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Estimating soil nitrogen in different land uses and landscape positions in North-western Himalayan regions

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Abstract
The variability of soil total nitrogen is greatly affected by land use pattern, plays an important role in agriculture and the environment especially with regard to soil fertility and soil quality. Little research has been done that address the patterns of total soil nitrogen under different land uses. We conducted a study to evaluate total soil nitrogen under different land uses. The total soil nitrogen was found highest in horticulture followed by agriculture, forest and fallow land use. On average, N concentration declined by per meter of soil depth compared with all the land uses. However, when land-use evaluated each soil layer independently, the total N declined in the top layer. The soil nitrogen forms were positively correlated, with correlation coefficients (R^2) between 0.504 and 0.725.

Keywords: Land use, total soil nitrogen, nitrate nitrogen

1. Introduction

Climate change, nitrogen deposition, rising carbon dioxide concentrations, and related implications on land-use changes need a trade-off between direct human requirements and ecosystem protection against inappropriate land use (Fu *et al*., 2015) [1]. SOC and N are critical for soil fertility, food production, and soil health. Changes in land use have significant impacts on SOC and N storage, losses, sequestration rate, and potential. Soil organic carbon and nitrogen storage, losses, and vegetation restoration factors must be studied (Lorenz *et al*., 2019) [2]. Changes in land use, mainly abandoned agriculture, may rapidly affect soil quality. Soil aggregate stability, soil, and water conservation may benefit from the "National Mission for sustaining the Himalayan agriculture ecosystem." Soil nitrogen has multiple patterns due to varied bioavailability, and each pattern's cycling mechanism is unique (Kanianska 2016) [3]. And the effects of adding soil nitrogen vary depending on the system. Soil nitrogen conditions and soil nitrogen cycle parameters must be studied. Many researchers have studied soils' carbon and nitrogen content in various land uses and landscapes globally. Due to traditional tillage, soil organic matter and total nitrogen levels in agricultural soils are much lower than in undisturbed forest soils. Land-use changes may affect land coverage, carbon and nitrogen stocks, crop residue biochemistry, and quantity (Abera *et al*., 2010) [4]. Soil formation and erosion are affected by the landscape location in small watersheds. Soil nitrogen levels vary throughout a hill slope, affecting plant growth, litter generation, and decomposition patterns. Land use influences various environmental factors that affect nutrient export.

Changes in land use may alter soil ecosystem material cycle processes, affecting soil transport and distribution from the surface to various depths and the distribution of soil properties. Human activity has influenced ecosystems in many ways. In the Northwestern Himalayan regions, increasing population pressure and extensive agriculture have resulted in environmental fragmentation and considerable soil erosion (Wakeel *et al*., 2005) [5]. Natural forests and farming were the primary land use categories in, with natural forests accounting for 46% of the total. Due to population growth, most natural forests were transformed into farmland. The Indian government has started several nationwide conservation programs focusing on vegetation and land recovery to prevent future ecological degradation. The national mission for sustaining Himalayan agriculture ecosystem initiative was established to reduce soil erosion, enhance land quality, and encourage the broad conversion of sloping agriculture to other uses (Owais *et al*., 2019) [6]. Soil nitrogen concentrations might help evaluate environmental restoration. The objectives of this study were to assess the impacts of land use and slope location on total nitrogen, nitrate-nitrogen, and ammonium nitrogen concentrations in soil and to examine the relationship between soil physicochemical qualities and nitrogen patterns

2. Materials and Methods

2.1 Outline of the study area

The study area is located in the temperate Himalaya of the North-western part of India between the latitude 34º12′ to 34º20′ North latitude and 74º20′ to 74 º 34′ East longitudes with an elevation of 1584 meters and an area of 3353 km^2 (Table 1). The region has high, mid and low altitudes consisting of mountains, hills and valleys. The part has an annual rainfall of 1270 mm and an average temperature of 24° C. The highland is separated by a wide valley stretched by the river Jhelum in the eastern and western directions. In the north western part is the Jhelum and in the southern part is Pakistan. The area's topography is steep sloppy to moderately sloppy, with some plain regions.

Table 1: Site characteristics of study area

Landuse	Latitude & Longitude	Elevation (amsl)	Topography	Slope (%)	Depth of soil (cm)
Agriculture	34°10'19 " N 74°31' 02 " E	1983	Undulating	3-8	0-179
Horticulture	34° 12' 57" N 74° 21' 49" E	2385	Rolling	8-16	0-83
Agro-Forestry	34°15' 50"N 74°18' 18" E	2162	Foot Hills	16-25	0-188
Fallow	34°2' 32" N 74°14' 06" E	2110	Rolling	8-16	0-114

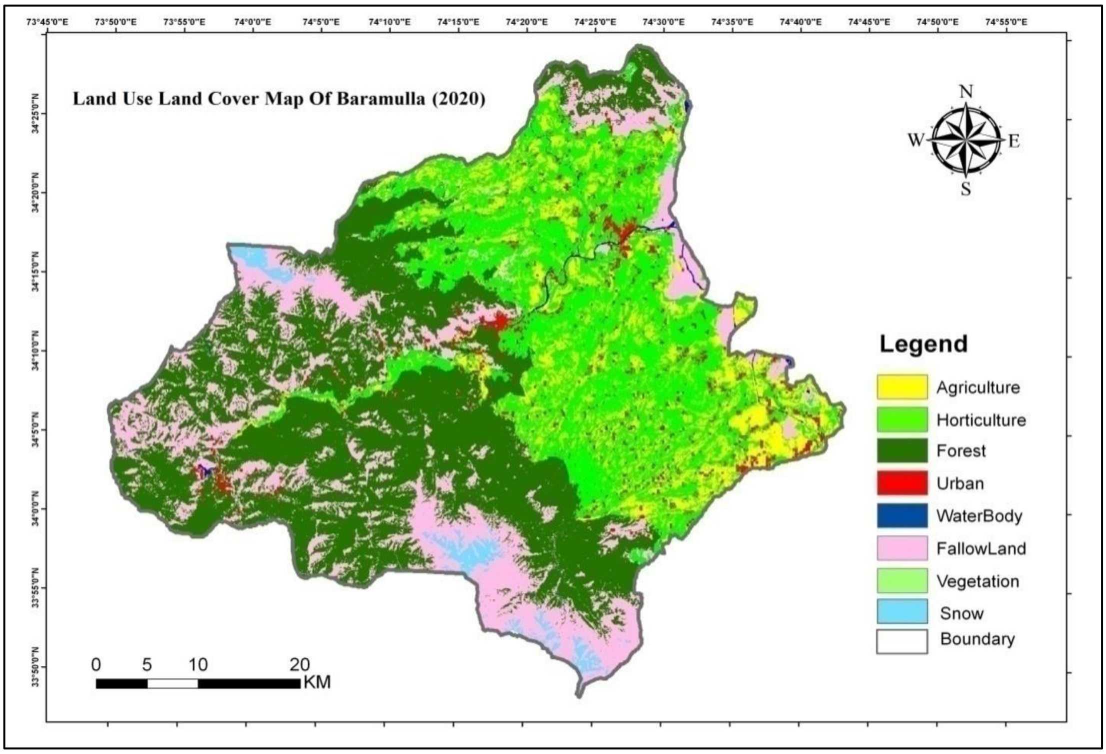

Fig 1: Land use Land Cover Map of study area

2.2 Sample collection and methods

Eighty-four samples were collected from various land uses and slopes in the research region. The sample number was validated by the area percentage of each land use and the landscape location. The sample site coordinates were acquired using a handheld GPS; basic information comprised land use, vegetation type, and dominant species. The samples were collected using a 20 cm 5 cm soil auger in 6–7 replications. Three layers were designed from 0–60 cm; three layers were designed: 0–15 cm, 15–30 cm, and 30–60 cm. Each fresh soil sample (1.5–2.0 kg) was bagged and air-dried for laboratory examination. Soil bulk density was measured in 2–3 duplicates, with each layer collected in a 100-cm^3 cylinder. The samples were all air-dried and polished using a 0.25-mm sieve. The total soil nitrogen was determined using micro-Kjeldahl (Bremer 1960) [7]. SOC was measured using the potassium dichromate volumetric technique (Walkley and Black 1934) [8].

2.3 Statistical analysis

The effects of land use, slope location, and soil depth on total soil nitrogen, ammonium nitrogen, and nitrate nitrogen were studied statistically. The significance of the mean differences was tested using a one-way ANOVA, with the major components being land use type, soil layer, and slope location. Before doing the ANOVA, a univariate approach was employed to assess the data's normality. For each classification component, the Duncan multiple-range approach was used to examine the means of each soil variable.

3. Results

3.1 Soil physicochemical properties

Organic carbon concentration in the soil and bulk density was evaluated as follows: agricultural land > fallow land > horticulture> forests. In contrast, the orchard and agricultural soils had the greatest pH values and lower C/N ratios, and forest and fallow land had higher C/N ratios. The sequence of soil pH levels is as follows: agricultural land> horticulture> forests > fallow lands (Table 2). The soil organic carbon concentration and C/N ratio declined with increasing soil profile depth, whereas soil pH and bulk density increased.

Table 2: Phyico-chemical properties of different land uses

Land use	Depth (cm)	pH	Bulk density (g/cm^3)	SOC g/kg	C/N ratio
Agriculture	0-15	6.54±0.21	1.24±0.16	11.31±0.18	10.22±0.44
	15-30	6.89±0.17	1.26±0.14	8.37±0.26	9.37±0.12
	30-60	7.43±0.37	1.33±0.25	7.77±0.29	9.01±0.56
Horticulture	0-15	6.45±0.15	1.m.n16±0.22	13.45± 0.48	10.45±0.43
	15-30	6.53±0.31	1.19±0.25	12.01±0.22	8.01±0.65
	30-60	7.09±0.45	1.33±0.18	10.09±0.98	8.23±0.53
Agro-forest	0-15	6.78±0.09	1.04±0.14	14.21±0.65	11.21±0.23
	15-30	6.83±0.32	1.09±0.16	13.83±0.32	10.83±0.72
	30-60	6.43±0.12	1.17±0.23	12.43±0.45	9.43±0.23
Fallow	0-15	7.14±0.1	1.36±0.16	8.19±0.33	9.19±0.01
	15-30	7.39±0.26	1.39±0.26	7.67±0.28	8.24±0.13
	30-60	7.32±0.07	1.43±0.37	7.02±0.56	7.26±0.18

3.2 Soil nitrogen distribution under different land uses

The content of total soil nitrogen (TN) varied significantly with land use and soil profile depth (Table 3). Soil total nitrogen contents differed considerably across land uses. The surface layer (0–15 cm) total N content was ordered as follows: horticulture > agriculture > forest> fallow lands. The total N content decreased from 10 to 15 per cent in various land uses. The agricultural land use was close to horticultural land uses and had a higher total N content than fallow, and forest land uses. 0-15 layer included the total soil nitrogen followed by 15-30 and 30-60 cm. Total soil nitrogen in 30-60 cm of various land uses was reported as agricultural land use (0.6 g kg^{-1}), horticultural land use (0.55 g kg^{-1}), forest (0.5 g kg^{-1}), and fallow (0.3 g kg^{-1}). On average, N concentration declined by per metre of soil depth compared with all the land uses. However, when land-use evaluated each soil layer independently, the total N declined in the top layer.

3.3 Distributions of soil nitrate nitrogen concentration (NO_3^--N)

The nitrate nitrogen (NO_3-N) concentration of soil varied dramatically with land use and soil profile depth (Table 3). Except for fallow and forest land uses, nitrate nitrogen concentrations varied considerably throughout land uses. Agriculture and horticultural soils exhibited greater nitrate nitrogen concentrations (0–15 cm) than other land uses. In the 10–30 cm layer, horticulture had the greatest nitrate nitrogen level, followed by agriculture>forest and fallow land uses. The 0–15 cm soil layer had the highest mean nitrate nitrogen content, with larger fluctuation between 15–30 cm and 30–60 cm. The 0–10 cm and 10–30 cm strata demonstrated no significant change when analyzed by land use.

3.4 Distribution of soil ammonium nitrogen concentration (NH_4^+-N)

There were significant differences in the concentrations of soil ammonium nitrogen (NH_4^+-N) depending on land use and soil profile depth (Table 3). Except for fallow land use, concentrations of ammonium nitrogen differed considerably across land uses. The surface layer (0–15 cm) had the highest concentration of soil ammonium nitrogen and was graded as follows: agricultural land use> horticultural land use> forest land use> fallow land use. In the 15–30 cm soil layer, the agricultural land use had the greatest ammonium nitrogen concentration (5.12 mg kg^{-1}), followed by the horticultural land use (4.04 mg kg^{-1}), forest land use (2.99 mg kg^{-1}), and fallow land use (2.81 mg kg^{-1}). The trend of soil ammonium nitrogen concentrations at 30–60 cm was identical to that at 0–10 cm, and followed the trend agricultural land use> horticultural land use> forest land use> fallow land use. Compared to the other soil layers, there were no noticeable changes between the land use types; additionally, the surface layer revealed no significant variation among the land use types when each soil layer was studied by the individual land use.

Table 3: Distribution of soil nitrogen under different land uses and depths

Land uses	Depth (cm)	Total Nitrogen (g/kg)	Nitrate nitrogen (mg/kg)	Ammoniacal nitrogen (mg/kg)
Agriculture	0-15	1.34±0.18	10.09±1.45	12.17±1.67
	15-30	1.21±0.33	7.37±1.56	10.26±1.47
	30-60	0.76±0.11	7.02±1.04	9.33±0.82
Horticulture	0-15	1.26±0.32	13.45±2.48	10.24±1.17
	15-30	1.26±0.24	11.23±2,25	9.09±2.55
	30-60	0.78±0.23	9.22±3.10	7.28±1.28
Agro-forestry	0-15	1.01±0.25	9.56±1.65	9.74±1.23
	15-30	0.90±0.24	8.83±1.87	7.99±2.38
	30-60	0.65±0.21	8.43±2.45	7.13±2.43
Fallow	0-15	0.82±0.32	7.45±1.23	8.17±1.67
	15-30	0.75±0.34	7.07±2.28	8.26±0.97
	30-60	0.60±0.13	7.02±0.99	8.33±0.82

3.5 Correlation coefficients between soil physicochemical properties and soil nitrogen

The soil pH and organic carbon content in the top layer were substantially correlated with the soil nitrogen (Table 4). In contrast, the relationships between the soil pH and nitrogen forms were negative, while the soil pH and soil organic carbon were positive. The soil nitrogen forms were positively and substantially connected, with correlation coefficients (R^2) between 0.504 and 0.725. The soil bulk density was not connected with any nitrogen form, and the C/N ratio was only substantially correlated with the total nitrogen (TN) concentration. In the 0–15 cm layer, the soil physicochemical parameters (except for the soil C/N ratio) were strongly connected with the soil nitrogen forms; the soil C/N ratio was only linked with the total soil nitrogen concentration. The association between the soil nitrogen forms and soil pH was negative, while the soil bulk density and C/N ratio were positive. In the 30–60 cm layer, the soil pH and bulk density were not connected with the total soil nitrogen but were correlated with the soil nitrate nitrogen and ammonium nitrogen. However, the soil organic carbon was positively and strongly associated with the soil nitrogen forms. No significant association was established between the total soil nitrogen and other nitrogen forms. The correlation coefficient (R^2) of the highest layer (0–10 cm) was greater than the other levels. As the soil depth grew, the association between the soil physicochemical qualities and soil nitrogen forms declined. There was a substantial positive link between the soil nitrogen patterns and organic carbon in the current research, which was negatively connected with the soil pH and bulk density.

Table 4: Correlation coefficients between soil physicochemical properties and soil nitrogen

Depth	Soil properties	Total Nitrogen (g/kg)	Nitrate nitrogen (mg/kg)	Ammoniacal nitrogen (mg/kg)
0-15	Soil pH	-0.587**	-0.479**	-0.387**
	Bulk	-0.368**	-0.464**	-0.313**
	SOC (g/kg)	0.756**	0.326**	0.563**
	C/N ratio	-0.453**	-0.425**	-0.148**
	Total Nitrogen (g/kg)	1	0.725**	0.658**
	Nitrate nitrogen (mg/kg)	0.752**	1	512**
	Ammoniacal nitrogen (mg/kg)	0.658**	0.512**	1
15-30	Soil pH	-0.423**	-0.562**	-0.241**
	Bulk density (g/cm3	-0.268**	-0.342**	-0.364**
	SOC (g/kg)	0.634**	0.318**	0.521**
	C/N ratio	-0.453**	-0.409**	-0.166**
	Total Nitrogen (g/kg)	1	0.398**	0.765**
	Nitrate nitrogen (mg/kg)	0.398**	1	549**
	Ammoniacal nitrogen (mg/kg)	0.765**	0.549**	1
30-60	Soil pH	-0.312**	-0.468**	-0.265**
	Bulk density (g/cm3	-0.438**	-0.389**	-0.383**
	SOC (g/kg)	0.441**	0.451**	0.442**
	C/N ratio	-0.235**	-0.516**	-0.236**
	Total Nitrogen (g/kg)	1	0.712**	0.658**
	Nitrate nitrogen (mg/kg)	0.712**	1	489**
	Ammoniacal nitrogen (mg/kg)	0.658**	0.489**	1

4. Discussion

Plant residue and organic matter input are affected by land-use change and vegetation covering, which impact inflow. Furthermore, variations in microclimate and soil conditions and different land use and management practices impact soil nitrogen mineralization and transformation (Xue *et al*., 2013) [9]. Soil moisture management, cultivation measures, and other agronomic measures, for example, impact soil nitrogen mineralization and transformation (Bhople and Sharma 2020) [10]. Losses of soil carbon and nitrogen will result from unreasonably intensive land usage. According to studies, the best design of land use has resulted in enhanced soil nitrogen patterns due to improved soil nitrogen patterns (Paustian *et al*., 2019) [11]. Agricultural land uses had the highest total soil nitrogen concentration and the greatest soil nitrogen mineralization. The organic matter content of the soil and the soil aggregate stability were significantly increased in forest fallow land uses. When planning a land-use transition, the soil depth is the most significant element to consider (Owais *et al*., 2021) [12]. The impacts of land use on soil nitrogen patterns are further complicated because they are dependent on the soil and microclimatic variables (Bangroo *et al*., 2020) [13]. As a result, favorable microclimatic conditions help maintain plant cover while also encouraging organic matter buildup, floral and faunal activity, soil structure development, and a reduction in erosion potential. While ecological restoration took place over ten years, the forest land uses benefited from favorable microclimatic conditions and abundant sustained plant cover, which resulted in higher soil nitrogen concentrations when compared to the fallow land use. In the forest land use, the abandonment of this area resulted in an improvement in such soil characteristics as organic matter content, water retention capacity, aggregation, and structural stability. Because of this, natural forests may result in an increased plant covering, which will affect the soil qualities and microclimatic features of the surrounding environment. It is desirable for plant development, nitrogen cycling and ecological restoration in the North-Western Himalayas to have a higher soil nitrogen concentration under various land uses (Albert 2015) [14].

The soil nitrogen mineralization capacity across all soils was favorably connected with the soil accessible carbon and nitrogen and negatively correlated with the soil C/N ratio (Huang *et al*., 2013) [15]. The soil organic matter (SOM) is a source of soil nitrogen that impacts soil nitrogen mineralization processes. Therefore, the content of SOM has a significant positive association with the soil mineralization capability.

There was a favorable association between the soil pH and nitrogen mineralization. These circumstances are good for nitrogen mineralization enhancement, and a lower soil pH (7.28–7.92) promoted the activity of microbes in the research area. As numerous studies have revealed that soil mineralization nitrogen has a negative link with the C/N ratio (Chu and Grogan, 2010) [16], our finding is distinct from most studies. There was a significant positive association among the total soil nitrogen, nitrate nitrogen and ammonium nitrogen concentrations, showing that each nitrogen cycle stage is closely associated (Naikoo *et al*., 2022) [17]. Enhancing soil nitrogen would boost the total mineralization of the material that is useful for increasing the quantity and activity of microorganisms. The benefits of a positive connection among the soil nitrogen patterns were shown in two aspects: on the one hand, it encourages growing soil nitrogen immobilization; on the other hand, it is favorable for boosting converted soil nitrate nitrogen and ammonium nitrogen concentrations. The vegetative litter, subterranean biomass and root secretion content in the 0–15 cm depth layer was more than in the deep soil layers, and the soil nitrogen patterns of the top layer were more significant than in the other deep layers.

4. Conclusion

The soil nitrogen distribution of land use and landscape in North-Western Himalayas varied. The amounts of nitrogen in the soils of agriculture and horticulture land use were greater than those of the other land uses. The conversion of forest to agricultural land use raised the total soil nitrogen concentration and stimulated soil nitrogen mineralization, crucial for ecological restoration. The greater CEC and gradient were advantageous for soil nitrogen enrichment in the valley; in fact, the valley had the highest value of soil nitrogen. As soil depth grew, the concentrations of total nitrogen and ammonium nitrogen in the uppermost layer of soil increased. Rainfall leaching removed soil nitrate-nitrogen from the top layer, and this process was substantially more pronounced for the 10–30 cm layer. Significant positive correlations existed between the soil nitrogen and organic carbon contents, which were negatively linked with the soil pH and bulk density and the total soil nitrogen, nitrate-nitrogen, and ammonium nitrogen concentrations. These data demonstrated that all nitrogen-cycling stages are interconnected. Increasing nitrogen in the soil would increase the creation of the basic mineralized material that is advantageous for boosting the quantity and activity of microorganisms.

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