

1 **Floristic Composition and Species Diversity of Wintering Herbs in Blue pine Forest of**
2 **Thimphu District, Bhutan**

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5 **ABSTRACT**

6 **Aims:** This study was carried out to document wintering herbs species in the blue pine
7 (Pinus wallichiana) forest of Kawang Gewog under Thimphu district, Bhutan. To generate
8 baseline data on species diversity and composition of the winter herbaceous layer in the
9 blue pine forests of the study area.

10 **Study Design:** To evaluate the floral diversity and composition of herbs, stratified random
11 sampling was used.

12 **Place and duration of study:** The study was conducted in Thimphu district within the
13 altitudinal range of 2400 m to 2700 m a.s.l. The fieldwork was conducted during the month of
14 December to January 2019 and during March 2020.

15 **Methodology:** Four line transects were established randomly, with sampling points placed
16 at 25-meter intervals along the transect. For adequate data collection, three 3X3 meter
17 quadrats were laid along a straight line perpendicular to the transect, using species-area
18 Type I curves (strictly nested curves). Each quadrat was then divided into 100 equal sub-
19 quadrats, with a distance of 5 meters separating each quadrat.

20 **Results:** A total of 60 herb species belonging to 46 genera and 22 families. The Shannon-
21 wiener index of species diversity (H') showed 1.73 value suggesting higher diversity in the
22 study site with an altitude of 2600 m to 2700 m compared to other sites with an altitude
23 range of 2400 m to 2500 m, H' value of 1.59.

24 **Conclusion:** The study conducted reports the finding on diversity and the composition of
25 herbs occurring in the winter season from Kawang gewog under Thimphu district. The
26 present study also discusses the diversity and evenness of herbs influenced by elevation
27 and anthropogenic influences.

28
29 **Keywords:** Bhutan, Blue pine, Herbs, diversity, Important Value index, Species richness,
30 Thimphu, Wintering Herb

31 **1. INTRODUCTION**

32 The herb species layers are mostly defined as the forest stratum or layer composed of all vascular
33 species that are 1 meter or less in height (Scholar & Gilliam, 2007). It is the structure and function of

34 forest ecosystems which constitutes less than 1% of the biomass of the forest, nevertheless can
35 include 90% or more of the plant species and contribute up to 20% of foliar litter to the forest floor
36 generally of higher nutrient content than that of trees (Lalramnghinglova, 2017). The herbaceous plant
37 layer are composed of maximum number of species in the community of forest and influences the
38 nutrient cycling (Gilliam, 2007; Rana *et al.*, 2015). Not only this, herbaceous vegetation acts as a key
39 strata and share largest proportions of species diversity in many forest ecosystem (Karki *et al.*, 2016).

40 According to Gilliam (2007), the loss of biodiversity is rampant and occurring on a global
41 scale, especially true for forest ecosystem near the areas of high human population density. The
42 resultant land use, inclusive of forest use, urban development and land conversion to agriculture have
43 led to the loss of native species as a result of habitat destruction or alteration. As per
44 Lalramnghinglova (2017), in forest stratum, herbaceous layer undergoes higher natural extinction
45 rates than that of plant species in other strata despite high species richness. Levin and Wilson (1976)
46 estimated that the extinction rates of herbs are more than three times that of hardwood tree species.
47 Therefore, threats to herbaceous layer species are most often a function of threat to forest biodiversity
48 (Jolls, 2003).

49 According to Vilardell (n.d.), blue pine (*Pinus wallichiana* A.B. Jackson) forests are semi-
50 mesic meaning dry ecosystems that grow at mid elevations ranging between 2100 m to 3000 m with
51 precipitation ranging from 450 to 1500 mm per year (Tenzin, 2001). Blue pines are early
52 successional species that are light demanding (Gratzer *et al.*, 2004) and grows rapidly (Tenzin, 2001),
53 forming secondary monospecific even-aged stands and grow adjacent to human settlements, mainly
54 in previously discarded agricultural fields (Dukpa *et al.*, 2018; Gyeltshen, 2016; Tenzin, 2001). Blue
55 pine ecosystems are highly susceptible to wildfires owing to its thin bark and high flammability
56 (Tenzin, 2001) and undergo high anthropogenic pressure since it thrives next to settlements (Dukpa
57 *et al.*, 2018). Therefore, the herbaceous vegetation of blue pine forests are at high risk of extinction
58 since the occurrence of wildfires is dominant mostly in blue pines than other types of forest and grows
59 adjacent to human settlements exposing to anthropogenic pressures. On addition, the occurrence of
60 understory vegetation is a wonder amidst harsh conditions of blue pine forest as mentioned above.

61 This study will contribute to the understanding of herbaceous ecosystem by generating
62 quantitative baseline information on species diversity and composition of herbaceous layer in blue
63 pine forests of Bhutan.

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65 **2. METHODOLOGY OF STUDY**

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67 **2.1. Study Site**

68 The study was carried out in Thimphu district within the altitudinal range of 2400 m to 2700 m a.s.l.
69 The area is dominated by blue pine forest and it lies in the Western part of the country with latitude
70 from 27°8' to 27°59' and longitude from 89°13 to 89°46'. The district has a temperate climatic
71 condition with warm summer and cold and dry winter. The annual rainfall varies between 450 mm and
72 1500 mm (Tenzin, 2001). In Thimphu, four types of forest can be found inclusive of blue pine with an
73 area of 26122.82 ha (14.69%) . The district has one Dungkhag and eight Gewogs (National Statistics

74 Bureau, 2010). Thimphu district is considered as one of the developed District in the country. Out of
75 1795.87 kms, approximately an area of 1380.18 ha or 0.78 % are inhabited by the human.

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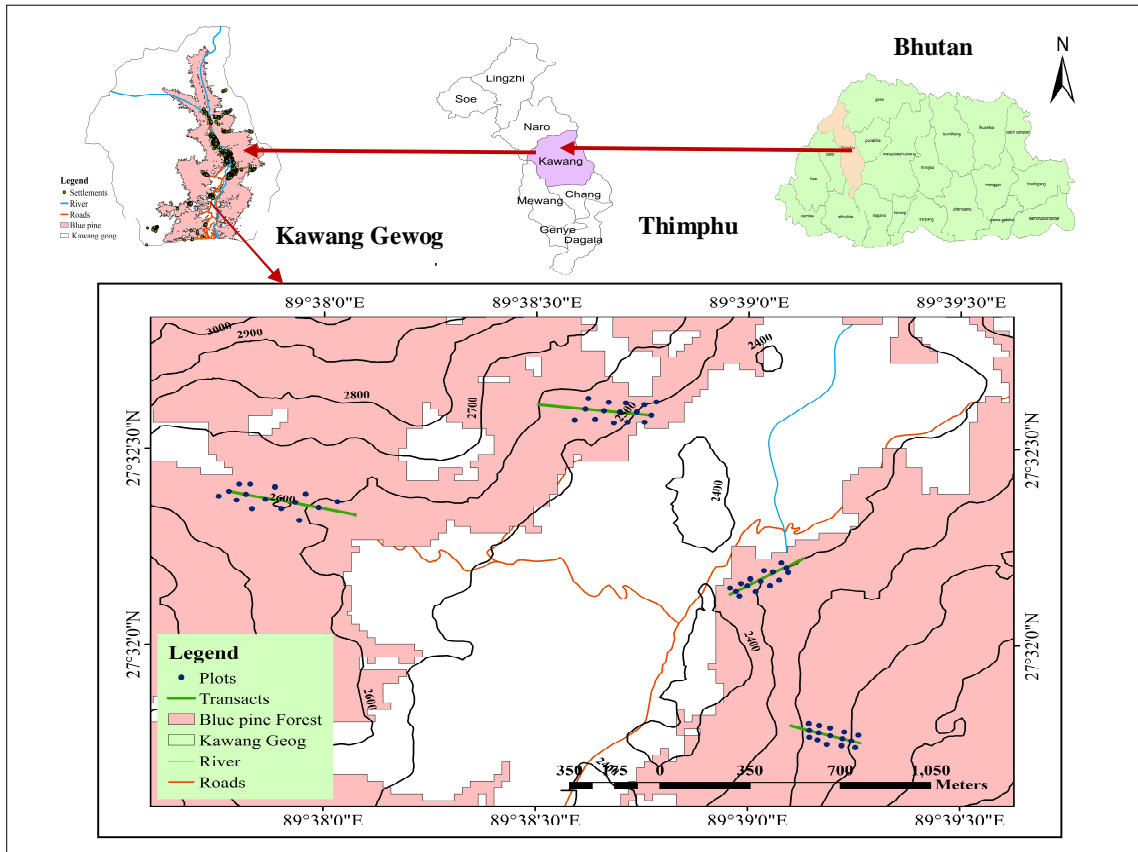


Figure 1. Map showing the study area

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2.2. Sampling Method

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To evaluate the floral diversity and composition of herbs, stratified random sampling was used. This method divides study area into number of non-overlapping subdivisions (or strata) and samples are randomly selected from each subdivision (Manly, 2015; Henderson and Southwood, 2016). The field work was conducted in blue pine forest of Kawang Gewog, Thimphu district with different elevation gradient (2400-2700 m). The four line transects were randomly laid in blue pine forest where sampling point was established at every 25 m distance along the transect line. Then three quadrats with the size of 3 X 3 m which was determined using species area Type I curves (strictly nested quadrats) (Scheiner, 2003) were laid perpendicularly along a straight line for the convenience of collecting sufficient amount of data (Kharkwal et al., 2004). This quadrat was further divided into 100 equal parts (sub-quadrat), with each quadrat separated by a distance of 5m from the next quadrat. Then the frequency of the herbaceous species was noted by counting each species that occurred in sub-quadrats in the format as shown in Table 1. The field work was conducted during the month of December to January, 2019 and during March of 2020. All the data collected from the sample plot were enumerated in the data collection sheet and the species were identified with the help of experts from Ministry of Agriculture and Forest.

111 **2.3. Data analysis**

112 **2.3.1. Species area curve for determination of sample size**

113 Species-area curve is a graphical visualization of how species diversity changes with sampling area.
114 It provides are snapshot of whether the sampling efforts are adequate to uncover all species of
115 interest in a study area. Adequateness in sampling effort is reached when the species-area curve
116 plateaus or flattens. The sampling area corresponding to the point at which the curve flattens is called
117 the minimal area and it represents the optimal area that could encompass all species of interest. In
118 other words, the species-area curve provides information on whether an area is sufficiently sampled
119 to exhaustively uncover all species of interest in an area (Cain, 1938).

120 The number of species found in an area is plotted on y-axis coordinate with the area of a
121 sample on x-axis. The species-area points determine a characteristic curve when examined. This
122 curves rises rapidly from the intersection of the y and x axes but later becomes nearly a straight line
123 and nearly horizontal (Scheiner, 2003). The data collected from the field were entered and species
124 curve was generated using Microsoft Excel 2013. The graph was plotted using number of species in
125 sampling area with respect to sampled area in y-axis and x-axis respectively.

126 **2.3.2. Vegetation data analysis**

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128 **Shannon-wiener index:**

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$$H' = \sum_{i=1}^s pi \ln pi \dots \dots \dots \text{equation I}$$

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131 Where, $pi = \frac{\text{No. of individuals of a species}}{\text{Total no. of individuals of all species}}$ - (Relative abundance)

132 \ln = natural logarithm or log

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S = Species richness (total no. of species in a plot or an area)

134 Shannon diversity index was used to study the plant species diversity (Ambasht, 1982; Kent & Coker,
135 1993) whereas; species evenness was calculated using Pielou's method of 1969. The evenness is a
136 measure of how similar the abundance of different species is in a plot or an area. The check list of
137 floristic composition data has been processed using pivot-table of the Microsoft excel as follows:
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Pielou's species evenness index (Shannon's equitability):

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$$J' = \frac{H'}{H_{max}} = \frac{H}{\ln S} \dots \dots \dots \text{equation II}$$

140 Where, H' = Shannon-Wiener Index

141 S = Total number of species in the sample/plot

142 \ln = Natural logarithm

143 **2.4.3. Importance Value Index (IVI)**

144 Importance Value Index (IVI) is a statistical quantity and the most important parameter that shows an
145 overall picture of ecological importance of the species in the vegetative community. It considers the
146 relative values of density, frequency and relative dominance of every species in a study area and the

147 added value obtained ranging from 0-300 is called IVI (Curtis, 1959). Since, it is difficult to determine
 148 the basal area for herbaceous species, relative cover was determined in percentage as follows
 149 (Baxter, n.d.);

150 **Importance value index (IVI)** = Relative density (RD) + Relative frequency (RF) + Relative
 151 dominance (RD).

152 **Relative density** = $\frac{\text{Density of a species}}{\text{Total density of all species}} \times 100$ equation III

153 **Relative frequency** = $\frac{\text{Frequency of a species}}{\text{Total frequency of all species}} \times 100$ equation IV

154 **Relative dominance** = $\frac{\text{Total basal area of the species}}{\text{Total basal area of all species}} \times 100$equation V

155 **Density** = $\frac{\text{Number of a species}}{\text{Total area sampled}}$ equation VI

156 **Frequency** = $\frac{\text{Area of plots in which a species occurs}}{\text{Total area sampled}}$ equation VII

157 **Relative cover (%)** = $\frac{\text{Total \% cover of spA in all plots}}{\text{Total no. of plots/quadrats}} \times 100$ equation VIII

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159 **3. Results and Discussion**

160 **3.1. Floristic composition of herbaceous plant**

161 A total of 60 herb species **belonging** 46 genera and 22 families were recorded. Families with
 162 maximum number of species include Asteraceae (19 species) followed by Rosaceae and Lamiaceae
 163 each with 5 and 4 species of herbs respectively from the study site (Table 2). At altitude 2600 m to
 164 2700 m, a total of 49 species belonging to 19 families and 37 genera (Table 2) were observed.
 165 Taxonomically, well-represented families were Asteraceae followed by Rosaceae with 5 species.
 166 Similarly, the most dominant families were Asteraceae with 9 species followed by Rosaceae (3
 167 species) at altitude 2400 m to 2500 m as shown in (Table 3). A total of 36 species belonging to 16
 168 families and 32 genera were observed.

169 **Table 1:** Species composition of herbs in study site

Species	Family	(2600-2700m)	(2400-2500m)
<i>Geranium procurrens</i>	Geraniaceae	+	+
<i>Pyrola corbieri</i>	Ericaceae	-	+
<i>Stellaria vestita</i>	Caryophyllaceae	+	-
<i>Stellaria media</i>	Caryophyllaceae	+	-
<i>Drymaria cordata</i>	Caryophyllaceae	-	+
<i>Oxalis corniculata</i>	Oxalidaceae	+	+
<i>Verbascum Thapsus</i>	Scrophulariaceae	+	+
<i>Hemiphragma heterophyllum</i>	Scrophulariaceae	+	+
<i>Selinum wallichianum</i>	Apiaceae	-	+

<i>Fragaria nubicola</i>	Rosaceae	+	+
<i>Potentilla lineate</i>	Rosaceae	+	+
<i>Potentilla indica</i>	Rosaceae	+	+
<i>Rubus fockeanus</i>	Rosaceae	+	-
<i>Rubus sp</i>	Rosaceae	+	-
<i>Bidens pilosa</i>	Asteraceae	+	+
<i>Gerbera piloselloides</i>	Asteraceae	-	+
<i>Ainsliaea aptera</i>	Asteraceae	+	+
<i>Galingsoga ciliate</i>	Asteraceae	-	+
<i>Anaphalis contorta</i>	Asteraceae	+	+
<i>Senecio scandens</i>	Asteraceae	+	+
<i>Senecio vulgaris</i>	Asteraceae	+	-
<i>Pseudognaphalium affine</i>	Asteraceae	+	-
<i>Taraxacum officinale</i>	Asteraceae	+	+
<i>Taraxacum sp 1</i>	Asteraceae	+	+
<i>Taraxacum sp 2</i>	Asteraceae	+	+
<i>Taraxacum sp 3</i>	Asteraceae	+	-
<i>Sonchus asper</i>	Asteraceae	+	-
<i>Cirsium verutum</i>	Asteraceae	+	-
<i>Cirsium sp</i>	Asteraceae	+	-
<i>Artemisia vulgaris</i>	Asteraceae	+	+
<i>Dichrocephala sp</i>	Asteraceae	+	-
<i>Erigeron sp</i>	Asteraceae	+	-
<i>Erigeron Canadensis</i>	Asteraceae	+	+
<i>Rumex nepalensis</i>	Polygonaceae	+	-
<i>Gentiana capitata</i>	Gentianaceae	+	+
<i>Gentiana pedicellata</i>	Gentianaceae	-	+
<i>Cynoglossom furcatum</i>	Boraginaceae	+	+
<i>Clinopodium umbrosum</i>	Lamiaceae	+	+
<i>Ajuga sp</i>	Lamiaceae	-	+
<i>Ajuga reptans</i>	Lamiaceae	+	-
<i>Salvia sp</i>	Lamiaceae	+	-
<i>Trifolium repens</i>	Fabaceae	+	+
<i>Lespedeza cuneata</i>	Fabaceae	-	+
<i>Cajanus mollis</i>	Fabaceae	-	+
<i>Rubia manjith</i>	Rubiaceae	+	+
<i>Galium elegans</i>	Rubiaceae	+	+
<i>Galium aparine</i>	Rubiaceae	+	-
<i>Plantago erosa</i>	Plantaginaceae	+	+
<i>Viola betonicifolia</i>	Violaceae	+	+
<i>Viola pilosa</i>	Violaceae	+	+
<i>Viola sp</i>	Violaceae	+	-
<i>Primula denticulate</i>	Primulaceae	+	-
<i>Dipsacus inermis</i>	Caprifoliaceae	+	-

<i>Capsella bursa-pasteris</i>	<i>Brassicaceae</i>	+	-
<i>Cardamine flexuosa</i>	<i>Brassicaceae</i>	+	-
<i>Ranunculus chinensis</i>	<i>Ranunculaceae</i>	+	-
<i>Ranunculus cantoniensis</i>	<i>Ranunculaceae</i>	-	+
<i>Thalictrum foliolosum</i>	<i>Ranunculaceae</i>	-	+
<i>Euphorbia griffithii</i>	<i>Euphorbiaceae</i>	+	-
<i>Astilbe rivularis</i>	<i>Saxifragaceae</i>	+	-

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171 **Table 2:** Family-wise distribution of species in study sites

Sl.No	Family	2600 to 2700 m		2400 to 2500 m	
		Genera	Species Number	Genera	Species Number
1	<i>Caryophyllaceae</i>	1	2	1	1
2	<i>Scrophulariaceae</i>	2	2	2	2
3	<i>Rosaceae</i>	4	5	3	3
4	<i>Ericaceae</i>	0	0	1	1
5	<i>Geraniaceae</i>	1	1	1	1
6	<i>Violaceae</i>	1	3	2	2
7	<i>Asteraceae</i>	11	17	8	9
8	<i>Polygonaceae</i>	1	1	0	0
9	<i>Gentianaceae</i>	1	1	1	2
10	<i>Boraginaceae</i>	1	1	1	1
11	<i>Lamiaceae</i>	3	3	2	2
12	<i>Fabaceae</i>	1	1	2	2
13	<i>Rubiaceae</i>	2	3	2	2
14	<i>Plantaginaceae</i>	1	1	1	1
15	<i>Primulaceae</i>	1	1	0	0
16	<i>Caprifoliaceae</i>	1	1	0	0
17	<i>Brassicaceae</i>	2	2	0	0
18	<i>Ranunculaceae</i>	1	1	2	2
19	<i>Euphorbiaceae</i>	1	1	0	0
20	<i>Saxifragaceae</i>	1	1	0	0
21	<i>Oxalidaceae</i>	0	0	1	1
22	<i>Apiaceae</i>	0	0	1	1

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173 3.2. Diversity and evenness of herbs species

174 The Shannon-wiener index of species diversity (H') showed 1.73 suggesting higher diversity in the
 175 study site with the altitude of 2600 m to 2700 m compared to other site with an altitude range of 2400
 176 m to 2500 m, H' value of 1.59. Similarly the Pielou's Evenness index was recorded highest in 2600 to
 177 2700 m (0.51) than at 2400 to 2500 m (0.26) (Figure 5) indicating maximum diversity at that site.

178 The magnitude of the differences in diversity and evenness among the plots are not high
 179 although, in study site of 2600 m to 2700 m, the highest H' was 2.18 of plot 15 and the lowest was

180 1.23 in plot 28. The evenness or equitability ratio of species was higher in plot 20 (0.96) and lowest in
 181 plot 9 (0.8). At 2400 m to 2500 m, the highest and lowest H' value were 2.21 (plot 1) and 1.04 (plot
 182 27) respectively. In terms of evenness, the highest value was 1.06 in plot 1 and lowest in plot 27
 183 (0.75) (Table 4). The result confirms similar findings by Zhang and Zhang (2007) that plant diversity is
 184 expected to be different with different elevations. Similarly, Sang (2009) also reported higher species
 185 richness with higher elevation.

186 **Table 3:** Species diversity and richness (H': Shannon-wiener index, J: Pielou's species evenness
 187 index)

Plot No.	2600 – 2700 m		2400 – 2500 m	
	H'	J	H'	J
1	1.88	0.90	2.21	1.06
2	1.40	0.87	1.71	0.95
3	1.39	0.86	1.78	0.86
4	1.78	0.86	2.01	0.97
5	1.70	0.95	1.62	0.90
6	1.59	0.89	1.66	0.93
7	1.95	0.89	2	0.96
8	1.71	0.88	1.48	0.76
9	1.43	0.80	1.67	0.93
10	1.87	0.90	1.61	0.90
11	1.59	0.89	1.6	0.82
12	2.09	0.95	1.37	0.85
13	1.92	0.92	1.65	0.85
14	1.84	0.88	1.99	0.96
15	2.18	0.95	1.24	0.89
16	2.00	0.91	1.83	0.94
17	2.01	0.91	1.78	0.91
18	2.03	0.92	1.58	0.88
19	1.52	0.85	1.42	0.88
20	1.87	0.96	1.39	0.78
21	1.66	0.93	1.47	0.91
22	1.54	0.86	1.54	0.96
23	1.63	0.84	1.75	0.98
24	1.62	0.90	1.48	0.92
25	1.52	0.85	1.3	0.94
26	1.71	0.95	1.52	0.94
27	1.94	0.93	1.04	0.75
28	1.33	0.83	1.29	0.80
29	1.66	0.93	1.35	0.97
30	1.63	0.91	1.29	0.80

189 The percent contribution of annuals at 2600 m to 2700 m was greater than at 2400 m to 2500 m while
 190 perennials was higher at 2400-2500 m than at 2600-2700 m (Figure 6). The annuals experience rapid
 191 growth of flowers and then seeds compared to perennials.

192 3.3. Importance value index

193 The IVI is commonly used in ecological studies as it shows ecological importance of a species in a
 194 given ecosystem. The IVI is also used for prioritizing species conservation whereby species with low
 195 IVI value need high conservation priority compared to the ones with high IVI. Since, IVI as an indicator
 196 of dominance, *Potentilla lineata* and *Anaphalis contorta* dominated the area having highest IVI of
 197 27.82 and 27.13 respectively followed by *Geranium procurrens* (26.08) (Figure 2). Thirty seven other
 198 species showed IVI range of 25.85 – 10.01 while twenty species showed IVI less than 10.

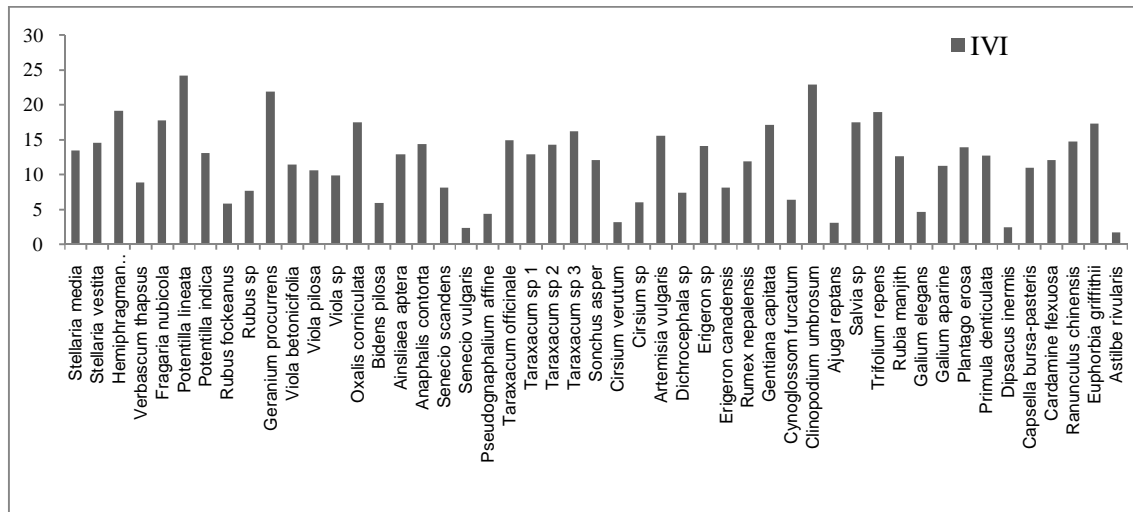
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200 **Table 4:** The dominance pattern of herbaceous species in the study area (RD: Relative density, RF:
 201 Relative frequency, Cover %: Relative cover, IVI: Family Importance Index).

Botanical Name	RD	RF	Cover %	IVI
<i>Geranium procurrens</i>	1.56	1.71	22.81	26.08
<i>Pyrola corbieri</i>	0.46	0.6	6.45	7.51
<i>Thalictrum foliolosum</i>	1.1	1.13	13.31	15.54
<i>Stellaria vestita</i>	0.44	0.52	23.95	24.91
<i>Stellaria media</i>	0.71	0.51	12.2	13.42
<i>Drymaria cordata</i>	0.58	0.45	7.85	8.88
<i>Oxalis corniculata</i>	0.99	0.65	12.68	14.32
<i>Verbascum Thapsus</i>	0.56	0.6	17.17	18.33
<i>Hemiphragma heterophyllum</i>	0.9	0.74	15.86	17.50
<i>Selinum wallichianum</i>	0.23	0.3	3.94	4.47
<i>Fragaria nubicola</i>	1.12	1.19	17.46	19.77
<i>Potentilla lineate</i>	1.57	1.52	24.73	27.82
<i>Potentilla indica</i>	0.82	0.9	11.18	12.90
<i>Rubus fockeanus</i>	0.36	0.26	5.17	5.79
<i>Rubus sp</i>	0.44	0.53	6.67	7.64
<i>Bidens pilosa</i>	0.8	0.91	11.72	13.43
<i>Gerbera piloselloides</i>	1.36	1.53	22.96	25.85
<i>Ainsliaea aptera</i>	0.75	0.85	12	13.60
<i>Galingsoga ciliate</i>	0.56	0.67	7.66	8.89
<i>Anaphalis contorta</i>	1.55	3.57	22.01	27.13
<i>Senecio scandens</i>	0.67	0.54	8.8	10.01
<i>Senecio vulgaris</i>	0.18	0.26	1.85	2.29
<i>Pseudognaphalium affine</i>	0.44	0.66	3.23	4.33
<i>Taraxacum officinale</i>	1.19	1.37	18.75	21.31
<i>Taraxacum sp 1</i>	0.3	0.28	7.03	7.61
<i>Taraxacum sp 2</i>	0.44	0.6	11.48	12.52
<i>Taraxacum sp 3</i>	0.87	1.06	14.29	16.22
<i>Sonchus asper</i>	0.44	0.53	11.11	12.08
<i>Cirsium verutum</i>	0.2	0.26	2.71	3.17

<i>Cirsium sp</i>	0.22	0.26	5.56	6.04
<i>Artemisia vulgaris</i>	1.09	0.94	15.04	17.07
<i>Dichrocephala sp</i>	0.44	0.26	6.67	7.37
<i>Erigeron sp</i>	1.31	1.59	11.11	14.01
<i>Erigeron Canadensis</i>	0.47	0.38	6.12	6.97
<i>Rumex nepalensis</i>	0.87	0.78	10.25	11.90
<i>Gentiana capitata</i>	0.93	1.02	13.18	15.13
<i>Gentiana pedicellata</i>	1.7	2.18	12.5	16.38
<i>Cynoglossom furcatum</i>	0.44	0.51	9.85	10.80
<i>Clinopodium umbrosum</i>	1.06	1.16	22.62	24.84
<i>Ajuga sp</i>	0.29	0.37	7.39	8.05
<i>Ajuga reptans</i>	0.22	0.26	2.5	2.98
<i>Salvia sp</i>	1.03	1.04	15.35	17.42
<i>Trifolium repens</i>	1.04	0.72	17.99	19.75
<i>Lespedeza cuneata</i>	1.02	1.09	13.8	15.91
<i>Cajanus mollis</i>	0.57	0.73	12.36	13.66
<i>Rubia manjith</i>	0.89	0.76	14.01	15.66
<i>Galium elegans</i>	1.1	1.00	17.07	19.17
<i>Galium aparine</i>	0.66	0.53	10	11.19
<i>Plantago erosa</i>	0.82	0.88	11.63	13.33
<i>Viola betonicifolia</i>	1.16	1	11.53	13.69
<i>Viola pilosa</i>	0.86	0.89	13.32	15.07
<i>Viola sp</i>	0.53	0.77	8.57	9.87
<i>Primula denticulate</i>	1.41	1.28	10.01	12.70
<i>Dipsacus inermis</i>	0.22	0.26	1.96	2.44
<i>Capsella bursa-pasteris</i>	0.66	0.53	9.8	10.99
<i>Cardamine flexuosa</i>	0.6	0.65	10.81	12.06
<i>Ranunculus chinensis</i>	0.66	0.79	13.33	14.78
<i>Ranunculus cantoniensis</i>	0.54	0.6	7.56	8.70
<i>Euphorbia griffithii</i>	0.64	0.53	16.1	17.27
<i>Astilbe rivularis</i>	0.18	0.26	1.3	1.74

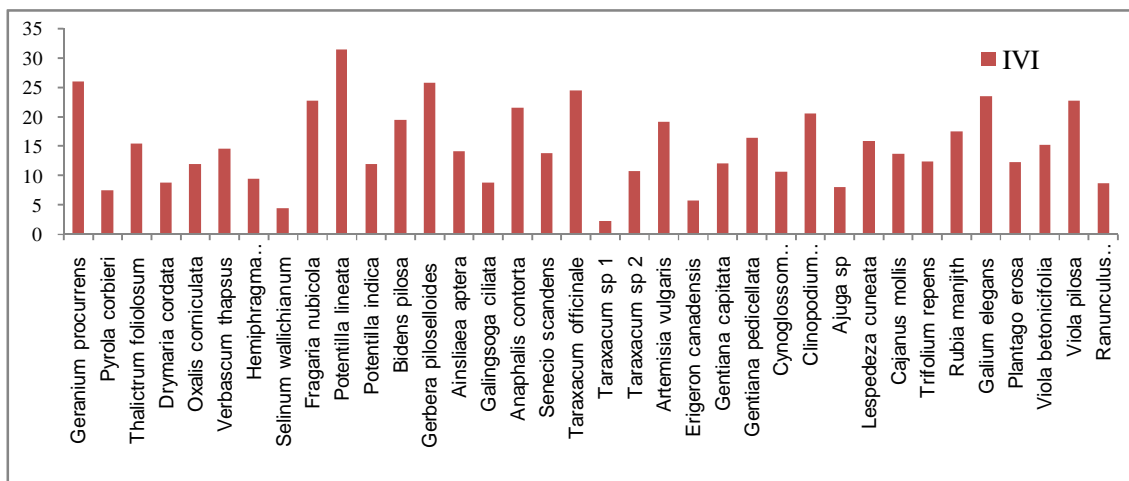
202 In study site of altitudinal range of 2600-2700 m, *Potentilla lineate* portrayed the highest IVI value
203 (24.13), followed by *Clinopodium umbrosum* (22.83) and *Geranium procurrens* (21.9) (Figure 9)
204 indicating that these species occupy most of the sampled area hence it is important plant species in
205 forest. Whereas, in study site with altitude 2400-2500 m, *Potentilla lineate* (31.4) exhibited highest IVI
206 followed by *Geranium procurrens* (26.06) and *Gerbera piloselloides* (25.85) (Figure 10). The high IVI
207 exhibited by these herbaceous species are largely due to its higher relative cover, frequency and
208 density compared to other species.



209

210

Figure 2: IVI values of individual plant species in site with altitude 2600-2700 m



211

212

Figure 3: IVI values of individual plant species in site with altitude 2400-2500 m

213 **4. Discussion**

214 The occurrence of 60 herbaceous understory species in *Pinus wallichiana* forests of Kawang geog of
 215 Thimphu indicates its associations with significant diversity of herbs species. The result depicted
 216 Asteraceae family as the most dominant in *Pinus wallichiana* understory vegetation followed by
 217 Rosaceae and Lamiaceae. Rahman *et al.*, (2017) had also reported same trends of family dominance
 218 in their studies whereas, Behera *et al.*, (2002), Paul (2008), and Bharali *et al.*, (2011) reported similar
 219 trends of family dominance (Asteraceae, Ericaceae and Rosaceae). The species diversity under
 220 monotype forest is possibly due to altitude, topographic and physiographic conditions. The plant
 221 diversity and richness was different with different elevations (Zhang & Zhang, 2007). The diversity at
 222 altitude 2600 m to 2700 m was higher than at altitude 2400 m to 2500 m which could be possibly due
 223 to gentle slope and the presence of matured stand of *Pinus wallichiana*. And the soil condition was
 224 moist compared to the study site of altitude 2400-2500 m consisting of regeneration stand, steep
 225 slope and dry soil.

226

227 In the study sites, *Potentilla lineate* portrayed the highest IVI value, followed by *Anaphalis*
228 *contorta* and *Gentiana capitata* indicating that these species occupies most of the sampled area
229 hence it is important plant species in forest. The high IVI exhibited by these herbaceous species are
230 largely due to its higher relative cover, frequency and density compared to other species. The
231 presence of many species with lower IVI values such as *Ranunculus cantoniensis*, *Ajuga reptans*,
232 *Astilbe rivularis*, *Crisium verutum*, *Capsella bursa-pasteris*, *Rubus fockeanus*, etc.) in this study is an
233 indication that the majority of species are in the forest. The rarity may be due to various reasons,
234 which include (1) poor dispersability of species, (2) natural or anthropogenic disturbances, (3)
235 prevailing environmental conditions and (3) competition within the forest (Gairola *et. al.*, 2008,
236 Ahamad *et. al.*, 2011, Rawat & Chandra, 2012).

237

238 **5. Conclusions and Recommendation**

239 In the forest stratum, all the vascular species that are 1 meter or less in height are defined as
240 herbaceous layer (Scholar & Gilliam, 2007). This stratum of forest vegetation is an essential
241 component of forest ecosystem sustaining a great portion of total floristic community providing
242 habitats and food sources for many types of animals. The threats to herbaceous layer species are
243 most often a function of threat to forest biodiversity. The study conducted imparts the information on
244 diversity and the composition of herbs occurring in winter from Kawang geog under Thimphu district.
245 The present study also discloses the diversity and evenness of herbs influenced by elevation and
246 anthropogenic influences.

247

248 The herbaceous cover diversity of the studied sites was represented by 60 plant species
249 belonging to 46 genera under 22 families. The species diversity and evenness was observed higher
250 at altitude 2600-2700 m than at altitude 2400-2500 m. The dominant family Asteraceae is represented
251 with 19 species, followed by Rosaceae (5 species) and Lamiaceae (4 species). In the study sites of
252 blue pine forest of Thimphu district, *Potentilla lineate* portrayed the highest IVI value (27.82), followed
253 by *Anaphalis contorta* (27.13) and *Geranium procurrens* (26.08), which indicated that the area is
254 productive and concludes that blue pine forest ecosystem can host numbers of herb species despite
255 its arid nature. The study also revealed that the herb species differs with different altitudes in the
256 study area.

257 The present study was conducted mainly on floristic composition and diversity neglecting
258 other factors such as humidity, soil pH, biomass, rainfall, canopy coverage and temperatures for a
259 short duration with limited budget during winter. If the research is carried out during different seasons
260 in long run with adequate resources, additional and divers species is expected to be discovered from
261 the study site. And also further study needs to be conducted highlighting on these factors influencing
262 the composition of herb species.

263 According to Bhandari and Tiwari (1999), any species in a community, plays a specific role
264 and there is a definite quantitative relationship between abundant and rare species. The activities
265 such as anthropogenic activities and the surrounding condition changes around the sites could be the
266 reason behind the differences in IVI. Anthropogenic pressure usually leads to the vegetation

267 degradation due to inadequate retrieval time and also contributes to the vanishing of ecologically,
268 medicinally or economically important plant species. Therefore, there is need to further study in the
269 future to explore whole flora and the impact of anthropogenic pressure on the vegetation on these
270 areas as these places are developing at a fast rate. Further, the present study can be used as a
271 source of basic data for the management and preservation of the indigenous species, particularly
272 those herbaceous species having low importance value index (IVI) and lastly, a series of more
273 comprehensive herbaceous ecosystem studies are required to provide knowledge and foundation for
274 future research as herbs dominate the forest.

275

276 **COMPETING INTEREST**

277 The authors declare no competing interest.

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