

Impact of land use/land cover on soil carbon and nitrogen fractions in north-eastern part of India

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Land use/land cover (LULC) plays a pivotal role in maintaining the carbon (C) and nitrogen (N) balance in the ecosystem. It is also important for controlling soil organic carbon (SOC) levels by affecting the quantity and quality of below- and above-ground litter inputs and subsequent decomposition. The aim of the present study was to understand the effect of LULC on the C and N fractions and their stocks in the Eastern Himalayan floodplain. The study was conducted at the Pundibari campus of Uttar Banga Krishi Viswavidyalaya, Cooch Behar, West Bengal, India, hosting four kinds of land uses – agricultural croplands, grasslands, plantation croplands and human-interfered lands. The soils were acidic (pH 5.13–5.68) irrespective of the LULC type and low in bulk density (1.02–1.27 g/cm³). Estimation of several forms of C and N, viz. SOC, total C, available N, ammoniacal N, nitrate N, total N, C stock, N stock, etc., indicated variations in these forms under different LULC types. Significant variations ($P < 0.05$) were found for SOC and ammoniacal N content in different LULC types. Both mean C and N stocks were found highest in grassland soils (18.91 and 2.64 t ha⁻¹ respectively), followed by plantation croplands (17.24 and 2.41 t ha⁻¹ respectively).

Keywords: Carbon and nitrogen stock, flood plain, land use/land cover, resource map, soil quality.

SOIL organic carbon (SOC) and nitrogen (N) are closely related and are important indicators of soil quality for their favourable effects on physical, chemical and biological properties, which influence terrestrial ecosystem productivity¹. The SOC pool is the largest carbon pool in terrestrial ecosystems. The soil can store twice as much carbon present in the atmosphere and three times that present in vegetation, and also act as a storehouse for several plant nutrients^{2–4}. Conserving this SOC is important for global climate change as the depletion of SOC is closely associated with the increase in atmospheric concentration of carbon dioxide (CO₂). The soil not only acts as the largest reservoir of C but is also a significant sink of N and supplies the same for plant uptake. Thus, soil N stock and its availability

in chemical forms like ammonium (NH₄⁺) and nitrate (NO₃⁻) directly influence world food productivity.

SOC and N contents may decrease or increase depending on various factors, including land use/land cover (LULC) types. Different LULC types and their natural and anthropogenic changes over time significantly impact SOC and N storage, loss and sequestration potential. LULC change is considered the second greatest cause of carbon emissions after the combustion of fossil fuels. Conversion of natural vegetation to cultivation results in the alternation of SOC and soil N status. Forest soil stores about 40% of the total organic carbon (TOC) in the terrestrial ecosystem⁵. Conversion of these natural forests to agricultural land has decreased SOC by 52%, 41% and 31% in temperate, tropical and boreal regions respectively⁶. Conversion of grasslands to croplands has destabilized SOC and induced about 50% loss of SOC globally. Organic matter input in agricultural soils, as a common farmer's practice, also increases carbon sequestration⁷. However, this carbon stored in the managed land cover depends on management practices adopted for cultivation⁸.

Shifting of LULC drives climate change and has a major impact on the global geochemical cycle, which declines the net productivity. Further, the expansion of agricultural practices into natural forests has resulted in the degradation of both soil and plants⁹. Such degradation can be attributed to climatic conditions, reduced inputs of organic matter, increased rate of decomposition of crop residues, and decreased physical protection due to tillage operations.

Quantifying temporal and spatial variation of LULC changes is an important indicator for understanding the dynamic changes occurring in the natural environment, which include its degradation under changing climatic conditions and global population pressure¹. Natural forests, forest plantation, agro-forestry, grasslands and cultivated lands are the major land cover types that store substantial amounts of SOC and total nitrogen (TN)¹⁰. Significant losses of soil organic matter (SOM) and TN occur in agricultural soil in comparison to original forest soil. On the contrary, organic matter input in agricultural land through natural or management practices influences SOC content¹¹.

In tropical soils, the restoration and maintenance of soil quality by SOC and N management is important. Dry tropical

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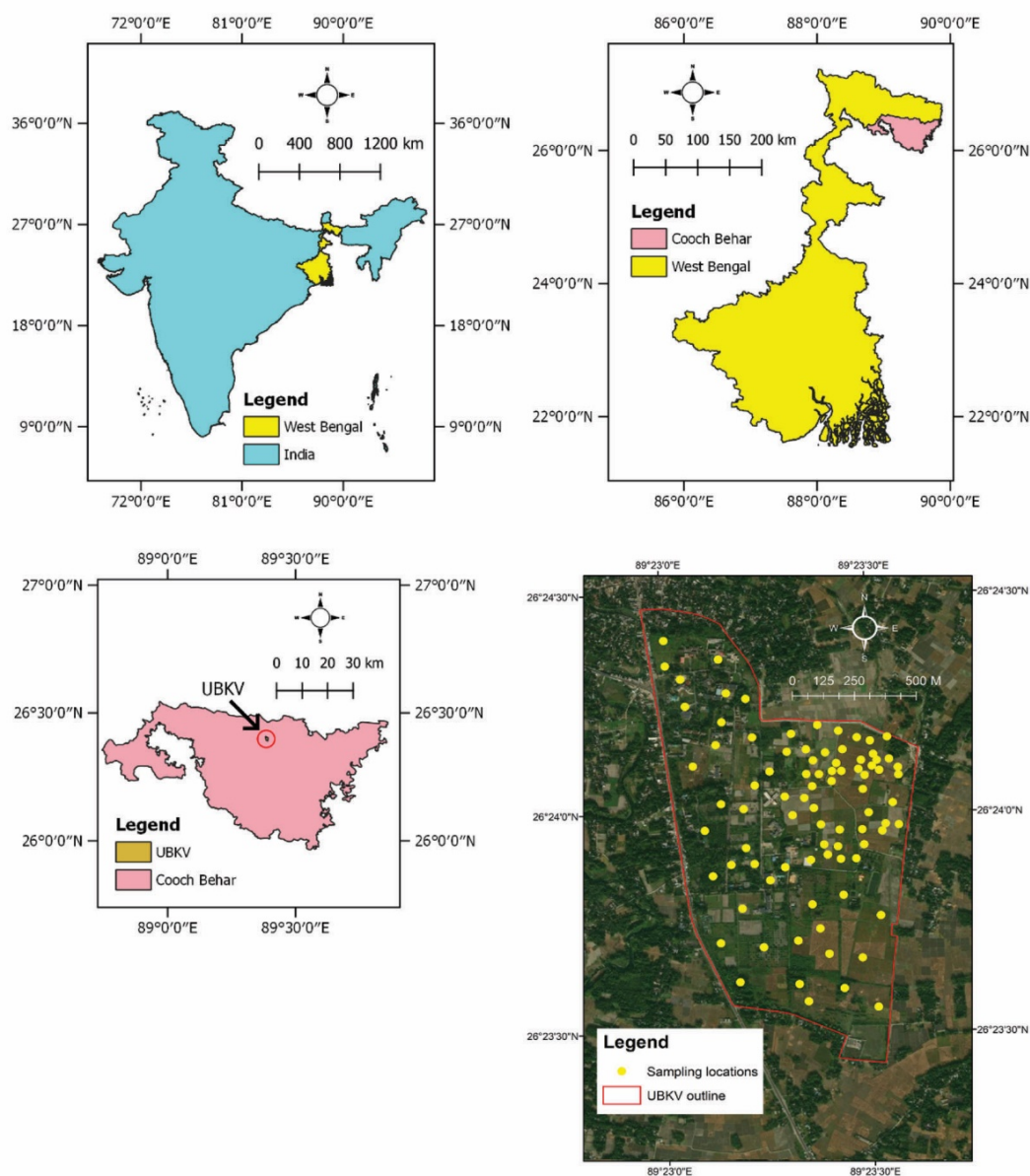


Figure 1. Location of the study area.

forests once covered half of the tropics, but now they are gradually being converted to grasslands and croplands due to forest harvesting for anthropogenic reasons and climate change. Such changes result in significant alteration in carbon and nitrogen cycling¹². Plantation forests or social forests implanted through reforestation are being considered to overcome such depletion as the planted perennial trees can store large quantities of atmospheric CO₂ into the tree biomass for a long period of time¹³.

Therefore, the knowledge of SOC and N is a prerequisite for sustainable soil management programmes. Several studies on the effect of LULC types on SOC and N stocks and availability are available in the literature. However, such studies are lacking in the floodplain soils of the Eastern Himalayas. For the present study, the Pundibari campus of

Uttar Banga Krishi Viswavidyalaya, Cooch Behar, West Bengal, India, located in the Eastern Himalayan floodplain, which holds a number of LULC types, including agricultural croplands, plantation croplands, grasslands and human-interfered areas was selected with an aim to determine the status of SOC, TC and forms of N in different LULC types as a case study.

Materials and methods

Location and description of the study area

This study was conducted at the campus of Uttar Banga Krishi Viswavidyalaya (lat. 26°24'27"N and long. 89°22'59"E; altitude 43 m amsl) (Figure 1), located 12 km away from

the Cooch Behar district, West Bengal. It is within the terai agro-climatic zone in the Himalayan floodplain in the northern part of West Bengal. The prevailing climatic condition of the study site is humid subtropical with mean annual precipitation of 2500–3500 mm, the bulk of which is received in the pre-monsoon and monsoon (June–September) seasons. Considerable variations were observed in the seasonal and diurnal temperatures in the study area. The mean night and day average temperatures varied from 20.2°C to 36.5°C in summer and 10.4°C to 24.1°C in winter season. The soil in this region is Typic Fluvaquent, light to medium in texture, characterized by sandy loam to silty loam with good drainage facility. The university campus is spread over 300 acres of land and holds various land use types like agricultural croplands, grasslands, plantation croplands and human-interfered lands. Generally, a rice-based cropping system is followed in the agricultural fields of the area. The major crops include rice (*Oryza sativa*), wheat (*Triticum aestivum*), jute (*Corchorus olitorius/Corchorus capsularis*), maize (*Zea mays*), mustard (*Sinapis alba/Brassica nigra*) and winter vegetables (*Solanum tuberosum*, *Solanum melongena*, *Brassica oleracea* var. *capitata* and *Brassica oleracea* var. *botrytis*). The plantation lands mostly consist of orchards and plantation forests. The dominant plants in the forests and orchards are *Mangifera indica*, *Tectona grandis*, *Albizia lebeck*, *Dalbergia sissoo*, *Gmelina arborea*, *Shorea robusta*, *Gmelina arborea*, *Manilkara zapota*, *Musa* sp., *Litchi chinesisnsis* and *Spathodea campanulate*. The grasslands are mostly covered by *Cyperus rotundus* and *Cynodon dactylon*. The human-interfered lands consist of several infrastructural facilities typical to an educational institution, like college buildings, offices, farm infrastructure and residential areas.

Collection of soil samples

Before collecting soil samples, the LULC pattern of the study area was delineated using Google Earth Pro and ground observations. The soil samples (0–15 cm) were collected between mid-March and mid-April prior to the onset of monsoon in 2020. Totally, 85 soil samples (0–20 cm soil depth) were collected from different land use types. The sampling points were selected in such a way that they were uniformly scattered over the total area of each LULC type. The locations of the sampling points were identified using the My Location mobile application. Sampling was done with the help of a spade. Small portions of soil samples were stored in a refrigerator to estimate NH_4^+ and NO_3^- -N, while the rest of the samples were air-dried at 35°C to constant weight and taken for further processing. The air-dried samples were ground and passed through a 2 mm sieve to estimate the selected soil properties and SOC. Undisturbed soil samples were collected using a core sampler from the same depth for bulk density determination. Among the 85 samples considered, 44 were from agricultural croplands,

20 from grasslands, 13 from plantation croplands and the rest eight were from human-interfered lands. The coverage of each LULC type was considered for the number of samples collected.

Laboratory analysis

The pH and EC of soil samples were measured using 1 : 2.5 soil–water suspension. The dry bulk density (BD) of the soil samples was measured by the core sampling method¹⁴. The available N content in the soil was measured by the alkaline permanganate method¹⁵.

The SOC content of the soil samples was measured by the wet oxidation method¹⁶. The lability index (LI) and recalcitrant index (RI) of SOC in the samples were measured by the modified Walkley and Black method¹⁷. This is similar to the conventional Walkley and Black method, except three separate amounts (5, 10 and 20 ml) of H_2SO_4 are used instead of a single amount (20 ml). The soil carbon stock was calculated using the following equation¹⁸:

$$\text{SOC stock (kg m}^{-2}\text{)} = \text{SOC (\%)} \\ \times \text{bulk density (kg m}^{-3}\text{)} \times \text{soil depth (m)} \times (1 - \text{Si}),$$

where Si is the volume of fraction of coarse fragments >2 mm. As all of the samples were passed through a 2 mm sieve and fractions of the coarse fragments were negligible, the (1 – Si) part was excluded in the calculation. SOC stock was expressed in tonnes per hectare by a conversion factor of 10.

The NH_4^+ and NO_3^- -N in the soil were determined using the steam distillation method¹⁹. The soil samples were steam-distilled using MgO to estimate the NH_4^+ -N and further distilled using Devadra's alloy to estimate the NO_3^- -N in the soil. The total N content in the soil samples was estimated using the micro-Kjeldahl method. The soil total nitrogen stock was calculated using the equation as that for SOC.

$$\text{TN stock (kg m}^{-2}\text{)} = \text{Total N (\%)} \\ \times \text{bulk density (kg m}^{-3}\text{)} \times \text{depth (m)} \times (1 - \text{Si}).$$

Statistical analysis and map preparation

The descriptive statistical analysis of the data was done using SPSS for Windows (IBM SPSS, ver. 17). Analysis of variance (ANOVA) at a 95% confidence level was performed taking sampling sites as replicates (random effects) and land use types as treatments (fixed effects). Tukey HSD post-hoc test was performed to indicate significant differences ($P < 0.05$) between the means using Statistical Analysis System, version 9.2 (SAS Institute Inc, North Carolina, USA). Box and whisker plot was used to compare the variation of data within and between LULC types for soil C and N stock by R (version 4.1.0) statistical software.

Table 1. Physico-chemical properties of the soil of different land use/land cover (LULC) types (mean \pm SD)

Soil properties	Agricultural croplands ($n = 44$)	Grasslands ($n = 20$)	Plantation croplands ($n = 13$)	Human-interfered lands ($n = 8$)
pH	5.15 (± 0.44) ^b	5.68 (± 0.51) ^a	5.13 (± 0.21) ^b	5.26 (± 0.25) ^b
EC (mS/cm)	0.41 (± 0.11) ^b	0.62 (± 0.29) ^a	0.43 (± 0.06) ^{ab}	0.42 (± 0.16) ^{ab}
BD (g/cm ³)	1.18 (± 0.05) ^b	1.22 (± 0.01) ^{ab}	1.04 (± 0.01) ^c	1.25 (± 0.01) ^a

EC, Electrical conductivity; BD, Bulk density; n , Number of samples. Superscripts in the same row indicate similarities and differences between compared groups by the Tukey HSD test at $P \leq 0.05$.

Open source QGIS (Quantum GIS) with IDW (inverse distance weightage) interpolation was used to prepare the carbon and nitrogen maps in different LULC types of the study area.

Results and discussion

Soil properties

The measured soil properties presented in Table 1 indicate variations of pH, EC and BD in soils of different LULC types. The pH of the soils was acidic, with the mean value ranging between 5.13 in plantation croplands and 5.68 in grassland soils. Grassland soil pH differed significantly ($P < 0.05$) from the soils of other LULC types. Low pH in the plantation cropland soil (5.13) may be attributed to huge leaf-fall around the year and the continuous decomposition of leaves, producing larger amounts of organic acids and CO₂ that cause subsequent decrease in the soil pH. The more acidic nature of the agricultural cropland soil than that of the grasslands and human-interfered lands may also be attributed to the use of acid-forming ammonia and amide-based nitrogenous fertilizers such as DAP ((NH₄)₂HPO₄) and urea (CO(NH₂)₂) and organic matter decomposition²⁰.

The mean EC of the soils of agricultural croplands and grasslands differed significantly ($P < 0.05$) from those of other LULC types. The relatively lower EC values in the cultivated cropland soil may be related to the leaching of exchangeable bases and soluble salts due to soil erosion from continuous cultivation²¹. Such erosion, as well as infiltration of water, is less in the grassland soil.

Significant ($P < 0.05$) differences were noticed in the mean BD of the different LULC types. The soil of human-interfered lands had the highest mean bulk density (1.25 g/cm³), followed by grasslands (1.22 g/cm³). The soil under grasslands for an extensive period is susceptible to compaction and increase in strength, leading to an increase in BD.

Soil organic carbon and soil carbon stock

Mean SOC content significantly ($P < 0.05$) differed in the soils of plantation croplands and human-interfered lands, but no significant difference was found between the soils of agricultural croplands and grasslands. Also, no significant differences were found in the soils of agricultural croplands

and grasslands with respect to the soils of plantation croplands, and human interfered lands (Table 2). The SOC content varied greatly within each LULC type. In the agricultural croplands, it varied between 0.42% and 1.05% (CV 16.45%). Such variations in agricultural soil may be attributed to manure application and various crop management practices. The highest average SOC content was found in the soil of plantation croplands (0.79%), followed by grasslands (0.77%), agricultural croplands (0.73%) and lowest in human-interfered lands (0.68%). The relatively higher SOC content in the grasslands and plantation croplands may be due to the generation of large amount of litter residues. A major portion of this litter is returned to the soil and forms soil organic matter by microbial decomposition²². Higher microbial activity in undisturbed grassland and plantation cropland soils is also conducive to atmospheric carbon fixation, thereby increasing its SOC content²³. When compared to plantation crops, the SOC content of agricultural croplands, grasslands and human-interfered lands was lower by 7.59%, 2.53% and 13.92% respectively. Therefore, SOC content in the soils followed the order: plantation croplands > grasslands > agricultural croplands > human-interfered lands. These results are consistent with earlier findings²⁴. Relative higher SOC content in the forests and grasslands was also reported in the soils of Mizoram, North East India²⁵.

SOC stock in soils of four LULC types of the study area did not differ significantly ($P < 0.05$) (Figure 2). Carbon stock in the study area of the university campus varied between 10.06 and 24.14 t ha⁻¹, irrespective of the LULC type (Figure 3). However, the mean carbon stock was highest in grassland soil (18.91 t ha⁻¹), followed by agricultural cropland soil (17.24 t ha⁻¹) and the least in plantation cropland soil (16.47 t ha⁻¹). When compared to the soil of the grasslands, C-stock in the soils of the agricultural croplands, plantation croplands, and human-interfered lands was lower by 8.83%, 12.9% and 9.68% respectively. The soil of grasslands remains untilled most of the time, resulting in less loss of soil carbon storage. The distribution of C-stock was positively skewed in grasslands and plantation croplands in the box and whisker plot (Figure 2), which confirms the tendency of storing more carbon in undisturbed grasslands and plantation croplands. It is skewed in the negative direction in human-interfered lands, indicating the tendency of soil carbon loss due to human activities. The more symmetric distribution in the plot of agricultural croplands indicates that the loss of carbon by disturbing

Table 2. Descriptive statistics of soil carbon status in different LULC types

SOC and indices	Descriptive parameters	Agricultural croplands (n = 44)	Grasslands (n = 20)	Plantation croplands (n = 13)	Human-interfered lands (n = 8)
SOC (%)	Max	1.05	0.97	0.96	0.77
	Min	0.42	0.44	0.58	0.63
	Mean	0.73 ^{ab}	0.77 ^{ab}	0.79 ^a	0.68 ^b
	SD	0.12	0.12	0.11	0.06
	CV (%)	16.45	15.14	13.51	8.79
	SEm	0.02	0.03	0.03	0.02
LI	Max	2.20	2.04	2.09	2.34
	Min	1.63	1.38	1.83	2.1
	Mean	1.99 ^b	1.78 ^a	1.97 ^b	2.17 ^c
	SD	0.14	0.17	0.07	0.08
	CV (%)	7.28	9.39	3.69	3.56
	SEm	1.10	2.10	1.02	1.26
RI	Max	0.85	1.52	0.67	0.34
	Min	0.23	0.33	0.43	0.25
	Mean	0.44 ^a	0.78 ^b	0.50 ^a	0.31 ^a
	SD	0.18	0.30	0.07	0.03
	CV (%)	40.35	39.29	15.03	10.33
	SEm	0.03	0.07	0.02	0.01

SOC, Soil organic carbon; LI, Lability index; RI, Recalcitrant index; n, Number of samples; Max, Maximum; Min, Minimum; SD, Standard deviation; CV (%), Coefficient of variation; SEm, Standard error of mean. Superscripts in the same row indicate similarities and differences between compared groups by the Tukey HSD test at $P \leq 0.05$.

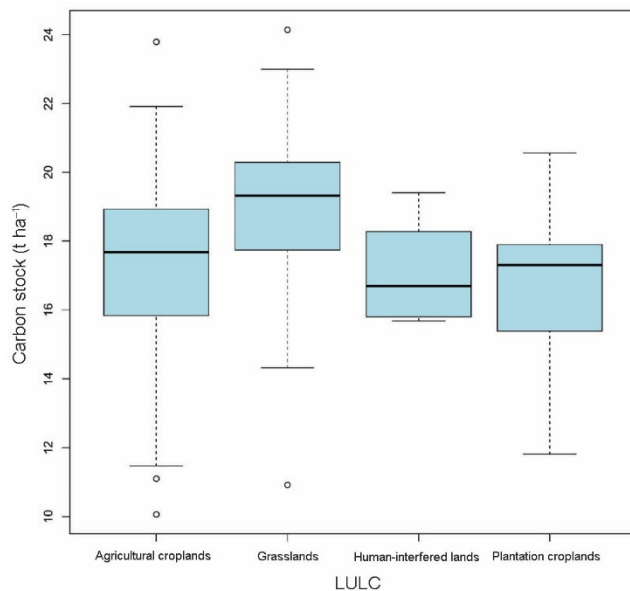


Figure 2. Soil organic carbon stock in different land use/land cover (LULC) types.

the soil with tillage operations in different directions may also be replenished by manure application and *in situ* dumping of crop residues in several crop cycles.

Lability indices and recalcitrant indices of the soil

The mean LI values were found to be the highest in soils of human-interfered lands (2.17), followed by agricultural croplands (1.99), plantation croplands (1.97) and lowest in

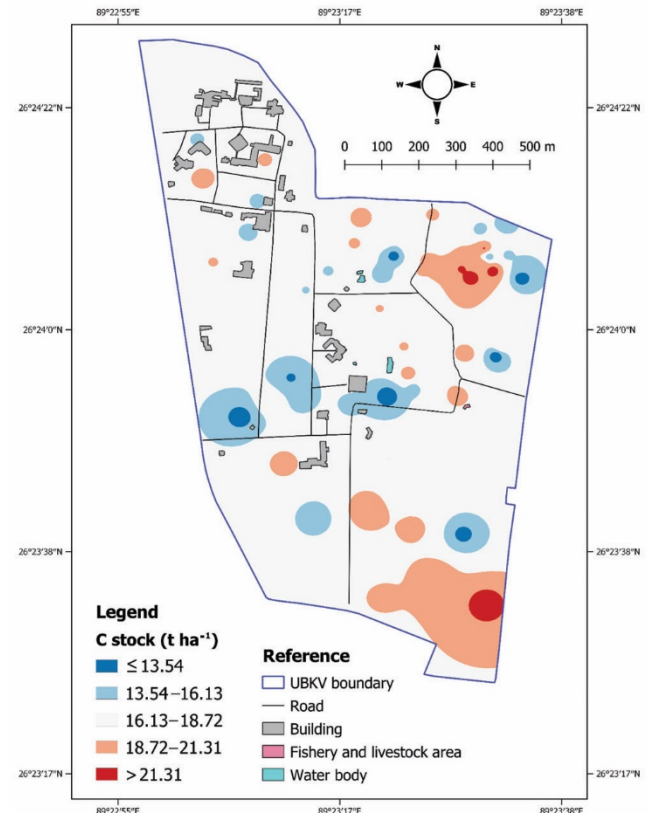


Figure 3. Distribution of carbon stock in the study area.

the soil of grasslands (1.78) (Table 2). No significant difference in LI was found in the soils of agricultural croplands and plantation croplands. Within the LULC types, variation

Table 3. Descriptive statistics of soil nitrogen status in different LULC types

Nitrogen forms	Descriptive parameters	Agricultural croplands (n = 44)	Grasslands (n = 20)	Plantation croplands (n = 13)	Human-interfered lands (n = 8)
Available-N (mg kg ⁻¹)	Max	130.20	121.80	100.80	77.00
	Min	18.20	30.80	46.20	46.20
	Mean	71.91 ^a	67.20 ^a	67.52 ^a	63.00 ^a
	SD	23.62	21.32	16.79	9.87
	CV (%)	32.84	31.73	24.87	15.67
	SEm	3.56	4.77	4.66	3.49
NH ₄ -N (mg kg ⁻¹)	Max	82.60	97.60	69.47	58.67
	Min	41.40	49.67	41.4	41.4
	Mean	62.54 ^a	66.34 ^a	61.14 ^a	49.23 ^b
	SD	8.41	10.09	7.42	6.05
	CV (%)	13.45	15.20	12.13	12.30
	SEm	1.27	2.25	2.06	2.14
NO ₃ -N (mg kg ⁻¹)	Max	57.27	64.13	29.20	13.00
	Min	2.67	4.13	2.90	4.33
	Mean	16.37 ^b	21.02 ^b	16.03 ^b	9.89 ^b
	SD	14.02	15.23	8.77	3.61
	CV (%)	87.18	72.48	54.69	36.49
	SEm	2.08	3.41	2.43	1.28
Total-N (%)	Max	0.27	0.27	0.27	0.12
	Min	0.07	0.06	0.09	0.03
	Mean	0.10 ^b	0.11 ^b	0.12 ^b	0.08 ^b
	SD	0.03	0.05	0.05	0.03
	CV (%)	31.49	42.79	42.59	30.84
	SEm	0.01	0.01	0.01	0.01

Superscripts in the same row indicate similarities and differences between compared groups by the Tukey HSD test at $P \leq 0.05$.

in LI was also less (CV 3.56%–7.28%). The mean RI was found to be highest in the soils of grasslands (0.78), followed by plantation lands (0.50), agricultural croplands (0.44) and lowest in the soil of human-interfered lands (0.31) (Table 2). No significant difference in RI was observed in the soils of agricultural croplands, plantation croplands and human-interfered lands. Higher LI in the soils of human-interfered lands and agricultural lands may be due to increased pedoturbation of the soil, which refers to the higher labile or available carbon in the soils of human-interfered lands and agricultural lands than those of plantation lands and grasslands. Again, the higher RI value in the soils of grasslands and plantation croplands implies that the turnover time of C increases in these soils more than that of the other soils, which indicates that mineral-associated carbon is more in these soils. Thus carbon sequestration is more in grasslands, followed by plantation croplands, agricultural croplands and human-interfered lands²⁶.

Available, ammoniacal, nitrate and total nitrogen and nitrogen stock

Available N content in these soils did not differ significantly ($P < 0.05$) for different LULC types (Table 3). However, it varied between 18.20 and 130.20 mg kg⁻¹. Both the lowest and highest values were observed in the agricultural cropland soil. This may be attributed to the application of nitrogenous fertilizers in different doses for various crops grown. The higher content of available nitrogen in the soil of

agricultural croplands might also be attributed to increased N-fertilization and consequent release of available N in the form of ammonia and nitrate. The mean available N content in these soils (63–71.91 mg kg⁻¹) was generally lower due to intense leaching by heavy rainfall in the light-textured soil of this zone. Higher variability (CV > 25%) of available N in these soils is also attributed to the different rates of external N application and leaching in different LULC types except human-interfered lands. The mean values of NH₄⁺-N and NO₃⁻-N were also not significantly different ($P < 0.05$) in the soils of different LULC types. Grassland soils had the highest NH₄⁺-N (66.34 mg kg⁻¹) and NO₃⁻-N (21.02 mg kg⁻¹), while human-interfered land soils had the lowest (49.23 and 9.89 mg kg⁻¹ respectively). Compared to the grassland soils, NH₄⁺-N content in agricultural croplands, plantation croplands and human-interfered lands had decreased by 5.73%, 7.84% and 25.79% respectively, whereas NO₃⁻-N content had decreased by 22.12%, 23.74% and 52.95% respectively. The variability of NH₄⁺-N was also low (<15%) within the LULC types. Soils in grasslands and plantation croplands remain covered most of the year, thus acting like an organic mulch, which does not allow much increase in soil temperature. Such conditions sometimes hinder microbial activity and may result in a lower rate of transformation of NH₄⁺-N to NO₃⁻-N. The higher NH₄⁺-N content in agricultural croplands may be due to the application of high doses of amide and ammoniacal nitrogenous fertilizers, namely urea and DAP for all the crops grown during the cropping sequences throughout the year. Large

variation (CV 87.18%) of NO_3^- -N in agricultural croplands and other land use types may be due to the differences in the application of nitrogenous fertilizers, variation in N mineralization rate and leaching. Nitrate-N content in the soil is also influenced by environmental factors such as tem-

perature, irrigation, rainfall, etc.²⁷. Mean total nitrogen content was found to be the highest in the soil of the plantation crops (0.12%), while the minimum value was noted in human interfered lands (0.08%). Similar observations have been reported by earlier studies¹⁰.

Nitrogen stock was also not significantly different ($P < 0.05$) in different LULC types (Figure 4). The extrapolated spatial distribution of nitrogen stock in the university campus varied between 0.69 and 6.94 t ha^{-1} (Figure 5). The difference between the N-stock of agricultural cropland and plantation cropland soils (0.026 t ha^{-1}) is not as high as that between the soils of grasslands and human-interfered lands. When compared to the grassland soil, the N stock in the soils of agricultural croplands, plantation croplands, and human-interfered lands had decreased by 8.71%, 9.85% and 21.97% respectively. Wide variation in N stock was observed for each LULC type (Figure 4). The variation of N stock in agricultural croplands was 34.51%, while in grasslands, plantation croplands and human-interfered lands, it varied by 42.76%, 41.76% and 30.36% respectively. The distribution of N stock in agricultural croplands, grasslands and plantation croplands was skewed positively, which may be due to the application of nitrogenous fertilizers as well as litter decomposition for a long time. Considerable root growth and subsequent decomposition of the dead roots may be responsible for higher N stock in the grasslands. In agricultural croplands, the source of such N stock is the application of N-fertilizers for different crops grown. Further, the natural addition of litter and dead roots increases SOC content, water retention capacity, structural stability and microclimatic conditions, which are beneficial for proliferated microbial growth, and subsequently increase N stock in the soil²⁷.

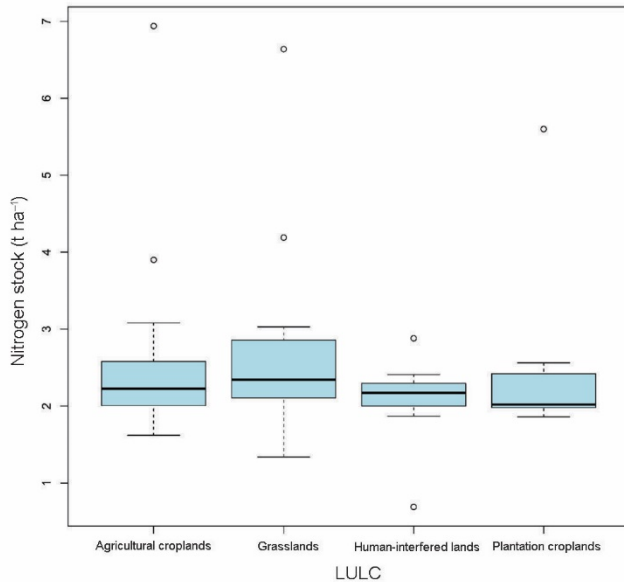


Figure 4. Total nitrogen stock in different land use/land cover (LULC) types.

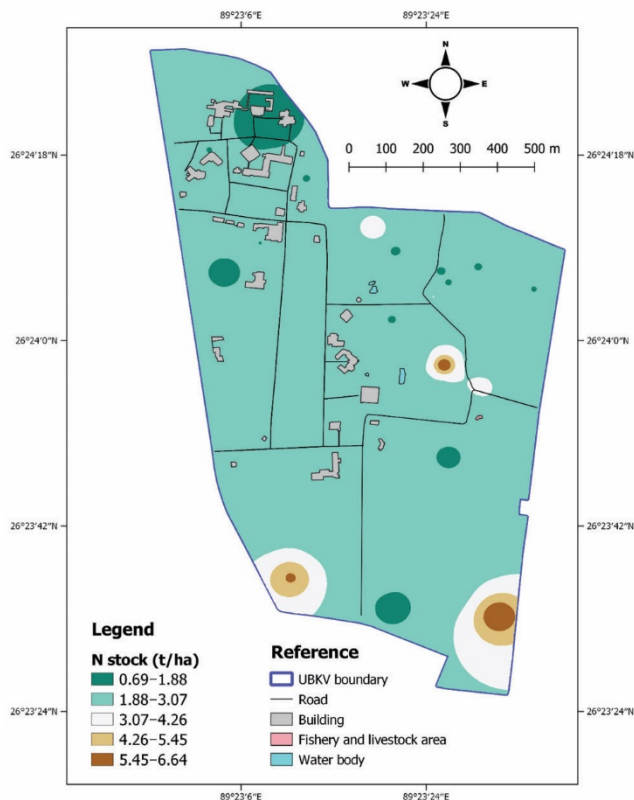


Figure 5. Distribution of total nitrogen stock in the study area.

Conclusion

The distribution of soil carbon and nitrogen fractions and their stocks was found to be affected by various LULC types in the study area. Human-interfered lands were less fertile than the other three LULC types. Grasslands were found to be rich in carbon and nitrogen status, followed by plantation croplands. The loss of SOC from the agricultural croplands due to conventional farming practices is likely to increase carbon emission to the environment and loss of nitrogen through leaching in the form of NO_3^- and NH_4^+ volatilization. In this high-rainfall area, leaching of NO_3^- may also contribute to denitrification loss and emission of N_2O to the atmosphere. LULC type is vital to both carbon and nitrogen sequestration and to combat global warming. Conversion of plantation croplands and grasslands into agricultural croplands to meet the food demand for an increasing population causes a decline in carbon and nitrogen status. However, several land use and management practices, including conservation agriculture, agroforestry, etc., may help increase the carbon and nitrogen status in intensive farming systems.

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