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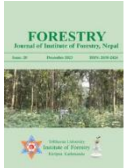

Effect of Various Bamboo Species on Soil Properties in Pani Kholsi Micro-Watershed, Nepal

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KEYWORDS

Bamboo species
Eco-restoration
Soil properties
Degraded land

ABSTRACT

The biological characteristics and growth habits of bamboo enormously contribute to improving physical and chemical properties of soil. This study focuses on understanding the influence of four bamboo species on soil properties: *Bambusa tulda, Bambusa balcooa, Dendrocalamus strictus and Bambusa nutans subsp*. cupulata. For this, 15 soil samples were collected from open space (degraded land site) and bamboo species plantation areas in Pani kholsi micro-watershed and analysed in laboratory to determine soil pH, organic carbon content, available Nitrogen, Phosphorus and Potassium in soil. The soil pH decreases under all bamboo species compared rather than in open space. Lowest soil pH was recorded in the surface soil of *B. balcooa and D. strictus.* The organic matter content was the highest in surface soils under B. tulda (1.68%) and the lowest in the soil of open space (0.08%). Similarly, availability of Nitrogen (0.14%) and Phosphorus (4.27 kg/ha) was the highest in surface layer soil under *B. tulda* but the lowest (0.1% and 0.71 kg/ha respectively) in open space. And, the surface soil under *B. tulda* had much higher potassium content (68.4 kg/ha) than the soil in open space (8.88 kg/ha). Overall, the soil chemical properties under *B. tulda* were found to be better than under other species.

INTRODUCTION

Bamboos are a diverse group of evergreen plants in the grass family Poaceae that can thrive in low-fertility, sloping, and degraded land conditions on riverbanks (Yeasmin et al., 2015). Bamboos grow globally covering about 3.2 percent of the forest areas of their host countries, which is around one percent of the global forest area (Kaushal et al., 2020). Around 80% of bamboo growing regions are located in South and Southeast Asia (Sharma, 1980). There are 75 genera and 1250 species of bamboos in subtropical, tropical, and mild temperate climates (Sharma, 1980). China has a record no of species in Asia, with over 500, followed by India, Indonesia, Myanmar, and Malaysia, each with over a hundred. Japan has roughly 84 species, Myanmar (Barma) has 90, the Philippines has 55, Thailand has 50, Malaysia has 44, Indonesia has 31, Nepal has 30 and Sri Lanka has 30 (Nirala et al., 2017). Bamboos are widely distributed throughout

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Nepal, but they are more common in the eastern half of the country. Out of 30 species of bamboo found in Nepal, 22 species of bamboo are found in eastern Nepal (Shrestha, 1998).

The Churia range features a large number of seasonal rivers that flow fast from north to south, bringing gravel and sand with them (Paudel and Kafle, 2012). Adhikari (2013) highlights that the Terai area in Nepal is characterized by a multitude of rivers, contributing to localized erosion and deposition. These rivers possess distinct physical characteristics which intensify flooding and inundation within the Terai region. Adhikari (2013) further describes the rivers originating from the Churia highlands as exhibiting flashiness, experiencing minimal to no flow during the dry season. Based on findings by Paudel et al. (2021), the annual soil loss in Nepal varies from 2 to 105 tons per hectare. This loss is attributed to different factors: 34% is due to water-induced erosion, 60% results from mass wasting or geological erosion, and wind erosion accounts for 3%. Additionally, other forms of land degradation, such as flooding (6%) and waterlogging (5%), are prevalent in Nepal's lower hills and plains. Overall, their study indicates that 28% of the land in Nepal is in poor condition due to these degradation processes (Paudel et al., 2021). From the study of Puno et al. (2017), the results revealed that the introduction of bamboo is effective as one of the best catchment management options as far as soil conservation is concerned. The study conducted by Sujatha et al. (2008) demonstrated that the presence and growth of reed significantly impact several soil characteristics. Specifically, they found that factors such as color, structure, texture, and the formation of subsurface horizons exhibit notable differences in areas where reed is present compared to adjacent non-reed areas.

Bamboos possess the capability to quickly inhabit disturbed lands due to their adaptability and efficient nutrient conservation abilities, as highlighted by (Dasog, 1995). Bamboo is an important alternative for soil conservation and rehabilitation of degraded land as it doesn't require good soil conditions to grow (Dasog, 1995). Bamboos are fast-growing plants with an extensive root system that aids in the improvement of soil's physical, chemical, and biological characteristics. It aids in management of soil erosion and filtration of sediment, making it ideal for the rapid restoration of degraded areas (Kaushal et al., 2020).

Different bamboo species have different effects on soil qualities; some have been observed to promote microbial biomass in the rhizosphere zone by giving a broad root surface, which aids in improving soil fertility (Arunachalam and Arunachalam, 2002). Sujatha et al. (2008) discovered that reed bamboo significantly enhances soil development and fertility compared to adjacent non-reed bamboo areas due to its protective canopy, litter, and root mat. A. N. Singh and Singh (1999) reported a rapid development of microbial biomass in the mine spoil which is an indication of the efficient restoration potential of *D. strictus* plantation. In the study of 11 bamboo species, Venkatesh et al. (2005) concluded that *D. gigantells*, followed by *D. hookerii* and *B. nutans*, emerged as the superior species for enhancing and sustaining the fertility of acid soils in the North Eastern Himalayan region of India. The significance of microbial biomass in soil productivity is widely recognized, given its substantial contribution to the dynamics of crucial nutrients such as nitrogen and phosphorus (Van der Lugt P., 2008). When compared to monoculture stands, mixed bamboo stands have higher levels of beneficial soil nutrients and superior soil properties, such as soil porosity, aeration, and bulk density (Venkatesh et al., 2005). As plantations mature, there is a tendency for higher proportions of organic carbon, nitrogen, and total soil phosphorus to become immobilized within the microbial biomass, signifying a soil redevelopment process (Singh and Singh, 1999). The composition of litter is considered indicative of both the inherent quality, such as decomposability, and environmental conditions of the soil and climate, which collectively influence the release of essential nutrient elements during decomposition processes (Shanmughavel et al., 2000).

The study area, Pani Kholsi, is a micro watershed that is restored from a critical stage of degradation by the continuous effort and dedication of Pani Kholsi micro watershed committee and the local community. There hadn't been enough studies regarding the changes in soil properties due to bamboo plantation. The main objective of this study was to find out the difference in chemical properties of soil of degraded land and bamboo plantation site at the same location as well as to compare the impact of different species of bamboo on soil chemical properties. So, this study was carried out to provide information about the impact of different bamboo species on soil properties of Pani Kholsi micro watershed area, which provides valuable insight for soil quality improvement and eco-restoration process. However, the study is not enough and the findings of this study will help add additional information to the database.

MATERIALS AND METHODS

Study area

The research was conducted in Pani kholsi micro-watershed located in Bardibas municipality of Mahottari district, Nepal (Figure 1). Mahotari district lies in Madhesh province and covers an area of 1002 square km. Mahottari district is located at 26°54'6.84" to 27°08'46.90" latitude and 85°47'42.67" to 85°56'42.97" longitude. Mahottari district lies mostly in the lower tropical climate zone.

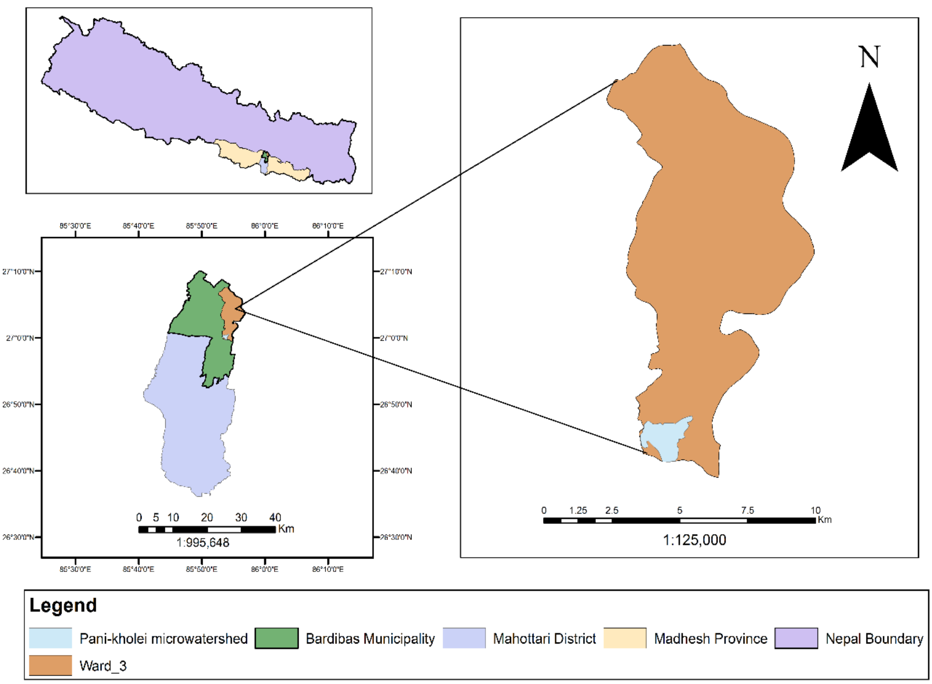

Figure 1: Map showing study area

Ratu watershed is one of the major watersheds in the Mahottari and Dhanusha districts. It is 67 km long which consists of 103 torrents. Flash flood, landslide and land cuttings due to sedimentation are the major problems of this watershed. Panikholsi is one of the major sub-tributaries of the Ratu River located in ward no. 1 of Bardibas municipality. It is a water stream located at the lower Siwalik region which used to be one of the major destructive torrents in Bardibas-1. The flash flood torrent used to cut the land and deposit debris in habitation area. It had directly affected 1,794 households. The micro watershed committee from the collective effort planted more than 10,000 bamboos of different species in Pani Kholsi micro watershed to control soil erosion and reduce the impact of water-induced disasters (FAO and INBAR, 2018). The efforts successfully controlled and reduced the water-induced disaster from a 300 m span to a 30-m-long section of the stream (FAO and INBAR, 2018). However, their impact on the soil properties of the area was unknown. Different species of bamboo such as *Bambusa nutans*, *Bambusa balcooa*, *Dendrocalamus* species have been planted for the purpose of soil conservation and economic support to local community along the stream line in mixed as well as individual plots.

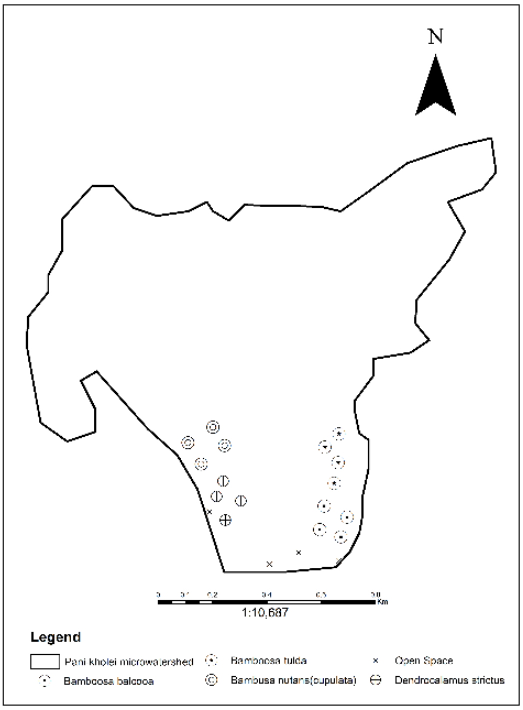

Figure 2: Map showing allocation of sample plots in the study area

Data collection

Soil sampling design

Data was collected through stratified random sampling method. Stratification was done on the basis of different bamboo species plantation site (Sites includes: *Bambusa tulda*, *Bambusa balcooa*, *Dendrocalamus strictus* and *Bambusa nutans subsp. cupulata*) and a degraded or eroded land as a control site. Soil sampling locations were selected to best represent each bamboo species site and the open space (degraded or eroded land). Soil samples were taken only from individual plots containing single species of bamboo. In this way there were five strata which includes four bamboo species sites, and one control site. Control site is alongside the bamboo plantation site.

Collection and preparation of soil sample

Composite soil samples were collected from depths of 0-15 cm, 15-30 cm and 30-45 cm depths using soil auger for measuring different parameters like soil pH, Nitrogen (N), Phosphorous (P), Potassium (K) and Soil Organic Matter (SOM). In each stratum, four soil samples were collected and combined to prepare three composite soil samples by depth. Hence, in total 15 soil samples were collected from the study site.

Standard procedures were followed for soil sampling in this research. In the case of bamboo, soil sampling was limited to a distance of 2 meters from the outermost culm of the respective species, ensuring collection well within the plant canopy (Arunachalam and Arunachalam, 2002). Venkatesh et al. (2005) gathered composite soil profile samples from three distinct depths (0-20, 20-40, and 40-60 cm) at two separate locations within Manipur and Meghalaya states, focusing on bamboo plantations aged 8-10 years. Soil auger was utilized to collect five random profile samples from each bamboo species plantation, which were then thoroughly mixed by depth to create one composite sample for each depth per species (Venkatesh et al., 2005). Additionally, composite profile samples were obtained from adjacent sites of each bamboo plantation to serve as controls (Venkatesh et al., 2005). Similar procedure is followed in this research.

Data analysis

Soil profile samples obtained from selected bamboo species were analysed at the Regional Soil Laboratory of Gandaki Province to assess their chemical and physical properties. The study compared observations on soil properties including pH, N, P, K content, and SOM with those of senile soil samples. Senile soil samples, defined as soil free from the influence of bamboo species and obtained from degraded land, were utilized as controls to monitor changes in soil properties influenced by different bamboo species grown in the study area. The soil chemical and physical properties were analysed by adopting standard methods, are presented in Table 1 (Panday et al., 2018).

Table 1: Soil chemical analysis methods followed by regional soil testing laboratory, Kaski, Nepal

SN	Parameter	Analysis method
1	pH	Beckman electrode pH meter in 1:2 soil and water (Cottenie, Verloo, Kiekens, Velghe, and Camerlynik, 1982)
2	Soil OM	Walkley and Black method (Houba, Van der Lee,Novozamsky, and Walinga, 1989)
3	Total N	Kjeldahl distillation (Bremner and Mulvaney, 1982)
4	Available P	Olsens's bicarbonate method (Olsen, Sommers, and Page, 1982)
5	Available K	Ammonium acetate method (Simard, 1993)

Data obtained after soil laboratory analysis were analyzed using Microsoft Excel for the comparison and analysis of results under different species and different parameters. Descriptive statistics was used for the purpose of data interpretation. Data were compared through graphical representation of the obtained results from laboratory analysis.

RESULTS AND DISCUSSION

Soil pH

All of the soil samples taken from the location were confirmed to be acidic. Despite the fact that all soil samples were acidic, acidity was found to be higher in bamboo locations than in non-bamboo areas as shown in Figure 2. Soil pH declined with increasing depth under *B. tulda*, increased with depth under *B. balcooa* and *Dendrocalamus strictus*, and remained constant at all depths under *B. Nutans (cupulata)* (0-15, 15-30 and 30-45 cm). In contrast to open space, there was no variation in soil pH in the highest layer, but there was a decline in soil pH in the lower levels of 15-30 cm and 30-45 cm in Bamboo species. Soil pH was found to be lowest at 0-15 cm depth beneath *B. balcooa*, followed by *B. tulda* and *B. nutans (cupulata)* at 30-45 cm depth.

Thomas and Sujatha (1992) observed a rise in pH with increasing depth within pure reed patches located in Kerala's Ranni Forest Division. Abiyot and Alemayeyu (2016) discovered that degraded bare land had a higher pH than recovered land and natural grassland. However, Singh et al. (2012) discovered that the pH of soil beneath Mango, Bamboo, and Haldu was lower than that of plain land (area without planting), with bamboo having a little lower pH than the other tree species. The soil beneath bamboo was found to be significantly fertile with an ideal pH range, and bamboo plantations were observed to aid in maintaining optimal soil pH conditions conducive to plant development (Singh et al., 2012). Kaushal et al. (2020) similarly showed that soil pH declined in all bamboo species as compared to a control plot (open space), with the greatest drop in *B. bambos* and *B. nutans*, which is comparable to our findings since *B. nutans* had the greatest fall in pH. Reduced soil pH may be caused by an increased leaf litter deposition, the breakdown of which may have resulted in pH drop (Kaushal et al., 2020). In contrast to our findings, Sujatha et al. (2008) found that soils supporting reed growth exhibited strong to moderate acidity levels, with surface layers showing higher acidity compared to the underlying layers.

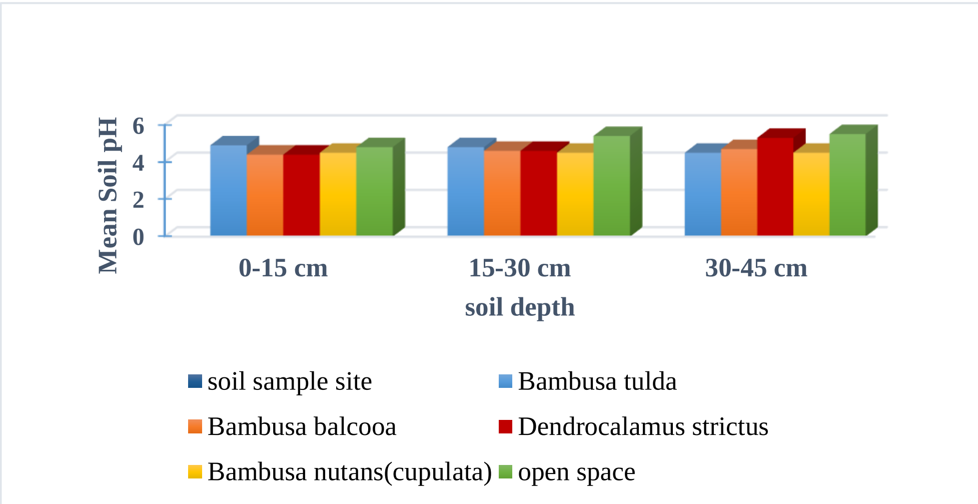

Figure 3: pH of soil under different species at different depth

The increased acidity of surface soils might be caused by a greater prevalence of organic matter at various stages of decomposition, which can release substantial volumes of organic acids (Sujatha et al., 2008). Growing vegetation, according to Juo and Manu (1996), tends to lower soil pH, a process they attribute to cation absorption by plants, with subsequent release of H+ ions, organic matter degradation into organic acids, and increasing carbon dioxide levels through root respiration and nitrification. The research region is dominated by sandy soil, which also contributes to the study area's low pH.

Organic Carbon Content

The maximum organic carbon content was found in the soil under *B. tulda* at a depth of 0-15 cm (1.68%), and it was the same at a depth of 15-30 cm and 30-45 cm (1.18%). This might be because of increased deposition of leaf litter and organic materials in the highest layers. Organic carbon content (1.18% and 1.51%, respectively) for *B. balcooa and D. strictus* was maximum in the soil depth of 15-30 cm and lowest in the soil depth of 30-45 cm, with carbon content of 1.01% and 0.84%, respectively as shown in Figure 3. The organic carbon (OC) content of *B. nutans subs. cupulata* was lower than that of other bamboo species. This species' OC concentration (0.92%) was highest at 30-45 cm soil depth and lowest (0.25%) at 15-30 cm. The maximum OC content was discovered to be at 15-30 cm with a very low value of 0.16% and was comparable OC content at 0-15 cm and 30-45 cm with a value of 0.08%. This is because there is no organic matter deposition due to strong erosion which washes away all the depositions and collects sand.

Upper soil layers had more organic carbon content than subsurface layers, which might be attributed to increased accumulation of litter fall and breakdown in the top layer. Differences in organic carbon concentration among species may be attributable to variable quantities of leaf litter and root residues added to soils (Venkatesh et al., 2005). In contrast to our findings, Venkatesh et al. (2005) found that the organic carbon content increased in all soils under various bamboo species, ranging from 0.99% (in *D. hamiltonii*) to 2.53% (in *D. longispathus*). In the study conducted by Kaushal et al. (2020), *D. hamiltonii* exhibited the highest values of SOC, measuring 1.68% at 0-15 cm depth and 1.20% at 15-30 cm depth. Kaushal et al. (2020) ascribed this variation in organic carbon to the input of varied amounts of leaf litter, fine roots, and decomposition rates. When compared to other forest plantings in the state, the soils under reed bamboos had a higher amount of organic carbon (2-2.5%) (Sujatha et al., 2008). This phenomenon could be attributed to the substantial contribution of a dense litter cover on the soil surface and the intricate, fine-fibered root structure of bamboo.

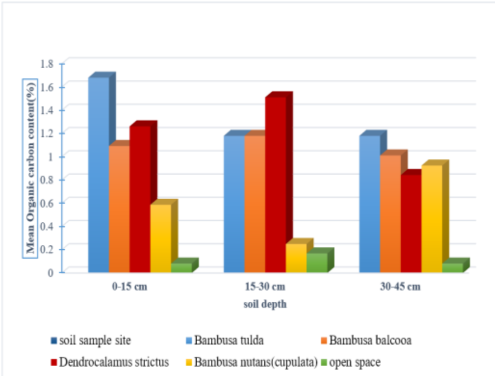

Figure 4. Organic Carbon content under different species according to soil depth

Total N

Following the trend of OC, the nitrogen content of bamboo was greater when compared to open space. The highest nitrogen level is observed in soil under B. tulda at a depth of 0-15 cm, with 0.14%. The open space location had a minimum nitrogen level of 0.01% at all depths.

According to Rao and Ramakrishnan (1989), bamboos accumulated more N, P, and K than the rest of the vegetation, whereas shrubs and trees gathered more calcium and magnesium. However, several researches revealed that nitrogen concentration decreased owing to vegetation due to fertilizer intake by different tree species. The Panikholsi micro watershed is a heavily eroded region that has been repaired using bamboo plantation. Soil beneath bamboo had higher nitrogen concentration than open space, which can be attributed to litter fall and organic matter deposition at various levels. Different microbial activities occur in the soil, which aid in the breakdown of organic materials and the release of N.

Singh et al. (2012) found that the soil beneath bamboo trees exhibited higher ammonia nitrogen (NH_3) content compared to soils under other agro-forestry trees and plain areas with no plantations. This suggests that bamboo trees are particularly effective in enhancing ammonia nitrogen (NH_3) content in soil, potentially contributing to increased soil productivity (Singh et al., 2012).

Kaushal et al. (2020) found an increase in N under bamboos compared to controls, with the highest levels (243.4 kg ha-1 at 0-15 cm soil depth) in *D. hamiltonii*, which was comparable to *B. balcooa*.

Dendrocalamus strictus has a greater nitrogen concentration than others at depths of 15-30 cm. *Bambusa tulda* has greater Total N concentration at depths of 30-45 cm. This pattern is comparable to the one found in OC. As a result, organic matter deposition aids in boosting nitrogen availability in soil, hence enhancing soil fertility.

Bamboo has greater N content in the leaves, which rises with age (Shanmughavel et al., 2000). The variance in nitrogen concentration in soil across bamboo species can be ascribed to differences in leaf litter output and age.

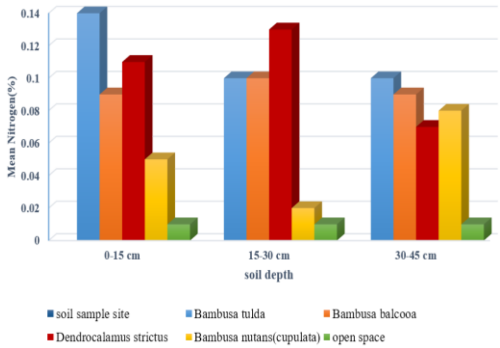

Figure 5: Total N content under different species according to depth

Available P

The results of soil analysis revealed that the phosphorus level in the soil was very low in all soil samples, ranging from 0.71 kg/ha to 4.27 kg/ha. Available P concentration was found to be highest *in Bambusa tulda* at 30-45 cm soil depth, with a Available P concentration of 4.27 kg/ha, and lowest in open space at 0-15 cm soil depth, which is comparable to *B. balcooa* at 30-45 cm soil depth and *D. strictus* at 15-30 cm soil depth, with Available P concentration of 0.71 kg/ha. *Bambusa tulda* showed greater Available P concentration in the soil than other bamboo species at all soil depths, which might be attributed to increased deposition and breakdown of leaf litter. *Bambusa balcooa* and *Dendrocalamus strictus* had low P level, which was similar to that of degraded land site soil.

Bambusa balcooa showed higher P content at the surface layer, but it appears to have decreased in the subsurface layer at depths of 15-30cm and 30-45cm compared to open space. *Dendrocalamus strictus* showed reduced Available P concentration in the intermediate layer compared to open space than in the surface layer and soil at 30-45 cm depth, which is similar to *Bambusa nutans*. The Available P concentration of *Bambusa nutans* subspecies *cupulata* was greater in the lower stratum of soil at a depth of 30-45 cm. The case of open space was exactly the reverse of the result of soil under bamboo species where the Available P concentration in the middle layer was found to be the highest while it was found to be the lowest.

Venkatesh et al. (2005) revealed findings similar to those in this research. The mean accessible P concentration in soils under various bamboo species ranged from 0.86 to 3.36 kg/ha, potentially influenced by the strongly acidic soil response. The variation in P concentration across different soil layers could be attributed to variations in the rooting patterns of different bamboo species, P extraction from different soil depths, soil leaching dynamics, and levels of sesquioxides in the soils (Venkatesh et al., 2005). Kaushal et al. (2020) discovered that soil P increased in all species when compared to the control plot (open space).

In the study by Kaushal et al. (2020), soil P levels increased in *B. balcooa*, *B. bambos*, *B. vulgaris*, and *D. hamiltonii*, while decreasing in *D. strictus*, *D. stocksii*, and *B. nutans*, although these differences were not statistically significant. The rise in soil P is attributed to the greater rooting intensity and biomass observed in *B. bambos*, *B. vulgaris*, and *D. hamiltonii*. Conversely, the P reduction in *D. strictus*, *D. stocksii*, and *B. nutans* may be linked to their elevated P uptake by above-ground biomass and lower turnover through litter fall, which could occasionally result in P immobilization in microbial biomass (Kaushal et al., 2020). Different species may differ due to differences in litter decomposition rates (Kaushal et al., 2020). The nutritional concentrations of N, P, K, Ca, and Mg in bamboo litter rose with age (Shanmughavel et al., 2000). So, the difference in Available P concentration across soils of various species might be attributable to planting age, varied rate of decomposition, and differences in rooting pattern reaching different depths.

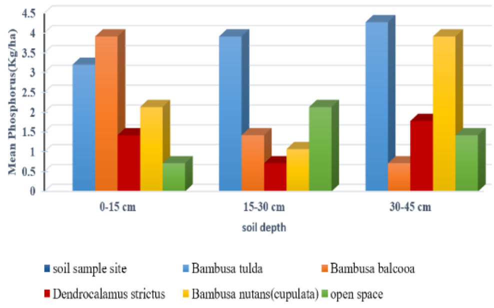

Figure 6: Total P content under different species according to depth

Available K

The results revealed that Available K concentration in soil beneath different bamboo species is higher than in open space, which is consistent to the findings of a previous study (Kaushal et al., 2020). The highest Available K concentration was found in soil under *B. tulda* at a depth of 15-30 cm, with a potassium value of 68.4 kg/ha. The soil of degraded land had the lowest K concentration at a depth of 0-15 cm, with a very low value of 8.88 kg/ha, which was equivalent to the K concentration *under D. strictus* at 30-45 cm. Available K concentration varies with soil depth which can be seen in Figure 6 as well, which might be attributed to differences in organic matter deposition at various layers under different species. Higher Available K deposition is found in the upper layers of soil in *Bambusa balcooa*, *D. strictus*, and *B. nutans subs. cupulata*, which may be due to higher organic matter deposition in the surface layer, but in the case of *B. tulda*, higher K concentration is found in 15-30 cm depth, which may be due to higher uptake rake of *B. tulda* from the surface layer as well as leaching, which has reduced K concentration .

Kaushal et al. (2020) discovered a fall in K concentration in the site following bamboo planted and explains this reduction in mean Available K to quicker growth, higher K absorption, and reduced soil turnover. Available K rose in soils of *D. hookeri*, *B. multiplex*, *D. giganteus*, *D. longispathus*, and

B. nutans compared to their control values, but reduced in *B. balcooa, B. pallida, D. hamiltonii, D. sikkimensis, M. baccidera*, and *T. wightii* (Venkatesh et al., 2005). Venkatesh et al. (2005) explain this differential influence of bamboo species on soil accessible K to differences in K absorption by bamboo species, K content, and leaf litter decomposition rate. According to the study (A. N. Singh and Singh, 1999), K absorption in bamboos is greater than N and P uptake, while reduced turnover of K was also documented and connected with quick accumulation by dominant bamboo species *D. hamiltonii* (Toky and Ramakrishnan, 1983) and slower release by litter fall. Bamboo is essential in K conservation because of its capacity to rapidly absorb and accumulate K in live biomass (Toky and Ramakrishnan, 1983).

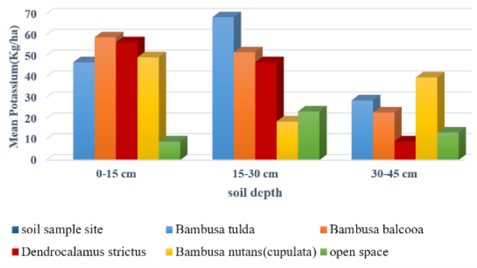

Figure 7: Total K content under different species according to depth

Table 2. Chemical Properties of soil under different bamboo species and degraded land

Species	Depth(cm)	pH	OC%	Total N (%)	Available P (kg/ha)	Available K (kg/ha)
Bambusa tulda	0-15	4.9	1.680233	0.14	3.2	46.8
	15-30	4.8	1.180233	0.1	3.91	68.4
	30-45	4.5	1.180233	0.1	4.27	28.56
Bambusa balcooa	0-15	4.4	1.093023	0.09	3.91	58.8
	15-30	4.6	1.180233	0.1	1.42	51.6
	30-45	4.7	1.011628	0.09	0.71	22.8
Dendrocalamus strictus	0-15	4.4	1.261628	0.11	1.42	56.4
	15-30	4.6	1.511628	0.13	0.71	46.8
	30-45	5.3	0.843023	0.07	1.78	8.88
Bambusa nutans subs. cupulata	0-15	4.5	0.587209	0.05	2.13	49.2
	15-30	4.5	0.25	0.02	1.07	18.48
	30-45	4.5	0.924419	0.08	3.91	39.6
Open Space	0-15	4.8	0.081395	0.01	0.71	8.88
	15-30	5.4	0.168605	0.01	2.13	23.28
	30-45	5.5	0.081395	0.01	1.42	13.2

CONCLUSION

From the study, it was revealed that the chemical properties of soil under different species vary. The soil pH, OC content, Total N, Available P and Available K of soil showed different result under different species and open space. OC content under *B. tulda* was maximum (1.68%) at the surface layer among bamboo species whereas degraded land had 0.16% at the surface layer. Soil under bamboo species was found to be more acidic than the soil in open space although *B. tulda* had the highest pH among other species. It was found that soil under *B. tulda* had more Total N, Available P and

Availabe K than the soil under other species of bamboo and in open space. Available P and Available K concentration of soil was found to be greater in the subsurface layer (15-30 cm) than in the surface layer (0-15 cm) under *B. tulda* compared to other species, which is attributed to the higher uptake of nutrients from the surface layer of soil and greater accumulation of organic matter in subsurface and leaching of nutrients from the surface layer.

B. tulda was the most abundantly distributed species of bamboo in the study area. Bamboo increases the nutrients availability in the soil through leaf litter accumulation and decomposition in the soil where other plant species can thrive well. Bamboo is already a good alternative for soil conservation but it is also an important species for eco-restoration of the degraded land. Comparatively, *B. tulda* was found to be the most suitable species in the Pani kholsi micro-watershed for soil conservation and increasing soil fertility as its organic carbon content and nutrient availability are higher. With some soil management practices such as regular soil testing, organic matter addition and mulching, degraded land could be rehabilitated to make it suitable for growing agricultural crops as well. So, it is a suitable species for the rehabilitation of degraded riverine land in similar regions of surrounding area. All four species of bamboo are very good for rehabilitation in terms of use. However, further study is required to learn which species is better in terms of improving soil chemical properties. Not any prior research was done in Nepal to find out the scope of Bamboo plantation in eco-restoration process as well as identification of suitable species for the soil conservation purpose. Statistical tests were not performed in this research to test the significance due to limited timeframe and budget to test the sigificance of the result. However, the obtained results provide a framework for future studies and overview of the condition of soil under bamboo species. Further investigation into the impact of bamboo species on soil properties and eco-restoration process is necessary. Governments, NGOs and INGOs need to launch different initiatives to explore the role of bamboo species in the eco-restoration process.

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