



# Soil Organic Carbon and Total Nitrogen Stocks Under Different Land Uses in Achanakmar-Amarkantak Biosphere Reserve, India

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## Abstract

Land use changes, essentially due to alteration from natural ecosystems into managed agro ecosystems, and subsequent deterioration in the quality of soil resources have become common phenomena in AABR. Soil reaction (pH), soil carbon, total N, available P contents, and potassium content are vital soil properties affected by such changes. This study was therefore conducted with the objective to assess the response of these vital soil chemical properties to changes in management practices arising from varying land uses (dense forest, plantation, degraded vegetation, agriculture, and agroforestry) and soil depth (0–20 and 20–40 cm). Results revealed that vital soil properties significantly ( $P \leq 0.01$ ) responded to changes in land use and with depth. Contents of soil carbon and total N, P, K were highly significantly affected by soil depth and land use types. However, interaction of land use and soil depth is to be found significant for pH and available P. The correlation between nitrogen and carbon content of the soil is found to be positive with all depth and land use types except depth 20–40 cm in case of agroforestry land use system. Available P contents were also significantly ( $P \leq 0.01$ ) reduced due to shift of land uses from natural forest to agricultural land uses but with soil depth and interaction effect. It can be noted that this situation is far from sustainability and has tremendous implications for productivity of the traditional low-input agriculture in the study area. This manuscript is an attempt to identify the LULC pattern and assess the carbon storage, soil organic carbon, and nitrogen stock in various land use systems in Central India along with potent productivity for natural resource management and the deficit that causes limitations in the sustainable development.

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**Keywords**

Available phosphorus · Crop-livestock systems · Land use change · Organic matter

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## 8.1 Introduction

Soil is an important factor, influences the production/productivity of terrestrial planet, and plays a crucial role in the existence of different life forms, fulfilling their nutritional requirement. Soil ecosystem is the pool of plenty of macro and micro nutrients, essential for growth and development of physiognomy of plants exist on terrestrial planet. The status of the soil nutrients pool (SNP) may greatly influence with environmental and anthropogenic driving factors. Land use is a key factor governing many processes of environmental change including the soil resources. The United Nations Framework Convention on Climate Change (UNFCCC) has introduced the Land Use, Land Use Change and Forestry (LULUCF) approach, which aims at C sequestration through afforestation, reforestation, re-vegetation, and forest-crop and grassland management as a form of GHG-offset activities (Izaurrealde et al. 2001; McCarl and Schneider 2001). With follow-up of this approach, in the recent years, across the globe major focus was given on the soil organic carbon (SOC) and soil total nitrogen (STN), which were highly altered with change in land use management practices. However all the nutrients more and less influence this phenomenon. SOC and soil total nitrogen (STN) can provide nutrients for plant growth and maintain good soil physical structure. Therefore, the research of SOC and STN concentration and stock is essential in increasing crop productivity and alleviating carbon emissions (Wang et al. 2016). The forest patch/fragmentation and land use land cover changes are key drivers of losses biodiversity, habitation, and ecosystem processes in tropical regions, which are intrinsically linked to composition. Soil nutrients, flora and faunal diversity, and functioning of ecosystems, which lead to the formation of varying sizes of forest patches, create isolation from dense forests and often form new forest edge (Kumar et al. 2017a, b; Thakur et al. 2019a, b; Kumar et al. 2021). It has been well observed that the SOC and STN stock of ecosystem was greatly influence with the change in land use practices (Wu et al. 2003; Gelaw et al. 2014; Gao et al. 2015 (Deforestation); Kucuker et al. 2015; Fujisaki et al. 2015 (Afforestation); (Bárcena et al. 2014; Omonode and Vyn 2006). However, nutrient status of soil not only bounded with land use changes but also affected through soil physical (Sakin 2014; Jiao et al. 2011) and chemical properties (Six and Paustian 2014). It has been well demonstrated or proved by researchers that forest ecosystems are important both ecologically and economically, and forest soil is the most fundamental terrestrial asset and natural resource (Agoumé and Birang 2009). There are certain factors like litter biomass and live biomass that directly contribute to the SNP; on the other hand inappropriate tillage operation and anthropogenic activity have negative impact on same. The SOC stocks of forest lands were higher than that in cropland in humid tropics or drought-less region (Fujisaki et al.

2015; Zhang et al. 2013). Land use in tropical areas causes significant modifications in soil properties in which agriculture has a major contribution (Pal et al. 2013), and especially cultivation of deforested land may rapidly diminish soil quality (Ayoubi et al. 2011). The conversion of natural forest to cultivated land is manifested the most in the on-site loss of SOM causing a reduction in nutrient stock, CEC, and structure stability (Hartemink et al. 2008). Beside, influence of land use on carbon content also influences the soil N cycling in tropics. There is a consistent finding that intact tropical forests have higher rates of N mineralization and nitrification than agricultural sites (Piccolo et al. 1994; Reiners et al. 1994; Neill et al. 1995, 1997), suggesting that N availability is greater (Nadelhoffer et al. 1983) where there is less human disturbance. However, soil stocks of inorganic N can be higher in agricultural sites than forest sites because of lower plant uptake (Neill et al. 1995). The change of forest land into non-forestry uses influences the emission of N<sub>2</sub>O in the atmosphere by the so-called process de-nitrification (Keller et al. 1993; Neill et al. 1997; Verchot et al. 1999). The understanding of pattern of N<sub>2</sub>O losses in the ecosystem is extremely desirable because it contributes in greenhouse gases as well as in ozone depletion at a large extent. These changes in land use are often localized and site specific; however their impacts collectively lead to changes in the larger global scale resulting in desertification, biodiversity loss, global warming, and ultimately change the ecosystem of the planet (Chase and Singh 2014; Kumar and Thakur 2017; Thakur 2018; Kumar et al. 2021; Thakur et al. 2021a, b). The recent study mainly focused on the objectives like estimating the nutrient status in different land use and on different depth and assessing the effects of land use changes on SNP.

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## 8.2 Materials and Methods

### 8.2.1 AABR and the Study Site

The Achanakmar-Amarkantak Biosphere Reserve (AABR) is spread between 21° 15' to 22° 58' N latitude and 81°25' to 82° 5' E longitude. This covers an area of 388733.5 ha. AABR is categorized into nine different regions, namely, the dense forest (212283.5 ha), the cropland area (130,500 ha), the open forest (17,391 ha), the degraded vegetation (9414 ha), the wastelands (5222 ha), the forest blank (3266 ha), the land with/without scrub (2381 ha), the ravines land (2391 ha), and the build-up (1092 ha). In addition, water structures cover 3593 ha, and 840 ha of the area is not a part of any of the abovementioned regions. The mean daily maximum temperature of AABR ranges from 24° to 42° C whereas its mean daily minimum temperature ranges from 10° to 25° C. Relative humidity in AABR varies from 39% to 90% with an average yearly rainfall between 1322 mm and 1624.3 mm. The geology of the area is unique and varies from schist and gneisses with granite intrusions to sand stones, shale, limestone, basaltic lava, and bauxite. The composition and texture of the soil varies from sandy to loamy-clays, generally light brown to brownish, and olive green clay at some places. Red soil which is rich in iron oxide is also present. It is porous and fertile. The banks of numerous streams in the tract are rich in alluvial

soil. The black cotton soil in many areas of AABR supports a large number of ecosystems and species. The site for the present study is spread over 15,100 ha with elevations ranging from 1053 to 1450 m.

## 8.2.2 Sampling Design and Methods

For the present study five different types of land uses are identified in AABR. These are the croplands (wheat), dense forests, plantations, degraded vegetation, and agroforestry (wheat and *Dalbergia sissoo*). Within each of the identified land uses 10 plots of sizes 20 m X 20 were set up. This made up 50 plots in total wherein each land use was replicated 10 times. Five sampling points with Z-shaped pattern in each plot were selected. The soil was excavated to a depth of 40 cm, and consolidated rock material was obtained.

Intact soil cores were sampled for a depth of 0–20 cm and 20–40 cm to estimate the stock of SOC and STN. From all the samples root particles, crop residues, and other inert material were removed manually with the help of a 2 mm sieve. After removing these particles, all samples were mixed by using quartering methods. This was followed by oven drying the material at 72 °C for 24 hours. The disturbed soil samples were used to determine the sand, silt, and clay contents, the pH value, the total phosphorus (STP), and the total potassium (STK) content. Core samples were also collected to quantify bulk density of soil at specific intervals with the help of cylinder (5 cm). In addition, pH and EC were also measured using multi-parameter.

The SOC and STN (both in Mg/ha) for each sampling site were estimated by using the following formulae (Chen et al. 2007):

$$\text{SOCs} = \sum_i (\text{SOC}_i \times B_i \times D_i \times 8.10)$$

$$\text{STNs} = \sum_i (\text{TN}_i \times B_i \times D_i \times 8.10)$$

where SOCs and STNs were the soil stocks of SOC and STN, respectively.  $\text{SOC}_i$  and  $\text{TN}_i$  are the carbon and nitrogen concentrations, respectively, in the  $i^{\text{th}}$  layer (gm/Kg).  $B_i$  is the bulk density of a particular layer in (g/cc) and  $D_i$  is the thickness of the core. The STP and STK were calculated by averaging all the samples of the plots.

## 8.2.3 Statistical Analyses

The difference in physical properties, namely, sand, silt, and clay, among different types of land uses was tested using one-way ANOVA. The bulk density, the nutrient content (STN, STP, STK, and SOC), and other chemical properties (pH and EC) of the soil are opined to vary with the type of land use and the depth of the soil. Hence, two-way ANOVA models with interaction were utilized to investigate the variation

in nutrient content (STN, STP, STK, and SOC), chemical properties (pH and EC), and the bulk density. This was followed by post hoc tests for respective ANOVA models for investigating the significance of the differences between effects of pairs of land use types on different parameters (sand, silt, clay, bulk density, STN, STP, STK, SOC, pH, and EC).

The correlation between STN and SOC content was investigated for all the combination of land use and selected depths. The correlations between the parameters for nutrient content, chemical properties, and the physical properties are also investigated for each of the selected depths. The dependence of STN, STP, STK, SOC, EC, pH, bulk density, silt, sand, and clay on the bulk density and depth was modelled using regression models. All analysis was carried out in SPSS, version 16.0.

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## 8.3 Results and Discussion

The effect of the type of land use is found to be significant on the nutrient content, the chemical properties, and the bulk density of soil (Table 8.1). The effects of selected depths are found to be significant on all the parameters. However, the interaction of land use and depth is found to be significant only in case of pH, STP, and bulk density. In addition, the one-way ANOVAs conducted for sand, silt, and clay indicated that the effect of land uses is significant ( $p$ -values  $<0.01$  for each of sand, silt, and clay).

### 8.3.1 Land Use Types and STN

Pair-wise comparisons show that the difference in the STN between different pairs of land use types is significant except for the DF-AF, P-DV, P-AG, and DV-AG (Table 8.2). The average STN is estimated to be more by 36.26, 41.46, and 56.12 Kg/ha in DF when compared to P, DV, and AG, respectively (Table 8.2). The average STN in P is 35 Kg/ha less than that for AF. The STN in DV is 40.2 Kg/ha less than AF whereas it is 55 Kg/ha more in AF when compared to Ag (Table 8.2). The effect of land use and soil depth was found to be significant for all chemical properties and land use types. However the interaction of the land used and depth was significantly in case of PH and available phosphorus content. The similar trend was observed by Emiru and Gebrekidan (2013), Bijalwan et al. (2017, 2019), Thakur et al. (2017), Thakur et al. (2018), Thakur et al. (2020), Darro et al. (2020), and Kumar et al. (2017a, b). This variation can be result of loss of base farming cations.

The nitrogen contents of land use and land depth show decline trend with land use and land depth. The N content was highest in dense forest with depth of 0–20 cm. The same founding was observed by Ross et al. (1999). Concurrently, organic carbon content was profoundly affected by soil depth and land use types, however interaction with land use and soil depth not shown any significant difference. This is attributed to be continuous accumulation of dead and decay matter on surface soil. In

**Table 8.1** Two-way ANOVA for different land use and depth

Parameters	Soil properties						
	STN	STP	STK	SOC	EC	pH	Bulk density
Land use	6.76 (< 0.01)	3.52 (0.01)	16.52 (< 0.01)	3.81 (0.01)	190.30 (< 0.01)	54.06 (0.000)	55.97 (< 0.01)
Depth	12.71 (< 0.01)	16.84 (< 0.01)	4.67 (0.03)	102.35 (< 0.01)	82.17 (< 0.01)	49.989 (0.000)	15.57 (< 0.01)
Land use*depth	0.03 (0.99)	6.46 (< 0.01)	0.08 (0.99)	2.10 (0.09)	0.68 (0.61)	21.77 (< 0.01)	10.19 (< 0.01)

**Table 8.2** Pair-wise comparison of effects of selected land use types for selected parameters for physical and chemical properties of soil

Land use type pairs	Different in effects (p-value)										
	STN	STP	STK	SOC	EC	pH	Bulk density	Clay	Sand	Silt	
Dense forest—Plantation	36.26 (0.01)	2.03 (0.10)	38.05 (0.17)	0.12 (0.03)	-0.004 (0.60)	0.04 (0.59)	0.04 (0.02)	0.50 (0.11)	-2.50 ( 0.01)	2.00 ( 0.01)	
Dense—Degraded vegetation	41.46 ( 0.01)	3.44 ( 0.01)	164.80 ( 0.01)	0.13 (0.02)	0.003 (0.70)	-0.43 ( 0.01)	0.07 ( 0.01)	0.55 (0.08)	-3.40 ( 0.01)	3.00 ( 0.01)	
Dense forest—Agriculture	56.12 ( 0.01)	3.80 ( 0.01)	160 ( 0.01)	0.21 ( 0.01)	-0.16 ( 0.01)	-1.00 ( 0.01)	0.24 ( 0.01)	-10.7 ( 0.01)	8.20 ( 0.01)	2.50 ( 0.01)	
Dense forest—Agroforestry	1.26 (0.92)	0.70 (0.58)	19.00 (0.49)	0.12 (0.03)	-0.08 ( 0.01)	-1.00 (0.23)	0.11 ( 0.01)	-3.6 ( 0.01)	2.90 ( 0.01)	0.80 (0.07)	
Plantation—Degraded vegetation	5.20 (0.70)	1.40 (0.26)	126.75 ( 0.01)	0.01 (0.82)	0.01 (0.33)	-0.49 ( 0.01)	0.03 (0.09)	0.05 (0.87)	-0.10 (0.03)	1.00 (0.03)	
Plantation—Agriculture	19.9 (0.15)	1.78 (0.16)	121.75 ( 0.01)	0.09 (0.10)	-0.16 ( 0.01)	-1.00 ( 0.01)	0.20 ( 0.01)	-11 ( 0.01)	10.70 ( 0.01)	0.50 (0.25)	
Plantation—Agroforestry	-35.00 (0.01)	-1.33 (0.29)	-19.05 (0.49)	-0.002 (0.97)	-0.08 ( 0.01)	-0.14 (0.08)	0.07 ( 0.01)	-4.1 ( 0.01)	5.40 ( 0.01)	-1.20 ( 0.01)	
Degraded vegetation— Agriculture	14.70 (0.29)	0.37 (0.77)	-5.00 (0.86)	0.08 (0.15)	-0.17 ( 0.01)	-0.58 ( 0.01)	0.17 ( 0.01)	-11 ( 0.01)	11.70 ( 0.01)	-0.50 (0.25)	

(continued)

**Table 8.2** (continued)

Land use type pairs	Different in effects (p-value)									
	STN	STP	STK	SOC	EC	pH	Bulk density	Clay	Sand	Silt
Degraded vegetation— Agroforestry	-40.20 ( < 0.01)	-2.73 (0.03)	-145.80 ( < 0.01)	-0.01 (0.80)	-0.08 ( < 0.01)	0.33 ( < 0.01)	0.04 (0.04)	-4.2 ( < 0.01)	6.40 ( < 0.01)	-2.20 ( < 0.01)
Agroforestry—Agriculture	55.00 ( < 0.01)	3.11 (0.01)	140.80 ( < 0.01)	0.09 (0.09)	-0.08 ( < 0.01)	-0.90 ( < 0.01)	0.13 ( < 0.01)	-7 (0.31)	5.37 ( < 0.01)	1.70 ( < 0.01)



general converting or disturbing natural ecosystem may result in difference of carbon content with land used. As forest vegetation shows closed type of nutrient cycling, add nutrient on surface layer by pulling nutrient from deeper layer and at the same time add nutrient with leaf and litter material from tree canopy. The same findings were observed by Woldeamlak and Stroosnijder (2003) and Genxu et al. (2004). The effect of land used and soil depth with its interaction was found to be significant. Shift of land use changes from natural forest to managed agro-ecosystem or biological interference may be caused to decline available phosphorus content with land use and depth of soil. This result is an agreement with findings made by Saikh et al. (1998) and Woldeamlak and Stroosnijder (2003) but contrasts with that made by Sánchez et al. (2002). The lowest concentrations of these parameters were found in agriculture land use practices. Sole cropping or agriculture system have open type of nutrient cycling, most of nutrient exhausted by crop rather adding nutrient in field ecosystem.

### 8.3.2 Land Use Types and SOC

In case of carbon, the content of carbon between different pairs of land use is significant except P-DV, P-AF, DV-AF, P-AG, DV-AG, and AF-AG. The average SOC is estimated to be more by 0.12, 0.13, and 0.21 g/kg and 0.12 in DF when compared to P, DV, AG, and AF, respectively (Table 8.2).

### 8.3.3 Land Use Types and STP

The STP of different land use pairs was found to be significantly different in DF-DV, DF-AG, DV-AF, and AF-AG. The STP in DF is found to be more than that of DV and AG by 3.44 kg/ha and 3.80 kg/ha, respectively. Similarly, the STP in AF is found to be 3.11 kg/ha more than that in AG. However, it is 2.73 kg/ha less in DV when compared to AF (Table 8.2). The remaining land use pair shows no significant differences with respect to the STP.

### 8.3.4 Land Use Types and STK

The potassium content between the land use pairs, namely, DF and P, DF and AF, and DV and AG, is not found to differ significantly (Table 8.2). However, for the rest of the land use type pairs, the difference is found to be significant. The STK is found to be higher in DF when compared to DV and AG. Similarly, it is found to be higher in P when compared to DV and AG. DV is found to have a lower STK when compared to AF. Further the STK of AF is found to be higher than that of AG.

### 8.3.5 Land Use Types and the EC

The differences in the EC are not found to be significant between the land types, namely, DF and P, DF and DV, and P and DV. EC of DF is found to be lesser than that of AG and AF. Similarly, EC of P is found to be lesser than that of AG and AF (Table 8.2). In case of DV it is found to be lesser than that of AG and AF, whereas the EC of AF is found to be lesser than that of AG.

### 8.3.6 Land Use Types and the pH

The pH of the selected land use types differs significantly from each other excepting DF and P, DF and AF, and P and AF (Table 8.2). DF is found to have a lower pH value when compared to DV and AG. P is also found to be having a lesser pH when compared to that of DV and AG. DV is found to have a lower value of pH than AG but a higher value of pH when compared to AF. The pH of AF is also found to be lesser than that of AG.

### 8.3.7 Land Use Types and Bulk Density

The bulk density of DF is found to be greater than those of P, DV, AG, and AF. Although the bulk density of P and that of DV is not found to differ significantly, P is found to have greater bulk density when compared to AG and AF. Similarly, DV is found to have a greater bulk density when compared to AG and AF (Table 8.2). AF is also found to have a greater bulk density than AG.

### 8.3.8 Land Use Types and Soil Structure Content

The clay content of DF is not found to differ significantly from that of P or DV. However, it is found to have a lesser clay content than that of AG and AF. Similarly, P is found to have a lesser clay than that of AG and AF (Table 8.2). DV is also found to have a lesser clay content when compared to AG and AF. The sand contents in DF, P, DV, AG, and AF are found to be significantly different from each other. DF is found to have a lower sand content when compared to that in P and DV, whereas it has a higher sand content when compared to that in AG and AF. P is found to have a lower sand content than that in DV and a higher sand content than that in AG and AF. The sand content in AF is also found to be higher than that in AG (Table 8.2). DF is found to have relatively higher silt content when compared to that in P, DV, AG, and AF. The silt content in P is found to be higher than that in DV and AG, but its silt content is found to be lesser than that in AF (Table 8.2). DV is found to have a less silt content when compared to that in AG and AF. AF is found to have higher silt content when compared to that in AG.

### 8.3.9 Correlation Between STN and SOC

The correlation between STN and SOC of the soil is found to be positive and high for DF, P, DV, AG, and AF for both the selected depths except in agroforestry for the depth 20–40 cm (Table 8.3). For a depth of 0–20 cm the highest correlation is observed in AG (0.99). It is followed by P (0.96), AF (0.93), DF (0.82), and DV (0.75) in the decreasing order of correlation (Table 8.3). For a depth of 20–40 cm the ordering of land use types in the decreasing order of correlations is AG (0.93), DF (0.91), DV (0.91), P (0.86), and AF (0.17). Storage of soil organic carbon (SOC) and nitrogen (N), availability of soil N and phosphorus (P) were found to be increased under agroforestry compared to crop monocultures (Thakur and Thakur 2014; Verma et al. 2017; Bijalwan et al. 2019). Agroforestry provides a significant pathway to sustainable agricultural systems and diversification of income and plays a critical role in preserving microclimate and by providing permanent cover for soil and water. It is considered economically feasible and sustainable practice with the ability to reduce emission and sequester carbon (Kumar et al. 2021; Thakur et al. 2021a, b).

### 8.3.10 Correlation Between Other Parameters for Selected Depths

In what follows the correlations between parameters of physical properties, chemical properties, and the nutrient content of the soil are discussed based on Table 8.4. The figures in the brackets denote the respective coefficient of correlation. For depths up to 0–20 cm, a significant and positive correlation is observed between the bulk density and STN (0.52), SOC (0.68), STK (0.37), and STP (0.65). On the other hand, a significant negative correlation is observed between pH and STN (−0.18), SOC (−0.39), STK (−0.44), and STP (−0.43). Similar to the findings on pH, the correlation between EC and STN (−0.16), SOC (−0.39), STK (−0.24), and STP (−0.32) is also found to be negative. STN is found to have a positive correlation with SOC (0.79), STK (0.27), and STP (0.67). STP is found to be positively correlated with STK (0.42) and SOC (0.67).

For depths beyond 20 cm, i.e., for 20–40 cm of depth the bulk density is found to be positively correlated with STN (0.33) and STK (0.30). STK (−0.50) and pH are

**Table 8.3** Correlation between STN and SOC for different combinations of selected land use types and selected depths

Depth	Selected land use types				
	Dense forest	Plantation	Degraded vegetation	Agriculture	Agroforestry
0–20 cm	0.82 (< 0.01)	0.96 (< 0.01)	0.75 (0.01)	0.99 (< 0.01)	0.93 (< 0.01)
20–40 cm	0.91 (< 0.01)	0.86 (< 0.01)	0.91 (< 0.01)	0.93 (< 0.01)	0.17 (0.63)

**Table 8.4** Correlation between selected parameters for physical and chemical properties of soil

Depth		BD	pH	EC	STN	STP	STK	SOC
0–20 cm	BD	1	−0.76*	−0.78*	0.52*	0.65*	0.37*	0.68*
	pH		1	0.82*	−0.18	−0.43*	−0.44*	−0.39*
	EC			1	−0.16	−0.32*	−0.24	−0.39*
	STN				1	0.67*	0.272	0.79*
	STP					1	0.42*	0.67*
	STK						1	0.29*
	SOC							1
20–40 cm	BD	1	−0.13	−0.66*	0.33*	−0.04	0.30*	0.23
	pH		1	0.21	−0.19	0.12	−0.50*	−0.08
	EC			1	−0.23	0.13	−0.25	−0.12
	STN				1	0.34*	0.26	0.65*
	STP					1	−0.11	0.46*
	STK						1	0.26
	SOC							1

\* indicates the significance ( $P < 0.05$ )

found to be negatively correlated. STN is found to have a positive correlation with STP (0.34) and SOC (0.65). STP and SOC (0.46) also show a positive correlation.

### 8.3.11 Dependence of STN, STP, STK, SOC, EC, pH, Bulk Density, Silt, Sand, and Clay on the Land Use Types and Depth

The regression of nitrogen content on land use and depth (Table 8.5) shows that when compared to DF, the STN is lesser by 36.26, 41.47, 56.17, and 1.27 kg/ha for P, DV, AG, and AF. Further it is lower by 30.89 kg/ha in depth of 20–40 cm when compared to the depth 0–20 cm. The regression of STP on land use and depth shows that when compared to DF, the phosphorus content is less by 2.03, 3.44, 3.81, and 0.70 kg/ha for P, DV, AG, and AF. Further it is lower by 3.25 kg/ha for depth 20–40 cm when compared to depth 0–20 cm. In case of STK, it is higher in all land use types when compared to DF except for the AF (Table 8.5). Further it is higher by 37.88 kg/ha and significant in the depth of 20–40 cm when compared to the depth of 0–20 cm. The regression of SOC on land use and depth shows that when compared to DF, the carbon content is lesser by 0.12, 0.13, 0.21, and 0.12 g/kg for P, DV, AG, and AF. Further it is lower by 0.35 g/kg in the depth of 20–40 cm when compared to the depth of 0–20 cm. The regression of EC and pH shows the various trends when compared to DF (Table 8.5). The EC concentration is lower only in DV (not significant) and in the depth of 20–40 cm but significant. While pH is found to be lower by 0.05 in P, it is not significantly different from the reference category DF. Further pH conc. is higher by 0.38 in the depth of 20–40 cm when compared to the depth of 0–20 cm (Table 8.5).



The regression on soil physical properties like bulk density and soil texture are carried out and compared with DF and depth (0–20 cm). The bulk density of P, AG, AF, and DV is found to be lower and significantly different from that of DF. However, it is found to be higher by 0.04 g/cc in the depth of 20–40 cm when compared to the depth of 0–20 cm. The regression on soil texture shows a different trend when compared to dense forest. The sand component of soil texture is lower in percentage in AG (−8.29) and AF (−2.91), while the clay content is lower in plantation and degraded vegetation. However, silt content of soil texture shows lower trend in all types of land use when compared to dense forest (Table 8.5).

### 8.3.12 SOC, STN, STP, and STK Concentration of the Soil

The concentration of these parameters (SOC, STN, STP, and STK) decreased with soil depth for all land use except in case of STP for DF and AG. Among all the selected land use types, the highest concentrations of nutrient were observed in the DF followed by AF in the depth of 0–20 cm. The concentration of SOC (6.59 Mg/ha), STN (2.28 Mg/ha), STP (0.018 Mg/ha), and STK (0.42 Mg/ha) was observed in DF, showing highest concentration among the all land uses at the top soil layer. However, the lowest concentration pattern of above-said parameters was found in AG land use practices (Table 8.6). Similar demonstration has been done by several workers (Thakur et al. 2014, 2018; Bijalwan et al. 2017; Kumar et al. 2021; Thakur et al. 2019b, 2020).

**Table 8.6** Total SOC, STN, STP, STK

Land use	SOC(Mg/ha)	STN(Mg/ha)	STP (Mg/ha)	STK(Mg/ha)
<i>Soil depth 0–20 cm</i>				
DF	6.54	2.28	0.018	0.42
P	3.8	2.05	0.017	0.38
DV	5.03	1.92	0.011	0.26
AG	3.37	1.52	0.010	0.25
AF	4.60	2.17	0.017	0.40
<i>Soil depth 20–40 m</i>				
DF	3.16	2.17	0.011	0.38
P	2.45	1.76	0.009	0.34
DV	2.51	1.74	0.012	0.21
AG	2.20	1.50	0.0128	0.23
AF	2.92	1.94	0.0122	0.36

## 8.4 Conclusion

The conclusions of this study showed that transformation of natural ecosystems into accomplished agroecosystems bring about significant changes in the quality of soil resources. The physio-chemical properties of soils change by cultivation practices, biological interference, or anthropogenic factors. These manmade changes not only are limited to surface soil but also show remarkable changes under subsurface of soil. So it is concluded human mismanagement leads to deterioration of quality and productivity of soil. Therefore, in order to improve fertility and productivity of soil, the following measures have been suggested:

1. Incorporation of existing cultural practices with recent appropriate technology like integrated farming, agroforestry, and silvi-pasture.
2. Strengthening fertilizer management through INM (integrated nutrient management), like composting, green manure, etc.
3. Adequate use of natural resources at sustainable basis to stop further soil degradation.

Finally, surrounding areas of AABR should be restricted to anthropogenic approach or have certain degree of limitation to improve soil health.

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