International Journal of Plant & Soil Science

34(23): 980-994, 2022; Article no.IJPSS.92893
ISSN: 2320-7035

Nutrient Transformation in Different Land Use Systems

D. Balaji Naik [a*] and K. T. Gurumurthy [a]

[a] *Department of Soil Science and Agricultural Chemistry, College of Agriculture, Shivamogga Keladi Shivappa Nayaka University of Agricultural and Horticultural Sciences, Shivamogga-577204, India.*

Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJPSS/2022/v34i232507

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/92893

Review Article

Received 22 August 2022
Accepted 26 October 2022
Published 31 October 2022

ABSTRACT

Land use is an emerging socio-economic activity wherein a region of one major specific purpose utility may be converted into another land for general purpose utility. Land use and management practices influence soil nutrients related to soil processes, such as erosion, oxidation, mineralization and leaching, consequently modifying the transport and redistribution processes. Deforestation is widespread in the tropics, and future changes in land use may have an impact on soil nutrient conversions. Understanding how the ecosystem operates and estimating the effects of future land use change on soil properties require characterising the spatial variability of soil nutrients in relation to site properties such as climate, land use, topography, and other variables.

Keywords: Land use; nutrients; nutrient transformations; mineralization.

1. INTRODUCTION

"Soil quality mainly depends on the response of soil to different land use systems and management practices, which may often modify the soil properties and hence soil productivity. Chemical properties *viz.,* soil organic carbon content and cation exchange capacity have been to be comparatively more in the soils under grass land than under cultivated land system" [1]. There is insufficient knowledge on the effect of land use regimes on soil quality to make suggestions for optimal and sustainable land resource exploitation. Land use integrates a

**Corresponding author: E-mail: balajinaikb998@gmail.com;*

number of environmental factors that affect the export of nutrients. The mechanisms of nutrient transport and redistribution are altered as a result of how land use and soil management practises affect soil nutrients-related soil processes such erosion, oxidation, mineralization, and leaching.

A land use system's inherent manifestation of nutrient changes. Nutrient cycles and biomass transformation are influenced by management practices. A strong land use system ensures sustenance over longer time periods. The best option for ecosystem survival is a combination of land use systems.

2. FORMS AND AVAILABILITY OF NUTRIENTS IN SOIL THEIR MOVEMENTS AND UPTAKE BY ROOTS

2.1 Land Use

Land use refers to man's activities and the various uses that occur on land. Land use and land cover are two technical terms used in geography. Land use refers to any type of permanent or cyclical intervention in land. It is the surface use of vacant or developed land for a specific purpose at a specific time. Land use is a new socioeconomic activity in which a region of one major specific purpose utility is converted into another for general purpose utility. Natural vegetation, water bodies, rock, soil, and other similar features are referred to as land cover.

Soil physicochemical and C dynamics are influenced by land use and vegetation cover type. Land use is an integrator of several environmental attributes that influence nutrient export use and soil management techniques, such as erosion, oxidation, mineralization, and leaching, and thus modify the functions of nutrient transport and re-distribution. Land-use change alters soil reaction, soil organic matter (SOM), nutrient status, soil physical quality, and microbial activity in the rhizosphere noticeably.

Different management techniques and the transition from one land use system to another can have an impact on the soil's structure, soil organic carbon content, and other nutrient restoration.

3. NUTRIENTS REACH ROOT SURFACES BY THREE MECHANISMS

- Mass flow – movement of nutrients in water flowing toward the root.
- Diffusion – movement down a concentration gradient from high – low.
- Interception – roots explore new soil areas containing unused soil nutrients. All three are in constant operation. Root hairs primarily responsible for the uptake

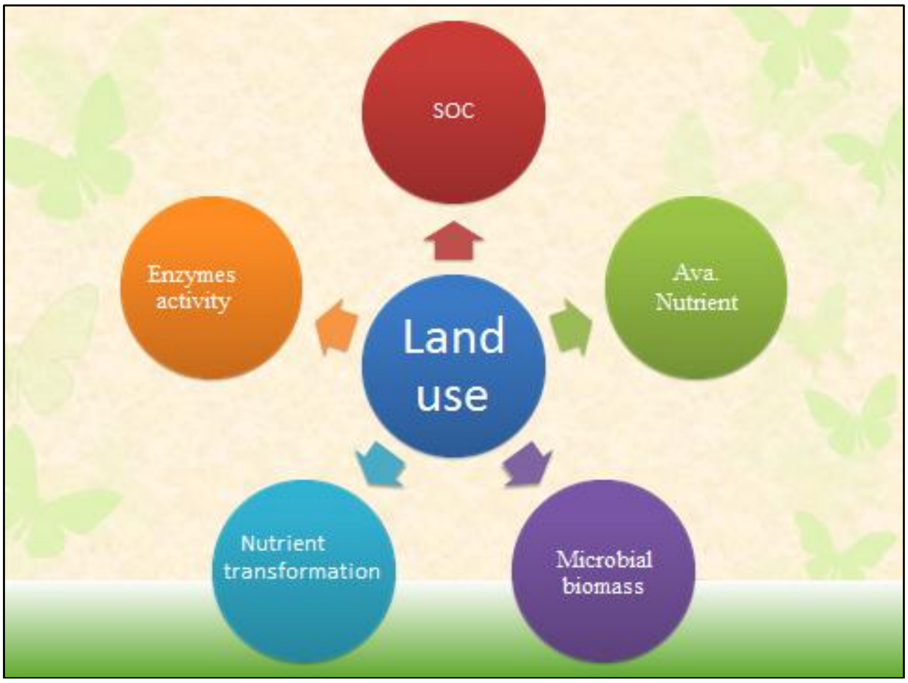

Image 1. Land use scenario

Image 2. Land use dictates nutrient transformation

Image 3. Mixed forest

4. NUTRIENT UPTAKE BY THE ROOTS DEPENDS ON ROOT GROWTH AND SOIL EXPLORATION ABILITY TO ABSORB NUTRIENT CONCENTRATION AS THE ROOT SURFACE

4.1 Forms of Nutrents

- Cation – positively charged ion
- Anion – negatively charged ion
- Neutral – uncharged
- Plants use the mineralized from of a nutrient

There are three major forms of nitrogen in the soil

- Organic nitrogen
- Ammonium nitrogen
- Nitrate nitrogen

Nutrient forms and availability in soils, movement and uptake by roots, and nutrient utilisation within plants are all interconnected. Soil micronutrient availability is heavily influenced by soil microenvironment as well as soil properties such as pH, calcium carbonate ($CaCO_3$), organic matter, and cation exchange capacity. Parent material, climatic factors, natural vegetation, and land use pattern all play important roles in regulating soil nutrient dynamics and fertility. Different agricultural land-uses have a significant impact on soil quality and physicochemical properties, as well as nutrient dynamics and supply.

4.2 Land Use Systems

Nature/man designed land use systems according to the availability of resources such as water and soil, as well as the requirements of the people depending on the system. The land use systems designed in this manner are aimed at biomass turnover and nutrient cycling over time. As a result, the system's self-sustainability is ensured; however, intensive systems require external input additions. The term is most frequently used in agriculture and relates to the process of planting crops in a specific pattern or succession of growth. Wheat fields, apple orchards, and grape vineyards are a few examples.

4.2.1 Agriculture-horticulture

Agriculture-horticulture is a combination of horticulture crops specially tree species and annual crops. e.g. Coconut and ragi, fruit crops and pulses.

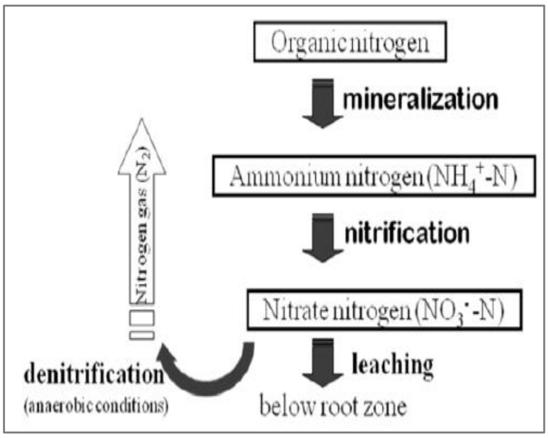

Image 4. Nitrogen transformation

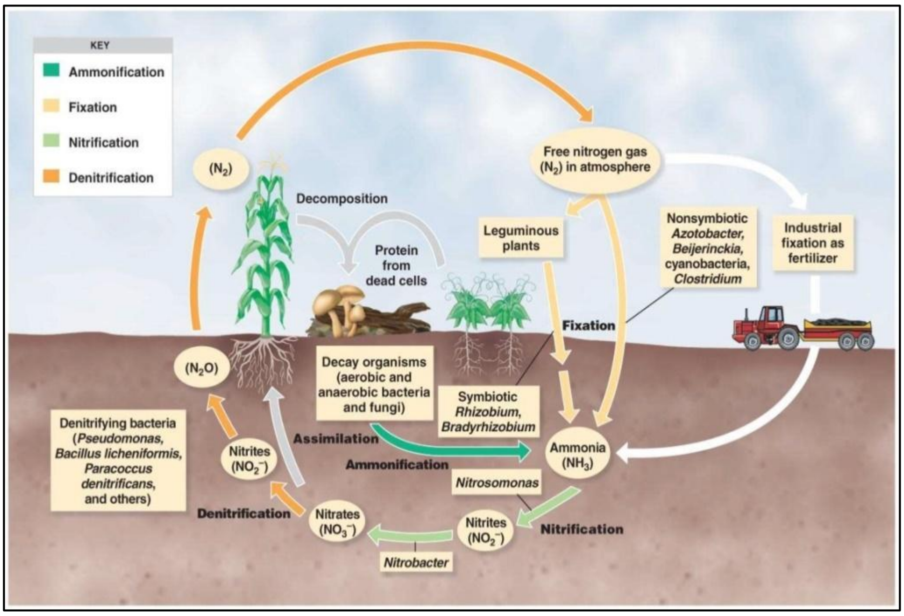

Image 5. Nitrogen transformation through ammonification, nitrification, mineralization and denitrification process

Image 6. Potato field

Image 7. Jatropha+soybean **Image 8. Mango+ Groundnut**

Image 9. Agroforestry systems

Image 10. Tropical grasslands

4.2.2 Agroforestry

Agroforestry is an age-old practice, which has been attempted by clearing forest to cultivate of crops.

There are three interactions between the various components of agroforestry systems that are both ecological and economical. Under the forest, the health and quality of the soil were preserved.

4.2.3 Grasslands (Greenswards)

Areas where the vegetation is dominated by grasses and other herbaceous (nonwoody) plants.

4.3 Land-use Effects on Native SOM Dynamics

The conversion of a natural forest to an agroecosystem alters the biological and chemical processes at the plant-soil interface significantly. As a result, SOM initially decreases. The magnitude and duration of the decrease in SOM, on the other hand, are determined by the method of forest conversion, the intensity of subsequent land use, the climate, and the physical and chemical properties of the soil.

4.4 Variation in SOC in Different Land Use Systems

- Pasture and grass land >5% SOC
- Forest land 2.5-4% SOC
- Mountain lands and waste land, Top –Less Soc. Bottom –High SOC, 0.1-0.7% SOC stable

Different land use practices soil conservation measure affect the rate of mineralization of soil organic matter, the transformation of nutrient in the soil.

4.5 Agricultural Land Use System

- **Legume based cropping system**: Legumes produce more dry matter per unit area and increases microbial activity hence organic carbon content rises over the time.
- **Cereal based cropping system**: Generally cereals are exhaustive crops and dry matter produced is not returned to the soil so SOM content decreases over the period.
- **Cereal legume intercropping and rotation:** Here exhaustiveness of cereal is neutralized by legume and this system is sustainable with respect to SOC.
- **Plantation crop based systems**: SOC content increases over the years with respect to plantation crops, generally SOC content is higher than in other systems.

Topographic and climate variation combined with humans and technological inputs are responses to the variation in land use patterns. Soil quality is primarily determined by the soil's response to various land use systems and management practises. Under forest cover, soil quality and health were preserved.

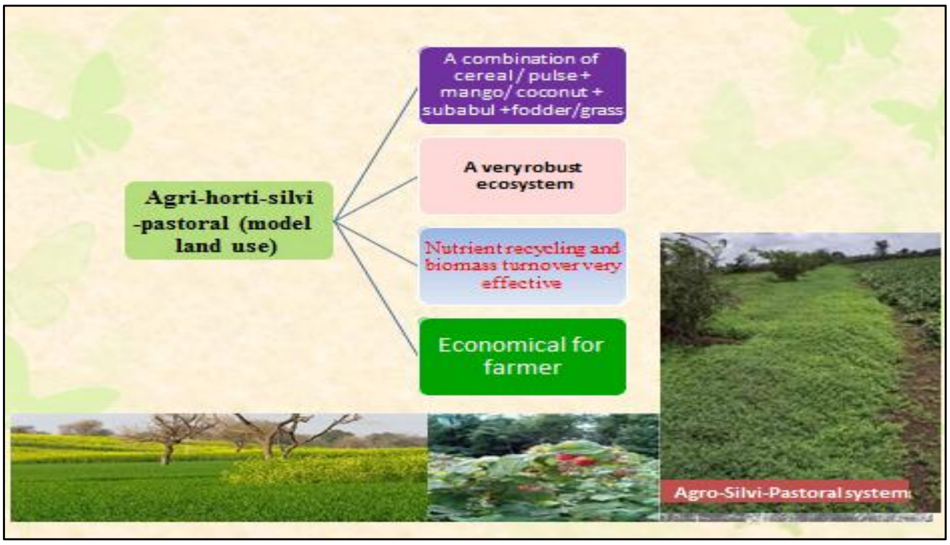

Image 11. Higher concentration of nutrients through the soil profile increases the opportunity for the nutrient movement to the plants

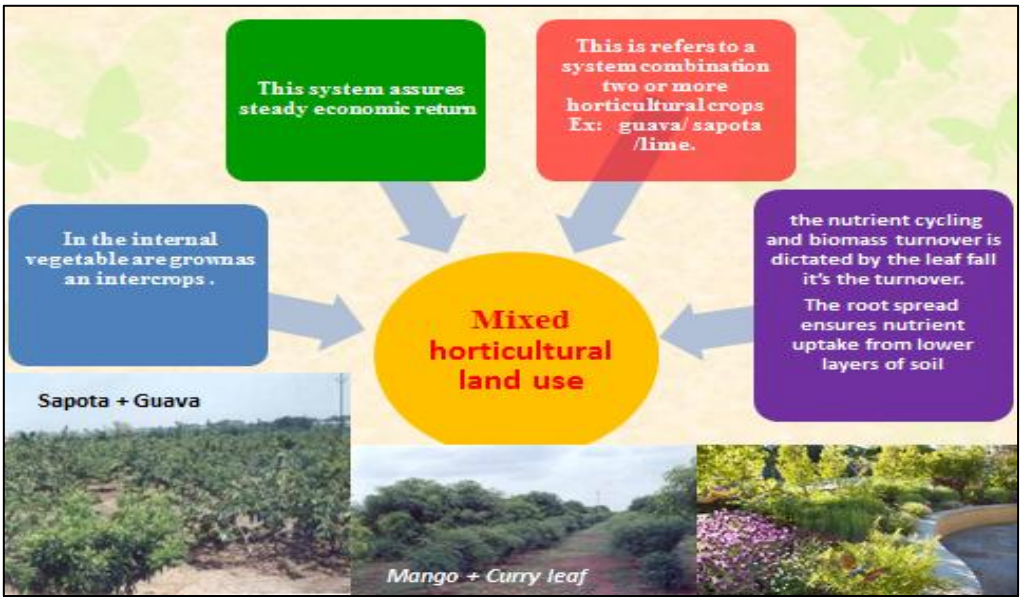

Image 12. Distribution and availability of nutrients different land uses biomass production and level of soil organic matter

5. LAND USE CHANGE AND SOIL NUTRIENT TRANSFORMATIONS IN THE LOS HAITISES REGION OF THE DOMINICAN REPUBLIC

Pamela Templer et al. [2] conducted "research at Los Haitises National Park (198000N, 698400E), which is located in the Dominican Republic's northeastern region. The experimental design compared four different types of land use: old forest, mogote forest, regenerating forest, and active agriculture sites. Using the above-described experimental design, randomly sampled three soil cores (6 cm d; 10 cm depth) from each site in July 1997 (wet season) and five soil cores from each site in January 1998 (dry season). In 1998, expanded our sample size to improve our statistical power".

Determining rates of net mineralization in incubated soils that were not fumigated by calculating the amount of NH_4 and NO_3 produced over 10 days. Determined the C and N contents

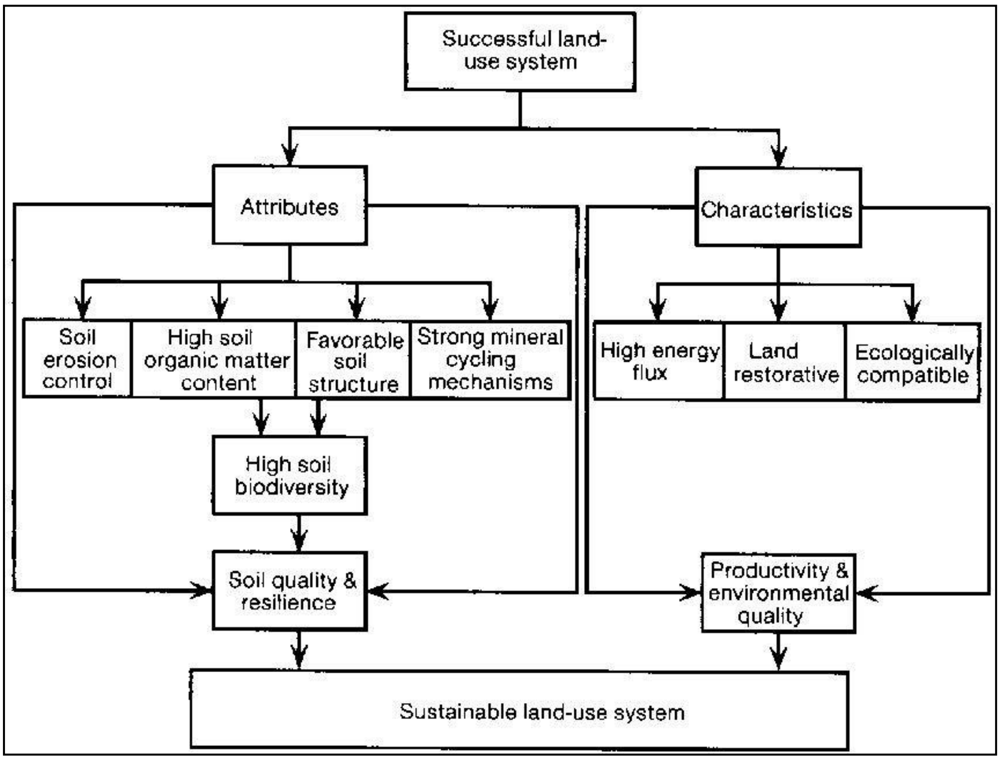

Image 13. Distribution of nutrients in relation to site characteristics include climate land use landscape position ant other variable is critical predicts races of an ecosystem process

of leaf litter collected from the soil surface during January, 1998 from three 10*10 cm quadrats within each site. Samples were dried at 60 ^{0}C for two days and ground (10.4 mm). Three randomly selected soil samples (10 cm depth) collected from each site in January, 1998 were analyzed by the Cornell College of Agriculture and Life Sciences Analysis Laboratories for K, Ca, and Mg. These base cations were extracted with a ratio of 1:5 sample: Morgan's solution (a Na acetate/acetic acid solution, pH 4.8).

The wet season (July 1997) had significantly more soil moisture than the dry season (January 1998) and the amounts were greater in regenerating and old forest sites compared to active agricultural sites (Table 1). Greater SOM (Table 1) was measured in their generating and old forest sites compared to active agricultural sites, with mogote forests having the highest amount g kg^{-1} soil. Bulk density in agricultural locations was much higher than in regenerating and old forest habitats. The amounts of soil basic cations (Mg, Ca, K) in regeneration areas were substantially higher than in agricultural sites (Table 1). Mogote forest soil had the highest concentration of base cations.) Abandoned pasture soils had almost five times the concentration of base cations as active pasture soils (Table 1). Mogote forests had the highest soil pH, followed by old forests, regenerating forests, and active agriculture. Abandoned pastures showed more soil moisture in both the wet and dry seasons, as well as higher levels of base cations (Table 1). Bulk density varies by land use type, with active agricultural areas having higher values than regenerative sites (Table 1).

"The active agricultural sites, the cacao agro ecosystems most closely resembled forests in structure and vegetation density in that they had a thick understory, a large amount of leaf litter and a well-developed forest floor. The dense vegetative cover in cacao could have provided the organic substrate necessary for the relatively high soil fertility and microbial activity (Table 1). Furthermore, the relatively low C-to-N ratio in the leaf litter of the cacaos compared to other active agricultural sites may have contributed to a higher quality SOM source for the soil microbes" [3].

"Agricultural sites have lower soil pH and base cations than regenerating sites. Base cation leaching losses in agricultural sites could have been significantly higher, resulting in higher soil acidity. Because soil pH was similar in both land use classes, differences in soil pH cannot be attributed to net mineralization or nitrification per soil volume. Furthermore, lower rates of net mineralization and nitrification g kg^{-1} soil were discovered in agricultural soils, which should result in a decrease in soil acidity" [4].

Amounts of microbial biomass N and C g^{-1} varied significantly among land use classes and were approximately two-fold larger in regenerating sites than in active agricultural sites (Fig. 1). On g^{-1} SOM basis, microbial biomass C was greater in active agricultural sites than regenerating sites (Fig. 1). Per unit soil volume (cm^{-3}), soil microbial biomass N was approximately 40% greater in the regenerating sites (229.7G11.6 mg N cm^{-3}) than the active agricultural sites (164.2G16.8 mg Ncm^{-3}).

"The quality of SOM in agricultural plant residue plays an important role in the effects of land use changes on soil C and N transformations We observed larger amounts of microbial C (Fig. 1), The soils within mogote forest sites are top hills that may not mirror the pre-disturbance fertility and C storage of the soils in the valleys below them because of differences in topography, water movement and soil erosion. The differences we found between the old forest and mogote forest sites underscore the importance of locating appropriate reference sites in land use change studies" [5].

In mogote forest areas, net mineralization and net nitrification of g^{-1} soil were highest (Fig. 2). Net mineralization and net nitrification rates (g^{-1} SOM) were highest in mogote forests and significantly higher in agricultural sites compared to regenerating areas. The rates of net mineralization and nitrification cm^{-3} were same for each kind of land use. The rate of microbial respiration in g^{-1} soil was highest in mogote forests and was noticeably higher in regenerative agricultural sites than in active agricultural sites. Microbial respiration g^{-1} SOM was higher in the agricultural sites compared to all of the other sites. Potential denitrification of g^{-1} soil was significantly lower in old forest than in regenerating sites (Fig. 2).

"Implying that compared to regenerating sites the SOM within agricultural sites was more labile and more easily used by soil microbes. Additional evidence for this is that the active pasture soils had significantly higher rates of net mineralization and approximately 1.5 times higher amounts of microbial biomass C g^{-1} SOM than the abandoned pastures. However, the C-to-N ratio and N content of the leaf litter did not differ between regenerating and active agricultural sites, despite the fact that these factors ten control decomposition" [3].

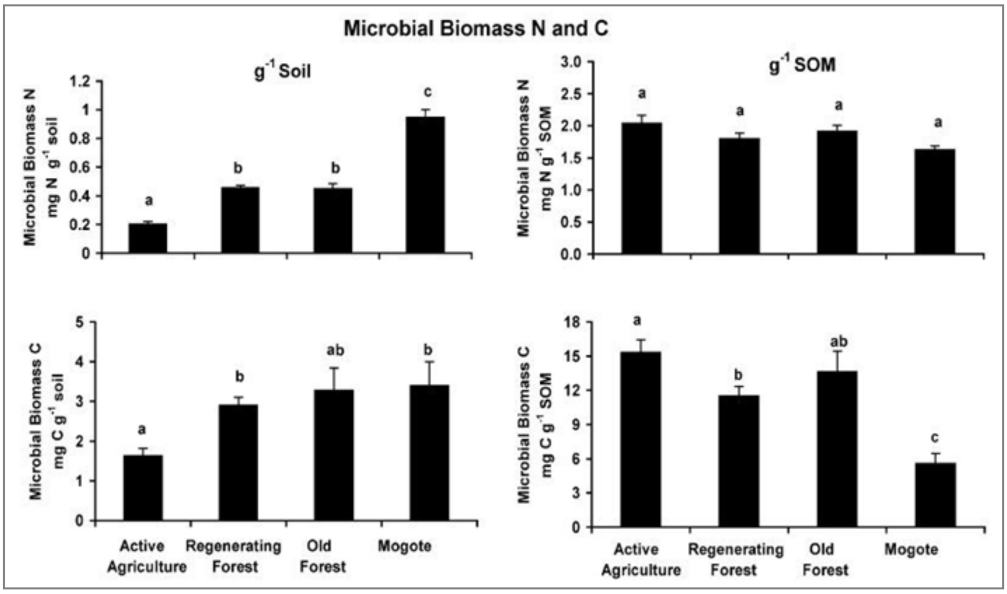

Fig. 1. Microbial biomass N and C g^{-1} soil and g^{-1} SOM (error bars represent standard error). Different letters above bars represent statistically significant differences at P= <0.05

Table 1. Properties of land uses soil (top 10 cm)

Land use	Dry season moisture (mg H_2O g^{-1} soil)	Wet season moisture (mg H_2O g^{-1} soil)	Organic matter (% dry wt)	Organic matter (mg cm^{-3})	Bulk density (mg cm^{-3})	pH	Base cations (g kg^{-1})
Active agriculture							
Oil palm	200.1	199.5	7.00	60.0	915.1	5.56	1.87
Active pasture	297.9	311.1	13.01	105.0	779.3	5.07	0.94
Cacao	320.4	412.6	12.79	92.0	774.1	5.91	2.40
Mean	**273**[a]	**295**[a]	**10.9**[a]	**86**[a]	**823**[a]	**5.50**[a]	**1.74**[a]
Regenerating forest							
Abandond pasture	407.2	424.2	22.70	94.0	441.9	5.62	4.58
Young mixed gardens	442.0	415.9	29.28	173.0	516.0	6.02	3.53
Old mixed gardens	442.8	424.2	26.94	144.0	544.0	6.23	6.51
Mean	427[b]	422[b]	25.7[b]	131[b]	492[b]	5.91[b]	**4.83**[b]
Old forest	**433**[b.c]	**523**[b,c]	**26.8**[b]	**142**[a,b]	**595**[b]	**6.14**[a,b]	4.21[a,b]
Mogote	**522**[c]	**563**[c]	**62.08**[c]	ND	ND	**6.90**[c]	**20.86**[c]

Base cations include K, Mg and Ca. Different letters above means represent statistically significant differences at P=<0.05. ND indicates no data available

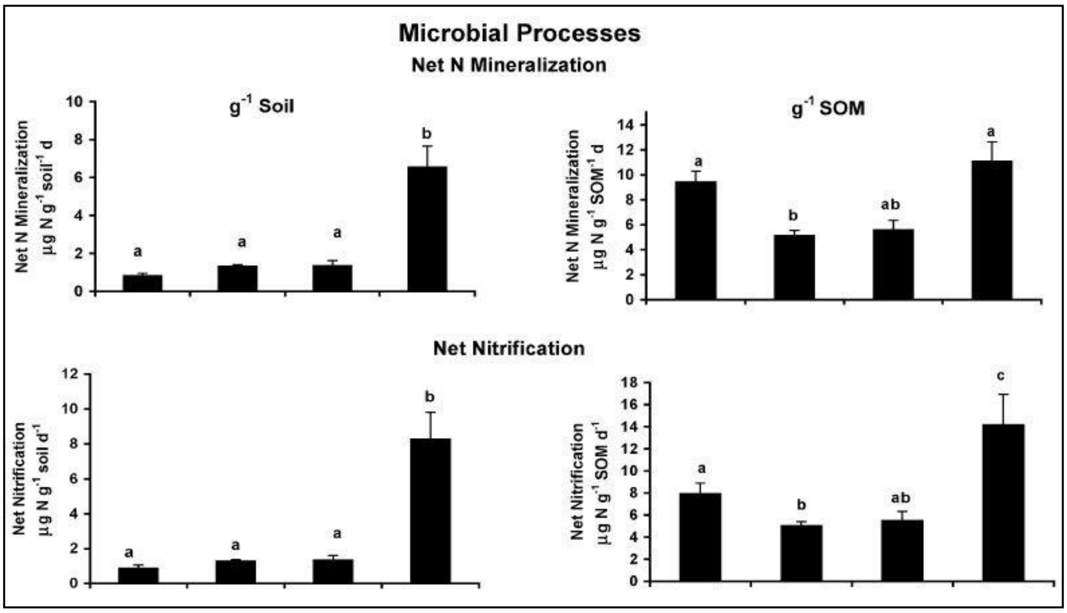

Fig. 2. Microbial processes including net mineralization g^{-1} soil and g^{-1} SOM (error bars represent standard error). Different letters above bars represent statistically significant differences at P= 0.05

6. EFFECTS OF DIFFERENT LAND USE SYSTEMS ON SELECTED SOIL PROPERTIES IN SOUTH ETHIOPIA

Alemayehu Kiflu and Sheleme Beyene [6] conducted research at the Delbo Atwaro watershed in Sodo Zuria Woreda of Wolayita zone, SNNP Regional State, Ethiopia. The toposequence was divided into three slope positions: upper N 06°54' and E 37°50.589' with altitude 2161 m a.s.l, middle N 06°54.522' and E 37°50.437 with altitude 2110 m a.s.l, and lower N 06°54.628' and E 37°50.388 with altitude 2087 m a.s.l/. Enset (*Enset ventricosum*) was chosen as a land use because it predates agriculture in the study area and is a staple food. Furthermore, maize is grown throughout the area and has been designated as the second land use system, while grassland has been designated as the third land use system.

Relatively higher sand content was recorded in grassland soils followed by that of enset and maize fields in the upper 0 to15 cm depth, whereas in the 15 to 30 cm depth silt was found to be higher in grass land soils followed by maize and enset fields (Table 2).

Table 2. Some chemical properties of the soil at 0-15 and 15-30 cm depth under different land use systems

Land use	TN	OC	Av. P	Fe	Mn	Zn	Cu
		%			mg/kg		
	0-15 cm depth						
Enset	0.20^{b}	2.44^{b}	36.35^{a}	58.82	21.87^{b}	8.63	0.323
Grass	0.29^{a}	3.25^{a}	3.68^{b}	45.40	44.95^{a}	8.61	0.443
Maize	0.18^{b}	2.08^{b}	14.44^{b}	21.87	27.70^{b}	7.94	0.350
	15-30 cm depth						
Enset	$0.18a^{b}$	1.95	9.12^{a}	18.13^{b}	23.58	8.45	0.30
Grass	0.19^{a}	2.11	1.16^{b}	35.95^{a}	29.32	6.30	0.31
Maize	0.15^{b}	1.79	5.06^{ab}	26.91^{ab}	24.14	8.24	0.31

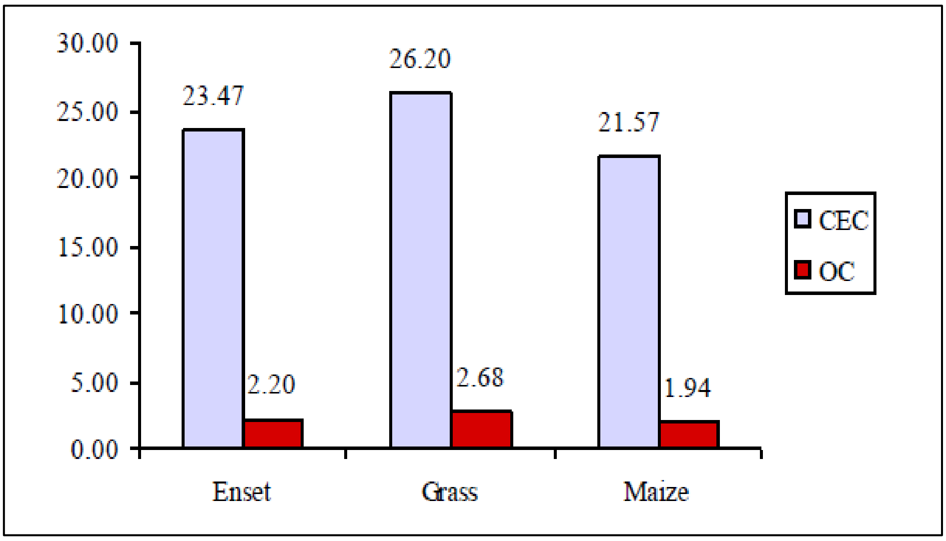

Fig. 3. Organic carbon and CEC contents of soil under different land use systems farms might be due to leaching, soil erosion

It was discovered that the upper layers of the various horizons and the different land use categories all had the same soil texture, with the exception of the grassland soil (15 to 30 cm depth), which was clay loam. Given that soil texture is an inherent soil attribute that is not affected over a short period of time, this shows that the various land use types did not have an impact on the soil texture of the studied area. “The pH value under enset was found to be the highest followed by maize in both sampling depths. The soil pH could be categorized as slightly acidic under enset and maize fields whereas that of grassland was moderately acidic, following the classification described” by Brady and Weil [4]

“The organic carbon content of the soils varied from 2.08-3.25 per cent for (0 to 15 cm depth). In (15 to 30 cm depth) it ranged from 1.79-2.11per cent. Significant differences (p=.05) in the OC content of soils were observed among the different land use systems. The average content of soil OC along slope positions was lower in maize and enset land use systems as compared to that of grassland. The difference could be attributed to the effect of continuous cultivation that aggravates organic matter oxidation. The roots of the grass and fungial hyphae in the grassland soils are probably responsible for the higher amount of total organic matter” [7].

All land use types were found to have greater available P contents than the surface horizons of the corresponding pedons. This can be as a result of the use of manure and P fertilisers in the respective cases of enset and maize fields. In grassland fields, the highest concentration of total nitrogen (TN) was found, followed by that of enset at both depths. This might be connected to the higher levels of organic matter seen in grassland soils.

The highest cation exchange capacity (CEC) values were observed under grassland (27.53 cmol(+)/kg^{-1} followed by that of enset (23.73 cmol (+)/kg^{-1} at both sampling depths.

The CEC values of the soil constantly dropped from grassland to enset and maize in accordance with the organic carbon content (Fig. 3). This was also evident from the positively and highly correlation (r=0.91***) and (r =0.41) of CEC with organic carbon for 0-15 and 15-30 cm depths, respectively. The depletion of organic carbon as a result of intensive cultivation had, therefore, reduced the CEC of the soils under maize land use. These results were in agreement with the pervious findings of Boke [8] and Negassa [9].

7. LAND USE CHANGE IMPACT ON SOIL ORGANIC MATTER

Agnieszka Sosnowska [10] conducted an experiment at Lublin Upland in an area called Działy Grabowieckie near the town of Krasnystaw. Four land use types were chosen for detailed examination in the study: arable, forest and two areas of abandoned land with secondary succession (one that was abandoned

5 years ago and another that was abandoned 20 years ago). The research material comprises 48 samples taken from the humus horizon (0-15 cm) of which 12 came from sites representing each type of land use considered in the study.

This is undoubtedly produced by shade and other plant decay that dissolves there. The lowest amounts were found in arable land, wherein organic carbon content varied from 0.68% to 1.27%, with an average of 0.98%. (Fig. 4). The functioning of the two ecosystems differs, with a discernible difference in the organic carbon content between the forest and arable fields. Every year, enormous volumes of organic materials produced by the decomposition of litter and animal remains in the forest are integrated into the cycle.

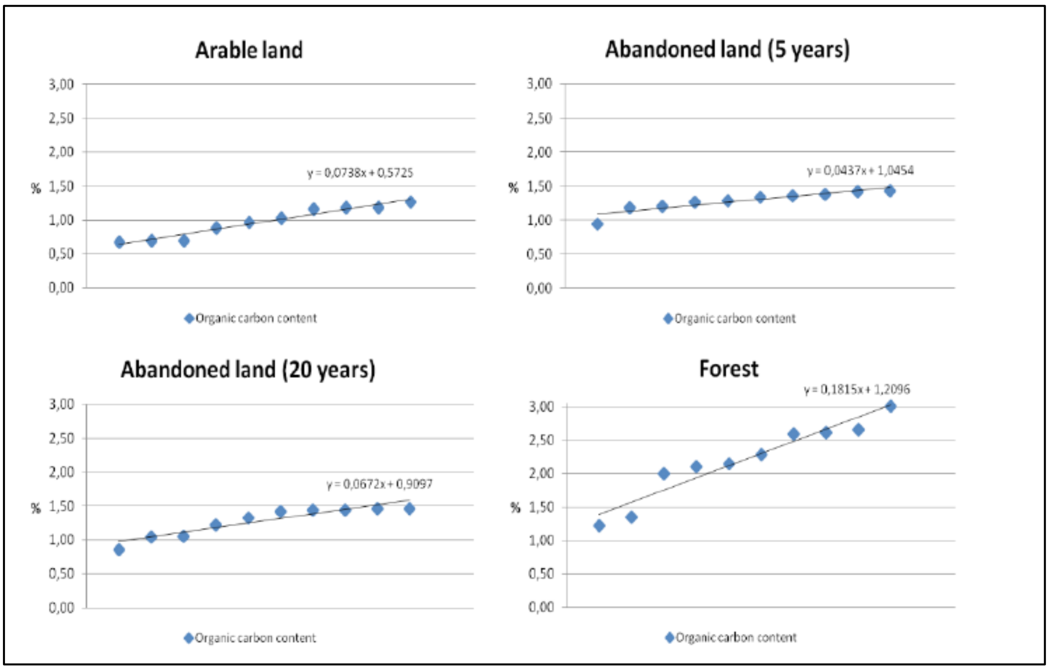

Fig. 4. Organic carbon content in the humus horizons of the examined soils

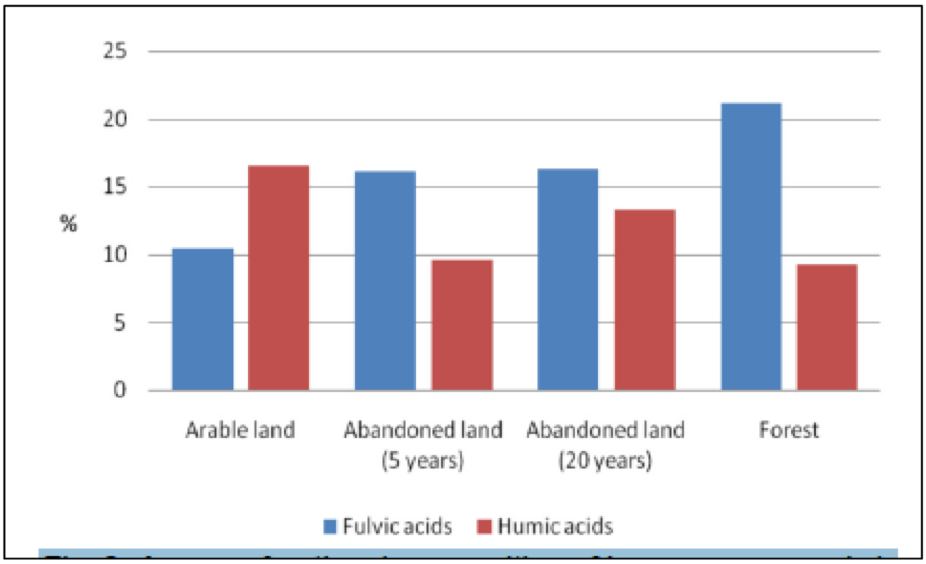

Fig. 5. Average fractional composition of humus compounds in the humus horizons of the examined soils

These similarities might suggest that regardless of the environmental factors, changes in land use have an effect on the amount of soil organic matter. According to Kosmas et al. [11] "abandonment of the land has significantly increased the soil organic carbon content only of soils created on molten and calcareous rock, while the soils formed on shale exhibit only small differences. Specify that the type of bedding proves to be more important for the soil organic matter content".

"The results of laboratory analysis revealed the dominance of humic acids in the humus horizon of the arable land (Fig. 5) at levels that ranged from 10.50-27.7 %, while the fulvic acid content ranged between 5.2 % and 19.3 %. The dominance of humic acids is due to the type of organic substance that decomposis (leaves, roots etc.) and the microorganisms that are causing this decomposition. The main component in these arable soils is cellulose, which is decomposed mainly by environmental bacteria and characterized by weak acid and neutral reactions" [12].

8. CONCLUSION

Vegetation and soils undergo a significant change as a result of land use change, which occurs when a forest ecosystem is converted into a tillage system. The amount of organic matter grows, and its breakdown immediately raises the amount of organic carbon in the organic carbon content in the humus horizon of the soil. Organic manuring of the soils under cultivated land use systems is a must for sustainable soil productivity. Agriculture, Agri-Horti-Silvi-pastoral and livestock based farming systems which received proper soil conservation measures along with manure, fertilizer and liming could improve and maintain a higher level of the various fractions of P as compared to other farming systems. Deforestation is common throughout the tropics and further changes in land use may have consequences for soil nutrient transformations. Understanding how the ecosystem functions and determining the consequences of additional land use change on soil characteristics require a thorough understanding of the spatial variability of soil nutrients in relation to site factors such as climate, land use, topography, and other variables.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Kumar SS, Mir SA, Wani OA, Babu S, Yeasin M, Bhat MA, Dar SR. Land-use systems regulate carbon geochemistry in the temperate Himalayas, India. Journal of Environmental Management. 2022;320: 115811.
2. Pamela Templer H, Peter M, Groffman B, Alex Fleckera S, Alison Powera G. Land use change and soil nutrient transformations in the Los Haitises region of the Dominican Republic. Soil Biology & Biochemistry. 2005;37:215–225.
3. Taylor BR, Parkinson D, Parsons WFJ. Nitrogen and lignin content as predictors of litter decay rates: a microcosm test. Ecology. 1989;70:97–104.
4. Brady NC, Weil RR. The nature and property of soils. Prentice Hall, Upper Saddle River; 1999.
5. Pickett STA, Parker VT. Avoiding old pitfalls: opportunities in a new discipline. Restoration Ecology. 1994;2:75–79.
6. Alemayehu Kiflu, Sheleme Beyene. Effects of different land use systems on selected soil properties in South Ethiopia. J. of Soil Sci and Environmental Management. 2013;4(5):100-107.
7. Urioste AM, Hevia AGG, Hepper EN, Anton LE, Bono AA, Buschiazzo DE. Cultivation effects on the distribution of organic carbon, total nitrogen and phosphorus in soils of the semiarid region of Argentinian Pampas. Geoderma. 2006;136:621–630.
8. Boke S. Soil phosphorus fractions as influenced by different cropping systems in Andosols and Nitosols in Kembata-Tembaro and Wolayta Zones, SNNPRS. MSc Thesis. Alemaya University, (AU). 2004;131.
9. Negassa W. Assessment of important physicochemical properties of nitosols under different management systems in Bako area, western Ethiopia. M. Sc. Thesis, Alemaya University, Alemaya. 2001;109.
10. Agnieszka Sosnowska. Land use change impact on soil organic matter. Miscellanea

Geographica – Region al Studies on Development. 2012;16(2):11-15.
11. Kosmas C, Gerontidis ST, Marathianou M. 'The effect of land use change on soil and vegetation over various litilogical formation on Lesvos (Greece). Catena. 2000;40:51-68.
12. Szujecki A. Ecological aspects of forest reconstruction on abandoned lands. Prace IBL. 1996; 27 (In Polish).

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/92893