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SPATIAL DISTRIBUTION OF MEDICINAL PLANTS USING MaxEnt MODELING TECHNOLOGY: A CASE STUDY OF LILOWNAI VALLEY, DISTRICT SHANGLA, PAKISTAN

IRFAN ULLAH,[1] SABEEQA USMAN MALIK[1*], NAVEED AHMAD[2], ZUHAIR HASNAIN[1] AND MUHAMMAD TAYYAB[1]

[1]Department of Forestry and Range Mgt. PMAS-Arid Agriculture University Rawalpindi, 46300, Pakistan,
[2]Center of Plant Biodiversity, University of Peshawar, Peshawar, 25120, Pakistan,
[3]Department of Agronomy. PMAS-Arid Agriculture University Rawalpindi, 46300, Pakistan
**Corresponding author: sabeeqa.usman@uaar.edu.pk*

Abstract

Medicinal plants are important in provisioning ecosystem service, and they are utilized as a whole or as components to cure illness as they contain useful chemical substances. The current study was conducted to find spatial distribution and ethnoecological knowledge of medicinal plants in Lilowani Valley, Shangla, Pakistan. Spatial distribution of medicinal plants was mapped through the **MaxEnt** model. During the study, 28 medicinal plants belonging to 23 different families were identified and collected. Results showed that the highest value of relative frequency citation (RFC) was found as 0.92 for *Berberis lycium* and *Dryopteris odontoloma* while the lowest recorded RFC is for *Verbascum thapsus* which is 0.05. Use Value recorded varied from 0.96-0.08. Important Value Index (IVI) was high for *Dryopteris odontoloma* i.e. 26.6 while the lowest was *Asparagus racemosus* i.e., 1.39. The linear regression model showed that R^2 values range from 0.1 to 0.97 for different medicinal plants. The highest correlation (R^2=0.97) was observed between the density of *Valeriana jatamansi* and environmental variables, followed by *Skimmia laurel*, *Gentiana moorcroftiana* and *Micromera biflora* with R^2 of 0.96, 0.95, and 0.86 respectively. Most of the medicinal plants showed a high correlation between 0.97 and 0.62. The most prominent climatic factor was BIO9 (Mean temperature of driest quarter/◦C) which contributed towards spatial distribution of 06 out of 10 species, followed by BIO19 (Precipitation of coldest quarter/mm) and BIO11 (Mean temperature of coldest quarter/◦C) with the highest values of 0.95 and 0.92 for *Trillium govanianum* and *Aconitum ferox* respectively.

Key words: Medicinal plants; Ecosystem services; NTFPs.

Introduction

Forests provide both goods (food, timber, and medicinal plants), and services (such as air and water purification, flood control, waste decomposition, and pollination). These services are grouped into provisioning, supporting, regulating, and cultural categories. Medicinal plants are the provisioning ecosystem service that is instantly related to human health. They serve as the primary source of medicine for preventing diseases in remote areas (Caballero-Serrano *et al.,* 2019). Floral resources offer ecosystem services (ES) that go more than the supply of food, medicine, and habitat, some of which are indirectly poorly managed, underestimated, and unappreciated (Nowok-Olejnik & Mocior, 2022).

Non-timber Forest Products (NTFPs) are provisioning ecosystem services that are significant in rural livelihoods, poverty reduction, biodiversity protection, and rural economic growth (Reta *et al.,* 2020). They can scale down the periodic malnourishment and food insecurity local communities (Shrestha *et al.,* 2020). In traditional forest communities, NTFPs are used for both sustenance and as a primary source of revenue (Sahoo *et al.,* 2020). Several NTFPs have cultural importance while others have medical significance and thus contribute to community health and well-being. NTFPs provide medicine, energy, nutrition, and an additional source of revenue (Angelsen & Wunder, 2003). In developing countries, it is believed that NTFPs may enhance the livelihood of the rural community (Kar & Jacobson, 2012). Millions of families throughout the globe rely significantly on NTFPs for their livelihoods, and almost 80% of communities in poor nations utilize NTFPs for pharmaceutical and dietary requirements (FAO, 2020). Furthermore, NTFPs contribute to rural and urban communities to fulfill their requirements and monetary income (Wahlén, 2017; Nguyen *et al.,* 2021).

Since the dawn of man's health, flora has been used as a source of medication. This information is transferred verbally from elders to youngsters (Shinwari & Qaisar, 2011; Ajaib *et al.,*2021). From the beginning, humans have utilized a range of natural materials as the foundation for medications. Herbs have always been essential to health and a healthy society. Through experimentation, one became familiar with the application of medicinal herbs, their qualities, and how to pass them on to upcoming populations (Shaheen & Shinwari, 2012). This essential knowledge of medicinal herb applications must be preserved because it is not always reliable for older generations to transmit knowledge to younger generations (Shinwari *et al.,* 2012). The process of revising and refining resulted in the development of a plant book describing drugs, chemicals, and medicinal preparations (Balunas & Kinghorn, 2005).

Conventional treatments are increasingly being used to treat various illnesses (Khan *et al.,* 2019). From the beginning, especially in faraway places, people have relied exclusively on natural solutions for all kinds of medical requirements. Medicinal plants are utilized for medication, and the public also uses the plant's parts as supplemental goods for all types of medical needs (Sarwat *et al.,* 2012). Approximately 80% of people in emerging nations still use plant-based medicines for their treatment instead of modern drugs (Tareen *et al.,* 2016). Both in advance and in developing countries people rely on herbal remedies for treatment (Gul *et al.*, 2012). Particularly in traditional medicine, medicinal herbs are a significant source of drugs that are useful for the treatment of a number of diseases (Alqethami & Aldhebiani, 2021). Traditional medicine makes use of a variety of plant components, including stems, barks, flowers, fruits, rhizomes, leaves, resins, seeds, and roots (El-Ghazouani *et al.*, 2021). The therapeutic efficacy of these plants is due to distinct chemical compounds found in various plant sections that have a particular physiological impact on people (Radha *et al.*, 2021).

Pakistan holds a special place among all the countries in the developing world because it has a wide variety of medicinal plants because of varying acceptance and climatic variables (Shuaib *et al.*, 2019). Pakistan has valuable biodiversity that is divided into nine important ecological zones. All of these areas are occupied with valuable medicinal plants (Abbasi *et al.*, 2010). It has been revealed that around 12% of Pakistan's tracheophytes are used for medicinal purposes (Ali *et al.*, 2019b). The northern and western regions of Pakistan include a variety of medicinal plants (Ali & Qaiser, 2009). Numerous plants in Pakistan have medicinal value and are used to treat variety of illnesses. In 1950, traditional medicine was the primary form of healthcare for 87% of Pakistan's population (Ali *et al.*, 2019a).

Medicinal Plant is a major natural resource and an important provisioning ecosystem service playing a vital role in the maintenance of ecosystems. These medicinal plants are under great threat due to the over-exploitation by the local communities for their domestic use and economic purposes (Muhammad *et al.*,2023). Due to this most of the species of medicinal plants become threatened, and some become extinct. There is very limited research work and research-based data on this valuable natural resource (Medicinal Plants) in the given research site. So, there was a dire need to conduct research-based work on the aforementioned problem to find the potential of the medicinal plants in the area. This research has three objectives; to assess the status and distribution of medicinal plants in the study site, to explore the role of medicinal plants on the socioeconomic condition of the local population, and to identify the major threats to medicinal plants and recommend conservation strategies.

Material and Methods

The study area: Lilownai is a valley in the Shangla district. The total area of the valley is 12281 hectares, consisting of various villages. The study area is situated between 34.9548°N Latitude and 72.6432°E Longitude. The site is confined to the north by Pirkhana, in the east by Damorai and Shahpur, in the west by Swat district, and in the south by Alpurai. The study area map is shown in Fig. 1 while the climatic variables of the study area are described in Fig. 2. The study area consists of valleys in the middle of the hillocks and is bounded by high mountains covered by forests. The area lies on elevation and has dense and open gymnosperm forests. The altitude of Union Council is 1450-3400m.

Field sampling and identification: Before sampling, the study area was divided into two strata based on elevation, slope, temperature, and precipitation with the help of ArcGIS. Then based on these strata 40 and 20 sample plots were taken in stratum I and stratum II respectively.

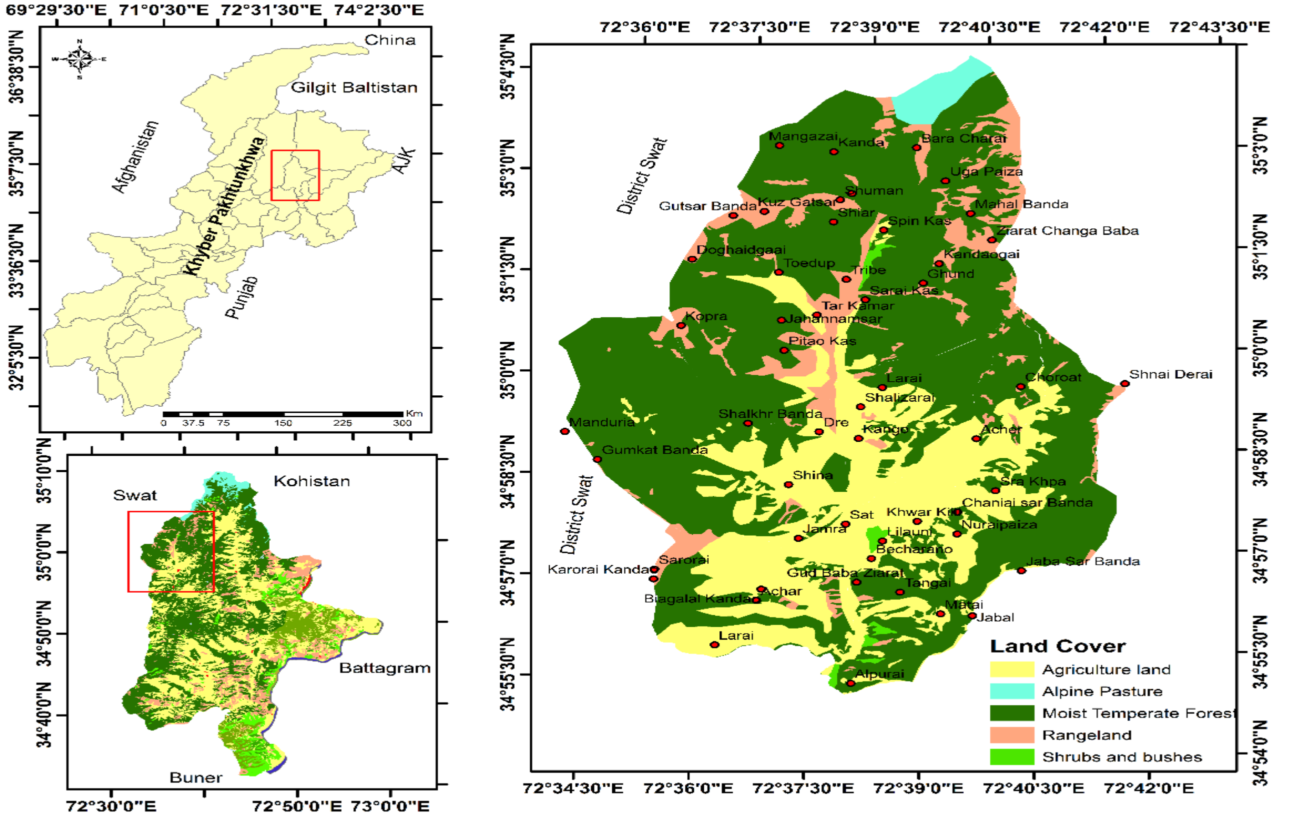

Fig. 1. Map of the Lilownai, part of Alpurai Forest division.

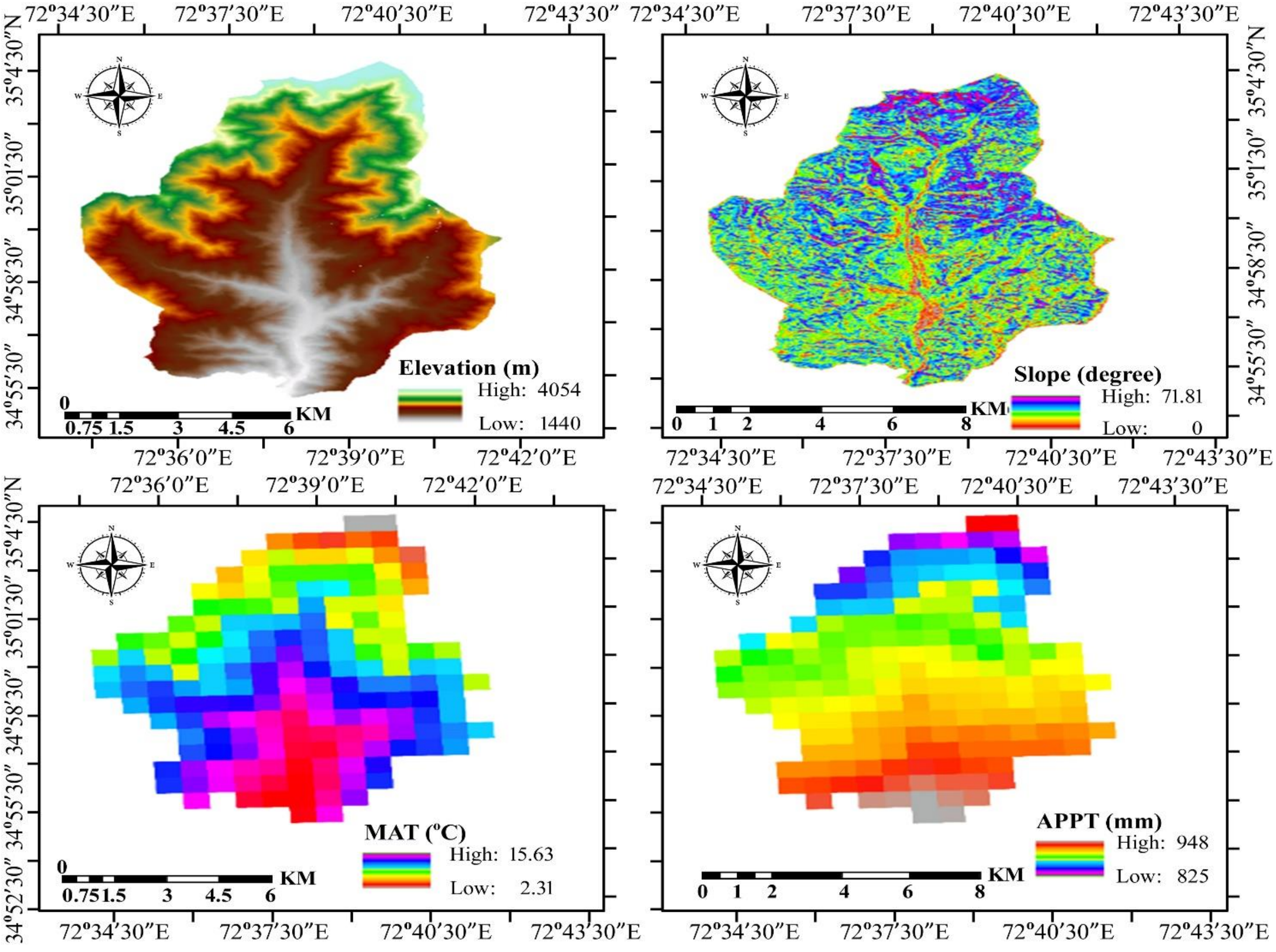

Fig. 2. Maps showing climatic and topographic factors.

During the field trip, data was collected from 60 sample plots and the size of each sample plot was 10x10 meters for trees and 2x2 meters for shrubs and herbs with random layout in the field. Plant specimens were collected and labeled with native names and related data were gathered on site. For identification and taxonomic confirmation, specimens were pressed, dried, mounted on herbarium sheets, and recognized with the assistance of accessible literature (Shuaib *et al.*, 2021). The International Plant Names Index was used for accurate botanical names and authorship. Moreover, plant specimens were also matched with specimens present in Quaid-e-Azam University, Islamabad. Different attributes were calculated such as density, frequency, RFC, UV and IVI for medicinal plant data.

Computation of topographic, climatic variables, and spectral index: The SRTM 30m based on the Digital Elevation Model (DEM) was obtained from USGS, data regarding climate was acquired from the website of Global Climate Data, and demographic data was collected in the field. The factors regarding elevation and slope were retrieved from the Digital Elevation Model. ArcGIS (10.3) was used to extract slope and elevation. Selections of climatic and topographic characteristics were founded on past literature in Table 2.

Spatial distribution of medicinal plants: To find the distribution of medicinal plants **MaxEnt** model was used. **MaxEnt** is a highly accurate distribution model for simulating outcomes, and its success depends on selecting appropriate sample distribution for simulating outcomes, and its success depends on selecting appropriate sample distribution data, using ecologically relevant environmental factors, and optimizing model parameters (Elith & Leathwick, 2009; Merow *et al.*, 2013). In this study, eleven (11) environmental variables were selected, including climatic and topographic factors, to use as predictor variables in our model construction (Table 3). The variables encompass elevation and 10 bioclimatic factors from the WorldClim dataset (version 2.1), specifically denoted as Bio1 to Bio19.

Table 1. Distribution of strata I and strata II.

Stratum	Area (ha)	Elevation (m)	Temperature (°C)	Precipitation (mm)	Slope (Degree)	Number of plots (n)
Stratum I (E1T1P1)	8348	1450-2650	9.0-15.5	888-948	0-53	40
Stratum II (E2T2P2)	3933	2651-3850	2.3-8.9	825-887	20-71.6	20

Table 2. Range of topographic and climatic factors.

S. No.	Variables	Unit	Source
1.	Elevation	Meter	Yang *et al.*, 2013
2.	Slope	Degree	Yang *et al.*, 2013
3.	Annual mean temperature	Celsius (◦C)	Hijmans *et al.*, 2005
4.	Annual precipitation	Millimeter	Hijmans *et al.*, 2005

Table 3. Environmental variables.

Variable	Description	Type
BIO1	Annual mean air temperature/◦C	Climatic
BIO4	Temperature seasonality	Climatic
BIO7	Temperature annual range/◦C	Climatic
BIO9	Mean temperature of driest quarter/◦C	Climatic
BIO10	Mean temperature of warmest quarter/◦C	Climatic
BIO11	Mean temperature of coldest quarter/◦C	Climatic
BIO12	Annual precipitation/mm	Climatic.
BIO15	Precipitation seasonality	Climatic
BIO18	Precipitation of warmest quarter/mm	Climatic
BIO19	Precipitation of coldest quarter/mm	Climatic
DEM	Elevation/m	Topographic

Statistical analysis

Statistical analysis comprises of multiple linear regression and correlation. Dependent variables include medicinal plant density which will be used separately against independent variables (climatic and topographic).

Results

Identification of medicinal plants: About 28 medicinal plants were collected belonging to 23 different families (Table 4). The collection was done based on four climatic and topographic factors i.e., temperature, precipitation, elevation, and slope. The most abundant family found was lamiaceae (3 species) and polygonaceae (3 species), followed by asteraceae (2 species) shown in Fig. 3. Parts of the plant used are whole plant 25%, followed by leaves 21% and rhizome 21%. (Fig. 4). Out of 28 species, 79% were herbs, followed by 21% shrubs while no medicinal tree was reported during the study (Fig. 5). Life span of the medicinal plants was recorded as perennial 72%, annual 19%, and biennial 9% (Fig. 5). The modes of use of decoction, extraction and infusion were dominant (43%), followed by powder (36%) shown in Fig. 6. Before fixing and mounting the specimens on a herbarium sheet, they were pressed and dried. The specimens were identified at Quaid-e-Azam University, Islamabad.

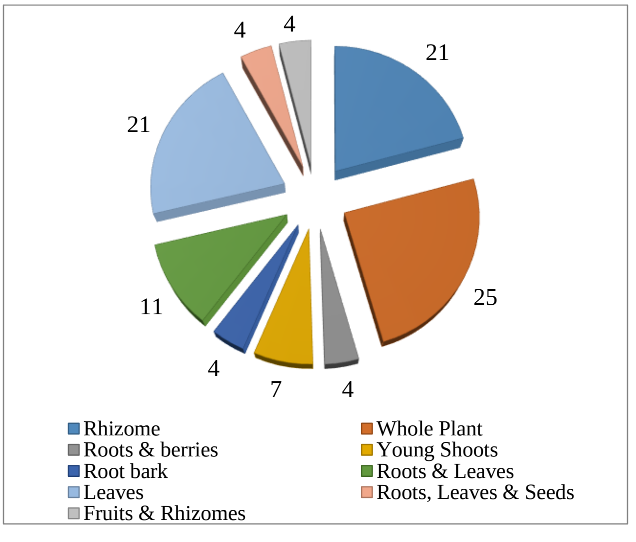

Fig. 3. Number of species per family.

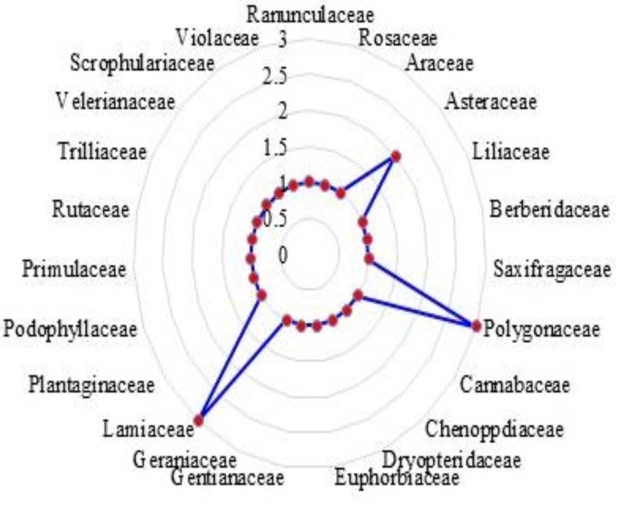

Fig. 4. Parts used of plant.

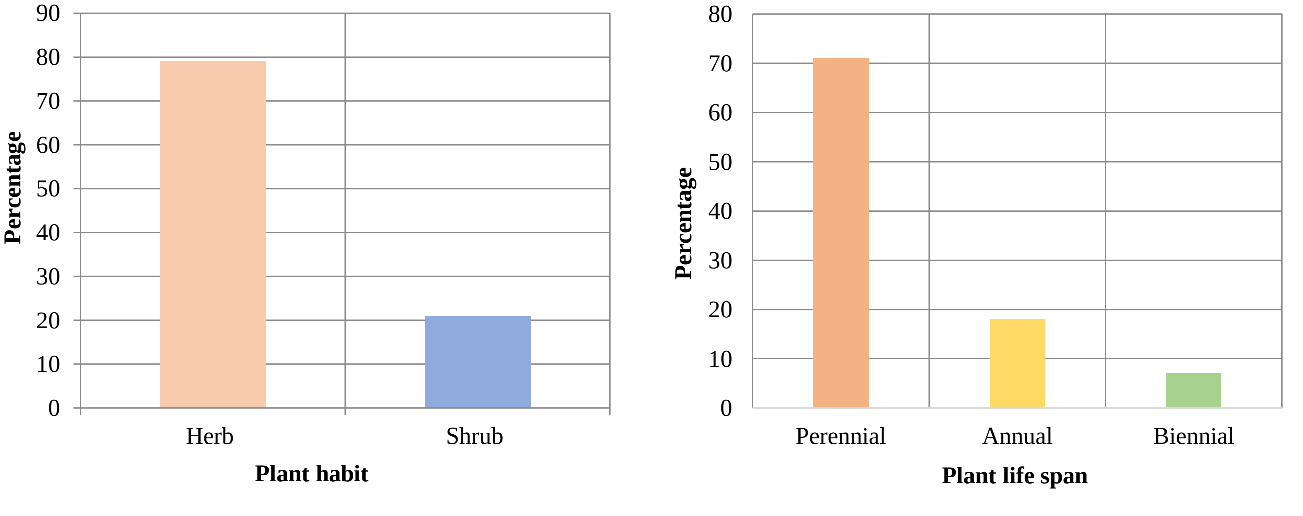

Fig. 5. Habit and life span of medicinal plants.

Table 4. Plant species with their local names, parts used, and traditional medicinal uses.

Species name	Local name	Family name	Habit	Life span	Part used	Mode of use	Local uses
Aconitum ferox	Zaharmohra	Ranunculaceae	Herb	Perennial	Rhizome	Powder	Highly poisonous, used for arthritis in minute amounts after boiling
Actaea spicata L.	Benaki	Rosaceae	Herb	Perennial	Roots & berries	Boiled	Used as a sedative and for joint pain
Arisaema triphyllum L.	Marjarai	Araceae	Herb	Perennial	Whole Plant	Grind and Paste	Reduce/vanish the effect of snake bite
Artemisia vulgaris L	Tarrkha	Asteraceae	Herb	Perennial	Young Shoots	Decoction	Fever, Body tonic
Asparagus racemosus Willd.	Phanja/Shalgvaety	Liliaceae	Herb	Perennial	Rhizome	Powder	Antiseptic, Control Dysentry and diarrhea
Berberis lyceum Royle	Kwaray	Berberidaceae	Shrub	Perennial	Root bark	Powder	Powder of roots bark is used in bone fractures, backache, healing of internal and external wounds and throat infections. Fruits is also edible
Bergenia ciliata (Haw.) Sternb.	Mukanpat	Saxifragaceae	Herb	Perennial	Whole Plant	Decoction	Anti-inflammatory, Wound Healer, Kidney Problems
Bistorta amplexicaulis (D. Don)	Tarvapanra	Polygonaceae	Herb	Perennial	Roots, Leaves	Powder	Sore throat, Swelling of mouth and tongue
Cannabis sativa L.	Bhang	Cannabaceae	Shrub	Annual	Whole Plant	Decoction, Juice	Muscle pain, Dry Cough, sedative, Narcotic
Chenopodium ambrosioides L.	Skhabotay	Chenoppdiaceae	Shrub	Biennial	Root & Leaves	Decoction, Extraction	Laxative, Liver diseases
Dryopteris odontoloma (Moore)	Kwanjay	Dryopteridaceae	Herb		Young Shoots	Boiled	Used as a vegetable and considered as digestive
Euphorbia wallichii Hook. f.	Shangla	Euphorbiaceae	Herb	Annual	Whole Plant	Latex	Used against worms
Gentianamoorcroftiana (Wall. ex G. Don) Airy Shaw	Bhangara	Gentianaceae	Herb	Annual	Rhizome	Powder	To enhance appetite
Geranium wallichianum D. Don	Srazela/Srajarai	Geraniaceae	Herb	Perennial	Rhizome	Powder, Infusion	Stomach disorders, Uterine Diseases
Mentha longifolia (L.) Hudson	Velany	Lamiaceae	Herb	Perennial	Whole Plant	Decoction, Powder	Digestive disorders, Stomach gas, Abdominal Pain
Micromeria biflora Benth	Shamakay	Lamiaceae	Herb	Perennial	Leaves	Powder	Stomach disorder, Throat infection
Plantago major L.	Jabae	Plantaginaceae	Herb	Perennial	Roots, Leaves & Seeds	Decoction, Infusion, Chopped	Seasonal fever, Constipation, Measles treatment in children
Plectranthusrugosus L.	Sperkay	Lamiaceae	Shrub	Perennial	Leaves	Powder	Anti inflammatory, Jaundice
Podophyllum hexandrum Royle	Kakora	Podophyllaceae	Herb	Perennial	Fruits & Rhizomes	Powder	Body Tonic, Jaundice, Liver Disease
Primula denticulata Smith	Mamera	Primulaceae	Herb	Perennial	Rhizome	Powder	Expectorant, Eye disorders
Rumex dentatus L.	Shalkhay	Polygonaceae	Herb	Perennial	Leaves	Decoction	diuretic, Treating Hepatitis, astringent and soothing irritation
Rumex hastatus D	Tharoky	Polygonaceae	Herb	Perennial	Leaves	Decoction, Powder	Urinary disease, Stomachache, Jaundice
Skimmia laureola (DC.) Decne	Nazarapanra/Nameer	Rutaceae	Shrub	Perennial	Leaves	Smoke	Burned Leaves smoke used for cool and cough, also believed that it repels evils.
Taraxacum officinale Weber	ZiarhGuly	Asteraceae	Herb	Perennial	Leaves	Decoction	Eye Disorders
Trillium govanianum (Wall. ex D. Don) Kunth	Yakhajarai	Trilliaceae	Herb	Perennial	Root	Decoction	Control Bleeding and diarrhea
Valeriana jatamansi Jones	Muskibala	Velerianaceae	Herb	Annual	Rhizome	Powder	Stomach Problems, Constipation, Fever, Treat Spasm
Verbascum thapsus (Linn.)	Khardag	Scrophulariaceae	Shrub	Biennial	Whole Plant	Powder and paste	Pulmonary and Skin diseases
Viola canescens Wall. ex Roxb.	Banafsha	Violaceae	Herb	Annual	Whole Plant	Decoction, Infusion	Sore throat, relieves muscle tension.

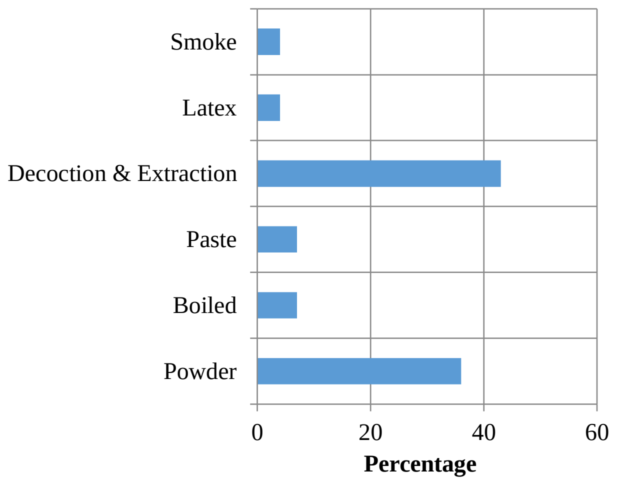

Fig. 6. Mode of use.

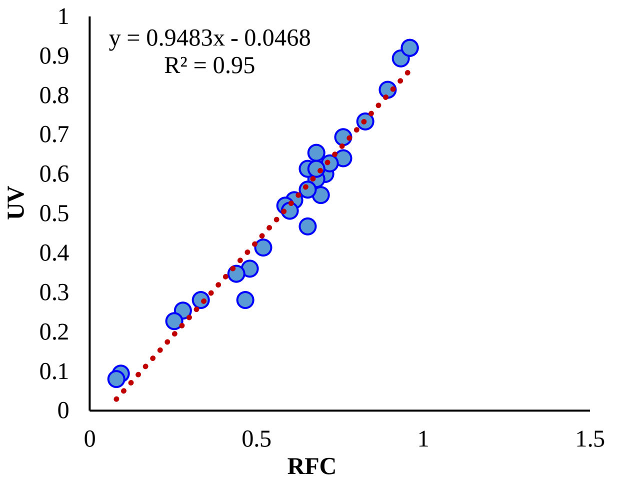

Fig. 7. Correlation of UV and RFC.

Relative frequency citation (RFC): The RFC value is a measure of the significance of a medicinal plant within the community of a particular study area. The range of RFC value is 0.9-0.08 (Table 5). The highest value documented was 0.92 for *Berberis lycium* and *Dryopteris odontoloma* followed by *Skimmia laureola* (RFC:0.89) and *Bergenia ciliate* (RFC:0.81). The lowest recorded RFC was for *Verbascum thapsus* which is 0.05.

Use value (UV): The aim of finding out the use value of different traded medicinal plants was to determine the relative importance of these plants that are known within the local community. It was noted in the study that the UV varies from 0.96-0.08. The highest recorded value is 0.96 for *Berberis lycium* and *Dryopteris odontoloma* followed by *Skimmia laureola* (UV:0.93), *Bergenia ciliate* (UV:0.89) and *Plectranthus rugosus* (UV: 0.83). The lowest recorded UV was for *Verbascum thapsus* which is 0.08.

Pearson correlation coefficient: The correlation was used as a tool to determine the relation between UV and RFC. A strong correlation was found between UV and RFC with R^2=0.95 (Fig. 7). This means that as one variable increases, the other variable also tends to increase predictably.

Important value index (IVI): The IVI is a useful tool in determining the significance of plant species within an ecological community. The dominant species within a community are typically identified by having the highest IVI value when considering factors such as abundance, frequency and dominance. Table 6 showed that the highest IVI is of *Dryopteris odontoloma* 26.6, followed by *Arisaema triphyllum* 23.1, and *Artemisia vulgaris* 22.7. The lowest value shown in the table is IVI of *Asparagus racemosus* 1.39.

Multiple linear regression: MLR models were developed between medicinal plant distribution and climatic and topographic factors (Temperature, precipitation, elevation, slope and latitude). MLR models showed that correlation range from 0.1 to 0.97 (Table 7). Most of the medicinal plants showed a high correlation between 0.97 and 0.62 for instance; *Valeriana jatamansi* Jones, *Skimmia laureola* (DC.) Decne, *Gentiana moorcroftiana* (Wall. ex G. Don) Airy Shaw, *Micromeria biflora Benth*, *Rumex dentatus* L., showed coefficient of correlation R^2 0.97, 0.96, 0.95, 0.86 and 0.83 respectively. Whereas the lowest *Arisaema triphyllum* L, *Bistorta amplexicaulis* (D. Don), *Geranium wallichianum* D. Don showed a coefficient of correlation R^2 0.1, 0.15, and 0.16 respectively.

Spatial distribution of important medicinal plants of which R^2 > 0.6: The analysis of environmental variable contributions (Table 8) and the outcomes from jackknife gain analysis (Fig. 9) revealed the cumulative impact of environmental factors influencing the distribution of various species. The most prominent climatic factor was BIO9 (Mean temperature of driest quarter/◦C) which contributed towards spatial distribution of 06 out of 10 species, followed by BIO19 (Precipitation of coldest quarter/mm) and BIO11 (Mean temperature of coldest quarter/◦C). The percent contribution of each environmental factor in the spatial distribution of ten important medicinal plants has been summarized in Table 8.

Figure 8 visualizes the Maxent model for medicinal plants. Warmer colors on the map indicate regions with more favorable predicted conditions. The white dots represent the presence locations used for training, while the violet dots mark the test locations. Further figure 8 showed that an abundance of *Gentiana moorcrofiana*, *Acconitum violaceum* Jacq, *Skimmia laureola,* and *Micromeia biflora*benth are at north west and central of the study area while at south west *Rumex dentatus* L and *Berberis lycium* Royle are in abundance.

Discussion

The present study documented twenty-eight species of medicinal plants that were collected from the study area, out of which, *Berberis lycium* Royle, *Geranium wallichianum* D. Don, and *Viola canescens Wall. ex Roxb* were considered most important concerning their ethnobotanical value. However, significant medicinal use of other species has also been determined, such as *Trillium govanianum* (Wall. ex D. Don) Kunth (Control Bleeding and diarrhea), *Primula denticulate* Smith (Expectorant, Eye disorders), and *Mentha longifolia* (L.) Hudson (Digestive disorders, Stomach gas, Abdominal Pain). Spatial distribution and ethnobotanical use of these medicinal plants are extended over the varied geographical extent covering the northern districts. The results of the present study are consistent with the findings of (Khan *et al.,* 2019) who reported 84 species, some of them are *Berberis lycium* Royle, *Geranium wallichianum* Oliv, *Mentha longifolia* (L) Hudson, and *Viola biflora* L. Moreover, the identified species are almost used for the same type of diseases such as *Berberis lycium* Royle used for backache (Khan *et al.,* 2019; Khan *et al.,* 2013), fractures, and wound healing (Aziz *et al.,* 2018). Similarly, *Podophyllum hexandrum* Royle is used for jaundice and liver diseases i.e., blood purifier (Ali & Qaiser, 2009). Hussain *et al.,* in 2018 reported 92 species with medicinal properties have been identified, encompassing 91 vascular plant species distributed across 50 different families, as well as a solitary mushroom species named Morchella. *Bergenia ciliate* (Haw) is used for stomach and joint pain, *Cannabis Sativa* L., is used for sedatives and refrigerants while in my study it was found that *Cannabis sativa* L., is used for muscle pain, dry cough, sedatives and narcotics. *Mentha longifolia* (L.) was used as an antidiarrheal, appetizer, and carminative while digestive disorders, stomach gas and abdominal pain were reported during this study. Similarly, *Valeriana jatamansai* Jones, *Verbascum thapsus* L, *Viola canescens* Wall. ex Roxb and *Taraxicum officinale* L., and *Rumex dentatus* L., was reported (Hussain *et al.,* 2018).

The study also determined the RFC of the species, the highest value documented is 0.92 for *Berberis lycium* and *Dryopteris odontoloma* followed by *Skimmia laureola* (RFC:0.89) and *Bergenia ciliate* (RFC:0.81) whereas in district Shangla-Kohistan, (Shinwari *et al.,*2017) reported RFC values for *Berberis lycium* Royle (0.39) and *Mentha spicata* L. (0.38). Likewise, the lowest recorded RFC is for *Verbascum thapsus* which is 0.05 in the present study. *Berberis lycium* Royle (RFC: 0.37) was documented by (Shah *et al.,* 2016). (Shuaib *et al.,* 2021) reported that the Relative frequency citation from 0.58-0.2 from Upper Dir. The highest value is for *Allium sativum* L (RFC: 0.58), for *Berberis lycium* Royle the RFC is 0.53 while RFC is 0.92 for *Berberis lycium* Royle in my study. Similarly, for *Bergenia ciliate* RFC is 0.13 compared to my findings which have 0.81. The medicinal use is almost the same in both study areas i.e. Upper Dir and Shangla. RFC reported by Hussain *et al.,*2018 for *Bergenia ciliate* (RFC:0.18), *Berberis lycium* Royle (RFC: 0.70), *Mentha longifolia* L., (RFC: 0.43), *Plantago major* L., (RFC: 0.31), *Taraxicum officinale* L., (RFC: 0.34) and *Verbascum thapsus* L. (RFC: 0.14).

Table 5. RFC and UV of medicinal plants.

S. No.	Species name	FC	RFC	ΣUi	UV
1.	*Berberis lycium* Royle	69	0.92	72	0.96
2.	*Podophyllum hexandrum* Royle	27	0.36	36	0.48
3.	*Rumex dentatus*L	31	0.41	39	0.52
4.	*Plantago major* L	35	0.47	49	0.65
5.	*Rumex hastatus* D	40	0.53	46	0.61
6.	*Mentha longifolia* (L) Hudson	52	0.69	57	0.76
7.	*Cannabis sativa* L	26	0.35	33	0.44
8.	*Chenopodium ambrosioides* L	21	0.28	25	0.33
9.	*Arisaema triphyllum*L	19	0.25	21	0.28
10.	*Trillium govanianum* (Wall. ex D. Don) Kunth	45	0.60	53	0.71
11.	*Asparagus racemosus* Willd.	21	0.28	35	0.47
12.	*Bergenia ciliata* (Haw.) Sternb.	61	0.81	67	0.89
13.	*Taraxacum officinale* Weber	39	0.52	44	0.59
14.	*Valeriana jatamansi* Jones	48	0.64	57	0.76
15.	*Geranium wallichianum* D. Don	44	0.59	51	0.68
16.	*Viola canescens* Wall. ex Roxb.	49	0.65	51	0.68
17.	*Bistorta amplexicaulis* (D. Don)	38	0.51	45	0.60
18.	*Micromeria biflora* Benth	47	0.63	54	0.72
19.	*Skimmia laureola* (DC.) Decne	67	0.89	70	0.93
20.	*Primula denticulata* Smith	41	0.55	52	0.69
21.	*Gentiana moorcroftiana* (Wall. ex G. Don) Airy Shaw	46	0.61	49	0.65
22.	*Aconitum ferox*	17	0.23	19	0.25
23.	*Euphorbia wallichii* Hook. f.	7	0.09	7	0.09
24.	*Artemisia vulgaris* L	46	0.61	51	0.68
25.	*Plectranthus rugosus* L	55	0.73	62	0.83
26.	*Dryopteris odontoloma* (Moore)	69	0.92	72	0.96
27.	*Verbascum thapsus* (Linn)	4	0.05	6	0.08
28.	*Actaea spicata* L.	42	0.56	49	0.65

Table 7. MLR between medicinal plants distribution and climatic, topographic factors.

Specie	R^2	Adj R^2	SE	Significance
Berlyc	0.62	0.51	1.33	0.002
Pod hex	0.47	0.14	0.14	0.310
Rum den	0.83	0.61	4.39	0.105
Ari tri	0.10	-0.06	7.88	0.690
Tri gov	0.67	0.26	1.66	0.324
Bercil	0.24	-0.51	4.72	0.883
Tar off	0.59	-0.08	9.43	0.581
Val jat	0.97	0.92	5.70	0.053
Gerwal	0.16	-0.15	6.40	0.763
Bis amp	0.15	-0.07	9.44	0.652
Mic bif	0.86	0.72	5.56	0.033
Ski lau	0.96	0.76	1.93	0.331
Pri den	0.66	0.32	2.31	0.238
Gen moo	0.95	0.73	1.40	0.351
Acovio	0.64	-1.10	8.38	0.838
Eupwal	0.45	0.10	6.78	0.346
Art vul	0.48	0.29	11.20	0.073
Ple rug	0.49	0.13	3.46	0.334
Dry odo	0.20	-0.007	5.60	0.464
Vertha	0.27	0.06	4.23	0.302
Act spi	0.58	0.06	4.22	0.465

Predictors variables: Latitude, Temperature, Precipitation, Elevation, Slope

The range of the Importance Value Index recorded during the study is in between 26.6-1.39. The highest IVI is Dryopteris odontoloma 26.6, *Arisaema triphyllum* 23.1, and *Artemisia vulgaris* 22.7. The lowest value shown is IVI of *Asparagus racemosus* 1.39. In addition to this *Berberis lycium* Royle values is (IVI: 10.2), *Bergenia ciliata* (Haw.) Sternb (IVI: 22.4), *Bistorta amplexicaulis* (D. Don) (IVI: 21.0), *Cannabis sativa* L., (IVI: 5.8), *Euphorbia wallichii* Hook. f. (IVI: 5.6), *Plantago major* L (IVI: 2.58), *Skimmial aureola* (DC.) Decne (IVI: 4.80), *Verbascum thapsus*(Linn) (IVI: 15.64) and *Viola canescens* Wall. ex Roxb (IVI: 1.82) while (Khan *et al.*, 2012) documented the IVI for the same species as *Berberis lycium* Royle values is (IVI: 15.6), *Bergenia ciliata*(Haw.) Sternb (IVI: 3.27), *Bistorta amplexicaulis*(D. Don) (IVI: 3.14), *Cannabis sativa* L (IVI: 2.83), *Euphorbia wallichii* Hook. f. (IVI: 2.57), Plantago *major* L (IVI: 1.68), *Skimmia laureola* (DC.) Decne (IVI: 0.97), *Verbascum thapsus* (Linn.) (IVI: 1.57) and *Viola canescens* Wall. ex Roxb (IVI: 8.4).

Furthermore, study revealed that the UV varies from 0.96-0.08 while (Shinwari *et al.*, 2017) reported the range from 0.04 to 0.21. The highest recorded value is 0.96 for *Berberis lycium* and *Dryopteris odontoloma* followed by *Skimmia laureola* (UV:0.93), *Bergenia ciliate* (UV:0.89) and *Plectranthus rugosus* (UV: 0.83). The lowest recorded UV is for *Verbascum thapsus which is 0.08.* The UV recorded by (Shinwari *et al.*, 2017) *Berberis lycium* Royle *is* (UV:0.11) while for *Bergenia ciliate* (UV:0.14). The UV value shifted from 0.96 to 0.06, and among the species, *Zataria multifora* had the highest UV of 0.96, followed by *Descurainia sophia* L. and *Medacago sativa* L., both with UV values of 0.90 (Sharafatmandrad & Khosravi, 2020).

Table 6. IVI of medicinal plants.

S. No.	Species name	Relative cover %	Relative density	Relative frequency	IVI
1.	*Berberis lycium* Royle	5.77	2.12	7.20	10.2
2.	*Podophyllum hexandrum* Royle	0.21	1.11	4.03	2.66
3.	*Rumex dentatus*L	0.95	2.74	2.88	4.65
4.	*Plantago major* L	1.16	0.84	1.73	2.58
5.	*Rumex hastatus* D	0.63	1.42	1.15	2.44
6.	*Mentha longifolia* (L.) Hudson	0.32	0.99	1.15	1.69
7.	*Cannabis sativa* L.	3.65	1.66	1.73	5.88
8.	*Chenopodium ambrosioides* L.	1.02	2.04	1.73	3.64
9.	*Arisaema triphyllum*L	11.9	8.25	8.93	23.2
10.	*Trillium govanianum* (Wall. ex D. Don) Kunth	0.20	1.08	3.17	2.33
11.	*Asparagus racemosus* Willd.	0.19	0.72	1.44	1.39
12.	*Bergenia ciliata* (Haw.) Sternb.	18.20	3.15	3.17	22.4
13.	*Taraxacum officinale* Weber	1.22	2.19	2.59	4.27
14.	*Valeriana jatamansi* Jones	1.18	7.98	2.31	9.93
15.	*Geranium wallichianum* D. Don	1.06	3.77	5.48	6.66
16.	*Viola canescens* Wall. ex Roxb.	0.26	0.99	1.73	1.82
17.	*Bistorta amplexicaulis* (D. Don)	6.06	12.72	6.92	21.08
18.	*Micromeria biflora* Benth	0.11	5.55	3.17	6.72
19.	*Skimmia laureola* (DC.) Decne	2.30	1.83	2.02	4.80
20.	*Primula denticulata* Smith	7.58	1.54	3.17	10.2
21.	*Gentiana moorcroftiana* (Wall. ex G. Don) Airy Shaw	1.82	0.77	2.02	3.26
22.	*Aconitum ferox* Jacq. ex Stap	0.23	2.04	2.02	2.95
23.	*Euphorbia wallichii* Hook. f.	1.45	2.88	4.03	5.68
24.	*Artemisia vulgaris* L.	7.75	13.10	5.76	22.8
25.	*Plectranthus rugosus* L	0.96	2.36	3.75	4.56
26.	*Dryopteris odontoloma* (Moore)	15.86	8.37	7.20	26.6
27.	*Verbascum thapsus* (Linn.)	7.40	6.03	6.63	15.6
28.	*Actaea spicata* L.	0.65	1.78	2.88	3.39

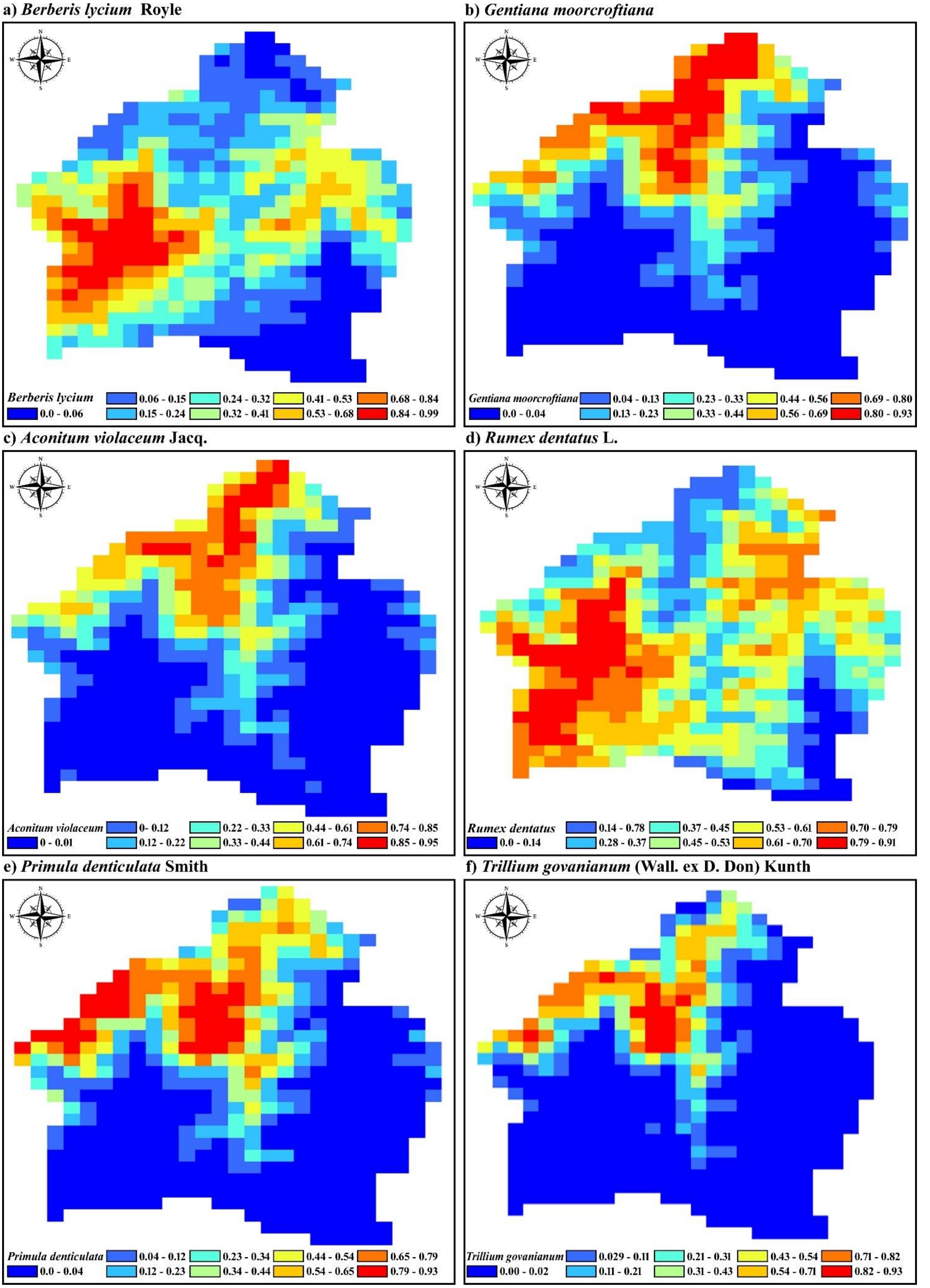

Fig. 8. Maps showing the distribution of medicinal plants.

Fig. 8 (Cont'd.).

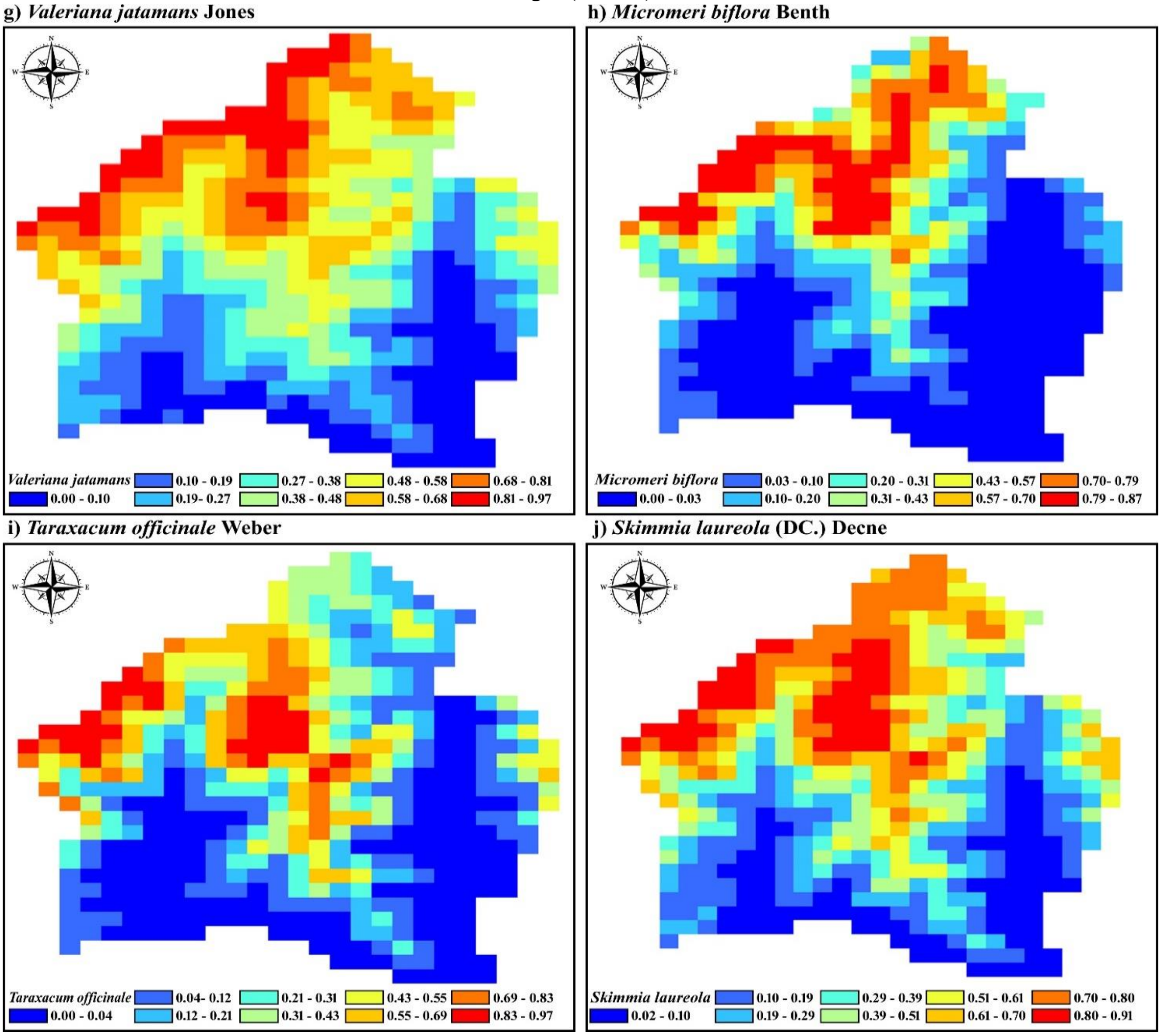

Table 8. Contribution percent of environmental variables adopted in the model for important medicinal plants.

Specie name	Variable	Description	Type	Contribution
Berberis lycium Royle	BIO19	Precipitation of coldest quarter/mm	Climatic	35.5%
	BIO12	Annual precipitation/mm	Climatic	31.7%
	BIO18	Precipitation of Warmest Quarter/mm	Climatic	24.6%
Gentiana moorcroftiana	BIO9	Mean temperature of driest quarter/◦C	Climatic	35.8%
	BIO19	Precipitation of coldest quarter/mm	Climatic	33.9%
Aconitum ferox	BIO9	Mean temperature of driest quarter/◦C	Climatic	41.2%
	BIO19	Precipitation of coldest quarter/mm	Climatic	34.5%
*Rumex dentatus*L	BIO18	Precipitation of Warmest Quarter/mm	Climatic	32.2%
	DEM	Elevation/m	Topographic	26.5%
	BIO11	Mean temperature of coldest quarter/◦C	Climatic	18.7%
Primula denticulate Smith	BIO9	Mean temperature of driest quarter/◦C	Climatic	69.8%
	BIO11	Mean temperature of coldest quarter/◦C	Climatic	14.6%
Trillium govanianum (Wall. ex D. Don) Kunth	BIO9	Mean temperature of driest quarter/◦C	Climatic	83.4%
	BIO11	Mean temperature of coldest quarter/◦C	Climatic	13.6%
*Valeriana jatamansi*Jones	BIO9	Mean temperature of driest quarter/◦C	Climatic	34.7%
	BIO10	Mean temperature of warmest quarter/◦C	Climatic	17.3%
	BIO7	Temperature annual range/◦C	Climatic	14.4%
Micromeria biflora Benth	BIO9	Mean temperature of driest quarter/◦C	Climatic	82.9%
	BIO11	Mean temperature of coldest quarter/◦C	Climatic	12.9%
Taraxacum officinale Weber	BIO7	Temperature annual range/◦C	Climatic	89.1%
	BIO19	Precipitation of coldest quarter/mm	Climatic	4.7%
Skimmia laureola (DC.) Decne	BIO19	Precipitation of coldest quarter/mm	Climatic	58.2%
	BIO7	Temperature annual range/◦C	Climatic	41.8%

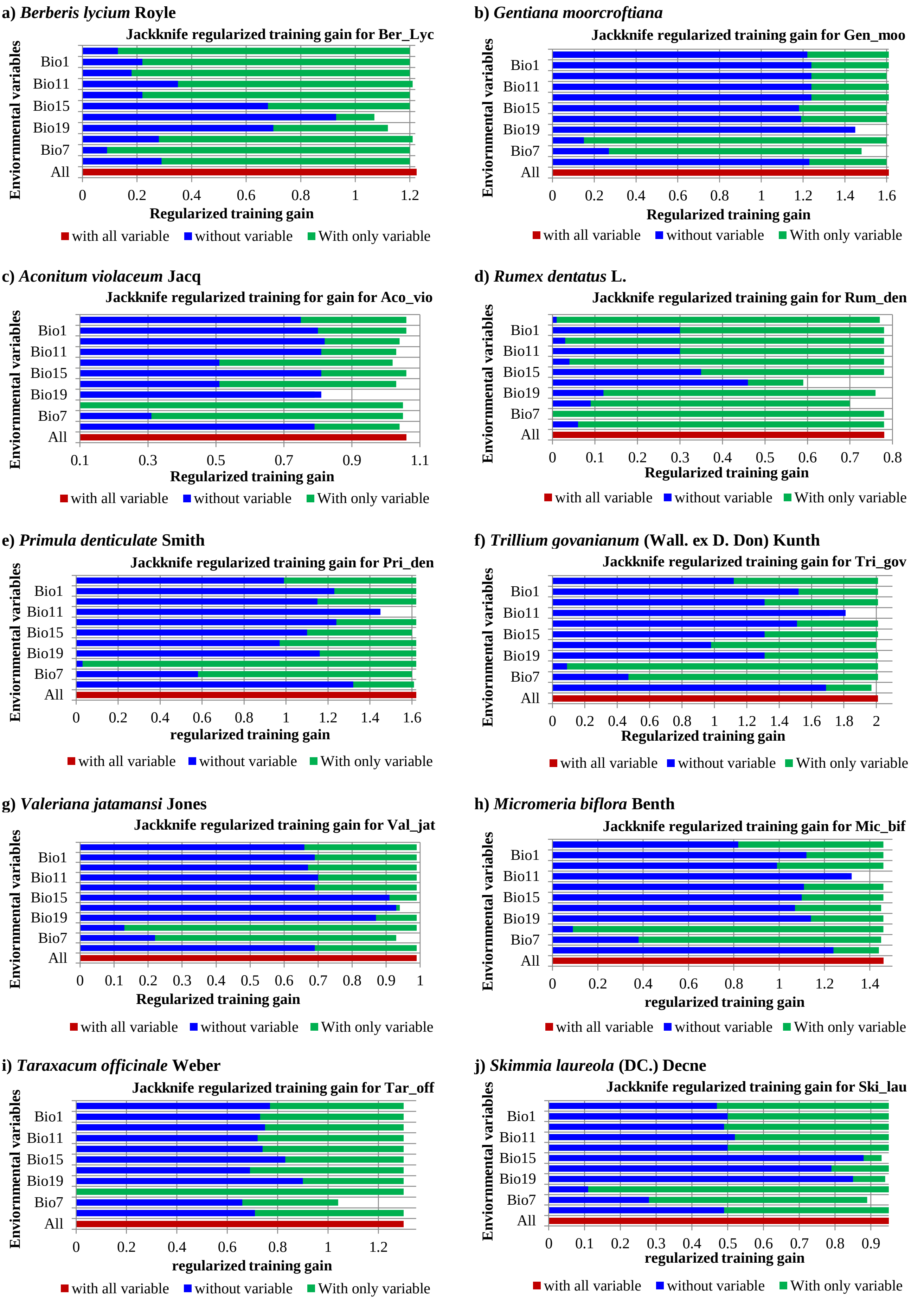

Fig. 9. Jackknife test of the importance of environmental variables in MaxEnt model.

Limitations of the study

1. Ethno-botanical use must be explored in state of the art scientific lab analysis because it is not explored in the current study.
2. Market chain analysis and value addition may be explored.
3. The potential of the sites for medicinal plant productivity may be explored concerning soil analysis.
4. Regeneration /carrying capacity/ trend/ condition of medicinal plants can be found ~~out.~~

Conclusion

The study was conducted in Lilownai Valley to assess the status and distribution of medicinal plants, the role of medicinal plants on the socioeconomic condition of the local population, identify the major threats to medicinal plants and recommend conservation strategies. Habitat suitability modeling (MaxEnt) was used to evaluate and predict the potential occurrence of the medicinal plants. Twenty-eight medicinal plants belonging to 23 different families were collected. The most abundantly family found was Lamiaceae. The highest value of relative frequency citation documented is 0.92 for *Berberis lycium* while the lowest recorded RFC is for *Verbascum thapsus* which is 0.05. The Use Value recorded varies from 0.96-0.08. A strong Pearson correlation was found between UV and RFC with R^2=0.95. The Important Value Index (IVI) is high for *Dryopteris odontoloma* (i.e., 26.6) while the lowest is that of *Asparagus racemosus* (i.e., 1.39). MLR model showed that *Valeriana jatamansi* Jones, *Skimmia laureola* DC.) Decne, *Gentiana moorcroftiana* (Wall. ex G. Don) Airy Shaw, *Micromeria biflora* Benth, *Rumex dentatus* L., showed coefficient of correlation R^2 0.97, 0.96, 0.95, 0.86 and 0.83 respectively. These findings could be helpful in the conservation and resource utilization of endangered medicinal plants.

References

Abbasi, A.M., M.A. Khan, M. Ahmed, and M. Zafar. 2010. Herbal medicines used to cure various ailments by the inhabitants of Abbottabad district, North West Frontier Province, Pakistan. *Ind. J. Trad. Know*., 9(1): 175-183.

Ajaib, M., M.IshtiaAjaib, M., M.Ishtiaq, K.H. Bhatti, K.S.Ahmed, M. Maqbool, and T. Hussain. 2021. Traditional ethnobotanical knowledge of wild plants of Tilla Jogian district Jhelum, Pakistan. *Pak. J. Bot*, *53*(4):1303-1406.

Ali, H. and M. Qaiser. 2009. The ethnobotany of Chitral Valley, Pakistan with particular reference to medicinal plants. *Pak. J. Bot*., 41(4): 2009-2041.

Ali, K., N. Akhtar, M. Shuaib, S. Ali, A. Ghaffar, M. Shah, and M. Iqbal. 2019. Impact of urbanization on vegetation: a survey of Peshawar, Pakistan. *Pol. J. Environ. Stud*., 28(4):2523-2530.

Ali, K., M. Shuaib, T. Malik, S.S. Shah, S. Ali, N.A. Shah, and Z. Li. 2019. Urban sprawl and its impact on soil and plant species in Peshawar, Pakistan. *Pol. J. Environ. Stud.*, 28(4): 1-8.

Alqethami, A. and A.Y. Aldhebiani. 2021. Medicinal plants used in Jeddah, Saudi Arabia: phytochemical screening. *Saudi J. Biol. Sci.*, 28(1): 805-812.

Angelsen, A. and S. Wunder. 2003. Exploring the forest-poverty link. *CIFOR Occasional Paper*, 40: 1-20.

Aziz, M.A., M. Adnan, A.H. Khan, A.A. Shahat, M.S. Al-Said, and R. Ullah. 2018. Traditional uses of medicinal plants practiced by the indigenous communities at Mohmand Agency, FATA, Pakistan. *J. Ethnobiol. Ethnomed.*, 14: 1-16.

Balunas, M.J. and A.D. Kinghorn. 2005. Drug discovery from medicinal plants. *Life Sciences*, 78(5): 431-441.

Caballero-Serrano, V., B. McLaren, J.C. Carrasco, J.G. Alday, L. Fiallos, J. Amigo, and M. Onaindia. 2019. Traditional ecological knowledge and medicinal plant diversity in Ecuadorian Amazon home gardens. *Global Ecol. Conser.*, 17(2019): 1-23.

El-Ghazouani, F., N. El-Ouahmani, I. Teixidor-Toneu, B. Yacoubi, and A. Zekhnini. 2021. A survey of medicinal plants used in traditional medicine by women and herbalists from the city of Agadir, southwest of Morocco. *Eur. J. Integ. Med.*, 42(2021): 1-8

Elith, J. and J.R. Leathwick. 2009. Species distribution models: ecological explanation and prediction across space and time. *Ann. Rev. Ecol. Evol. Sys.*, 40(1): 677-697.

FAO. 2020. Food and Agriculture Organization of the United Nations (FAO): About Non-Wood Forest Products.http:// www.fao.org/forestry/nwfp/6388/en/. Accessed 30 June 2021.

Gul, F., Z.K. Shinwari, and I. Afzal. 2012. Screening of indigenous knowledge of herbal remedies for skin diseases among local communities of North West Punjab, Pakistan. *Pak. J. Bot.*, 5: 1609-1616.

Hussain, W., L. Badshah, M. Ullah, M. Ali, A. Ali, and F. Hussain. 2018. Quantitative study of medicinal plants used by the communities residing in Koh-e-Safaid Range, northern Pakistani-Afghan borders. *J. Ethnobiol. Ethnomed.*, 14(1): 1-18.

Kar, S.P. and M.G. Jacobson. 2012. NTFP income contribution to household economy and related socio-economic factors: Lessons from Bangladesh. *Forest Pol. Econ.*, 14(1): 136-142.

Khan, S.A., F. Hadi, M. Ibrar, and U. Samreen. 2019. Indigenous utilization of plant biodiversity in Malakkheil-Kotkay Village, District Shangla, Pakistan. *Pak. J. Sci. Ind. Res., Series B: Biol. Sci.*, 62(1): 15-23.

Khan, S.M., S. Page, H. Ahmad, H. Shaheen, Z. Ullah, M. Ahmad, and D.M. Harper. 2013. Medicinal flora and ethnoecological knowledge in the Naran Valley, Western Himalaya, Pakistan. *J. Ethnobiol. Ethnomed.*, 9(2013): 1-13.

Merow, C., M.J. Smith, and J.A. Silander Jr. 2013. A practical guide to MaxEnt for modeling species' distributions: what it does, and why inputs and settings matter. *Ecography*, 36(10):1058-1069.

Muhammad, S., M. Hussain, Z. Saqib, J. Alam, G. Mujtaba, Z.A.Shah, M. Ali, G. Qadir, and Z.Abideen.2023. Flora of the Kurram Valley (Tribal Area), Pakistan: Diversity, Physiognomy and Conservation Issues. *Pak. J. Bot*, *55*(1):199-212.

Nguyen, L.Q., P.O. Fernandes, and J.P. Teixeira. 2021. Analyzing and forecasting tourism demand in Vietnam with artificial neural networks. *Forecasting*, 4(1): 36-50.

Nowok-Olejnik, A. and E. Mocior. 2022. Provisioning ecosystem services of wild plants collected from semi-natural habitats: a basis for sustainable livelihood and multi-functional landscape conservation. *Mount. Res. Develop.*, 42(1): R11-R19.

Radha, K.M., S. Puri, A. Pundir, S.P. Bangar, S. Changan, and M. Mekhemar. 2021. Evaluation of nutritional, phytochemical, and mineral composition of selected medicinal plants for therapeutic uses from cold desert of Western Himalaya. *Plants*, 10(7): 1429-1444.

Reta, Z., Y. Adgo, T. Girum, and N. Mekonnen. 2020. Assessment of contribution of non-timber forest products in the socio-economic status of peoples in Eastern Ethiopia. *J. Biogen. Sci. Res.*, 4(4): 2692-1081.

Sahoo, S.R., N.K. Panda, S.N. Subudhi, and H.K. Das. 2020. Contribution of non-timber forest products (NTFPs) in the socio-economic development of forest dwellers in Odisha. *J. Pharmacog. Phytochem.*, 9(4): 81-85.

Sarwat, S.Z. and N. Ahmad. 2012. Screening of potential medicinal plants from District Swat specific for controlling women's diseases. *Pak. J. Bot.*, 44(4): 1193-1198.

Shah, S.A., N.A. Shah, S. Ullah, M.M. Alam, H. Badshah, S. Ullah, and A.S. Mumtaz. 2016. Documenting the indigenous knowledge on medicinal flora from communities residing near Swat River (Suvastu) and in high mountainous areas in Swat, Pakistan. *J. Ethnopharm.*, 182(2016): 67-79.

Shaheen, H. and Z.K. Shinwari. 2012. Phyto diversity and endemic richness of Karambar Lake vegetation from Chitral, Hindukush-Himalayas. *Pak. J. Bot.*, 44(1): 17-21.

Sharafatmandrad, M. and A. Khosravi Mashizi. 2020. Ethnopharmacological study of native medicinal plants and the impact of pastoralism on their loss in arid to semiarid ecosystems of southeastern Iran. *Sci. Rep.*, 10(1): 15526-15543.

Shinwari, S., M. Ahmad, Y. Luo, and W. Zaman. 2017. Quantitative analyses of medicinal plants consumption among the inhabitants of Shangla-Kohistan areas in Northern Pakistan. *Pak. J. Bot.*, 49(2): 725-734.

Shinwari, Z.K. and M. Qaiser. 2011. Efforts on conservation and sustainable use of medicinal plants of Pakistan. *Pak. J. Bot.*, 43(1): 5-10.

Shinwari, Z.K., S.A. Gilani, and A.L. Khan. 2012. Biodiversity loss, emerging infectious diseases and impact on humans and crops. *Pak. J. Bot.*, 44(1): 137-142.

Shrestha, S., J. Shrestha and K.K. Shah. 2020. Non-timber forest products and their role in the livelihoods of people of Nepal: a critical review. *Grassroots J. Nat. Resour.*, 3(2): 42-56.

Shuaib, M., S. Ahmed, K. Ali, M. Ilyas, F. Hussain, Z. Urooj, and F. Hussain. 2019. Ethnobotanical and ecological assessment of plant resources at District Dir, Tehsil Timergara, Khyber Pakhtunkhwa, Pakistan. *Acta Ecologica Sinica*, 39(1): 109-115.

Shuaib, M., F. Hussain, A. Rauf, F. Jan, M. Romman, R. Parvez, and N.A. Shah. 2021. Traditional knowledge about medicinal plants in the remote areas of Wari Tehsil, Dir Upper, Pakistan. *Braz. J. Biol.*, 83(2023): 1678-4375.

Tareen, N.M., M.A. Rehman, Z.K. Shinwari, and T.A.H.I.R.A. Bibi. 2016. Ethnomedicinal utilization of wild edible vegetables in District Harnai of Balochistan Province, Pakistan. *Pak. J. Bot.*, 48(3): 1159-1171.

Wahlén, C.B. 2017. Opportunities for making the invisible visible: towards an improved understanding of the economic contributions of NTFPs. *Forest Pol. Econ.*, 84(2017): 11-19.

Yang, X.Q., S.P.S. Kushwaha, S. Saran, J. Xu, and P.S. Roy. 2013. Maxent modeling for predicting the potential distribution of the medicinal plant Justicia adhatoda L. in Lesser Himalayan foothills. *Ecol. Eng.*, 51(2013): 83-87.

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