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Medicinal Plants in the Broad-Leaf Mixed Coniferous Forest of Tshothang Chiwog, Bhutan: Floristic Attributes, Vegetation Structure, Ethnobotany, and Socioeconomic Aspects

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The Himalayan Kingdom of Bhutan, located in one of the global biodiversity hotspots, is endowed with abundant floral wealth, including a wide array of medicinal plants (MPs). However, over-exploitation of these resources is widespread, and only a few studies have assessed the richness and diversity of Bhutanese forests and in particular about the MP resources. A vegetation survey was conducted in Tshothang Chiwog, south-eastern Bhutan to characterize the floristic structure of the broad-leaf mixed coniferous forests with a special focus on MPs. A questionnaire survey involving 40 farmers was also conducted to assess the ethnobotanical and socioeconomic aspects of MP extraction. A total of 157 plant species (38 trees, 19 shrubs, 85 herbs and ferns, and 15 climbers), representing 74 families and 137 genera were identified from the study area, of which 69 species (14 trees, 10 shrubs, 38 herbs and ferns, and seven climbers), belonging to 41 families and 69 genera were medicinally important. The most species-rich families of medicinal plants were: Asteraceae (eight spp.), Apiaceae (four spp.), Polygonaceae, Brassicaceae, Zingiberaceae, and Urticaceae (three species each). Herbaceous flora exhibited the highest diversity (Simpson diversity index, $D = 0.97$ and Shannon-Weiner index, $H' = 5.82$), followed by trees and shrubs ($D = 0.95$ and 0.92 and $H' = 4.86$ and 3.97, respectively). All but one herb showed abundance-to-frequency ratio (A/F) $\geq$0.05, signifying a contagious distribution pattern (large aggregated distribution). Girth class distribution of trees followed an inverse J-shaped pattern. Results of the ethnobotanic study documented 55 MPs. MP collection, as reported by the interviewees, generally improved the socioeconomic status of the people of Tshothang Chiwog. Apart from improving the livelihood security of the local people, aspects relating to health care and culture are also important. Respondents were also concerned about the declining MP wealth of the Chiwog over the years, due to over-exploitation. Monitoring the plant resources and adopting conservation programmes in the Chiwog, in their opinion, may improve the MP wealth of the locality. The lessons learned from the study may have applicability over the south-eastern part of Bhutan and other regions with similar eco-climatic features.

Keywords: Himalayas, floristic composition, vegetation structure, medicinal plant collection, socioeconomic status

INTRODUCTION

Bhutan is endowed with abundant floral wealth including medicinal plants (MPs). Located in one of the world's biodiversity hotspots (Eastern Himalayas), the country has 70.46% forest cover with over 224 potential MPs, which are broadly categorized into high and low altitude MPs based on their location of occurrence (Wangchuk and Samten, 2009). Medicinal plants are primary ingredients of the traditional health-care systems (gSo-ba rig-pa and folk medicine) of Bhutan (Wangchuk et al., 2009) and they abound in the Bhutanese forests (Govil, 1999; NEC, 2016). Historically, collection of MPs offered a mode of subsistence for the indigenous people of Bhutan and many other countries, and presumably, such operations were occurring at low-impact levels. Over a period of time, however, MPs began to play a more important role in commercial income generation and employment in many ethnic groups and cultures of indigenous peoples (Runk, 1998). Although this led to improvements in the economic status of the collectors (Robbins, 2000; Ticktin et al., 2002), there was widespread over-exploitation of the MP resources in the wild. For example, Wangchuk et al. (2016) reported that Menjong Sorig Pharmaceuticals (MSP), the firm that produces more than 100 poly-ingredient medicines for the traditional gSo-ba-rig-pa hospitals of Bhutan, has been extracting MPs from the Lingzhi region for nearly 50 years, which increased the harvesting pressure on the MP resources in the locality.

As MPs become commercially valuable, their level of extraction increased—often exceeding sustainable levels—threatening the prospects of long-term revenue generation (Ngawang, 1996; Kala, 2005). With the result, numerous non-timber forest products have come nearer to extinction in many parts of the world (Nepstad et al., 1992; Daniels et al., 1995; Murali et al., 1996). MPs are thus facing growing threats worldwide from damage to their habitats, bioprospecting for alternate sources, and overharvesting of commercially important species (Roberson, 2008). However, only very few studies have assessed the distribution pattern, population status, and ecological pressure that MPs are experiencing in the Bhutanese context (e.g., Wangchuk et al., 2016), presumably because of the inaccessibility of the MP bearing forest areas in the country.

Tshothang Chiwog (a basic electoral precinct of Bhutan), under Lauri Gewog (block), is a part of Sakteng Wildlife Sanctuary in Eastern Bhutan (**Figure 1**), where the people have traditionally harvested MPs, at low intensities. However, as the demands for MPs increased due to potential contributions on drug discovery, income, and employment, the trend of low-level harvest gradually shifted to more intensive forms (FAO, 1996). This in turn, resulted in large scale extraction of MPs from these forests. For instance, 94,000 kg chiretta (*Swertia chirata*), 24,000 kg common madder (*Rubia cordifolia*), and 5,024 kg star anise (*Illicium griffithii*) were collected by the farmers of Lauri Gewog in 2007 (Pannozzo et al., 2012). At present, MPs like *S. chirata*, *R. cordifolia*, leafless mistletoe (*Viscum nepalense*), ginseng (*Paris polyphylla*), and pisa (*Parasassafras confertiflora*) are primarily regarded as commercial commodities (Pannozzo et al., 2012). Furthermore, the collection of MPs has been a source of income and health security for the inhabitants of Tshothang Chiwog. For example, in 1996–1997, more than 42% of total cash income of Lauri Gewog was obtained by the sale of *S. chirata* (Tshering, 2006). Similarly, in 2007, a total amount of Nu. 9,23,000 (USD ≈14,290) was made from the sale of MPs, chiefly *S. chirata*. Different parts of these plants are also used to cure and treat various ailments like a headache, stomach disorder, cough and cold, fractures, fever, etc. (Ugyen, 2004). Of late, the large-scale exploitation of MPs (Pannozzo et al., 2012) has reached alarming levels.

Indiscriminate extraction of forest plants may lead to changes in species composition, abundance, stand density, recruitment of individuals and vegetation structure (Shankar et al., 1998; Muraleedharan et al., 2005), which will affect not just the local biodiversity but also other ecosystem services and the livelihood security of the people (Paul et al., 2015). The idea of judicious extraction of MPs to ensure sustainability and for maintaining the diversity of the forests is, therefore, important. However, it is often jeopardized by the ever-increasing demand for such products and the consequential mounting anthropogenic pressures. It is thus, crucial to evolve appropriate conservation and management strategies for MP resources.

Although the MP spectrum may get disturbed during the exploitation of resources, a comprehensive account of the disturbances, imminent threats, ethnobotanical study and related changes in the vegetation attributes of the Chiwog is lacking. Likewise, information relating to MP diversity and structure are also lacking for the Chiwog. Therefore, an attempt was made to elucidate the floristic spectrum and diversity of plants in the broad-leaf mixed coniferous forests of Tshothang Chiwog, the principal forest type of the Chiwog, and to characterize the MP resources for their uses. We hypothesized that although Bhutanese forests are endowed with abundant medicinal plant diversity, over exploitation may pose a serious threat to these resources in the wild, as elsewhere in the world (e.g., Roberson, 2008). Specifically, the study addressed the following questions: (i) what is the floristic spectrum of the broad-leaf mixed coniferous forest of Tshothang Chiwog with a special focus on the MPs? (ii) what are the principal MPs collected by the local people? (iii) what are the therapeutic properties of MPs according to the traditional knowledge? and (iv) what are the impacts of MP collection on the socioeconomic status of the community? Although this study focused on one of the Chiwogs, the results may have wider applicability across other Dzongkhags (Districts) of Bhutan, with similar edaphic and floristic attributes.

MATERIALS AND METHODS

An ethics approval was not required as per the Nalanda University guidelines and national regulations. However, the dissertation committee of Nalanda University has reviewed and approved the study. Field research work in the State Reserved Forests/Community Forest/ Protected Areas of Bhutan was approved (ex post facto) by the Chairman of the Research Steering Committee, Department of Forests and Park Services, Ministry of Agriculture and Forests, Royal

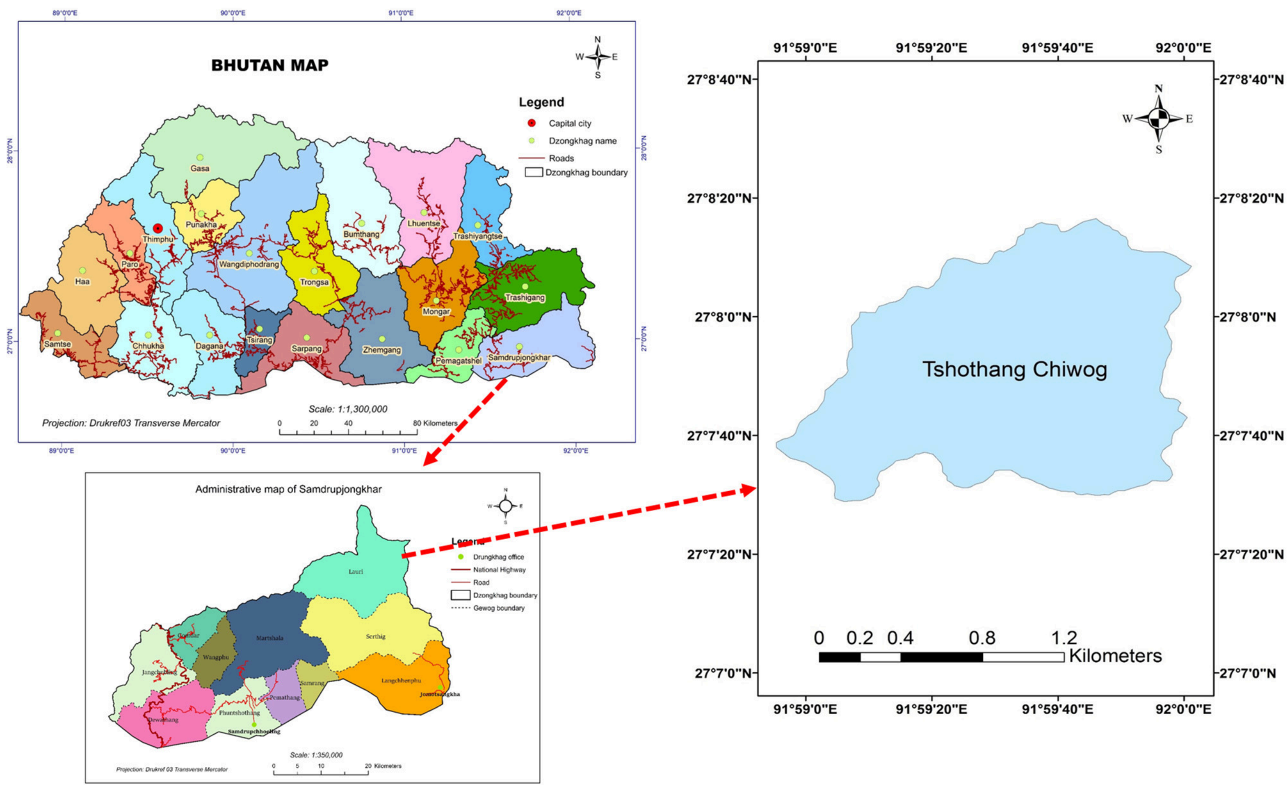

FIGURE 1 | Map of Bhutan showing the location of the study site (Tshothang Chiwog in Lauri Gewog, Samdrup Jongkhar). Bhutan and Samdrup Jongkhar maps reproduced with permission of the National Land Commission, Thimphu.

Government of Bhutan (Ref # 10126905005A2FEB83D234F). Verbal informed consent was also obtained from all research participants (both focus groups participants and semi-structured-interview participants) of the ethnobotanical study according to institutional and national requirements and no minors (non-adults) participated in this research.

Study Site

The study was conducted in Tshothang Chiwog, Lauri Gewog, South-Eastern Bhutan. The site lies between 27°7′30″ and 27°8′15″ N latitude and between 91°59′0″ and 92°0′00″ E longitude (**Figure 1**). The topography of the Gewog is rugged with an altitude range of 600 to 3,000 m above mean sea level. Soils in the southern belt of Bhutan covering the study location are mostly fluvisols, which together with cambisols (widespread in the medium-altitude zone) cover ∼27% of Bhutan (FAO-UNESCO, 1977). The area experiences a warm humid subtropical climate. Mean maximum temperature recorded at Lauri during the period from November 2014 to September 2017 ranged from 12.1°C (January) to 25.3°C (July) and mean minimum temperature ranged between 11.6°C (January) and 23.6°C (July) (source: The National Center for Hydrology and Meteorology, The Royal Government of Bhutan, Thimphu, Bhutan). Mean annual precipitation during the reporting period was 1,052 mm, characterized by a monomodal distribution pattern with most of the precipitation occurring during the months from June to September. October to March is the dry season. Relative humidity at Lauri ranged from 63% (January) to 84% (June). The forests of the Chiwog broadly fall under the category of broad-leaf mixed coniferous forest.

Tshothang Chiwog consists of three villages, viz., Rashuthang, Makhawoong, and Tshothang with 57 households and a total population of 428. A representative area was selected for the study after a reconnaissance. The criteria used for selection of the study location were: (i) abundances of MPs, and (ii) local farmers' dependence on MP collection to improve their livelihood security.

Vegetation Analysis

A vegetation survey was carried out from 30 November 2016 to 12 January 2017 to assess the floristic diversity and structure of the forest, following the quadrat method. A total of 50 quadrats, of size 10 × 10 m, was randomly established to characterize the trees (girth at breast height, GBH $\geq$ 15 cm). Similarly, a total of 50 quadrats of size 5 × 5 m nested inside the original 10 × 10 m quadrats was used to document the shrubs species (low woody perennials generally <5 m height). All trees and shrubs, and climbers in each quadrat were enumerated. The girth of trees and shrubs were measured respectively at 1.37 m and 2 cm above ground using a measuring tape. For characterizing the herbs, 50 quadrats of size 1 × 1 m nested inside the 5 × 5 m quadrats were used. Specimens were collected from all quadrats and identified by comparing with published reports (Grierson and Long, 1991; Thinley, 2004; Wangchuk and Samten, 2009). All potential MPs of various life forms (trees, shrubs, herbs and ferns, and climbers) were also recorded.

Vegetation data of plant population were quantitatively analyzed for density (no./ha), abundance, frequency, abundance-to-frequency ratio (A/F ratio; Curtis and McIntosh, 1950). The A/F ratio was used to interpret distribution pattern of the species. Simpson diversity index (Simpson, 1949), Shannon-Weiner index, and important value index (IVI; as a sum of relative density, relative frequency and relative basal area for trees and shrubs and as a sum of relative density and relative frequency for herbs and climbers; Muraleedharan et al., 2005) were computed.

Ethnobotanical and Socioeconomic Aspects

The ethnobotanical study was undertaken to gather information on the predominant MPs collected by the local people, characterize the traditional knowledge on therapeutic properties of important MP resources in the locality and to elucidate information on the ecological impacts of MP collection. The socioeconomic survey focused on gathering details such as mode of collection, prospects for cultivation and income generated. Information on ethnobotanical and socioeconomic aspects were elucidated through an open-ended focus group discussion and through semi-structured interviews during the month of December 2016, following standard methods for social surveys. The sample size for the socioeconomic survey was determined using Yamane (1967) formula. Accordingly, a total of 40 respondent farmers (heads of the families) were called in for the focus group discussion and interview. The participants were asked to assemble in the local community hall (*tshokhang*) on an auspicious day according to the Bhutanese calendar (i.e., 29 December 2016, when the farmers were free from field work). Aspects relating to the spectrum of MPs in their locality (using vernacular names), parts used, habit, and the therapeutic values were discussed. Information on ethnobotanical aspects was instantaneously recorded in a field notebook. In parallel, respondents were also interviewed on socioeconomic status using a semi-structured questionnaire, which covered aspects such as personal characteristics of the respondents (age, gender, education), mode of MP collection (e.g., who collects, major products collected, method, frequency, and season of collection), prospects for cultivation (which MPs are cultivated), annual income level (how much income is generated and where the products are sold), and the current scenario and management of MPs (species rank order of abundance, changing patterns of MP availability in the locality, factors causing depletion of MPs, and presence or absence of guidelines for MP collection/management). Information on ethnobotanical aspects and medicinal properties of the plants were supplemented with published information (State of an Environment, 2007; Wangchuk and Samten, 2009; Wangchuk et al., 2011). The data on socioeconomic variables were analyzed using percentage frequency distribution.

RESULTS

Floristic Composition, Important Value Index, and Diversity of the Broad-Leaf Mixed Coniferous Forest of Tshothang Chiwog, Bhutan

A total of 157 plant species (38 trees, 19 shrubs, 85 herbs and ferns, and 15 climbers), representing 74 families and 137 genera were identified from the study area (Appendix 1 in Supplementary Material). The most species-rich plant families were: Asteraceae (15 spp.), Poaceae (nine spp.), Solanaceae (seven spp.), Polygonaceae and Urticaceae (five spp. each). Of the total plants encountered in the study area, only 69 species (14 trees, 10 shrubs, 38 herbs and ferns, and seven climbers), belonging to 41 families, and 69 genera were medicinally important (**Table 1**). The most species-rich families of medicinal plants were: Asteraceae (eight spp.), Apiaceae (four spp.), Polygonaceae, Brassicaceae, Zingiberaceae, and Urticaceae (three species each).

The total density of trees and shrubs was 784 and 1,448 individuals per hectare with a corresponding stand basal area of 24.86 and 5.38 m^2 ha^{-1}, respectively (Appendix 1 in Supplementary Material). Mountain bamboo (*Borinda grossa*: 66 trees ha^{-1}), flowering or evergreen ash (*Quercus griffithii*: 62 trees ha^{-1}), and Himalayan blue pine (*Pinus wallichiana*: 42 trees ha^{-1}) contributed the three top tree densities and *titeypati* (*Artemisia dubia*: 216 individuals ha^{-1}), Indian stinging nettle (*Girardinia diversifolia*: 208 individuals ha^{-1}) and blackberry (*Rubus fruiticosus*: 96 individuals ha^{-1}) represented the three top shrub species at the study site. The total per hectare count of herbs/ferns was 1,91,800 and that of climbers 330. Among the herbaceous plants, *S. chirata* was the most abundant (13400 plants ha^{-1}), followed by saim weed (*Chromolaena odorata*: 7200 plants ha^{-1}), *P. polyphylla* (6800 plants ha^{-1}), and elatostema (*Elastostema platyphyllum*: 6200 plants ha^{-1}). Asteraceae accounted for 23,600 of the total density of 1,91,800 individuals ha^{-1} (Appendix 1 in Supplementary Material).

Importance Value Index (IVI) expresses the overall importance of a species in a community. *Q. griffithii*, *P. wallichiana*, sunda oak (*Lithocarpus elegans*) and Chinese sumac (*Rhus chinensis*) exhibited the three to four top IVI for tree species (Appendix 1 in Supplementary Material). Similarly, *A. dubia* and *S. chirata* represented the highest IVI for shrubs and herbs, respectively (Appendix 1 in Supplementary Material). *R. cordifolia* showed the highest IVI among climber species. All plant species showed abundance-to-frequency ratio (A/F) $\geq$0.05, except for *P. polyphyll*a (Melanthiaceae), which had an A/F-value of 0.04.

The floristic diversity (Simpson's Diversity Index, Shannon-Wiener Diversity Index) and important attributes (Density, Important Value Index, and Equitability) of all categories of plant species are summarized in **Table 2**. Simpson's diversity indexes were the highest for the herbaceous species (0.97) and the lowest for climbers (0.92) at this study site. Shannon index (H') values ranged from 3.69 (climbers) to 5.82 (herbs/ferns).

TABLE 1 | Density, basal area, percentage frequency, A/F ratio and important value index of medicinal plant species in the broad-leaf mixed coniferous forests of Tshothang Chiwog, Bhutan.

Sl. no.	Species	Family	Density (no. ha^{-1})	Frequency %	BA (m^2 ha^{-1})	IVI	A/F
TREES							
1	*Alnus nepalensis*	Betulaceae	12	8	0.48	4.97	0.38
2	*Azadirachta indica*	Meliaceae	8	6	0.09	2.53	0.44
3	*Cinnamomum impressinervium*	Lauraceae	10	10	0.12	3.65	0.20
4	*Debregeasia longifolia*	Urticaceae	22	10	0.42	6.38	0.44
5	*Erythrina arborescens*	Leguminosae	12	10	0.50	5.43	0.24
6	*Ficus elastica*	Moraceae	24	14	1.38	11.25	0.24
7	*Juglans regia*	Juglandiaceae	28	20	0.54	9.52	0.14
8	*Myrica esculenta*	Myricaceae	16	16	1.04	9.24	0.13
9	*Parasassafras confertiflora*	Lauraceae	38	26	1.08	14.10	0.11
10	*Pinus roxburghii*	Pinaceae	4	4	0.38	2.79	0.50
11	*Quercus griffithii*	Fagaceae	62	38	3.16	27.79	0.09
12	*Rhus chinensis*	Anacardiaceae	36	30	1.40	15.88	0.08
13	*Rhododendron arboreum*	Ericaceae	12	10	0.22	4.30	0.24
14	*Zanthoxylum alatum*	Rutaceae	8	4	0.08	2.10	1.00
SHRUBS							
1	*Aconogonum molle*	Polygonaceae	64	8	0.28	13.47	0.50
2	*Adhatoda vasica*	Acanthaceae	56	8	0.22	11.88	0.44
3	*Artemisia dubia*	Asteraceae	216	20	0.32	30.48	0.27
4	*Berberis aristata*	Berberidaceae	48	4	0.13	7.62	1.50
5	*Cannabis sativa*	Cannabaceae	72	10	0.70	22.72	0.36
6	*Daphne bholua*	Thymelaeaceae	72	14	0.13	14.08	0.18
7	*Dichroa febrifuga*	Hydrangeaceae	64	6	0.10	9.09	0.89
8	*Girardinia diversifolia*	Urticaceae	208	28	1.44	54.59	0.13
9	*Gaultheria fragrantissima*	Ericaceae	120	22	0.80	33.73	0.12
10	*Rubus ellipticus*	Rosaceae	64	10	0.09	10.86	0.32
HERBS AND FERNS							
1	*Acorus calamus*	Acoraceae	3,400	14	–	3.09	0.35
2	*Ageratum conyzoides*	Asteraceae	1,400	4	–	1.11	1.75
3	*Allium sativum*	Amaryllidaceae	400	4	–	0.58	0.50
4	*Bidens pilosa*	Asteraceae	4,200	14	–	3.51	0.43
5	*Brassica juncea*	Brassicaceae	400	4	–	0.58	0.50
6	*Capsella bursa-pastoris*	Brassicaceae	600	2	–	0.50	3.00
7	*Capsicum annuum*	Solanaceae	200	2	–	0.29	1.00
8	*Centella asiatica*	Apiaceae	200	2	–	0.29	1.00
9	*Chromolaena odorata*	Asteraceae	7,200	38	–	7.33	0.10
10	*Cirsium falconeri*	Asteraceae	400	2	–	0.40	2.00
11	*Colocasia esculenta*	Araceae	1,800	10	–	1.88	0.36
12	*Coriandrum sativum*	Apiaceae	3,000	18	–	3.26	0.19
13	*Crassocephalum crepidioides*	Asteraceae	5,400	18	–	4.51	0.33
14	*Cynodon dactylon*	Poaceae	200	2	–	0.29	1.00
15	*Dioscorea pentaphylla*	Dioscoreaceae	1,800	8	–	1.69	0.56
16	*Dryopteris cochleata*	Dryopteridaceae	800	6	–	0.98	0.44
17	*Elettaria cardamomum*	Zingiberaceae	400	4	–	0.58	0.50
18	*Equisetum arvense*	Equisetaceae	1,800	6	–	1.50	1.00
19	*Eryngium foetidum*	Apiaceae	2,800	16	–	2.96	0.22
20	*Fagopyrum esculentum*	Polygonaceae	400	4	–	0.58	0.50
21	*Hedychium spicatum*	Zingiberaceae	800	6	–	0.98	0.44
22	*Heracleum wallichii*	Apiaceae	2,200	16	–	2.65	0.17
23	*Houttuynia cordata*	Saururaceae	4,200	32	–	5.20	0.08

(Continued)

TABLE 1 | Continued

Sl. no.	Species	Family	Density (no. ha^{-1})	Frequency %	BA (m^2 ha^{-1})	IVI	A/F
24	*Lycopodium* spp.	Lycopodaceae	4,200	18	–	3.88	0.26
25	*Nephrolepis cordifolia*	Nephrolepidaceae	3,600	30	–	4.70	0.08
26	*Oryza sativa*	Poaceae	400	4	–	0.58	0.50
27	*Paris polyphylla*	Melanthiaceae	6,800	56	–	8.81	0.04
28	*Physalis divaricata*	Solanaceae	3,200	18	–	3.36	0.20
29	*Plantago depressa*	Plantaginaceae	200	2	–	0.29	1.00
30	*Raphanus sativus*	Brassicaceae	400	4	–	0.58	0.50
31	*Rumex nepalensis*	Polygonaceae	4,600	16	–	3.90	0.36
32	*Solanum nigrum*	Solanaceae	2,600	14	–	2.67	0.27
33	*Swertia chirata*	Gentianaceae	13,400	56	–	12.25	0.09
34	*Taraxacum officinale*	Asteraceae	200	2	–	0.29	1.00
35	*Tupistra nutans*	Asparagaceae	2,400	12	–	2.38	0.33
36	*Urtica dioica*	Urticaceae	3,800	16	–	3.48	0.30
37	*Xanthium strumarium*	Asteraceae	3,400	26	–	4.22	0.10
38	*Zingiber officinale*	Zingiberaceae	200	2	–	0.29	1.00
CLIMBERS							
1	*Crawfurdia speciosa*	Gentianaceae	10	4	–	4.99	1.25
2	*Dendrobium crumenatum*	Orchidaceae	22	14	–	13.53	0.22
3	*Drynaria propinqua*	Polypodiaceae	18	2	–	6.43	9.00
4	*Holboellia latifolia*	Berberidaceae	22	16	–	14.51	0.17
5	*Pisum sativum*	Leguminosae	6.0	4.0	–	3.78	0.75
6	*Rubia cordifolia*	Rubiaceae	50	34	–	31.82	0.09
7	*Viscum nepalense*	Santalaceae	26	18	–	16.70	0.16

BA, Basal area (GBH^2/ 4 π); IVI, Important Value Index; A/F, Abundance-to-frequency ratio. GBH of trees and shrubs were measured at 1.37 m and 2 cm above the ground, respectively.

TABLE 2 | Diversity attributes of trees, shrubs, herbs, and ferns and climbers in the broad-leaf coniferous forests of Tshothang Chiwog, Bhutan.

Life form	No. of species ha^{-1}	Number of individuals ha^{-1}	Basal area (m^2 ha^{-1})	IVI	D	H′	Hmax	E
Trees	38	784	24.86	300	0.95	4.86	5.08	0.95
Shrubs	19	1448	5.38	300	0.92	3.97	4.11	0.96
Herbs/ferns	85	191600	–	200	0.97	5.82	6.19	0.94
Climbers	15	330	–	200	0.92	3.69	3.87	0.95

IVI, Important Value Index; D, Simpson's Diversity Index; H′, Shannon-Wiener Diversity Index; Hmax, the maximum dispersion taking into account the number of species present in the plot (Hmax = 3.3219 $log_{10}S$, where S is the total number of species), E, Equitability (Where E = H′/Hmax).

Vegetation Structure of Trees and Shrubs

Girth frequency distribution showed a characteristic inverse J-shaped distribution pattern implying a negative exponential relationship between density and size classes, implying adequate regeneration potential for the woody flora (**Figure 2**). The GBH class of 15 to 29 cm had the highest number of individuals for tree species. *Q. griffithii*, *B. grossa*, *L. elegans*, walnut (*Juglans regia*) and prickly ash (*Zanthoxylum bungeanum*) were the predominant species in this size class (data not presented). The GBH distribution pattern of shrubs also showed an inverse J-shaped pattern, except for the GBH class 0 to 5 cm, which was truncated (**Figure 3**), implying poor regeneration status of the smallest size class, which is a matter of concern.

Ethnobotanical and Socioeconomic Aspects

The ethnobotanical study documented 55 MPs representing 37 families, which included 27 herbaceous plants, 15 trees, eight shrubs and five climbers (**Table 3**). The most species-rich families were: Asteraceae (five spp.), Lauraceae and Polygonaceae (three spp. each). The data presented in **Table 3** also indicate that MPs are important in the local health care delivery system. As much as 67.5% of respondents reportedly used MPs to cure various ailments like cold, cough, headache, body pain, wounds, blood pressure, etc. (data not presented). The farmers in the focus group have indicated as their opinions that *S. chirata*, *A. dubia*, *C. odorata*, and *V. nepalense* are the commonly used MPs for treating diseases like headache, cough and cold, body pain, and stomach ache. At the national scale, some of these plants are also used for drug discovery, which is known to cure a wide array of diseases. Local people deemed MPs complementary to western medicine.

Medicinal plants also have cultural significance. In fact, the traditional belief systems of the local people (e.g., giving protection from evil spirits) are intricately inter-woven with MP usage in this locality. Species like tree rhododendron

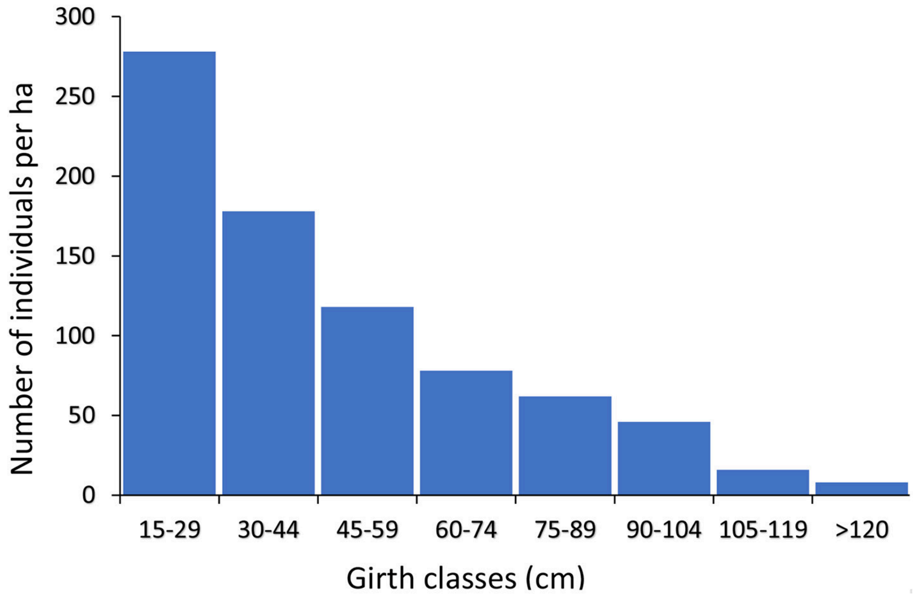

FIGURE 2 | Girth frequency distribution of trees (≥15 cm girth at breast height) in the broad-leaf mixed coniferous forest of Tshothang Chiwog, Bhutan.

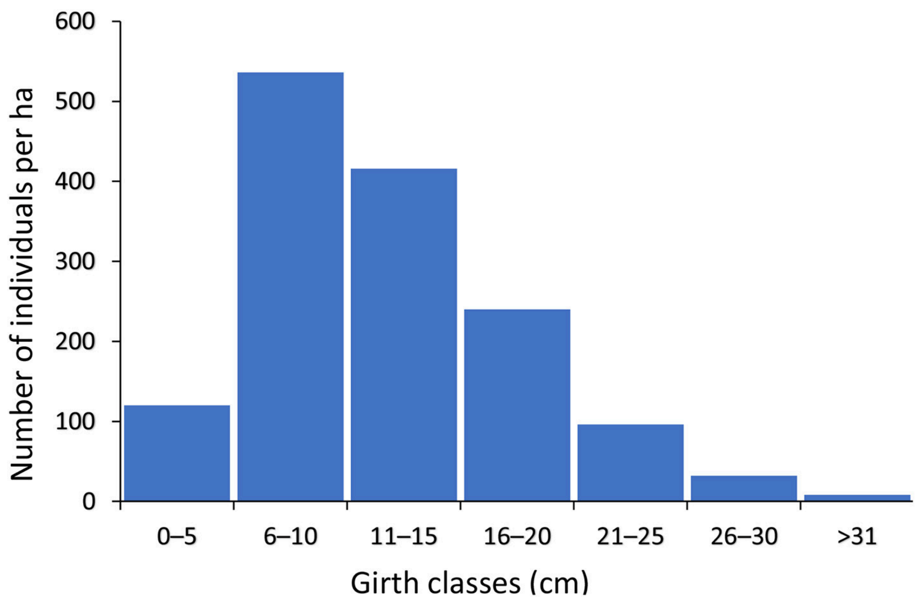

FIGURE 3 | Girth frequency distribution of shrubs (low woody perennials generally <5 m height) measured at 2 cm above ground in the broad-leaf mixed coniferous forest of Tshothang Chiwog, Bhutan.

(*Rhododendron arboretum*), oriental thuja (*Thuja orientalis*), Japanese cedar (*Cryptomeria japonica*), and *A. dubia* are used for making smoke (*Saang*) every morning and evening to ward off evil spirits. Consistent with the tenets of Mahayana sect of Buddhism, it is believed that smoke drives away evils and devils, and serves as a remedy for quenching thirst and hunger of evils and devils. Furthermore, several species of *Cupressus* spp. and *Juniperus* spp. are traditionally used for making the mainline or life tree (*Sog-shing*) in prayer wheels, stupa (*Choertens*) and statues. Circumambulating and rotating prayer wheels and stupa may accumulate good fortune, purify one's soul, make them healthier and enable them to live longer.

A total of 40 farmers were randomly interviewed (75% male and 25% female) to assess the socioeconomic status of MP collectors in Tshothang Chiwog. The average age of the respondents fell in the range of 23 to 78 years with a mean of

TABLE 3 | List of medicinal plant species in the broad-leaf mixed coniferous forests of Tshothang Chiwog, Lauri Gewog, Bhutan, and the ethnobotanical knowledge associated with them elucidated from the survey.

Sl. no	Species	Vernacular name	Family	Habit	Part used	Medicinal uses
1	*Aconogonum molle* D. Don	Chokom	Polygonaceae	Shrub	Aerial shoot	Astringent
2	*Acorus calamus* L.	Zhingbartse	Acoraceae	Herb	Root/rhizome	Eupeptic and allay indigestion
3	*Adhatoda vasica* Nees.	Khatsherma	Acanthaceae	Shrub	Leaf/flower	Relieves cough, stop bleeding
4	*Ageratum conyzoides* (L.) L		Asteraceae	Herb	Leaves	Wound healing
5	*Allium sativum* L.	Lam	Amaryllidaceae	Herb	Bulb	Cures disorders arising from defective bile and air like a headache, nausea, shivering
6	*Alnus nepalensis* D.Don	Gongtsa shing	Betulaceae	Tree	Leaves/branches	Reduces swelling, prevent sweating
7	*Artemisia dubia* L. & ex B.D. Jacks	Meyrangma	Asteraceae	Shrub	Leaf	Stop bleeding and believed to be useful against breast cancer
8	*Azadirachta indica* A. Juss	Neem shing	Meliaceae	Tree	Root/bark/leave	Used as toothbrush and in the treatment of stomach disorders and diarrhea
9	*Berberis aristata* DC	Kerpa shing	Berberidaceae	Shrub	Root/bark	Allays conjunctivitis and chronic cough and cold
10	*Bidens pilosa* L.	Roba	Asteraceae	Herb	Whole plant	Wound healing, ulcer, ear and eye problem
11	*Brassica juncea* (L.) Czern	Memba	Brassicaceae	Herb	Seed	Antitoxin, antiseptic. Allays affliction by evil spirits
12	*Cannabis sativa* L.	Phagpanam	Cannabaceae	Shrub	Stem/seed/leave	Used for stomach disorders
13	*Capsicum annuum* L.		Solanaceae	Herb	Fruit	Optimize digestion
14	*Centella asiatica* (L.) Urb.		Apiaceae	Herb	Leaves	Used to treat cuts and skin diseases
15	*Chromolaena odorata* (L.) R.M.King & H.Rob.	Nera ngon	Asteraceae	Herb	Leaves	Extract from leaves used in cut and wounds
16	*Cinnamomum impressinervium* Mesin.	Solo encha shing	Lauraceae	Tree	Bark	Antifungal, antimicrobial, stimulants and carminative
17	*Colocasia esculenta* (L.) Schott	Bozong	Araceae	Herb	Leaves, rhizome	Used for fever and cough
18	*Coriandrum sativum* L.	Wusu	Apiaceae	Herb	Seed	Disintegrates pebble like mass formed in the stomach
19	*Crassocephalum crepidioides* (Brnth.) S. Moore	Depshang ngon	Asteraceae	Herb	Whole plant	Stops wound bleeding. Cure headache
20	*Crawfurdia speciosa* C.B. Clarke		Gentianaceae	Climber	Root/flower	Believed to reduce blood pressure
21	*Daphne bholua* Buch. Ham ex D. Don	Shogo shing	Thymelaeaceae	Shrub	Bark/root	Bark decoction is given to treat fever
22	*Debregeasia longifolia* (Burm.f.) Wedd.	Zangrushing	Urticaceae	Tree	Fruits/leaves	Juice is applied to an area infected with scabies
23	*Dioscorea pentaphylla* L.	Fantang	Dioscoreaceae	Herb	Tuber	Cures stomach disorders and improve appetite
24	*Dryopteris cochleata* (D. Don) C. Chr.		Dryopteridaceae	Herb	Whole plant	Plant paste applied on wounds, rhizomes are anti-bacterial
25	*Elettaria cardamomum* (L.) Maton	Alenchi	Zingiberaceae	Herb	Fruits	Heals kidney disorders
26	*Erythrina arborescens* Roxb.	Kharshing	Leguminosae	Tree	Seed	Febrifuge and heals renal disorders
27	*Fagopyrum esculentum* Moench	Khala	Polygonaceae	Herb	Whole plant	Reduce blood pressure, anti-diabetic, pain relief and anti-oxidant
28	*Gaultheria fragrantissima* Wall.	Shak chung ma	Ericaceae	Shrub	Leaves	Used as anti-septic and in rheumatism
29	*Holboellia latifolia* Wall.		Berberidaceae	Climber	Fruit	Used for treating rheumatism
30	*Houttuynia cordata* Thunb.	Momring	Saururaceae	Herb	Whole plant	Used against dysentery and or diarrhea
31	*Juglans regia* L.	Khe shing	Juglandiaceae	Tree	Nut	Heals air disorder like a headache, nausea, blurred vision.
32	*Lindera neesiana* (Wall. ex Ness) Kurz	Ningshing	Lauraceae	Tree	Bark/fruits	Used as carminative, in diarrhea and scabies
33	*Myrica esculenta* Buch. Ham. ex D. Don	Tsutsu shing	Myricaceae	Tree	Bark	Used to treat cough
34	*Nephrolepis cordifolia* (L.) C. Presl		Nephrolepidaceae	Herb	Rhizome	Use d to treat cough, rheumatism, and nose blockage
35	*Oryza sativa* L.		Poaceae	Herb	Seed	Anti-diarrheal, anti-emetic
36	*Parasassafras confertiflora* (Meisner) Long	Seyshing	Lauraceae	Tree	Fruit	Anti-viral, anti-bacterial and anti-protozoans
37	*Paris polyphylla* Sm.	Thoksam	Melanthiaceae	Herb	Rhizome	Anthelmintic, and treat cancer

(Continued)

(Muraleedharan et al., 2005). The occurrence of a large number of plant species in the study area is presumably because of the prevalence of many micro-habitats in the mountainous terrain. The density of trees and shrubs reported from the study site is similar to that of the broad-leaf forests of Dagana Dzongkhag, Bhutan (662 individuals ha^{-1}; Tenzin and Hasenauer, 2016) and the stand basal area similar to that of the logged over plots of Chimithanka within Gidakom Forest Management Unit, Bhutan (29.77 m^2 ha^{-1}; Covey et al., 2015). The stand basal area, however, was less than that of a humid mixed conifer forest at Dochula Ridge Top, Bhutan (66.4 m^2 ha^{-1}; Wangda and Ohsawa, 2006).

The plant distribution pattern in the study location ranged from random to contagious (highly aggregated distribution). According to Odum (1971), contagious distribution is the commonest, random distribution is found only in a uniform environment, and regular distribution occurs when severe competition occurs between individuals. Hanief et al. (2016) reported similar observations (A/F: 0.01 to 0.08) from the Darhal watershed in Jammu and Kashmir Himalayas, India.

Species diversity contributes to ecosystem richness (Muraleedharan et al., 2005). Herbaceous flora exhibited the highest diversity and species richness followed by trees, shrubs, and climbers, as expected. The Simpson and Shannon-Weiner diversity index ranged from 0.92 to 0.97 and 3.69 to 5.82, respectively (**Table 2**). High diversity in the study site can be explained by the low to moderate levels of disturbances occurring at the site such as MP collection, grazing etc. This is perhaps consistent with the "intermediate disturbances" hypothesis of Connell (1978), according to which stress limits species at the lower end of the disturbance gradient, whereas increased competition is the limiting factor at the upper end of the gradient. Tenzin and Hasenauer (2016), reported similar diversity ($D = 0.88$ and $H' = 3.39$) for the broad-leaf forests of Dagana, Bhutan. Overall, the floristic composition, diversity, and vegetation structure are comparable to other studies within Bhutan and the north-western Himalayan region (Buffum et al., 2008; Wangchuk, 2013; Wangchuk and Gurung, 2016).

The poor regeneration status of shrub species in the lower size classes (**Figure 3**) is presumably because of occurrence of constraints like ground fire, browsing, and livestock grazing, which affects the shrubs more than the trees. According to Narayanan and Swarupanandan (1996), fire kills the young seedlings and encourages the invasion of seedlings and saplings. It also causes damages and loss of species richness and diversity (Buffum et al., 2008; Wangchuk, 2013; Wangchuk and Gurung, 2016). Cattle and yaks are major sources of grazing pressure in the study area (author's observations). It was also reported that farmers collect shrubs like Sikkim knotweed (*Aconogonum molle*) and *A. dubia* for fodder and green manure purposes.

Ethnobotanical and Socioeconomic Aspects

An array of MP resources are utilized in the study locality and adjoining areas of Bhutan for curing various ailments and the indigenous knowledge system appears to be profound in this respect (55 species; **Table 3**). The number of MP species presently reported, however, was marginally lower than that from the results of the vegetation study (69 species; **Table 1**). Such differences are plausible in view of the differences in experience and knowledge of the respondents and the investigators. The concordance between ethnobotanic and vegetation studies for the most species-rich families was also less evident. For example, Asteraceae, Lauraceae, and Polygonaceae formed the dominant plant families (with more than three plants per family) according the ethnobotanical survey (**Table 3**), while the species-rich families of medicinal plants according to the vegetation analysis were: Asteraceae, Polygonaceae, Apiaceae, Brassicaceae, Zingiberaceae, and Urticaceae (**Table 1**).

Apart from the medicinal uses, MPs are also used in drug discovery in the indigenous Bhutanese medical systems. Indeed, there are two indigenous medical systems prevailing in the country. These are: (i) the formalized traditional medicine system- *gSo-ba rig-pa* (pronounced as *So-wa Rig-pa*) and (ii) the traditional local healing practices or folk medicine (*Nang-pai mempa*). *gSo-ba rig-pa* is a codified medical system in the country, which is estimated to use over 200 species of MPs, 35 different types of animal parts and 18 different types of minerals to produce 103 types of drugs (Jamphel, 2011; Choden and Dorji, 2014). The traditional healing practices, however, are transmitted through oral traditions from either father to son or from elderly to young and lacks proper documentation; but uses a wide spectrum of MPs. Regarding the choice of MPs in the indigenous medical systems, factors such as ease of collection, accessibility, and affordability appear to be major determinants (Pannozzo et al., 2012). Results of our ethnobotanical study (e.g., medicinal and other uses of plant resources: **Table 3**) are comparable to what Namsa et al. (2011) documented previously for the *Monpa* tribe of Kalaktang, Arunachal Pradesh, India, and Prakash (2011) for the tribals of Uttar Pradesh in India, implying strong similarities in the usage of MP resources by the tribal communities of the Eastern Himalayan belt. Apart from this, MPs in Bhutan have been a cardinal source of food and food supplements, socioeconomic and religious uses too (Wangchuk et al., 2008; Wangchuk and Olsen, 2011).

Traditionally, the economic well-being and social status of the rural community of Lauri Gewog is dependent on MP collection (Pannozzo et al., 2012). Accordingly, farmers were actively engaged in collecting and selling MPs. However, the way in which local people collect MPs are dependent on the commercial value it fetches in the market. Although 55 MPs were documented through participatory discussion (**Table 3**), only five species are commercially exploited. These are: *S. chirata*, *P. polyphylla*, *R. cordifolia*, *V. nepalense,* and *P. confertiflora*. The annual income of farmers from MP collection ranged from USD 30 to 330. Wangchuk and Gurung (2016) reported that farmers of Lingzhi and Langthel of western and central Bhutan had also improved their socioeconomic status by the collection of MPs. Studies in Nepal (Ghimire, 2008), and South India (Muraleedharan et al., 2005) also reported similar trends.

The respondents also opined that MP resources in the Chiwog have been diminishing over the years. According to some estimates, in the year 2000, farmers collected as much as 20 tonnes of MPs, chiefly *S. chirata*. However, it dropped to less than five tonnes by 2006 (Pannozzo et al., 2012), presumably because of the reduced availability in the wild. The situation has further deteriorated now. *S. chirata*, *I. griffithii*, Indian bay leaf (*Cinnamomum impressinervium*), and *P. polyphylla* are apparently threatened in this locality, as informed by the respondents. Most farmers (45% respondents), cited the ban on shifting cultivation, illegal poaching, encroachment by others (highlanders), forest fires and grazing as probable reasons for the declining MP wealth. More importantly, it could be due to over-harvesting and unsustainable extraction. Although the declining resources warrant domestication of the prominent MPs, none of the respondents except one had successfully cultivated MPs, particularly *S. chirata*.

Most notably, the way in which local people collect MPs are dependent on their usages and the commercial value it fetches in the market. Farmers highlighted the challenges of lack of farm roads for carrying the produce to the markets and the distance to market as hindrances in getting reasonable returns. Similar difficulties and challenges were reported by Pannozzo et al. (2012) for marketing MPs in another location of Lauri Gewog. Poor accessibility to markets especially for Tamang in Sandhu Marunche and Kanche CF User Groups in Lamjung district of Nepal also resulted in greater dependence on intermediaries and lower sale prices for the MP resources (Gaire, 2005).

The method of MP extraction also has changed over a period of time. Traditionally, farmers of Tshothang Chiwog selectively collected tubers, fruits, or climbers using simple tools such as hoe and knife/sickle. Xhosa and Sotho people of South Africa, also used similar tools to collect MPs (Liu et al., 2007). And the traditional method of extraction is often regarded as eco-friendly. However, contradictory practices were observed in the study area. For example, whole trees were cut down to collect fruits of *P. confertiflora* and *V. nepalense*, primarily to avoid the effort of climbing (author's observation). Similarly, the bark was destructively removed from *Cinamomum impressinervium*. Rhizomes of *P. polyphylla* also were dug out extensively. These practices would eventually deplete the MP resources of Tshothang Chiwog. Other workers also reported that MPs in some localities of Bhutan have been shrinking over the years (e.g., Wangchuk and Tobgay, 2015). Rai et al. (2000) and Muraleedharan et al. (2005) also reported that overexploitation is a principal reason for the shrinking non-wood forest product resources in Sikkim Himalayas and Western Ghats of India, respectively.

Furthermore, there are no management plans, rules, and regulations for extraction, storage, and utilization of MPs in the Chiwog. The only rule available (formulated within the villages) and that is orally transmitted among the villagers is with respect to the time of collection (when and for how long to collect MPs) and the number of collectors (viz. how many people from each household are allowed to collect MPs). The respondents were also not aware of any collection guidelines for MPs. Interestingly, all respondents (100%) favored the formulation of management rules, strategies, and plans for MP extraction, implying that the farmers are well aware of negative anthropogenic impacts on MPs, although their practices do not corroborate with that line of thinking. The solution to vexed problems such as over-exploitation of MP resources in Bhutan and associated threats to local and regional biodiversity, may lie in carrying out advocacy and awareness programmes, formulating stringent policies for better MP resource management and domestication of the more valuable MPs (e.g., *S. chirata* and *P. polyphylla*).

CONCLUSIONS

Results of the present study underscore the fact that Tshothang Chiwog harbors a considerable number of plant species, which are of ethnobotanical and cultural significance. Broad-leaf mixed coniferous forest, which is the predominant forest type of this locality, is endowed with high diversity, species richness, and adequate regeneration potential of the woody flora. Results of the socio-economic survey indicated that medicinal plant collection, in general, have improved the socioeconomic status and livelihood security of the local inhabitants. However, the Chiwog lacks proper guidelines and regulations for MP collection, because of which the farmers often resort to over-extraction, threatening the sustainability of the MP resources. Hence, it is vital to implement rigorous plans and policies for the management and surveillance of MP resources in this and other localities of Bhutan. Yet another strategy to augment MP resources is to domesticate the prominent species such as *S. chirata* and *P. polyphylla*. However, no serious attempts have been made in this direction till now at the study location or elsewhere in the country. Although our data pertain to one location in south-east Bhutan, the results may have wider applicability over other locations with similar edaphic characteristics, climatic regimes and floristic spectrum.

AUTHOR CONTRIBUTIONS

NJ and BK: conceived the study; NJ with the help of the field survey teams conducted the survey; NJ and BK: analyzed the data and prepared the manuscript; BK: revised the manuscript.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fenvs.2017.00096/full#supplementary-material

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