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continued on the back inside cover

Cover: A Warty Hammer Orchid *Drakaea livida* gets pollinated by a male thynnine wasp through 'sexual deception' — a colour pencil reproduction of photos by ron_n_beths (flickr.com) and Rod Peakall; Water colour reproduction of Flame Lily *Gloriosa superba* -- photo by Passakoran_14; and a bag worm and its architectural genius (source unknown). Art work by Pannagasri G.

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ARTICLE

Potential distribution, habitat composition, preference and threats to Spikenard *Nardostachys jatamansi* (D.Don) DC. in Sakteng Wildlife Sanctuary, Trashigang, Bhutan

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Abstract: Bhutan stands out as one of the native areas where *Nardostachy jatamansi* grows. At an international level, a rampant rate of harvesting of its rhizome for medicinal and religious purposes has resulted in the species being categorized as 'Critically Endangered' as per the IUCN Red List Assessment, 2025. A survey was conducted in August 2021 within Sakteng Wildlife Sanctuary to identify the growing area of *N. jatamansi* within the sanctuary, determine species composition in the *N. jatamansi* growing area, assessing the threat within the sanctuary, and the potential distribution using current, and future climate scenarios. The survey found most of the species favouring rocky outcrops and high altitudes, given the harsh climatic conditions it tolerates. The studies recorded 19 individuals per m^2 of the species across Merak and Sakteng and presented Shrubs as dominant life forms and *Carex* spp as the indicator species in *N. jatamansi* growing area. We found 49.8 km^2 of the sanctuary area as the potential suitable habitat for *N. jatamansi,* with elevation and temperature-related variables as the most contributing factors in determining its distribution. Change in area under the ssp 245 future climate scenario for year 2041–2060 and 2061–2080 showed net increase in area of 125.5 ha and 126 ha respectively from current to future.

Keywords: AUC, climate, elevation, habitat, indicator, maxent modelling, Pangpoi, temperature, threat.

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Author contribution: Dorji Phuntsho and Pema Rinzin—conceptualization, conducted fieldwork, curated the data, performed formal analysis, investigated the study, and drafted the original manuscript. Namgay Shacha and Tshewang Tenzin— conducted formal analysis, curated the data & visualized the outputs, conducted formal & software analyses, visualized the outputs, and editing. All authors contributed to manuscript final writing and editing.

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INTRODUCTION

Nardostachys jatamansi locally known as 'Pangpoi', belonging to a family Caprifoliaceae (Sahu et al. 2016) is an alpine medicinal and aromatic herb, monotypic species of the genus *Nardostachys,* which has been enlisted in Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES) Appendix II and the Red Data Book of Indian Plants (Mulliken 2000). The species has been listed as 'Critically Endangered' under criteria A2cd of the IUCN Red List of Threatened Species (Chauhan 2021). The typical habitat preference of *N. grandiflora* includes rocky outcrop, but it also inhabits alpine meadows, juniper scrubs, dwarf rhododendron forest, open pine forests, and turf of glacial flats, characterized by typical monsoon precipitation (Weberling 1975; Amatya & Sthapit 1994; Ghimire et al. 2005). *Nardostachys jatamansi* is listed under Schedule II of Forest and Nature Conservation Act of Bhutan, 2023 (FNCA 2023; RGoB 2023). It is the only species within its genus, and it is native to Bhutan, China, India, Myanmar, and Nepal, and grows in high-altitude alpine Himalayan regions (CITES 2022) at elevations ranging from 3,810–5,155 m (Grierson & Long 2001). In Bhutan, it is found in Thimphu, Haa, Paro, Bumthang, Chukha, Gasa, Samtse, Trashigang, Tashi Yangtse, Wangdue Phodrang, Dagana, and Tsirang districts. The growing season is short, starting in May and ending by early October. Flowering occurs in June–July and fruiting from August onwards. It grows into a dense clump because successive shoots emerge very close together from a given mother plant (Ghimire et al. 2005).

A huge variety of medicinal plants, which make up a substantial percentage of non-timber forest products (NTFPs) collected from the Himalaya, are seriously threatened due to increased demand from medicinal plant enterprises (Tandon et al. 2001). Globally the species is threatened as more than 80% of the world's population currently use this species for some form of traditional medicine as a primary means of healthcare, given its low side effects (Sherpa et al. 2023; WHO 2023). The *N. jatamansi* has a wide range of uses, ranging from medicinal purposes to making perfumes globally, and in Bhutan, it is generally confined to the production of traditional medicine, and incense (Gyeltshen et al. 2022). In countries like Nepal, it is used as brain & uterine tonics, stimulants, external pain killers, antiseptic, treatment for epilepsy, hysteria, convulsions, heart palpitations, high blood pressure, and insomnia (Larsen & Olsen 2008). Epilepsy, wounds, coughs, colds, and high blood pressure are treated using their rhizome (Ghimire et al. 2005).

With the inevitable climate change, species' original habitat conditions will change, along with their distribution area, and they will progressively migrate to new environments that are better suited to their own growth and reproduction (Zhong et al. 2023). The species within the alpine zone of the sanctuary faces increasing pressure due to livestock grazing, climate change, and land use changes. Despite its global significance, there is a little knowledge on the potential distribution, and the severity of threat it faces in the region. A combination of factors play a huge role in depletion of such endangered species from the wild. Hence, identifying potential areas of high suitability can guide conservation efforts, ensuring the conservation, and prioritization of crucial current, and future potential habitats of *N. jatamansi* in the sanctuary.

Species distribution modelling (SDM), a widely adopted method in ecological research (Peterson et al. 2015; Razak et al. 2024) has become increasingly important in the context of accelerating climate change, and anthropogenic impacts on the biosphere (Novoseltseva 2024). Maximum entropy (MaxEnt) is one of the machine learning methods, (Elith & Leathwick 2009) widely used in predicting habitat suitability of species using presence only data. Maxent's ability to reduce the possibilities of overfitting makes it one of the best methods for species distribution modelling (Valavi et al. 2022). An accurate model prediction is important for guiding effective management and adaptation efforts to help protect the species. Hence, the main aim of the paper is to determine: (i) the potential distribution of *N. jatamansi* within Sakteng Wildlife Sanctuary (SWS), (ii) associated species and indicator species in the *N. jatamansi* growing area, and (iii) existing threats to the population.

METHODS

Study Area

The study was conducted in two gewogs (block) within SWS: Merak and Sakteng. Sakteng WS is one of the protected areas in Bhutan which represents the eastern temperate ecosystem (27.150°–27.468° N & 91.7844°–92.1172° E). It is adjacent to the Indian state of Arunachal Pradesh with an area of 742.46 km^2 covering two gewogs, Merak and Sakteng, under Trashigang Dzongkhag (district). The sanctuary experiences four distinct seasons (winter, spring, summer, autumn) and is characterized by five major forest types such as dry alpine scrub, rhododendron scrub, fir, hemlock, and cool broadleaved.

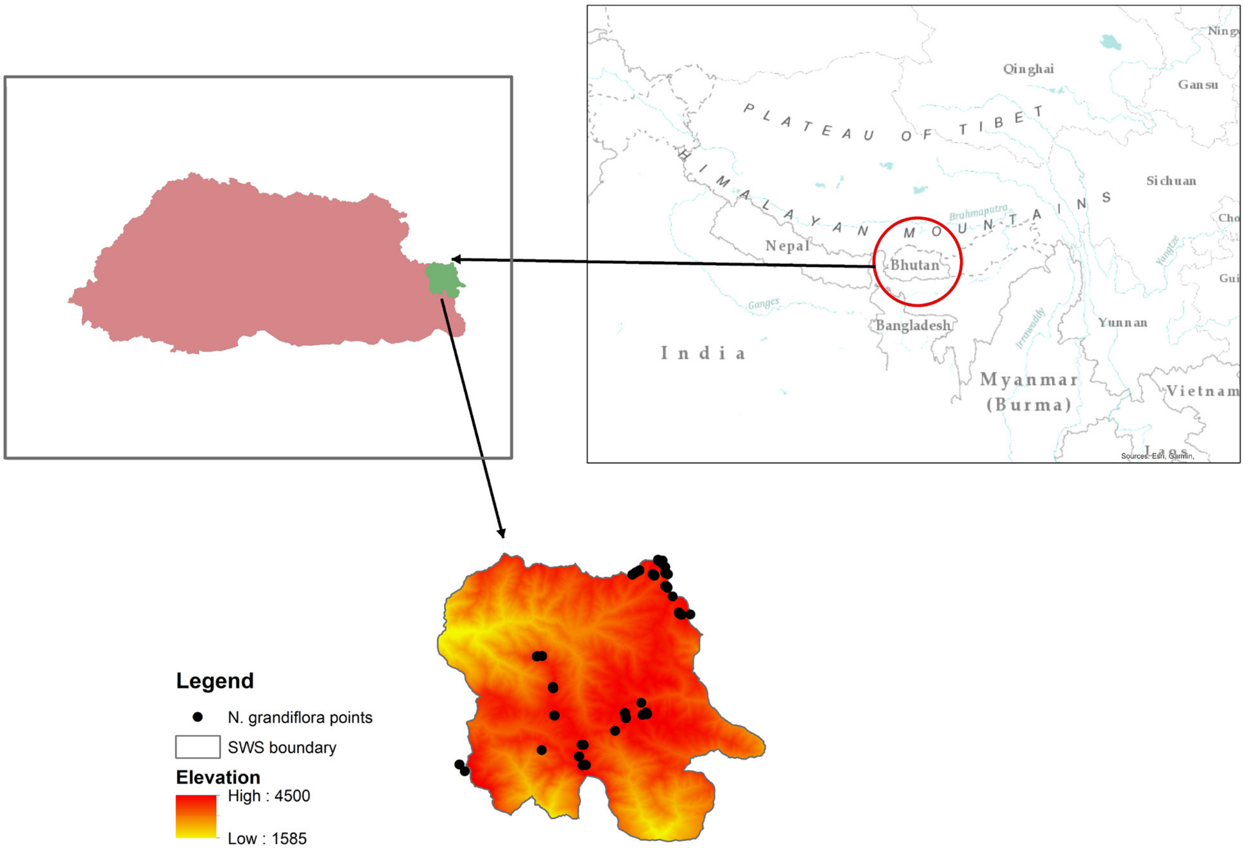

Image 1. *Nardostachys jatamansi* locations under Sakteng Wildlife Sanctuary.

Sakteng WS is also an origin of rivers such as Jomori, Nyera ama chhu, and Gamri chhu, which have the potential for hydro power generation. It connects Jomotsangkha WS to the south through a biological corridor 6 (BC 6) and Bumdeling WS through BC 9. The elevation ranges from 1,500 m in warm broadleaved forest to 4,500 m in alpine scrub. The park's rich biodiversity includes over 858 species of plants with 141 families under 35 orders, 39 mammals, 283 species of birds, 63 species of butterflies, five species of reptiles, and three species of amphibians. The sanctuary is home to 5,000 people across 13 villages with 772 households (SWS 2019). The wide range of elevation gradient provides suitable growing conditions for many important medicinal plants including the highly threatened *Nardostachys jatamansi*.

Data collection and analysis

In August 2021, preliminary listing and mapping of the *N. jatamansi* growing sites were determined through participatory mapping approach with the involvement of local communities. For plot layout, 8 m flexible electric wire and thread was used for every area of occupancy (AOO) plots measuring (2m x 2m) to enumerate the data. Thirty-two AOOs with an area of 20.93 ha within SWS were taken. Vegetation plot size of 2m x 2m quadrate plot was established for data collection. Height of the tallest species was measured using the 5 m fibre glass tape. Eterex global positioning system (GPS), compass, clinometer, measuring tape were some of the tools used during the survey. The details, including height, cover percentage, volume, and relative density of herbs, shrubs, and graminoids were recorded. Slope, aspect, barren area cover, and organic layer depth were also recorded. A total of 95 plots (48 plots in Merak and 47 plots in Sakteng Gewog) were enumerated (Image 1). Data collected from the field was compiled and processed using PivotTable of the Microsoft Excel 2016. PC-ORD version 5.1.0 was used for cluster analysis to determine the cluster solution using distance measure of Sorensen (Bray-Curtis) and group linkage methods using Ward's to determine the floristic species classification in *N. jatamansi* growing areas. Species area curve was generated through PC-ORD 5.1.0. Rank abundance curve for the species in each plot were produced using Excel 2016.

Habitat preference

A logistic regression generalized linear model (GLM) and general additive model (GAM) was performed for habitat preference for *N. jatamansi* using presence-absence data in R studio. Habitat variables such as temperature, precipitation, aspect, slope, and elevation were used. To determine the best fit model, multi-model inferences were conducted, selecting the model with lower Akaike information criterion (AIC). AIC is a mathematical method for evaluating how well a model fits the data it was generated from. Subsequently, GAM outperformed GLM.

Species Distribution Modelling (SDM)

Of the 95 geographic points of *N. jatamansi,* eight points falling outside the sanctuary boundary were clipped and the remaining 87 points that fell inside the boundary were used for species distribution modelling. Nineteen bioclimatic variables with a spatial resolution of 30 arc-second (~1 km at the equator) were downloaded from Worldclim (Fick et al. 2017) website (www.worldclim.org), and slope & aspect (30 m resolution) were extracted from digital elevation model (DEM). Accordingly, multicollinearity test was done using statistical software R v.4.4.1 (R Core Team, 2023) using the package 'usdm' (Naimi et al. 2014) and 'raster' (Hijmans 2024). Those bioclimatic variables with VIF ≥ 10 were considered as highly correlated and subsequently removed from further analysis (Zuur et al. 2009; Montgomery et al. 2012; Yoon & Lee 2021) and only four bioclimatic variables out of the total 19 variables were retained. Variables such as bio3 (isothermality (bio2/bio7) (×100)), bio5 (max temperature of warmest month), bio7 (temperature annual range (bio5–bio6)), bio14 (precipitation of driest month), aspect, slope and elevation were used. Maximum entropy modelling, MaxEnt (Phillips et al. 2025) executable jar file was used for generating species distribution modelling using presence only data with 10,000 background points. Seventy-five percentage of the occurring data were used as training data and the remaining 25% as test data. The ASC file generated by MaxEnt was further reclassified using ArcGIS v 10.8.

For future potential distribution of *N. jatamansi*, general circulation model (GCM) BCC-CSM2-MR was selected as it is broadly recognised as one of the most effective climate models for predicting the impacts of past and future climate change on plant distributions in eastern Asia, and the Himalayan region (Xin et al. 2013; Abdelaal et al. 2019; Rana et al. 2020). Among the four shared socio-economic pathway (ssp 126, ssp 245, ssp 370, and ssp 585), ssp 245, which shows an intermediate development scenario, was used in the future distribution for year 2041–2060 and 2061–2080. The SSPs are a set of reference pathways that describe alternative patterns in the evolution of society and ecosystems over a century, assuming no change in climate trends or climate policies (O'Neill et al. 2014).

RESULTS

The largest number of individuals were counted in plot 78 with organic layer depth of 3 cm, 55° slope, and 280° aspect. The highest relative density (RD) of *N. jatamansi* recorded was in plot 39 with RD 99.72% and least in plot 49 with RD 2.07% with slope gradient ranging 10–55 °. Likewise, the highest coverage of *N. jatamansi* was recorded in plot 34 with 94%, and least in plot 30 with 2%. The survey recorded 7,497 counts of species in 95 plots under the sanctuary.

Vegetative Composition

A total of 159 species comprising 40 families were recorded from 95 plots covering 18 sites at Merak and Sakteng gewog. From the 40 families, Compositae family was observed the highest with 27 species followed by Saxifragaceae and Polygonaceae with 14 and 11 species respectively. Fifteen families, including Valerianaceae, have recorded the lowest species count, with only one species per family (Figure 1).

The likelihood of encountering new species decreases with increased sample efforts. However, this species list is not exhaustive based on the species accumulation curve that did not flatten (Figure 2). The *N. jatamansi* growing area were composed of herbs, shrubs and graminoids (Figure 5). From the rank abundance curve, *N. jatamansi* was found to be the most abundant (Figure 6). This could be attributed to the opportunistic survey method practised, whereby plots were laid out only in *N. jatamansi* presence areas.

Habitat Preferences

Among the variables, slope has a significant effect on the distribution of *N. jatamansi* (edf = 1.0, Ref.df = 1.0, Chi sq. = 19.996, p-value = 8.15e-06), whereas aspect (edf = 1.0, Ref.df = 1.00, Chi sq. = 2.699, p-value = 0.100) does not have a significant effect on the species. There is a linear effect indicating a direct relationship between slope and the plant's presence. This supports the plant's preference for rocky and mountainous areas.

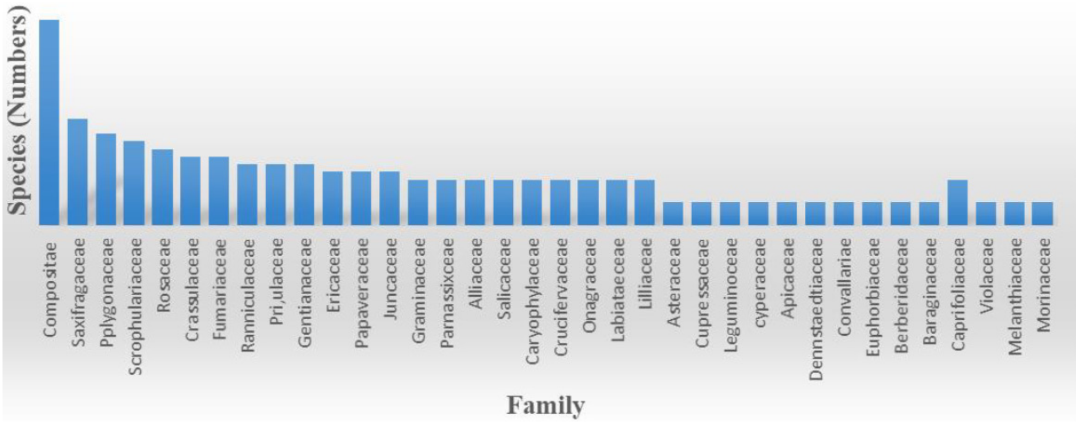

Figure 1. Families with number of species encountered.

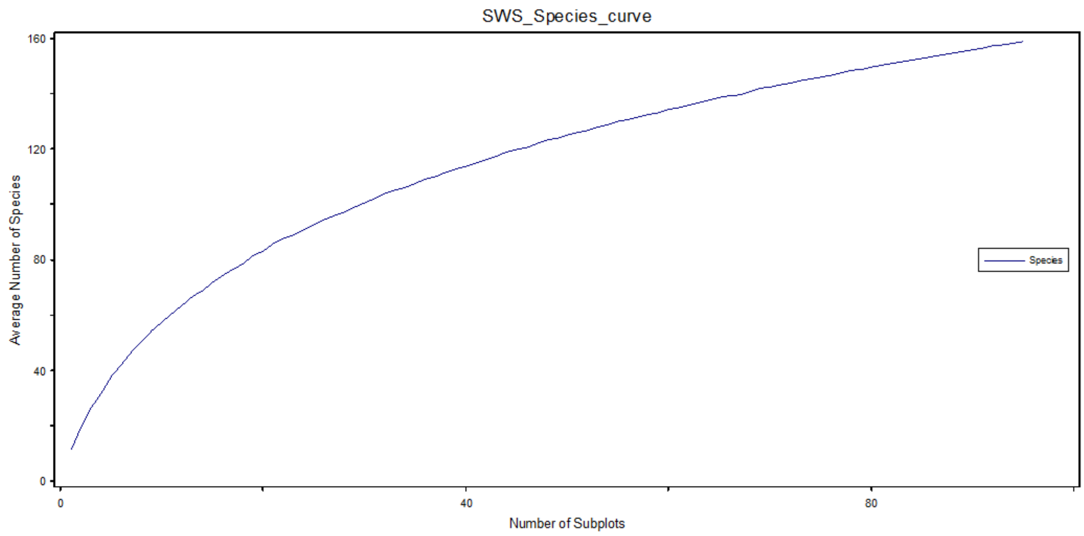

Figure 2. Species distribution curve indicating the likelihood of occurrence of additional species.

Species Distribution Modelling

The result generated by MaxEnt showed 16.64 km^2 of sanctuary area as highly suitable, 33.17 km^2 as moderately suitable, and 691.93 km^2 as unsuitable (Figure 8). Further, it showed elevation and aspect as the most important variables contributing to maxent modelling with a contribution of 73.3% and 9.8%, respectively (Table 1), and the jackknife test showed bio5 and elevation as the most important factors in in determining the distribution (Figure 3). The percent contribution of each variable is shown in Table 1. A jackknife analysis was used to calculate the importance of each environment variable in the model and the results are shown in the Figure 3. The training and test data which was set at 75% and 25% respectively provided a reliable accuracy for the model (Figure 4). The distribution modeling under the future climate scenario using global climate model BCC-CSM2-MR under scenario ssp 245 for year 2061–80 showed an increase in 1,063 ha of habitat from current unsuitable area and decrease of 937 ha from current suitable area while year 2041–2060 showed increase of 1,027 ha of suitable area from current unsuitable area, and decrease of 901.5 ha from current suitable area (Figure 9). The model predicted an overall increase in area of 125.5 ha for year 2041–2060 and 126 ha for year 2061–2080.

The similarity cluster analysis was carried out for species (n = 159) with adjusted relative abundance from the total composition. Monte Carlo test of indicator species was calculated following Dufrêne & Legendre (1997) method for the proportional abundance of a particular species in a particular group relative to the abundance of that species in all groups. The similarity index of 44% was performed using the distance measure of Sorensen (Bray-Curtis) and group linkage method

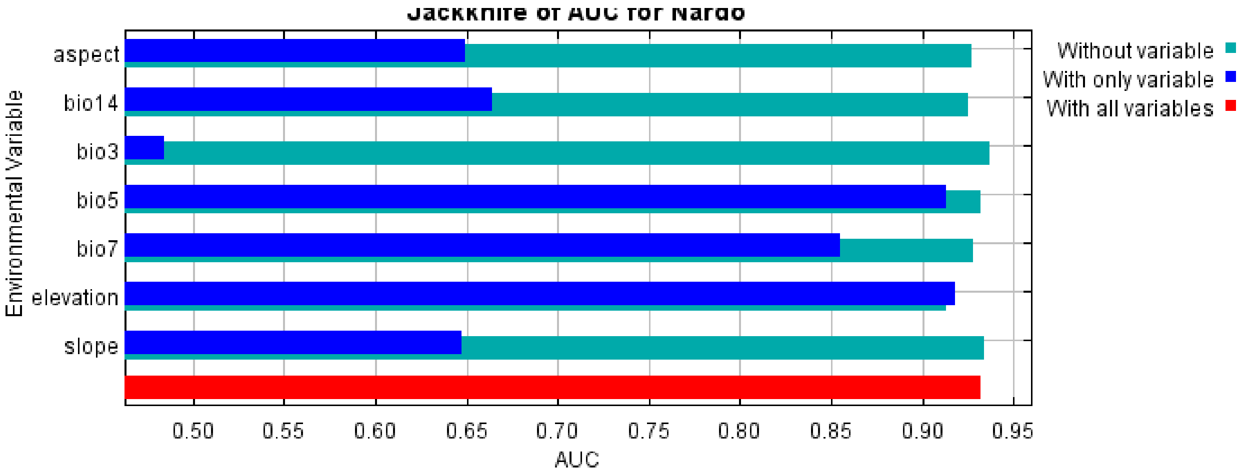

Figure 3. Jackknife test of variable importance using Area Under Curve on test data.

Table 1. Relative contributions of the environmental variables to the MaxEnt model.

Variable	Percent contribution	Permutation importance
elevation	73.3	85.8
aspect	9.8	2.2
bio14	5.1	0.5
slope	3.8	1.4
bio3	3.2	0.7
bio7	2.4	0.5
bio5	2.4	8.9

using Ward's to determine the composition of species in *N. jatamansi* growing habitat. The indicator species was *Acanthocalyx nepalensis* (IV = 27.1 | Mean = 30.0 | SD = 4.65 | p* = 0.6707) in cluster I, *Carex* species (IV = 80.9 | Mean = 25.1 | SD = 4.13 | p* = 0.0002) in cluster II, *Rhododendron setosum* (IV = 24.2 | Mean = 28.1 | SD = 4.06 | p* = 0.843) in cluster III and *Nardostachys jatamansi* (IV = 73.3 | Mean = 53.3 | SD = 2.62 | p* = 0.0002) in cluster IV representing 36 plots from 95 survey sites (Figure 7). The result highlights *Carex* sp. as one of the main indicator species in *N. jatamansi* growing area ($p < 0.05$).

DISCUSSION

The survey found *Nardostachy jatamansi* distributed within the elevation range of 3,730–4,394 m in the sanctuary as they are better acclimatized to harsh climatic conditions with the majority of species distributed in rocky outcrops (31.23%) (Ghimire et al. 2005).

Although higher growth rates and faster recovery in meadow populations appear to be due to higher recruitment and faster vegetative growth, slow growth, and low fecundity are observed in outcrops due to slow recovery after harvesting (Ghimire et al. 2007). *Nardostachys jatamansi* favoured southwestern slope as per our study, while Sharma et al. (2021) and Ugyen & Dorji (2021) observed a contrasting result with species favouring west facing slope and south-east facing slope, respectively, demonstrating aspect as not an important variable in distribution of the species. Our study shows density of *N. jatamansi* at 19.72 /m^2 across the sanctuary. Airi et al. (2000) and Nautiyal et al. (2003) also reported population density, which ranged from 8.52–25.58 individuals /m^2 in Kumau and 19.0–32.2 individuals /m^2 in Garhwal, India. In comparison, Lakey & Dorji (2016) estimated *N. jatamansi* density in Jigme Dorji Wangchuk National Park, Bhutan at 8.9 individuals /m^2. In alpine regions of Sikkim Himalaya, Sherpa et al. (2023) reported 2.64–6.49 individuals /m^2. The comparatively higher density within the sanctuary could be ascribed to the opportunistic survey conducted in *N. jatamansi* growing area. In habitat composition, Asteraceae family had the highest representation with 27 species similar to the findings of Ugyen & Dorji (2021). The survey presented that the *N. jatamansi* growing area was dominated by high altitude shrubs. Comparable studies carried out by Sharma et al. (2021) and Ugyen & Dorji (2021), yielded similar findings, but however contradicts with the findings of Tashi & Dorji (2021).

Ascertaining the current and future potential distribution of species is critical in setting up management strategies for the habitat conservation and sustainability of species (Sinclair et al. 2010; Profirio

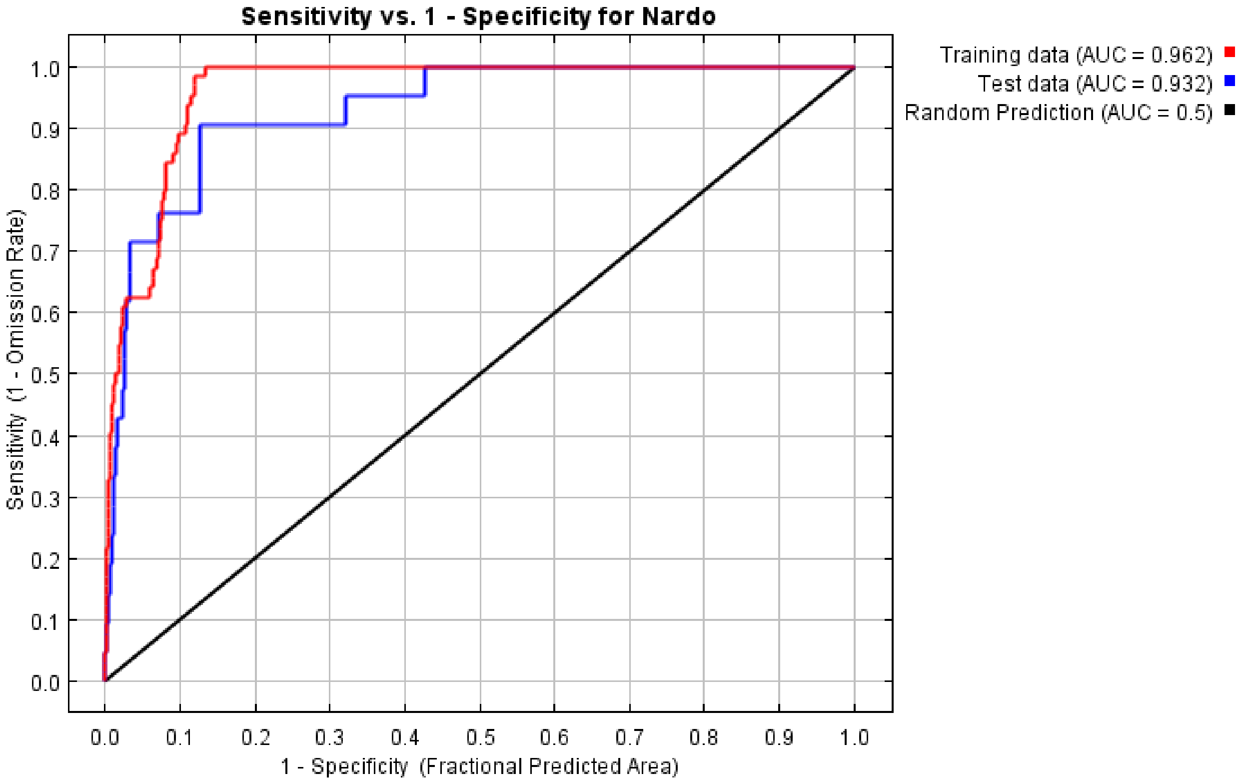

Figure 4. Receiver Operating Curve (ROC) graph showing sensitivity and specificity for *Nardostachys jatamansi* distribution model.

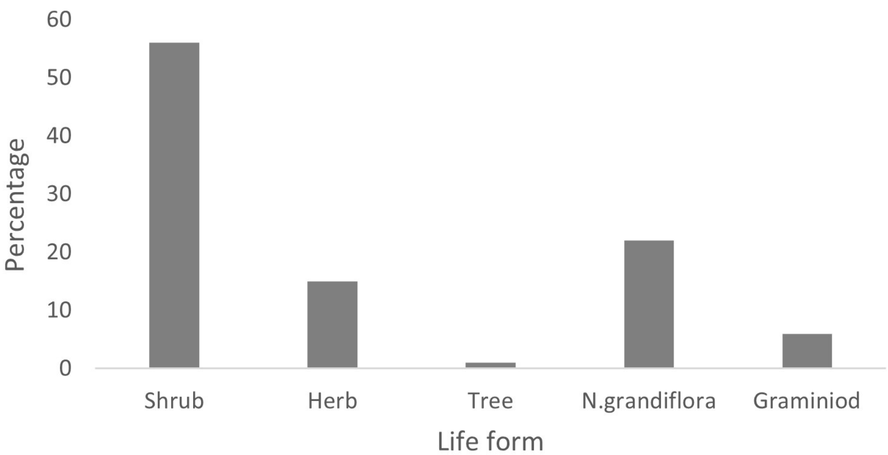

Figure 5. Life forms in *Nardostachys jatamansi* growing area.

et al. 2014). This plays a useful role in conservation management due to the interrelationship between the size of species geographic range and species extinction risk (Purvis et al. 2000; Cardillo et al. 2008). Therefore, SDM is one of the vital tools for defining species' niches (Lozier et al. 2009) and the modelling algorithms such as MaxEnt perform well with a limited number of presence-only data to produce distribution ranges (Ranjitkar et al. 2014). Further, studies carried out by Pearson & Dawson (2003), Rana et al. (2020), and Koç et al. (2024) considered climate as the most important variable in determining the species occurrence. The area under the receiving operator curve (AUC) is a performance measure applicable for any species modelling method. A random ranking on an average AUC is 0.5 and the perfect ranking achieves best possible AUC 1.0. Models

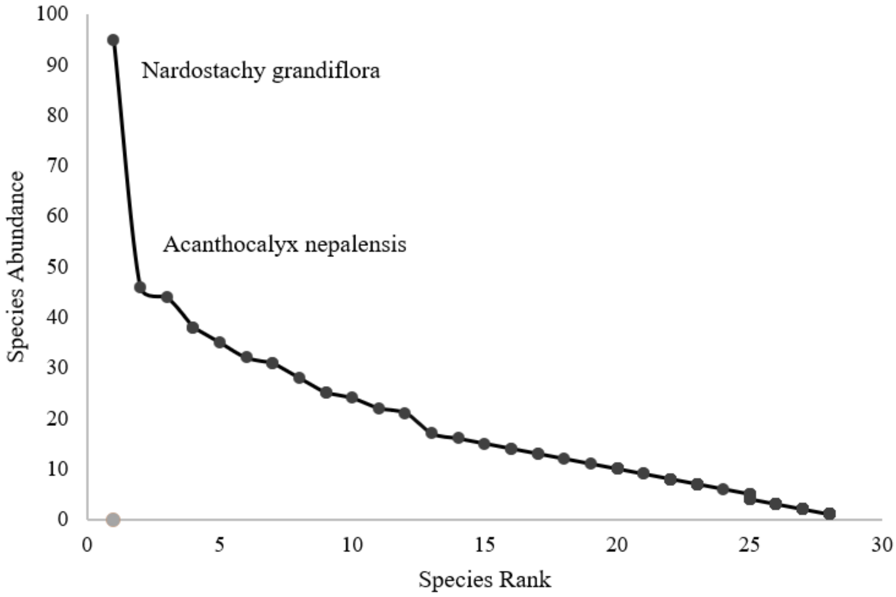

Figure 6. Rank Abundance Curve in *Nardostachys jatamansi* growing area.

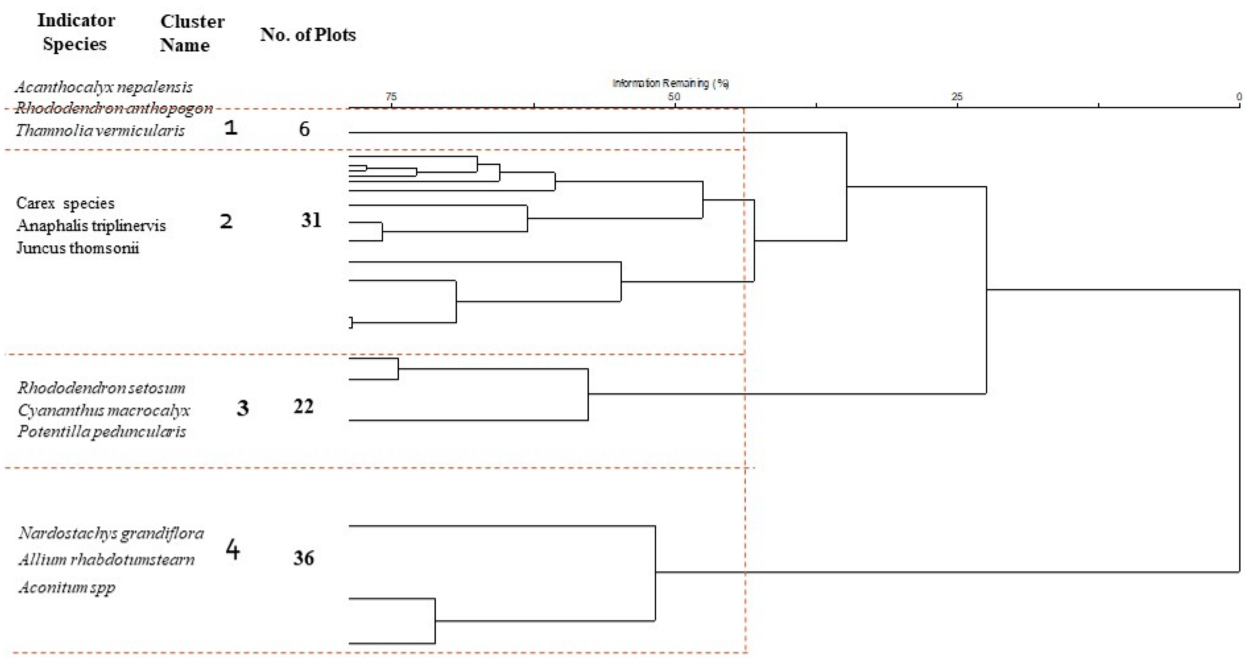

Figure 7. Similarity cluster analysis using 44% similarity index.

with values above 0.75 are considered potentially useful (Elith 2002; Phillips & Dudik 2008). The current modelling generated mean AUC of 0.93 indicating reliable accuracy of the modelling. The model generated around 6.7% of the total sanctuary area as highly suitable with elevation as the most contributing factor in determining their potential distribution. Under the maxent modelling, *N. jatamansi* exhibited strong preference to increasing elevation above 4,000 m, validating its suitability for northward expansion as reported by Rana et al. (2017). Climate change results in shifting distribution of species particularly toward higher elevations (Parmesan & Yohe 2003; Lenoir et al. 2008). The result also inferred the species' preference to temperature. The species suitability increases from 12^0 C and peaks at around 13^0 C. However, a sharp decline is observed after 13^0 C

Table 2. Minimum, maximum, mean, and standard deviation of environmental variables in *Nardostachys jatamansi* growing area.

Habitat Type	Minimum	Maximum	Mean	SD
Alpine scree				
Environmental variables				
Elevation (m)	3730	4394	4190.6	148.3
Aspect (degree)	30	280	204.6	58.8
Slope (degree)	10	55	36.4	12.3
Barren Area Cover (%)	0	50	17	14.7
Juniper Scrub				
Environmental variables				
Elevation (m)	4149	4372	4226.6	83.3
Aspect (degree)	90	240	191	61.1
Slope (degree)	15	50	36.8	12.2
Barren Area Cover (%)	2	77	37.7	31.2
Meadow				
Environmental variables				
Elevation (m)	4105	4393	4233.3	87.1
Aspect (degree)	40	300	206.6	82.9
Slope (degree)	10	61	35	15.2
Barren Area Cover (%)	0	51	19.1	17.6
Rhododendron scrub				
Environmental variables				
Elevation (m)	3964	4344	4148.6	190.2
Aspect (degree)	110	280	170	95.4
Slope (degree)	20	45	29.2	13.8
Barren Area Cover (%)	0	4	2.5	2.2
Rocky Outcrop				
Environmental variables				
Elevation (m)	3900	4391	4103.7	86.7
Aspect (degree)	70	310	163.6	84
Slope (degree)	25	65	48.6	13.1
Barren Area Cover (%)	0	77.7	48.4	25.1

indicating its aversion from increasing temperature.

The suitable habitat of *N. jatamansi* varies greatly under different climate scenarios and was more influenced by climate change (Li et al. 2019). Our results are consistent with the findings that temperature-related variables rather than precipitation variables were more significant in predictive models for medicinal species (Rana et al. 2020).

Although model predicted 49.81 km^2 of the SWS as a potential suitable habitat (fundamental niche), actual habitat (realized niche) could be comparatively less since the correlative species distribution model predicts fundamental niche which is relatively larger than the realized niche (Polechová & Storch 2019). The difference in the actual habitat suitability and predicted suitability was due to the inclusion of the model that generally over predicts. The result showed increase in net change of 125.5 ha of area suitable for *N. jatamansi* under the future climate scenario for the year 2041–2060 and 126 ha for the year 2061–2080 supporting the findings of Rana et al. (2020) which inferred increase in potentially suitable habitats of *N. jatamansi* under the future climate. Further, the distribution of species can be limited by other factors such as land use, edaphic, competition, and anthropogenic disturbances (Ranjitkar et al. 2014; Rana et al. 2020). However, findings of Shrestha et al.

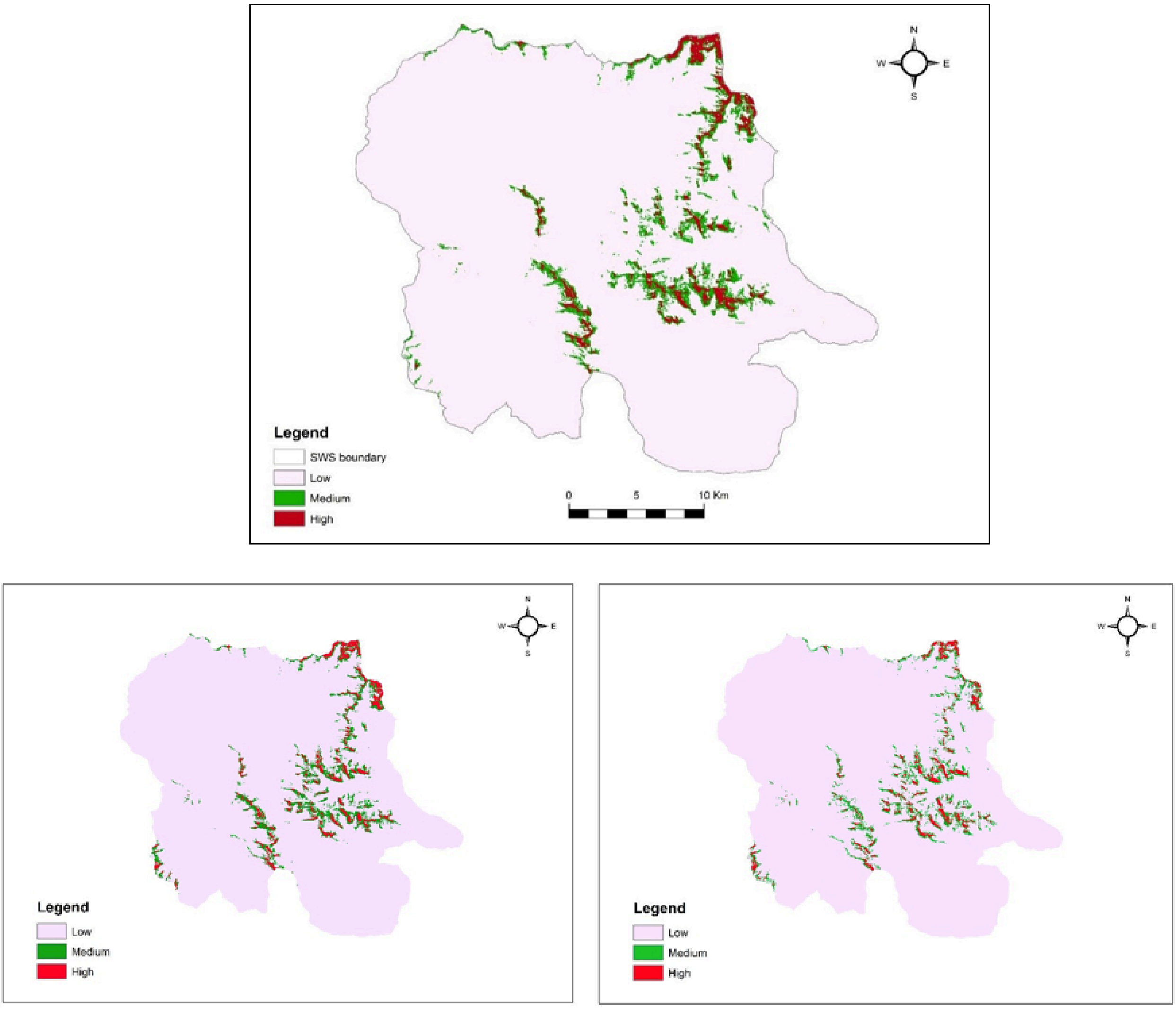

Figure 8. Distribution modelling of *Nardostachys jatamans*i in Sakteng Wildlife Sanctuary under current (top) and future climate (right 2041–2060 and left 2061–2080) under ssp 245 scenario showing its suitability.

(2022) contradict with our study through reduction in climatically suitable areas under future climate change for majority of the traded medicinal plants in Himalayan countries like Nepal. Various paper discusses the ecological status of *N. jatamansi* in the Himalayas and observed a significant decline in its density (Mulliken 2000; Nautiyal et al. 2003; Larson & Olsen 2008). Overburden on natural habitat, lack of awareness among the local people, and poor harvesting practices have pushed this species to the list of endangered (Chauhan 2021). The seasonal grazing grounds of the seminomadic herders' overlap with *N. jatamansi* growing areas as per the survey data with an estimated cattle density of 30.5 heads/km^2 (SWS 2019) making grazing as a common phenomenon. Given its unpalatable nature (Ghimire et al. 2005), *N. jatamansi* is likely to experience trampling effects from cattle movement and competition from the growth of other unpalatable species. The species slow growth in nature, poor seed setting, preference for specific habitat, low population density (Nautiyal 2003; Sherpa et al. 2023) combined with frequent disturbance by livestock trampling could be a major factor in population depletion of the species in their natural habitat. Severe overharvesting of *Nardostachys* throughout the Himalayas has jeopardized many natural populations, motivating a variety of experiments, such as enrichment planting in community forests (Aumeeruddy-Thomas et al. 2005). Local communities in Bhutan uses *N. jatamansi's* rhizome in incense and for a few other religious purposes (Gyeltshen et al. 2022) thereby limiting large quantity harvest. Domestication of such species at household level through cost sharing

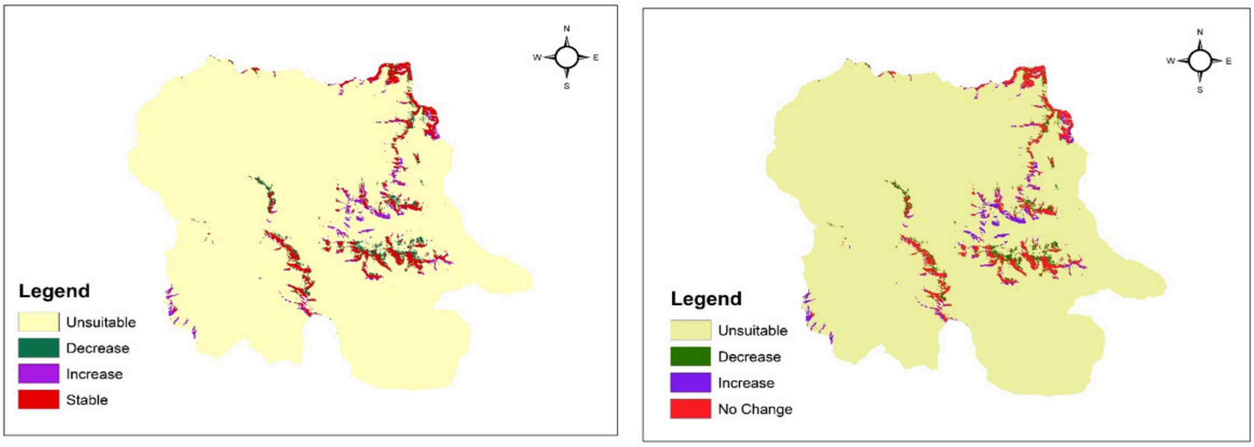

Figure 9. Gain, loss, and stable areas of *Nardostachys jatamansi* under future scenario 2041–2060 (left) and 2061–2080 (right) under ssp 245 scenario.

mechanism can save the species from extinction, while benefitting the community. Given the huge volume of rhizome harvest for its medicinal and religious purposes along with its slow recovery rate post-harvest, an illustrious method of building stewardship through establishment of management group, and conservation plans that solely manage harvest & sale of species through appropriate scientific harvesting techniques can encourage wild population distribution**.**

CONCLUSION

Given the global scenario of harvesting, there is a need to protect and conserve this species and address the unsustainable harvesting methods by local people through awareness. Although slope and aspect don't determine its distribution, their presence was prominent in higher altitude and shrub dominated areas. *Carex* sp. was one of the indicator species in *N. jatamansi* growing area. The sanctuary boasts 19.72 numbers of *N. jatamansi* per m^2 with 49.8 km^2 of the area as the potential suitable habitat for the species. This highlights the stringent laws & policies put in place by the country and the role sanctuary plays in conserving its wild resources. Elevation and bio5 were the most contributing factors, whereas bio3 was the least contributing factor in determining the species distribution. Under the future climate scenario, an overall net increase in suitable habitats was predicted. The findings of this study gives an insight to the park management to designate potential area under conservation for ensuring sustainability of the species for times to come. Although no rampant harvest is carried out within the sanctuary, proper awareness must be given to avoid future harvest. Besides its threat of harvest, other notable factor include slow growth rate, trampling by cattle, low population density, demand for ethnomedicine, climate change, and habitat specificity of the species. This calls for a need for prioritization of potential areas within the sanctuary.

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