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"IMPACT OF LAND USE ON SOIL PROPERTIES"

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ARTICLE ID: 023

Introduction:

Land use is defined as the arrangements, activities and inputs people undertake in a certain land cover type to produce, change or maintain it (Ufot *et al.*, 2016). Successful agriculture requires the sustainable use of soil resource, because soil can easily lose its quality and quantity within a short period of time for different reasons such as intensive cultivation, leaching and soil erosion (Kiflu and Beyene, 2013). Agricultural practice, therefore, requires basic knowledge of sustainable use of the land (Takele *et al.*, 2014). A success in soil management to maintain the soil quality depends on the understanding of how the soil responds to agricultural practices over time (Duguma *et al.*, 2010). However, the basis of this sustainable agricultural development is good quality of the soil, since maintenance of soil quality is an integral part of sustainable agriculture and the convenient witness to enhance the crop productivities (Liu *et al.*, 2010). Soil resource has also provided a great contribution in the production of food and fibre, in the maintenance of local, regional, and worldwide environmental quality (Bore and Bedadi, 2015).

Unequivocally, scientists emphasize that human activity rather than natural forces is responsible for the modification of the global environment. Land-management practices have modified landscapes throughout the world, impacting the diversity of plants, animals, and microbes, as well as soil quality and ecosystem services. Agriculture, forestry, and associated management practices such as tillage, grazing, and afforestation affect the cycling of nutrients, carbon stocks, and biodiversity. Population increase and development are the drivers for the pressure on land use; more food is needed for a growing population; despite advances in biotechnology, mechanization, and inputs, the land area on which it is grown remains the same; and continued intensive land use has direct effects on soil quality.

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On the other hand, land changes have direct effects on water storage, soil carbon, degradation, biodiversity, and ecosystem behaviour. It is the scientists' task to provide support for policy decisions about land uses, which should take into consideration both human needs and the response of the ecosystem. Land-use pattern terms indicate the interaction of human activities with natural environment (such as forest) and their utilization by man in time and space. Information on land-use changes is important for planning and implementation of schemes for the welfare of people and natural resources (Rawat & Kumar 2015). Conversion of the important resource of forest land into different land-use types is a primary cause of resource degradation, which in turn alters nutrient and carbon cycles, land productivity and diversity of species (Borrelli *et al.* 2018).

Given that the consequences of deterioration in soil fertility associated with land use change are dire, it is important to understand which specific soil quality parameters are affected by agricultural land use and which agricultural practices or environmental factors are responsible for the greatest decline in critical soil quality parameters. Although it is important to assess how agricultural land use influences specific soil fertility parameters, we find a dearth of knowledge on how soil fertility parameters change with land use change and farming practices.

Studies done on impacts of land-use on soil properties in the world

Knowledge and understanding of soil properties and processes ensures remediation or reclamation of disturbed or damaged soils. This special issue brought together an international group of scientists presenting results from field trials and data harvesting carried out in a range of different soils and environments, from Poland, Italy, Spain, and USA to China, Indonesia, Venezuela, Brazil, and Argentina, together with laboratory experiments, reviews, and modeling with advanced mathematical tools. The strength of such issue was derived from a mutual interest in the mechanisms that regulate the impact of land use and changes in land use on soil properties and processes and also in the development and use of the most advanced methods and procedures for assessing them. Drawing on the latest research and opinion, first this issue contains one state-of-the-art review and two research articles highlighting the usefulness and efficiency of the approach adopted here in a general context. W. Zhou *et al.* reviewed the effect of paddy upland rotation on soil properties. W.

Shangguan *et al.* addressed the soil pedodiversity of China, mapping the distribution and extent of different soil taxa; this allowed identification of nearly 90 endangered soils, also suggesting that at least two dozen of soils have already gone extinct due to inadequate land use. J. Rejman *et al.* addressed the role of land use change in soil losses and relief modification in Loess areas of Poland.

Various authors reported laboratory experiments aiming to clarify the role of external inputs (amendments, irrigation, etc.) in selected soil properties. More specifically, A. D. Karathanasis *et al.* used several amendment materials together with extracts from crop biomass to accelerate fragmentation of fragipans and, therefore, to increase the water holding capacity of these soils. L. Chu *et al.* assessed the potential of micro sprinkler irrigation as a method to alleviate soil salinization, allowing crop growth. M. Garc´ıa-Albacete *et al.* conducted leaching experiments to analyse phosphorus mobility in both soil-compost ad soil-digestate systems, showing that phosphorus losses were higher for the former than for the latter; in addition, this study provided evidence of the importance of waste's wettability for assessing P sorption mechanisms and risk of leaching losses. M. Garc´ıa- S´anchez *et al.* using a batch experiment showed that both organic amendments and a sulphur compound added to two different Hg contaminated soils (luvisol and chernozem) were able to reduce Hg mobile fractions and increased availability of macro- and micronutrient. The role of land use in soil organic matter and nitrogen dynamics has been illustrated by case studies carried out in contrasting soil and climatic conditions. A. F. Gonz´alez- Pedraza and N. Dezzeo studied soil nitrogen seasonality in the Western Llanos of Venezuela. S. Dori *et al.* addressed soil carbon dynamics in different regions of Europe and discussed the efficiency of management practices that control the potential of sequestration of soil organic carbon. A. Liang et al. analysed the mechanisms of soil organic carbon turnover on agricultural systems using a combination of isotopic tracer and physical fractionation under no-tillage and mouldboard ploughing; results showed that shot term impact of the studied tillage treatments varied in the different fractions analysed. D. A. McGranahan *et al.* analysed the reliability of carbon sequestration estimations associated with the effect of unexplained variability and due to interactions of vegetation, land use management, and soil properties with belowground ecosystem function; subsequently, even if rangeland soils are important carbon pools, it is

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unlikely that rangeland plant communities can be effectively categorized by their carbon sequestration potential.

Land use impacts on greenhouse gasses have been a major topic of this special issue. Z. S. Zhang *et al.* conducted a field trial to evaluate the effect of mulching from residues of a previous crop on paddy fields under no-tillage; this management system was found to significantly increase CO_2 and N_2O emissions, while decreasing CH_4 emissions. S. F. Smith and K. R. Brye reported results from a field trial on a silt loan soil under soybean, showing that the impact of irrigation on seasonal CO_2 emissions differed between years, whereas no-tillage management reduced seasonal CO_2 emissions; the tillage effect on total CO_2 emissions was not dependent on the irrigation scheme used. L. N. L. K. Choo and O. H. Ahmed used a lysimeter experiment to analyse both CO_2 emissions and dissolved organic carbon leaching in a drained peat land cropped to pineapple under tropical conditions. Y. Lu and H. Xu performed an incubation experiment to test the effects of soil temperature, flooding, and organic matter addition on N_2O emissions in a wetland soil.

Two manuscripts addressed the role of land use in soil organism. G. M. Siqueira *et al.* used the classical pitfall trap method to study the interactions between the soil arthropod community and land use and management of an entisol under semiarid climate in Brazil; the arthropod abundance under native forest was much lower than under native biomes with tropical climate. Agricultural land use strongly decreases the abundance of Formicidae compared to natural biome. E. E. Kuramae *et al.* studied the role of several land uses in the structure and composition of microbial communities in Netherlands using DNA analysis; the functional gene diversity found in different soils did not group the sites accordingly to land management, and the main factors driving differences in functional genes between land uses or management systems were carbon: nitrogen ratio, phosphatase activity, and total nitrogen.

New experimental and conceptual methods are needed to assess the effects of land use changes on soil properties and processes. J. L. M. P. de Lima *et al.* mapped soil surface macropores using infrared thermography; this technique is expected to provide a better understanding of the complex relationships between soil pores and soil physical and hydraulic properties. C. Moreno et al. developed an image analysis method to estimate the soil cover by different types of mulching materials during degradation in the field; particular attention was paid to thresholding methods in image treatment; proportion of areas lacking mulch have been automatically assessed. The applications of fractals and multifractals in soil and earth sciences are increasing, since many soil properties and processes have been shown to depend on complex interactions that could be assessed by fractal models. Also, there is an increasing availability of data sets allowing computation and modelling using these mathematical tools. J. de Castro et al. described fractal analysis of Laplacian pyramidal and applied this method to segmentation of soil micromorphology; the algorithm used produced more reliable results than the commonly employed OTSU algorithm. Geostatistics was used to evaluate the spatial variability of several soil properties as related to land use at various sampling scales. G. M. Siqueira *et al.* used soil apparent electrical conductivity for devising soil sampling schemes in an agricultural field that in a further step were analysed by geostatistical techniques; as a result, a first manuscript was devoted to estimated spatial patterns of soil compaction and a second one provided insight into the spatial variability of selected general soil properties. L. A. Morales *et al.* studied the patial distribution of ammonium-nitrogen, phosphorus, and potassium in a paddy field at Argentina during three different vegetative periods of the rice crop. X. Tan *et al.* analysed the spatial variability of sixteen soil properties, including several soil enzymes, focusing on soil quality assessment; it was concluded that the spatial patterns of soil quality were better reflected using an integrated index based on soil enzyme activities. P. L. Aguado *et al.* used multifractal analysis to characterize a landscape, based on a high-resolution digital elevation model; it was shown that the use of the multifractal approach with mean absolute gradient data is a useful tool for analysing topographical features. We believe that the present special issue reflects recent advances on the effects of land use over a range of soil properties and processes, complemented with insightful case studies using advanced mathematical techniques and new experimental methods for assessing soil surface characteristics.

Land-use and its impacts in general

Changing land use from forests to croplands leads to a change in the chemical, physical and biological properties of the soil (Houghton *et al.*, 1999; Zhang *et al.* 2004; Viollete *et al.*, 2009). Anthropogenic activities are changing the Earth's surface hence they change the physicochemical properties of the soil, its structure and reduce soil fertility. Deforestation

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increases soil erosion because of the reduction of the soil stability, which leads to floods, drought and natural ecosystem degradation (Arévalo *et al.*, 2015). Land use change to cropland have changed significantly from the twentieth century, it is estimated that 25% of the Earth's surface will be occupied by cropland, shifting cultivation and livestock production in the twenty first century. Globally the decreasing rate of forests was about 1.7% in the period of 1990 to 2005, especially in Africa where 1.6 million hectares of forest areas were lost per year (FAO & JRC, 2012).

Generally, a sound understanding of land use and management effects on soil properties provides an opportunity to evaluate sustainability of land use systems (Woldeamlak 2003). Land use and soil management practices influence the soil nutrients and related soil processes, such as erosion, oxidation, mineralization, and leaching, etc (Celik, 2005; Liu *et al.*, 2010). Land use/land cover (LULC) changes influence the biogeochemistry, hydrology, and climate of the earth. Elucidating the impact of LULC at the local to regional scales on soil quality status is not direct but rather complex to guarantee any generalizations (Hoogsteen *et al.* 2015).

Land use is one of the main drivers of many processes of environmental change, as it influences basic resources within the landscape, including the soil resources. Poor soil management can rapidly deteriorate vast amounts of land, which frequently becomes a major threat to rural subsistence in many developing and developed countries. Conversely, impact of land use changes on soil can occur so unnoticed that land managers hardly contemplate initiating ameliorative measures.

Kumar *et al.* (2006) studied soils under different land uses in dry temperate zone of the state and found wide variation in soil pH, available phosphorus, maximum increase was recorded in soils of wasteland and minimum in soils under grasses and maximum increase in available potassium was observed in soils under hops cultivation and minimum in wasteland soils. Based on soil properties land capabilities classes were fixed and suitable land use plan was suggested for sustaining yields of crops in Ramachandrapuram mandal of Andhar Pradesh (Vara Prasad *et al.*, 2008). Ganeshamurthy *et al.* (2009) studied improvement in soil quality due to pulse crops which enriches soil with nitrogen, and they also studied about the impact of continuous cultivation of pulses on soil health.

Implications made based on case studies.

- **Impact on soil physical properties**
- Sand fraction is usually lowest in natural forest
- Clay fraction highest under natural forest
- Bulk density is usually high in degraded land

Table 1: Variations in soil physical properties under different land-use types.

Soil properties	Forest land	Savanna land	Cultivated land	Degraded land
Soil moisture content (%)	12	10	18	6
Water holding capacity (%)	44	37	30	25
Bulk density (g/cm^3)	1.24	1.33	1.43	1.65
Soil porosity (%)	53	50	46	39
Soil temperature (°C)	12	13	10	23

(Source : R Srivastava *et al.*, 2020)

Table 1: Soil physicochemical properties in different land-use types

Soil properties	Subtropical forest	Cardamom agroforestry	Paddy cropland
Sand (%)	42.80	47	39
Silt (%)	30.62	30	32.70
Clay (%)	26.58	23	28.30
B. D	0.75	0.70	0.62
Moisture (%)	35.40	37	41.02
pH	5.61	5.40	5.05
C (%)	4.34	4.09	3.16

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TN (%)	0.32	0.30	0.22
P (%)	0.05	0.04	0.02
SOC stock	40.99	40.41	34.16
C/N (%)	13.36	13.63	14.36

(Source : Lepcha *et al.*, 2020)

- **Impact on chemical properties**

➢ Soil organic carbon (SOC) is usually observed to be higher in forest which also results in higher N.

➢ P & K are also observed to be higher under forest

➢ CEC of natural forest observed to be very high as compared to other land-us.

Table 2. Variation in soil chemical properties under different land use changes.

Soil parameters	Forest land	Savanna land	Cultivated land	Degraded land
Soil pH	6.9	7.3	6.6	7.4
Soil EC (ds/m)	0.28	0.26	0.19	0.16
Soil organic carbon (%)	3.4	2.4	0.8	0.5
Total nitrogen (%)	0.36	0.25	0.09	0.04
C/N ratio	9.5	9.7	9.4	12.6

(Source: R Srivastava *et al.*, 2020)

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Table 2 Soil attributes as influenced by different land uses under study

Soil attributes	Land use systems					
	NFL	CLL	CUT	SC	PL	GL
pH (1:2 soil/water)	5.3^{a}	4.3^{e}	4.6^{d}	5.3^{a}	4.9^{c}	5.1^{b}
Soil organic carbon (g kg^{-1})	28.7^{a}	14.6^{d}	10.7^{f}	12.1^{e}	15.5^{c}	26.5^{b}
Sand (g kg^{-1})	559.3^{e}	537.5^{f}	682.2^{b}	611.7^{c}	702.6^{a}	562.5^{d}
Silt (g kg^{-1})	138.6^{c}	210.5^{a}	92.8^{e}	110.6^{d}	89.3^{f}	148.4^{b}
Clay (g kg^{-1})	302.1^{a}	252.0^{d}	225.1^{e}	277.7^{c}	208.1^{f}	289.2^{b}
Exch. acidity [cmol(P^{+})kg^{-1}]	0.62^{e}	1.72^{b}	1.66^{c}	0.54^{f}	1.75^{a}	0.69^{d}
Exch. Al [cmol(P^{+})kg^{-1}]	0.51^{d}	1.17^{a}	0.96^{b}	0.40^{e}	1.12^{f}	0.57^{c}
CEC [cmol(P^{+})kg^{-1}]	18.5^{a}	9.4^{d}	8.3^{f}	11.4^{c}	8.6^{e}	15.6^{b}
ECEC [cmol(P^{+})kg^{-1}]	6.8^{a}	3.3^{e}	3.2^{f}	3.6^{c}	3.4^{d}	5.1^{b}
% Base saturation	34.2^{a}	22.5^{e}	27.1^{d}	27.9^{c}	26.7^{d}	28.9^{b}
% Al saturation	7.4^{e}	35.6^{a}	29.9^{c}	11.2^{d}	32.7^{b}	11.2^{d}
Available N (mg kg^{-1})	184.1^{a}	139.2^{d}	113.7^{f}	127.9^{e}	157.3^{c}	172.6^{b}
Available P (mg kg^{-1})	8.5^{a}	8.1^{c}	7.1^{f}	8.2^{b}	7.9^{d}	7.6^{e}
Available K (mg kg^{-1})	159.9^{a}	124.8^{e}	89.8^{f}	141.2^{c}	136.1^{d}	152.8^{b}
Exch. Na [cmol(P^{+})kg^{-1}]	0.19^{a}	0.16^{b}	0.15^{c}	0.17^{b}	0.13^{d}	0.17^{b}
Exch. Ca [cmol(P^{+})kg^{-1}]	3.8^{a}	1.2^{e}	1.0^{f}	1.6^{c}	1.4^{d}	2.8^{b}
Exch. Mg [cmol(P^{+})kg^{-1}]	1.9^{a}	0.4^{f}	0.8^{d}	1.1^{c}	0.5^{e}	1.2^{b}
DTPA Fe (mg kg^{-1})	71.2^{f}	90.1^{a}	86.7^{b}	76.9^{d}	81.3^{c}	75.1^{e}
DTPA Mn (mg kg^{-1})	36.3^{c}	32.8^{e}	42.5^{a}	34.7^{d}	34.2^{d}	38.7^{b}
DTPA Cu (mg kg^{-1})	2.81^{b}	2.48^{f}	2.57^{d}	2.64^{c}	2.53^{e}	2.86^{a}
DTPA Zn (mg kg^{-1})	3.02^{a}	2.14^{f}	2.72^{c}	2.66^{d}	2.37^{e}	2.83^{b}
Available B (mg kg^{-1})	0.40^{b}	0.52^{a}	0.32^{c}	0.29^{d}	0.30^{d}	0.24^{e}
Available Mo (mg kg^{-1})	0.18^{b}	0.22^{a}	0.14^{c}	0.10^{d}	0.08^{e}	0.14^{c}
SMBC (μg g^{-1})	712.2^{a}	257.9^{c}	207.1^{e}	240.3^{d}	252.7^{c}	589.4^{b}
SMBN (μg g^{-1})	35.2^{a}	24.6^{c}	11.7^{f}	21.1^{d}	14.2^{e}	31.3^{b}
SMBP (μg g^{-1})	5.21^{b}	3.15^{c}	1.07^{e}	1.84^{d}	1.26^{e}	5.84^{a}
Dehydrogenase (μg g^{-1} h^{-1})	18.2^{a}	15.1^{c}	10.3^{e}	12.8^{d}	12.4^{d}	16.7^{b}
SR (μg CO_2-C g^{-1} h^{-1})	12.2^{a}	5.13^{c}	1.57^{e}	3.29^{d}	3.14^{d}	9.65^{b}
qCO_2 (μg CO_2-C μg^{-1} SMBC h^{-1})$\times 10^{-3}$	17.1^{b}	19.9^{a}	7.60^{e}	13.7^{c}	12.4^{d}	16.4^{b}

Values followed by different letters within the same parameter under different land uses are significantly different ($P<0.05$) by the Duncan's multiple range test

NFL natural forestland, *CLL* cultivated lowland, *CUT* cultivated upland terrace, *SC* shifting cultivation, *PL* plantation land, *GL* grassland, *SR* soil respiration, qCO_2 metabolic quotient

(Source: Singh *et al.*, 2014)

- **Impact on soil biological properties**

➢ No significant interaction between land use and season was observed for all the soil parameters except for microbial biomass carbon (MBC).

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Table 4 Seasonal and mean annual microbial biomass carbon (MBC) across soil depths (0-30 cm) in study site (Means ±SE followed by common letter are not statistically different by Tukey's HSD test at 5% level of significance)

Land-use type	Soil Depth (cm)	MBC ($\mu g\,g^{-1}$)				MBC ($\mu g\,g^{-1}$)			
		Summer	Rainy	Winter	Annual Mean	Summer	Rainy	Winter	Annual Mean
		1st Year				2nd Year			
Subtropical Forest	0-15	539.30 ± 12.32 [a]	758.29 ± 17.22 [b]	442.23 ± 13.34 [c]	579.94 ± 14.29 [d]	546.10 ± 17.23 [a]	764.30 ± 21.42 [b]	436.20 ± 12.34 [c]	582.20 ± 16.99 [ad]
	15-30	318.96 ± 09.21 [a]	403.22 ± 08.78 [b]	234.70 ± 06.34 [c]	318.96 ± 08.11 [ad]	324.98 ± 07.87 [a]	421.27 ± 06.67 [b]	270.81 ± 05.32 [c]	339.02 ± 06.62 [ad]
	Mean	**429.13 ± 10.76** [a]	**580.75 ± 13.00** [b]	**338.46 ± 09.84** [c]	**449.44 ± 11.20** [ad]	**435.54 ± 12.55** [a]	**592.78 ± 14.04** [b]	**353.50 ± 08.83** [c]	**460.61 ± 11.80** [ad]
Cardamom Agroforestry	0-15	461.08 ± 11.65 [a]	604.75 ± 13.45 [b]	417.90 ± 09.89 [ac]	494.57 ± 11.66 [d]	471.20 ± 10.43 [a]	592.41 ± 08.21 [b]	427.70 ± 07.87 [c]	497.10 ± 08.83 [d]
	15-30	252.76 ± 08.11 [a]	394.94 ± 08.32 [b]	222.67 ± 05.99 [c]	290.12 ± 07.47 [d]	257.59 ± 07.54 [a]	388.71 ± 08.32 [b]	222.70 ± 07.66 [c]	289.66 ± 07.89 [d]
	Mean	**356.92 ± 09.88** [a]	**499.84 ± 10.88** [b]	**320.28 ± 07.94** [c]	**392.34 ± 09.56** [d]	**364.39 ± 08.98** [a]	**490.56 ± 08.26** [b]	**325.20 ± 07.76** [c]	**393.38 ± 08.36** [d]
Paddy Cropland	0-15	399.80 ± 13.32 [a]	458.23 ± 17.33 [b]	356.91 ± 8.76 [c]	404.98 ± 13.13 [ad]	400.10 ± 12.32 [a]	435.55 ± 15.34 [b]	344.87 ± 6.78 [c]	393.51 ± 11.48 [ad]
	15-30	252.76 ± 10.23 [a]	258.78 ± 11.56 [a]	192.58 ± 8.78 [c]	234.71 ± 10.19 [ad]	228.64 ± 9.79 [a]	294.88 ± 12.83 [b]	186.54 ± 7.88 [c]	236.69 ± 10.16 [ad]
	Mean	**326.56 ± 11.77** [a]	**358.50 ± 14.44** [b]	**274.74 ± 8.77** [c]	**319.84 ± 11.66** [ad]	**314.37 ± 11.05** [a]	**365.21 ± 14.08** [b]	**265.70 ± 07.33** [c]	**315.10 ± 21.64** [ad]
					HSD (α = 5%) = 4.53				

HSD = Tukey's honestly significant difference at 5% level of significance

(Source: Lepcha *et al.*, 2020)

Conclusion:

Based on the studies and experiments that have been carried out in relation to the impact of land use on soil properties, we can conclude the following. Land use does alter the soil properties: physical, chemical as well as biological. Moderate increase in pH, available P and K are observed in agricultural croplands. Higher organic carbon, CEC and available N are observed in agroforestry than agricultural land use. In some cases, the changes may be negligible but it still helps to study the relation between them. Knowledge and understanding of soil properties and processes ensures remediation or reclamation of disturbed or damaged soils.