Original Article

An Agro-ecological Zoning Model Highlighting Potential Growing Areas for Medicinal Plants in Punjab

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ABSTRACT

Background: The Ministry of AYUSH, Government of India has decided to emerge cultivation of medicinal plants as an attractive farming option due to a sharp increase in demand for medicinal plants. Punjab produces approximately twenty and nine percent of India's wheat and rice, respectively. At present, less than 1% of the state's land is under Medicinal and Aromatic Plant (MAP) cultivation. Agro-ecological zoning for potential medicinal plants is one of the major constraints faced by the farmers. The present study is aimed to determine the land potential for selected medicinal plants such as *Asparagus racemosus* Willd. and *Rauvolfia serpentina* (L.) Benth. ex Kurz. in Punjab. **Materials and Methods:** Agro-ecological aptitudes for the plants were defined by analysing the edaphic and climatological data of the past years. Base maps of rainfall, temperature, benchmark soil were prepared, defined and superimposed using Arc. GIS 10.3 to highlight optimally suitable, suitable and lesser suitable zones for selected medicinal plants. **Results and Discussion:** *Asparagus racemosus* Willd. was: Optimally suitable to zones-II, III; Suitable to I; Lesser suitable to zone IV and V. Similarly, *Rauvolfia serpentina* (L.) Benth. ex Kurz, was: Optimally suitable to zone I; Suitable to II and III; Lesser suitable to IV and V. **Conclusion:** This agro-ecological zoning model can act as a baseline study for other medicinal plants with same or different bioclimatic indices and can be used in any part of the world for determining potential growing areas for new crops.

Key words: Agro-climatic zoning, *Asparagus racemosus* Willd., Geographical Information System, *Rauvolfia serpentina* (L.) Benth. ex Kurz.

INTRODUCTION

Punjab is an Indian state located between 29'30" N to 32'32" N latitude and 73'55 E to 76'50 E longitude in the north-west of the Indian subcontinent.[1,2] Punjab falls in the Agro Climatic Zone-VI, which is called the "Trans-Gangetic Plains Region".[3] Most of Punjab lies in the fertile plain; toward the southeast one finds semi-arid and desert landscape; a belt of undulating hills extends along the northeast at the foot of the Himalayas.[4,5] Two-third of the total production of the food grain is contributed by Punjab.[6] As per WHO (World Health Organization), 60-80% of the world's population seeks plants or plant-derived natural products for the prevention and curing of various diseases.[7] The Ministry of AYUSH has decided to emerge medicinal plants as an attractive farming option in view of generating income for farmers (https://pib.gov.in/PressReleseDetailm.aspx?PRID=1624153). At present, Punjab has only 12.52000 Ha of its total area under MAP (Medicinal and Aromatic Plants) out

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of which 2.43000 MT is the production which is far less than its potential.[8,9] The lack of knowledge among farmers regarding the potential growing zones for medicinal plants in Punjab is the major bottleneck that can be addressed by mapping climatic and land pattern data with the ecological requirements of the selected medicinal plants.

Asparagus racemosus Willd. (Shatavari) belonging to the family Asparagaceae is a spinous under-shrub, highly branched, woody climber, with length ranging from 1-2 m.[10] The roots are tuberous with longitudinal wrinkles tapering at the ends having length and thickness of 10-20 cm and 0.1-0.5 cm respectively.[11] Roots of Shatavari are described in ancient Ayurvedic texts for treatment and prevention of dyspepsia, gastric ulcers and acting as a galactagogue.[12-14] Due to its huge pharmacological potential, it is known as the "Queen of herbs" in Ayurveda.[15] *Rauvolfia serpentina* (L.) Benth. ex Kurz (Sarpgandha) is another perennial, erect evergreen undershrub with 75 cm to 1 m height belonging to the Apocynaceae family that originated from South-East.[16] Sarpgandha is popularly known as Indian snakeroot, because of its effectiveness against snake and reptiles bites.[17] The root of the plant tuberous usually branched, 8 to 15 cm long and 0.5 to 2.5 cm in diameter.[18,19] Roots of Sarpgandha are used by various ethnic groups to treat mental illnesses such as schizophrenia, hypertension, pneumonia, malaria, asthma, scabies, AIDS and rheumatism.[20]

In the present work, the authors have devised the agro-ecological zoning model for commercially important medicinal plants i.e. Shatavari and Sarpgandha in Punjab, employing Geographic Information System (GIS). The model highlighted optimally suitable, suitable and lesser suitable zones for plants by identifying their bio-climatic needs and analyzing climatic (temperature, rainfall) and edaphic data (soil pH, texture) of Punjab.

MATERIALS AND METHODS

Collection of meteorological data

To define temperature and rainfall zones, meteorological data was collected from the available meteorological stations in Punjab. Annual temperature and rainfall records were analysed after obtaining the climatic data from IMD (Indian Meteorological Department) and PAU (Punjab Agricultural University) meteorological research stations present. The temperature records were collected from 08 research stations, similarly rainfall data was collected from 12 research stations present in Punjab. Depending upon the availability of meteorological data in the stations, the period for the meteorological record was selected.

Preparation of base maps

The base maps were digitalized online and digital information layers were created using GIS Arc.GIS 10.3 software. The climatic data obtained from the different meteorological stations were utilized for the preparation of temperature and rainfall digital base maps. The thermal regime was defined by the average annual temperature and similarly, the moisture regime was plotted based on annual rainfall data. The research stations from where meteorological data was collected were geo-tagged using their latitude and longitude specifications on digital maps using GIS. On the other hand, an agro-eco-subregion based benchmark soils network was utilized for the preparation of digital soil maps based on texture and pH. In the agro-eco-subregion model, soils in the same family generally required the same management practices and maximum production result acquired from a soil family can be utilized as production targets of other soils belonging to the same family.[21-23] The base maps for temperature, rainfall and soil were integrated with agro-ecological zones map of Punjab delineated by ENVIS center, Punjab (http://punenvis.nic.in/index1.aspx?lid=5617&mid=1&langid=1&linkid=1257). All the base maps were superimposed to highlight optimally suitable zone (having all the climatic and edaphic parameters common with the bio-meteorological requirements of selected medicinal plants), suitable zone (having only two parameters common with the bio-meteorological needs of selected medicinal plants) and lesser suitable zone (having only one parameter common with the bio-meteorological need of the plant).

RESULTS AND DISCUSSION

The climatic data *viz:* temperature and rainfall obtained from the research stations is described in Table 1 and 2. The maximum average temperature i.e. 31.3 was observed in the research station present in the Bathinda district of Punjab represented in zone-IV, similarly the minimum average temperature i.e. 15.5 was observed in the research station present in Amritsar district of Punjab represented in zone-II.

In the temperature base map, the meteorological station present in the specific agro-climatic zone represented the temperature range of the particular agro-climatic zone as mentioned in Figure 1. The cropping pattern in Punjab is divided into Kharif and Rabi season representing the

sowing of crops at the beginning and the end of the rainy season respectively.[24] Two major crops of Punjab i.e. Rice and Wheat are sown in Kharif and Rabi season respectively. As per the reports, the mean maximum temperature during the Rabi and Kharif season was 25°C and 38°C respectively. However, the mean maximum and minimum temperature can reach 44°C and 8°C minimum. Long term historical meteorological analysis, of Punjab, revealed that the frequency of occurrence frost was limited to only two days in December, five days in January and one day in February.[25] The bibliographic data for the selected plants suggested their tolerance to these extreme conditions.[26] The Indian climate is mainly characterized by monsoon rainfall as supported by several studies.[2]

Rainfall data collected from the research stations ranged from 350-1500 mm as represented in Figure 2 and most of the rainfall is received during the southwest monsoon occurring from June to September. There is a high variability of rainfall in space and time in Punjab. The annual rainfall variability in Punjab is 25 to 30 percent while monthly variability ranges between 35 to 230 percent.[27] The zone-I represented the highest level of rainfall ranging from 1000-1500 mm followed by Zone-II, III, IV and V. Zone-V represented the lowest range of rainfall in Punjab covering south western districts of Punjab such as Fazilka.

The agro-eco-subregion based benchmark soils highlighted that zone-I was dominated with sandy skeletal, loamy sand to sandy loam. Similarly, sandy loamy to clay was dominated in zone-II and sandy loam to silt calcareous dominated in zone-III and sand to loamy sand to calcareous dominated zone IV and V as represented in Figure 3. Similarly, the soil pH in Punjab encompassed a range from 6.8 to 9.3. The undulating mountainous zone-I represented the range between 7.5 to 8.2, similarly, zone II, III IV and V represented pH ranges of 6.8-8.3; 7.5-9.3; 8.1-8.5 respectively.

Agro-ecological zoning model

Shatavari is found throughout tropical to sub-tropical parts of the country up to 2000 m. It can also be grown in a sub-temperate agro-climatic region up to 1400 m. It required a temperature range between 17-40°C as it

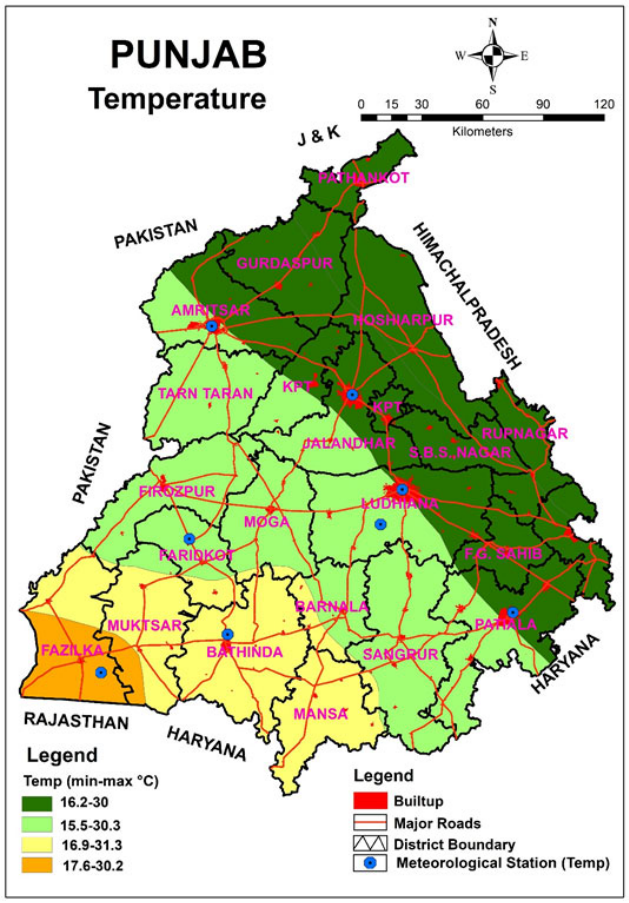

Figure 1: Spatial distribution of meteorological research stations representing average maximum and minimum temperature ranges.

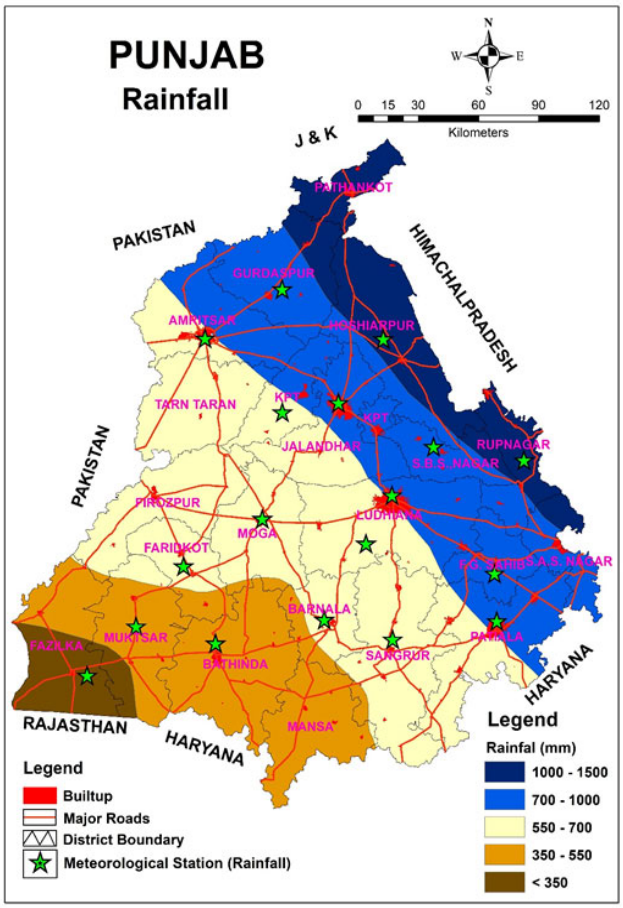

Figure 2: Spatial distribution of meteorological research stations representing average rainfall ranges.

responses well to hot and tropical climate.[28] Shatavari is a perennial plant and its seeds are sown in April for raising the nursery and 15-25°C is required for good spear development. Subsequently, the temperature should not be less than 8°C for better germination of seeds.[26,29] Sowing of Shatavari can be done from March till October and harvested in May and June after 1.5 years.[28] After observing the monthly mean minimum and maximum annual temperature from April to October, the temperature remained suitable for its cultivation. Subsequently, it required annual rainfall from 600-1000 mm that was optimum to zone-II and III of Punjab. Similarly, sandy loam to clay loam soil with pH 6-8 is best suited for the cultivation of Shatavari.[30] According to the present agro-ecological zoning model, Shatavari was: Optimally suitable (15.5-30.3°C; rainfall 550-1000mm; Sandy skeleton, loam to clayey loam to silt clay and calcareous with pH range 6.8-9.3) corresponding to agro-climatic zones II, III; Suitable (16.9-30°C; rainfall 1000-1500mm; sandy to loamy sand and calcareous with pH 7.5-8.2) corresponding to zone I; Less suitable (16.9-30.0°C; rainfall 550 to less than 350; sandy to loamy sand and calcareous with pH 8.1-8.5) corresponding to zone IV and V. Therefore, for the cultivation of Shatavari, zone-II and III were optimally suitable, followed by zone I which is suitable and received higher annual rainfall as compared to the requirement of the plant. Subsequently, zone III and IV were lesser suitable zones for Shatavari as the zones satisfied only the temperature conditions of the plant as represented in Figure 4.

Based on available bibliographic data, the climatic requirements for Sarpgandha were identified. It is a perennial plant that can be grown under a diverse range of climates.[19] However, it prefers hot humid conditions. Sowing of Sargandha seeds starts from April to June and the plant is harvested after 18 months. Sarpgandha was best suited in a temperature range between 10-38°C with rainfall requirement from 1100 to 4000 mm annually. Sandy loam to clay-loam soil with 6-8 pH is highly suited for the plant.[31,32] The bio-meteorological requirements and climatic conditions for the plant suggested that it was: Optimally suitable (16.2-30°C; rainfall 1000-

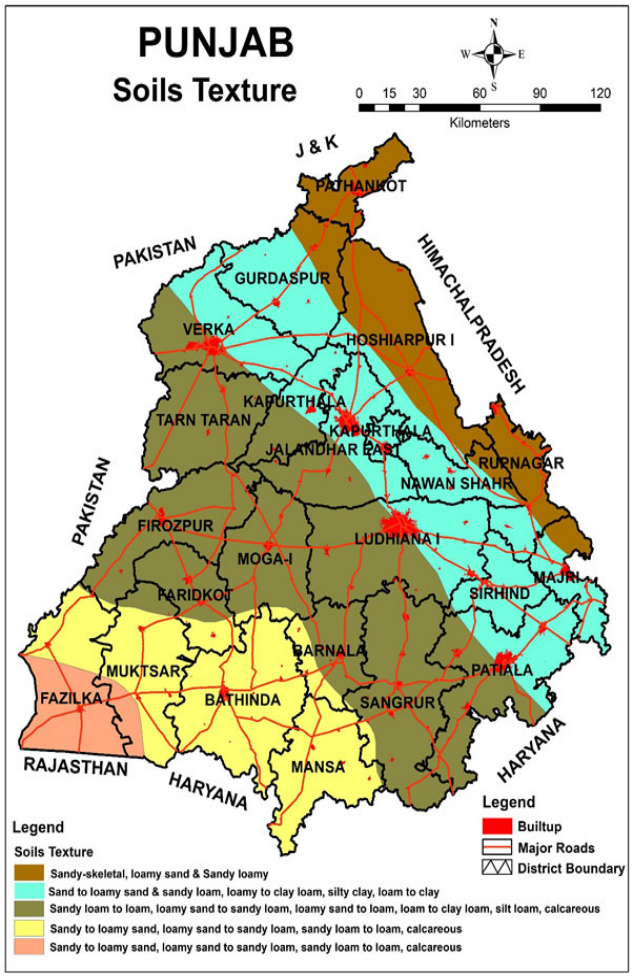

Figure 3: Soil texture of benchmark soils present in Punjab.

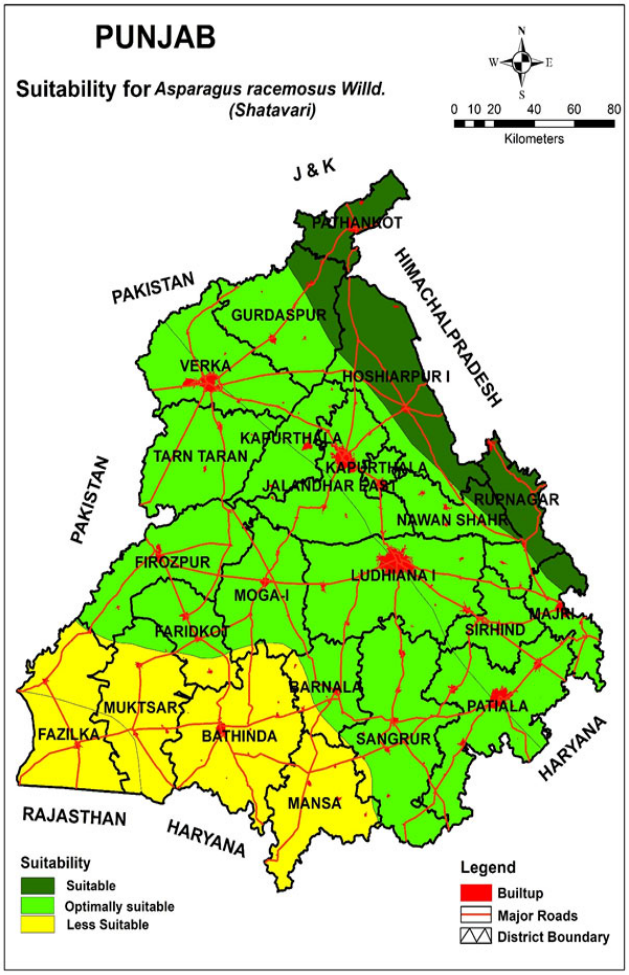

Figure 4: Potential growing zones for Shatavari in Punjab.

Table 1: Research stations with temperature ranges in Punjab.

Research stations	Location co-ordinates of research stations	Period of collected data	Representing Agro-climatic zone	Average maximum and minimum temperatures ranges (°C)
Ballowal Saunkri	31.0993°N, 76.3870° E	1984-2015	Zone-I and II	16.2-30.0
Amritsar	31.6340°N, 74.8723° E	1970-2018	Zone-II and III	15.5-30.3
Jalandhar	31.3260°N, 75.5762° E	1971-2015	Zone-II and III	16.4-29.3
Ludhiana	30.9010°N, 75.8573° E	1970-2018	Zone- II and III	16.7-29.8
Patiala	30.3398°N, 76.3869° E	1970-2018	Zone-II and III	17.6-30.2
Bathinda	30.2110°N, 74.9455° E	1977-2015	Zone-IV	16.9-31.3
Faridkot	30.6769°N, 74.7583° E	2000-2015	Zone-IV	20.3-29.9
Abohar	30.1469°N, 74.2008° E	2004-2015	Zone-V	17.6-30.2

Table 2: Research stations with rainfall ranges in Punjab.

Station	Location co-ordinates	Period of collected data	Total rainfall (mm)	Representation of agro-climatic zone	Annual Rainfall Range (mm)
Ballowal Saunkri	31.0993°N, 76.3870° E	1984-2015	1049	Zone-I and II	1000-1500
Roopnagar	30.9661°N, 76.5231°E	2004-2018	1005		
Gurdaspur	32.0414° N, 75.4031° E	2002-2018	1063		
Jalandhar	31.3260°N, 75.5762° E	1971-2018	990	Zone-II and III	550-1000
Amritsar	31.6340°N, 74.8723° E	1970-2018	722		
Patiala	30.3398°N, 76.3869° E	1970-2018	774		
Ludhiana	30.9010°N, 75.8573° E	1970-2018	759		
Nawashahr	31.1256° N, 76.1186° E	2004-2018	749		
Bathinda	30.2110°N, 74.9455° E	1977-2018	517	Zone-IV	350-550
Faridkot	30.6769°N, 74.7583° E	2000-2018	468		
Mukstar	30.4762° N, 74.5122° E	2004-2018	368		
Abohar	30.1469°N, 74.2008° E	2004-2015	323	Zone-V	<350

1500mm; Sandy skeleton loamy sand to sandy loam pH range 7.5-8.2) corresponding to agro-climatic zone I; Suitable (15.5-30.3°C; rainfall 550-1000mm; sandy to loamy sand, silt clay-loam and calcareous with pH 6.8-9.3) corresponding to zone II and III; Less suitable (16.9-31.3°C; rainfall <350-550 mm; sandy to loamy sand and calcareous with pH 8.1-8.5) corresponding to zone IV-V as represented in Figure 5.

Wheat-rice cropping pattern is reliant on underwater resources, extensive use of chemical fertilizers, pesticides and agricultural machinery leading to massive exploitation of natural resources.[33] Sustainable and rational use of land has become the key issue for policymakers, government and land users for preserving the resources for present and future generations. In view of the above, Punjab required potential crops for diversification that can be achieved through agro-ecological zoning studies to highlight potential growing areas for new crops especially the medicinal plants.[34,35] Medicinal plants are reported to have an important ecological role that helps check runoff, erosion, purify water and controls flooding. Many studies related to the development of the agro-ecological zoning model have been conducted in past. In the year 2012, Falasca and co-workers have established a suitable agro-ecological zoning model to determine production areas of castor bean. The study utilized meteorological data such as average temperature, annual rainfall, frost-free days for highlighting suitable production zones of the crop.[36] Similarly, potential growing areas for *Cyamopsis tetragonoloba*, *Acrocomia aculeate, Lesquerella fendleri* (a multipurpose oilseed crop), *Jatropha curcas*, *Salicornia bigelovii* and *Camelina sativa*, *Panicum virgatum* and *Argania spinosa* (L.) Skeels were highlighted in different zones of Argentina.[37-45] Most of the studies on the agro-climatic zoning model were limited to analyzing the meteorological data such as temperature, rainfall, frost-free days, etc. for highlighting potential zones, however, the inclusion of significant land pattern data like soil texture and pH could have added more strength to the work. Since benchmark soil network

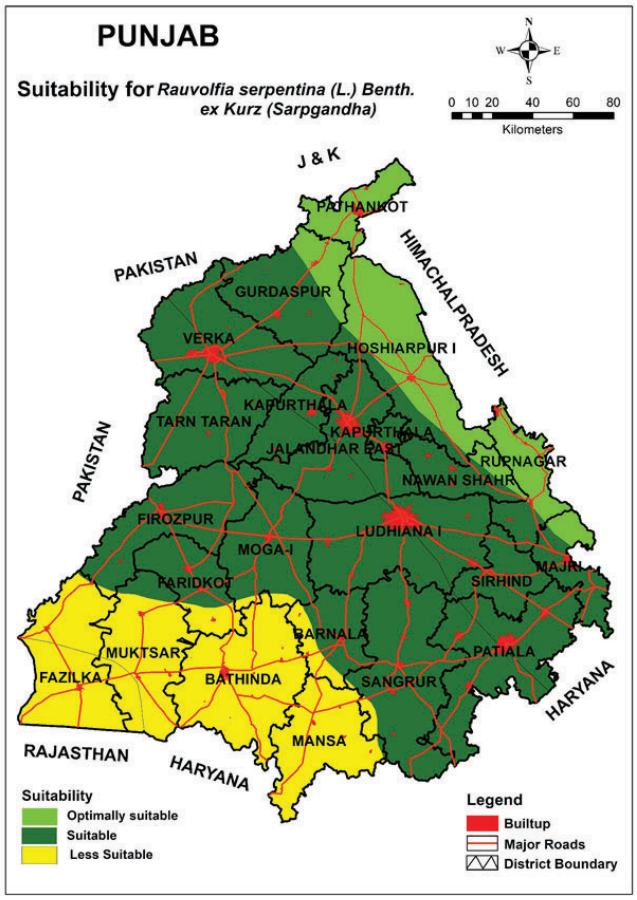

Figure 5: Potential growing areas for Sarpgandha in Punjab.

based on soil texture and pH had played a pivotal role in determining the land potential for selected medicinal plants, consideration of both meteorological as well as land pattern data was the major advantage of the present study. The present study was limited to the climatic data available at research stations, however, the findings could have been more specific if more meteorological stations were set up in the state. The study was limited to the findings based on temperature, rainfall, soil pH and texture, however other climatic and edaphic variables can be considered in future studies taking this model as a case study. Besides following this agroecological model, the authors recommend proper agronomic management based on GAP (Good Agricultural Practices) guidelines of selected medicinal plants.

IITM, Pune prepared PRECIS (Providing Regional Climates for Impact Studies) model having simulated baseline (1961-1990) and simulated mid to end century (2021-2100) climatic data for different agro-climatic zones was downscaled to check the projected climatic variability in Punjab. The model analyzed the changes in temperature and rainfall by mid (2021-2050) and (2071-2100) under different scenarios classified as A1B (describing the future world of rapid economic growth), A2 (describing heterogeneous world), B2 (describing world emphasizing on local solutions to social, economic and environmental sustainability). The temperature trend analysis revealed that by the end of the 21st century, the maximum temperature is expected to increase at the rate of 0.07 to 0.02°C/year under different scenarios of research stations. On the other hand, by the end of the 21st century, rainfall trend analysis revealed that rainfall in expected to increase at the rate of 14.42, 10.36 and 10.95 mm/year under A1B, A2 and B2 respectively at Ballowal Saunkhri research station. Similarly, a 7 mm/year maximum increase is the predicted rainfall in other research stations present in Punjab.[25] As the projected climatic variability in Punjab had no significant effect on the climatic conditions of Punjab in context to the bio-climatic requirements of selected medicinal plants, it can be assumed that the present agro-ecological zoning model would be suitable up to at least 50 years for the domestication of selected medicinal plants.

CONCLUSION

Based on the literature, the authors delineated the agro-ecological zoning model resulting in determining potential growing areas of selected medicinal plants in Punjab. Agro-climatic zones II and III comprising of Gurdaspur, Taran Taran, Kapurthala, Jalandhar, Patiala, Sirhind, Ludhiana, Moga, Barnala, etc. districts of Punjab were highlighted as potential land growing areas for cultivation of Shatavari. Similarly, the land of Pathankot, Hoshiarpur, Roopnagar districts of Punjab classified under zone-I, were considered optimally suitable for the cultivation of Sarpgandha. Furthermore, zone-IV and V comprising of Bathinda, Mansa, Mukstar and Fazilka districts were found lesser suitable for the cultivation of selected plants due to inappropriate rainfall and soil ranges. Using bio-meteorological limits, the model presented in this work can be applied to different parts of the world to assess the feasibility of the cultivation of specific medicinal plants in a particular area.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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ABBREVIATIONS

AIDS: Human immunodeficiency virus infection and acquired immune deficiency syndrome; **AYUSH:** Ayurveda, Yoga and Naturopathy, Unani, Siddha and Homeopathy; **Cm:** centimetre; **GIS:** Geographic information system; **Ha:** Hectare; **i.e.:** that is; **IMD:** Indian meteorological department; **IITM:** Indian institute of tropical meteorology; **m:** Meter; **MAP:** Medicinal and aromatic Plants; **mm:** Millimetre; **MT:** Metric ton; **PAU:** Punjab agricultural university; **pH:** Potential of hydrogen; **PRECIS:** Providing regional climates for impact studies; **%:** per cent; °C**:** Degree Celsius; **WHO:** World health organization.

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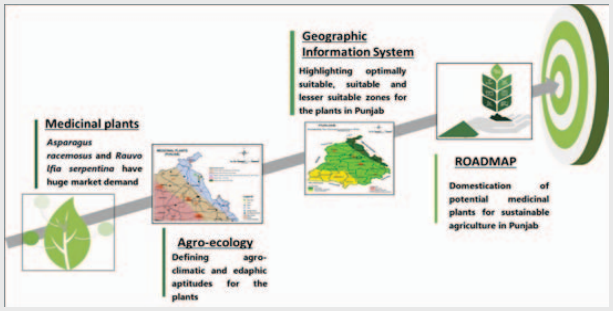
PICTORIAL ABSTRACT



SUMMARY

Punjab has less than 1% of its agricultural land under Medicinal and Aromatic Plants cultivation. Identification of potential areas for cultivation of medicinal plants is one of the major constraints faced by the farmers. In the present study, potential growing areas for *Asparagus racemosus* Willd. and *Rauvolfia serpentina* (L.) Benth. ex Kurz. has been identified in Punjab using climatic as well as land pattern data for the past years. With the help of GIS, base maps of temperature, rainfall, benchmark soils were made and it was found that *Asparagus racemosus* was optimally suitable to zones-II, III; Suitable to I; Lesser suitable to zone IV and V. Similarly, *Rauvolfia serpentina* (L.) Benth. ex Kurz, was: Optimally suitable to zone I; Suitable to II and III; Lesser suitable to IV and V.

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