Review Article

# NUTRIENT TRANSFORMATION IN DIFFERENT LAND USE SYSTEMS

Abstract

Landuse 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 soil management practice influence the soil nutrients related soil processes, such as erosion, oxidation, mineralization, and leaching, consequently modify the processes of transport and re-distribution of nutrients. Deforestation is common throughout the tropics and further changes in land use may have consequences for soil nutrient transformations. Characterizing the spatial variability of soil nutrients in relation to site properties such as climate, land use, topography and other variables is important for understanding how the ecosystem works and assessing the effects of further land use change on soil properties.

Keywords: Landuse, nutrients, nutrient transformations, mineralization



## 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 reported to be comparatively more in the soils under grass land than under cultivated land system. The information on effect of land use systems on soil quality to give recommendations for optimal and sustainable utilizations of land resources is scanty. Land use is an integrator of several environmental attributes which influence nutrients export. Land use and soil management practice influence the soil nutrients related soil processes, such as erosion, oxidation, mineralization, and leaching, consequently modify the processes of transport and re-distribution of nutrients.

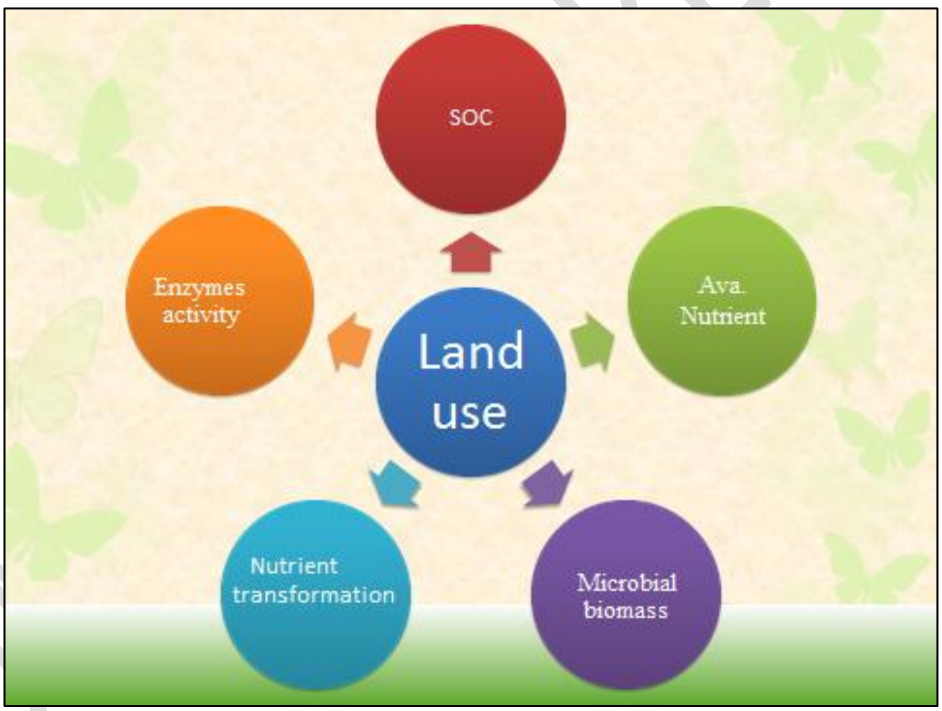
- Nutrient changes are an inherent manifestation of a land use system
- Management practices influence nutrient cycles and biomass transformation
- A robust land use system ensures sustenance for longer periods
- A combination of land use systems is the best option for ecosystem survival

**Forms and availability of nutrients in soil their movements and uptake by roots**.

## Landuse

- Land use refers to man's activities and the various uses which are carried out on land.
- Here are two technical terms used in geography as landuse and landcover.
- Any kind of permanent or cyclic intervention of a land is called as landuse.
- It is the surface utilization of a vacant land or a developed land for a clear purpose at a given time.
- Landuse 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 cover refers to the natural vegetation, water bodies, rock, soil and similar features

**Image 1: Land use scinario**




- ➢ Land use and vegetation cover type influence soil physico-chemical and C dynamics in soil
- ➢ Land use is an integrator of several environmental attributes which influence nutrients export. Land use and soil management practice influence the soil nutrients related soil processes, such as erosion, oxidation, mineralization, leaching and consequently modify the processes of transport and re-distribution of nutrients.

- Land-use change causes significant alteration of soil reaction, soil organic matter (SOM), nutrient status, soil physical quality and microbial activity in the rhizosphere.

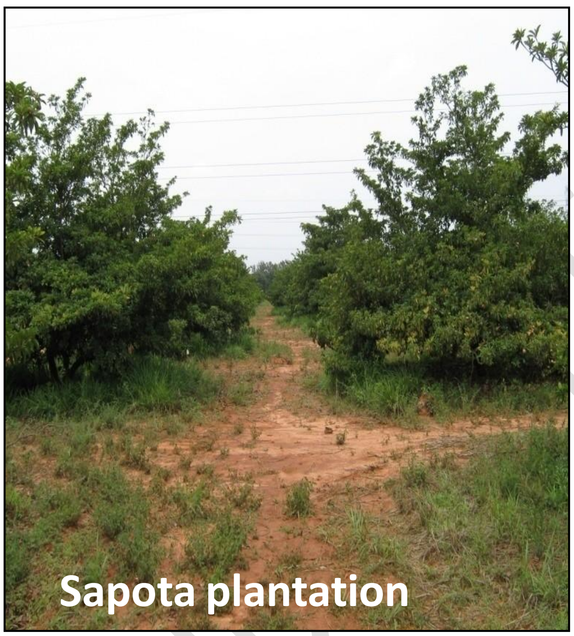




**Image2: LandUse Dictates Nutrient Transformation**

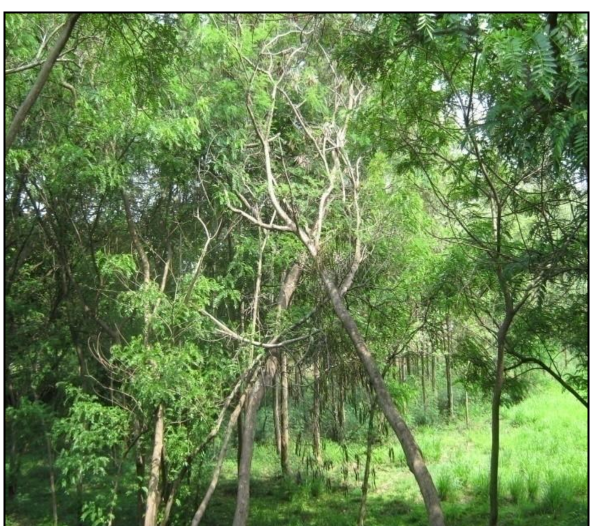


**Image3: Mixed forest**

- Transformation of one land use system onto another system and different management practices can affect the soil structure soil organic carbon and other nutrient restore.

## 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 in constant operation
- ✓ Root hairs primarily responsible for the uptake

**Nutrient uptake by the roots depends on root growth and soil exploration ability to absorb nutrients nutrient concentration as the root surface.**

## Forms in which nutrients exist

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

**Image4 Nitrogen Transformation:**

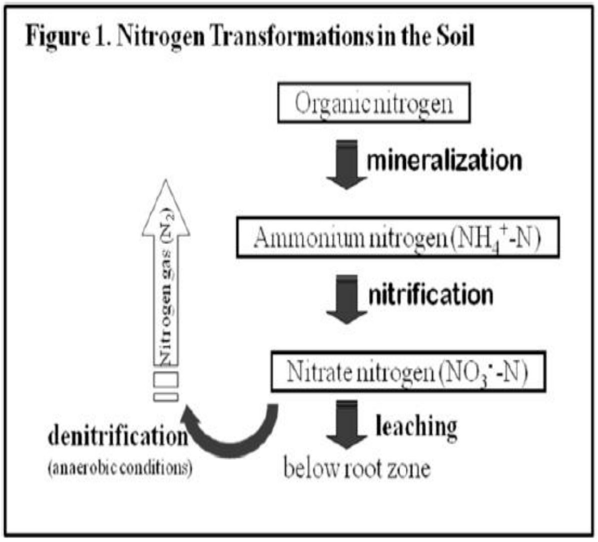
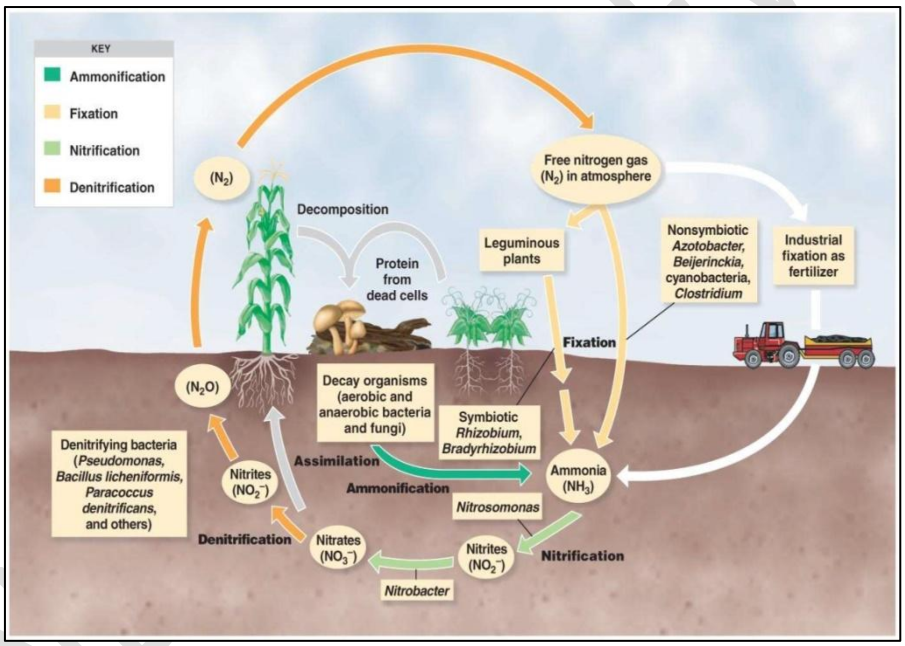


Figure 1. Nitrogen Transformations in the Soil

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




Three major forms nitrogen in soil

- Organic nitrogen,
- Ammonium nitrogen,
- Nitrate nitrogen
- Plant cannot use the nitrogen in the organic form.

- Forms and availability of nutrients in soils, their movement and their uptake by roots and the utilization of nutrients within plants are closely related.

- The availability of soil micronutrients is largely influenced by the soil microenvironment as well as soil properties, such as pH, calcium carbonate ($CaCO_3$), organic matter and cation exchange capacity.
- parent material, climatic factors and natural vegetation, land use pattern also plays a vital role in governing the nutrient dynamics and fertility of soils
- Different agricultural land-uses greatly influence soil quality and physico-chemical properties and affect the nutrient dynamics and supply

## Land use systems

- Land use systems have been designed by nature /man considering the availability of resources such as water, soil and the need of the people depending on the system
- The land use systems so designed is aimed at biomass turnover and nutrient cycling over the years. There by ensuring self-sustainability of the system however intensive systems need to be supported by external additions of inputs
- The term is mostly used in agriculture and is described as the practice of planting crops in a definite pattern or continuity of growth. Examples wheat fields or apple orchards or grape vineyards .

**Image 6** **Potato Field**

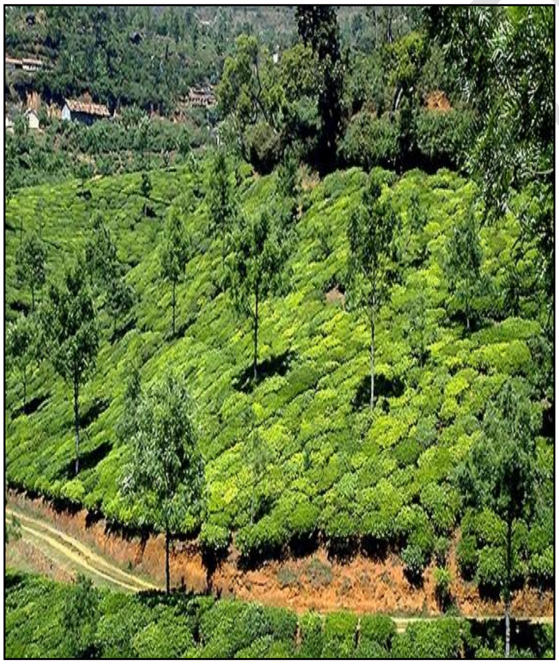
**Agri-horticulture**: refers to a combination of horticulture crops specially tree species and an annual crops. e.g. Coconut and ragi, fruit crops and pulses.

**Image 7:** **Jatropha + Soybean** **Image 8: Mango + Groundnut**

**Agroforestry**: is an age-old practice, which has been attempted by clearing forest for cultivation of agricultural crops.

In agroforestry systems three are both ecological and economical interactions between the different components. Soil quality and health were maintained under the forest.





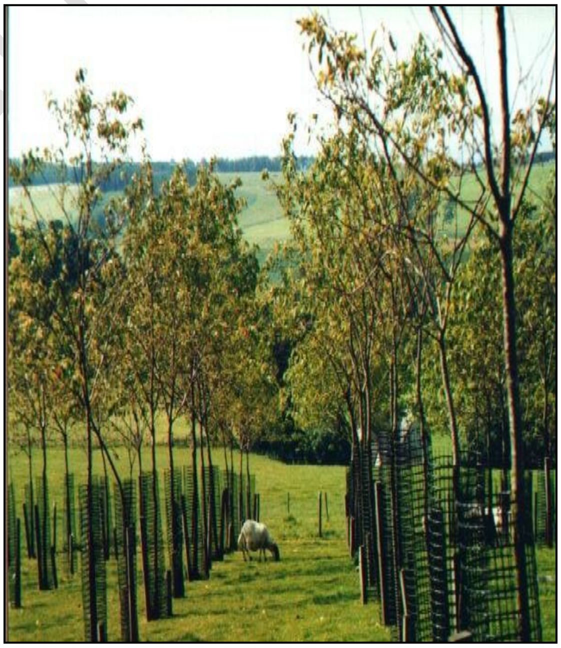


**Image 9:**

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

**Image 10:** **Tropical grasslands**

## Land-use effects on native SOM dynamics

- The conversion of natural forest to an agro ecosystem, results in profound changes in the biological and chemical processes at the plant-soil interface
- The net result is an initial decline in SOM
- The magnitude and duration of the decrease in SOM, however, depends upon the method of forest conversion, the intensity of subsequent land use, the climate and the soil physical and chemical properties

## 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, transformation of nutrient in soil**

## Agricultural land use system

- **Legume based cropping system**: Legumes produce more dry matter per unit area and increases microbial activity hence organic carbon content increases over the time
- **Cereal based cropping system**: Generally cereals are exhaustive crops and dry matter produced are not returned to the soil so SOM content decreases over the period
- **Cereal legume intercropping & rotation:** Here exhaustiveness of cereal is neutralised 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 higher than other systems.

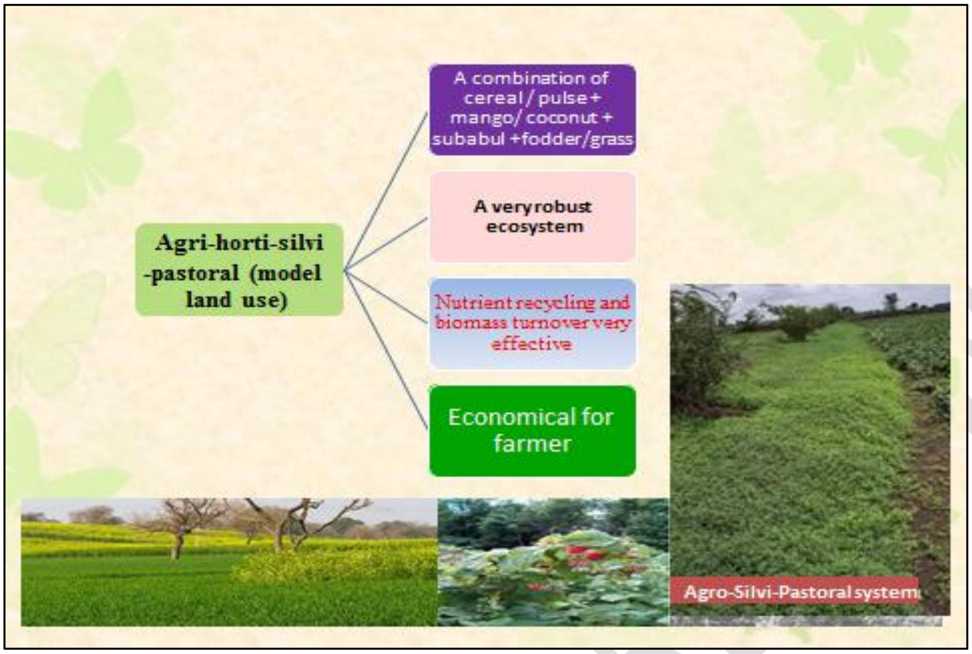
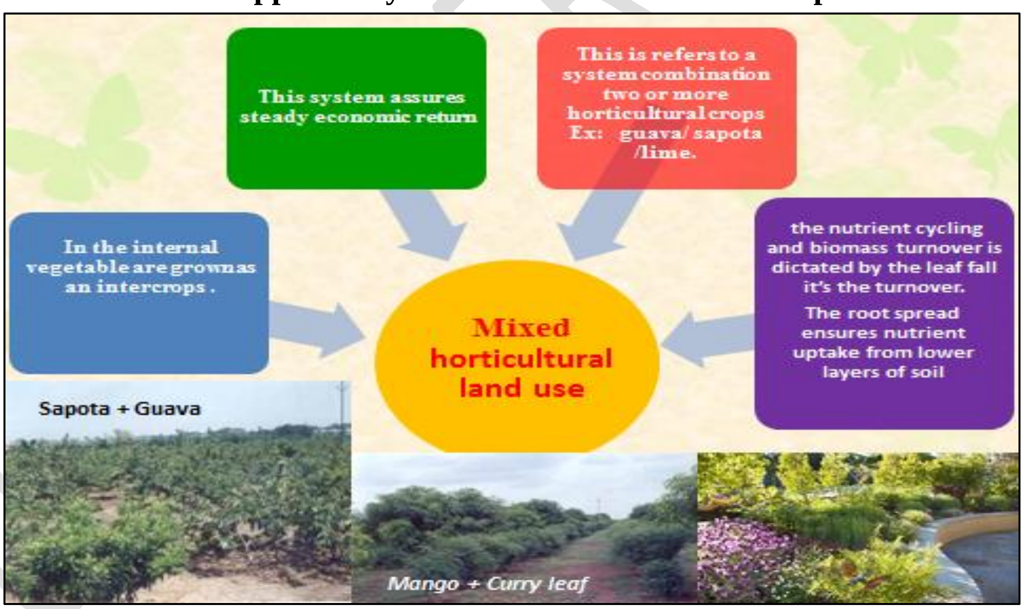



**Image 11: Higher concentration of nutrients through the soil profile increases the opportunity for nutrient movement to the plants.**




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

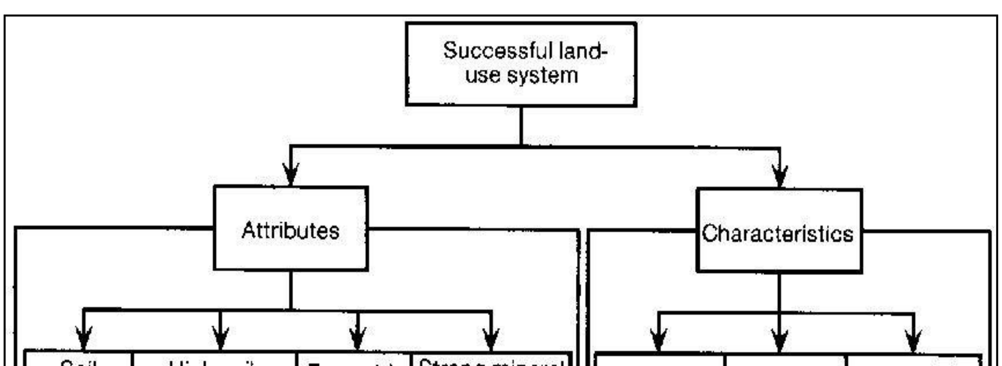


**Image 13: Distribution of nutrients in relation to site charaterics include climate landuse landscape position ant other variable is critical predicts races of ecosystem process**

- Topographic and climate variation in combination with human and technological inputs are response for the variation in landuse pattern.

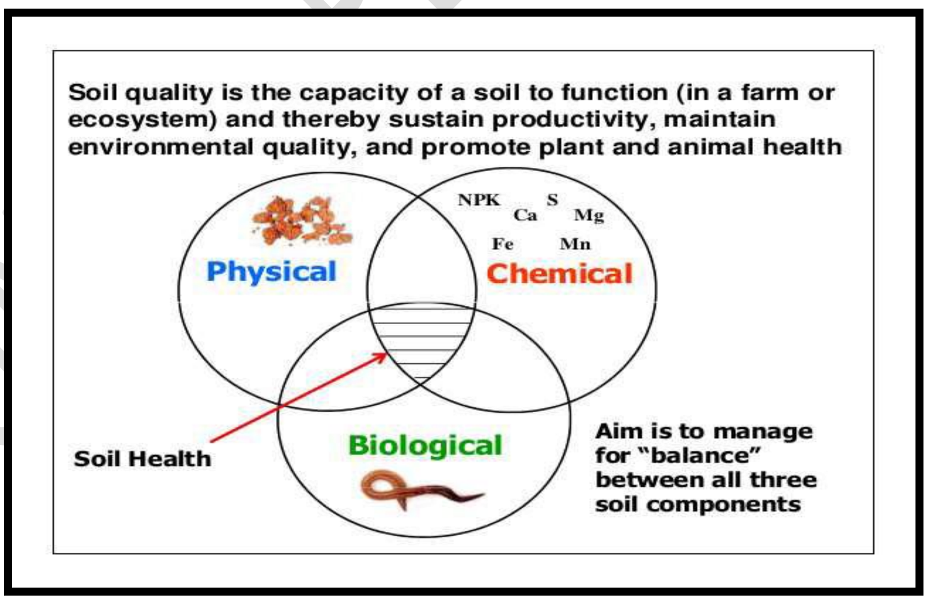



Image 14:

- Soil quality mainly depends on the response of soil to different land use systems and management practices,

➢ The soil quality and health were maintained under forest.

## Research Papers

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

- Pamela Templer *et al.* (2005) conducted research at Los Haitises National Park (198000N, 698400E), located in the northeastern region of the Dominican Republic. Experimental design compared four major land use classes: old forest, mogote forest, regenerating forest and active agriculture sites. Experimental design described above, we randomly sampled three soil cores (6 cm d; 10 cm depth) from each site during July 1997 (wet season) and five soil cores from each site during January 1998 (dry season). We augmented our sample size in 1998 to increase our statistical power.
- Determined 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 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 8C for 2 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).

**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 | 407.2 | 424.2 | 22.70 | 94.0 | 441.9 | 5.62 | 4.58 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| pasture | | | | | | | |
| 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.**

There was significantly more soil moisture in the wet season (July 1997) than in the dry season (January 1998) and the amounts were greater in the regenerating and old forest sites compared to active agricultural sites (Table 1). We measured greater SOM (Table 1) in there generating and old forest sites compared to the active agricultural sites, and the greatest amount gK1 soil in mogote forests. Bulk density was significantly higher in the agricultural sites compared to regenerating and old forest sites Amounts of soil base cations (Mg, Ca, K) were significantly greater in regenerating sites compared to agricultural sites (Table 1). Mogote forest soil contained the largest amount of base cations) Abandoned pasture soils had approximately five times the amount of base cations as active pasture soils (Table 1). Soil pH was highest in mogote forests, followed by old forest, regenerating forest and active agriculture. Abandoned pastures had greater soil moisture in the wet and dry seasons in addition to greater amounts of base cations (Table 1). Bulk density also varied among land use types with greater values in the active agricultural than regenerating 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 (Tables 1). Furthermore, the relatively low C-to-N ratio in leaf litter of the cacaos compared to other active agricultural sites may have contributed to a higher quality SOM source for the soil microbes (Taylor *et al*., 1989).

Lower soil pH and soil base cations in the agricultural sites than the regenerating sites. There may have been significantly larger leaching losses of base cations in the agricultural sites, which may have result higher soil acidity. We cannot attribute differences in soil pH to net mineralization or nitrification per soil volume because they were similar in both of these landuse classes. Furthermore, we found lower rates of net mineralization and nitrification gK1 soil in the agricultural soils, which we would expect to cause a decrease in soil acidity (Brady and Weil, 1999).

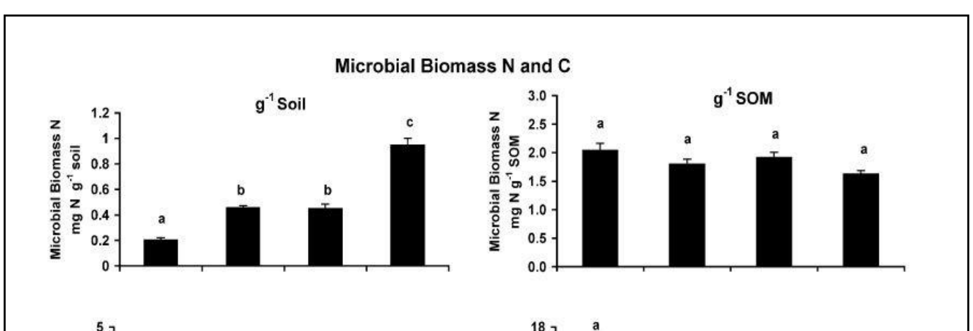


**Fig. 1. Microbial biomass N and C $g^{-1}$ soil and $g^{-1}$ SOM (error bars represent standard error). Different letters above bars represent statistically significant differences at P<0.05.**

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 a 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 (Pickett and Parker, 1994).

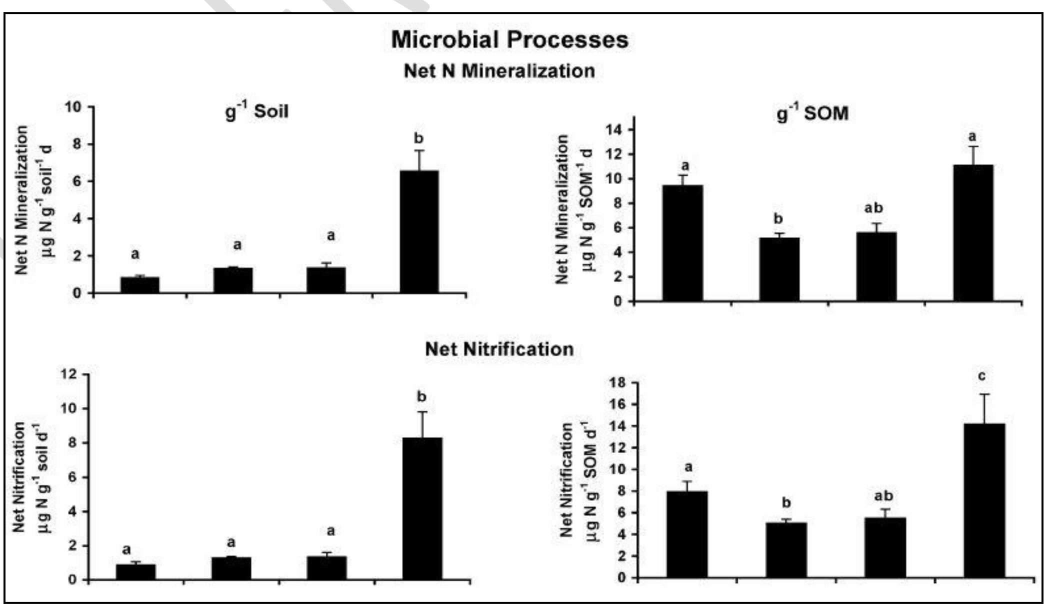


**Fig. 2. Microbial processes including net mineralization $g^{-1}$ soil and $g^{-1}$ SOM (error bars represent standard error). Different letters above bars represent statistically significant differences at P= 0.05.**

Net mineralization and net nitrification $g^{-1}$ soil were highest in mogote forest sites (Fig. 2). Rates of net mineralization and net nitrification $g^{-1}$ SOM were significantly greater in agricultural sites than regenerating sites and were largest in mogote forests. There was no difference in rates of net mineralization and nitrification $cm^{-3}$ among land use types. Microbial respiration $g^{-1}$ soil was significantly greater in regenerating than in active agricultural sites and was highest in mogote forests. Microbial respiration $g^{-1}$ SOM was higher in the agricultural sites compared to all of the other sites. Potential denitrification $g^{-1}$ soil was significantly lower in old forest than 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 of ten control decomposition (Taylor *et al*., 1989).

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

Alemayehu Kiflu and Sheleme Beyene., (2013) studied at location Delbo Atwaro watershed, which is located 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 2161 m a.s.l,
- •middle topographic position N 06°54.522’ and E 37°50.437 with altitude 2110 m a.s.l
- •lower topographic position N 06°54.628’ and E 37°50.388 and 2087 m a.s.l/.

Enset (*Enset ventricosum*) was selected as one of the land uses because it is as old as agriculture in the study area and used as a staple food. Moreover, maize is grown everywhere in the area and selected as the second land use, whereas grassland is selected as third land use system for the sake of comparison.

**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 | | | | |
| 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 | | | | |
| 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 |

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).

The soil texture of the different land use types and the upper layers of the different horizons were found to be the same except for that of grassland soil (15 to 30 cm depth), which was clay loam. This suggests that the different land use types did not have effect on the soil texture of the study area, since texture is an inherent soil property that not influenced in short period of time.

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 (2002).

The organic carbon content of the soils varied from 2.08 to 3.25% for 0 to 15 cm depth. In 15 to 30 cm depth it ranged from 1.79 to 2.11%. Significant differences ($p \leq 0.05$) in OC content of soils were observed among the different land use systems. The average content of soil OC along slope positions, were lower in maize and enset land use systems as compared to that of grassland. The difference could be attributed tothe 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 (Urioste *et al*., 2006).

Available P content in all land use types was found to be higher than that of the surface horizons of the respective pedons. This could be due to the application of manure, P fertilizers in the case of enset and maize farms, respectively.

The Higher total nitrogen (TN) was observed in grassland fields followed by that of enset at both depths. This could be related to the higher organic matter content in the soils of grassland.

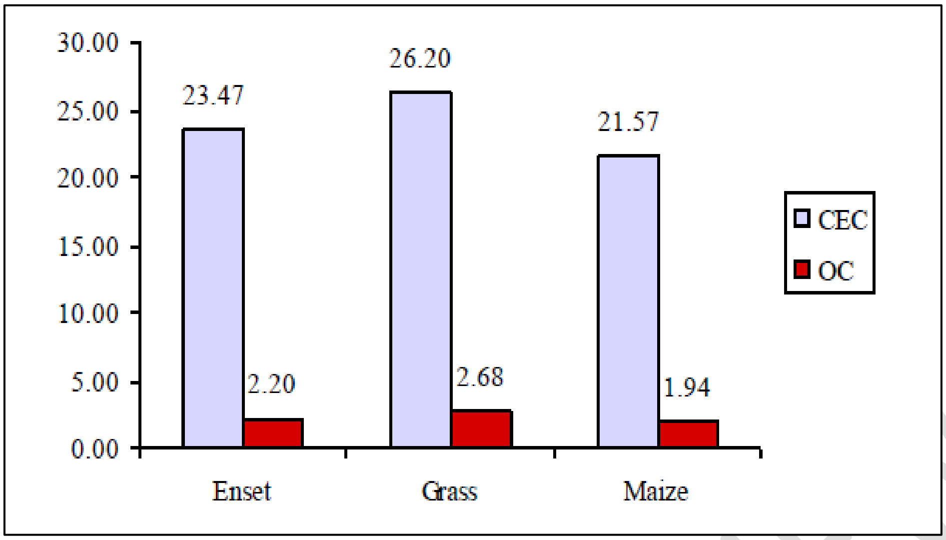



**Figure 3. Organic carbon and CEC contents of soil under different land use systems farms might be due to leaching, soil erosion**

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 depth .

In accordance with the organic carbon content, CEC values of the soil decreased consistently from grassland to enset and maize (Figure 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 to 15 and 15 to 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 pervious findings of Boke (2004) and Negassa (2001).

## LAND USE CHANGE IMPACT ON SOIL ORGANIC MATTER

Agnieszka Sosnowska., (2012) conducted 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 of 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.

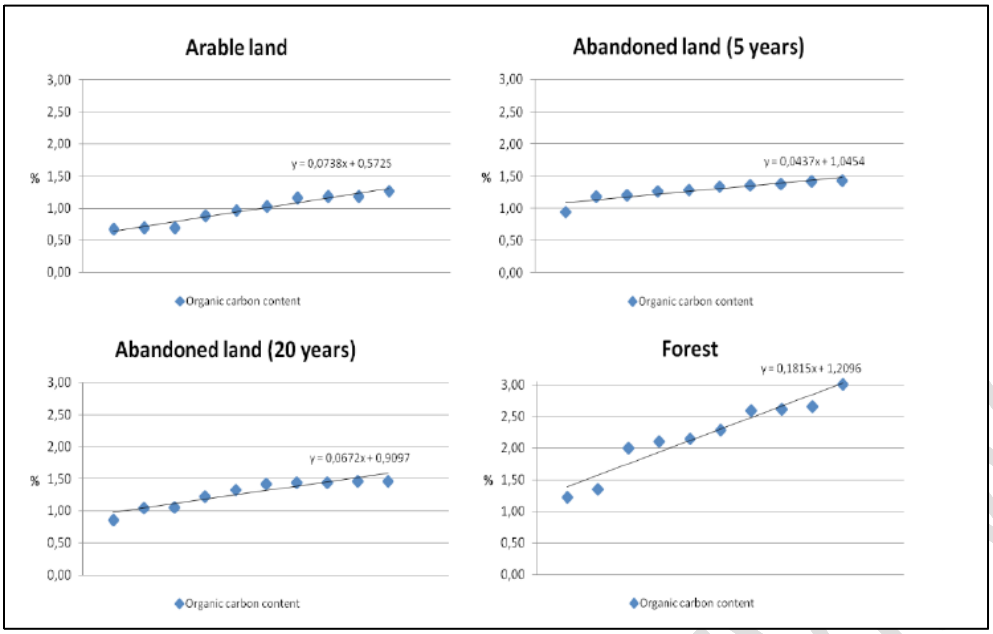



**Fig. 4: Organic carbon content in the humus horizons of the examined soils**

This is definitely caused by shade and different plant downfall that dissolves there. The lowest levels were found in the arable land, where the organic carbon content ranged from 0.68 % to 1.27 % with an average of 0.98 % (Fig. 4). A perceptible difference in the organic carbon content between the arable lands and the forest is a result of differences in how the two ecosystems function. In the forest, huge amounts of organic matter created by decomposition of litter and animal remains are incorporated into the cycle every year.

These similarities may indicate that land use change has an impact on the soil organic matter content regardless of the environmental conditions. What is more, according to (Kosmas *et al*. 2000) 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.

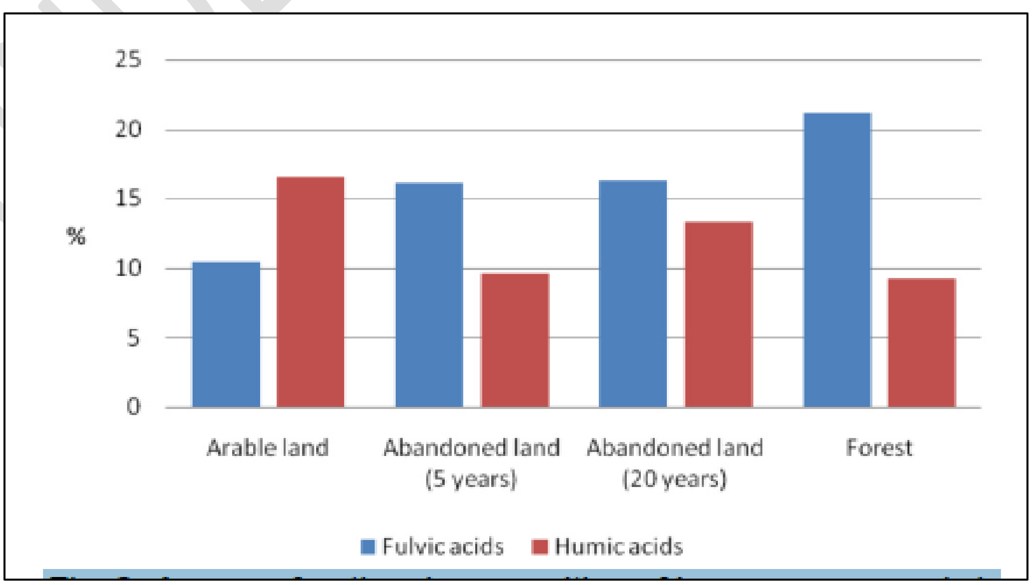


**Fig 5. Average fractional composition of humus compounds in the humus horizons of the examined soils**

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 10.5 % to 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 decomposing (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 (Szujecki 1996).

## Conclusion

Land use change (when a forest ecosystem turns into a tillage system) leads to a vast transformation in vegetation and soils. The amount of organic matter increases and its decomposition contributes directly to an increase 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 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. Characterizing the spatial variability of soil nutrients in relation to site properties such as climate, land use, topography and other variables is important for understanding how the ecosystem works and assessing the effects of further land use change on soil properties.

## References


AGNIESZKA SOSNOWSKA., 2012, Land use change impact on soil organic matter. *Miscellanea Geographica – Region al Studies on Development*, **16**(2): 11-15.

ALEMAYEHU KIFLU AND SHELEME BEYENE., 2013, Effects of different land use systems on selected soil properties in South Ethiopia. *J. of Soil Sci and Environmental Management,* **4**(5): 100-107.

BOKE, S., 2004, 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).*, P. 131.

BRADY, N. C., WEIL, R. R., 1999, The Nature and Property of Soils. Prentice Hall, Upper Saddle River.

KOSMAS, C, GERONTIDIS, S. T. AND MARATHIANOU, M., 2000, 'The effect of land use change on soil and vegetation over various litilogical formation on Lesvos (Greece)', *Catena*., **40**: 51-68.

NEGASSA W., 2001, Assessment of i*m*portant physicochemical properties of nitosols under different management systems in Bako area, western Ethiopia. *M. Sc. Thesis, Alemaya University, Alemaya.p*. 109.

PAMELA TEMPLER, H., PETER, M., GROFFMAN, B., ALEX FLECKERA, S. AND ALISON POWERA., G., 2005), Land use change and soil nutrient transformations in the Los Haitises region of the Dominican Republic. *Soil Biology & Biochemistry*, 37: 215–225.

PICKETT, S. T. A., PARKER, V. T., 1994, Avoiding old pitfalls: opportunities in a new discipline. *Restoration Ecology.*, 2: 75–79.

SZUJECKI, A., 1996, Ecological aspects of forest reconstruction on abandoned lands, *Prace IBL*, vol. 27 (In Polish).

TAYLOR, B. R., PARKINSON, D., PARSONS, W. F. J., 1989. Nitrogen and lignin content as predictors of litter decay rates: *a microcosm test. Ecology* **70**: 97–104.

URIOSTE, A. M., HEVIA, A. G. G., HEPPER, E. N., ANTON, L. E., BONO, A. A. AND BUSCHIAZZO, D. E., 2006, Cultivation effects on the distribution of organic carbon, total nitrogen and phosphorus in soils of the semiarid region of Argentinian Pampas. Geoderma, **136**: 621–630.