 °C occurred during July. Water bodies such as streams and rivers commonly exist in the area. There is also a lake which surrounds two of the kebeles” [10].

2.2 Study Site

The experiments were carried out in three sites: site 1(farm land), site 2 (grass land) and site 3 (Woody land).

2.3 Soil Sampling and Sample Preparation

Soil parameters were measured in each sampling plot. Soil was sampled from 0-20cm depth, sieved (2mm mesh size) and air-dried. Then samples were analyzed for different soil parameters in Araka Agricultural Research center. The soil physical parameters like soil texture and the soil chemical parameters like soil PH, organic carbon, total nitrogen, available phosphorus, available potassium, available calcium and sodium were analyzed (Table 1).

2.4 Soil pH

Soil pH was measured using a pH meter at the ratio of 1:2.5 soils: water as described by Mclean [11].

2.5 Total Nitrogen

Total nitrogen was determined by micro-Kjeldahl digestion-distillation method as described by Bremner and Mulvaney [12]. “One g of soil digested with concentrated H_2SO_4 in presence of mixed catalyst (K_2SO_4, $CuSO_4$ and selenium powder mixed in the ratio of 10:10:1 by weight). The digest was distilled in the presence of 40% NaOH. The ammonia liberated were collected in 4% boric acid (with mixed indicator) and then titrated with standard H_2SO_4. The titre was used to calculate the total N of the soil sample” [12].

2.6 Phosphorus

“Available P was extracted by the Bray-1 procedure” [13]. “The extracting solution containing NH_4F 0.025 HCl was used. A sample of 3 g air-dried soil were placed in a plastic bottle, with 25 ml of the extracting solution added, shaken for one minute and filtered. Five ml of the filtrate were pipetted and placed in 50 cm3 volumetric flask with 20 ml distilled water. The P was determined in the filtrates by spectrophotometry at 884 nm following colour development by the molybdenum blue method” [14].

Table 1. Parameters and methods adopted for the laboratory analysis

Physical	parameters	Methods
	Soil texture	Hydrometer
Chemical	Soil pH	By PH meter.
	Organic carbon	Wakley and Black method
	Total N	micro- Kjeldahl digestion-distillation method
	Available P2O5	Bray-1 procedure
	Available K2O	Ammonium acetate
	Available Ca	EDTA Titration

2.7 Organic Carbon

The organic carbon was determined using Wakley and Black method [15]. "To a 1g soil sample, 10 ml of 1M K2Cr2O7 and 20 ml of concentrated H2SO4 were added to oxidize organic carbon. The amount of dichromate reduced was used to estimate the organic carbon content of the soil" [15].

2.8 Soil Invertebrate Sampling: Pilot Sampling

Invertebrate community samples were collected from three different sampling sites (forest land, grass land, crop cultivated land). The sampling site were 50 cmx50cm plots for each sampling site and soil to a depth of 20 cm dug out using a metal frame as a guide. The soil were placed onto a plastic sheet and hand sorted for macro invertebrates [16]. The sample were in duplicate for each sampling site.

2.9 Species Diversity

The following formula was used to calculate Shannon diversity index as followed by Magurran [17], and Jarvis and Crook [18].

$$H' = -\Sigma pi * \ln(pi) \ldots\ldots (1)$$

Where
H' is Shannon-winner index, *pi* is estimated as *ni/N*, where *ni* is the proportion of the total population of the i^{th} species and N= -Σ*ni.* This use proportions rather than absolute abundance values to reduce the effects of order of magnitude deference in invertebrate numbers between species. This index provides a measure of `**evenness'** in the proportion of each species occurring within squares.

$$J' = H'/\ln(S) \ldots\ldots (2)$$

Where
J' is Evenness index, *H'* is Shannon winner index and used the formula one and *S* is species richness.

Relative abundance (RA) (%) = $n/N \times 100$, where *n* is the number of individuals of particular species recorded and *N* is the total number of individuals of the species [19].

2.10 Macro Invertebrate Identification

Sampled invertebrates were washed twice in clean tap water and afterwards narcotised in 20 % ethanol. Invertebrates were preserved in ethanol, clearly marked with labels and transported to the Wachemo University biology laboratory for further identification.

2.11 Data Analysis

Data was analyzed by SPSS software version 20 for windows. The analyzed data were presented in the form of tables, graphs, text and etc.

Image 1. Field experiment

4. RESULTS AND DISCUSSION

4.1 Macro-invertebrate Community Composition

Different macro invertebrate were identified from different sampling sites. The main macro invertebrates identified were Termites (order Isoptera), Beetles (order Coleoptera), Wasps (Hymenoptera), Millipedes (order diplopoid), Centipedes (chilopoda), Ants (Hymenoptera) and Earthworm (*order* Opisthopora) (Table 1).

4.2 Relative Abundance of Soil Microfauna

The relative abundance Soil macro inveretebrate from different land use sytem were identified. The most abundant taxa identified were Termites (order Isoptera), Beetles (order Coleoptera, Earthworm (*order* Opisthopora) and Ants (Hymenoptera) (Fig. 1).

Table 2. Invertebrate macrofauna observed across different land use systems

No	Taxa	Land use system		
		Grass land	Woody land	Farm land
1	Termites (orderIsoptera)	+	+	+
2	Beetles (order Coleoptera)	+	+	+
3	Earthworm (*order* Opisthopora)	+	+	+
4	Millipedes (order diplopoid)	+	+	+
5	Centipedes (chilopoda)	+	+	_
6	Ants (Hymenoptera)	+	+	_
7	Wasps (Hymenoptera)	+	+	_

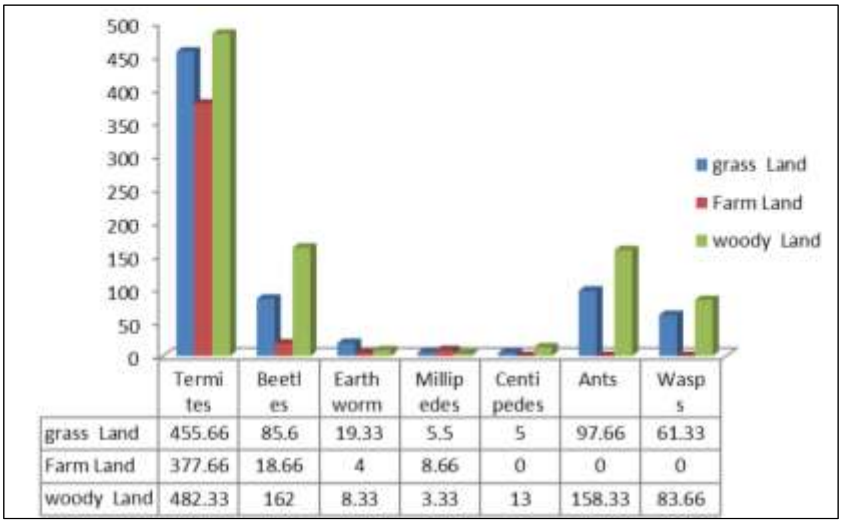

Fig. 1. Relative abundance of soil macro invertebrates from different land use system

Table 3. Soil physical characteristics from different land use system

No	No parameters	Land use		
		Grass Land (Average)	Farm Land (Average)	Woody Land (Average)
1	**Sand (%)**	45.33	60.11	29.72
2	**Silt (%)**	32.22	21.89	37.67
3	**Clay (%)**	22.44	19	33.61

Table 4. Soil chemical characteristics from different land use system

No	parameters	Grass Land	Farm Land	Woody Land
1	Soil PH	5.7	5.21	5.91
2	Total Nitrogen (%)	0.25	0.17	0.28
3	Organic carbon (%)	2.65	1.67	3.16
4	Phosphorus (g/Kg)	2.75	1.6	3.55
5	Calcium (g/Kg)	24.56	17.2	26.43
6	Sodium (g/Kg)	0.06	0.07	0.16
7	Potassium (K)	0.43	0.3	0.4

4.3 Soil Physical Characteristics from Different Land Use System

The soil texture was examined from different land use system (grass land, farm land and woody land) presented in (Table 3).

4.4 The Soil Chemical Parameters from Different Land Use System

The soil chemical parameters were examined from different land use system (grass land, farm land and woody land) presented in (Table 4).

"Organic materials in and on the soil are broken down and transformed –mainly by soil organisms– into nutrient elements, which are, in turn taken up by plants and micro-organisms. The macro-fauna densities recorded in this study is within the range of what has been observed in different studies" [20,21]. "Individuals belonging to Termites order Isoptera, Earthworm (*order* Opisthopora), Beetles (order Coleoptera) and Ants (Hymenoptera) dominated these regions with high localized populations being observed. Our results are in accordance with previous studies which have documented the dominances of ants, termites and beetles larvae in Savannah regions" [22]. "Recent studies in other parts in Kenya have also documented high densities of Hymenoptera and Isoptera" [20].

Our study shows that soil macro-fauna were sensitive to land use and management. Forestland systems had higher abundance and diversity than any other type of land use. Our results are in support of other studies that have shown that land use can exert a strong influence on the overall abundance, diversity and community composition of soil macro-fauna [23]. as well as soil physical, chemical and biological properties and processes [24].

"Extremely low densities and species numbers were observed in farm land soil. Similarly, agriculture negatively altered macro-fauna communities by declining individual. Agriculture has previously been shown to negatively affect macro-fauna communities" [20]. "This loss of biodiversity can result in reduction in ecosystem services such as pest control, nutrient cycling and maintenance of soil structure. These changes are associated with destruction of nesting habitats, modification of soil micro-climate within cultivated soils, removal of substrate, low diversity and availability of food as well as physical destructions of macro-fauna individuals with management practices such as use of agrochemicals. In addition, annual cropping systems decrease the diversity and abundance of soil fauna communities due to soil disturbance and the absence of a permanent soil cover" [23].

Soil physical properties were significantly influenced by different land use types. The mean values of soil texture of three land uses (woody, grass land and cultivated land) was different. Cultivated land had significantly high sand proportion and low silt and clay fraction (Table3). In contrast, woody and grass lands had lowest mean value of sand fraction and high silt and clay fraction. This might be due to soil texture which is not easily changed as a result of conservation difference within short period of time. Jamala and Oke [25] also reported that "soil texture is intrinsic soil property, but intensive cultivation could contribute to the variations in particle size distribution at the surface horizon of cultivated and natural fallow land".

Soil pH value was significantly affected by land uses. Lowest mean pH value was observed in the farm land while the highest pH value was recorded in the woody and grass land (Table 4). The reason for lowest pH value in the cultivated land might be attributed to the excessive removal of basic cations. The results are in lined with Selassie et al. [26] who observed that "washing away of solutes and basic cations lowers pH value in the Zikre watershed North West Ethiopia". The result agree with [27] who stated that, "H^+ released by nitrification of NH4+from chemical fertilizer lowers the pH value of cultivated land as compared with non-cultivated land".

The result confirmed that "available Phosphors were significantly affected by land use types. farm land had significantly lower available phosphors. This could happen due to high erosion, low organic and inorganic fertilizer application and crop residue removal in the cultivated land as compared with other land use types" [28]. The average available phosphors of woodyland>grass land>farm land (Table 4).

Organic carbon and total nitrogen also showed variation due to land uses and conservation difference. The average means value of organic carbon and total nitrogen of farm land<grass land>woody land. This could be due to soil erosion processes and different anthropogenic activities like land fragmentation and grazing intensity which is very high in the farm land [29]. also observed low soil organic matter in the farm land.

5. CONCLUSION

The present study demonstrates that quantitative changes in diversity and density of soil macro invertebrate communities were various for different land use systems. These changes in soil macro fauna were associated with different land management practices such as use of land for agriculture, for grass and plant cultivation (forest land). Such land use systems would have a favorable effect on the development of an abundant and diverse soil and macro-fauna, which in turn may assist in the conservation of soil fertility and productivity.The significant association between soil macro invertebrate groups with selected soil physical and chemical properties shows that, soil physical and chemical characteristics influenced by diversity and abundance of soil macro invertebrates.

ACKNOWLEDGEMENT

The authors are thankful to Wachemo University for funding to conduct this research and the participants who involved in this study.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Admasu A. Study of sediments yield from the watershed of Angereb reservoir Msc thesis Department of Agricultural Engineering Alemaya University,Ethiopia. 2005;98.
2. Descheemaeker K, Raes D, Nyssen J, Poessen J, Muys B, Haile M and Deckers J. Two rapid appraisals of FAO-56 crop coefficients for semiarid natural vegetation of northern Ethiopian highlands. Journal of Arid Environments.2011;75(4):353-359.
3. Gruhn P, Francesco G, Montague Y. Integrated nutrient management, soil fertility and sustainable agriculture: Current issues and challenges. Vision Discussion Paper. Washington, DC.; 2000.
4. Hikson M, Keith L. The attitudes and perceptions of high school administrators toward agricultural science teachers in Texas. Proceedings of the Southern Agricultural Education Research Conference. Lexington KY; 2000.
5. Stockdale E, Watson C, Black H, Philipps L. Do farm management practices alter below-ground biodiversity and ecosystem function? Implications for sustainable land management. JNCC Report No. 364. Peterborough, UK: Joint Nature Conservation Committee; 2000.
6. Lavelle P, Bignell D, Lepage M, Wolters V, Roger P, Ineson P, Heal OW, Dhillion S. Soil function in a changing world: the role of invertebrate ecosystem engi-neers. Eur. J. Soil Biol. 1997;33:159–193.
7. Zhang Q, Hendrix P. Earthworm (*Lumbricus rubellus* and *Aporrectodea*

caliginosa) effects on carbon flux in soil. Soil Sci. Soc. Am.1995;59(3):816- 823.

8. Curry JP, Doherty P, Purvis G, Schmidt O. Relationships between earthworm populations and management intensity in cattle-grazed pastures in Ireland. Applied Soil Ecology. 2008;39 (1):58-64
9. Brown GG, Barois I, Lavelle P. Regulation of soil organic matter dynamics and microbial activity in the drilosphere and the role of interactions with other edaphic functional domains. Eur. J. Soil Biol. 2000; 36:177–198.
10. Terefe E, Dessie T, Haile A, Mulatu W. Mwai O. On-farm phenotypic characterization of Mursi cattle in its production environment in South Omo Zone, Southwest Ethiopia. Animal Genetic Resources/Resources génétiques animales/Recursos genéticos animals. 2015;57**:**15-24.
11. Mclean EO. Soil pH and Lime Requirement. In: Page, A.L., Ed., Methods of soil analysis. part 2. chemical and microbiological properties, American Society of Agronomy, Soil Science Society of America, Madison. 1982;199-224.
12. Bremner JM, Mulvaney CS. Nitrogen-Total. In: Methods of soil analysis. Part 2. Chemical and microbiological properties, Page, AL, Miller RH, Keeney DR. Eds., American Society of Agronomy, Soil Science Society of America, Madison, Wisconsin.1982;595-624.
13. Bray RH, Kurtz LT. Determination of Total, Organic, and Available Forms of Phosphorus in Soils. Soil Science. 1945;59:39-45.
Available://doi.org/10.1097/00010694-194501000-00006
14. Murphy J, Riley JP. A Modified Single Solution Method for the Determination of Phosphate in Natural Waters. Analytica Chimica Acta.1962;27:31-36.
Avaialble:http://dx.doi.org/10.1016/S0003-2670(00)88444-5
15. Allison LE. Organic carbon. In: Black C.A., Ed., Methods of Soil Analysis, ASA-CSSA-SSSA, Madison, 1965;1367-1389.
16. Haynes RJ. Dominy CS, Graham MH. Effect of agricultural land use on soil organic matter status and the composition of earthworm communities in KwaZulu-Natal, South Africa. Agriculture, Ecosystems & Environment. 2003;95(2–3):453-464.
17. Magurran AE. Ecological Diversity and Its Measurements. Princeton University Press, Princeton NJ;1988.
Available:https://doi.org/10.1007/978-94-015-7358-0
18. Crook DA, Robertson AI. Relationships between riverine fish and woody debris: implications for lowland rivers. Marine and Freshwater Research. 1999;50:941-953.
Available:https://doi.org/10.1071/MF99072
19. Bibby CJ, Burgess ND, Hill DA. Bird census techniques. Cambridge: Cambridge Univ. Press;1992.
20. Ayuke FO, Karanja NK, Muya EM, Musombi BK, Mungatu J, Nyamasyo GH. Macro-fauna diversity and abundance across different land use systems in Embu, Kenya. Trop. Subtrop. Agroecosyst. 2009;11:371-384.
21. Doblas-Miranda E, Sánchez-Piñero F, Gonza´-Lez-Megi´As A. Soil macroinvertebrate fauna of a Mediterranean arid system: Composition and temporal changes in the assemblage. Soil Biol. Biochem. 2007;39(8):1916-1925.
22. Dangerfield JM. Abundance and Diversity of Soil Macro-fauna in Northern Botswana Author(s). J. Trop. Ecol. 1997;13(4):527-538.
23. Barros E, Pashanasi B, Constantino R, Lavelle P. Effects of land-use system on the soil macro-fauna in western Brazilian Amazonia. Biol. Fertil. Soils. 2002;35:338-347.
24. Barrios E. Soil biota, ecosystem services and land productivity. Ecol. Econ. 2007;64:269-285.
25. Jamala GY, Oke DO. Soil organic carbon fractions as affected by land use in the Sourthern Guinea Savanna ecosystem of Adamawa State, Nigeria. 2013;4(6):116-122.
26. Selassie YG, Anemut F, Addisu S. The effects of land use types, management practices and slope classes on selected soil physico-chemical properties in Zikre watershed, North-Western Ethiopia. Environ. Syst.Res. 2015;4(1):3.
Available:http://www.environmentalsystemsresearch.com/content/4/1/3.
27. Habitamu A. Fertility status of soils under different land uses at Wujiraba Watershed, North-Western Highlands of Ethiopia. Agriculture, Forestry and Fisheries. 2014;3(5):410.
Availablet:http://www.sciencepublishinggroup.com/journal/paperinfo.aspx

28. Bezabih B, Regassa A, Lemenih M. Soil Fertility Status as Affected by Different Land Use Types and Topographic Positions: A Case of Delta Sub-Watershed, Southwestern Ethiopia. 2014; 4(27): 91-106.

29. Khan F, Hayat Z, Ahmad W, Ramzan M, Shah Z, Sharif M, MianI A, Hanif M. Effect of slope position on physico-chemical properties of eroded soil. Soil Environ. 2013;32(1):22-28.