Bamboo Diversity Assessment and its Relationship with Soil Properties in Sarpang, Bhutan

Jambay and Pinkey Dahal

Abstract

The bamboo diversity study was conducted in three *gewogs* of Sarpang Dzongkhag. Diversity was studied, both in the forests and in the villages, using nets covering the *gewogs*. A total of 15 bamboo species from four genera were recorded. Bambusa was the most dominant genus in the study area. Species diversity, uniformity, and richness showed medium diversity (H = 2.239), high uniformity (J = .827), and high richness (D = 2.682) in the study area. Biodiversity and uniformity across land use types showed forest areas with the highest diversity (H = 2.91) and uniformity (J = .96), followed by agricultural land (H = 2.65; J = .88) and built-up area (H=2.20; J=0.86). Soil analysis showed that bamboo can grow in soils with organic carbon ranging from 0% (zero is not possible..)to 4.98%, with a mean of 1.87%. Similarly, soil moisture also ranged from 0.20 to 24.07% with a mean of 7.17% and organic matter from 0 (..not possible..?)to 2.90% with a mean organic matter of 1.28%. Soil pH ranged from 4.10 to 5.10 with a mean pH of 4.68, indicating that bamboo requires slightly acidic soil to grow. The Kruskal-Walli's test found that there was a significant difference ($p<0.05$) in bamboo diversity and soil properties across different land use types. Woodland had the highest culm count. Spearman's correlation showed a low to moderate correlation between bamboo diversity and different soil properties. Conic correlation analysis showed a correlation of bamboo species with soil properties that varied from species to species. The suitable habitat of bamboo covers about 40.92% of the total area. This study provides baseline data for future research and management purposes of bamboo in the country.

Keywords: Culm, Bamboo, Diversity, Habitat, LULC, Soil nutrients

Introduction

Bamboos, also known as green gold, belong to the Bambusoideae subfamily of the grass family Poaceae. It is one of the largest members of the grass family with a wide range of habitats and the species in which it grows varies. Bamboos are found on every continent except Antarctica and Europe with a total of 1,575 species worldwide, and the East Asian and Southeast Asian regions have the largest bamboo forests, comprising about 80% of the world's species (Yuming & Jiru, 1998). According to Stapleton (1994), Bhutan hosts about 30 native species from 14 genera. The total number of bamboo species increased to 33 species in 15 genera in the country (Thomas, 2017).

Bamboo plays an important role in the livelihoods of many cultures, both ecologically and economically. Not only is it useful for protection against soil erosion and small landslides, it is also an important non-timber forest product in many cultures (Stapleton, 1994). Due to its efficient root systems, bamboo is useful for improving soil properties in a short span of time. In addition, bamboo growing on slopes prevents erosion and landslides (Bystriakova, Kapos & Lysenko, 2004). In Bhutan, bamboo is widely used for handicrafts, construction, consumption of edible shoots, and fodder (Jambay, 2014). Due to its diversity and multiple usages, it plays an important role in development in mountainous countries such as Bhutan (Yuming, Kanglin, Shengji & Jiming, 2004).

Bhutan, one of the global Himalayan biodiversity hotspots, is known for its diverse floral composition (Wambulwa et al., 2021). The country, located in the ecologically fragile Eastern Himalayas, however, is vulnerable to climate change and development activities (Gross National Happiness Commission, 2019). Still, gauging by the inventories conducted in its neighboring countries, Bhutan is expected to host a significant number of bamboo species (Dorjee, 2019). The actual numbers have not yet been established as the national inventory of bamboo resources for Bhutan has not been conducted to date. The only comprehensive study of bamboo in the country was conducted by Stapleton (1994) and bamboo research has hardly developed since then.

In addition, information on the appropriate growing conditions for bamboos in the country are lacking and more studies on bamboo are needed before proceeding to species-level management strategies. The aim of this study is to provide information on soil composition and diversity of bamboo forests to understand better its growth needs. These data are intended to serve as reference data for further research and management of bamboo in the country.

Objectives:

1. Assess bamboo species diversity in Samtenling, Gelephu, and Chhuzagang gewogs under Sarpang District;
2. Compare bamboo diversity in different land use types;
3. Determine the relationship between soil properties and bamboo diversity; and
4. Construct suitable habitat for bamboos in the study area

Materials and Methods

Study area

The study was conducted in three *gewogs* of Sarpang Dzongkhang (Samtenling, Gelephu, and Chhuzagang) from January to Feburary of 2022. Sarpang Dzongkhag lies between 26.8643˚N and 90.2690˚E. The elevation of the study site ranged from 200masl to 500masl.

Sampling design

The systematic sampling procedure was applied using fishnets laid out with ArcGIS for three *gewogs* separately. Sample plots of 20 x 20m were plotted at each point. The distance between sampling points was 200m. The total number of culms of each species was recorded for each plot (Tran, 2010). At each point where a new species was encountered, soil samples were collected with the help of an augur at depths of 35cm, as most bamboo species develop at that depth due to their rhizome systems (Xiao, 1991; Fu, 2001. as cited in Tran, 2010). In order to ensure representativeness of the samples and to form a composite sample, the soil samples were taken in a zigzag fashion from each plot (Ministry of Agriculture, 2016).

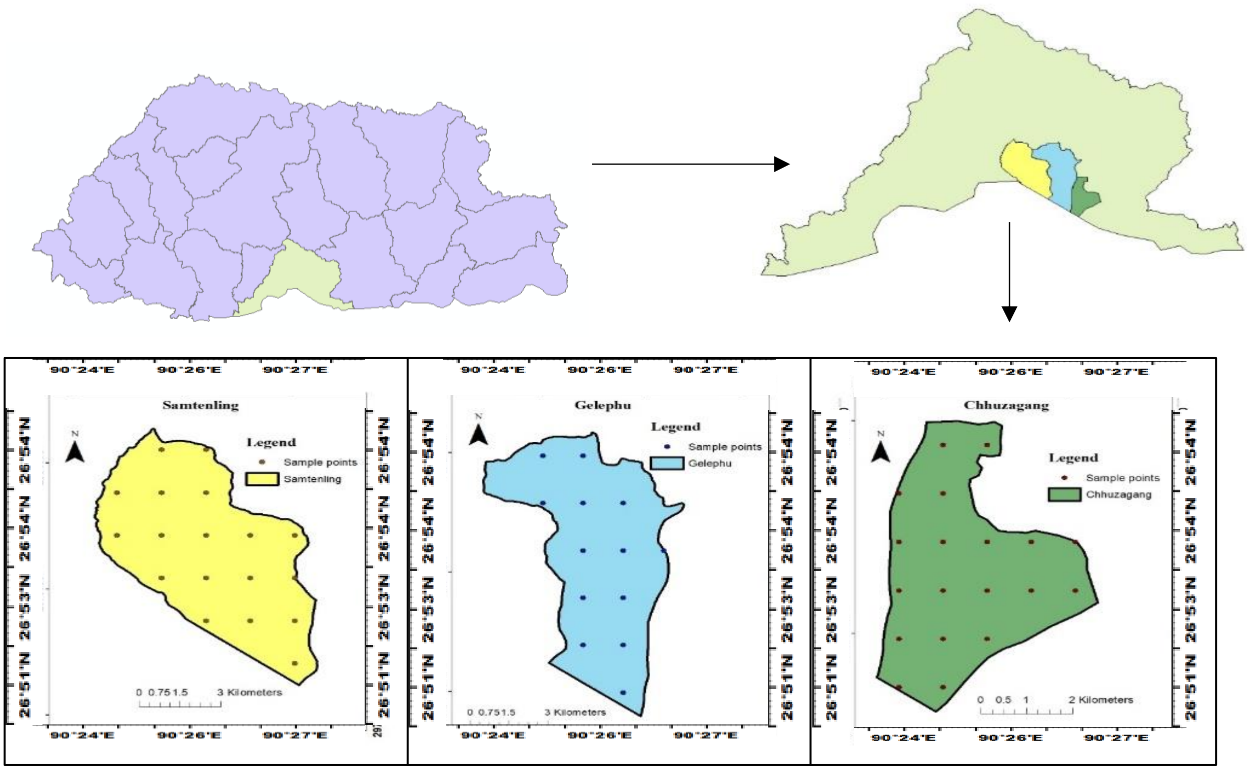

Figure 1. Study site

Results and Discussion

Species richness and evenness

A total of 15 species of bamboo were found in the study area which included three *gewogs* of Sarpang Dzongkhag (Table 1). The different bamboo species were found in their natural habitats as well as domesticated in the villages. Similarly, Dorjee (2019) recorded 18 species from a study conducted in Samdrup Jongkhar Dzongkhag at elevations ranging from 200 – 3600masl. The species recorded in the current study belonged to four different genera, namely *Bambusa, Dendrocalamus, Pseudostachuym,* and *Thamnocalamus*, with *Bambusa* being the most dominant genus. Out of these species, *Thamnocalamus* was recorded growing outside its native habitat range of 2800m – 3500m (Stapleton, 1994) with the elevation of the current study ranging from 193.6 to 498.9masl. However, the species was cultivated as an ornamental plant and was found only in one plot. Of the total 15 species recorded, *Bambusa clavata* Stapelton is listed as a vulnerable species on the IUCN Red List (International Union for Conservation of Nature and Natural Resources, 2022).

Bambusoideae species diversity

The species diversity, evenness, and richness indicated medium diversity *(H = 2.24),* high evenness *(J' = .83),* and high richness *(D = 2.68)* overall in the study area. Within the study area, Chhuzagang had the highest diversity *(H = 2.24),* evenness *(J' = .96)* and richness *(D = 2.23),* followed by Gelephu *(H' = 1.70, J' = .88)* and Samtenling *(H' = 1.63, J' = .71).* However, Samtenling had higher species richness *(D = 2.01)* as compared to Gelephu *(D = 1.65)*. Since other factors such as altitude, temperature, and precipitation were in constant range in all three *gewogs*, the diversity and evenness of the study site depended upon soil properties. As soil properties vary from one land use type to another (Ngo-Mbogba, Yemefack, & Nyeck, 2015), the diversity, evenness, and richness here too could have been affected by the soil properties of the land use type of a given area. The two *gewogs* of Samtenling and Gelephu had high anthropogenic activities such as development of airport and town areas, resulting in the decrease of forested and agricultural lands. Correspondingly, the Dzongkhag Administration of Sarpang (2021) also stated that developmental activities in Gelephu have already started leading to deforestation and loss of species.

Table 1. Bamboo checklist from the study area

SI No	Scientific name	Local name	IUCN Status
1	*Bambusa alamii*	Mugi bans (L)	NA
2	*Bambusa balcooa* Roxb.	Ban bans (L)	NA
3	*Bambusa clavata* Stapleton	Chile bans (L)	VU
4	*Bambusa multiplex var. riviereorum* Maire	-	NA
5	*Bambusa pallida*	Soh (D)	NA
6	*Bambusa nutans subsp. Cupulata*	Mal bans (L)	NA
7	*Bambusa tulda Roxb.*	Jushing (D)	NA
8	*Bambusa vulgaris* Schrad. Ex J. C. Wendl.	Soh (D)	LC
9	*Bambusa vulgaris striata*	Soh (D)	NA
10	*Bambusa vulgaris wamin*	-	NA
11	*Dendrocalamus hamiltonii* Munro *var hamiltonii*	Choya bans (L)	NA
12	*Dendrocalamus sikkimensis*	Demtshar (D)	NA
13	*Dendrocalamus strictus (Roxb.)* Nees	Latthi bans (L)	NA
14	*Pseudostachuym polymorphum*	Philing (L)	NA
15	*Thamnocalamus spathiflorus var. bhutanensis*	Pagshi (D)	LC

Table 2. Phyto-sociological parameters of Bambusoideae species

Sl. No	Gewog	*H'*	*D*	*J'*
1	Samtenling	1.627	2.010	.706
2	Gelephu	1.704	1.649	.876
3	Chhuzagang	2.222	2.226	.965
	Study site	**2.239**	**2.682**	**.827**

Species diversity in different Land Use types

Table 3. shows forested land to consist the highest species diversity *(H' = 2.91)* and evenness *(J' = .96),* followed by agricultural land *(H' = 2.65; J' = .88*), and built up area *(H' = 2.20; J' = .86).* This is in agreement with Aloyce, Manyanda, Macrice,

Mugasha, & Malimbwi (2019) who also concluded that bamboo diversity was highest in forested areas, followed by agricultural areas in a study conducted in Tanzania. However, built up area had the highest species richness *(D = 2.73),* followed by agricultural area *(D = 2.67)* and the least species richness was recorded in forested land *(D = 1.97).* This may be due to the domestication of several varieties of bamboos in the residential areas, whereas, only naturally occurring species are found in the forested land.

Table 3. Phyto-sociological parameters of Bambusoideae in different Land Use types

Sl. No	LULC	*H′*	*D*	*J′*
1	Agricultural area	2.65	2.67	.88
2	Built up area	2.20	2.73	.86
3	Forested land	2.91	1.97	.96

Edaphic factors assessment

The study analyzed basic soil nutrients required by bamboos for its growth. The result of this analysis determined that bamboos can grow in soils with soil organic carbon ranging from 0 – 4.98% with mean organic carbon content of 1.87% *(SEM±.30).* Similarly, soil moisture also ranged from .20 – 24.07% with a mean of 7.17% *(SEM±1.41),* and organic matter from 0 – 2.90% with mean organic matter of 1.28% (*SEM±.18)*. Soil pH ranged from 4.10 – 5.10 with a mean of 4.68 *(SEM±.09),* indicating that bamboos require a slightly acidic soil for its growth. The study site was composed of very strongly acidic soil (4.5 – 5.0 pH) with high content of organic matter (>.75) as compared to the standard soil nutrient content (Moktan, Wangmo, Dhal, & Rai, 2021). According to Toppo (2022), bamboos grow best between pH 4.5 – 6.0, which indicates that the soil in the study site was best suited for bamboo growth.

The analyses of primary nutrients such as Nitrogen, Phosphorous, and Potassium revealed lower Nitrogen content 0 – .25% with a mean N content of .10% (*SEM±.058)*, P content 9.39 – 39.17 mg/kg with an average of 23.39 mg/kg (*SEM±.13)*, and K content 4.10 – 45.0 with an average K content of 11.56 (*SEM±2.11)*. The findings were in line with Dorjee & Rai (2018) whose mean organic carbon, moisture, Nitrogen, and pH were 1.93%, 4.15%, .10%, and 5.87 respectively. The nutrient content of the current study was also in a similar range as the above study. The study site contained low N content (.07 - .15%), medium P content (<11.60 – 24.55 mg/kg), and low K content (<40.92 mg/kg) as compared to the standard soil nutrient content (Moktan, Wangmo, Dhal, & Rai, 2021).

Diversity and soil properties in different Land Use and Land Cover types

Kruskal-wallis test was used to determine differences in bamboo diversity and soil properties in different land use types such as Agricultural areas, Built up areas, and Forested lands. The results showed a significant difference in bamboo diversity in different land use types *($p = .05$).* Likewise, significant difference in soil properties such as soil organic carbon, moisture, organic matter, pH, nitrogen, and potassium also denotes difference in its contents across different land use types. Li et al., (2022), also state that soil properties such as organic carbon, nitrogen, potassium, and pH differed from one land use type to another. However, in the current study, phosphorous content did not show a significant difference *($p<.05$)* in different land use types, indicating that P content did not differ in different land use types. While the results agree with Brown, Reilly, & Peet (2016) who stated that the difference in bamboo diversity is due to the difference in soil properties in different land use types, it also contradicts Sofiah, Setiadi, & Widyatmoko (2018), who stated that Phosphorous had significant difference in bamboo diversity.

Table 4. Soil properties of the study area

	Culm Count	**Elevation (m)**	**OC (%)**	**Moisture (%)**	**N (%)**	**P (mg/kg)**	**K (mg/kg)**	**pH**	**OM (%)**
Min	22.00	205.70	.00	.20	.00	9.39	4.10	4.10	.00
Max	425.00	498.90	4.98	24.07	.25	39.17	45.00	5.40	2.90
Sum	2590.00	6126.90	33.73	129.08	1.82	420.99	208.00	84.21	23.03
Mean	143.89	340.38	1.87	7.17	.10	23.39	11.56	4.68	1.28
Std. error	29.30	24.42	.30	1.41	.01	2.16	2.11	.09	.18
Variance	15457.87	10732.26	1.58	35.80	.00	4.95	80.36	.16	.59
Stand. dev	124.33	103.60	1.26	5.98	.06	9.17	8.96	.40	.77
Median	100.00	341.75	1.86	5.60	.09	23.60	10.10	4.71	1.10
25 prcntil	48.00	237.75	1.07	2.83	.07	15.69	7.18	4.26	.82
75 prcntil	228.00	442.48	2.48	10.20	.12	30.43	13.15	5.01	1.99
Skewness	1.21	.22	.85	1.45	.67	-.77	3.31	-.03	.35
Kurtosis	.67	-1.59	.94	2.51	1.20	-18.36	12.75	-1.21	-.29
Geom. mean	100.62	325.45	.00	4.71	.00	21.46	9.78	4.66	.00
Coeff. var	86.41	30.44	67.01	83.43	59.07	666.78	77.58	8.46	60.18

Bamboo density in different Land Use types

The density of bamboos in different land use types was determined in terms of culm count. The highest culm count was observed in forested land, followed by agricultural area, and the least in built up area. This may be due to favorable growing conditions of bamboos where there was less human disturbance as well as good soil condition as compared to other land use types. Figure 4.4. illustrates that the culm count was highest where the soil nutrients were higher (within the optimum range). The above result is validated by Fentie, Jembere, Fekadu, & Wasie (2020), who also concluded that forested areas had the highest Phosphorous, Nitrogen, and Organic Matter whereas, agricultural area had the least Nitrogen and Organic Matter content.

Table 5. Kruskal-wallis test for soil properties and bamboo species diversity with LULC as the grouping factor

	OC	**Moisture**	**N**	**P**	**K**	**pH**	**OM**	**H'**
X^2	7.636	6.962	6.727	2.144	6.659	7.000	6.045	5.803
p	.022	.031	.035	.342	.036	.030	.049	.055

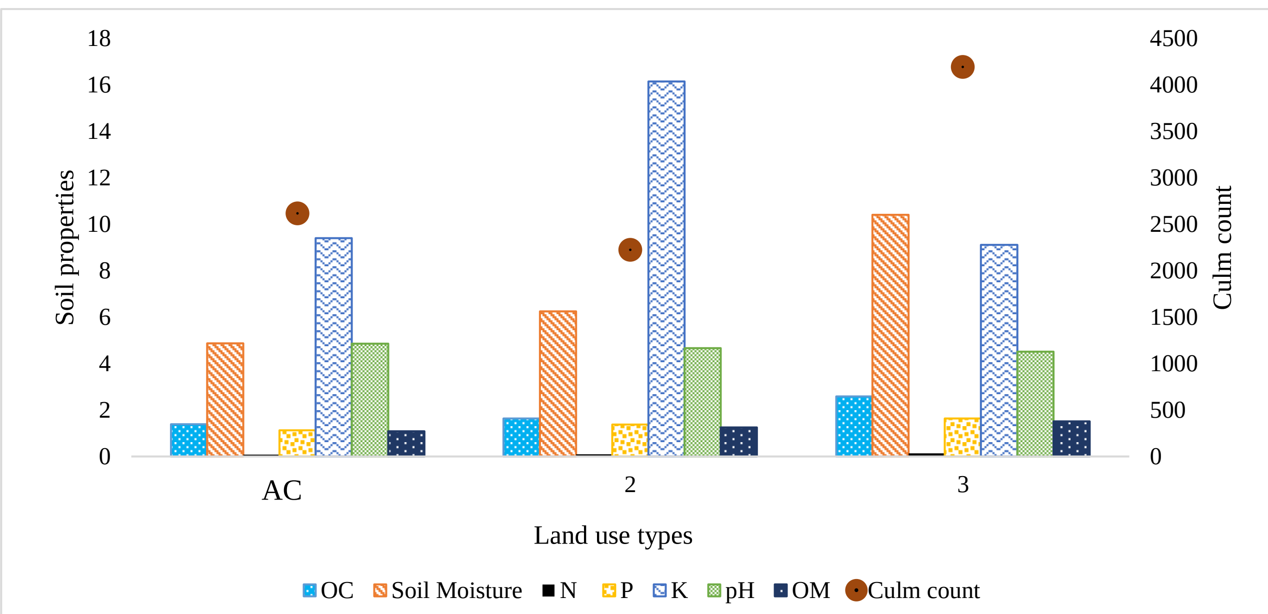

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Figure 2. Culm count and soil properties in different land use types

Spearman's correlation between soil properties and culm count

To determine how strongly each soil properties determined density, Spearman's correlation was conducted. The results of correlation revealed that elevation, organic carbon, soil moisture, and Phosphorous content had moderate negative correlation *(r > -.33)* with culm count. Whereas, Nitrogen, Potassium, and organic matter content had weak negative correlation *(r < -.33)* with culm count.

According to Piouceau et al. (2014), culm count increase with increase in nutrient contents, however, high nutrient contents reduce the overall culm count of bamboos. The study site may also have contained soil nutrients higher than its optimum level to illustrate negative correlation with culm count. The result is also supported by Kumari & Bhardwaj (2017), where the primary nutrients (NPK) and organic carbon had low to moderate negative correlation with culm count per hectre. Moreover, the negative correlation of culm count with organic carbon was justified with decrease in organic carbon with increase in soil depth (20 – 40cm). Similar methods were also employed in the current study where soil samples were collected from the depth of 30cm.

However, soil pH displayed moderate positive correlation *(r > .33)* with culm count. Likewise, another study also illustrated positive correlation between soil pH and culm count. (Gao, et al., 2021). This finding indicated that bamboos grow best in acidic soil, which makes bamboos suitable for plantation in degraded lands in the sub-tropical regions where soils have low pH (Kleinhenz & Midmore, 2001).

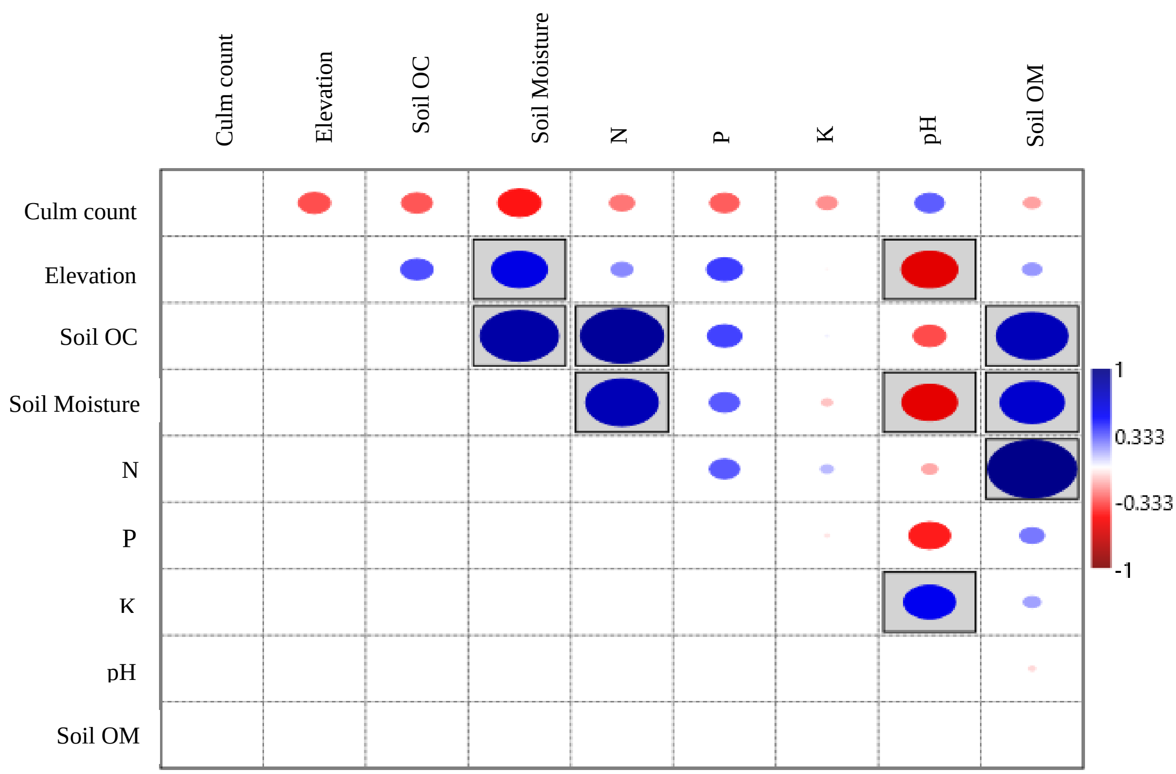

Figure 3. Spearman's correlation matrix

Conical Correlation Analysis between bamboo species and edaphic factors

A Conical correlation analysis was conducted with eight different edaphic factors as predictor variables for 15 species of bamboos to determine the shared relationship between the two variable sets. The two components of the following graph explain about 49.58% of all variability of soil properties observed in the study site. Figure 4. illustrates that elevation and Phosphorous content had the highest influence on bamboo species. *Dendrocalamus hamiltonii* displayed a positive correlation with Phosphorous content in the soil and *Bambusa alamii* also illustrated a positive correlation with soil organic matter and Nitrogen content,but a negative correlation with Phosphorous content.

Species such as *Bambusa pallida, Bambusa tulda, Bambusa vulgaris wamin, Dendrocalamus sikkimensis,* and *Thamnocalamus spathiflorus* were, however, not affected by any of the soil properties. In agreement with the above statement, Uchimura (1980), stated that bamboos can grow in wide range of soil conditions and the above species may had been growing in unfavourable soil conditions.

A majority of bamboo species such as *Bambusa balcooa, Bambusa multiplex, Bambusa nutans, Bambusa vulgaris, Bambusa vulgaris striata, Dendrocalamus strictus,* and *Pseudostachuym polymorphum* displayed positive correlations with elevation, pH, soil moisture, and Potassium content, while they displayed negative correlations with soil organic matter, Carbon, Nitrogen, and Phosphorous content. The above result was supported by Kaushal et al. (2020), in which soil properties such as pH, organic carbon, and Phosphorous content had no significant changes among the species although total Nitrogen and Potassium displayed significant variation among the species. The difference in correlation among different species and soil properties is authenticated by Sofiah, Setiadi, & Widyatmoko (2018), who state that some soil properties have stronger impact on a particular species than others. A majority of all land use types showed negative correlation with Phosphorous content and positive correlation with the remaining soil properties. Moreover, Bhimala, Rakesh, Prasad,& Mohapatra (2020), also stated that vegetation changes depended mostly on soil moisture and LULC changes.

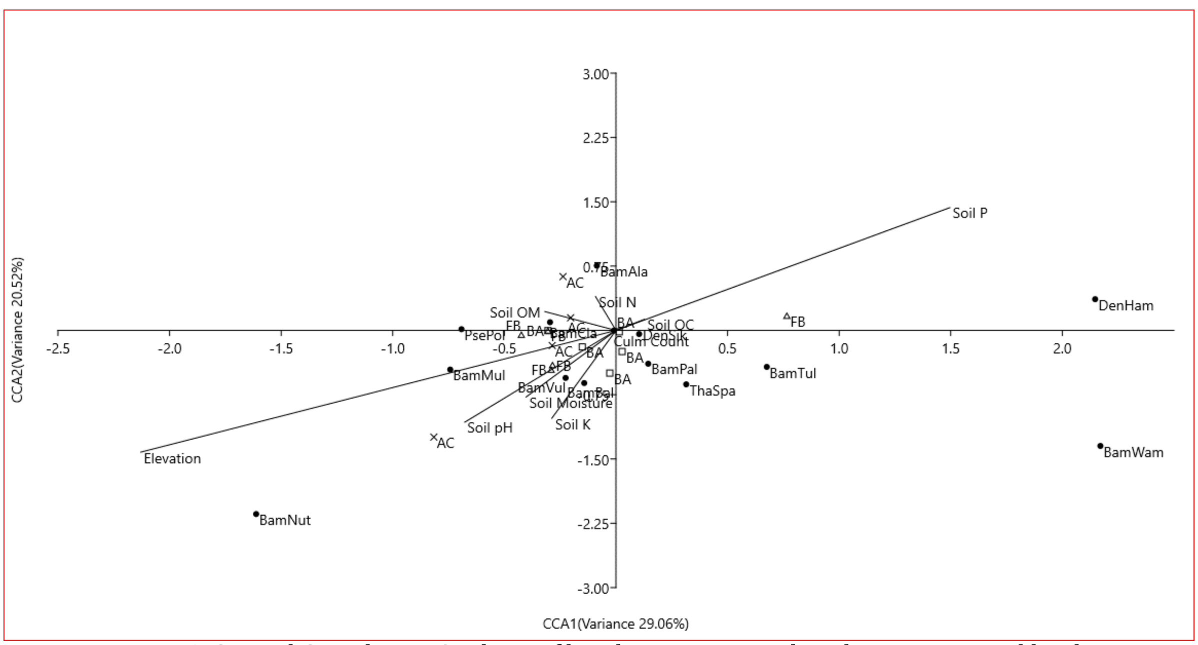

Figure 4. Conical Correlation Analysis of bamboo species with soil properties and land use types

Suitable habitat for Bambusoideae subfamily in the study area

The ArcGIS suitability model resulted a total of 53.40275 km^2 as suitable habitat for growth of Bambusoideae subfamily from the total study area of 130.5336 km^2. The suitable habitat covers about 40.92% of the total area. However, some species were encountered in areas which were not suitable in the habitat model. This may be due to plantation of bamboos by the local people in their agricultural or residential areas. Habitat modelling can be used to design management strategies for conservation of species (Rosas, Peri, Herrera, Pastore, & Pastur, 2017). The study recommends for conservation assessment and management in the areas marked as low for habitat preference for bamboo growth.

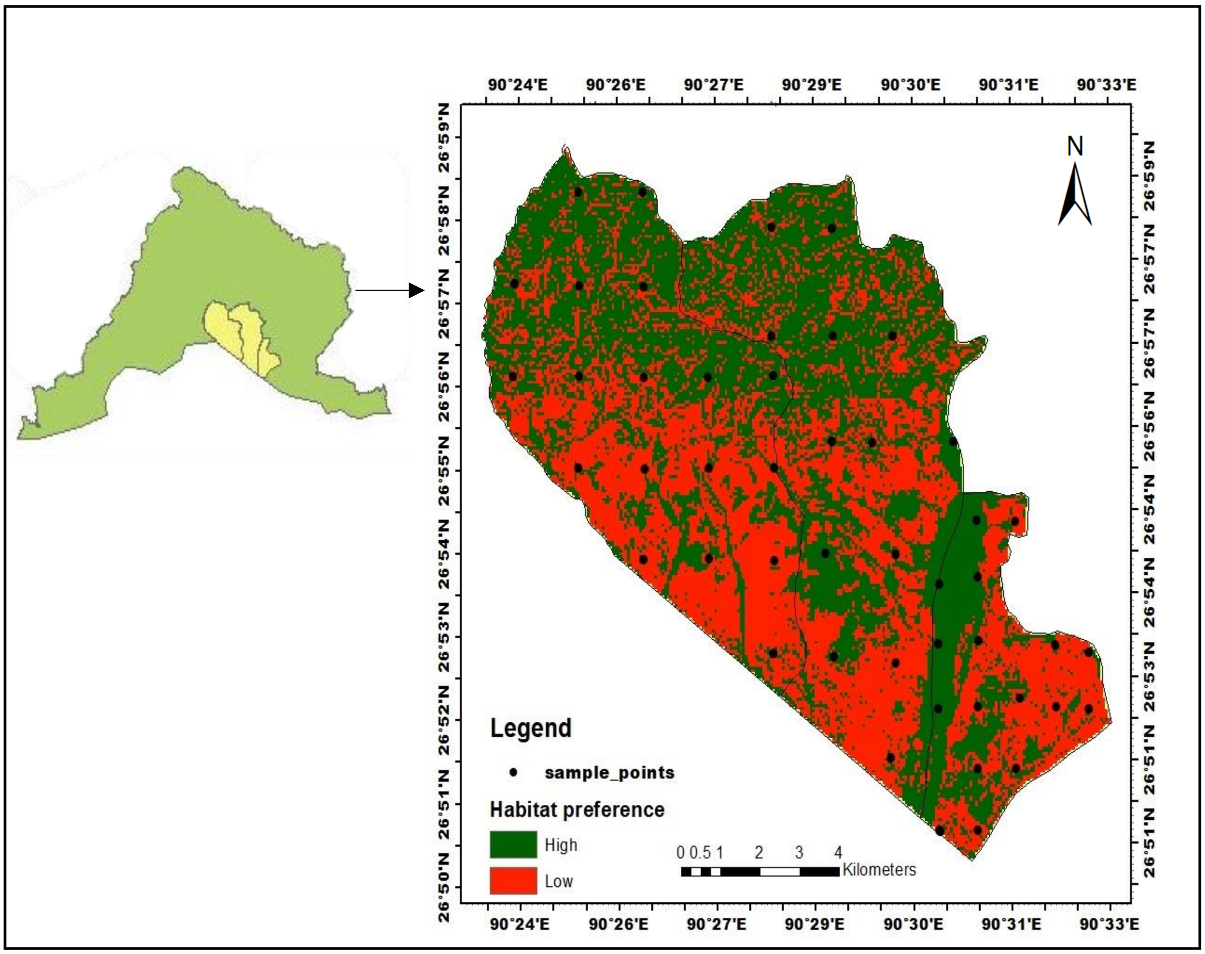

Figure 5. Suitable habitat of Bambusoideae subfamily in the study area.

Conclusion

A total of 15 species belonging to four genera were recorded from 50 plots surveyed in three different *gewogs*. The species belonged to genus *Bambusa, Dendrocalamus, Pseudostachuym,* and *Thamnocalamus.* However, Thamnocalamus was growing outside its native habitat range. In general, the subfamily Bambusoideae was found in slightly acidic soil and high OC, OM, P and K content and low soil N content.

The study compared the species diversity, evenness, and richness of bamboos in three different *gewogs* of the study area which determined that Chhuzagang Gewog had the highest diversity, evenness, and richness as compared to Samtenling and Gelephu. Since the study area covered the entirety of the three *gewogs*, different land use types with bamboos were encountered from which forested land had the highest diversity. The bamboo density was highest in forested land due to favorable soil conditions. Conical Correlation Analysis also displayed correlations of bamboo species with soil properties which varied from species to species. The habitat suitability model of the study area illustrated favorable sites for bamboo occurrence.

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