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ORIGINAL ARTICLE

Habitat distribution modeling for conservation of *Rheum australe* D. Don in Himalayas

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Abstract

Rheum australe, an important medicinal plant from the Polygonaceae family, is primarily found across the Himalayas. However, due to overharvesting, its population has witnessed a substantial decline. The present study aims to predict the present and future favorable distribution of *R. australe* in the Himalayan region by employing the Maxent species distribution model. According to the model output, the optimal habitat for cultivating *R. australe* in the North-West Himalayas spans approximately 75,409 km^2. However, our projection model for the year 2050 indicates a reduction in this habitat area, showing the most advantageous geographical distribution to be around 59,612 km^2. While the projected future distribution of *R. australe* remains largely similar to its current distribution, the model results highlight a decline of 20.94% in the area deemed highly suitable for its growth. The key predictors determining its distribution include Mean Temperature of Coldest Quarter (bio 11), Annual Mean Temperature (bio 1), and Precipitation of the warmest quarter (bio 18).

Keywords: *Rheum australe*, Maxent, Species distribution, bio 11, bio 1

Introduction

Nature has been a source of medicinal treatments for thousands of years, and plant-based system continues to play an essential role in primary health care of 80% of world's population (Gupta 2001). In the beginning, these were the main source of the folk or ethnomedicine (Bargali and Shrivastava 2002). Plants are important repositories of terrestrial biodiversity and play a key role in influencing socio-ecological (Bargali *et al.* 2003) and cultural attributes of human societies including livelihood activities and health care of traditional societies living as well as associated to these forests (Hermann 2006; Awasthi *et al.* 2022; Bargali *et al.* 2014 and 2015). In developing countries, a large number of people depend on products derived from plants for curing human and livestock ailments (Parihaar *et al.* 2014; Padalia *et al.* 2015; Vibhuti *et al.* 2022).

The global demand for medicinal plants has surged, driven by the growing popularity and acceptance of herbal medicines. This escalating demand is primarily satisfied through extensive harvesting of medicinal plants and their components from wild populations. Unfortunately, the harvesting techniques employed are often unstructured and lack refinement. This leads to an accelerated rate of natural habitat destruction, and the exploitation rates risk exceeding the pace of local natural regeneration (Hanski, 2011).

Most medicinal plants are sourced directly from the wild, leading to a significant reduction in numerous species populations within their natural habitats due to persistent commercial exploitation. Poverty, population pressure, agricultural expansion/intensification and infrastructural development have also been the major threats to biodiversity, habitat loss and environment (Baboo *et al.* 2015; Bisht *et al.* 2022 and 2024; Manral *et al.* 2020;). Overexploitation of the natural resources like plants has created a big gap between the demand and supply of the natural resources (Kumar *et al.* 2023). Notably, only a minimal portion of these plants are cultivated and harvested sustainably, while a staggering 90% of the material originates from the wild. The destructive harvesting practices account for 70% of this collection, with

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various parts of the plants - including roots, barks, twigs, flowers, leaves, fruits, seeds, and the entire plant - being harvested for use in herbal remedies (Suman 2006). As a result of this rampant commercial exploitation coupled with burgeoning international trade, the Threatened Plants Species Committee of Survival (TPSSC) of the International Union for Conservation (IUCN) now estimates that one in ten species of vascular plants worldwide are either endangered or threatened. This grim situation is further underscored by reports (Bhardwaj and Sood, 2022; Maikhuri *et al.* 2000; Nautiyal *et al.* 2003;) suggesting that nearly 60,000 plant species could face extinction within the next 30-40 years due to gene erosion.

Rheum australe D. Don (Polygonaceae) is a high altitude threatened medicinal plant commonly known as "Revandchini" (Bhardwaj and Sood, 2022). Though an official IUCN assessment for *R. australe* remains unavailable, various reports categorize the plant as threatened (Bhardwaj and Sood, 2022; Kumar *et al.* 2023). The natural population of the species faces a significant threat due to human activities, thereby impacting its natural regeneration process. The plant's roots are rich in several anthraquinones derivatives such as emodin, emodin 3-monoethylether, chrysophanol, and rhein, and have purgative, astringent, tonic, stomachic, and aperient properties (Nautiyal *et al.* 2003). The petioles of *R. australe* are pickled, and its powdered roots are used for dental hygiene and as an effective treatment for ulcers (Nautiyal *et al.* 2003). Moreover, the plant is particularly beneficial in addressing infant stomach issues and has been identified as a potent anti-inflammatory drug (Chauhan, 1999; Nautiyal and Nautiyal, 2004). Given these attributes, the species is in high demand, resulting in overharvesting from its natural habitats and consequent habitat destruction.

The application of suitable ecological methods, such as phytosociological analysis and environmental niche modeling, plays a crucial role in preserving and conserving the natural populations of endangered species. However, without a clear understanding of the population status, habitat distribution, and climatic preferences of *R. australe*, it proves challenging to formulate effective measures and management strategies for its conservation, cultivation, or reintroduction. Due to increasing demand in traditional and modern systems of medicine, *R. australe* is overexploited in their natural habitats (Kumar *et al.* 2023). Despite being an important species, there is a lack of information on suitable habitat distribution range. This study, therefore, sets forth the following objectives: (1) to construct a habitat suitability map and predict suitable habitats for reintroduction and conservation under current climatic conditions; (2) to conduct an area change analysis under future climatic conditions projected for 2050; and (3) to identify the influence of various environmental factors on habitat suitability through a jackknife-based analysis.

Methodology

Study Area

The study has been done to predict the present and future favorable distribution area of *R. australe* in the Himalayas. The Himalayan Mountain range is located between the Indian Subcontinent in the south and the Tibetan Highland in the north, and extends from Afghanistan in the northwest (c. 36°N and 70°E) to Yunnan in the southeast (c. 26°N and 100°E) (Bobrowski *et al.* 2017).

The Himalayan mountains show a distinct three-dimensional geoecological differentiation, with a high variation of climate, rainfall, altitude, and soils (Troll, 1972; Zurick and Pacheco, 2006). The climate ranges from tropical in the Indian lowlands to permanent ice and snow at the highest elevations and from more continental in the NW to more oceanic in the SE. The amount of annual precipitation increases with increasing monsoonal influence in the same direction along the southern front of the range (Bohner *et al.* 2015; Schickhoff, 2005). The small-scale heterogeneity of habitats and site conditions supports a high diversity of species and communities.

Occurrence data collection

Primary occurrence data for model building and evaluation were collected through field surveys in different parts of Western Himalayan Region. We also obtained occurrence records from the web resource of Global Biodiversity Information Facility (http://www.gbif.org) and published literature (Bhardwaj and Sood, 2022; Mala *et al.* 2021; Pandith *et al.* 2018; Shrestha *et al.* 2022;). The coordinates of all the occurrence points obtained through field surveys were recorded to an accuracy of ≤ 10 m using a Global Positioning System (GPS) (Garmin). These coordinates were then converted to decimal degrees for use in modeling the distribution of habitats of the species. To avoid spatial autocorrelations, only one location per grid (1km ×1km) was used in modeling. Finally, a total of 56 occurrence points of *R. australe* were compiled and included in this study to model current and future potential distribution of the species.

Climatic data

Bioclimatic variables (Booth *et al.* 2014; Hijmans *et al.* 2005) with 30 seconds spatial resolution, downloaded from World Clim dataset (www.worldclim.org) were used in the present study. The WorldClim data (for the period from 1950 to 2000) are compiled from measurements of temperature and precipitation collected from weather stations worldwide. These data are often used in species distribution modeling (Kumar and Stoghlgren 2009; Sanchez *et al.* 2011; Khanum *et al.* 2013; Adhikari *et al.* 2015). The 19 bioclimatic variables from the WorldClim dataset were used to assess current climatic conditions. These variables are frequently used in modeling species distributions (Kumar *et al.* 2009;Evangelista *et al.* 2011; Sanchez *et al.* 2011), and capture annualranges, seasonality, and limiting factors such as monthly and quarterly temperature and precipitation extremes (Hijmans *et al.* 2005).Future climate scenario data for 2050 (A2a emission scenario) were obtained from Consultative Group on International Agricultural Research (CGIAR)'s Research Program on Climate Change, Agriculture and Food Security (CCAFS) climate data archive (http://ccafsclimate.org). These future climate projections are based on IPCC 4th assessment data and were calibrated and statistically downscaled using the data for 'current' conditions.

Predictive modeling

The habitat model was constructed using the Maximum Entropy Distribution software, Maxent version 3.3.3 (Phillips *et al.* 2006; http://www.cs.princeton.edu/wschapire). This selection is based on the model's superior performance with small sample sizes compared to other modeling methods (Elith *et al.* 2006; Pearson *et al.* 2007; Kumar and Stohlgren, 2009). Maxent, which is based on the principle of maximum entropy, utilizes presence-only data to predict species distribution, while aiming to estimate a probability distribution of species occurrence that aligns as closely as possible with uniformity but is still subject to environmental constraints (Elith *et al.* 2011). The Maxent model inherently includes variable interactions and can manage both continuous and categorical predictor variables. It employs a set of features, such as linear, quadratic, product, threshold, and hinge, which are functions of environmental variables that limit the geographic distribution of a species. Additionally, it utilizes an empirically determined regularization parameter to prevent model overfitting.

This software generates a likelihood estimation for the presence of species, providing a range from 0 to 1, where 0 signifies the lowest probability and 1 indicates the highest probability. Of the 56 records, seventy-five percent were used for model training and twenty-five percent for testing. To validate the model robustness, 10 replicated models runs for the species with a threshold rule of 10 percentile training presence was executed. In the replicated runs, cross validation technique was employed, where samples were divided into replicate folds and each fold was used for test data. Other parameters were set to default as the program is already calibrated on a wide range of species datasets (Phillips and Dudík 2008). From the replicated runs average, maximum, minimum, median and standard deviation were generated. Jackknife procedure and percent variable contributions were used to estimate the relative influence of different predictor variables. Receiver operating characteristics (ROC) analyses the performance of a model at all possible threshold by a single number called, the area under the curve (AUC). AUC is a measure of model performance and varies from 0 to 1 (Fielding and Bell 1997). Higher AUC values correspond to better model quality and accuracy. The Area under the ROC curve was used to evaluate model performance.

Results

The Maxent model for *R. australe* exhibited strong performance, boasting an average AUC value of 0.955 (Fig. 1). In an effort to reduce potential inaccuracies in species occurrence data, any duplicated records were removed. The model predicts the North West Himalaya to be the most suitable habitat, with a significant area of 75,409 km^2 deemed highly suitable (Fig. 2a and 2b). The relative contributions of each predictor variable in the Maxent model for the distribution of *R. australe* shows that the Mean Temperature of the Coldest Quarter (bio 11), Annual Mean Temperature (bio 1), and Precipitation of the Warmest Quarter (Bio 18)

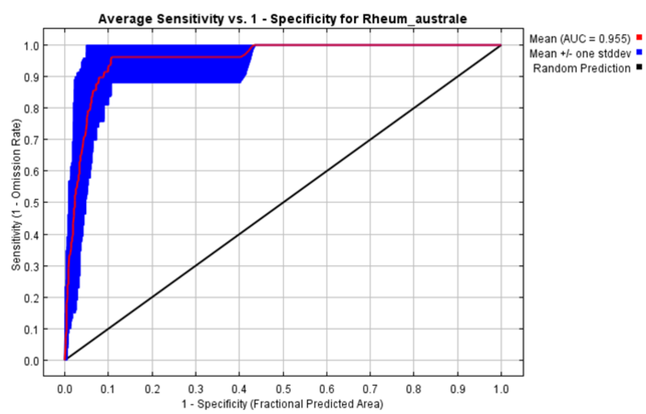

Figure 1: Result of AUC in developing habitat suitability model for *R. austrlae*

Table 1: Selected environmental variables and their percent contribution in maxent model for *R. australe*

Environment Variables	*Percent Contribution*
Mean Temperature of Coldest Quarter (Bio 11)	26.5
Annual Mean Temperature (Bio 1)	19.3
Precipitation of Warmest Quarter (Bio 18)	19.1
Temperature Annual Range (Bio 7)	12.9
Precipitation Seasonality (Bio 15)	7
Precipitation of Driest Quarter (Bio 17)	6.9
Mean Temperature of Driest Quarter (Bio 9)	1.9
Precipitation of Driest Month (Bio 14)	1.4
Precipitation of Wettest Month (Bio 13)	1.2
Annual Precipitation (Bio 12)	1.1
Precipitation of Coldest Quarter (Bio 19)	1
Isothermality (Bio 3)	0.9
Mean Diurnal Range (Bio 2)	0.5
Min Temperature of Coldest Month (Bio 6)	0.2
Temperature Seasonality (Bio 4)	0.1

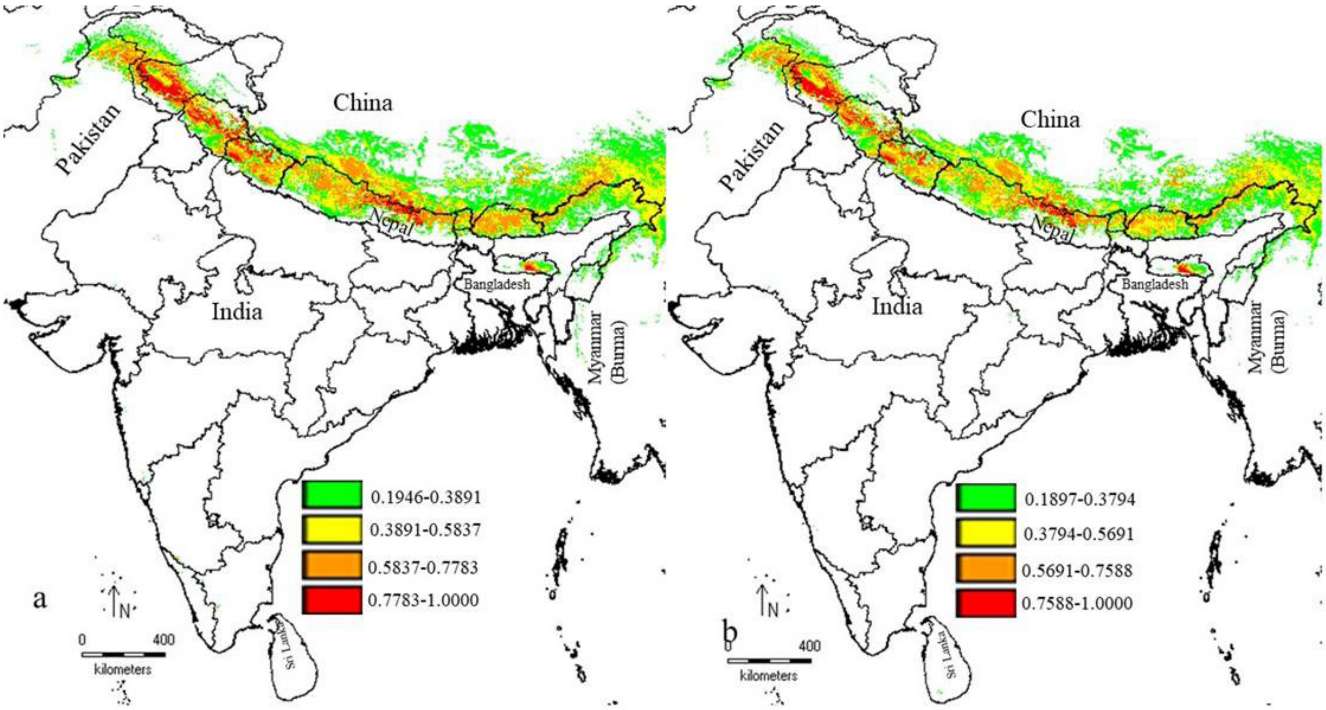

Figure 2: Predicted current (a) and future (b) potential suitable habitat of *R. australe*

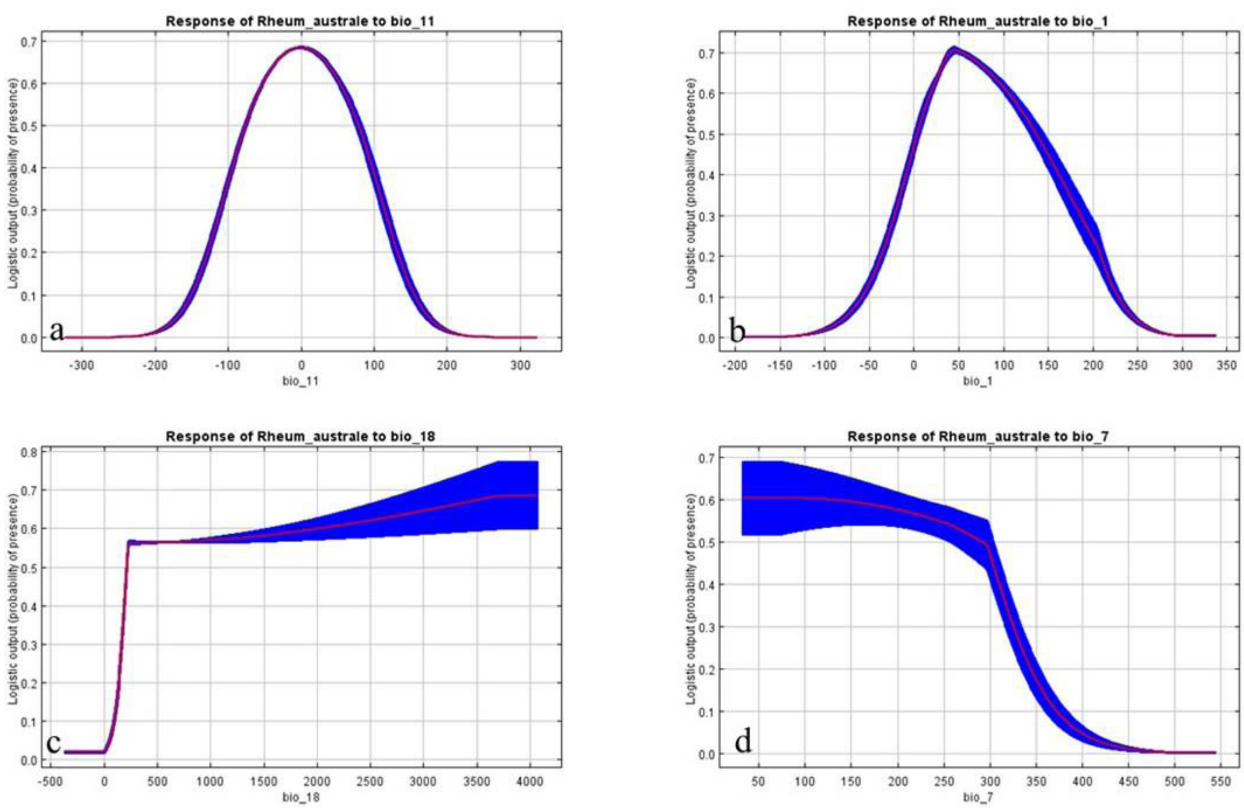

Figure 3: Response curves showing relationships between probability of presence of a species and top bioclimatic predictor of *R. austrlae*(a) Precipitation of wettest quarter (Bio 11); (b) Annual Mean Temperature (Bio 1); (c) Precipitation of Warmest Quarter (Bio 18); (d) Temperature Annual Range (Bio 7)

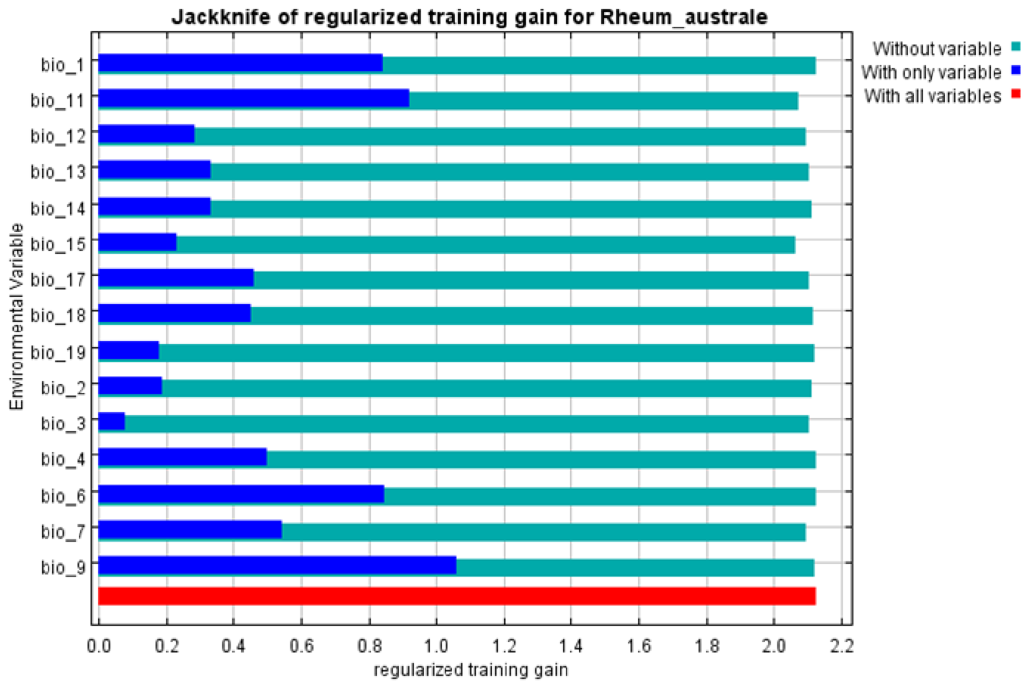

Figure 4: Relative predictive power of different bioclimatic variables based on the jackknife of regularized training gain in maxent model for *R. austrlae*

emerged as the most potent predictors for the distribution of *R. australe*, with contributions of 26.5%, 19.3%, and 19.1% respectively (Table 1). The presence probability of *R. australe* was found to rise with an increase in Precipitation of the Warmest Quarter (Fig. 3). The comparative importance of distinct environmental variables, as tested through Maxent's jackknife results (Fig. 4) shows that the temperature-based variables consistently outperformed precipitation-based variables in predicting the distribution of *R. australe*. This pronounced preference for temperature-based climatic parameters indicates that *R. australe* responds significantly to these factors, which are crucial for its distribution.

When compared to the currently predicted most suitable habitat area of 75,409 km^2, the future prediction model for 2050 (under the A2a emission scenario) indicates a reduction in habitat, as illustrated in Figure 2b, with an optimal geographic distribution measuring 59,612 km^2. While the prospective distribution of *R. australe* closely mirrors the existing potential distribution, the model's findings suggest a decrease in highly suitable habitat by 20.94% in terms of area.

Discussion

The natural populations of *R. australe* have experienced considerable depletion due to overharvesting, increased human activities, and shifting climatic conditions in their habitats. Species like *R. australe*, which possess recognized economic value, face dual pressures: 1) habitat loss resulting from rapid climate change, land use and land cover alterations, and 2) overexploitation due to their known usefulness (Khanum *et al.* 2013). Land transformations for agricultural and urban purposes, along with climate changes, will lead to an expansion of unsuitable habitats in the species range. In the study area, most of the suitable habitats for *R. australe* have already been converted to agricultural land or urbanized (Kumar *et al.* 2023). Consequently, proper planning is essential to preserve the species through the successful execution of *in-situ* conservation within protected areas offering suitable habitats, as well as *ex-situ* conservation (Urbina and Flores, 2010; Adhikari *et al.* 2012). Both macro- and micropropagation techniques should be employed to cultivate plantlets, which can then be introduced to appropriate protected sites identified via ecological niche modeling.

The model outputs show that the Mean Temperature of the Coldest Quarter (Bio 11) significantly influences the potential habitat distribution of *R. australe*. The model identifies the North West Himalaya as the most suitable natural habitat for the species. The areas pinpointed through current distribution modeling can be utilized for the re-introduction of the species. Regarding future species predictions, Maxent modeling indicates a loss of habitat in Himachal Pradesh and Jammu and Kashmir by 2050 within the presently predicted areas (Fig. 2b). Given the forecast of habitat contraction in the future, it is essential to prioritize and diligently preserve potential suitable areas.

The current study indicates that habitat distribution modeling can be highly beneficial in identifying suitable habitats for reintroducing *R. australe*. The predicted areas in this research may aid in the species' rehabilitation and enhancement of its conservation status. Employing various integrative in-situ conservation approaches, along with captive propagation in controlled settings like natural habitats, botanical gardens, and other conservation facilities, could boost species recovery rate and promote germplasm conservation. The Maxent model, used for predicting the appropriate habitat of a species, can be applied to forecast the potential suitable habitats of other medicinal plants, thereby assisting in conservation planning for these species.

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References

Adhikari D, Barik SK and Upadhayay K (2012). Habitat distribution modeling for reintroduction of *Ilex khasiana* Purk., a critically endangered tree species of northeastern India. *Ecol. Eng.* **40:** 37-43

Adhikari U, Nejadhashemi AP and Herman MR (2015). A review of climate change impacts on water resources in East Africa. *Trans. ASABE*. ***58*(6):** 1493-1507

Awasthi P, Bargali K and BargaliSS (2022). Relative performance of woody vegetation in response to facilitation by *Coriaria nepalensis* in Central Himalaya, India. *Russ. J. Ecol.* **53(3):** 191-203

Baboo B, Sagar R, Bargali SS and Verma H (2017). Tree species composition, regeneration and diversity within the protected area of Indian dry tropical forest. *Trop. Ecol.* **58(3):** 409-423

Bargali SS and Shrivastava SK (2002). Exploration of Valuable medicinal vegetal wealth from the tribal belt of Bastar district in Chhattisgarh. *Bot.* **52**: 75–82

Bargali SS, Shrivastava SK, Dixit V K and Bargali K (2003) Some less known ethnomedicinal plants of Jagdalpur District of Chattisgarh State. *Bot.* **53**: 192–7

Bargali K, Joshi B, Bargali SS and Singh SP (2014) Diversity within Oaks. *International Oaks.* **25:** 57-70

Bargali K, Joshi B, Bargali SS and Singh SP (2015). Oaks and the Biodiversity They Sustain. *International Oaks*. 26:65-76

Bhardwaj R andSood M (2022). *Rheum australe*: An endangered high-value medicinal herb of North Western Himalayas. *Int. J. Econ. Plants*. ***9*(2):** 106-110

Bisht S, Bargali SS, Bargali K, Rawat GS, Rawat YS and Fartyal A (2022). Influence of Anthropogenic Activities on Forest Carbon Stocks-A Case Study from Gori Valley, Western Himalaya. *Sustainability.* **14:**16918

Bisht S, Rawat GS, Bargali SS, Rawat YS and Mehta A (2024). Forest vegetation response to anthropogenic pressures: a case study from Askot Wildlife Sanctuary, Western Himalaya. *Environ. Dev. Sustain*. **26:**10003–10027

Bobrowski M, Gerlitz L and Schickhoff U (2017). Modelling the potential distribution of *Betulautilis* in the Himalaya. *Glob. Ecol. Conserv.* **11:** 69-83

Böhner J, Miehe G, Miehe S and Nagy L (2015). Climate and weather. *Nepal: An Introduction to the Natural History, Ecology and Human Environment in the Himalayas*. Royal Botanic Garden, Edinburgh. pp23-89

Chauhan NS (1999) *Medicinal and aromatic plants of Himachal Pradesh*. Indus publishing

Elith J, Graham CH, Anderson RP, Dudík M, Ferrier S, Guisan A, ...and Zimmermann NE (2006). Novel methods improve prediction of species' distributions from occurrence data. *Ecography*. **29(2)**: 129-151

Elith J, Phillips SJ, Hastie T, Dudík M, CheeYE and Yates CJ (2011). A statistical explanation of MaxEnt for ecologists. *Divers. Distrib.* **17(1):** 43-57

Fielding AH and Bell JF (1997). A review of methods for the assessment of prediction errors in conservation presence/ absence models. *Environ. Conserv.* **24(1):** 38-49

GBIF.org (31 May 2024) GBIF Occurrence Download https://doi.org/10.15468/dl.kwynnx

Gupta SK (2001). Pharmacology and Therapeutics in the New Millennium. Narosa Publishing House, New Delhi

Hanski I (2011). Habitat loss, the dynamics of biodiversity, and a perspective on conservation. *Ambio*, **40(3):** 248-255

Hermann TM (2006). Indigenous knowledge and management of *Araucaria araucana* forest in the Chilean Andes: Implication for native forest conservation. *Biol. Conserv.* **15:** 647-662

Hijmans RJ, Cameron SE, Parra JL, Jones PG and Jarvis A (2005). Very high-resolution interpolated climate surfaces for global land areas. *Int. J. Climatol.* **25(15):** 1965-1978

Kumar A, Bisht Y, Rautela K, Jugran A, Bhatt ID, Bargali SS (2023). Morphological and genetic diversity assessment of *Rheum australe* D. Don - A high value medicinal herb from the Himalaya, and implications for conservation strategies. *S. Afr. J. Bot.* **163:** 620-629

Khanum R, Mumtaz AS and Kumar S (2013). Predicting impacts of climate change on medicinal asclepiads of Pakistan using Maxent modeling. *Acta Oecol.* **49:** 23-31

Kumar S and Stohlgren TJ (2009). Maxent modeling for predicting suitable habitat for threatened and endangered tree *Canacomyrica monticola* in New Caledonia. *J. Ecol. Nat. Environ.* **1(4):** 94-98

Kumar, A, Bisht, Y, Rautela, K, Jugran, AK, Bhatt, ID and Bargali, SS (2023). Morphological and genetic diversity assessment of *Rheum australe* D. Don–A high value medicinal herb from the Himalaya, and implications for conservation strategies. *S. Afr. J. Bot.* **163:** 620-629

Maikhuri RK, Nautiyal S, Rao KS and Saxena KG (2001). Conservation policy–people conflicts: a case study from Nanda Devi Biosphere Reserve (a world heritage site), India. *For. Policy Econ.* **2(3-4):** 355-365

Mala D, Awasthi S, Sharma NK, Swarnkar MK, Shankar Rand Kumar S (2021). Comparative transcriptome analysis of *Rheum australe*, an endangered medicinal herb, growing in its natural habitat and those grown in controlled growth chambers. *Sci. Rep.* **11(1):** 1-16.

Manral V, Bargali K, Bargali SS and Shahi C (2020). Changes in soil biochemical properties following replacement of Banj oak forest with Chir pine in Central Himalaya, India. *Ecol. Process.* **9:** 30

Nautiyal BP, Prakash V, Maithani UC, Chauhan RS, Purohit H and Nautiyal MC (2003). Germinability, productivity and economic viability of *Rheum emodi* Wall. ex Meissn. cultivated at lower altitude. *Curr. Sci.* **84(2):** 143-148

Nautiyal MC and Nautiyal BP (2004). Agro-techniques for high altitude medicinal and aromatic plants. Bishen Singh

Mahendra Pal Singh. *International Book Distributors, Dehradun*. pp 1-202

Pandith SA, Dar RA, Lattoo SK, Shah MA andReshi ZA (2018). *Rheum australe*, an endangered high-value medicinal herb of North Western Himalayas: a review of its botany, ethnomedical uses, phytochemistry and pharmacology. *Phytochem. Rev.* **17:** 573-609

Padalia K, Bargali K, Bargali SS (2015). How does traditional home-gardens support ethnomedicinal values in Kumaun Himalayan bhabhar belt, India? *Afr. J. Tradit. Complement. Altern. Med.***12(6):** 100-112

Parihaar RS, Bargali K and Bargali SS (2014). Diversity and uses of Ethno-medicinal plants associated with traditional agroforestry systems in Kumaun Himalaya. *Indian J. Agric. Sci.* **84(12):**1470-1476

Pearson RG, Raxworthy CJ, Nakamura M, and Townsend Peterson A (2007). Predicting species distributions from small numbers of occurrence records: a test case using cryptic geckos in Madagascar. *J. Biogeogr.* **34(1):** 102-117

Phillips SJ, Anderson RP andSchapire RE (2006). Maximum entropy modeling of species geographic distributions. *Ecol. Model.* **190(3-4):** 231-259

Phillips SJ andDudík M (2008). Modeling of species distributions with Maxent: new extensions and a comprehensive evaluation. *Ecography*. **31(2):** 161-175

Sanchez AC, Osborne PE andHaq N (2011). Climate change and the African baobab (*Adansonia digitata* L.): the need for better conservation strategies. *Afr. J. Ecol.* **49(2):** 234-245

Schickhoff U (2005). The upper timberline in the Himalayas, Hindu Kush and Karakorum: a review of geographical and ecological aspects. *Mountain ecosystems: studies in treeline ecology*. pp. 275-354

Shrestha UB, Lamsal P, Ghimire SK, Shrestha BB, Dhakal S, Shrestha S and Atreya K (2022). Climate change-induced distributional change of medicinal and aromatic plants in the Nepal Himalaya. *Ecol. Evol*. **12(8):** e9204

Suman KP (2006). Inventory to invention: The utilization route for medicinal and aromatic plants in India, as for Asia. *JMAPS*. **28(2):** 1

Swets JA (1988). Measuring the accuracy of diagnostic systems. *Science*. **240(4857):** 1285-1293.

Troll C (1972). The three-dimensional zonation of the Himalayan system. *Geoecology of the high mountain regions of Eurasia* pp 264-275

URBINA-CARDONA JN and Flores-Villela OSCAR (2010) Ecological-niche modeling and prioritization of conservation-area networks for *Mexican herpetofauna*. *Conservation biology*. **24(4):** 1031-1041

Vibhuti, Bargali K and Bargali SS (2022) Changing pattern of plant species utilization in relation to altitude and their relative prevalence in homegardens of Kumaun Himalaya, India. *Natural Resources for Human Health*. https://doi.org/10.53365/nrfhh/144792

Zurick D and Pacheco J (2006) *Illustrated atlas of the Himalaya*. India Research Press