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POTENTIAL DISTRIBUTION OF ENDEMIC *SCUTELLARIA CHAMAEDRIFOLIA*; GEOGRAPHIC INFORMATION SYSTEM AND STATISTICAL MODEL APPROACH

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Abstract

Potential distribution and habitat suitability analyses are basic requirements for conservation of rare and endangered species. *Scutellaria chamaedrifolia* Hedge & Paton (Lamiaceae) is a rare endemic species confined to northern mountain ranges of Pakistan with small geographic range. Potential habitats suitable for species survival were determined using species occurrence records obtained through field surveys. Twenty two topoclimatic factors derived from globally interpolated datasets using Arcmap were used as predictor variables. Look up tables generated through Generalized Regression Analysis and Spatial Prediction (GRASP) program were used to produce prediction maps. The results revealed that annual mean temperature, mean diurnal range, mean temperature of the driest quarter, mean temperature of the warmest quarter, precipitation of wettest month and precipitation of the coldest quarter were significantly affecting species distribution. Localities from Mansehra, Batagram, Torghar and adjoining Shangla and Buner districts were identified as best suitable habitats (p = 0.9) for the species. Establishment of the protected areas and seed banks are imperative for conservation of the species.

Key Words: *Scutellaria chamaedrifolia*, Labiatae, Potential distribution, GRASP, GIS, Pakistan

Introduction

Species distribution and habitat suitability models are emerging as an effective tool for identification of new populations, decision making in choosing conservation areas and re introduction sites for a species, climate change and ecological behaviour of a species (Guisan & Zimmermann, 2000; Peterson 2001; Store & Jokimäki, 2003; Hijmans & Graham, 2006; Lu *et al*., 2012; Mcshea, 2014). Along that, these are also helpful in obtaining desired results in little time and at low cost (Guisan *et al*., 2006). Methodological advances utilized for such studies include statistical, environmental and geographic information systems tools, in combination with computer programs for targeted outcomes (Store & Kangas, 2001; Austin, 2002; Elith & Leathwick, 2009; Khan, 2012). Currently species distribution models (SDM) are being successfully applied over a range ecological and conservation studies including species potential range, ecological niche studies, invasive species dispersal, plant communities analyses, species response to climate change etc. (Higgins *et al*., 1999; Van-Kleunen & Johnson, 2007; Khan *et al.,* 2011; Lozier & Mills, 2011; Crall *et al*., 2013). However the use of distribution models in conservation planning of the rare species have remained scarce because of certain limitations i.e., very few occurrence points, insufficient location accuracy, small sample size etc. (Elith & Burgman, 2002; Williams *et al*., 2009; Gogol-Prokurat, 2011). For rare and endangered species, availability of information through museums and herbaria is also inadequate (Newbold, 2010). Keeping in view importance of rare species, new approaches have been taken into account in past few years with successful results (Engler *et al*., 2004; Guisan & Thuiller, 2005; Khan *et al.,* 2013). Studies suggested that model approach is four to six times more effective as compared to random sampling of a species in least time period saving considerable amount of money. GRASP is one among such models which could have been most effectively applied. The model is based on generalized regression analysis where relationship between a response variable and a set of predictor variables is determined for which point measurements of response variable along with regional cover of the predictors is required (Lehmann *et al*., 2002; Guisan *et al*., 2006). Current study aims at mapping the distribution of a rare endemic plant with small population size and few records. This is ever first approach focusing on an endemic plant species from the country. In a country like Pakistan, the approach will also be helpful in identifying new localities as most of the areas are unexplored (Saqib *et al*., 2006; Ali, 2008; Rahman *et al.,* 2015).

Materials and Methods

Species selection: *Scutellaria chaemdrifolia* Hedge & Paton (Lamiaceae) is an endemic species, confined to North-eastern mountain ranges of Hindukush and Himalaya. Plant is a perennial herb with ascending to erect habit with characteristic serrate, acute, lanceolate leaves and beautiful flowers (Fig. 1). Type was described from Chitral. Literature survey and herbarium record reveals that plant has only been collected from twelve localities of the country. Species grows in temperate region at an altitude between 1500-2300m (Hedge, 1990).

Study area: Keeping in view the previous reports (Table 1) Hazara division was selected as project area. The study area is located between 33º-44'and 35º-35' north latitude and between 72º-33' and 74º-05' east longitude (Fig. 3),

having 6 districts including newly established Torghar, with a total area of c.18000 Km^2. Geologically the area can be divided into four zones; metamorphic rocks and silt of mica granite, ancient slate series, series of marine deposits mostly lime stone rocks and sand stone (Shams, 1961; Tahirkheli, 1979). The region is the joining point of Himalayas with Hindukush range providing unique climatic variations responsible biodiversity. Because of variations in topography and vegetation cover, climate shows marked variations. Even with in the same range inner and outer parts contrastingly differ. Altitude varies from less than 500 meters to 5000 meters. Rain fall has been recorded as 500mm in the foot hills reaching up to 1400mm in subtropical zone. In temperate zone it varies from 1500-1800mm. Winter precipitation in the form snow remains prominent (Hussain & Ilahi, 1991). Geographical, geological and bioclimatic factors makes the area as an important biodiversity hot spot with about 2000 reported vascular plant species with considerable number of endemics harbouring the mountain ranges (Stewart, 1972; Rafiq, 1996).

Field data collection: As information available through herbaria did not have geographic coordinates in our case, it was impossible to locate the actual habitat of species keeping accuracy. For this reason, data obtained through personal field surveys was mainly relied. Subpopulations were identified after through survey over a period of three years. Locations were georeferenced using GPS (Garmin Etrex Vista H). Species absence points at regular intervals were also taken. GPS data were regularly saved in computer system using Mapsource™. Locations were reconfirmed through Google Earth™, removing ambiguous points from the data. 13 presence points along with 1913 absence points were used in the final analysis.

Fig. 1. *Scutellaria chamaedrifolia* habit and habitat

Predictor variable selection: Nineteen climatic variables along three topographic variables were selected for the current studies. Climatic variable layers were obtained through Worldclim (www.worldclim.com) and data was extracted using ArcGIS 9.3 (Anon, 2008). Table 1 enlists the predictors used during current study

Table 1. Topo-climatic variables used as predictor in GRASP modeling.

S. No	Predictor Variables
1	Annual Mean Temperature**
2	Mean Diurnal Range (Mean of monthly (max temp - min temp))**
3	Isothermality (BIO2/BIO7) (* 100)
4	Temperature Seasonality (standard deviation *100)
5	Maximum Temperature of Warmest Month
6	Minimum Temperature of Coldest Month
7	Temperature Annual Range (BIO5-BIO6)
8	Mean Temperature of Wettest Quarter
9	Mean Temperature of Driest Quarter**
10	Mean Temperature of Warmest Quarter**
11	Mean Temperature of Coldest Quarter
12	Annual Precipitation
13	Precipitation of Wettest Month**
14	Precipitation of Driest Month
15	Precipitation Seasonality (Coefficient of Variation)
16	Precipitation of Wettest Quarter
17	Precipitation of Driest Quarter
18	Precipitation of Warmest Quarter
19	Precipitation of Coldest Quarter**
20	Elevation
21	Slope
22	Aspect

** Variable significantly contributed in modeling suitable habitats

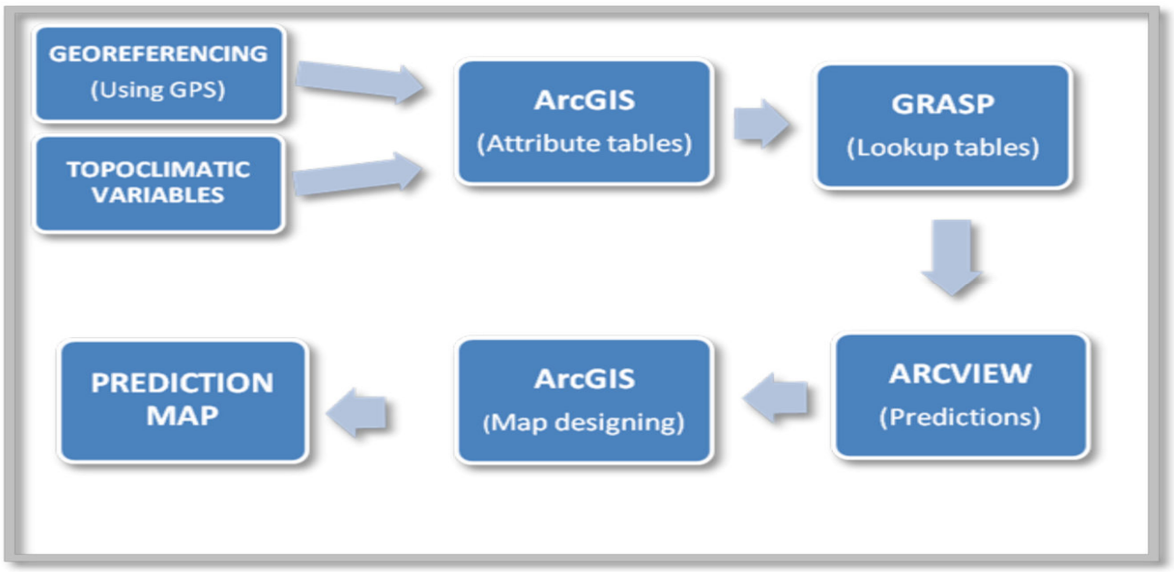

Fig. 2. Flowchart of the methodology adopted during modeling

Model selection: Generalized Additive models were used with binomial distribution and logistics link with backward selection adopting stepwise procedure. For showing spatial prediction on map using geographic coordinates, look up tables generated. Custom script was used in Arcview (Anon., 2000) for implementation and calculation of the final map. The whole procedure was automated with GRASP library of S-plus Insightful Corp. (Lehmann *et al*., 2002). All analyses were conducted at the native 30″ (1 × 1 km pixels) spatial resolution of the environmental datasets. Final map was designed using Arc GIS 9.3 (Anon., 2008), (Fig. 2).

Results and Discussion

Previous records and current status: Survey of herbarium record reveals that species was known from twelve localities only thus confined to northern range of the country (Table 2). However detailed field visits during 2005-2007 could not report any population from Chitral district, the type locality of the species (Ali, 2010; Hussain *et al.,* 2015). Also no recent records from Murree hills could be found (Hameed *et al*., 2012). This shows continuous decline in the population where range is becoming narrower. The possible reasons may be the climatic factor especially precipitation and temperature making its marginal population areas unsuitable for species survival (Türe & Böcük, 2010). Changes in driest and coldest quarter and precipitation, may also affect plant distribution (Walther *et al*., 2002). Field surveys resulted in identification of only 13 subpopulations from the Siran valley, Kunhar Valley and Chattar plains areas of Mansehra District and from Chail Sar range of Batagram describing narrow range of the species confined to a small geographic area.

Table 2. Herbarium record describing species occurrence records.

S. No.	Reported Locations	Voucher Number along herbarium acronym	Collector(s)
1	Jambatai (Chitral)	16477K	Harris
2	Parith Gol (Chitral)	456 K	Toppin
3	Galiat (Abbottabad)	s.n K	Deane
4	Murre Hills	6180 RAW	R. R. Stewart
5	Miandam (Swat)	28014 E, RAW	R. R. Stewart
6	Dir	s.n KUH	Qazilbash
7	Khawazekhiela, Shangla	1706 E	Lomond
8	Oghi-Btagram	971 E	Burtt
9	Oghi	5497KUH, RAW	Nasir and Zafar
10	Topa Muree hills	143 E	Flemming
11	Charrapani-Tret	3221 KUH	Kazmi
12	Batagram	s. n HUP	Faizul Haq

Climatic variables and species distribution: Annual mean temperature, mean diurnal range, mean temperature of the driest quarter, mean temperature of the warmest quarter, precipitation of wettest month and precipitation of the coldest quarter were significantly contributing towards the plant distribution. However the role of topographical variables (aspect, slope, altitude) was negligible. Temperature and moisture are most important factors in species distribution describing the species niche (Pitt & Heady, 1978; Woodward & Williams, 1987; Peterson & Nakazawa, 2008). Annual mean temperature is the most studied parameter effectively contributing toward species survival at certain position while mean diurnal range define the temperature fluctuations often important in seed germination (Thompson *et al*., 1977). Mean temperatures of the warmest and coldest quarters play their role in seed germination, maturity and spread. In case of *Scutellaria chamaederfolia* the plant starts germination soon in March, actively grows in April and produce seed. At the end of May it completes seed dispersal. Precipitation of the coldest quarter is responsible for narrowing its range between the areas with least snowfall (Inouye *et al*., 2002).

Precipitation of the wettest month is another important variable, which indicated the species likelihood in the areas lying in monsoon range. One of the reasons that model predicted no area from Kohistan and Upper Kaghan valley as they were lying outside the monsoon range. Our results are in agreement with such other studies (Ohsawa, 1996; Marone *et al*., 2000). This may explain the species probable extinction from Chitral areas. Over all, species is adopted to a narrow climatic niche, where little change may leads the area unsuitable for plant survival.

Model success and predicted areas: GRASP has shown significant success regarding the predicted localities. Model performed best as ROC remained (0.99) describing model stability, r^2 =0.568 (more than half) and r=0.403 showing insignificant correlation among predictors. Lehmann *et al*. (2002) while applying the model on *Cyathea* found the predictions satisfactory lying in the similar range. Highest probability level was shown in mid ranges targeting the areas where species had been collected in past. Model also predicted new localities from the Amazai area of Haripur district adjoining the Buner District, Dubair area of Kohistan District along the borders of Swat and Shangla district (Fig. 3). Some of the recent reports from the adjoining areas of Swat support current predictions (Ilyas *et al*., 2013). The whole area from west to east make a continuous range with high probability value (0.9) reflecting the evolution and spread of *S. chamaedrifolia* from this region. The other important area outside of this range is Galiat area of Abbottabad district with p=0.8 at maximum. Despite through field visits no population could be found in this area, however a population has been reported from adjoining areas of Kunhar valley.

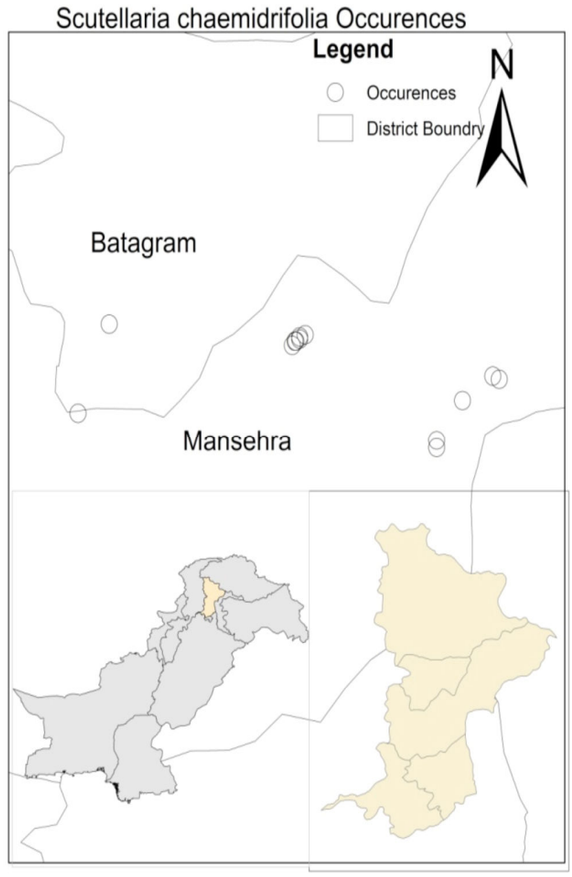

Fig. 3. Species occurrence records obtained through field surveys.

Suitable habitats for conservation and reintroduction: As is evident from prediction map (Fig. 4), central areas with highest distribution probability are most suitable, may be declared as conservation sites to cope with the future extinction for the species. Other marginal populations may also be protected if focus is made on the least disturbance of the ecosystem as deforestation, logging and land clearing for agriculture indirectly affect temperature and precipitation (Lewis & Wang, 1998; Betts, 2001). Current population can best be conserved declaring the predicted area as natural reserve with effective conservation measures. In this case, predicted un-fragmented habitats will be ideal as also suggested in some other studies (Seddon *et al*., 2007).

Future trends: Model predicted the middle range with highest probability while marginal areas with small value. Keeping in view the current increase in temperature, marginal areas would be more vulnerable which may result in narrowing down the species habitat. Keeping in view, the current environmental changes, species survival chances would be minimum within the area having low probability value ($p<0.5$). The other likely chance is species range shift toward higher altitude. The disappearance of the species from Chitral area is the indication of low survival potential.

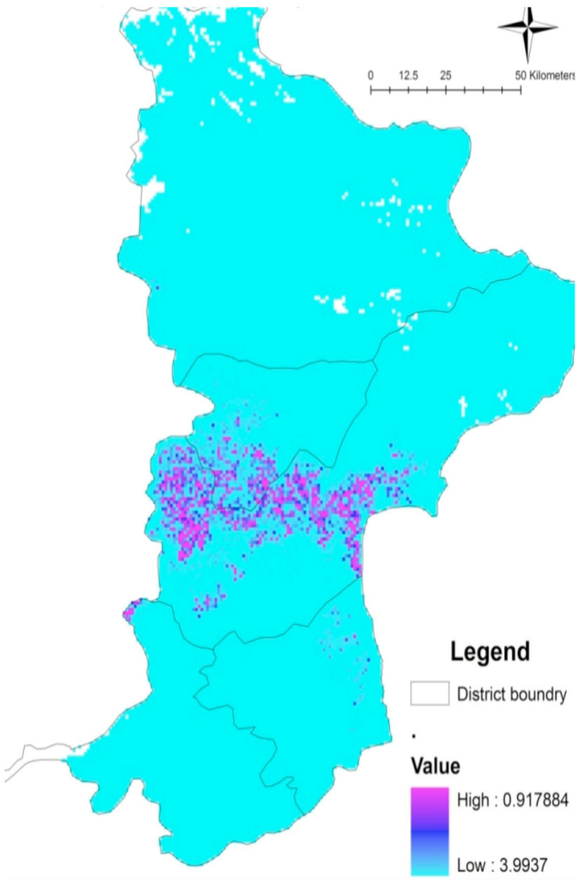

Fig. 4. Prediction map of *Scutellaria chamaedrifolia.*

Conclusion

Based on the current study, it can be concluded that *Scutellaria chamaedrifolia* occupy a narrow ecological niche where temperature and precipitation significantly affecting its survival. Keeping the current environmental scenario going on, species future range would become more narrow. For conservation of the species, establishment of conservation site at central ranges of the species habitat is imperative where plant can be used as flagship species.

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