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STUDY OF THE HABITAT, AND POTENTIAL DISTRIBUTION OF HIMALAYAN GINSENG (*Panax pseudoginseng* Wall.), AND THE DIVERSITY OF ITS ASSOCIATED SPECIES IN NANGKOR AND SHINGKHAR GEOGS, ZHEMGANG, BHUTAN

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Abstract

Panax pseudoginseng Wall. is a highly sought-after medicinal plant in Bhutan, but little is known about its distribution and habitat in the country. Therefore, this study aimed to determine suitable habitat, and potential distribution of *P. pseudoginseng*, and the diversity of its associated species in Nangkor and Shingkhar Geogs, Zhemgang, Bhutan. A total of 42 plots were laid using a purposive sampling method. Various parameters like slope, aspect, soil nutrients, soil pH, humidity, temperature, and soil water tension were collected. The Spearman's correlation test indicated that the temperature and canopy cover had negative association with the counts of *P. pseudoginseng*. The Spearman's correlation test for NPK indicated that Phosphorus had significant difference with the counts of *P. pseudoginseng*. A total of 1,277 species distributed in 87 genera of 66 families were recorded including the trees, herbs and pteridophytes. Fagaceae was the most dominant family in the study area. Seven types of forest were classified based on the floristic composition of trees. Potential distribution was obtained using ArcGIS that combined observation data, reclassification and Weighted Overlay. Overall, 95.39% of an area under Zhemgang District is suitable for the growth of *P. pseudoginseng*.

Keywords: Altitude, Humidity, NPK, Suitability, Temperature

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Introduction

The genus *Panax* was derived from the Greek words 'pan' and 'axos' which means all and cure respectively by Russian botanist C.A. Meyer as its rhizome is useful in traditional medicine (Radad *et al*., 2004). There are 17 species under the genus *Panax* (Zhang *et al.,* 2020). *P. pseudoginseng* is native to India (Sharma and Sett, 2001), and is found in China, South Tibet, North Burma (Lolen *et al.,* 2016), North-East India and Bhutan (Royal Government of Bhutan [RGoB] and European Union [EU], 2008).

Flora of Bhutan contains 13 genera with 27 species in the Araliaceae family. Only one species (*P. pseudoginseng*) is found in Genus *Panax* (Grierson and Long, 1991). It is known as Bhreeng-geera-dza (Dzongkha term) (RGoB and EU, 2008), and listed in Schedule I as a totally protected plant species (RGoB, 1995). *P. pseudoginseng* has several nomenclatural synonyms, including *Aralia quinquefolia* Decne. and Planch. var. *pseudoginseng* (Wall.) Burkill, *Aralia pseudoginseng* (Wall.) Benth. ex C.B. Clarke, and *Panax sikkimensis* R.N. Banerjee. It is also known as Indian Ginseng, False Ginseng and Himalayan Ginseng in commercial trade (Becker, 2012).

The plant contains an active ingredient in the root (rhizome) called Ginseng saponins, which is useful in diverse ginseng products. Ginseng saponins are also called Ginsenosides (Radad *et al.,* 2004). It prefers habitat under canopy cover not less than 80% shade in undisturbed areas (Kumar *et al.,* 2019) within the altitude range of 3000 - 4000 masl. It normally grows in a cold climate where dew, hoar frost and snow falls regularly (Lolen *et al.*, 2016) with rich organic matter, thick forest soil and compost having the moist area (Merry *et al.,* 2017). A study was done on the medicinal plants including *P. pseudoginseng* in Bhutan (Wangchuk *et al*., 2016), but it contained limited information about its presence and distribution (RGoB and EU, 2008).

The over harvesting has led the species to be highly endangered (Merry *et al.,* 2017). Due to its high demand, it is harvested in huge quantities risking its sustainability (Jamir, 2014; Twyford, 2017). Therefore, apart from showing the potential distribution, this study will serve as the baseline data on habitat studies such as soil nutrients, soil moisture, soil pH, aspects, altitude, canopy cover, and associated floristic composition which will help in conservation of *P. pseudoginseng*.

Materials and Methods

Study site

Zhemgang District is located at 27°12’50.60" N and 90°39'19.32" E with an annual rainfall of 126.5 mm and a mean temperature of 16.1°C (National Center for Hydrology and Meteorology [NCHM], 2017). The Central Bhutan was chosen as the study area particularly at Nangkor and Shingkhar Geogs, under Zhemgang District. The district has warm and humid climatic conditions.

Table 1: Showing the different attributes of the two study areas

Attributes	Nangkhor Geog	Shingkhar Geog
Area	543 sq.km	325 sq.km
Elevation	500-1700 masl	1000-4000 masl
Population	2,602	1,276

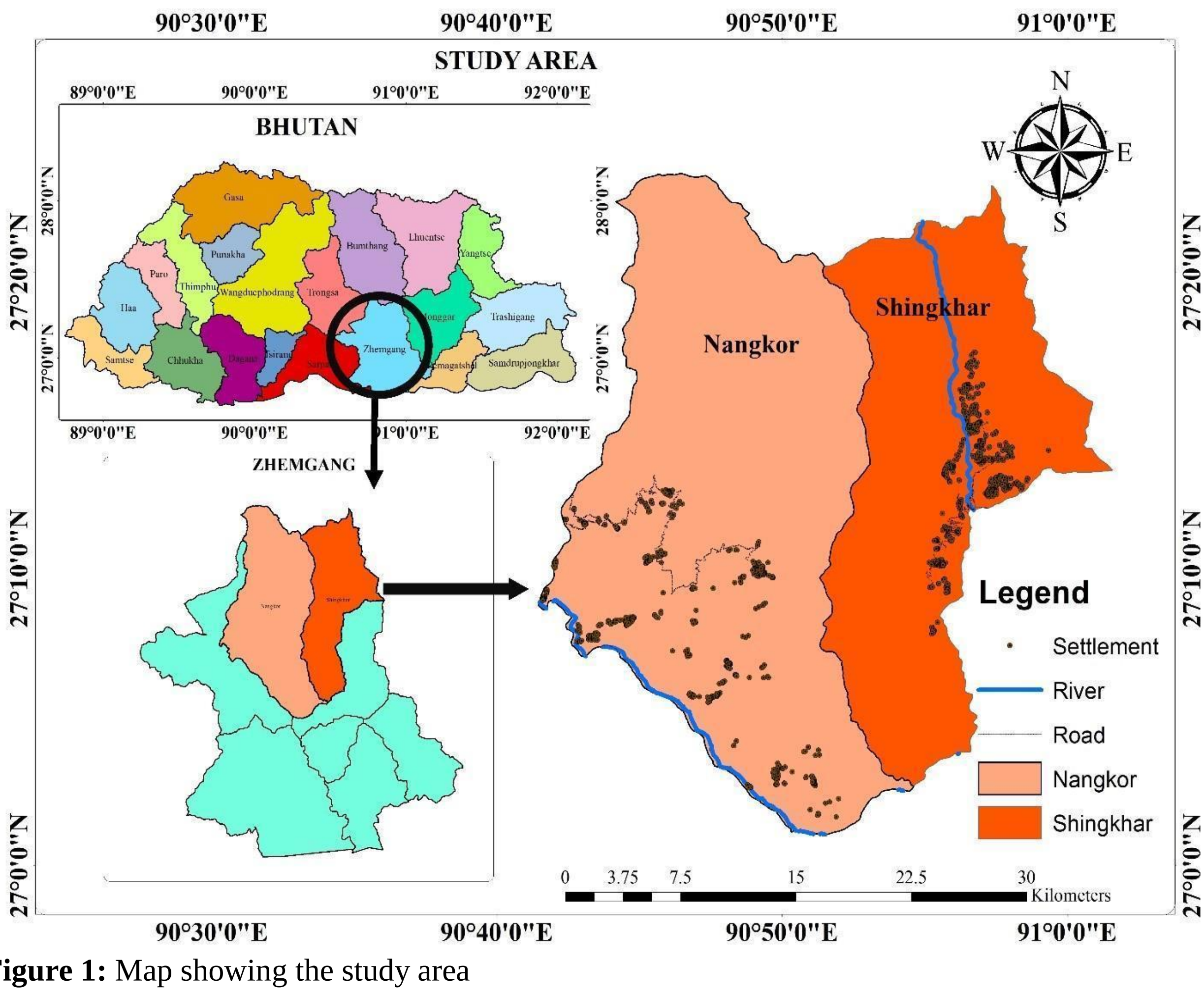

Figure 1: Map showing the study area

Northern regions have moderately cool temperature (Tourism Council of Bhutan [TCB], 2020), which is favorable to collect data during late winter and early spring. Nangkor Geog, consists of 5 Chiwogs, 513 households as per Geog Census Record, 2017 (Zhemgang Dzongkhag Administration [ZDA], 2018). Shingkhar lies to the North-East of the District, which comprises of 5 Chiwogs and falls in the temperate zone with an altitude range from 1000 - 4000 masl. The Geog consists of 325 sq.km of which 77% is under forest coverage with different micro-climate favoring various floristic compositions (ZDA, 2018). The northern part of Geog falls under Phrumsengla National Park (Department of Forest and Park Services [DoFPS], 2020).

Sampling methods

The study was carried out in 2021 in early spring in two Geogs. The species were counted using a purposive sampling method, since *P. pseudoginseng* is less abundant in nature. For the associated species evaluation, a total of 42 sample plots (major) (Figure 2) were laid using the quadrat method of 20 m x 20 m (400 m^2) for tree species (Wheater *et al.*, 2011), and for ground cover species (shrubs) a plot of 5 m x 5 m (25 m^2), and 1 m x 1 m (1 m^2) plots were laid for herbs. *P. pseudoginseng* was counted within the center of the major plot (Forest Resource Management Division [FRMD], 2012). In the major plot, for all the trees (≥1.3 m), Diameter at Breast Height (DBH) were enumerated and other associated species within the sample plot were recorded.

For the habitat study, soil samples were collected from the nearby area where *P. pseudoginseng* was found within the plot of 10 cm x 10 cm (100 cm^2). Commonly used sample depth for soil sample collection is 0 to 15 cm for the Soil Organic Carbon (SOC) and nutrients (Pennock *et al.*, 2007). The soil samples were analyzed in the soil laboratory of the College of Natural Resources (CNR). Relative humidity and temperatures were collected using a Data logger. Altitude was recorded using GPS, slope with Clinometer and soil water tension with Tensiometer.

Its potential distribution was analyzed using ArcGIS (Model Builder). It was used for combination of vectors (road, study area and river), and raster data (Aster DEM and land use and land cover), with the output being raster data that were analyzed for suitability using the significant parameter. Rivers, roads and settlements were buffered with 30 m, 50 m and 1 km respectively. These combined observation data on environmental variables such as settlement, land use and land cover, forest types, elevation, and aspects. All the factors were reclassified with high weightage given to the highly suitable factors, and used Weighted Overlay from Arc Tool Box (Latif *et al*, 2019). The output clearly displayed the suitability, and areas were calculated from the Attribute table of ArcGIS.

Data analysis

The data collected from the field was compiled in Excel and analyzed using Statistical Package for Social Sciences 23 (SPSS) to find the species diversity and abundance of associated species in the habitat of *P. pseudoginseng.* Vegetation analysis was done using PC-ORD software. The Shannon's Diversity Index, Pielou's Evenness and Margalef's species richness (Yeom and Kim, 2011; Olawusi and Ajibare, 2014) were used for analyzing the diversity, species evenness and richness respectively. Berger-Parker's Dominance index (Olawusi and Ajibare, 2014) was used to determine the dominant species.

To calculate the most dominant associated plant species with *P. pseudoginseng*, Important Value Index (IVI) analysis was conducted following Nguyen *et al.* (2014). Soil pH was analyzed by the Electrometric method. Nitrogen content in the soil was determined through the Loss of Ignition method, which was used to determine Soil Organic Matter. Total potassium content was determined by decomposition of the sample through HF, followed by flame photometric determination (Sakar, and Haldar, 2005). Phosphorus content was determined using the Bray II extraction method followed by spectrophotometric determination (Sakar and Haldar, 2005).

Results and discussion

Species composition

Including trees, herbs and pteridophytes, a total of 1,277 species of 87 genera belonging to 66 families were recorded in the entire study sites. Fagaceae was the most dominant family in the entire study site.

Major life form of tree

In the study area, 210 tree species of 31 genera belonging to 19 families were distributed with maximum number of species in Fagaceae (*n* = 94), Lauraceae (*n* = 32) and Symplocaceae (*n* = 19). The following were the top ten dominant tree species in the decreasing order on the species counts in the entire study area; *Castanopsis hystrix* J. D. Hooker & Thomson ex A. de Candolle, *Lithocarpus elegans* (Blume) Hatus. ex Soepadmo, *Quercus lamellosa* Sm., *Beilschmiedia gammieana* King ex Hook. Fil., *Symplocos ramosissima* Wallich ex G. Don, *Cinnamomum* *impressinervium* Meisn., *Castanopsis tribuloides* (Smith) Lindley., *Lindera pulcherrima* (Nees) Benth. ex Hook. F., *Cinnamomum bejolghota* (Buch.Ham.) Sweet., and *Daphniphyllum himalayense* (Benth.) Müll. Arg. The floristic composition such as *Alnus nepalensis* (Betulaceae), *Schima wallichii* (Theaceae), and *Cinnamomum impressinervium* Meisn (Lauraceae) were found as a major life form of tree in association of *P. pseudoginseng* (Lolen *et al*., 2016). Sharma and Sett (2001) found out that *Quercus* sp. was most dominant tree, supporting our finding.

Major life form of understorey

The life form understorey includes shrubs (deciduous and semi-evergreen), climbers, pteridophytes and mosses. A total of 381 ground cover species consisting of 21 genera of 19 families were recorded from the major ground cover species. The top three dominant families in decreasing order were Athyriaceae (*n* = 36), Dryopteridaceae (*n* = 33) and Polygonaceae (*n* = 25) respectively. The top 10 dominant species were *Selaginella monospora* (Spring) Baker., *Diplazium esculentum* (Retz.) Sw., *Persicaria chinensis (*L.) H. Gross., *Dryopteris nidus* (Baker) Zhang, *Plagiogyria pycnophylla* (Kunze) Mett., *Hedera nepalensis* K. Koch, Hort. Dendrol, *Rubus ellipticus* Smith, *Strobilanthes oligocephala* T. Anderson ex C. B. Clarke in J. D. Hooker, Fl. Brit., *Tetrastigma* sp., and *Daphne boula* Prezi. The study done by Pandey *et al.* (2007) mentioned that it grew in association with pteridophytes particularly *Plagiogyria* sp., *Strobilanthes* sp. and *Polygonum* sp. which was a similar finding.

Major life form of underground cover

The major ground cover species consisted of 677 species with 34 genera of 28 families. The species consisted of herbs (annual, biennial, perennial, and climber) which dominated the underground cover. The top three dominant families in decreasing order were Urticaceae (*n* = 271), Violaceae (*n* = 83) and Araliaceae (*n* = 69) respectively. The most dominating species of herbs were *Pilea pumila* Linnaeus, *Elatostema lineolatum* Wright, *Elatostema* sp., *Viola pilosa* Blume, *P. pseudoginseng*, *Oplismenus* sp., *Viola* sp., *Pilea* sp., *Ageratina adenophora* (Spreng.) R.M. King & H. Rob, and *Girardinia diversifolia* (Link) Friis, Kew Bull. *P. pseudoginseng* was among the top ten dominant species in the study area. The study done by Lolen *et al*. (2016) also found that it grew in association with *Dicentra* sp. (Fumariaceae), *Impatiens* sp. (Balsaminaceae), and *Pilea umbrosa* Blume (Urticaceae) which were usually found in damp and moist areas.

Diversity and Evenness

Shannon-wiener index of species diversity for trees ('H') showed 3.13, for herbs *H'* = 3.18 and *H'* = 3.07 for ground cover species (including shrub, climber and fern species), stating higher diversity of trees (Jost, 2010) within the ecological range of *P. pseudoginseng.* Similar report of Shaheen *et al.* (2011) supported the finding that higher herbs and shrubs diversity may be due to thin canopy of the tree which provides the required amount of light favoring the growth of herbs and shrubs. The diversity of trees were high due to suitable microclimate and environmental factors. Similarly, the Pielou's Evenness Index (J) for trees showed 0.83, *J* = 0.79 for herbs and *J* = 0.86 for other ground cover species, indicating that the species are almost evenly distributed (Help *et al.,* 1998).

Species richness (S_R)

Table 2: Species Richness of Associated Species

	S_R (Trees)	**Plots**	**S_R (Shrubs)**	**Plots**	**S_R (Herbs)**	**Plots**
High SR	9	23	1	13	46	17
	8	6, 7 & 11	29	22	43	19
	7	1, 2 & 8	23	4, 18 & 42	38	19
Low SR	5	29, 31, 36, 37, 39 & 42	19	7	3	21
	4	4, 5, 9, 14, 15, 17, 18, 20 & 38	3	27	2	4
	3	12, 16, 33, 34, 40 & 41	21	5,12,16,32,3 & 37	1	7

The habitat of *P. pseudoginseng* was outnumbered by herbs with the highest number of species ($S_{R\,=}$ 46) followed by shrubs (S_R = 29) and tree species (S_R = 9). Pearson correlation test of species richness within the plot showed that species richness patterns were positively correlated with total plant species richness S_R = 0.32 (*P* = 0.039) as supported by Herzog and Kessler (2009). Since the vegetation composition in the study areas were found to be heterogeneous, differences in the number of individual trees, climber, herb and shrub species and their indices in the study area may be due to differences in different micro climatic and local factors observed in the study area (Dash, 2016).

Important Value Index (IVI)

Table 3: IVI of Associated Species

	Species (Tree)	IVI	Species (Pteridophytes)	IVI	Species (Herbs)	IVI
Most dominant	*Castanopsis hystrix*	26.24	*Diplazium esculentum*	26.24	*Panax pseudoginseng*	26.24
	Lithocarpus elegans	23.84	*Persiaria chinensis*	23.84	*Pilea pumila*	23.84
	Quercus lamelosa	22.48	*Dryopteris nidus*	22.48	*Elatostema lineolatum*	22.48
Least dominant	*Prunus cerasoides*	0.56	*Cyathea spinulosa*	3.00	*Calanthe plantaginea*	0.56
	Litsea glutinosa	0.54	*Hedychium* sp.	3.00	*Chirita macrophylla*	0.54
	Brassaiopsis hainla	0.49	*Smilax lanceifolia*	3.00	*Hydrocotyle himalaica*	0.49

Castanopsis hystrix A. DC. UPOV, *Lithocarpus elegans* (Blume) Hatus. ex Soepadmo, and *Quercus lamellosa* Sm. were the most dominant species while *Prunus cerasoides* D. Don, *Litsea glutinosa* (Loureiro) C. B. Robinson, and *Brassaiopsis hainla* (Buch. Ham.) Seem were the least dominant tree species just as reported by Chettri (2010). This is because the dominant species have a high ability to regenerate in the micro environment while least dominant species are less viable to germination (Turner, 2001).

Plots 11 and 19 had a high number of dominant species, while plots 4 and 13 had few dominant species. The proximity of the plots from the pasture land and the difference in the presence of the anthropogenic activities could be the probable reasons for such difference. However, the result contradicts Rol (2013) as the dominance of this species could vary due to habitat adaptation and favorable environmental conditions that favor dispersal, pollination and eventual establishment of the species. Similar situations were reported by Pausas and Austin (2001) on species richness in relation to the environment. In this study, *P. pseudoginseng* was the most dominant species due to the purposive sampling method employed to do the survey. The result of understorey (Shrubs) contradicts Rol (2013), and this could be due to differences in environmental conditions and the canopy cover of the forest stand.

P. pseudoginseng response to environmental factors

Temperature

The annual temperature of the study site ranged from 14.5 - 26.6°C, with a mean annual temperature of 20.56°C (± 2.96 *SD*). The Spearman's correlation test indicated that the temperature had a negative association (*r* = -0.137, *p* = 0.03) with the count of *P. pseudoginseng*, indicating a decline in the number of plants with the increase in temperature. Sakutemsu *et al.* (2016) reported that the temperature below 30°C is favorable for the growth of *P. pseudoginseng*. However, Shahrajabian *et al.* (2019) reported that it grows best in 10 - 25°C, and high temperature adversely affects ginseng by initiating photosynthesis cessation, drying of leaves, and early defoliation.

Table 4: *P. pseudoginseng* response to environmental factors

	***P. p* count**	**Alt**	**Slope**	**SWT**	**RH**	**Tem**	**Cc**	**pH**
P. p count	1							
Alt	-0.15	1						
Slope	-0.07	-0.03	1					
SWT	0.28	0.09	0.09	1				
RH	0.07	0.00	-0.10	-0.1	1			
Tem	-0.13	-.42**	0.08	-0.1	-.54**	1		
CC	0.03	-0.02	0.13	0.05	0.09	-0.20	1	
pH	0.16	-0.23	0.18	0.03	0.05	-0.12	-0.08	1

**Correlation is significant at the 0.01 level (2-tailed)

P. p count = *P. pseudoginseng* count, Alt = Altitude, SWT = Soil Water Tension, RH = Relative humidity, Tem = Temperature, Cc=Canopy cover

Slope

The slope range was between 15 - 49° with a mean of 34.81° (± 9.171 *SD*). The Spearman's correlation test indicated that the slope had a negative correlation (*r = -0.07, p = 0.001*) with the number of plants as the slope increased. For the favorable growth of *P. pseudoginseng* the slope range should not exceed more than 49°, because the dispersal of seed and its rooting is often found difficult, especially in the steep slopes (i.e., fluctuating asymmetry) (Auslander *et al.*, 2003). Not only slope has a large impact on the quantity and function of plant communities, but also plays a key abiotic factor in plant diversity and change in soil nutrients. The effects of slope on plant communities are primarily reflected in plant communities' growth conditions and soil erosion, plant abundance, community diversity, and vegetation distribution patterns, among other things. Hence, as the slope increases, the number of *P. pseudoginseng* decreases (Zhang *et al.*, 2018).

Elevation

The Spearman's correlation test indicated that the altitude ($r = -0.15$, $p = 0.053$) did not significantly affect the number of *P. pseudoginseng*, as the plant was found in a similar elevation. Elevation range of the study site was 1,609 - 2,655 masl with a mean of 2,024.93 (± 242.598 *SD*), and it is favorable for the growth of *P. pseudoginseng* was found at an elevation of 1800 masl as supported by Tanaka *et al.* (1990).

Soil pH

The soil pH ranged from 4.79 - 6.71 with mean soil pH of 5.66 (± 0.48 *SD*). The Spearman's correlation test indicated that the pH ($r = 0.16$, $p = 0.31$) did not have a significant difference as almost all the values were close to each other. It grows in an area where the soil is slightly acidic. Thach *et al.* (2014) supported that with an increase in pH ($r = 0.16$, $p = 0.31$), the development of adventitious roots also increased to some extent as it induces root elongation. The plant best survives at pH 5.5 - 6.5 (Jamir, 2014).

Canopy cover

The canopy cover ranged from 30 - 95% in the habitat with mean canopy cover range (61.45%) (± *16.29 SD*). The Spearman's correlation test indicated that the canopy cover had a weak negative correlation ($r = -0.03$, $p = 0.026$) to the number of *P. pseudoginseng.* A similar finding confirms that *P. pseudoginseng* were physiologically adapted to low light intensity. The increase in light does not increase photosynthesis (Muir *et al.*, 2011). Therefore, it grows naturally and survives better under the shade of tall trees (Court, 2006).

Table 5: Summary of environmental attributes of the study area

Environmental Attributes	Minimum	Maximum	Mean	Std. Deviation
P. *pseudoginseng* count	1	9	1.74	1.32
Altitude (masl)	1609	2655	2024.93	242.59
Slope	15	49	34.81	9.17
Soil water tension (mb)	37	63	49.79	6.42
Relative humidity of Air (%RH)	39.1	64.3	52.46	5.62
Temperature (°)	14.5	26.64	20.59	2.96
Canopy cover (%)	30	95	61.45	16.29
pH	4.79	6.71	5.66	0.48

Relative humidity of air (% RH)

Relative humidity of air ranged from 39.1 - 64.3 with a mean relative humidity of 52.466 (± *5.62 SD*). Spearman's correlation test indicated that the humidity ($r = 0.07$, $p = 0.653$) did not significantly affect the number of *P. pseudoginseng* as most of the plants were found in moist and damp areas. Growth of *P. pseudoginseng* was favored with 60% of relative humidity of air (Mcgraw *et al*., 2013).

Soil water tension (mb)

The soil water tension (mb) ranged from 37 - 63 mb with a mean soil water tension of 49.79 mb (± *49.79 SD*). The Spearman's correlation test indicated that the soil water tension (mb) ($r = 0.281$, $p = 0.072$) did not significantly affect the number of *P. pseudoginseng*. According to Court (2006), the soil must have high water content with rich organic matter which enhances seed germination.

Potential distribution of *P. pseudoginseng*

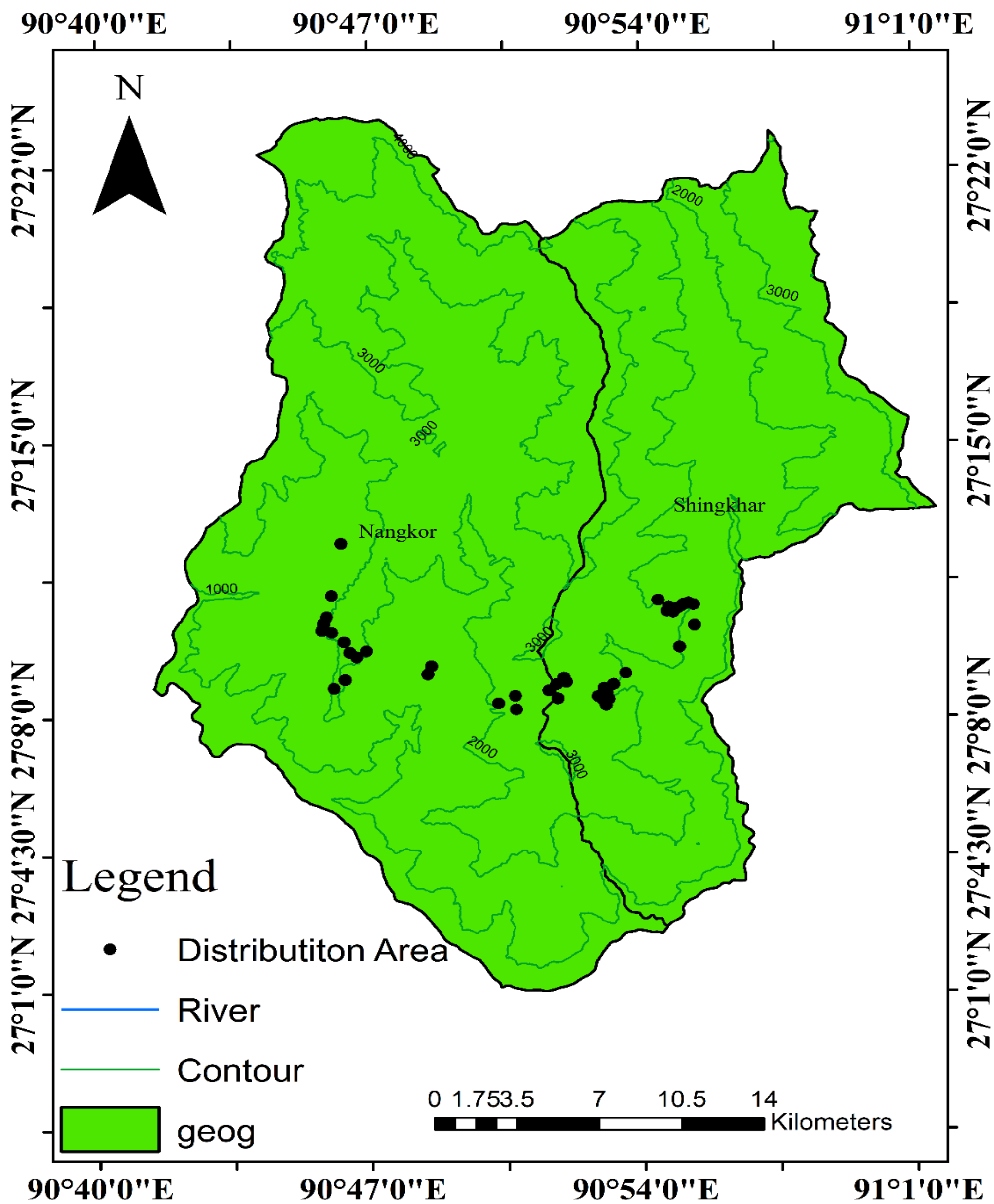

Figure 2: Distribution map of *P. pseudoginseng*

P. pseudoginseng was distributed in loam - sandy loam in a broad-leaved forest with a mean temperature of 20.5°C, south-southwest aspect. It was found at an altitude above 1600 masl, under the high canopy cover, and in an area with moderate slope (30 - 45°). All variables found from the sampling plots were used in Arc GIS and reclassified with the highest value given to the values within which *P. pseudoginseng* was found. The habitat excluded conifer forest due to less soil moisture (Figure 2).

Most of the areas were moderately suitable from the suitability map, consisting of 81.8% followed by the most suitable area with 13.37%. The least suitable areas consisted of 0.228% and non-suitable areas consisted of 4.59% of the total area respectively (Table 6). Overall, there were more suitable areas in Zhemgang District. However, the most suitable area was minimal, and the moderately suitable area covers most area beyond settlement and dense forest (Figure 3). The species were primarily distributed in a site free of anthropogenic activities. There was no potential for growth in most of the high-altitude areas due to lack of rainfall data. However, Merry (2018) reported that suitability shifts towards higher altitudes due to climate change.

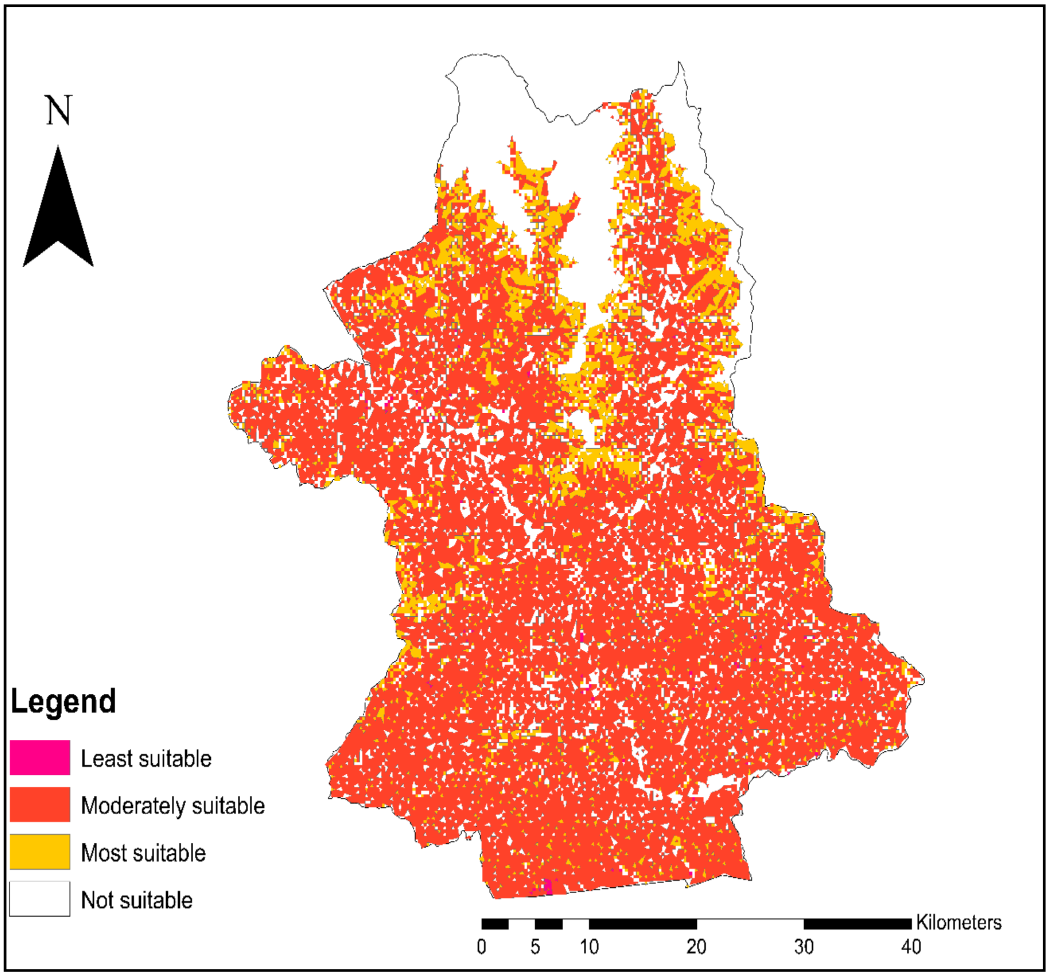

Figure 3: Potential distribution of *P. pseudoginseng*

Table 6: Suitability area of *P. pseudoginseng* from GIS

Suitability	Non-suitable	Least suitable	Moderately suitable	Most suitable
Area (ha)	8991.85	445.12	159979.864	26153.75
area (%)	4.59	0.228	81.8	13.37

Correlation between NPK and P. pseudoginseng

Table 7: Correlation between NPK and *P. pseudoginseng* count

	P. pseudoginseng	**Potassium**	**Nitrogen**	**Phosphorus**
P. pseudoginseng	1			
Potassium	-0.035	1		
Nitrogen	0.032	0.052	1	
Phosphorus	-0.109	0.029	0.091	1

**Correlation is significant at the 0.01 level (2-tailed)

The Spearman's correlation test indicated that phosphorus ($r = -0.109$, $p = 0.042$) had weak negative correlation. Available nitrogen and potassium in the soil to the *P. pseudoginseng* counts did not have significant differences, as reported by Zhang *et al*. (2015) (Table 7).

Forest type classification

Forest type was classified based on site variables (temperature, relative humidity, soil water tension, altitude, canopy cover and soil pH) and maximum relative basal area (of each plot) using PC-ORD software. The cluster analysis grouped homogeneous plant communities and site factors. With a 50% similarity index, the entire study area was categorized into seven types (Figure 4).

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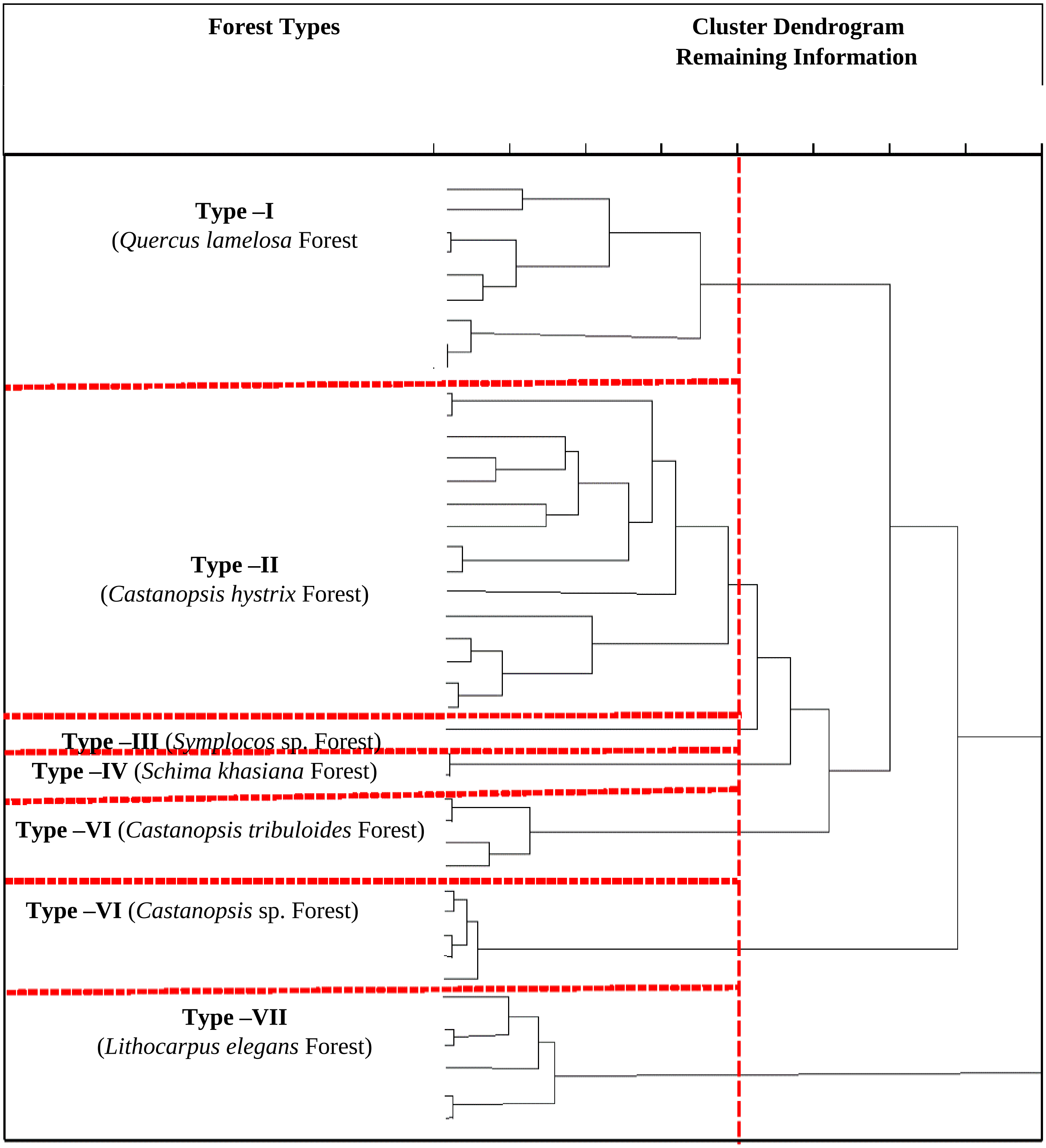

Figure 4: Dendrogram showing different forest types

Table 8: Forest Types and the associated species

Forests Type	Associated Species	Plots
Type –I (*Quercus lamellosa* **Forest)**	*Castanopsis tribuloides, Cinnamomum impressinervium, Lithocarpus elegans, Persea clarkeana, Rhododendron arboreum, Rhododendron falconeri, Rhododendron grande, Beilschmiedia gammieana,* and *Daphniphyllum himalayense.*	1, 21, 23, 25, 26, 12 and 17
Type-II (*Castanopsis hystrix* Forest)	*Lithocarpus elegans, Beilschmiedia gammieana, Cinnamomum impressinervium, Castanopsis tribuloides, Cinnamomum bejolghota, Daphniphyllum himalayense, Rhus succedanea, Acer campbellii, Alnus nepalensis, Betula alnoides, Betula utilis, Brassaiopsis hainla, Casearia glomerata, Elaeocarpus lanceifolius, Engelhardia spicata, Exbucklandia populnea, Litsea glutinosa, Macropanax dispermus, Magnolia campbellii, Michelia doltsopa, Persea fructifera, Phoebe cathia, Quercus oxyodon,* and *Symplocos glomerata.*	2, 41, 11, 29, 34, 14, 27, 38, 39, 42, 6, 13, 37, 32 and 33.
Type-III (*Symplocos* sp. Forest)	*Quercus oxyodon* and *Lindera pulcherrima.*	16
Type -IV (*Schima khasiana* Forest)	*Beilschmiedia gammieana, Castanopsis hystrix, Lithocarpus elegans,* and *Phoebe cathia.*	36 and 10
Type-V (*Castanopsis tribuloides* Forest)	*Lindera pulcherrima, Symplocos ramosissima, Beilschmiedia gammieana, Castanopsis hystrix, Cinnamomum impressinervium, Macropanax dispermus, Persea odoratissima, Prunus cerasoides, Quercus lamellosa,* and *Symplocos glomerata.*	5, 15, 7 and 9.
Type -VI (*Castanopsis* sp. Forest)	*Eurya acuminata, Exbucklandia populnea, Lithocarpus elegans, Lyonia ovalifolia, Persea fructifera, Phoebe cathia, Quercus lamellosa, Quercus oxyodon,* and *Symplocos lucida*	3, 35, 8, 28 and 4
Type-VII (*Lithocarpus elegans* Forest)	*Castanopsis hystrix, Altingia excelsa, Casearia glomerata, Cinnamomum* sp., *Lindera pulcherrima, Symplocos ramosissima,* and *Symplocos lucida.*	18, 30, 31, 20, 19 and 40.

Conclusion and way forward

P. pseudoginseng prefers area with loamy soil and slightly alkaline soil, moderate soil moisture, moderate temperature, and high canopy cover. The Spearman's correlation test indicated that phosphorus had a negative correlation whereas available nitrogen and potassium in the soil did not have significant effect on the counts of *P. pseudoginseng*. A total of 1,277 species distributed in 87 genera of 66 families were recorded including the trees understorey, herb and pteridophyte. Overall, Zhemgang District had 95.35 % of areas that are suitable for the growth of this species.

Future research in the same line would be better, if the time frame for the survey is increased to cover at least two seasons (spring and summer). Also, larger areas for sampling would increase the precision of the results. The potential distribution would be more accurate if annual rainfall and temperature data are included. This way, the species extinction can be minimized through species specific action, site and habitat-based interventions, policy making and education.

Conflict of interest

None

Authors' contribution statement

Tashi Dendup devised the general idea, collected data, analyzed data, wrote and edited the content. Sushila Rai contributed ideas, provided insight and suggestions to improve the results and edited the contents.

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References

Auslandera, M., Nevob, E., Inbar, M., 2003. The effects of slope orientation on plant growth, developmental instability and susceptibility to herbivores, *Journal of Arid Environments*. 55: 405–416. https://doi.org/ 10.1016/S0140-1963(02)00281-1

Becker, C.L., Bergfeld, F.W., Belsito, V.D., Hill, A.R., Klaassen D.C., Liebler, C.D., Jr, M.G.J., Shank, C.R., Slaga, J.T., Snyder, W.P., Andersen, A.F., 2012. Safety Assessment of *Panax* spp. Root-Derived Ingredients as Used in Cosmetics, *International Journal of Toxicology*. 34(3): 5-42. https://doi.org/10.1177/1091581815610508

Chettri, A., 2010. *Effect of forest fragmentation on vascular plant diversity in Khangchendzonga Biosphere Reserve Sikkim with emphasis on regeneration of some important taxa*. <http://hdl.handle.net/10603/5274>. Accessed on 25 March, 2020

Court, E. W., 2006. *Ginseng; The Genus Panax*. Harwood Academic Publishers imprint, USA.

Dash, A. K., 2016. Floristic Composition and Biological Spectrum Study Near the Mining Cluster at Keonjhar District, Odisha, India. *International Journal of Engineering Sciences & Research Technology*. 5(2): 441–447.

DoFPs, 2020. *Phrumsengla National Park.* <http://www.Dofps.gov.bt>. Accessed on 2 November, 2020

FRMD, 2012. *Field Manual, National Forest Inventory of Bhutan*, Department of forest and park services. Thimphu, Bhutan.

Grierson, A.J.C., Long, D.G., 1991. *Flora of Bhutan*. Vol. II Part 1, Edinburgh, U.K.: Royal Botanical Garden Edinburgh

Help, C. H. R., Herman, P. M. J., Soetaert, K., 1998. *Indices of diversity and evenness*. 24(2459): 61–87

Herzog, S. K., Kessler, A. M., 2009. *Non-woody life-form contribution to vascular plant species richness in a tropical American forest*. 87–99. https://doi.org/10.1007/s11258-008- 9505-z

Jamir, S. L., 2014. Studies on Seed Biology and Mass Multiplication of Two Medicinally Important Plant Species: *Panax pseudoginseng* W. (Araliaceae) and *Paris polyphylla* Smith. (Trilliaceae). *Journal of Ginseng*. 8(5): 224-236

Jost, L., 2010. The relation between evenness and diversity. *Diversity*. 2(2): 207–232.

https://doi.org/10.3390/d2020207

Kumar, D., Singh, M., Sharma, S., 2019. Fate of Important Medicinal Plants in the Eastern Himalaya in Changing Climate Scenarios: A Case of *Panax pseudoginseng* Wall. *Applied Ecology and Environmental Research.* 17(6): 13493-13511 http://dx.doi.org/10.15666/aeer/1706_1349313511

Latif, S.Q., Haas, R.J., Saab, A.V., Dudley, G.J., 2019. FIRE-BIRD: A GIS-Based Toolset for Applying Habitat Suitability Models to Inform Land Management Planning. *Rocky Mountain Research Station.* 74.https://doi.org/10.2737/RMRS-GTR-391

Lolen, S., Ranjan, C., Saku, N., 2016. Studies on Reproductive Biology and Seed Biology of *Panax pseudoginseng* Wall. (Araliaceae): A Threatened Medicinal Plant, *International Journal of Conservation Science.* 7(4):1127-1134 http://ijcs.org// NT J CONSERV SCI 7, 4, OCT-DEC 2016: 1127-1134 (accessed on: 15 September, 2019).

McGraw, B.J., Lubbers, L.A., Voort, D.V.M., Mooney, H. E., Furedi, A.M., Souther, S., Turner, B.J., Chandler, C., 2013. Ecology and conservation of ginseng (*Panax quinquefolius*) in a changing world. *Annals of the New York Academy of Sciences*. 1286(1): 62–91. https://doi.org/10.1111/nyas.12032

Merrey, J.D., Hussain, A., Tamang, D.D., Thapa, B., Prakash, A., 2018. Evolving high altitude livelihoods and climate change: a study from Rasuwa District, Nepal. food security.10: 1055–1071. https://doi.org/10.1007/s12571-018-0827-y

Merry, M., Shankar, V., Evelin, H., 2017. Diversity of Arbuscular Mycorrhizal Fungus Inhabiting the Rhizosphere of *Panax pseudoginseng* and *Solanum khasianum* Plants Growing Under Natural Conditions in Ziro, Arunachal Pradesh, India. *Journal of Bioresources*, 4(2): 13-19.

Muir, J. P., Pitman, W. D., Foster, L.J., 2011. Sustainable, low-input, warm-season, grass– legume grassland mixtures: mission (nearly) impossible? The Journal of the British Grassland Society. 66: 301–315. https://doi.org/10.1111/j.1365-2494.2011.00806.x

NCHM, 2017. *Bhutan State of the Climate 2017*. National Center for Hydrology and Meteorology, Royal Government of Bhutan. http://nchm.gov.bt/attachment/ckfinder/userfiles/files. Accessed on 25

June, 2020.

Nguyen, H., Lamb, D., Herbohn, J., Firn, J., 2014. Designing Mixed Species Tree Plantations for the Tropics: Balancing Ecological Attributes of Species with Landholder Preferences in the Philippines, *Plos one*. 9(4); 1-11. https://doi.org/10.1371/journal.pone.0095267

Olawusi-Peters, O.O., Ajibare, A. O., 2014. Species richness, diversity and abundance of some Decapod Crustaceans in coastal waters of Ondo State, South West, Nigeria. *International Journal of Fauna and Biological Studies*. 1(5): 44-51.

Pandey, N.B., Pande, D.S., Josh, D.B., 2007. Biodiversity. *Biodiversity and livelihood of the Poor in India.* A.P.H Publishing Corporation, New Delhi, India.

Pausas, J. G., Austin, M. P., 2001. Patterns of plant species richness in relation to different environments*: An appraisal Journal Vegetation Science*. 12: 153- 166. https://doi.org/10.2307/3236601

Pennock, D., Yates, T., Braidek, J., 2007. Soil Sampling. In M.R., Carter E.G. Gregorich (Eds.). *Soil Sampling and Methods of Analysis*. Boca Raton, US. Canadian Society of Soil Science. pp.1-14.

Radad, K., Gille, G., Rausch, W., 2004. Use of Ginseng in Medicine: Perspectives on CNS Disorders. *Iranian Journal of Pharmacology & Therapeutics*. 3(2): 30-40 1735-2657/04/32-30-40

RGoB, EU, 2008. *Guidelines for Identification & collection of Medicinal Plants in Bhutan*. Ministry of Agriculture, Thimphu, Bhutan.

RGoB, 1995. *Forest and Nature Conservation Act of Bhutan.* Royal Government of Bhutan; Thimphu, Bhutan.

Rol, N., 2013. Species composition, diversity and distribution in a disturbed Takamanda Rainforest, South West, Cameroon. *African Journal of Plant Science*. *7*(12): 577–585. https://doi.org/10.5897/ajps2013.1107

Sakar, D., Haldar, A., 2005. *Physical and Chemical Analysis in Soil*. New Age International Limited, Publishers, New Delhi.

Shaheen, H., Khan, M. S., David, M. Harper, Ullah, Z., Qureshi, A.R, 2011. Species Diversity, Community Structure and Distribution Patterns in Western Himalayan Alpine Pastures of Kashmir, Pakistan, *Mountain Research and Development*, 31(2): 153-159. 2011. https://doi.org/10.1659/MRD-JOURNAL-D-10-00091.1

Shahrajabian, H.M., Sun, W., Cheng, Q., 2019. A review of Ginseng species in different regions as a multipurpose herb in traditional Chinese medicine, modern herbology and pharmacological science. *Journal of Medicinal Plants Research*. 13(10): 213–226. https://doi.org/10.5897/JMPR2019.6731

Sharma, P., Sett, R., 2001. Micropropagation of Indian Ginseng (*Panax pseudoginseng* Wall): A Proposition to Save an Endangered Commercial and Medicinal Forest Plant. *Journal of Human Ecology*. 12(3): 201–205. https://doi.org/10.1080/09709274.2001.11907603

Tanaka, O., 1990. Recent studies on glycosides from plant drugs of Himalaya and south western China: chemo-geographical correlation of *Panax* species in Eastern Himalaya and south-western China. *Pure & Applied Chemistry*. 62 (7): 2235-2244.

TCB, 2020. Zhemgang. <https://www.bhutan.travel/destinations/zhemgang>. Accessed on 25 September, 2020.

Thach, D.B., Linh, T.L., Thuy, T.N., Thi, T.V., Truong, B.N., Ho, H.N., 2014. A study on the formation and development of *Panax bipinnatifidus* Seem. adventitious root. *Journal of Developmental Biology and Tissue Engineering*, 6(1): 1–7. https://doi.org/10.5897/jdbte2014.0069

Turner, I. M., 2001. *The Ecology of Trees in the Tropical Rain Forest*. Cambridge University Press, Cambridge. U.K

Twyford, A. D., 2017. New insights into the population biology of endoparasitic rafflesiaceae. *American Journal of Botany*. 104 (10): 1433–1436. https://doi.org/10.3732/ajb.1700317

Wangchuk, P., Namgay, K., Gayleg, K., Dorji, Y., 2016. Medicinal plants of Dagala region in Bhutan: Their diversity, distribution, uses and economic potential. *Journal of Ethnobiology and Ethnomedicine*. 12(1): 556-562. https://doi.org/10.1186/s13002-016-0098-7

Wheater, P.C, Bell, R.J., Cook, A.P., 2011. *Practical Field Ecology. A Project Guide*. Technical and Medical business with Blackwell Publishing, Southern Gate, Chichester, West Sussex, UK.

Yeom, D. J., Kim, J. H. (2011). Comparative evaluation of species diversity indices in the naturaldeciduous forest of Mt. Jeombong. *Forest Science and Technology*. 7(2): 68–74. https://doi.org/10.1080/21580103.2011.57394

ZDA, 2018. *Shingkhar Geog Administration*. www.zhemgang.gov.bt. Accessed on 2 November, 2020.

Zhang, H., Abid, H., Ahn, C.J., Mathiyalagan, R., Kim, Y.J., Yang, C.D., Wang, Y., 2020. Characteristics of *Panax ginseng* Cultivars in Korea and China, *molecules*. 25(2): 2635-2643. https://doi.org/10.3390/molecules25112635

Zhang, J., Zhao, Z., Xia, Z., Dai, L., 2015. A metal-free bifunctional electrocatalyst for oxygen reduction and oxygen evolution reactions. *Nature Nanotechnology*. 10: 444–452. https://doi.org/10.1038/nnano.2015.48

Zhang, Q., Wang, J., Gu, L.H., Zhang, G.Z., Wang, Q, 2018. Effects of Continuous Slope Gradient on the Dominance Characteristics of Plant Functional Groups and Plant Diversity in Alpine Meadows. S*ustainability*, 10(12): 4805.