International Journal of Botany Studies
www.botanyjournals.com
ISSN: 2455-541X
Received: 08-10-2021, Accepted: 23-10-2021, Published: 09-11-2021
Volume 6, Issue 6, 2021, Page No. 189-193

The effects of *Acacia catechu* willd. Plantation on soil properties based on the comparison between Tarai and Bhabar region, India

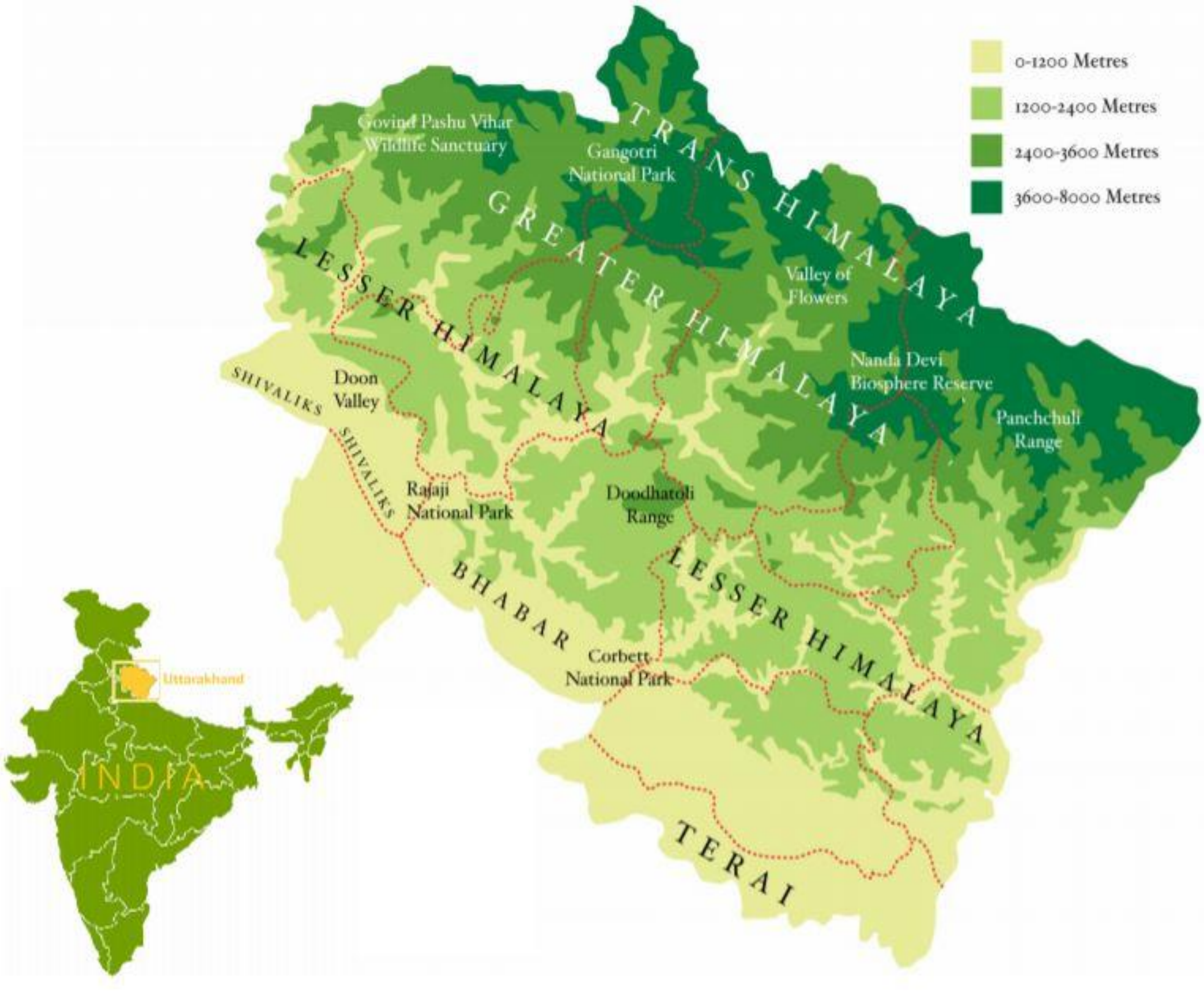
Neha Chopra[1*], Lalit M Tewari[2], Ashish Tewari[3]
[1] Research Scholar, Department of Botany, D.S.B. Campus, Kumaun University, Nainital, Uttarakhand, India
[2] Professor, Department of Botany, D.S.B. Campus, Kumaun University, Nainital, Uttarakhand, India
[3] Department of Forestry and Environmental Science, D.S.B. Campus, Kumaun University, Nainital, Uttarakhand, India

Abstract
Soil is an essential component that serves as the source of nutrients for plants. The present study highlights the properties of soils in the *Acacia catechu* Willd. Plantations at the Tarai-Bhabar region, Uttarakhand, India. The results showed a higher mean value of sand, silt, porosity, available nitrogen, and potassium in the Bhabar region at the surface layer (0-15cm). In contrast, the mean value of clay, moisture content, water holding capacity, bulk density, soil organic matter, soil organic carbon, and available phosphorus was reported significantly highest in the Tarai region. The pH indicates the nature of the soil, which was slightly acidic in all the sites and depths except the Tarai region at the subsurface layer (16-30cm) only. In general, the Tarai region plantation could improve the soil quality, especially for SOC. Principal Component analysis (PCA) was performed to evaluate the influence of plantations on soil properties.

Keywords: soil properties, soil fertility, soil nutrient, plantations, *A. catechu*, tarai-bhabar region

Introduction
On land surfaces, Weathering process (chemical and hydrological, etc.) results in soil formation. A soil profile is the vertical stratification of the concentration of elements produced by the continual influence of percolating water and biota. The solid phase of soil is composed of two broad classifications of compounds *viz* inorganic mineral compounds and organic matter [1]. Soil texture is the number and size of its mechanical elements of particles after all the compounds holding them together have been destroyed [2]. In the dynamic soil system, soil solution is the medium of biological, physical, and chemical processes in the soil environment. It is in equilibrium with soil atmosphere, minerals, microorganisms, and organic matter. Thus, it is the bottleneck of transforming and transporting vital and detrimental molecules and ions in the ecosystems [3].
The recent large-scale afforestation in the Tarai and Bhabar region of Kumaun Himalaya represented a significant land-use change in Central Himalaya and developed ecological and economic relationships. The substantial accumulation in all macro and micronutrients occurred in the soil (N, P, K, etc.). This change attributed healthy plantations to expectations of increased future returns from forestry. Closer examination of changes in soil properties over time explains that the different tree species are necessary to understand the mechanisms responsible for changes in the soil organic matter and nutrient availability [4]. Braver *et al.* [5] conducted a study on certain edaphic and agronomic factors vis-à-vis soil physical and chemical properties that govern the fertility status of the soil. The heat flows through the soil are essential in plant culture practices like plant productivity, those uptakes of nutrients water, etc. Soil parameters develop reactions between soil components, terrain, and geographic location.
Vegetation plays an essential role in soil formation [6]. It influences and improves the soil structure, infiltration rate, water holding capacity, etc. In the Indian system of medicine, *A. catechu* belongs to the family Fabaceae is used extensively in folk and traditional system of medicine in India and Asia. *A. catechu* is a multipurpose tree predominantly found in tropical and subtropical regions of India. The tree produces nitrogen-rich fodder and green manure, high-quality fuel wood, charcoal, solid and durable poles, timber, and precious heartwood used in the production of Katha and Katch. The rich alluvial soil of this region is slightly different from the bare soil of mountain and desert-like soil of the trans- Himalayan zone of Uttarakhand [7].
In the study area, large-scale conversion of various tree plantation forests is managed for timber and industrial raw material in the century wood and pulp paper industry. It is possible to see the alteration in the canopy brings record changes in soil properties. To our knowledge, very few attempts have been made under this region for soil analysis. So, this study was undertaken to evaluate the physicochemical properties in plantation forests of *A. catechu* tree species.

Material and Methods
Study area
The study was conducted in the Tarai (Ti) and Bhabar (Bh) region of Kumaun Himalaya (Fig. 1). It is situated at about 250-300 m above mean sea level. The climate of this region is monsoonal.



Physiographic map of Uttarakhand with location indicated within India
Source: http://uttarakhand.org/?portfolio=relief-map

Fig 1: Location map of the study site.

Collection of soil samples

The soil samples were collected from two depths, i.e., the surface layer (0-15cm) and sub-surface layer (16-30cm), with three replicates in each plantation forest. The samples were packed in polyethylene bags and brought to the laboratory for further analysis.

Analysis of soil samples

The collected soil samples were oven-dried at 45o C for 24 hours and passed the oven-dried soil through a. 2 mm sieve for getting soil texture [8]. Used the processed soil samples for determining the soil moisture content (MC%) [9], water holding capacity (WHC%), soil bulk density (bD in g cm^{-3}) [10], soil organic carbon (%SOC) by wet digestion method and soil organic matter (%SOM) by Walkley and Black [11], available nitrogen (N kg ha^{-1}) by Kjeldahl digestion method [12], available phosphorus (P kg ha^{-1}) by 0.5 M $NaHCO_3$ (pH 8.5) extraction method [13], available potassium (K kg ha^{-1}) by 1 N NH_4OAc (pH 7.0) extraction method [10].

Statistical analysis

The data were analyzed by one-way Analysis of Variance (ANOVA), and the means were compared by Duncan tests at a level of significance of $p < 0.05$ using SPSS 16.0 statistical software. Correlation coefficients were also computed among different soil properties in each plantation forest. The principal component analysis (PCA) by XLSTAT software analysed the multivariate relationship between variables.

Results and Discussion

The physicochemical characteristics of the soil from the study area are summarized in table 1. The result showed that mean values of sand (%), silt (%), porosity (%), soil pH, organic carbon (%), soil organic matter (%), nitrogen (kg ha^{-1}), and potassium (kg ha^{-1}) were decreased with increasing depth. The mean clay (%), moisture content (%), water holding capacity (%), bulk density (g cm^{-3}), and phosphorus (kg ha^{-1}) were increased with increasing depth (Table 1). The correlation analysis among the different soil parameters in both study sites is shown in Tables 2 and 3.

Ewetola *et al.* [14] reported a relationship between slope position and soil properties where the middle slope showed the highest clay content. The sub-surface layer exhibited higher clay content as compared to the surface layer. Among all the profiles, high sand content ranged from 22.03% to 46.84% and was highest at the surface layer of the Bhabar region. The sand content in the solum of lowland profiles was comparatively less than in midland and upland profiles recorded by Balpande *et al.* [15]. Silt content ranged from 39.57% to 40.36%. The mean clay content ranged from 22.61% to 47.96%. Clay was found to be highest at the subsurface layer of the Tarai region. Gupta [16] reported that silty clay to sandy loam type of soil texture is suitable for regenerating high-quality trees, supporting the present study. Sandy loam texture is prevalent in the Tarai region of Shiwalik and Dun valley [17], and this type of soil supports the forest of valuable timber trees [18] (Table 1).

The results described that moisture content ranged from 8.30% to 11.18%. The present study supports other researchers [19]. The WHC increases with the increasing depth of organic carbon and is highest at the subsurface of Tarai (54.98%). The pH range between 6.13 to 7.62 in the present study also reported similar results by Sigdel [20] in Koshi Tappu Wildlife Reserve and Singh and Singh [21] in Sal dominated central Himalayan forests. According to Bhatnagar [22], good Sal regeneration areas have low pH in the soil. The highest mean percentage of OC and SOM was observed for the samples collected from the Tarai region at surface layer viz. 0.64% and 1.11%, respectively. Organic matter was low, which suggested that the soils can be classified as low-level organic soils (3 to 19% OM content). Champion and Seth [23] reported organic matter of Deodar forest as 16.05% and considered that the soil organic matter is the main pool of carbon and nutrients and regulated the soil's physical, chemical, and biological properties [24] largely. Joshi and Negi [25] had recorded significantly lower organic carbon in the pine forest (0.46-1.64) than in the Oak soil (0.85-3.28). Similar results were observed in our study of forest soils.

Moreover, different tree species can differ significantly in their influence on soil properties and soil fertility. Phosphorus, potassium, and nitrogen are primary macronutrients sources of soil that provide the performance and vitality of the plant. Among both the forests, the mean available soil nitrogen (353.29 kg ha^{-1}) and available potassium (158.51 kg ha^{-1}) content were higher at the surface layer of the Bhabar region, respectively. Singh and Singh [26] recorded the percentages of organic matter and nitrogen in the subtropical zone of Kumaun Himalaya that varied from 1.5 to 3.0% and 0.1 to 0.3%, respectively. The low nitrogen content in soil may be due to the continuous losses through leaching and run-off [18, 27]. The mean value of available phosphorus was ranged from 13.35 kg ha^{-1} (surface layer of Bhabar region) and 16.36 kg ha^{-1} (subsurface layer of Tarai region). Tisdale *et al.* [28] suggested that about 50% of phosphorus is present in organic form, and humus present in organic matter forms complex with A1 and Fe and thus, protect phosphorus fixation. According to Chauhan *et al*. [29], *Acacia catechu, Melia azedarach,* and *Dalbergia sissoo* had phosphorus content of 26.6, 24.4, and 28.3 kg ha^{-1}, respectively, which is slightly higher than present findings. The available potassium content in the soil ranged from 142.74 kg ha^{-1} to 158.51 kg ha^{-1} at the sub-surface and surface layer of the Tarai region. The highest (158.51 kg ha^{-1}) content was at the surface layer of the Tarai region (Table 1). The mean available K content under these plantations was significantly higher than control by 58 %. In these plantations, the mean potassium content was higher at the surface layer is attributed to the liberation of potassium by litterfall decomposition and by solubilization of insoluble form of potassium content present in soil due to organic decay. Under plantations, higher potassium content may be due to the litterfall of trees. It may also be the presence of grasses in a particular area. Our findings are supported by Swamy *et al*. [30] (2006) and Singh and Sharma [31] (2007). The study of Das and Chaturvedi [32] (2008) was conducted under different tree species to record the improvement in soil chemical properties.

A significant maximum positive correlation has been observed in the Tarai region of Kumaun Himalaya (Table 3). The correlation matrix between all the physicochemical properties in the Bhabar region indicated that the sand, porosity, nitrogen, and phosphorous showed a significant positive correlation with maximum soil properties (Table 2). The porosity showed a significant positive correlation with maximum soil properties (sand, pH, soil organic matter, organic carbon, available nitrogen, available potassium, and available phosphorous) followed by available nitrogen (six physicochemical properties), organic carbon, available potassium, and available phosphorous with five physicochemical properties in Tarai region (Table 3). Forest sites and depths has significantly affected the soil Physico-chemical properties. The coordination of two different sites and depths based on the Physico-chemical properties of soil is presented in Fig.2. The PCA axis F1 accounted for 67.75% variation in properties composition, while PCA axis F2 accounted for 26.73% variation. The PCA axis 1 was related to active sites, and the PCA axis 2 represented the dynamic variables.

The present study can conclude that establishing such a type of plantation with good soil quality in this region will conserve the quality of the plantation. Studying soil organic carbon in *A. catechu* plantation at the Tarai-Bhabar region will help collect data and essential information at the initial stage. This information is handy for knowing the nutrient status and overcoming soil constraints for further development and maintenance of plantation forests. In addition, the care of these plantations with the enhancement of soil quality will improve the environment, vegetation, micro-climate, and carbon sequestration potential of the particular forest.

Table 1: Physicochemical analysis (mean ± SE) of *A. catechu* plantation

Physicochemical properties	Bhabar region		Tarai region	
	Bh 1	Bh 2	Ti 1	Ti 2
Sand%	46.84 ± 0.42^{l}	38.81 ± 0.00^{j}	24.37 ± 0.03^{f}	22.03 ± 0.48^{cd}
Silt%	40.24 ± 0.68^{ef}	36.67 ± 0.26^{b}	40.36 ± 0.01^{ef}	39.57 ± 0.60^{de}
Clay%	22.61 ± 0.60^{a}	23.13 ± 0.18^{ab}	35.27 ± 0.07^{e}	47.96 ± 0.52^{jk}
MC%	8.30 ± 0.40^{a}	8.38 ± 0.51^{ab}	9.70 ± 0.04^{bcd}	11.18 ± 0.10^{efg}
WHC%	48.74 ± 0.42^{a}	48.87 ± 0.03^{a}	51.26 ± 0.01^{bcd}	54.98 ± 0.36^{g}
bD(gm cm^{-3})	0.69 ± 0.01^{a}	0.73 ± 0.01^{ab}	0.87 ± 0.03^{abcde}	1.05 ± 0.07^{e}
Porosity%	72.63 ± 0.02^{n}	72.58 ± 0.01^{n}	66.98 ± 0.06^{j}	60.42 ± 0.48^{e}
pH	6.13 ± 0.08^{a}	6.36 ± 0.03^{b}	6.75 ± 0.02^{de}	7.62 ± 0.03^{h}
SOM%	0.98 ± 0.02^{bc}	0.78 ± 0.07^{a}	1.11 ± 0.06^{bc}	0.83 ± 0.01^{ab}
OC%	0.57 ± 0.01^{abc}	0.45 ± 0.04^{a}	0.64 ± 0.03^{abc}	0.48 ± 0.01^{ab}
N kg ha^{-1}	353.29 ± 0.01^{m}	293.53 ± 0.01^{d}	309.84 ± 0.59^{g}	285.37 ± 0.06^{c}
K kg ha^{-1}	158.51 ± 0.15^{kl}	142.74 ± 0.11^{c}	154.26 ± 0.78^{i}	146.15 ± 0.59^{de}
P kg ha^{-1}	13.35 ± 0.59^{cd}	15.37 ± 0.15^{ef}	14.55 ± 0.58^{de}	16.36 ± 0.53^{f}

Bh 1: Bhabar (0-15cm); Bh 2: Bhabar region (16-30cm); Ti 1: Tarai (0-15cm); Ti 2: Tarai (16-30cm); MC: moisture content; WHC: water holding capacity; bD: bulk density; SOM: soil organic matter; C: carbon; N: nitrogen; K: potassium; P: phosphorus.

Table 2: Correlation between soil parameters of *A. catechu* plantation in Bhabar region

	Correlations Bh										Nutrients (kg ha^{-1})		
	Sand %	**Silt %**	**Clay %**	**MC %**	**WHC %**	**bD %**	**Porosity %**	**pH**	**SOM %**	**OC %**	**N**	**K**	**P**
Sand%	1	.957**	-0.288	-0.579	-.864*	-.975**	.995**	-0.731	0.792	.815*	.994**	.996**	.987**
Silt%		1	-0.004	-0.345	-0.699	-.874*	.926**	-0.504	.813*	.835*	.925**	.930**	.943**
Clay%			1	.917*	0.711	0.488	-0.381	.862*	-0.122	-0.126	-0.383	-0.369	-0.3
MC%				1	.911*	0.743	-0.66	.946**	-0.467	-0.473	-0.662	-0.649	-0.597
WHC%					1	.953**	-.911*	.953**	-0.69	-0.706	-.912*	-.906*	-.869*
bD%						1	-.993**	.858*	-0.757	-0.779	-.993**	-.991**	-.966**
Porosity%							1	-0.793	0.788	0.811	1.000**	1.000**	.985**
pH								1	-0.483	-0.499	-0.794	-0.785	-0.731
SOM%									1	.999**	0.788	0.785	.849*
OC%										1	0.811	0.808	.871*
N kg ha^{-1}											1	1.000**	.985**
K kg ha^{-1}												1	.986**
P kg ha^{-1}													1

**Significant at 0.01 and * at 0.05; Bh: Bhabar region; MC: moisture content; WHC: water holding capacity; bD: bulk density; SOM: soil organic matter; OC: organic carbon; N: available nitrogen; K: available potassium; P: available phosphorus.

Table 3: Correlation between soil parameters of *A. catechu* plantation in Tarai region

	Correlations Ti										Nutrients (kg ha^{-1})		
	Sand %	**Silt %**	**Clay %**	**MC %**	**WHC %**	**BD %**	**Porosity %**	**pH**	**SOM %**	**OC %**	**N**	**K**	**P**
Sand%	1	.827*	-.890*	-0.733	-0.783	-0.643	.955**	-.905*	.878*	.880*	.925**	.942**	.874*
Silt%		1	-0.481	-0.226	-0.3	-0.127	0.623	-0.516	0.546	0.544	0.553	0.624	0.539
Clay%			1	.962**	.981**	.910*	-.985**	.997**	-.916*	-.921**	-.995**	-.959**	-.914*
MC%				1	.997**	.975**	-.902*	.949**	-.846*	-.852*	-.934**	-.871*	-.846*
WHC%					1	.963**	-.933**	.970**	-.873*	-.879*	-.959**	-.903*	-.873*
bD%						1	-.834*	.901*	-0.728	-0.735	-.869*	-0.776	-0.727
Porosity%							1	.989**	.927**	.931**	.995**	.978**	.925**
pH								1	-.905*	-.910*	-.995**	-.954**	-.903*
SOM%									1	1.000**	.941**	.979**	1.000**
OC%										1	.945**	.980**	1.000**
N kg ha^{-1}											1	.980**	.939**
K kg ha^{-1}												1	.978**
P kg ha^{-1}													1

**Significant at 0.01 and * at 0.05; Ti: Tarai region; MC: moisture content; WHC: water holding capacity; bD: bulk density; SOM: soil organic matter; OC: organic carbon; N: available nitrogen; K: available potassium; P: available phosphorus.

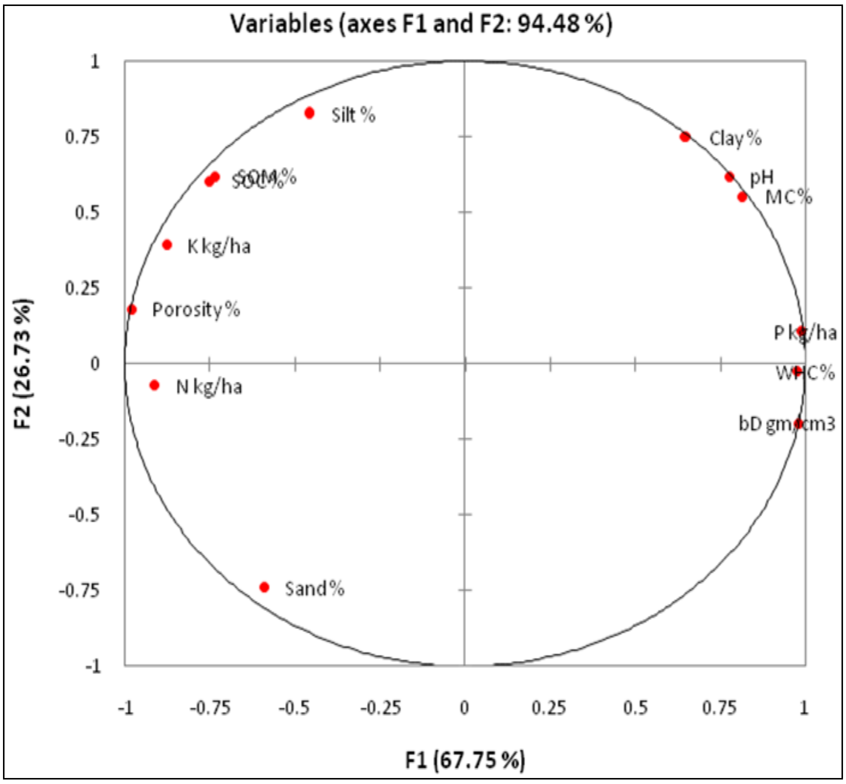


Fig 2: Principle component analysis of physicochemical properties of soil in the tarai and bhabar region. PCA axis 1(67.75%) and 2 (26.73%) represent for first and second coordinates (scores) of sites, respectively (MC: moisture content; WHC: water holding capacity; bD: bulk density; SOM: soil organic matter; OC: organic carbon; N: available nitrogen; K: available potassium; P: available phosphorus)

Conclusions

The present study can conclude that establishing such a type of plantation with good soil quality in this region will conserve the quality of the plantation. The study of soil organic carbon in *A. catechu* plantation at Tarai-Bhabar region will be helpful in collect data and essential information at the initial stage. This information is handy for knowing the nutrient status and overcoming soil constraints for further development and maintenance of plantation forests. In addition, the care of these plantations with the enhancement of soil quality will improve the environment, vegetation, micro-climate, and carbon sequestration potential of the particular forest.

Acknowledgement

The authors thank the Uttarakhand Forest Department for access to their sites and infrastructure. The authors also thank the Head, Department of Botany, D.S.B.Campus, Kumaun University, Nainital for providing the necessary lab facility.

References

1. Helmko, Philip, Summer ME. Edited, Handbook of Soil Science, CRC Press London, B-3, 2000.
2. Zonn SV. Tropical and Subtropical Soil Science, Mri Publishers, Moscow, 1986.
3. Huang PM, Summer ME. Edited, Handbook of Soil Science, CRC Press, London, B-10, 2000.
4. Binkley D, Högberg P. Does atmospheric deposition of nitrogen threaten Swedish forests? For. Ecol. Manag,1997:92:119-152.
5. Braver ID, Gardner WH, Gardner WR. Soil physics. Fourth edition John Willey and Sons. New York, 1978, 498.
6. Chapman JL, Reiss MJ. Ecology: Principles and applications. Cambridge. Cambridge University Press, 1992.
7. Negi SS. Himalayan Forests and Forestry. Indus Publishing Company, New Delhi, India, 1990.
8. Piper CS. Soil and Plant Analysis. InterScience Publications Inc., New York, USA, 1966.
9. Jackson ML. Soil chemical analysis. Verlag: Prentice Hall, Inc., Englewood Cliffs, N. J. Zeitschrift für Pflanzenernährung, Düngung, Bodenkunde, 1958, 214-221.
10. Black CA. Method of soil analysis (Part -I and II). Amer. Soc. Agron. Inc. Madison, Wisconsin, USA, 1965, 770.
11. Walkley A, Black IA. An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chronic acid titration method. Soil Science,1934:37(1):29-38.
12. Kjeldahl J. Neue Methode zur Bestimmung des Stickstoffs in organischen Körpern. Zeitschrift für analytische Chemie,1883:22(1):366-382.
13. Olsen SR, Sommers LE. Phosphorus. In: Methods of soil analysis. Part 2 Chemical and microbiological properties. 2nd edition. Page, A.L. (Ed.). American Society of Agronomy, Madison, WI, USA,1982:9:403-430.
14. Ewetola EA, Oyediran GO, Owoade FM, Ojo, OI. Variations in Soil Physical Properties Along Toposequence of an Alfisol in Southern Guinea Savanna of Nigeria. Int. j. environ. agric. Biotech,2010:3:303-305.
15. Balpande HS, Challa O, Prasad J. Characterization and classification of grape-growing soils in Nasik district, Maharashtra. J. Indian Soc. Soil Sci,2007:55:80-83.
16. Gupta RS. Recurrence in drought conditions in mortality in sal forests of Uttar Pradesh. J. Ind. Bot. Soc,1951:40(1):25-33.
17. Shah R. Soils: Their problems and management. In: Majupuria TC (ed), Nepal: Nature’s paradise. Kathmandu: Hillside Press Ltd, 1999, 64-68.
18. Paudel S, Sah JP. Physiochemical characteristics of soil in tropical sal (Shorea robusta Gaertn.) forests in eastern Nepal. Himalayan Journal of Science,2003:1(2):107-110.
19. Khera N, Kumar A, Ram J, Tewari A. Plant biodiversity assessment in relation to disturbances in mid elevational forest of Central Himalaya, India. Trop. Ecol,2001:42(1):83-95.
20. Sigdel ER. Physico-chemical properties of soil in Royal Chitwan National Park [thesis]. Kathmandu: Central Department of Botany, Tribhuvan University, 1994, 49.
21. Singh SP, Singh JS. Structure and function of the forest ecosystem of central Himalayas: Implication for management. In: Singh JS (ed), Environmental regeneration in Himalayas. Nainital: The Central Himalayan Environment Association and Gyanodya Prakashan, 1985, 83-113
22. Bhatnagar HP. Soils from different quality sal (*S. robusta*) forests of Uttar Pradesh. Trop. Ecol,1965:6:56-62.
23. Champion HG, Seth SK. A Revised Survey of Forest Types of India, Govt. of India Press, New Delhi, 1968, 404.
24. Gupta SR, Malik V. Soil ecology and sustainability. Trop. Ecol,1996:37(1):43-55.
25. Joshi G, Negi GCS. Physico-chemical properties along soil profile of two dominant forest types in Western Himalaya. Current Science,2015:109(4):798-803.
26. Singh JS, Singh SP. Forest vegetation of the Himalaya. The Botanical Review,1987:53(1):80-192.
27. Allen JRL. Sedimentation in the Modern Delta of the River Niger, West Africa. Developments in Sedimentology,1964:1:26-34.
28. Tisdale SL, Nelson WL, Beaton JD, Havlin JL. Soil fertility and fertilizers. Macmillan, New York, 1993, 176-229.
29. Chauhan SK, Singh S, Sharma S, Vashist BB, Sharma R, Saralch HS. Soil health (physical, chemical and biological) status under short rotation tree plantations on riverain soils. Journal of Pharmacognosy and Phytochemistry,2018:7(5):1599-1605.
30. Swamy SL, Mishra A, Puri S. Comparison of growth, biomass and nutrient distribution in five promising clones of *Populus deltoides* under an agri-silviculture system. Bioresource Tech,2006:97:57-68.
31. Singh B, Sharma KN. Tree growth and nutrient status of soil in a poplar (*Populus deltoides* Bartr.) based agroforestry system in Punjab, India. Agroforestry Systems,2007:70:113-124.
32. Das DK, Chaturvedi OP. Root phytomass recovery and rooting characteristics of five agroforestry tree species in eastern India. Journal of Tropical Forest Science,2008:20:156-166.