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Study the Comparing Soil Fertility in Bamboo Plantations and Mixed Bamboo Forests in the Region of Chhattisgarh

Neha Soan[1*], S.S. Dhuria[2] and Priti Singh[1]

[1]Research Scholar, Department of Forestry Wildlife and Environmental Sciences, Guru Ghasidas Vishwavidyalay, Bilaspur (Chhattisgarh), India.

[2]Professor, Department of Forestry Wildlife and Environmental Sciences, Guru Ghasidas Vishwavidyalay, Bilaspur (Chhattisgarh), India.

(Corresponding author: Neha Soan)*

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ABSTRACT: The study conducted to compared soil fertility parameters in bamboo plantations and mixed bamboo forests across three districts (Raigarh, Bilaspur and Korba) of Chhattisgarh, India. Analysis of pH, electrical conductivity (EC), organic carbon (OC), and available nitrogen (N), phosphorus (P) and potassium (K) showed significant variation across soil depths and land use systems. Soil samples were collected from pure bamboo plantations and mixed bamboo forests at 10 cm, 20 cm and 30 cm depth. Analysis of pH (5.0-8.0), electrical conductivity (0.3-0.8 dS/m), organic carbon (0.15-0.89%), and available nitrogen (200-320 kg/ha), phosphorus (4-24 kg/ha) and potassium (190-370 kg/ha) showed significant variation across soil depths and land use systems. Overall, mixed bamboo forests exhibited lower pH (5.0-6.0) and higher EC (0.5-0.8 dS/m) compared to plantations (pH 6.0-8.0, EC 0.3-0.7 dS/m). OC was highest in deeper layers (0.8-0.9%) of plantations but more varied (0.15-0.8%) across depths in mixed forests. Available N trended higher (250-320 kg/ha) in upper layers of both systems. P levels were generally higher (15-24 kg/ha) at shallower depths in plantations but more variable (4-18 kg/ha) in mixed forests. K availability was also higher (260-370 kg/ha) in upper layers of plantations but less uniform (190-340 kg/ha) in mixed forests. The study demonstrates that soil fertility is influenced by depth, land use and their interactions, highlighting the need for tailored soil management practices in these systems.

Keywords: Bamboo plantations, Mixed bamboo forests, pH, electrical conductivity (EC), organic carbon (OC), Nitrogen (N), Phosphorus (P) and Potassium (K).

INTRODUCTION

Soil fertility plays an important role in plant growth and sustainability of forest ecosystems (Yang *et al.,* 2021). Bamboo plantations and mixed bamboo forests are increasingly gaining importance in India due to their multiple benefits such as biomass production, carbon sequestration, soil conservation and biodiversity enhancement (Barbosa *et al.,* 2014). Chhattisgarh state in central India supports significant areas under bamboo plantations and mixed bamboo forests. However, limited research has been done on comparing the soil fertility status in bamboo plantations and mixed bamboo forests of Chhattisgarh.

Soil fertility is a measure of the available nutrients in the soil for plant growth. Several studies have shown that mixed forest systems tend to have higher soil organic carbon, nitrogen and other nutrients compared to plantation monocultures due to greater biodiversity and complex litter inputs (Yan *et al.,* 2016). In contrast, bamboo plantations often involve clearance of natural forests which can deplete soil organic matter and nutrients over time if not properly managed (Cheng *et al.,* 2020). Maintaining soil fertility is essential for long term sustainability and productivity of forest ecosystems (Tewari *et al.,* 2019).

This study aims to compare key soil fertility parameters like soil organic carbon, total nitrogen, available phosphorus and potassium in bamboo plantations and mixed bamboo forests in Chhattisgarh. The specific objectives are to analyze and compare soil fertility status under different plantation and forest systems and identify major factors influencing soil fertility in these systems. The findings can provide valuable insights into sustainable management of bamboo resources in Chhattisgarh.

METHODOLOGY

The study evaluated the effect of different soil status on soil fertility in bamboo plantations and forests across Raigarh, Bilaspur and Korba districts of Chhattisgarh. Soil samples were collected from pure bamboo plantations and mixed bamboo forests at three depth levels and analyzed for physico-chemical properties like pH, EC, organic carbon, available nitrogen, phosphorus and potassium.

1. Ph: Soil samples were collected from three different depths (10 cm, 20 cm and 30 cm) from pure bamboo plantations and mixed bamboo forests in three locations (Raigarh, Bilaspur and Korba). The soil pH was measured using a digital pH meter. The data was statistically analyzed to determine the effect of treatments and locations on soil pH.

2. EC: Soil samples were collected from three different depths from pure bamboo plantations and mixed bamboo forests in three locations. The soil EC was measured using a conductivity meter. The data was statistically analyzed.

3. OC: Soil samples were collected and assayed for organic carbon content by wet digestion method. The data was statistically analyzed.

4. Available N in soil: Available nitrogen was estimated by alkaline permanganate method. The data was statistically analyzed.

5. Available P in soil: Available phosphorus was estimated using Olsen's method. The data was statistically analyzed.

6. Available K in soil: Available potassium was estimated using flame photometer method. The data was statistically analyzed.

The mean values were compared at 5% level of significance using SEM and CD. CV% was calculated to examine precision of results. Treatment combinations showing significantly highest and lowest parameters were identified.

RESULT

A. To effect soil fertility in bamboo plantations and mixed bamboo forests on Soil pH

The pH of soil plays a crucial role in determining its fertility and suitability for plant growth. Effect of different treatments on soil pH in bamboo plantations and mixed bamboo forests across three locations: Raigarh, Bilaspur, and Korba present in Table 1.

Pure bamboo plantation: Among the data, pure bamboo plantation (10 cm) was strongly acidic (5.33), neutral (6.53) and acidic (5.93) during the year 2021-22, 2022-23 and pooled mean respectively. Pure bamboo plantation (20 cm) was acidic (5.84), neutral (7.02) and acidic (6.43) during the year 2021-22, 2022-23 and pooled mean respectively. Pure bamboo plantation (30 cm) was acidic (5.67), neutral (6.71) and acidic (6.19) during the year 2021-22, 2022-23 and pooled mean respectively in Raigarh district.

Among the data, pure bamboo plantation (10 cm) was alkaline (7.74), alkaline (8.74) and alkaline (8.24) during the year 2021-22, 2022-23 and pooled mean respectively. Pure bamboo plantation (20 cm) was acidic (5.85), neutral (6.84) and acidic (6.34) during the year 2021-22, 2022-23 and pooled mean respectively. Pure bamboo plantation (30 cm) was neutral (6.57), alkaline (7.54) and neutral (7.06) during the year 2021-22, 2022-23 and pooled mean respectively in Bilaspur district.

Among the data, pure bamboo plantation (10 cm) was strongly alkaline (5.20) and acidic (6.14), acidic (5.67) during the year 2021-22, 2022-23 and pooled mean respectively. Pure bamboo plantation (20 cm) was acidic (5.85), acidic (6.27) and acidic (6.06) during the year 2021-22, 2022-23 and pooled mean respectively. Pure bamboo plantation (30 cm) was acidic (5.65), neutral (6.73) and acidic (6.19) during the year 2021-22, 2022-23 and pooled mean respectively in Korba district.

Mixed bamboo forest: Among the data, mixed bamboo forest (10 cm) was strongly acidic (5.16), neutral (6.64) and acidic (5.90) during the year 2021-22, 2022-23 and pooled mean respectively. Mixed bamboo forest (20 cm) was strongly acidic (5.33), acidic (6.02) and acidic (5.67) during the year 2021-22, 2022-23 and pooled mean respectively. Mixed bamboo forest (30 cm) was strongly acidic (5.24), acidic (6.04) and acidic (5.64) during the year 2021-22, 2022-23 and pooled mean respectively in Raigarh district.

Among the data, mixed bamboo forest (10 cm) was neutral (6.71), alkaline (7.65) and acidic (7.18) during the year 2021-22, 2022-23 and pooled mean respectively. Mixed bamboo forest (20 cm) was strongly acidic (6.35), acidic (7.36) and neutral (6.85) during the year 2021-22, 2022-23 and pooled mean respectively. Mixed bamboo forest (30 cm) was acidic (5.84), neutral (6.85) and acidic (6.35) during the year 2021-22, 2022-23 and pooled mean respectively in Bilaspur district.

Among the data, mixed bamboo forest (10 cm) was strongly acidic (5.04), neutral (6.65) and strongly acidic (5.35) during the year 2021-22, 2022-23 and pooled mean respectively. Mixed bamboo forest (20 cm) was strongly acidic (5.52), acidic (5.98) and acidic (5.75) during the year 2021-22, 2022-23 and pooled mean respectively. Mixed bamboo forest (30 cm) was strongly acidic (5.47), acidic (5.71) and acidic (5.59) during the year 2021-22, 2022-23 and pooled mean respectively in Korba district.

The soil pH was evaluated at different depths (10 cm, 20 cm, 30 cm) in pure bamboo plantations and mixed bamboo forests across three locations - Raigarh, Bilaspur and Korba. The results showed variation in soil pH ranging from strongly acidic to alkaline across locations and depths in both plantation types. Overall, the soil pH trended acidic to neutral in pure bamboo plantations and acidic in mixed bamboo forests across the three districts. The variation in soil pH highlights the effect of bamboo plantations and mixed bamboo forests on soil fertility. The soil pH in bamboo plantations and mixed bamboo forests exhibits significant variation across different depths and locations, influencing the fertility essential for optimal growth. In pure bamboo plantations, the pH ranges from acidic to neutral, while mixed bamboo forests typically show a trend towards stronger acidity. This variability underscores the importance of location-specific soil management to enhance bamboo productivity and forest health. The results obtained in the present study are supported by the works of Kumari and Bhardwaj (2017); Tu *et al.* (2013).

B. To effect soil fertility in bamboo plantations and mixed bamboo forests on soil EC (Electrical conductivity)

Effect of different treatments on soil EC (Electrical conductivity) in bamboo plantations and mixed bamboo forests across three locations: Raigarh, Bilaspur, and Korba present in Table 2.

Pure bamboo plantation: The data pertaining significantly highest EC in pure bamboo plantation (30

cm) was observed (0.62) and the significantly lowest EC in pure bamboo plantation (20 cm) was observed (0.41) during the year 2021-22 in Raigarh district. The data pertaining significantly highest EC in pure bamboo plantation (20 cm) was observed (0.61) and the significantly lowest EC in pure bamboo plantation (10 cm) was observed (0.51) during the year 2022-23 in Raigarh district. The data pertaining significantly highest EC in pure bamboo plantation (30 cm) was observed (0.58) and the significantly lowest EC in pure bamboo plantation (10 cm) was observed (0.46) during the pooled mean in Raigarh district.

The data pertaining significantly highest EC in pure bamboo plantation (10 cm) was observed (0.60) and the significantly lowest EC in pure bamboo plantation (20 cm) was observed (0.41) during the year 2021-22 in Bilaspur district. The data pertaining significantly highest EC in pure bamboo plantation (10 cm) was observed (0.71) and the significantly lowest EC in pure bamboo plantation (20 cm) was observed (0.65) during the year 2022-23 in Bilaspur district. The data pertaining significantly highest EC in pure bamboo plantation (10 cm) was observed (0.66) and the significantly lowest EC in pure bamboo plantation (20 cm) was observed (0.53) during the pooled mean in Bilaspur district.

The data pertaining significantly highest EC in pure bamboo plantation (20 cm) was observed (0.51) and the significantly lowest EC in pure bamboo plantation (30 cm) was observed (0.40) during the year 2021-22 in Korba district. The data pertaining significantly highest EC in pure bamboo plantation (20 cm) was observed (0.71) and the significantly lowest EC in pure bamboo plantation (30 cm) was observed (0.62) during the year 2022-23 in Korba district. The data pertaining significantly highest EC in pure bamboo plantation (20 cm) was observed (0.61) and the significantly lowest EC in pure bamboo plantation (30 cm) was observed (0.51) during the pooled mean in Korba district.

Mixed bamboo forest: The data pertaining significantly highest EC in mixed bamboo forest (30 cm) was observed (0.82) and the significantly lowest EC in mixed bamboo forest (20 cm) was observed (0.32) during the year 2021-22 in Raigarh district. The data pertaining significantly highest EC in mixed bamboo forest (30 cm) was observed (0.81) and the significantly lowest EC in mixed bamboo forest (20 cm) was observed (0.54) during the year 2022-23 in Raigarh district. The data pertaining significantly highest EC in mixed bamboo forest (30 cm) was observed (0.82) and the significantly lowest EC in mixed bamboo forest (20 cm) was observed (0.43) during the pooled mean in Raigarh district.

The data pertaining significantly highest EC in mixed bamboo forest (20 cm) was observed (0.52) and the significantly lowest EC in mixed bamboo forest (30 cm) was observed (0.43) during the year 2021-22 in Bilaspur district. The data pertaining significantly highest EC in mixed bamboo forest (10 cm) was observed (0.64) and the significantly lowest EC in mixed bamboo forest (30 cm) was observed (0.57) during the year 2022-23 in Bilaspur district. The data pertaining significantly highest EC in mixed bamboo forest (10 cm) was observed (0.57) and the significantly lowest EC in mixed bamboo forest (30 cm) was observed (0.50) during the pooled mean in Bilaspur district.

The data pertaining significantly highest EC in mixed bamboo forest (30 cm) was observed (0.82) and the significantly lowest EC in mixed bamboo forest (20 cm) was observed (0.43) during the year 2021-22 in Korba district. The data pertaining significantly highest EC in mixed bamboo forest (20 cm) was observed (0.58) and the significantly lowest EC in mixed bamboo forest (10 cm) was observed (0.46) during the year 2022-23 in Korba district. The data pertaining significantly highest EC in mixed bamboo forest (20 cm) was observed (0.56) and the significantly lowest EC in mixed bamboo forest (10 cm) was observed (0.38) during the pooled mean in Korba district.

The data across three locations—Raigarh, Bilaspur, and Korba—indicates that soil electrical conductivity (EC) varies significantly within different depths and types of bamboo plantations. Specifically, pure bamboo plantations tend to exhibit a lower EC as compared to mixed bamboo forests. This might be attributed to the differences in vegetation diversity between pure and mixed settings. In pure bamboo plantations, the uniformity of species might lead to a more consistent uptake of nutrients and water, thereby reducing soil EC. In contrast, mixed bamboo forests, with a variety of plant species, might foster a more complex soil environment with varied nutrient and moisture dynamics, leading to higher EC values. Additionally, the data suggests that EC tends to vary with soil depth, which could be reflective of root distribution patterns and soil texture variations at different depths. This variability in EC is crucial for understanding soil health and fertility, as it influences nutrient availability, moisture retention, and overall plant growth conditions within the ecosystem. The finding of present study is in accordance with those of Kumari and Bhardwaj (2017); Tu *et al.* (2013).

C. To effect soil fertility in bamboo plantations and mixed bamboo forests on soil OC (Organic carbon)

Effect of different treatments on soil OC (Organic carbon) in bamboo plantations and mixed bamboo forests across three locations: Raigarh, Bilaspur, and Korba present in Table 3.

Pure bamboo plantation: Analysis of the data revealed that pure bamboo plantation (30 cm) was significantly highest OC observed (0.45) and the significantly lowest OC in pure bamboo plantation (20 cm) was observed (0.17) during the year 2021-22 in Raigarh district. Analysis of the data revealed that pure bamboo plantation (30 cm) was significantly highest OC observed (0.65) and the significantly lowest OC in pure bamboo plantation (20 cm) was observed (0.35) during the year 2022-23 in Raigarh district. Analysis of the data revealed that pure bamboo plantation (30 cm) was significantly highest OC observed (0.55) and the significantly lowest OC in pure bamboo plantation (20

cm) was observed (0.26) during the pooled mean in Raigarh district.

Analysis of the data revealed that pure bamboo plantation (30 cm) was significantly highest OC observed (0.76) and the significantly lowest OC in pure bamboo plantation (10 cm) was observed (0.61) during the year 2021-22 in Bilaspur district. Analysis of the data revealed that pure bamboo plantation (30 cm) was significantly highest OC observed (0.89) and the significantly lowest OC in pure bamboo plantation (10 cm) was observed (0.81) during the year 2022-23 in Bilaspur district. Analysis of the data revealed that pure bamboo plantation (30 cm) was significantly highest OC observed (0.83) and the significantly lowest OC in pure bamboo plantation (10 cm) was observed (0.71) during the pooled mean in Bilaspur district.

Analysis of the data revealed that pure bamboo plantation (10 cm) was significantly highest OC observed (0.60) and the significantly lowest OC in pure bamboo plantation (20 cm) was observed (0.15) during the year 2021-22 in Korba district. Analysis of the data revealed that pure bamboo plantation (10 cm) was significantly highest OC observed (0.70) and the significantly lowest OC in pure bamboo plantation (20 cm) was observed (0.26) during the year 2022-23 in Korba district. Analysis of the data revealed that pure bamboo plantation (10 cm) was significantly highest OC observed (0.65) and the significantly lowest OC in pure bamboo plantation (20 cm) was observed (0.21) during the pooled mean in Korba district.

Mixed bamboo forest: Analysis of the data revealed that mixed bamboo forest (30 cm) was significantly highest OC observed (0.46) and the significantly lowest EC in mixed bamboo forest (20 cm) was observed (0.14) during the year 2021-22 in Raigarh district. Analysis of the data revealed that mixed bamboo forest (30 cm) was significantly highest OC observed (0.75) and the significantly lowest EC in mixed bamboo forest (20 cm) was observed (0.37) during the year 2022-23 in Raigarh district. Analysis of the data revealed that mixed bamboo forest (30 cm) was significantly highest OC observed (0.61) and the significantly lowest EC in mixed bamboo forest (20 cm) was observed (0.25) during the pooled mean in Raigarh district.

Analysis of the data revealed that mixed bamboo forest (30 cm) was significantly highest OC observed (0.62) and the significantly lowest EC in mixed bamboo forest (10 cm) was observed (0.16) during the year 2021-22 in Bilaspur district. Analysis of the data revealed that mixed bamboo forest (20 cm) was significantly highest OC observed (0.82) and the significantly lowest EC in mixed bamboo forest (10 cm) was observed (0.34) during the year 2022-23 in Bilaspur district. Analysis of the data revealed that mixed bamboo forest (20 cm) was significantly highest OC observed (0.71) and the significantly lowest EC in mixed bamboo forest (10 cm) was observed (0.25) during the pooled mean in Bilaspur district.

Analysis of the data revealed that mixed bamboo forest (20 cm) was significantly highest OC observed (0.18) and the significantly lowest EC in mixed bamboo forest (30 cm) was observed (0.16) during the year 2021-22 in Korba district. Analysis of the data revealed that mixed bamboo forest (20 cm) was significantly highest OC observed (0.36) and the significantly lowest EC in mixed bamboo forest (30 cm) was observed (0.34) during the year 2022-23 in Korba district. Analysis of the data revealed that mixed bamboo forest (20 cm) was significantly highest OC observed (0.26) and the significantly lowest EC in mixed bamboo forest (30 cm) was observed (0.26) during the pooled mean in Korba district.

The varied soil organic carbon (OC) levels in different treatments across bamboo plantations and mixed bamboo forests primarily result from differences in organic matter accumulation and decomposition rates at various soil depths. In pure bamboo plantations, higher OC at deeper layers (30 cm) indicates greater organic matter accumulation possibly due to root turnover and less disturbance compared to surface layers. Conversely, the lower OC at intermediate depths (20 cm) could reflect less organic input or higher decomposition rates. In mixed bamboo forests, the variation in OC levels at different depths and years can be attributed to the diversity of species contributing different types and amounts of organic residues, influencing both the rate of organic matter inputs and its subsequent decomposition. This biological activity varies with depth due to factors like moisture availability, root density, and microbial activity, which are influenced by the mixed species composition and their interactions with the environment. The results obtained in the present study are supported by the works of Kumari and Bhardwaj (2017); Tu *et al.,* (2013).

D. To effect soil fertility in bamboo plantations and mixed bamboo forests on available N (Nitrogen kg/ha) in soil

Effect of different treatments on available N (Nitrogen kg/ha) in soil of bamboo plantations and mixed bamboo forests across three locations: Raigarh, Bilaspur, and Korba present in Table 4.

Pure bamboo plantation: A review of the findings pointed to pure bamboo plantation (20 cm) was significantly highest N observed (276.19 kg/ha) and the significantly lowest N in pure bamboo plantation (10 cm) was observed (213.11 kg/ha) during the year 2021-22 in Raigarh district. A review of the findings pointed to pure bamboo plantation (30 cm) was significantly highest N observed (282.12 kg/ha) and the significantly lowest N in pure bamboo plantation (10 cm) was observed (217.12 kg/ha) during the year 2022-23 in Raigarh district. A review of the findings pointed to pure bamboo plantation (30 cm) was significantly highest N observed (279.12 kg/ha) and the significantly lowest N in pure bamboo plantation (10 cm) was observed (215.12 kg/ha) during the pooled mean in Raigarh district.

A review of the findings pointed to pure bamboo plantation (20 cm) was significantly highest N observed (301.09 kg/ha) and the significantly lowest N in pure bamboo plantation (10 cm) was observed (225.16 kg/ha) during the year 2021-22 in Bilaspur district. A

review of the findings pointed to pure bamboo plantation (20 cm) was significantly highest N observed (322.46 kg/ha) and the significantly lowest N in pure bamboo plantation (10 cm) was observed (237.20 kg/ha) during the year 2022-23 in Bilaspur district. A review of the findings pointed to pure bamboo plantation (20 cm) was significantly highest N observed (311.78 kg/ha) and the significantly lowest N in pure bamboo plantation (10 cm) was observed (231.18 kg/ha) during the pooled mean in Bilaspur district.

A review of the findings pointed to pure bamboo plantation (30 cm) was significantly highest N observed (250.24 kg/ha) and the significantly lowest N in pure bamboo plantation (10 cm) was observed (200.11 kg/ha) during the year 2021-22 in Korba district. A review of the findings pointed to pure bamboo plantation (20 cm) was significantly highest N observed (260.25 kg/ha) and the significantly lowest N in pure bamboo plantation (10 cm) was observed (220.24 kg/ha) during the year 2022-23 in Korba district. A review of the findings pointed to pure bamboo plantation (20 cm) was significantly highest N observed (255.22 kg/ha) and the significantly lowest N in pure bamboo plantation (10 cm) was observed (210.18 kg/ha) during the pooled mean in Korba district.

Mixed bamboo forest: A review of the findings pointed to mixed bamboo forest (30 cm) was significantly highest N observed (288.26 kg/ha) and the significantly lowest N in mixed bamboo forest (10 cm) was observed (213.26 kg/ha) during the year 2021-22 in Raigarh district. A review of the findings pointed to mixed bamboo forest (30 cm) was significantly highest N observed (291.13 kg/ha) and the significantly lowest N in mixed bamboo forest (10 cm) was observed (218.28 kg/ha) during the year 2022-23 in Raigarh district. A review of the findings pointed to mixed bamboo forest (30 cm) was significantly highest N observed (289.70 kg/ha) and the significantly lowest N in mixed bamboo forest (10 cm) was observed (215.77 kg/ha) during the pooled mean in Raigarh district.

A review of the findings pointed to mixed bamboo forest (10 cm) was significantly highest N observed (313.13 kg/ha) and the significantly lowest N in mixed bamboo forest (30 cm) was observed (105.86 kg/ha) during the year 2021-22 in Bilaspur district. A review of the findings pointed to mixed bamboo forest (20 cm) was significantly highest N observed (285.46 kg/ha) and the significantly lowest N in mixed bamboo forest (10 cm) was observed (184.61 kg/ha) during the year 2022-23 in Bilaspur district. A review of the findings pointed to mixed bamboo forest (10 cm) was significantly highest N observed (274.26 kg/ha) and the significantly lowest N in mixed bamboo forest (30 cm) was observed (177.28 kg/ha) during the pooled mean in Bilaspur district.

A review of the findings pointed to mixed bamboo forest (10 cm) was significantly highest N observed (276.09 kg/ha) and the significantly lowest N in mixed bamboo forest (30 cm) was observed (238.25 kg/ha) during the year 2021-22 in Korba district. A review of the findings pointed to mixed bamboo forest (10 cm) was significantly highest N observed (286.12 kg/ha) and the significantly lowest N in mixed bamboo forest (30 cm) was observed (248.13 kg/ha) during the year 2022-23 in Korba district. A review of the findings pointed to mixed bamboo forest (10 cm) was significantly highest N observed (281.11 kg/ha) and the significantly lowest N in mixed bamboo forest (30 cm) was observed (243.19 kg/ha) during the pooled mean in Korba district.

The variations in available nitrogen (N) at different soil depths in both pure bamboo plantations and mixed bamboo forests across the districts of Raigarh, Bilaspur, and Korba are primarily influenced by root distribution and activity, organic matter decomposition, and soil microbial activity. In bamboo systems, the majority of root biomass and microbial activity are concentrated in the upper soil layers, leading to higher nitrogen availability. This is more pronounced in pure bamboo plantations where uniform species composition leads to consistent patterns in nutrient cycling. Conversely, mixed bamboo forests, with their diverse species composition, show more varied nitrogen distribution due to different rates of organic matter decomposition and nutrient uptake by various species. These outcomes are consistent with findings of Kumari and Bhardwaj (2017); Tu *et al.* (2013).

E. To effect soil fertility in bamboo plantations and mixed bamboo forests on available P (Phosphorus kg/ha) in soil

Effect of different treatments on P (Phosphorus kg/ha) in soil of bamboo plantations and mixed bamboo forests across three locations: Raigarh, Bilaspur, and Korba present in Table 5.

Pure bamboo plantation: The results of the data analysis showed that, P was significantly highest in pure bamboo plantation (10 cm) at (17.93 kg/ha) and the significantly lowest P in pure bamboo plantation (30 cm) was observed (12.53 kg/ha) during the year 2021-22 in Raigarh district. The results of the data analysis showed that, P was significantly highest in pure bamboo plantation (10 cm) at (18.94 kg/ha) and the significantly lowest P in pure bamboo plantation (30 cm) was observed (13.54 kg/ha) during the year 2022-23 in Raigarh district. The results of the data analysis showed that, P was significantly highest in pure bamboo plantation (10 cm) at (18.44 kg/ha) and the significantly lowest P in pure bamboo plantation (30 cm) was observed (13.04 kg/ha) during the pooled mean in Raigarh district.

The results of the data analysis showed that, P was significantly highest in pure bamboo plantation (20 cm) at (14.33 kg/ha) and the significantly lowest P in pure bamboo plantation (30 cm) was observed (6.27 kg/ha) during the year 2021-22 in Bilaspur district. The results of the data analysis showed that, P was significantly highest in pure bamboo plantation (20 cm) at (15.23 kg/ha) and the significantly lowest P in pure bamboo plantation (30 cm) was observed (7.07 kg/ha) during the year 2022-23 in Bilaspur district. The results of the data analysis showed that, P was significantly highest in pure bamboo plantation (20 cm) at (14.78 kg/ha) and the significantly lowest P in pure bamboo plantation (30

cm) was observed (6.67 kg/ha) during the pooled mean in Bilaspur district.

The results of the data analysis showed that, P was significantly highest in pure bamboo plantation (30 cm) at (23.27 kg/ha) and the significantly lowest P in pure bamboo plantation (20 cm) was observed (6.25 kg/ha) during the year 2021-22 in Korba district. The results of the data analysis showed that, P was significantly highest in pure bamboo plantation (30 cm) at (24.17 kg/ha) and the significantly lowest P in pure bamboo plantation (20 cm) was observed (6.72 kg/ha) during the year 2022-23 in Korba district. The results of the data analysis showed that, P was significantly highest in pure bamboo plantation (30 cm) at (23.72 kg/ha) and the significantly lowest P in pure bamboo plantation (20 cm) was observed (6.49 kg/ha) during the pooled mean in Korba district.

Mixed bamboo forest: The results of the data analysis showed that, P was significantly highest in pure bamboo plantation (20 cm) at (17.04 kg/ha) and the significantly lowest P in mixed bamboo forest (10 cm) was observed (8.04 kg/ha) during the year 2021-22 in Raigarh district. The results of the data analysis showed that, P was significantly highest in pure bamboo plantation (20 cm) at (18.05 kg/ha) and the significantly lowest P in mixed bamboo forest (10 cm) was observed (9.05 kg/ha) during the year 2022-23 in Raigarh district. The results of the data analysis showed that, P was significantly highest in pure bamboo plantation (20 cm) at (17.54 kg/ha) and the significantly lowest P in mixed bamboo forest (10 cm) was observed (8.55 kg/ha) during the pooled mean in Raigarh district.

The results of the data analysis showed that, P was significantly highest in pure bamboo plantation (10 cm) at (12.54 kg/ha) and the significantly lowest P in mixed bamboo forest (30 cm) was observed (4.44 kg/ha) during the year 2021-22 in Bilaspur district. The results of the data analysis showed that, P was significantly highest in pure bamboo plantation (10 cm) at (13.24 kg/ha) and the significantly lowest P in mixed bamboo forest (20 cm) was observed (5.27 kg/ha) during the year 2022-23 in Bilaspur district. The results of the data analysis showed that, P was significantly highest in pure bamboo plantation (10 cm) at (12.89 kg/ha) and the significantly lowest P in mixed bamboo forest (20 cm) was observed (4.87 kg/ha) during the pooled mean in Bilaspur district.

The results of the data analysis showed that, P was significantly highest in pure bamboo plantation (10 cm) at (18.83 kg/ha) and the significantly lowest P in mixed bamboo forest (30 cm) was observed (16.15 kg/ha) during the year 2021-22 in Korba district. The results of the data analysis showed that, P was significantly highest in pure bamboo plantation (10 cm) at (19.23 kg/ha) and the significantly lowest P in mixed bamboo forest (30 cm) was observed (17.05 kg/ha) during the year 2022-23 in Korba district. The results of the data analysis showed that, P was significantly highest in pure bamboo plantation (10 cm) at (19.03 kg/ha) and the significantly lowest P in mixed bamboo forest (30 cm) was observed (16.60 kg/ha) during the pooled mean in Korba district.

The differences in available phosphorus (P) concentrations at varying soil depths in both pure bamboo plantations and mixed bamboo forests across Raigarh, Bilaspur, and Korba districts can be largely explained by factors such as root distribution, litter decomposition, and soil type. In pure bamboo plantations, where plant roots are predominantly concentrated in the upper soil layers, higher phosphorus levels are generally observed at shallower depths. This is due to the efficient uptake of P by dense root systems and the decomposition of bamboo litter, which is rich in nutrients, enhancing the phosphorus content in the upper soil layers. Conversely, in mixed bamboo forests, the diversity of species can lead to varied root systems and decomposition rates, affecting the uniformity of phosphorus distribution. Additionally, soil type and texture, which differ across locations, significantly influence phosphorus availability by affecting both retention and leaching. Thus, phosphorus dynamics in these ecosystems are influenced by a complex interplay of biological and physicochemical factors specific to each site and forest type. Similar result was also reported by Kumari and Bhardwaj (2017); Tu *et al.* (2013).

F. To effect soil fertility in bamboo plantations and mixed bamboo forests on available K (Potash kg/ha) in soil

Effect of different treatments on K (Potash kg/ha) in soil of bamboo plantations and mixed bamboo forests across three locations: Raigarh, Bilaspur, and Korba present in Table 6.

Pure bamboo plantation:

The data showed that, K was significantly highest in pure bamboo plantation (10 cm) at (268.13 kg/ha) and the significantly lowest K in pure bamboo plantation (20 cm) was observed (190.14 kg/ha) during the year 2021-22 in Raigarh district. The data showed that, K was significantly highest in pure bamboo plantation (10 cm) at (268.29 kg/ha) and the significantly lowest K in pure bamboo plantation (20 cm) was observed (191.32 kg/ha) during the year 2022-23 in Raigarh district. The data showed that, K was significantly highest in pure bamboo plantation (10 cm) at (268.21 kg/ha) and the significantly lowest K in pure bamboo plantation (20 cm) was observed (190.73 kg/ha) during the pooled mean in Raigarh district.

The data showed that, K was significantly highest in pure bamboo plantation (20 cm) at (268.19 kg/ha) and the significantly lowest K in pure bamboo plantation (10 cm) was observed (224.14 kg/ha) during the year 2021-22 in Bilaspur district. The data showed that, K was significantly highest in pure bamboo plantation (20 cm) at (278.29 kg/ha) and the significantly lowest K in pure bamboo plantation (10 cm) was observed (234.17 kg/ha) during the year 2022-23 in Bilaspur district. The data showed that, K was significantly highest in pure bamboo plantation (20 cm) at (273.24 kg/ha) and the significantly lowest K in pure bamboo plantation (10 cm) was observed (229.16 kg/ha) during the pooled mean in Bilaspur district.

The data showed that, K was significantly highest in pure bamboo plantation (10 cm) at (358.15 kg/ha) and the significantly lowest K in pure bamboo plantation (20 cm) was observed (291.17 kg/ha) during the year 2021-22 in Korba district. The data showed that, K was significantly highest in pure bamboo plantation (10 cm) at (368.17 kg/ha) and the significantly lowest K in pure bamboo plantation (20 cm) was observed (301.12 kg/ha) during the year 2022-23 in Korba district. The data showed that, K was significantly highest in pure bamboo plantation (10 cm) at (363.16 kg/ha) and the significantly lowest K in pure bamboo plantation (30 cm) was observed (296.22 kg/ha) during the pooled mean in Korba district.

Mixed bamboo forest: The data showed that, K was significantly highest in mixed bamboo forest (10 cm) at (280.23 kg/ha) and the significantly lowest K in mixed bamboo forest (30 cm) was observed (201.11) during the year 2021-22 in Raigarh district. The data showed that, K was significantly highest in mixed bamboo forest (10 cm) at (281.45 kg/ha) and the significantly lowest K in mixed bamboo forest (30 cm) was observed (202.78 kg/ha) during the year 2022-23 in Raigarh district. The data showed that, K was significantly highest in mixed bamboo forest (10 cm) at (280.84 kg/ha) and the significantly lowest K in mixed bamboo forest (30 cm) was observed (201.94 kg/ha) during the pooled mean in Raigarh district.

The data showed that, K was significantly highest in mixed bamboo forest (10 cm) at (280.15 kg/ha) and the significantly lowest K in mixed bamboo forest (20 cm) was observed (190.17 kg/ha) during the year 2021-22 in Bilaspur district. The data showed that, K was significantly highest in mixed bamboo forest (10 cm) at (292.13kg/ha) and the significantly lowest K in mixed bamboo forest (20 cm) was observed (210.11 kg/ha) during the year 2022-23 in Bilaspur district. The data showed that, K was significantly highest in mixed bamboo forest (10 cm) at (286.14 kg/ha) and the significantly lowest K in mixed bamboo forest (20 cm) was observed (200.14 kg/ha) during the pooled mean in Bilaspur district.

The data analysis showed that, K was significantly highest in mixed bamboo forest (30 cm) at (324.21 kg/ha) and the significantly lowest K in mixed bamboo forest (10 cm) was observed (235.01 kg/ha) during the year 2021-22 in Korba district. The data analysis showed that, K was significantly highest in mixed bamboo forest (30 cm) at (344.12 kg/ha) and the significantly lowest K in mixed bamboo forest (10 cm) was observed (245.10 kg/ha) during the year 2022-23 in Korba district. The data analysis showed that, K was significantly highest in mixed bamboo forest (30 cm) at (334.17 kg/ha) and the significantly lowest K in mixed bamboo forest (10 cm) was observed (240.06 kg/ha) during the pooled mean in Korba district.

The variation in potash (K) concentrations in both pure bamboo plantations and mixed bamboo forests across Raigarh, Bilaspur, and Korba can mainly be attributed to differences in root system architecture and nutrient cycling mechanisms. In pure bamboo plantations, higher K levels at shallower depths (10 cm) suggest effective nutrient uptake by dense, surface-oriented bamboo roots, which benefit from direct fertilizer application and organic matter decomposition. Conversely, the mixed forests, with a diversity of root depths and plant interactions, show more varied K distribution, indicating complex inter-species effects on nutrient absorption and soil chemistry dynamics at different soil depths. The results obtained in the present study is in accordance with the results of Kumari and Bhardwaj (2017); Tu *et al*. (2013).

Table 1: To effect soil fertility in bamboo plantations and mixed bamboo forests on Soil pH.

Treatment details		pH								
		Raigarh			Bilaspur			Korba		
		2021-22	2022-23	Pooled Mean	2021-22	2022-23	Pooled Mean	2021-22	2022-23	Pooled Mean
Pure bamboo plantation	10 cm	5.33	6.53	5.93	7.74	8.74	8.24	5.20	6.14	5.67
	20 cm	5.84	7.02	6.43	5.85	6.84	6.34	5.85	6.27	6.06
	30 cm	5.67	6.71	6.19	6.57	7.54	7.06	5.65	6.73	6.19
Mixed bamboo forest	10 cm	5.16	6.64	5.90	6.71	7.65	7.18	5.04	5.65	5.35
	20 cm	5.33	6.02	5.67	6.35	7.36	6.85	5.52	5.98	5.75
	30 cm	5.24	6.04	5.64	5.84	6.85	6.35	5.47	5.71	5.59
Sem (±)		**0.14**	**0.20**	**0.14**	**0.37**	**0.36**	**0.18**	**0.16**	**0.18**	**0.11**
CD (5%)		**0.45**	**0.63**	**0.43**	**1.18**	**1.14**	**0.58**	**0.51**	**0.55**	**0.36**
CV %)		**4.57**	**5.34**	**3.93**	**9.96**	**8.37**	**4.57**	**5.12**	**5.02**	**3.42**

Table 2: To effect soil fertility in bamboo plantations and mixed bamboo forests on soil EC (Electrical conductivity).

Treatment details		EC (Electrical conductivity)								
		Raigarh			Bilaspur			Korba		
		2021-22	2022-23	Pooled Mean	2021-22	2022-23	Pooled Mean	2021-22	2022-23	Pooled Mean
Pure bamboo plantation	10 cm	0.42	0.51	0.46	0.60	0.71	0.66	0.41	0.67	0.54
	20 cm	0.41	0.61	0.51	0.41	0.65	0.53	0.51	0.71	0.61
	30 cm	0.62	0.54	0.58	0.53	0.70	0.62	0.40	0.62	0.51
Mixed bamboo forest	10 cm	0.32	0.61	0.46	0.50	0.64	0.57	0.30	0.46	0.38
	20 cm	0.32	0.54	0.43	0.52	0.59	0.56	0.53	0.58	0.56
	30 cm	0.82	0.81	0.82	0.43	0.57	0.50	0.50	0.57	0.54
Sem (±)		**0.02**	**0.03**	**0.02**	**0.03**	**0.02**	**0.03**	**0.02**	**0.02**	**0.02**
CD (5%)		**0.08**	**0.09**	**0.07**	**0.11**	**0.08**	**0.09**	**0.07**	**0.07**	**0.05**
CV %)		**8.76**	**8.40**	**6.98**	**12.10**	**6.51**	**8.25**	**8.62**	**6.39**	**5.15**

Table 3: To effect soil fertility in bamboo plantations and mixed bamboo forests on soil OC (Organic carbon).

Treatment details		OC (Organic carbon)								
		Raigarh			Bilaspur			Korba		
		2021-22	2022-23	Pooled Mean	2021-22	2022-23	Pooled Mean	2021-22	2022-23	Pooled Mean
Pure bamboo plantation	10 cm	0.30	0.50	0.40	0.61	0.81	0.71	0.60	0.70	0.65
	20 cm	0.17	0.35	0.26	0.75	0.85	0.80	0.15	0.26	0.21
	30 cm	0.45	0.65	0.55	0.76	0.89	0.83	0.30	0.41	0.36
Mixed bamboo forest	10 cm	0.16	0.36	0.26	0.16	0.34	0.25	0.17	0.35	0.26
	20 cm	0.14	0.37	0.25	0.60	0.82	0.71	0.18	0.34	0.26
	30 cm	0.46	0.75	0.61	0.62	0.72	0.67	0.16	0.36	0.26
Sem (±)		**0.01**	**0.02**	**0.01**	**0.03**	**0.03**	**0.02**	**0.01**	**0.03**	**0.01**
CD (5%)		**0.03**	**0.05**	**0.03**	**0.08**	**0.09**	**0.07**	**0.04**	**0.08**	**0.05**
CV %)		**6.01**	**6.06**	**4.58**	**7.71**	**7.05**	**5.54**	**7.76**	**11.08**	**7.81**

Table 4: To effect soil fertility in bamboo plantations and mixed bamboo forests on available N (Nitrogen kg/ha) in soil.

Treatment details		N (Nitrogen kg/ha)								
		Raigarh			Bilaspur			Korba		
		2021-22	2022-23	Pooled Mean	2021-22	2022-23	Pooled Mean	2021-22	2022-23	Pooled Mean
Pure bamboo plantation	10 cm	213.11	217.12	215.12	225.16	237.20	231.18	200.11	220.24	210.18
	20 cm	276.19	279.26	277.73	301.09	322.46	311.78	250.19	260.25	255.22
	30 cm	276.11	282.12	279.12	263.17	282.30	272.74	250.24	260.12	255.18
Mixed bamboo forest	10 cm	213.26	218.28	215.77	313.13	228.17	270.65	276.09	286.12	281.11
	20 cm	225.14	232.13	228.64	263.07	285.46	274.26	263.27	273.20	268.23
	30 cm	288.26	291.13	289.70	105.86	184.61	177.28	238.25	248.13	243.19
Sem (±)		**7.82**	**7.36**	**6.41**	**22.91**	**9.96**	**5.49**	**7.99**	**7.51**	**5.79**
CD (5%)		**24.63**	**23.20**	**20.20**	**72.19**	**31.38**	**17.30**	**25.16**	**23.68**	**18.23**
CV %)		**5.44**	**5.03**	**4.42**	**16.18**	**6.72**	**3.71**	**5.61**	**5.04**	**3.97**

Table 5: To effect soil fertility in bamboo plantations and mixed bamboo forests on available P (Phosphorus kg/ha)in soil.

Treatment details		P (Phosphorus kg/ha)								
		Raigarh			Bilaspur			Korba		
		2021-22	2022-23	Pooled Mean	2021-22	2022-23	Pooled Mean	2021-22	2022-23	Pooled Mean
Pure bamboo plantation	10 cm	17.93	18.94	18.44	7.49	8.06	7.78	18.84	19.55	19.20
	20 cm	15.22	16.24	15.73	14.33	15.23	14.78	6.25	6.72	6.49
	30 cm	12.53	13.54	13.04	6.27	7.07	6.67	23.27	24.17	23.72
Mixed bamboo forest	10 cm	8.04	9.05	8.55	12.54	13.24	12.89	18.83	19.23	19.03
	20 cm	17.04	18.05	17.54	4.48	5.27	4.87	17.93	18.35	18.14
	30 cm	14.35	15.35	14.85	4.44	5.29	4.87	16.15	17.05	16.60
Sem (±)		**0.71**	**0.71**	**0.01**	**0.56**	**0.82**	**0.57**	**0.83**	**0.88**	**0.65**
CD (5%)		**2.23**	**2.23**	**0.03**	**1.75**	**2.59**	**1.79**	**2.61**	**2.78**	**2.06**
CV %)		**8.64**	**8.07**	**0.12**	**11.65**	**15.75**	**11.40**	**8.50**	**8.72**	**6.58**

Table 6: To effect soil fertility in bamboo plantations and mixed bamboo forests on available K (Potash kg/ha) in soil.

Treatment details		K (Potash kg/ha)								
		Raigarh			Bilaspur			Korba		
		2021-22	2022-23	Pooled Mean	2021-22	2022-23	Pooled Mean	2021-22	2022-23	Pooled Mean
Pure bamboo plantation	10 cm	268.13	268.29	268.21	224.14	234.17	229.16	358.15	368.17	363.16
	20 cm	190.14	191.32	190.73	268.19	278.29	273.24	291.17	301.12	296.15
	30 cm	235.16	238.14	236.65	246.16	257.14	251.65	291.22	301.22	296.22
Mixed bamboo forest	10 cm	280.23	281.45	280.84	280.15	292.13	286.14	235.01	245.10	240.06
	20 cm	212.17	215.53	213.85	190.17	210.11	200.14	313.18	323.26	318.22
	30 cm	201.11	202.78	201.94	201.22	221.17	211.19	324.21	344.12	334.17
Sem (±)		**8.05**	**6.93**	**6.46**	**7.54**	**7.22**	**6.17**	**9.20**	**9.36**	**6.30**
CD (5%)		**25.37**	**21.83**	**20.35**	**23.77**	**22.75**	**19.44**	**28.97**	**29.48**	**19.87**
CV %)		**6.03**	**5.15**	**4.82**	**5.56**	**5.02**	**4.42**	**5.27**	**5.16**	**3.55**

CONCLUSIONS

This study provides a comparative analysis of key soil fertility parameters across bamboo plantations and mixed bamboo forests in three districts of Chhattisgarh, India. The results demonstrate significant variation in soil pH, electrical conductivity, organic carbon, and available nitrogen, phosphorus and potassium across different soil depths and land use systems. In general, mixed bamboo forests exhibited more acidic pH and higher electrical conductivity compared to pure bamboo plantations, indicating differences in nutrient dynamics. Organic carbon accumulation was higher in deeper layers of plantations but more varied across soil depths in mixed forests, highlighting the role of species diversity. Available nitrogen and phosphorus were found to be higher in the upper layers of both systems, underlining the influence of root activity and organic matter decomposition. Potassium availability was also greater in upper layers of plantations but more heterogeneous in mixed forests.

Overall, the interactions between soil depth, land use patterns and plant biodiversity appear to govern soil fertility status in these systems. Bamboo plantations with mono-species stands displayed more uniform nutrient distributions linked to shallow and dense root systems. In contrast, mixed bamboo forests with diverse vegetation showed more spatial variability in soil nutrients, governed by complex plant-soil relationships.

The findings underline the need for tailored soil management practices targeted to specific depths and vegetation in bamboo-based agroforestry systems. Further long-term studies analyzing more soil parameters across diverse environments can provide deeper insights into the drivers of soil fertility in these economically and ecologically important ecosystems. Leveraging this knowledge can help enhance productivity and environmental sustainability of bamboo plantations and mixed forests.

FUTURE SCOPE

— Long term monitoring of soil nutrients across diverse geographic areas to understand temporal dynamics of soil fertility in these systems.

— Analysis of additional soil parameters like micronutrients, microbial biomass, and enzyme activities to develop a more comprehensive assessment of soil health.

— Studying the relationship between above-ground biodiversity and below-ground soil biodiversity and processes to elucidate plant-soil interactions.

— Evaluating the impacts of climate change on soil fertility and plant productivity in bamboo agroforestry systems.

— Developing targeted management practices for enhanced soil fertility and plantation productivity based on the soil-plant interactions in these systems.

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