

Vertical Distribution of Soil Organic Carbon and Soil Nutrients in Sericulture-Based Agroforestry System of Assam, North Eastern India.

Tulshi Upadhyay

Assistant Professor of Botany, Tyagbir Hem Baruah College,
Jamugurihat, Sonitpur, ASSAM, PIN-784180
Email: tulshiupadhyay@gmail.com

Abstract

This study aimed to evaluate the available soil nutrients and soil organic carbon at different soil depths. The study was carried out in five selected sites, located in different agro-climatic zones of Assam. In this investigation nitrogen contents in the studied soil layers ranged from $374.28 \pm 4.23 \text{ Kg.ha}^{-1}$ to $272.56 \pm 3.90 \text{ Kg.ha}^{-1}$, soil available phosphorus ranged from $29.06 \pm 1.58 \text{ Kg.ha}^{-1}$ to $18.25 \pm 3.13 \text{ Kg.ha}^{-1}$ and soil available potassium from $301.45 \pm 9.34 \text{ Kg.ha}^{-1}$ to $182.90 \pm 5.76 \text{ Kg.ha}^{-1}$. Soil organic carbon, in this study, showed a decreasing trend from the topsoil (0-10cm) to the bottom soil (20-40cm), and a significant difference ($p < 0.05$) in the SOC contents in all three soil depths was observed from the study site Kohora, but no significance difference ($p > 0.05$) was recorded from Jogduar and Boko.

Keywords: Argo-climatic zone, Soil organic carbon, Soil-depth, Significant.

Mathematics Classification No: 62P12

Journal of Economic Literature (JEL) Classification No: Q50

1: INTRODUCTION

India's North Eastern region has a glorious agroforestry tradition (Ahmed and Hazarika, 2007). More than 80% of its population depends on agriculture (Mandal, 2014). Apart from jhum, other prominent agroforestry systems of this region are tea and coffee gardens, bamboo groves (Das *et al.*, 2015), and sericulture-based agroforestry systems (Dhyani *et al.*, 1996). Sericulture is an age-old tradition that primarily covers the cultivation of host plants, the rearing of the silkworm, and the production of silk (Chowdhury, 1982; Pandey *et al.*, 2005). In this region, more than 14441.72 hectares of land have been used for the cultivation of the host plants which are mostly woody perennial species such as *Machilus gamblei* King ex Hook.f., *Morus alba* Linn., *Morus aciosa* Griff. and others (Anonymous, 2004; Upadhyay and Baruah, 2019). Besides serving as an important component in the traditional agroforestry systems of North Eastern India, these plant species also provide environmental

services in soil nutrient cycling, water conservation, carbon sequestration, and climate change mitigation (Choudhury and Vajczikova, 2002). Since a woody perennial plant, planted in an agroforestry system serves the same ecological role as that of forest trees (Negas *et al.*, 2013), these plants have a promising role in sequestering atmospheric carbon in plants and in the soil as well as increasing soil fertility of the agroforestry farms (Upadhyay, 2022). There are reports on soil nutrient cycling in different agroforestry systems of North East India (Rao *et al.*, 2018). However, information on the vertical distribution of soil nutrients and seasonal variations in available soil organic carbon in sericulture-based agroforestry systems is lacking. The present study was carried out to generate data on the vertical distribution of available soil nutrients under sericulture-based agroforestry systems of Assam, North Eastern India.

2: MATERIALS AND METHODS

2.1: Study area

This study was carried out in the Brahmaputra valley, at five different sites, located in five agro-climatic zones (Figure 1) of Assam (21.16°E to 26.77°E and 85.29°N to 94.18°N). The selected sites were Tupia, Podumoni, Kohora, Jogduar, and Boko. The elevation of the study areas ranges from 173.88 ft. to 301.83ft, average annual rainfall from 2000 mm to 3750 mm, and mean annual temperature ranges from 11.2°C to 35.5°C. The valley has an undulating topography characterized by hills, hillocks, wide plains, and low-lying areas (Taher and Ahmed 2005). The soil types in the hills and plains of the region exhibit a marked difference in composition. The soil in the plain is mostly alluvial in origin but there are laterite types of soil in some areas. The soil nature is such that water can easily percolate through it.

2.2: Soil sampling

Soil samples were collected randomly from the five selected plantation sites (Figure 1) in 2020 during four typical months representing four seasons, following Gosain *et al.*, (2015). On each sampling date, soil samples were collected in replicate from the depth of 0-10cm, 10-20cm, and 20-40 cm, randomly, using soil augur. A composite soil sample of each depth was also prepared and brought to the laboratory. The collected composite soil samples were dried, ground, and sieved through a 3mm sieve and kept in air-tight polythene bags for further estimation. For the estimation of soil moisture, soil samples were collected separately.

2.3: Soil analysis

Soil p^H was determined using a digital p^H meter (Systronic p^H 362). The bulk density was determined by volume and weight ratio following Anderson and Ingram (1993). Soil organic carbon was estimated using Walkey and Black's

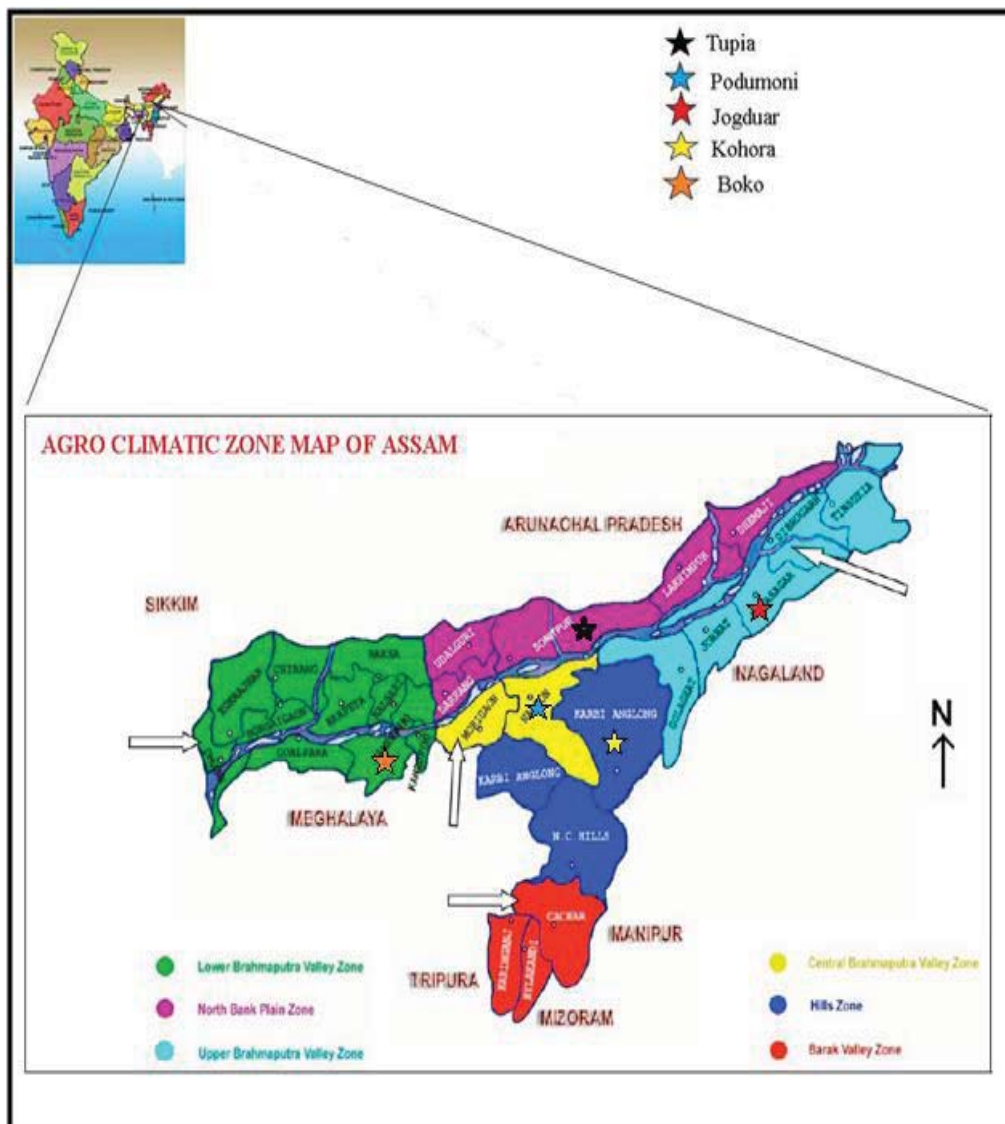


Fig. 1- Map of the study areas, adopted from Dept. of Agriculture. Govt. of Assam

☆ Indicates study sites

(1934) rapid titration methods. For the estimation of nitrogen micro Kjeldahl method was used. Available soil phosphorous was determined using Molybdenum Blue methods (Jackson, 1973). The flame photometry method following Jackson (1967) was adopted for the estimation of exchangeable Potassium from the soil extract. Nutrients estimated from gm^{-1} soil were converted to nutrients ha^{-1} following Pribyl (2010).

2.4: Statistical analyses

Statistical analyses were conducted using SPSS version 20 (IBM Inc., USA). The data in this paper are presented as the mean $\pm$ standard deviation ($n=3$). Basic soil properties and SOC were analyzed using one-way ANOVA at a 5% level of significance.

3. RESULTS

3.1: Vertical distribution of soil nutrients

Soil physico-chemical properties of different studied sites were analyzed and results are presented in Table 1. The bulk density (BD) of soil in the present study was found to range from $1.34 \pm 0.12 \text{ gm.cm}^{-3}$ to $1.23 \pm 0.23 \text{ gm.cm}^{-3}$. Among the different study sites, the maximum BD was recorded from the topsoil (0-10cm) of Tupia, and the minimum BD was recorded from the bottom soil (20-40cm) of Boko. The BD showed an increasing trend from topsoil to bottom soil in all five different study sites (Table 1). P^H value in the present study revealed that the sub-soil (10-20cm) was the most neutral with a p^H value of 7.23 ± 0.32 recorded from the sub-soil (10-20cm) of Tupia and the topsoil (0-10cm) as the most acidic with a p^H value of 4.95 ± 0.56 observed from the topsoil of Kohora. The p^H value in all study sites showed an increasing trend from topsoil to subsoil and again decreased down in the bottom soil. Soil nitrogen contents in different soil layers of the present study ranged from $374.28 \pm 4.23 \text{ Kg.ha}^{-1}$ to $272.56 \pm 3.90 \text{ Kg.ha}^{-1}$, the maximum from the sub soil (10-20cm) of Tupia and minimum also from the sub-soil (10-20cm) of Podumoni (Table 1). In most study sites the soil available phosphorus (SAP) showed a decreasing trend from topsoil (0-10cm) to bottom soil (20-40cm) except in Tupia and Podumoni where the SAP content was recorded to increase from topsoil to subsoil and again decreased down in the bottom soil. The maximum value ($29.06 \pm 1.58 \text{ Kg.ha}^{-1}$) of SAP in the present study was recorded from the topsoil of Jogduar and the minimum value ($18.25 \pm 3.13 \text{ Kg.ha}^{-1}$) was recorded from the bottom soil of Kohora. The soil available potassium (SAK) in the present study showed a decreasing trend from the topsoil to the bottom soil (Table 1). The maximum value ($301.45 \pm 9.34 \text{ Kg.ha}^{-1}$) of SAK was recorded from the topsoil of Kohora and the minimum value ($182.90 \pm 5.76 \text{ Kg.ha}^{-1}$) was recorded from the bottom soil of Tupia. The soil moisture contents of the present study showed increasing trends from topsoil to the sub-soil and again decreased down in the bottom soil. The maximum value of soil moisture ($24.28 \pm 2.59\%$) was recorded from the sub-soil of Tupia whereas the minimum value ($18.04 \pm 1.48\%$) was recorded from the bottom soil of Jogduar.

3.2: Seasonal variation of Soil Organic Carbon (SOC)

Seasonal variations of SOC contents in three soil layers of five different studied sites are presented in Figure 2. In the Pre-monsoon season the maximum content of SOC was recorded from the topsoil (0-10cm) of Kohora and the minimum was recorded from the subsoil (10-20cm) of Boko. A significant difference ($p < 0.05$) in the SOC contents in all three soil depths was observed from Kohora plantation sites, but no significant difference ($p > 0.05$) was recorded from Jogduar and Boko (Figure 2). In the Monsoon season, the maximum content of SOC was recorded from the subsoil (10-20cm) of Tupia, and the minimum was recorded from the bottom soil (20-40cm) of Podumoni. A significant

difference ($p < 0.05$) in SOC contents in the three soil layers was observed from Podumoni, Kohora, and Jogduar but no significant difference ($p > 0.05$) was recorded from Tupia and Boko (Figure 2).

In the post-monsoon season maximum content of SOC was observed from the topsoil (0-10cm) of Tupia and the minimum content of SOC was recorded from the bottom soil (20-40cm) of Podumoni. A significant difference ($p < 0.05$) in SOC contents among the different soil depths was observed from all study sites except Boko, where the value SOC content was recorded as almost equal in three soil depths (Figure 2). In the Winter season, maximum SOC content was recorded from the subsoil (10-20cm) of Tupia, and the minimum was recorded from the bottom soil (20-40cm) of Podumoni and Boko. No significant ($p > 0.05$) difference was observed in the SOC contents in different soil depths of Tupia and Boko (Figure 2).

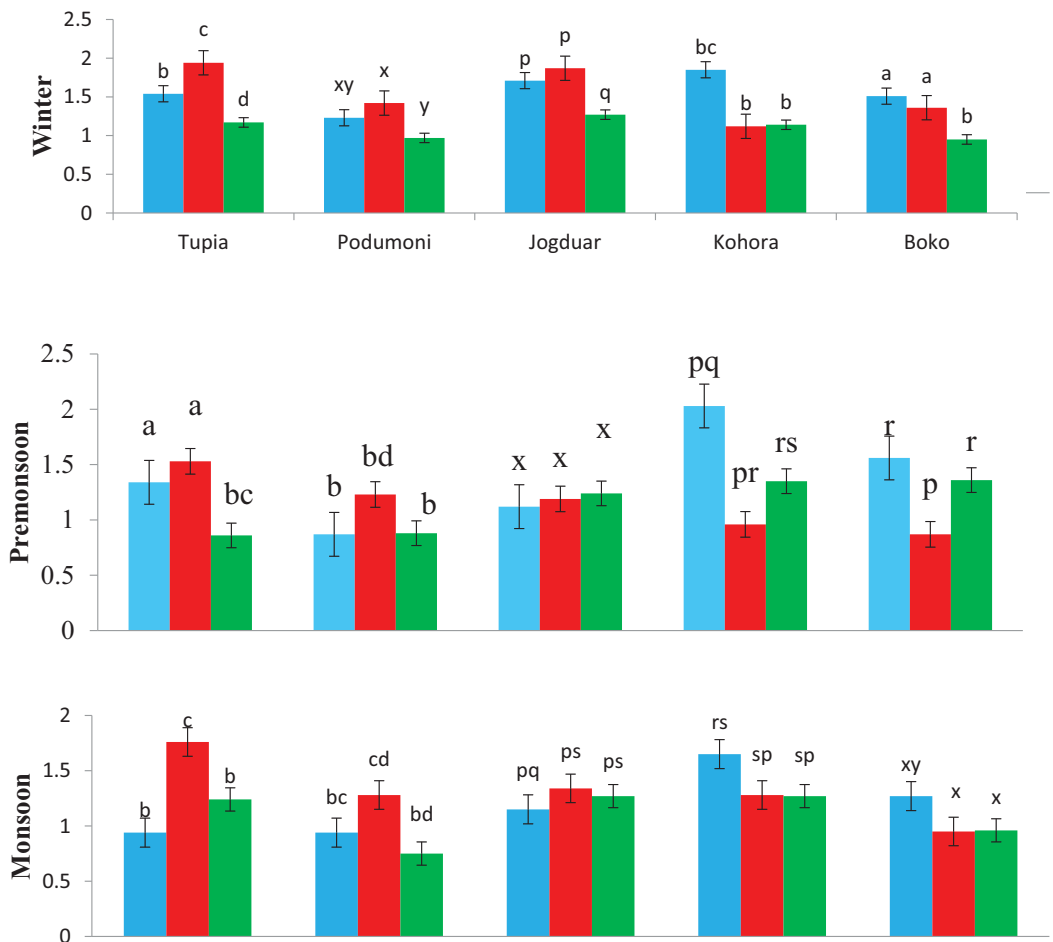


Fig. 2 Seasonal variations in SOC contents at different soil depths (0–10, 10–20, 20–40cm) in different study sites. Different lowercase letters indicate significant differences among different study sites for the same soil layer and season ($P < 0.05$).

Study site	Soil depth	BD-gm cm ⁻³	pH	N -Kg ha ⁻¹	P-Kg ha ⁻¹	K-Kg ha ⁻¹	Soil Moisture (%)
Tupia	0-10	1.29±0.12	5.21±0.54	351.23±5.76	23.08±2.56	215.04±8.56	18.54±2.13
	10-20	1.31±0.14	7.23±0.32	374.28±4.23	23.76±2.90	210.35±3.80	24.28±2.59
	20-40	1.34±0.12	5.41±0.20	310.86±7.85	18.90±3.40	182.90±5.76	21.35±3.03
Podumoni	0-10	1.25±0.13	5.85±0.12	289.23±3.46	21.12±1.25	216.90±5.73	21.09±1.76
	10-20	1.31±0.21	6.43±0.34	272.56±3.90	24.03±1.45	215.36±2.84	22.14±2.16
	20-40	1.32±0.14	5.75±0.40	282.57±5.82	20.21±2.35	214.84±2.20	18.29±1.25
Jogduar	0-10	1.25±0.18	5.47±0.24	312.70±3.64	29.06±1.58	257.04±6.56	23.27±1.15
	10-20	1.29±0.28	6.75±0.28	324.26±3.25	24.15±2.15	238.05±1.87	24.18±1.06
	20-40	1.30±0.21	6.32±0.25	311.80±3.25	20.70±2.94	189.04±4.29	18.04±1.48
Kohora	0-10	1.24±0.16	4.95±0.56	308.54±6.05	26.14±2.45	301.45±9.34	20.13±1.87
	10-20	1.28±0.64	6.35±0.60	315.14±5.64	20.15±1.64	286.79±7.83	23.08±1.07
	20-40	1.32±0.17	5.58±0.62	301.29±5.28	18.25±3.13	269.46±5.24	19.87±2.14
Boko	0-10	1.23±0.23	5.85±0.21	309.24±4.03	28.03±1.50	245.04±5.26	19.08±1.73
	10-20	1.26±0.32	6.87±0.26	315.86±3.83	25.03±3.15	230.56±4.84	23.09±2.87
	20-40	1.27±0.14	5.41±0.20	321.23±5.06	22.06±3.92	212.54±2.70	18.56±1.90

Table 1- Bulk density, soil moisture, and contents of the main soil nutrients (mean ± standard deviation, n=3) in the 0–40cm layer of the five plantation sites. BD: bulk density, P: Phosphorus, K: Potassium, N: Nitrogen.

4: DISCUSSION

In an agroforestry system, nutrient succession depends on different factors including location, climatic condition, topography, and biotic components of the area. (Bhattarai and Mandal, 2016). The addition of organic substances in the form of litter and fine roots regulates the amount of soil nutrients. Decomposition and mineralization of organic substances by soil microorganisms are the main processes of nutrient input in the different soil depths (Dash *et al.*, 2019). Results in the present study also revealed that soil depth and land use systems affect soil properties like pH, bulk density, organic matter, and other nutrient concentrations. The increasing trends of pH with depth in the present study may be due to the leaching of bases with the percolation of water, which conforms with the findings of Haque *et al.*, (2020). The other factors may be due to the frequent uptake of nutrients by the crops and the decrease in organic matter accumulation with the soil depth (Saini and Grewal, 2014). The bulk density in the present study showed an increasing trend from the topsoil to the subsoil and again decreased down in the bottom soil. A similar trend of variation in soil bulk density was earlier reported by Tian *et al.*, (2021) in a study conducted in the Loess Plateau of China. The increase in bulk density with increasing soil depth in the present study may be due to the low accumulation of organic matter and overburden of the upper soil layers as reported by Pathak and Reddy (2021).

Soil nitrogen(N) is essentially a critical element in the soil ecosystem and plays a crucial role in various processes. Though it is a key component of important biomolecules, the bio-available forms of

N in the soil are often limited and can constrain plant growth and overall ecosystem functioning in different soil layers (Bangroo *et al.*, 2018, Ashraf *et al.*, 2022). Available N present in this study showed an increasing trend from the topsoil (0-10cm) to the subsoil (10-20cm) and again decreased down in the bottom soil (20-40cm). A decrease in total nitrogen from top soil to bottom soil was also reported by Malo *et al.*, (2005) who explained that a decrease in total nitrogen with increasing depth was due to declining humus with depth.

Soil-available phosphorus (SAP) and soil-available potassium (SAK) are also important components of soil and essential parts of plant growth and development. SAP is influenced by many factors, including the soil-forming material, geographical location, and soil properties (Provost *et al.*, 2016). The content of SAP in some previous studies (Li *et al.*, 2015) showed a downward trend in different sampling sites. In the present study, the SAP showed an increasing trend from topsoil (0-10cm) to the subsoil (10-20cm) and decreased down in the bottom soil which conforms with the findings of Satish *et al.*, (2018) who studied about the vertical distribution of soil nutrient of in Andhra Pradesh, India. The higher SAP contents in subsoil (10-20cm) in the present study, may be due to the presence of organic matters and supplementation of depleted SAP by external sources like fertilizers as observed by Paul (1984). Soil available potassium (SAK), in the present study, showed a decreasing trend from topsoil to the bottom soil which is in line with the findings of Sharma *et al.*, (2013) who studied the distribution of plant nutrients in the alluvial soil of Aravalli range of India.

Plant biomass and soil C pools in agroforestry systems can be considered of great importance for reducing carbon dioxide from the atmosphere (Jiang *et al.*, 2006)). Soil Organic Carbon (SOC) is the most stable pool that receives inputs from leaf litter, root exudates, and straws from trees and intercrops (Brar *et al.*, 2013). Globally, the vertical distribution of SOC had a stronger association with vegetation than with climate (Jobbagy and Jackson, 2000). Among the five different study sites in the present study, a significant difference in SOC contents in different soil layers was recorded (Figure 2) which can be explained partly due to the differences in the distribution of roots that affect the relative amount of carbon in the soil (Jackson *et al.*, 1996). In the present study, the SOC contents in four different seasons were recorded maximum in the topsoil (0-10cm) and sub-soil (10-20cm) and minimum in the bottom soil (20-40cm) which conforms with the findings of Roy and Singh (1995) who studied about the seasonal dynamics of soil nutrients in relation to the fine roots.

5: CONCLUSION

Knowledge of soil properties and the contents of soil organic matter is important in assessing the long-term nutrient-supplying capacity of soil for crops. It is also important in formulating an effective and sustainable fertilizer program for a given set of soil. Soil depth has significant effects on soil properties and nutrient availability and plays a major role in influencing plant growth. In the present study soil pH was lower but BD and organic matter content were higher in the top soil compared to the sub-soil and bottom soil layers. Soil nutrients such as N, P, and K were also higher in upper soil layers in comparison to subsurface soil, showing variation among the different study sites. This suggests that the topsoil might be more fertile and can support better plant growth. Soil organic carbon (SOC) in the

present study, showed distinct seasonal variation in all the study sites. The maximum value of SOC recorded during the monsoon season might be due to its accumulation when plant growth and nutrient demands are minimal. In the future, a thorough study of soils of different locations may help planners to formulate an effective nutrient fertilizer.

6: REFERENCES

- Ahmed, A. A., and Hazarika D. N., 2007, *Agroforestry Systems and Practices Prevailing in Assam*, in Puri, S., and Panwar, P., (Eds.), *Agroforestry Systems and Practices*, New India Publishing Agency, New Delhi, India, 347-366.
- Anonymous, 2004, *Manual of Sericulture*, Directorate of Sericulture, Government of Assam, India, 121-123.
- Ashraf, M., Bhat, G.A., and Ashraf, N., 2022, *Impact of Cement Dust on Soil Physico-Chemical Characteristics Around Khrew Cement Factory in District Pulwama*, *Journal of Himalayan Ecology and Sustainable Development*, **22**, 1-116.
- Bangroo, S.A., Itoo, H., Mubarak, T., and Malik, A.R., 2018, *Soil Organic Carbon and Total Nitrogen in Temperate Apple Orchards of South Kashmir*, *International Journal of Ecology and Environmental Sciences*, **44** (3), 287-292
- Bhagabati, A., Bora, A.K., and Kar, B.K., 2001, *Geography of Assam*, Rajesh Publication, New Delhi, 232-243
- Bhattarai, K.P., and Mandal, T.R., 2016, *Relationship Between Soil Microbial Biomass and Fine Roots in Tarai and Hill Sal (Shorea robusta Gaertn.) Forests of Eastern Nepal*, *International Journal of Ecology and Environmental Sciences*, **42**(S), 19-28.
- Brar, B.S., Singh, K., Dheri, G.S., and Kumar, B., *Carbon Sequestration and Soil Carbon Pools in a Rice–Wheat Cropping System: Effect of Long-Term Use of Inorganic Fertilizers and Organic Manure*, *Soil and Tillage Research*, **128**, 30-36.
- Choudhury, S.N., 1982, *Muga Silk Industry*, Directorate of Sericulture, Government of Assam, India, 121-154.
- Choudhury, S.N., and Vajczikova, I., 2002, *Variation in the Essential Oil Composition of Persea bombycina (King ex Hook.f.) Kost and its Effect on Muga Silk Worm (Antheraea assama Ww.) – A New Report*, *Indian Journal of Chemistry*, **42**, 641-647.
- Das, A.K., Nath, A.J., and Kalita, R.M., 2015, *Allometric Equations for Estimating Above and Belowground Biomass in Tea (Camellia sinensis (L.) O. Kuntze) Agroforestry System of Barak Valley, Assam, Northeast India*, *Biomass Bioenergy*, **83**, 42-49.
- Dash, P.K., Mishra, A., and Saren, S., 2019, *Vertical Distribution of Available Nutrients in an Eastern Indian Catena*, *Annals of Plant and Soil Research*, **21**(4), 320-325.
- Dhyani, S.K., Chauhan, D.S., Kumar, D., Kushwaha R.V., and Lepcha, S.T., 1996, *Sericulture-Based Agroforestry Systems for Hilly Areas of North-East India*, *Agroforestry Systems*, **34**, 247-258.
- Gosain, B.G., Negi G.C.S., Dhyani, P.P., Bargali, S.S., and Saxena, R., 2015, *Carbon Stock in Vegetation and Soil Components in a Watershed of Kumaun Himalaya*, *International Journal of Ecology and Environmental Sciences*, **41** (3-4), 177-188
- Haque, T.S., Afrin, S., Jahan, I., Mian, M.J.A., and Hossain, M.A., 2020, *Vertical Distribution of Soil Nutrients under Different Land Use Systems in Bangladesh*, *Journal of Arid land Agriculture*, **6**, 6-12.
- Jackson, M.L., 1967, *Soil Chemical Analysis*, Prentice Hall of India, New Delhi. 67-87.

- Jackson, M.L., 1973, *Soil Chemical Analysis*, Prentice Hall of India, New Delhi.
- Jackson, R. B., Canadell, J., Ehleringer, J.R., Mooney, H.A., Sala, O.E., and Schulze, E.D., 1996, *A Global Analysis of Root Distributions for Terrestrial Biomes*, *Oecologia* **108**,389–411.
- Jiang, P.K., Xu, Q.F., Xu, Z.H., Cao, Z.H., 2006, *Seasonal Changes in Soil Labile Organic Carbon Pools within a Phyllostachys Praecox Stand under High-rate Fertilization and Winter Mulch in Subtropical China*, *Forest Ecology and Management*, **236**, 30–36.
- Jobbagy, E.G., and Jackson, R.B., 2000, *The Vertical Distribution of Soil Organic Carbon and its Relation to Climate and Vegetation*, *Ecological Applications*, **10**(2), 423–436.
- Li, L., Yao, Y., Qin, F., 2015, *Spatial Variability of Soil Total Nitrogen, Available Phosphorus and Available Potassium in Huanghuadianzi Watershed*, *Chinese Journal of Ecology*, **34**,373–379.
- Ling-fei, X., Peng Z., Qing-fang, H., Zhi-hui, L., Bao-ping, Y., and Jung-feng, N., 2013, *Spatial Distribution of Soil Organic Matter and Nutrients in the Pear Orchard Under Clean and Sod Cultivation Models*, *Journal of Integrative Agriculture*, **12**(2), 344-351.
- Malo, D.D., Schumacher, T.E., and Doolittle, J.J., 2005, *Long-Term Cultivation Impacts on Selected Soil Properties in the Northern Great Plains*, *Soil and Tillage Research*, **81**(2),277-291.
- Mandal, R., 2014, *Flood, Cropping Pattern Choice and Return in Agriculture: A Study of Assam Plains, India*, *Economic Analysis and Policy*, **44**, 333-344.
- Negash, M., Starr, M., Kanninen, M., and Berhe, L., 2013, *Allometric Equation for Estimating Aboveground Biomass of Coffea Arabica L. Grown in the Rift Valley Escarpment of Ethiopia*, *Agroforestry Systems*, **87**,953-966.
- Pandey, H. N., Tomar, J.M.S., Tripathi, O.P., and Upadhyay, K., 2007., *Agroforestry Systems and Practices Prevailing in Meghalaya*, in S Puri, S., and Panwar, P., (Eds), *Agroforestry Systems and Practices*, New India Publishing Agency, New Delhi, India, 357-365.
- Pandey, P.N., Sharan, S.K., and Mishra, P.K., 2005, *Silk culture, A Biochemical Approach*. IBH Publishing Corporation, New Delhi 110002.
- Paul, E.A.,1984, *Dynamics of Organic Matter in Soils*, *Plant and Soil*, **7**, 275- 285.
- Pribyl, D.W., 2010, *A Critical Review of the Conventional SOC to SOM Conversion Factor*, *Geoderma*,**156**(3-4), 75-83.
- Provost, R., Hodgkins, D., Raman, A., and Nicol, H., 2016,*Isolated Trees in Pasture Landscapes Contribute to and Enhance Soil Health: A Study in Central-West New South Wales, Australia*, *International Journal of Ecology and Environmental Sciences*, **42** (2), 93-107.
- Rao R. G., Prabhakar, M., Venkatesh, G., Srinivas, I., and Sammi Reddy, K., (Eds),2018, *Agroforestry Opportunities for Enhancing Resilience to Climate Change in Rainfed Areas*, ICAR - Central Research Institute for Dryland Agriculture, Hyderabad, India.
- Roy, S., and Singh J.S., 1995, *Seasonal and Spatial Dynamics of Plant Available N and P Pools and Mineralisation in Relation to the Fine Roots in Dry Tropical Forest Habitat*, *Soil Biology and Biochemistry* **27**, 33-40.
- Saini, J., and Grewal, K.S., 2014, *Vertical Distribution of Different Forms of Potassium and Their Relationship with Different Soil Properties in Some Haryana Soil Under Different Crop Rotation*, *Advances in Plants and Agriculture Research*, **2**, 48-52.
- Satish, S., Naidu, M.V.S., and Ramana, K.V., 2018, *Vertical Distribution of Available Nutrients in Soils of Brahmanakotkur Watershed of Kurnool District in Andhra Pradesh*, *International Journal of Chemical Studies*, **6**, 2916-2925

- Sharma, R.P., Singh, R.S., and Sharma, S.S., 2013, *Vertical Distribution of Plant Nutrients in Alluvial Soils of Aravalli Range and Optimization of Land Use*, International Journal of Pharmaceutical and Chemical Sciences, **2 (3)**, 24-32.
- Taher, M., and Ahmed, P., 2005, *Assam: A Geographical Profile*. Mani Manik Prakash, Guwahati.
- Tian, H., Qiao, J., Zhu, Y., Jia, X., and Shao, M., 2021, *Vertical Distribution of Soil Available Phosphorus and Soil Available Potassium in the Critical Zone on the Loess Plateau, China*. Scientific Reports 11:3159 | <https://doi.org/10.1038/s41598-021-82677-4>.
- Upadhyay, T., 2022, *Machilus gamblei (Lauraceae): A Potential Plant for Carbon Sequestration*, Journal of Indian Botanical Society, **103(3)**, 252-256, <https://doi.org/10.5958/2455-7218.2022.00036.5>
- Upadhyay, T., and Baruah, P.P., 2019, *Allometric Models for Estimating Biomass of Persea bombycina Kost. Agroforestry Systems of Assam*, International Journal of Ecology and Development, **34(3)**, 105-112.
- Walkley, A., and Black, I.A., 1934, *An Examination of the Degtjareff Method for Determining Soil Organic Matter and a Proposed Modification of the Chromic Acid Titration Method*, Soil Science, **37**, 29–39.