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Distribution Pattern of Medicinal Plants Prioritized by Government of Nepal

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Abstract

Government of Nepal (GoN) prioritized 33 medicinal plants (MPs) for the research and development in Nepal. Among those 33 MPs 13 MPs are prioritized for the agro-technology development. The distribution pattern in phytogeographical regions, bioclimatic zones, and elevational gradients of those prioritized MPs were reviewed from different literatures and data collected were analyzed. The analysis revealed that among the 33 prioritized MPs, all the MPs are distributed in Central Nepal. East Nepal harbours 31 and West Nepal harbours 25 prioritized GoN prioritized MPs. Maximum numbers of 19 prioritized MPs are present in lower temperate zone followed by 18 MPs in subtropical region. However, subalpine zone harbours more MPs prioritized for agro-technology development than other zones. Maximum richness for the GoN MPs is found at the elevation of 2100 -2300 m and at 2500 m.

***Key words*:** Research and Development, Distribution, Prioritized, Medicinal plants, Nepal.

INTRODUCTION

From the time immemorial, indigenous plants had the history of therapeutic or prophylactic use as human and veterinary medicine, the properties of which are because of presence of bioactive chemical compounds with active physiological effects against different ailments. Nepal is endowed with the huge source of medicinal plants, which is mainly attributed because of wide range of altitudinal gradients, accompanied with climatic and edaphic factors within the small area. Use of local medicinal plants in Nepalese healthcare has the long history. Still, majority of the people residing in the rural area rely on the locally available flora or traditional medicine prepared from the plants for their health care. Medicinal plants (MPs), commonly known by the term "Jadibuti" in Nepali, the most important Non-timber Forest Products (NTFPs), is the important source of revenue collection to the government and main or additional source of income generation and livelihood for the people residing in the rural areas of the country, specially the developing like Nepal. Moreover, for the people residing in rural areas, the allopathic medicines are usually unavailable and thus have to depend on locally available MPs. About 60 % population of the world and 80% population of Nepal are reported to rely on the traditional medicinal herbs to cure the health ailments (Shrestha & Dillion 2003). Moreover, 50% of rural households in Nepal are reported to derive their income from collection and trade of the medicinal plants (Edward 1996). Despite the high dependency of people in locally available medicinal plants either for health care or as the main or additional source of household income, the exact number of medicinal plants present in the country is still uncertain or the data differs with different literatures. Department of Plant Resources (DPR 1970, 1984) compiled 571 species, Malla and Shakya (1999)

reported 630 species, Baral and Kurmi (2006) compiled 1792 species and Ghimire (2008) revealed 1950 species of medicinal plants in Nepal. However, at least 1463 species of herbal medicinal plants are reported to be used by people in Nepal (MoFSC 2006).

Due to effectiveness of herbal drugs and without any adverse side effects, the regional and global demands for those medicinal plants are increasing. Besides, more than 65% of the patients who used the local therapy are satisfied with such treatment (Manandhar 2002).

A bulk of literatures is available on the systematic documentation and ethnobotanical survey and traditional usage of the MPs of Nepal. Among the huge number of medicinal plants, GoN has prioritized 33 MPs for the research and economic development of the country. Commercial cultivation and trade of those prioritized and other valuable MPs are necessary for the economic growth of the country. Among the 33 prioritized MPs, GON has again selected 13 MPs for agro-technology development. However, research and development and for commercial cultivation and conservation, the distribution patterns of the species along the horizontal and vertical gradients are to be identified first. But the natural distribution patterns of those prioritized MPs are found to be variable with different literatures. As the market demand for the medicinal plants are increasing drastically in national and global level, the wild collection of those plants will not sustain for the long term survival of the species. The alternative for the wild collection is the cultivation, for which distribution patterns, habitat and suitable climatic conditions for the proper cultivation are to be evaluated and must needed. More over the relationship between species richness and elevation is important for conservation and management of species diversity (Grytnes 2003). Thus the information about the natural distribution of prioritized MPs in different phytogeographical regions and in bioclimatic zones with elevation gradients and relationship between species richness and elevation is crucial for research as well as conservation and management and agro-technology development.

The main aim of this work is to evaluate the distribution pattern of MPs prioritized by GoN in different phytogeographical regions, find elevation gradients, distribution in bioclimatic zones and species richness in elevation gradient in Nepal Himalaya to facilitate the research and development of the nation.

MATERIALS AND METHODS

Data source

Nepal Himalaya, endowed with diverse climatic, edaphic and topographic factors, harbours a large number of medicinal plants, some of which are highly valuable and proper management and propagation of those MPs have potentialities for the national development. Medicinal plants in Nepal are reported to have distributed from low land forest with <100 m altitude to as high as 6100 – 6300 m altitudes (Ghimire 2008). The present study of the distribution pattern MPs in different phytogeographical regions and at different elevation gradient was focused on only 33 MPs prioritized by the GoN. The range of distribution at phytogeographical regions viz. West, Central and East and minimum and maximum vertical elevation levels were acquired from different literatures (Joshi *et al*. 2017; Tripathi 2015; DPR 2011; Baniya *et al*. 2010; Devkota 2010; Ghimire *et al.* 2008; Rajbhandary & Ranjitkar 2006; ANSAB 2003; Press *et al*. 2000). The valid names of the species were verified from the website (http://www.tropicos.org; http://www.theplantlist.org). The changed families of the taxa were based on the APG III (https://en.wikipedia.org/wiki/APG_III_system).

Data analysis

The data was analyzed by the Excel software. The distribution in different phytogeographical regions was analyzed by pie chart. The phytogeographical regions given by Stearn (1960);

West Nepal with up to 83° E latitude, Central Nepal between 83° E to 86°30' E and East Nepal from 86°30' E onwards, was followed here. The distribution of species in different bioclimatic zones was analyzed by bar diagrams. Six bioclimatic zones with 11 subzones given by Dobremez (1976) was recognized for the analysis. The species richness at particular elevation was determined by scattered plot method. The vertical elevation band of 100 m interval was made for overall elevation range from 100 m to 6000 m. The species is considered to be present in each elevation band within its minimum level of occurrence to maximum level of occurrence. The total number of MPs present in each band was determined by interpolation (Vetaas & Grytnes 2002; Bhattarai *et al.* 2004).

MPs prioritized by GoN

Department of Plant Resources, GoN has identified and prioritized 33 plants for the research and economic development of Nepal. (DPR 2006, 2016). The list of the prioritized MPs along with their family and Nepali name are given in Table 1.

Table 1. List of Medicinal Plants prioritized by Government of Nepal.

Sl. No.	Scientific Name	Family	Nepali Name
1.	***Aconitum heterophyllum*** Wall. ex Royle	Ranunculaceae	Atish
2.	***Aconitum lethale*** Griff. [Synonyms: *Aconitum spicatum* (Bruhl) Stapf; *Aconitum ferox* var. *spicatum* Bruhl	Ranunculaceae	Bikha
3.	***Acorus calamus*** L.	Acoraceae	Bojho
4.	***Asparagus racemosus*** Willd.	Asparagaceae	Satawari
5.	***Azadirachta indica*** A.Juss.	Meliaceae	Neem
6.	***Bergenia ciliata*** (Haw.) Sternb.	Saxifragaceae	Pakhanbhet
7.	***Cinnamomum glaucescens*** (Nees) Hand.-Mazz.	Lauraceae	Sugandha kokila
8.	***Cinnamomum tamala*** (Buch.-Ham.) T.Nees & Eberm	Lauraceae	Tejpat
9.	***Curculigo orchioides*** Gaertn.	Hypoxidaceae	Kalo Musali
10.	***Dactylorhiza hatagirea*** (D. Don.) Soo	Orchidaceae	Panch aaule
11.	***Dioscorea deltoidea*** Wall. ex Griseb.	Dioscoreaceae	Bhyakur
12.	***Fritillaria cirrohosa*** D. Don.	Liliaceae	Kakoli
13.	***Gaultheria fragrantissima*** Wall.	Ericaceae	Dhasingare
14.	***Juglans regia*** Linn.	Juglandaceae	Ookhar
15.	Lichens spp	-	Jhyau
16.	***Morchella*** spp.	Pezizaceae	Khoya Chyau/Guchchi Chyau
17.	***Nardostachys jatamansi*** (D.Don.) DC. [Synonym: *Nardostachys grandiflora* DC.]	Caprifoliaceae	Jatamansi
18.	***Neopicrorhiza scrophulariiflora*** (Pennell) D.Y.Hong [Synonym: *Picrorhiza scrophulariiflora* Pennell]	Plantaginaceae	Kukti
19.	***Ophiocordyceps sinensis*** (Berk.) G.H. Sung & J.M.Sung, Hywel-Jones & Spatafora [Synonym: *Cordyceps sinensis* (Berk.) Sacc.] (Fungus)	Clavicipitacea e	Yarsagumba
20.	***Paris polyphylla*** Sm.	Melanthiaceae	Satuwa
21.	***Phyllanthus emblica*** L.	Phyllanthaceae	Amala
22.	***Piper longum*** L.	Piperaceae	Pipala

Sl. No.	Scientific Name	Family	Nepali Name
23.	***Rauvolfia serpentina*** (L.) Benth. ex Kurz	Apocynaceae	Sarpagandha
24.	***Rheum australe*** D.Don [Synonym: *Rheum emodii* Wall. ex Meisn.]	Polygonaceae	Padamchal
25.	***Rubia manjith*** Roxb. ex Fleming	Rubiaceae	Majitho
26.	***Sapindus mukorossi*** Gaertn.	Sapindaceae	Riththa
27.	***Sinopodophyllum hexandrum*** (Royle) T.S. Ying [Synonyms: *Podophyllum hexandrum* Royle; *Podophyllum emodi* Wall. ex Hoof. f. & Thomos]	Berberidaceae	Laghupatra
28.	***Swertia chirayita*** (Roxb.ex Fleming) Karsten [Synonym: *Swertia chirata* (Wall.) C.B.Clarke; *Gentiana chirayita* Roxb. ex Fleming]	Gentianaceae	Chiraito
29.	***Tagetes minuta*** L.	Asteraceae	Jangali Sayapatri
30.	***Taxus wallichiana*** Zucc. [Synonym: *Taxus baccata* subsp. *wallichiana* (Zucc.) Pilg.]	Taxaceae	Lautha Salla
31.	***Tinospora sinensis*** (Lour.) Merr.	Menispermaceae	Gurjo
32.	***Valeriana jatamansii*** Jones	Caprifoliaceae	Sugandhawal
33.	***Zanthoxylum armatum*** DC.	Rutaceae	Timur

Among the 33 prioritized MPs, three species viz. *Curculigo orchioides* Gaertn., *Fritillaria cirrohosa* D. Don. and *Paris polyphylla* Sm. were prioritized in 2016 (DPR 2016) and the remaining 30 MPs had been prioritized much earlier in 2006 (DPR 2006). Moreover, within the 33 prioritized MPs 13 MPs are prioritized for agro-technology development (DPR 2006, 2016). The list of MPs prioritized for agro-technology development are: (1) *Curculigo orchioides,* (2) *Dactylorhiza hatagirea,* (3) *Fritillaria cirrohosa,* (4) *Morchella* spp. (5) *Nardostachys jatamansi,* (6) *Neopicrorhiza scrophulariiflora,* (7) *Ophiocordyceps sisnensis,* (8) *Paris polyphylla,* (9) *Piper longum,* (10) *Rauvolfia serpentine,* (11) *Swertia chirayita,* (12) *Taxus wallichiana,* and (13) *Tinospora sinensis.*

RESULTS AND DISCUSSION

Among the 33 prioritized MPs two species are fungi (one mushroom and one parasite), one is of lichen group, 16 species are herbs, four species are climbers, two species are shrub and eight species are trees (Table 1). The total prioritized MPs thus constitute 49 % of herbs, 24% of trees, 12 % of climbers, 6 % of shrub and 3 % each of mushroom, parasite and lichen (Figure 1).

Within the fungi, *Ophicordyceps sinensis* [Syn. *Cordyceps sinensis*] the high value medicinal plant used as tonic, is the entomopathogenic fungus belonging to the family Ascomycetes. It is endemic to the Himalayas and Tibetan Plateau and the most valued medicinal species in the world for its medicinal property (Thapa *et al.* 2014). The fungus parasitizes the Lepidopteran larvae especially the Himalayan bat moth *Hepialus armonicanus* (Gae *et al.* 2003; Holliday *et al.* 2005; Wang & Yao 2011). Mushroom *Morchella* Pers., commonly known as the "morels" are also the members of sac fungi Ascomycetes and are highly cherished edible fungi (Sher & Shan 2014) with many pharmacological values. In Nepal four species of *Morchella*; *Morchella conica* Pers. (Singh & Nisha 1976; Adhikari

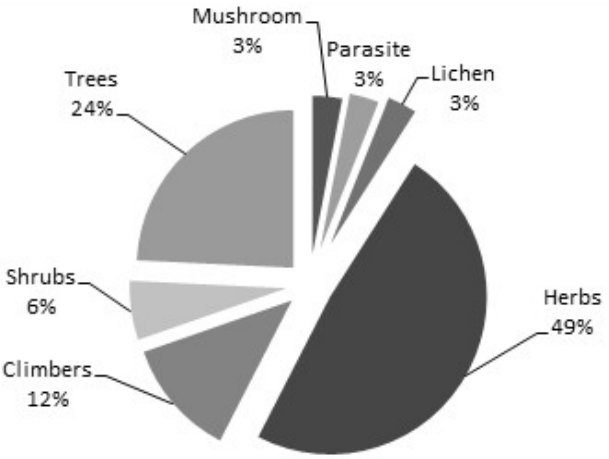

Figure 1. Different habit groups represented in the prioritized MPs.

1991), *M. deliciosa* Fr. (Singh & Nisha 1976), *M. esculenta* Pers. (Adhikari 1991) and *M. vulgaris* (Pers.) Boud. (Adhikari & Durrieu 1996), are reported.

Lichens, the symbiotic association of algae and fungi, of different species are also prioritized by GoN for the research and economic development of the Nation. In Nepal 465 species of lichens accounting the 2.3 % of known species in the world, are reported (GoN/ MoFSC 2014). Among them, different species such as *Heterodermia* sp. *Ramalina* sp. (Devkota *et al.* 2017), *Stereocaulon* sp. (DPR 2011) are reported to have the medicinal properties. Although the distribution of lichens are influenced by the diversity of environmental variables at multiple scales (Lalley *et al*. 2006), for the convenience, all valued lichens species are considered here as one MP for determining distribution in phytogeographical region, bioclimatic zones and species richness.

Among the prioritized spermatophytes MPs only one species *Taxus wallichiana* Zucc., commonly known as Himalayan yew is the gymnosperm that is well known for the medicinal properties, especially the anticancer property of the alkaloid "taxol" produced from it (DPR 2011).

From the prioritized angiosperm MPs, six species viz. *Acorus calamus* Linn.*, Asparagus racemosus, Curculigo orchioides*, *Dactylorhiza hatagirea, Fritillaria cirrohosa.,* and *Paris polyphylla* are monocotyledons and other remaining MPs are dicotyledons.

MPs Distribution in Phytogeographical regions

The distribution of the prioritized MPs in different phytogeographical regions and the elevation gradients are given in Table 2.

Among the 33 MPs prioritized, 24 species (1. *Aconitum lethale*; 2. *Acorus calamus*; 3. *Asparagus racemosus*; 4. *Bergenia ciliata*; 5. *Cinnamomum glaucescens*; 6. *Cinnamomum tamala*; 7. *Dactylorhiza hatagirea*; 8. *Dioscorea deltoidea*; 9. *Fritillaria cirrohosa*; 10. *Gaultheria fragrantissima*; 11. *Juglans regia*; 12. Lichens; 13. *Morchella* spp.; 14. *Nardostachys jatamansi*; 15. *Neopicrorhiza scrophulariiflora*; 16.*Ophiocordyceps sinensis*; 17. *Phyllanthus emblica*; 18. *Piper longum*; 19. *Rheum australe*; 20. *Sapindus mukorossi*; 21. *Sinopodophyllum hexandrum*; 22. *Taxus wallichiana*; 23. *Valeriana jatamansii* and 24. *Zanthoxylum armatum*) accounting the 73 % of the total prioritized MPs are well distributed from West Nepal to East Nepal, one species *Tagetes minuta*, accounting

Table 2. Life form, phytogeographic distribution and elevational gradients of prioritized MPs of Nepal.

SN	Name of Plant	Habit group	Altitudinal distribution (m)	Region	Reference for altitude	
					Minimum	Maximum
1.	***Aconitum heterophyllum***	Herb	3200 -3700	C	Press *et al.* 2000	Press *et al*.,2000
2.	***Aconitum lethale***	Herb	1800 – 4300	WCE	Press *et al.* 2000	Ghimire *et al.* 2008
3.	***Acorus calamus***	Herb	100 - 2300	WCE	Press *et al.* 2000	Press *et al.* 2000
4.	***Asparagus racemosus***	Herb	150 – 2740	WCE	DPR 2011	Ghimire *et al.* 2008
5.	***Azadirachta indica***	Tree	Upto 1500	CE	-	ANSAB 2003
6.	***Bergenia ciliata***	Herb	1200 – 3600	WCE	ANSAB 2003	Rajbhandary & Ranjitkar 2006
7.	***Cinnamomum glaucescens***	Tree	450 -2500	WCE	ANSAB 2003	Press *et al.* 2000
8.	***Cinnamomum tamala***	Tree	450 – 2500	WCE	Press *et al.* 2000	DPR 2011
9	***Curculigo orchioides***	Herb	500	CE		Press *et al.* 2000
10.	***Dactylorhiza hatagirea***	Herb	2800 – 4200	WCE	DPR 2011	Ghimire *et al*. 2008
11.	***Dioscorea deltoidea***	Climber	450 – 3100	WCE	Joshi *et al*. 2017	Joshi *et al.* 2017
12.	***Fritillaria cirrohosa***	Herb	3000 - 4600	WCE	Ghimire *et al*. 2008	Ghimire *et al.* 2008
13.	***Gaultheria fragrantissima***	Shrub	1200 – 2700	WCE	ANSAB 2003	ANSAB 2003
14.	***Juglans regia***	Tree	1200 – 3000	WCE	DPR 2011	ANSAB 2003
15.	Lichens spp.	Lichen	100 – 7406	WCE	ANSAB 2003	DPR 2011
16.	***Morchella*** spp.	Mushroom	2000 – 3500	WCE	DPR 2011	DPR 2011
17.	***Nardostachys jatamansi***	Herb	3000 – 5000	WCE	DPR 2011	Joshi *et al*. 2017
18.	***Neopicrorhiza scrophulariiflora***	Herb	3000 – 4800	WCE	ANSAB 2003	DPR 2011
19.	***Ophiocordyceps sinensis***	Entomopathogenic Parasite	3540 – 5050	WCE	Devkota 2010	Devkota 2010
20.	***Paris polyphylla***	Herb	1800 - 3500	CE	Ghimire *et al.* 2008	Ghimire *et al.* 2008
21.	***Phyllanthus emblica***	Tree	150 – 1600	WCE	Press *et al.* 2000	Rajbhandary & Ranjitkar 2006
22.	***Piper longum***	Climber	200 -1000	WCE	DPR 2011	ANSAB 2003
23.	***Rauvolfia serpentina***	Shrub	100 – 900	CE	Joshi *et al.* 2017	Joshi *et al.* 2017
24.	***Rheum australe***	Herb	2750 – 4200	WCE	Ghimire *et al*. 2008	Press *et al*. 2000
25.	***Rubia manjith***	Climber	1200 – 3150	CE	Press *et al.* 2000	Ghimire *et al.* 2008
26.	***Sapindus mukorossi***	Tree	1000– 1500	WCE	DPR 2011	DPR 2011
27.	***Sinopodophyllum hexandrum***	Herb	2400 -4500	WCE	DPR 2011	DPR 2011
28.	***Swertia chirayita***	Herb	1200 – 3000	CE	DPR 2011	DPR 2011
29.	***Tagetes minuta***	Herb	1250 – 2500	WC	DPR 2011	DPR 2011
30.	***Taxus wallichiana***	Tree	1800 – 4400	WCE	DPR 2011	Triphathi 2015
31.	***Tinospora sinensis***	Climber	300 – 1500	CE	DPR 2011	DPR 2011
32.	***Valeriana jatamansii***	Herb	1500 – 3600	WCE	DPR 2011	DPR 2011
33.	***Zanthoxylum armatum***	Tree	900 – 2500	WCE	DPR 2011	DPR 2011

Note: W = West Nepal; C = Central Nepal; E = East Nepal; Min = Minimum; Max = Maximum.

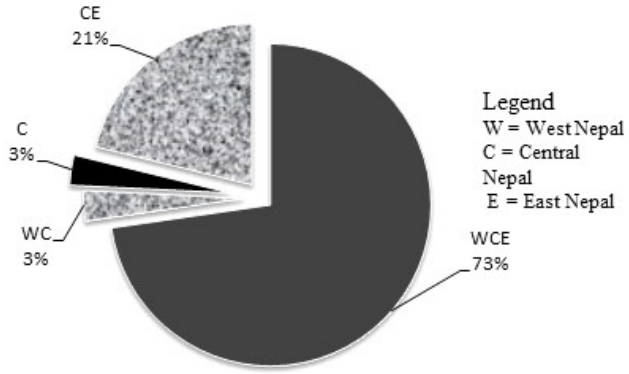

Figure 2. Distribution of prioritized MPs in Phytographical regions

3%, is confined only in West and Central Nepal and one species *Aconitum heterophyllum* accounting 3%, is confined only in Central Nepal and seven species (1. *Azadirachta indica*; *2. Curculigo orchioides*; 3. *Paris polyphylla*; 4. *Rauvolfia serpentina*; 5. *Rubia manjith*; 6. *Swertia chirayita* and 7. *Tinospora sinensis*) accounting the 21 % of the total prioritized MPs are distributed in Central and East Nepal (Figure 2).

All the 13 MPs prioritized for agro-technology development are well distributed in Central and East Nepal. Among the 13 MPs, 5 MPs viz. *Curculigo orchioides*, *Paris polyphylla*, *Rauvolfia serpentina*, *Swertia chirayita* and *Tinospora sinensis* are absent from West Nepal.

The analysis thus revealed that Central Nepal harbours all 33 GoN prioritized MPs followed by East Nepal with 31 species and West Nepal with 25 species (Table 1). In Nepal, the intensity of rainfall decreases gradually from east to west and increases from plain to certain elevation between 800 to 2000 m to north and then again decreases (Acharya *et al.* 2009). More prioritized MPs being confined to Central and East Nepal could possibly due to this pattern of precipitation. Dryness of west Nepal could possibly related with less number of prioritized MPs in this region.

MPs distribution in Bioclimatic Zones and elevation gradients

Among the prioritized 33 MPs, maximum number of 19 prioritized MPs are present in lower temperate region followed by 18 MPs in upper subtropical region, 17 in lower subtropical region, 16 each in upper temperate and lower subalpine region, 13 in upper subalpine, 12 in upper and lower tropical region, 10 in lower alpine region, 5 in upper alpine region and 2 species in above the alpine region (Figure 3). The lists of prioritized MPs distributed in different bioclimatic zones are as follow:

Tropical zone

Among the 33 MPs prioritized, 12 species present in lower tropical zone are: 1. *Acorus calamus*; 2. *Asparagus racemosus*; 3. *Azadirachta indica*; 4. *Cinnamomum glaucescens*; 5. *Cinnamomum tamala* ; 6. *Curculigo orchioides*; 7. *Dioscorea deltoidea*; 8. Lichens; 9. *Phyllanthus emblica*; 10. *Piper longum*; 11. *Rauvolfia serpentina*; and 12. *Tinospora sinensis*.

Among the 33 MPs prioritized, 13 species present in upper tropical zone are: 1. *Acorus calamus*; 2. *Asparagus racemosus*; 3. *Azadirachta indica*; 4. *Cinnamomum glaucescens*; 5. *Cinnamomum tamala*; 6. *Dioscorea deltoidea*; 7. Lichens; 8. *Phyllanthus emblica*; 9. *Piper longum*; 10. *Rauvolfia serpentina*; 11. *Sapindus mukorossi*; 12. *Tinospora sinensis* and 13. *Zanthoxylum armatum*.

Altogether 14 prioritized MPs are found in tropical zone. Within those MPs *Curculigo orchioides* is distributed only in lower tropical zone and *Sapindus mukorossi* is present only in upper tropical zone.

Among the 14 prioritized MPs present in this zone, 4 MPs (*Curculigo orchioides*, *Piper longum*, *Rauvolfia serpentina*; and *Tinospora sinensis*) are prioritized for agro-technology development.

Subtropical zone

Among the 33 MPs prioritized, 17 species present in lower subtropical zone are: 1. *Acorus calamus*; 2. *Asparagus racemosus*; 3. *Azadirachta indica*; 4. *Bergenia ciliata*; 5. *Cinnamomum glaucescens*; 6. *Cinnamomum tamala*; 7. *Dioscorea deltoidea*; 8.

Gaultheria fragrantissima; 9. *Juglans regia*; 10. Lichens; 11. *Phyllanthus emblica*; 12. *Rubia manjith*; 13. *Sapindus mukorossi*; 14. *Swertia chirayita*; 15. *Tagetes minuta,* 16. *Tinospora sinensis* and 17. *Zanthoxylum armatum*.

Among the 33 MPs prioritized, 18 species present in upper sub-tropical zone are: lower tropical zone are: 1. *Aconitum lethale*; 2. *Acorus calamus*; 3. *Asparagus racemosus*; 4. *Bergenia ciliata*; 5. *Cinnamomum glaucescens*; 6. *Cinnamomum tamala*; 7. *Dioscorea deltoidea*; 8. *Gaultheria fragrantissima*; 9. *Juglans regia*; 10. Lichens; 11. *Paris polyphylla*; 12. *Phyllanthus emblica*; 13. *Rubia manjith*; 14. *Swertia chirayita*; 15. *Tagetes minuta* Linn.; 16. *Taxus wallichiana*; 17. *Valeriana jatamansii* and 18. *Zanthoxylum armatum*.

Altogether 21 species of prioritized MPs are found in subtropical zone. Within those MPs *Azadirachta indica*, *Sapindus mukorossi* and *Tinospora sinensis* are distributed up to lower subtropical region and MPs *Aconitum lethale*, *Taxus wallichiana* and *Valeriana jatamansii* are distributed from only upper subtropical zone.

Among the 21 prioritized MPs present in this zone, 4 MPs [*Paris polyphylla, Swertia chirayita*, *Taxus wallichiana* and *Tinospora sinensis*] are prioritized for agro-technology development.

Temperate zone

Among the 33 MPs prioritized, 19 species present in lower temperate zone are: 1. *Aconitum lethale*;, 2. *Acorus calamus*; 3. *Asparagus racemosus;* 4. *Bergenia ciliata*; 5. *Cinnamomum glaucescens*; 6. *Cinnamomum tamala*; 7. *Dioscorea deltoidea*; 8. *Gaultheria fragrantissima*; 9. *Juglans regia*; 10. Lichens; 11. *Morchella* spp.; 12. *Paris polyphylla*; 13. *Rubia manjith*; 14.*Sinopodophyllum hexandrum*; 15. *Swertia chirayita*; 16. *Tagetes minuta*; 17. *Taxus wallichiana*; 18. *Valeriana jatamansii* and 19. *Zanthoxylum armatum*.

Among the 33 MPs prioritized, 16 species present in upper temperate zone are: 1. *Aconitum lethale*; 2. *Asparagus racemosus*; 3. *Bergenia ciliata*; 4. *Dactylorhiza hatagirea*; 5. *Dioscorea deltoidea*; 6. *Gaultheria fragrantissima*; 7. *Juglans regia*; 8. Lichens; 9. *Morchella* spp.; 10. *Paris polyphylla*; 11. *Rheum australe*; 12. *Rubia manjith;* 13. *Sinopodophyllum hexandrum*; 14. *Swertia chirayita*; 15. *Taxus wallichiana* and 16. *Valeriana jatamansii*.

Altogether 21 species of prioritized MPs are thus present in temperate zone. Among them MPs *Acorus calamus*, *Cinnamomum glaucescens*, *Cinnamomum tamala*, *Tagetes minuta* and *Zanthoxylum armatum* are distributed up to the lower temperate region only and MPs *Dactylorhiza hatagirea* and *Rheum australe* are distributed only from upper temperate zone.

Among the 21 prioritized MPs present in this zone, 5 MPs [*Dactylorhiza hatagirea*, *Morchella* spp., *Paris polyphylla, Swertia chirayita* and *Taxus wallichiana*] are prioritized for agro-technology development.

Subalpine zone

Among the 33 MPs prioritized, 16 species present in lower subalpine zone are: 1. *Aconitum heterophyllum*; 2. *Aconitum lethale*; 3. *Bergenia ciliata*; 4.. *Dactylorhiza hatagirea*; 5. *Dioscorea deltoidea*; 6. *Fritillaria cirrohosa*; 7. Lichens; 8. *Morchella* spp.; 9. *Nardostachys jatamansi*; 10. *Neopicrorhiza scrophulariiflora*; 11. *Paris polyphylla*; 12. *Rheum australe*; 13. *Rubia manjith*; 14. *Sinopodophyllum hexandrum*; 15. *Taxus wallichiana* and 16. *Valeriana jatamansii*.

Among the 33 MPs prioritized, 13 species present in upper subalpine zone are: 1. *Aconitum heterophyllum*; 2. *Aconitum lethale;* 3. *Bergenia ciliata*; 4. *Dactylorhiza hatagirea*; 5. *Fritillaria cirrohosa*; 6. Lichens; 7. *Nardostachys jatamansi*; 8. *Neopicrorhiza scrophulariiflora*; 9. *Ophiocordyceps sinensis*; 10. *Rheum australe*; 11. *Sinopodophyllum hexandrum*; 12 *Taxus wallichiana* and 13. *Valeriana jatamansii*.

Altogether 17 prioritized MPs are present in subalpine zone. Among those prioritized MPs *Dioscorea deltoidea*, *Morchella* spp, *Paris polyphylla* and *Rubia manjith* have the upper limit up to the lower subalpine region only and one Medicinal Plant *Ophiocordyceps sinensis* starts its distribution from the upper subalpine zone only.

Among the 17 prioritized MPs present in this zone, 8 MPs [*Dactylorhiza hatagirea*, *Fritillaria cirrohosa*, *Morchella* spp., *Nardostachys jatamansi*, *Neopicrorhiza scrophulariiflora*, *Ophiocordyceps sinensis*, *Paris polyphylla* and *Taxus wallichiana*] are prioritized for agro-technology development.

Alpine zone

Among the 33 MPs prioritized, 10 species present in lower alpine zone are: 1. *Aconitum lethale* Griff.; 2. *Dactylorhiza hatagirea*; 3. *Fritillaria cirrohosa*; . 4. Lichens; 5. *Nardostachys jatamansi*; 6. *Neopicrorhiza scrophulariiflora*; 7. *Ophiocordyceps sinensis*; 8. *Rheum australe*; 9. *Sinopodophyllum hexandrum*; and 10. *Taxus wallichiana*.

Among the 33 MPs prioritized, 5 species present in upper alpine zone are: 1. *Fritillaria cirrohosa*; 2. Lichens spp.; 3. *Nardostachys jatamansi*; 4. *Neopicrorhiza scrophulariiflor*; and 5. *Ophiocordyceps sinensis*.

Altogether 10 prioritized MPs are present in alpine zone. Among those them 5 MPs *Aconitum lethale*, *Dactylorhiza hatagirea*, .*Rheum australe*, *Sinopodophyllum hexandrum* and *Taxus wallichiana* are found up to the lower alpine zone and only 5 MPs *Fritillaria cirrohosa*, Lichens, *Nardostachys jatamansi*, *Neopicrorhiza scrophulariiflora* and *Ophiocordyceps sinensis* are found up to the upper alpine zone.

Among the 10 prioritized MPs present in this zone, 6 MPs [*Dactylorhiza hatagirea*, *Fritillaria cirrohosa*, *Nardostachys jatamansi*, *Neopicrorhiza scrophulariiflora*, *Ophiocordyceps sinensis* and *Taxus wallichiana*] are prioritized for agro-technology development.

Above Alpine zone

Only two prioritized MPs, lichen species and *Ophiocordyceps sinensis* are reported from above alpine zone. *Lecanora polytropa* lichen is reported from about 7406 m (DPR 2011). *Ophiocordyceps sinensis* (Yarsagumba) is reported up to 5050 m which is almost up to alpine zone only.

The analysis thus revealed that the MPs prioritized gradually increased in number from lower tropical zone with 12 species and peaked at the lower temperate zone with the maximum of 19 MPs and again decreased gradually with the higher elevation showing the humped relationship with the bioclimatic zones (Figure 3). However the subalpine zone harbours more MPs prioritized for agro-technology development than other bioclimatic zones.

The species like *Aconitum heterophyllum* and *Curculigo orchioides* have the narrow elevational gradient of about 500 m only while the species like *Dioscorea deltoidea* has the wide elevational gradient of about 2650 m (Table 1). More over the tropical species such as *Curculigo orchioides*, *Piper longum*, *Rauvolfia serpentina* are limited only to the tropical

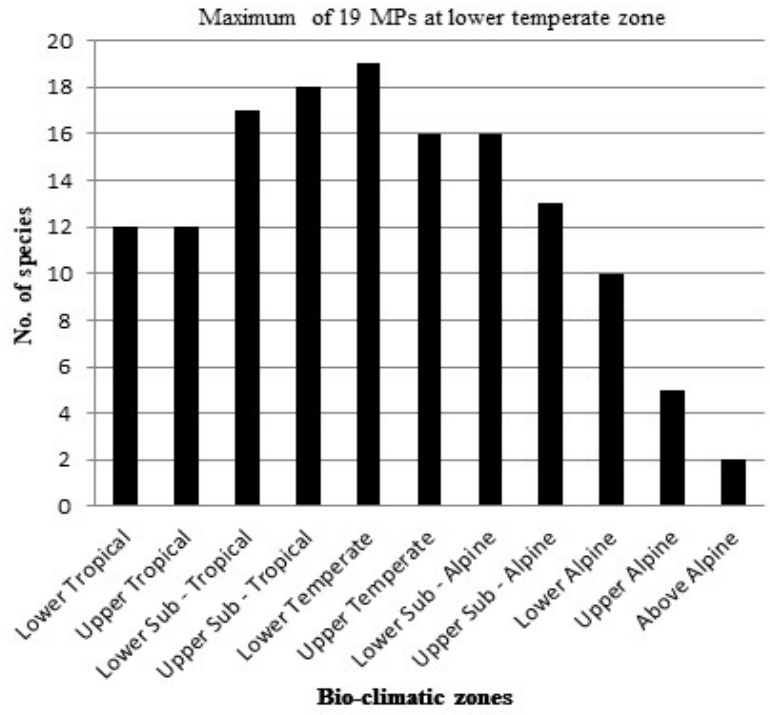

Figure 3. Prioritized MPs in Bio-climatic Zones

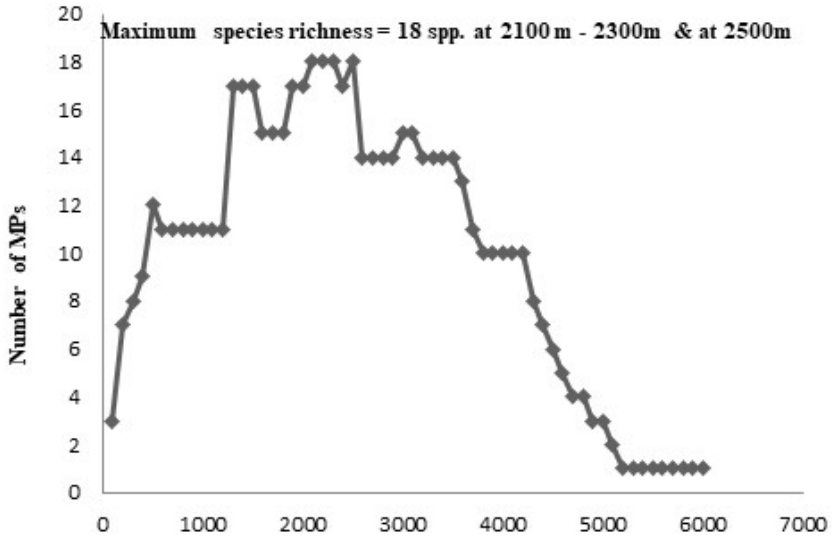

Figure 4. Relationship between elevation and prioritized MPs.

zone (Table 2). Though the lichens have the maximum elevation gradient up to 7406 m for the species *Lecanora polytropa* (DPR 2011) but the species like *Parmelia nepalensis* and *Ramalina subcomplanata* are reported to have the elevation range from 100 m to 3000 m (ANSAB 2003). In general, the temperate zone represents the maximum lichen richness (Baniya *et al.* 2010).

Species richness

The maximum number of 18 prioritized MPs are distributed from 2001 m to 2300 m (at 2100 m -2300 m) and from 2401 m to 2500 m (at 2500 m) at lower temperate zone followed by the 17 prioritized MPs at subtropical zone from 1201 m to 1500 m (at 1300 m – 1500 m) and from 1801 m to 2000 m (at 1900 m to 2000 m) and at 2400 (Figure 4). However, the species richness for the 60 species of MPs of various risk categories was observed at lower subtropical zone at elevation of 1100 m (Acharya *et al.* 2009). Moreover the species richness was observed at 1000 m for the medicinal vascular plants (Rokaya *et al.* 2012). The present result on the species richness on the GoN prioritized MPs is in contrary to the previous results for MPs. Similarly, the foliose lichens are reported to have their maximum richness between 2400 – 2500 m (Baniya *et al.* 2010). The present analysis thus revealed that the high value MPs that have the potentiality for the economic development of nation are peaked at the lower temperate zone. More prioritized MPs at lower temperate and upper subtropical zones could possibly due to optimum environmental conditions, edaphic factors and less anthropogenic disturbance.

Conservation Status

Some of the prioritized MPs are also under the risk category of IUCN. Among them *Aconitum heterophyllum* and *Taxus wallichiana* are endangered and *Nardostachys jatamansi* is critically endangered (http://www.iucnredlist.org/search).

Among the prioritized MPs *Dactylorhiza hatagirea*; *Dioscorea deltoidea*, *Nardostachys jatamansi*, *Sinopodophyllum hexandrum*, *Rauvolfia serpentina* and *Taxus wallichiana* are under the CITES Appendix II (Joshi *et al.* 2017).

GoN under the Forest Act 1993 has protected some of the MPs which also includes some MPs prioritized by GoN (GoN 2001, 2003). Those include MPs *Dactylorhiza hatagirea*, *Neopicrorhiza scrophulariiflora*, *Juglans regia* (Bark) under category I (Plants banned for collection, use, sale, distribution transportation and export); *Cinnamomum glaucescens*, *Nardostachys jatamansi*, *Rauvolfia serpentina*, *Taxus wallichiana*, *Valeriana jatamansii* under category II (Plants banned for export outside country in unprocessed form) and *Juglans regia* under Category III (Plants banned for transportation, export and felling for commercial purpose).

CONCLUSION

The present study revealed that all GoN prioritized MPs are distributed in Central Nepal followed by the East Nepal with 31 prioritized MPs and 25 MPs in West Nepal. Among the 33 prioritized MPs 19 MPs are present in lower temperate zone followed by 18 MPs at upper subtropical zone indicating that the upper subtropical to lower temperate zones are the most suitable habitats for the prioritized MPs. The maximum prioritized MPs richness is found at the elevation of 2100 – 2300 m and at 2500 m which is in contrary to 1100 m and 1000 m revealed by Acharya *et al.* (2009) and Rokaya *et al*. (2012) respectively analyzed for the MPs of Nepal. It probably indicates the MPs with potentialities for development of the nation are more at the higher elevation than on the lower elevations. Knowledge about the distribution patterns on horizontal and vertical gradients are crucial for the conservation and management as well as the cultivation of the MPs that could contribute to the economic development of the nation. It is thus envisaged the present study will help in conservation practices as well as in research for developing the Good Agriculture and Collection Practices (GACP) of GoN prioritized MPs.

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