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Population status and habitat suitability of *Vatica chinensis* L., an endangered Dipterocarp from the Western Ghats, India

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Abstract. *Vatica chinensis* L. is an endangered Dipterocarp, sparsely confined to the west-coastal regions of the Kerala and Karnataka part of the Western Ghats, especially in the sacred groves and the agro-ecosystems. The current population structure and distribution of the species in the Western Ghats region is poorly studied. Hence, the study attempts to assess the status of the existing populations and their potential distribution by using the Ecological Niche Modeling (ENM). The results indicated that the populations of *Vatica chinensis* were present outside the forest areas, with a very scattered distribution. Three large populations were identified in the Malabar region, especially in the sacred groves of poyilkavu, muchukunukavu and in the premises of the parappanangadi railway station. The poyilkavu sacred grove showed a higher density (68) compared to the other two sites. The potential distribution prediction, using the ENM, showed a higher probability in the central part of the Western Ghats and a moderate one in the northern part of the Western Ghats region. Furthermore, the high habitat specificity, the restricted distribution along with the anthropogenic intervention (construction of roads and railway lines) has significantly reduced the existing populations of *Vatica chinensis*. Therefore, urgent interventions are required to restore the populations of this endangered species. As part of initiating the restoration activity we have identified the potential niches and also raised sufficient seedlings for the restoration.

Key words: conservation status, distribution, Maxent modeling, population structure, species diversity

1. Introduction

The resinous trees of the genus *Vatica* L. belongs to Dipterocarpaceae family with a total of 65 species, distributed in the Indo-malayan region (Mabberley 2008). In India only two species have been reported – *Vatica chinensis* L. and *Vatica lanceifolia* (Roxb.) Blume (formerly as: *Vatica lanceaefolia*) (Tewary & Sarkar 1986; Janardhanan 1993). The species *V. chinensis* is endangered (A2c+3c. ver 3.1) (Deepu *et al.* 2021), whereas *V. lanceifolia* is critically endangered (Ashton 1998a). *V. chinensis* was earlier reported from the coastal sandy belt or the evergreen forest in the Kerala and Karnataka region of the Western Ghats (Tewary 1984; Janardhanan 1993; Bhat 2003; Sasidharan 2004). However, *V. lanceaefolia* is distributed in the Northeastern India in Assam, Arunachal Pradesh, Nagaland, Meghalaya and Manipur (Janardhanan 1993; Borah & Devi 2014).

V. chinensis is locally known as 'Adakkapine' in Malayalam and 'Kirudhupa' in Kannada. The wood is in high demand for boat construction, flooring, interior joinery and cabinetworks (Chudnoff 1984). The resin exudating from the bark is nearly transparent, pale yellow in colour and is used in varnishes (Shiva &

Jantan 1998). Moreover, the root extracts of *V. diospyroides* are also used as anticancer agents (Srisawat *et al.* 2015). A consistently excessive harvest in the past few decades has resulted in a drastic reduction to the earlier placement of the species under the critically endangered A1cd, C2a ver 2.3 category (Ashton 1998b). The National Conservation Review (1991-1996) could not record *V. chinensis* in Sri Lanka forests, which suggested that the species is either extremely rare or possibly extinct on the Island (Sukesh & Chandrashekar 2013). The Western Ghats region now remains the only location to harbor *V. chinensis*.

Though *V. chinensis* has been reported in the Western Ghats no updates on its natural distribution is available. Moreover, the taxonomic revision of the *Vatica* genus by Tewary and Sarkar (1986) fails to mention its natural distribution in Kerala and Karnataka, though few representations from the coastal regions have been cited. Thus, the information on the population diversity and distribution, which is essential to identify the critical biological community for the conservation of the endangered species (Thomsan *et al.* 2002), is clearly lacking. Predictive modeling of the species distribution is currently used as an important tool in biogeography, evolution, ecology and conservation management (Peterson *et al.* 1999, 2000). The habitat suitability or the niche prediction is done through several approaches, which usually integrates the species occurrence information with the environmental data from the known populations. Hence, the species distribution modeling is important in the case of the IUCN red listed species for identifying the unexplored areas to plan a long-term conservation programme (Thomsan *et al.* 2002). Since very little is known about the geographic distribution and populations of *V. chinensis* in the Western Ghats, suitable environmental variables for its restoration have not been fully explored. Hence, the study intends to determine the status of the existing populations, its geographic distribution, the associated species and to further predict the potential niche using the Maxent modeling for biodiversity conservation and monitoring.

2. Material and methods

Field surveys were conducted throughout the Western Ghats during the period of 2015-2019 to identify the naturally distributed areas of *Vatica chinensis*. The occurrence records of *V. chinensis* were collected from the regional floras (Saldanha 1984; Janardhanan 1993; Sasidharan 2004; Nayar *et al.* 2014), previously published research papers (Sukesh & Chandrashekar 2013) and also from different herbaria (BSI, CAL, CALI, MH, TBGT). Specific locations were identified and number of individuals in each population was recorded. The specimen samples were collected in the preparation of the herbarium and deposited in the Kerala Forest Research Institute herbarium (KFRI).

2.1. Vegetation analysis

The sample plots were established based on the distribution range, habitat and number of individuals in each population. Since different sites had scattered distribution with few mature individuals, except for three locations (poyilkavu, muchukunukavu and parappanangadi), a detailed vegetation survey was conducted. Five quadrats of 50 × 20 m (0.5 ha) were laid in the poyilkavu and muchukunukavu sacred groves (Kozhikode) and ten quadrats of 10 × 10 m (0.1 ha) in Parappanangadi (Malappuram). For the population structure all of the *V. chinensis* trees were counted in the above-mentioned populations (>30) followed by the measurement of the GBH (Girth at Breast Height) at 1.37 m above the ground level. In order to understand the species composition a complete enumeration of the tree species was carried out in each plot (>30). The structural and ecological aspects; density, frequency, basal area and the IVI (Importance Value Index) were calculated for the study, using the standard method (Curtis & Mcintosh 1950) and the suitable software Invent-NTFP (Sivaram *et al.* 2006). To find the class distribution patterns the enumerated trees were grouped into six girth classes: 30-60 cm, 60.1-90 cm, 90.1-120 cm, 120.1-150 cm, 150.1-180 cm, and > 180.1 cm. The number of *V. chinensis* seedlings is comparatively less, therefore the regeneration status could not be determined.

2.2 Ecological Niche Modeling (ENM)

The Maximum Entropy Modeling (MaxEnt) was used in this study to predict the potential distribution, which is more accurate than other modeling algorithms (Elith *et al.* 2006; Phillips *et al.* 2006). The Maxent software Version 3.3.3 k (Phillips *et al.* 2006) was used for the potential prediction of *V. chinensis* and the final map was prepared using GIS platform software. Presence records along with the elevation of *V. chinensis* were collected directly from the field using the Global Positioning System. From the 19 bioclimatic variables: the annual mean temperature, the mean diurnal range (Mean of monthly max temp – min temp), the maximum temperature of warmest month, the minimum temperature of the coldest month, annual precipitation, the precipitation of the wettest month and the precipitation of the driest month, were used here as bioclimatic variables for modeling in the peninsular India (Hijmans *et al.* 2004). The elevation, slope and aspect from the CliMond dataset (Kriticos *et al.* 2012) were used for obtaining the environmental background for modeling. The random test percentage in the settings was turned up to 50%, which randomly split the dataset into two,

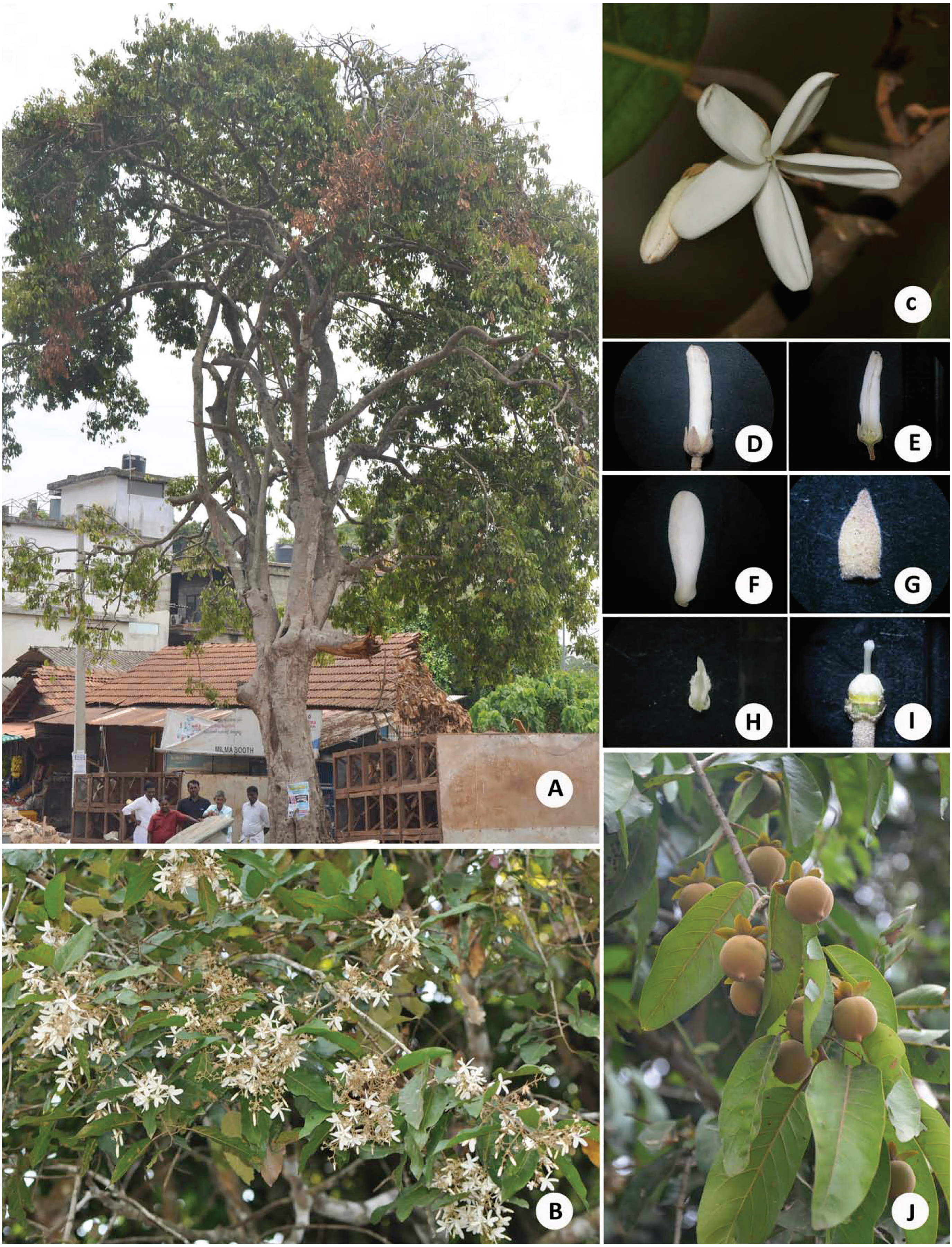

Fig. 1. Photo plate of *Vatica chinensis*

Explanations: A – habit, B – flowering branchlet, C – a single flower, D – flower bud, E – L.S. of flower bud, F – petal, G – calyx, H – stamen, I – stigma, J – fruiting branchlet (2016, photograph by M. S. Sanil) where the first one was trained to produce the model and the second one was used to validate it (Fielding & Bell 1997). The Area Under Curve (AUC) was used to evaluate the model's quality.

Table 1. Details of existing locations of *Vatica chinensis* in the Western Ghats

Population ID no.	Place	GPS readings	Number of individuals	Current status of the population
P1	Chentrappinni	N 10° 21' 32.19" E 76° 7' 37.40"	4	Along the road side and the existing population is under threat due to road expansion
P2	Gurukkan Kavu	N 11° 30' 07.29" E 75° 37' 38.12"	5	Poor fruit set and regeneration
P3	Hebri	N 11° 26' 31.34" E 74° 58' 04.26"	6	Along the road side
P4	Kaliyamvelli Bhagavathi Temple Kavu	N 11° 39' 33.49" E 75° 36' 39.42"	4	No regeneration
P5	Muchukunu Kavu	N 11° 29' 52.56" E 75° 39' 53.29"	32	Good population and no regeneration
P6	Parappanangadi	N 11° 02' 49.14" E 75° 51' 36.58"	26	Along the railway station, poor fruit set and regeneration
P7	Peralam Kavu	N 11° 16' 36.5" E 75° 49' 52.4"	4	Medium sized trees
P8	Perumballli Kavu	N 11° 16' 34.7" E 75° 50' 57.5"	5	Medium sized trees
P9	Poyil Kavu	N 11° 24' 33.53" E 75° 42' 52.31"	68	Good population and poor regeneration
P10	Shree Kattil Kariyathan Kavu	N 11° 19' 34.30" E 75° 49' 04.40"	3	Medium sized trees
P11	Tanur	N 11° 59' 05.54" E 75° 52' 29.22"	7	Along the road side and no fruit setting
P12	Thazhepurakkal Kavu	N 11° 16' 38.2" E 75° 51' 21.7"	3	Medium sized trees
P13	Thekkayil Bhagavathi Kavu	N 11° 25' 9.07" E 75° 43' 38.26"	5	Medium sized trees
P14	Thirkkottoor Kavu	N 11° 30' 7.05" E 75° 37' 38.02"	6	Medium sized trees
P15	Thirumangalam Naga Temple	N 11° 15' 51.1" E 75° 49'18.2"	2	Medium sized trees
P16	Thenmala	N 8° 57' 58.57" E 77° 03' 09.43"	1	Healthy and moderate regeneration
P17	Malabar Botanic Garden	N 11° 14' 32.38" E 75° 49' 41.09"	2	Medium sized trees
P18	Kodakkad	N 11° 05' 29.05" E 75° 52' 05.12"	2	Along the road side
P19	Kuppivalavu	N 11° 05' 02.39" E 75° 51' 44.17"	2	Along the road side
P20	Kalarippadi	N 11° 01' 03.11" E 75° 52' 24.05"	2	Along the road side
P21	Kizhur Shiva temple	N 11° 31' 39.55" E 75° 38' 08.16"	3	Unhealthy trees
P22	Vellayilkkode Bhagavathi Temple	N 11° 11' 16.6" E 75° 48' 06.2"	4	Medium sized trees

3. Results

The species are highly restricted to the coastal belt of the central and the northern part of Kerala and the southern part of Karnataka with an altitude ranging from 10 to 80 m. Most of the distribution locations of *V. chinensis* in Kerala were found in the coastal region of the sacred groves (Malappuram and Kozhikode). The flowering period initiated during the last week of December and continued up to the first week of April followed fruit initiation and fruit maturity which took approximately 3 months. A total of twenty-two distribution localities were identified in different parts of the Western Ghats.

3.1. Species description

Medium-sized, resinous trees, up to 25 m in height, with a smooth bark, pale grey in colour. Elliptic-lanceolate or elliptic-oblong, coriaceous and glabrous leaves, with an obtuse or broadly cuneate base, with an obtusely acute apex, 10-13 pairs of lateral nerves, white and fragrant flowers, 5 calyxes, from ovoid to lanceolate, a very short tube, adnate to the base of the ovary. Five, white, oblong petals, with 15 stamens in two rows, oblong, apiculate anthers, 3 celled ovary, with 2 ovules in each cell, short style. Fruit: from ovoid to globose, 2.5-5.5 cm long and shortly pointed, reticulated, surrounded at the base by the enlarged sepals (Fig. 1).

Table 2. Population structure of *Vatica chinensis*

Populations	Basel area (M^2 ha^{-1})	Rel. Density	Rel. Frequency	IVI
Muchukunu Kavu (P5)	0.66	4.39	3.51	9.77
Parappanangadi (P6)	37.94	33.68	21.28	101.22
Poyil Kavu (P9)	14.99	35.44	9.09	94.48

Out of all of these locations, only three (poyilkavu, muchukunukavu and parappanangadi) were dominated with mature individuals of *V. chinensis*. However, one location outside Kerala, Hebri (Karnataka), represented few scattered individuals along the road sides.

3.2. Species composition and diversity

The natural populations of *V. chinensis* were identified from eight sacred groves of the Kozhikode districts of Kerala. Out of the eight sacred groves, only two were dominated by *V. chinensis* (poyilkavu and muchukunukavu),

Table 3. List of dominant species

Sl. No.	Associated species	Populations		
		P5	P6	P9
1	*Adenanthera pavonina* L.	*	*	*
2	*Aglaia elaeagnoidea* (A. Juss.) Benth.	*	-	-
3	*Albizia saman* (Jacq.) Merr.	-	*	-
4	*Alstonia scholaris* (L.) R. Br.	-	*	-
5	*Artocarpus hirsutus* Lam.	-	*	-
6	*Caryota urens* L.	*	*	-
7	*Diospyros candolleana* Wight	*	-	*
8	*Gmelina arborea* Roxb.	*	-	*
9	*Haldina cordifolia* (Roxb.) Ridsdale	*	-	*
10	*Holigarna arnottiana* Hook.f.	*	*	*
11	*Hopea ponga* (Dennst.) Mabb.	*	-	*
12	*Hydnocarpus* pentandrus (Buch.-Ham.) Oken	*	*	*
13	*Litsea coriacea* Hook.f.	-	-	*
14	*Macaranga peltata* (Roxb.) Müll. Arg.	*	*	*
15	*Mimusops elengi* L.	*	-	*
16	*Scleropyrum pentandrum* (Dennst.) Mabb.	-	-	*
17	*Sterculia guttata* Roxb. ex G. Don	-	-	*
18	*Strychnos nux-vomica* L.	*	-	*
19	*Syzygium caryopyllatum* (L.) Alston	*	-	-
20	*Vateria indica* L.	*	*	*
21	*Vitex altissima* L.f.	*	-	*

Explanations: * – present, - – absent

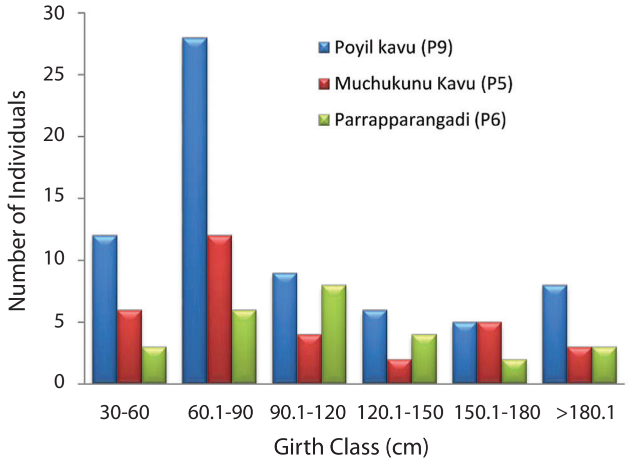

Fig. 2. Girth class distribution of *Vatica chinensis*

while others were represented by less than five individuals (Table 1). Another large population was identified from the parappanangadi railway station premises and a few large trees were observed along the road sides of the surrounding areas, with a great probability of them being removed any time from now.

In the present study we have isolated 196 individuals of *V. chinensis* from the 22 sample sites (Table 1). Among the three sampled areas (population number 5, 6 and 9) 126 individuals of *V. chinensis* were identified. The remaining six out of all the identified sacred groves and other locations were represented by 70 individual trees. The comparison among the three populations revealed that the highest number of *V. chinensis* was observed in poyilkavu (n=68) followed by muchukunukavu (n=32) and parappanangadi (n=26). The population structure between the plots showed the importance value index of *V. chinensis* at 101.22, 94.48 and 9.77 with a basal area of 37.94 m^2 ha^{-1}, 14.99 m^2 ha^{-1} and 0.66 m^2 ha^{-1} in parappanangadi, poyilkavu and muchukunukavu respectively (Table 2). The species composition of these population was dominated by *Alstonia scholaris*, *Holigarna arnottiana*, *Hopea ponga*, *Scleropyrum pentandrum*, *Strychnos nux-vomica*, *Vateria indica* and *Vitex altissima* etc. in the sacred grove and *Albizia saman*, *Vateria indica* and *Caryota urens* in the Parappanangadi region (Table 3). In poyil kavu, *Vatica chinensis* – *Holigarna arnottiana* – *Scleropyrum pentandrum* – *Hydnocarpus pentandrus* association was observed. When we analysed the girth class distribution

Fig. 3. A view of seed damage through human intervention

Fig. 4. Anthropogenic activity (A & B) of *Vatica chinensis* at parappanangadi areas

patterns of *V. chinensis* the majority of the individuals in poyilkavu and muchukunukavu occurred in the girth class of 60.1-90 cm. The comparison of the individuals in the lower girth class of 30-60 cm with 60.1-90 cm revealed that the number of individuals was high in the 60.1-90 cm class (Fig. 2). This indicates that the regeneration of seedling is very poor in each population. The field observation during the data collection confirmed high disturbance in *V. chinensis* population at parappanangadi due to anthropogenic activities which affect the fruiting, seed dispersal and seed germinations (Fig. 3, Fig. 4A, 4B).

3.3. Habitat suitability model

The predicted potential distribution is high in the central part of the Western Ghats and moderate in the northern part of the Western Ghats region (Fig. 5). Out of the three habitat suitability classes the high habitat category covered 21461.25 km^2 (1.88%), the medium habitat category covered 94558.35 km^2 (8.30%) and the low habitat category covered 1023226.95 km^2 (89.82%) of the total predicted geographic area. Out of the 22 reported localities 20 were from Kerala and only 2 from Karnataka. Based on these proportions we found that 11 points fall under the medium category, 6 under the

Table 4. Factors influencing the potential distribution of *Vatica chinensis*

Sl. No.	Variables	Code	Unit	Percent contribution	Permutation Importance
1	Mean diurnal range	BIO2	°C	32.1	5.7
2	Minimum temperature of coldest month	BIO6	°C	27.6	9.1
3	Annual precipitation	BIO12	Mm	18.7	21.7
4	Max temperature of warmest month	BIO5	°C	9.5	10.3
5	Precipitation of wettest month	BIO13	Mm	5.7	22.6
6	Elevation	-	M	5	29.9
7	Annual mean temperature	BIO1	°C	0.7	0.1
8	Slope	-	Degree	0.7	0.6

high and 5 points under the low category. The AUC test and the training values were at 0.988 and 0.989 respectively, which indicated the significance of the predicted model output. The Jackknife evaluation results showed that the mean diurnal range, the minimum temperature of the coldest month and the annual precipitation are the major factors that influence the potential prediction of the species (Fig. 6). Their individual contribution is 32.1%, 27.6% and 18.7% respectively. The other variables and their percentage contribution are provided in table 4. The predicted high probability area revealed that the Karnataka region possess the maximum cover of

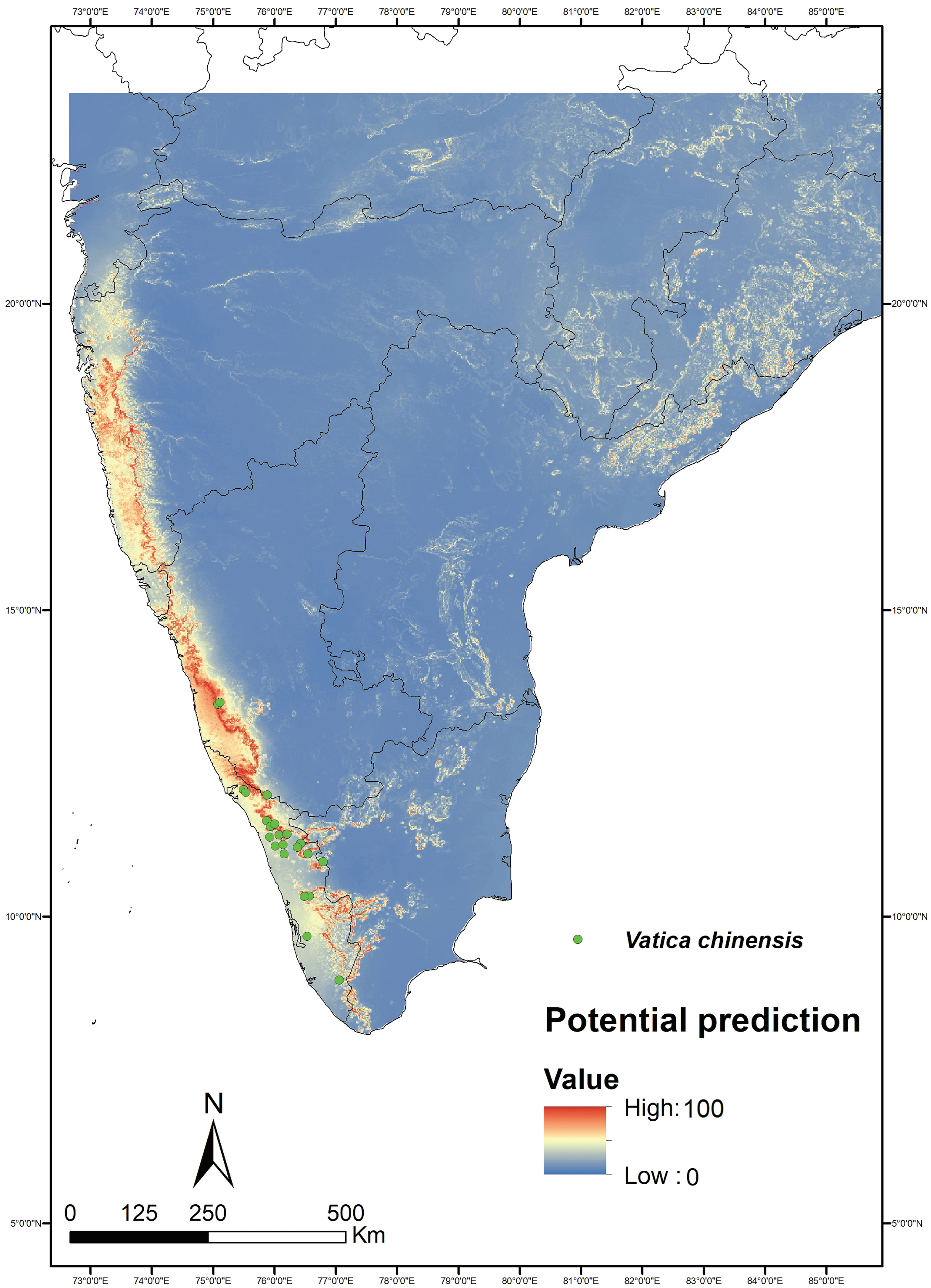

Fig. 5. Maxent prediction of *Vatica chinensis*

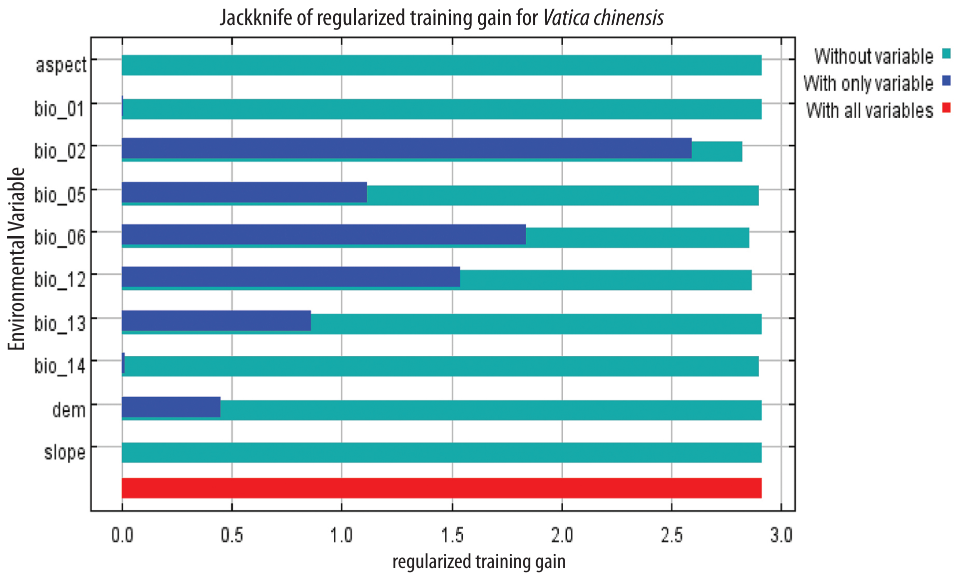

Fig. 6. Jackknife test for evaluating the relative importance of environmental variables of *Vatica chinensis*

35.40% followed by Maharashtra, 26.50% and Kerala, 21.72% out of the total predicted geographic area. Furthermore, the major district wise prediction showed Udupi with the maximum covers at 10.29%, followed by Raigarh, (8.36%), Uttara Kannada (7.67%), Ratnagiri (6.52%) and Kozhikode (4.85%) respectively.

4. Discussion

In the conservation efforts special interest has to be given to the protection of the rare and endangered species as it plays a major role in the forest ecosystem (Bascompte & Jordano 2007; Potts *et al.* 2010). To design a proper conservation strategy scientific background is necessary, as it is vital in understanding the issues and taking proper measures to rectify the problems. The Western Ghats inhabit 18 species of Dipterocarps, 11 of which excluding *Hopea ponga*, *Hopea parviflora* Bedd. and *Vateria indica* are restricted to certain pockets of the Western Ghats (Nayar *et al.* 2014). The IUCN listed *V. chinensis* under the critically endangered category from 1998 to 2020 (Ashton 1998b). Yet, this species was not listed under the threatened species of Kerala in the study carried out by Sasidharan (2017). As part of our study we could reassess the IUCN status of this species. Further the revised status of the species, from the critically endangered category to the endangered has been updated in the IUCN portal (Deepu *et al.* 2021).

The observations during the vegetation survey revealed that flowering was followed by successful fruit development in *V. chinensis*. However, some mature trees showed slight fluctuations in the flowering pattern, where mass flowering was seen in one season and the same individuals might or might not flower for the next season or two, influencing the fruit set and the subsequent seed production. Asynchronous flowering was also witnessed in few of the other populations. Low regeneration of the species was also identified for other reasons – one of them being the damage of the fallen seeds by the vehicles and the public, especially in the *V. chinensis* populations (Parappanangadi) located near a public road and a railway line. Furthermore, the cutting of the tree branches for the expansion of the road and railway line has also contributed to the significant reduction in the seed germination and the population size (Fig. 3, Fig 4A, 4B). The recalcitrant nature of the seeds (Sasaki 1980; Yap 1981) along with poor seedling survival additionally affects the species regeneration. Usually low regeneration is attributed to the seeds being generally short lived and unable to withstand the desiccation (Aguliar *et al.* 2006) as in the case of *V. chinensis*. The moisture content plays a significant role in the germination and according to Sukesh & Chandrashekar (2013) the seeds lose their viability completely within five days in the open environment and did not germinate when the moister content was lower than 61%. The seed germination without any dormancy period (within 6-10 days) was also reported in the case of *V. lanceifolia* (Borah & Devi 2014). These constrains in the natural regeneration, in terms of the seed set, seed germination and sustainable management of the existing population need to be strictly monitored followed by proper measures to avoid any harm to the tree in the vicinty of public's interest to retain the available resource.

Various studies incorporating both the field survey and the exploration based on the model output, have been used to discover new populations as well as allied species (Raxworthy *et al.* 2003; Siqueira *et al.* 2009).

These modeling studies help in data exploration by identifying potential information on the distribution pattern and similar ecological niches, thereby providing crucial scientific data and proper direction for the field-work design during the conservation and restoration activities (Engler *et al.* 2004). The ENM carried out in our study showed the potential distribution and the overall good performance of the species in the central and the northern part of the Western Ghats region of India. Most of the predicted areas were identified to belong outside the occurrence points investigated in our study. No information regarding the presence of the species has been documented in most of the predicted and highly suitable areas, indicating the probable loss of the species' habitat. A similar habitat loss was also reported in the case of *Dipterocarpus lamellatus* Hook.f. and *Dipterocarpus ochraceus* Meijer in Sabha, Malaysia (Maycock *et al.* 2012). Nevertheless, these predicted, highly suitable areas can be considered for the restoration activities of the species, as they share the same ecological niche. The high and medium suitability area for *V. chinensis* was largely represented by the disturbed / undisturbed forest patches, agro ecosystem, grasslands, settled areas and sacred groves, which was in accordance with our field survey. However, the results contradicted the earlier reports, which indicated the evergreen forests as their habitat (Sasidharan 2004). From our study the mean diurnal range, the minimum temperature of the coldest month and the annual precipitation were identified as the major bioclimatic variables to influence the potential distribution prediction for the species. Likewise, the precipitation of the coldest quarter and the annual mean temperature played a crucial role in the distribution of *Dipterocarpus indicus* (Malik *et al.* 2022). However, in the case of *Dipterocarpus littoralis* Blume in Nusakambangan the distance from the coastline and the elevation significantly contributed towards its distribution (Robiansyah 2017). The information gathered on the potential distribution regions of *V. chinensis*, especially the high probability areas, could help in designing the conservation priority area in the Western Ghats. The conservation priority needs to be strengthened; there is an urgent need to adopt the *in situ* and the *ex situ* conservation methodologies for the effective conservation of the species and their habitat. As an initiative we have collected some seeds of *V. chinensis* followed by raising the seedlings in the nursery and planting them at the KFRI Arboretum at Peechi.

5. Conclusion

The study on the distribution, population structure, vegetation analysis and the ENM of *V. chinensis* indicated an urgent need for prioritizing the sustainability and implementation of the proper conservation and restoration activity. The prediction made on the potential distribution of *V. chinensis* using the ENM could be used as a guideline to reintroduce/ introduce this species in the predicted suitable areas with similar ecological niches, thereby increasing their population status. Furthermore, proper maintenance and germination of the seeds is vital for providing the essential planting material for the *ex-situ* or the *in-situ* conservation.

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References

Aguliar R., Ashworth L., Galetto L. & Aizen M. A. 2006. Plant reproductive susceptibility to habitat fragmentation: Review and synthesis through a meta-analysis. Ecol Lett 9: 968-980. https://doi.org/10.1111/j.1461-0248.2006.00927.x

Ashton P. 1998a. *Vatica lanceaefolia*. The IUCN red list of threatened species 1998: e.T33031A9751387, Downloaded on 24 June 2019.

Ashton P. 1998b. *Vatica chinensis*. The IUCN red list of threatened species 1998: e.T33030A9751247, Downloaded on 24 June 2020.

Bascompte P. & Jordano P. 2007. Plant-animal mutualistic networks: The architecture of biodiversity. Annu Rev Ecol Evol Syst 38: 567-593. https://10.1146/annurev.ecolsys.38.091206.095818

Bhat K. G. 2003. Flora of Udupi. 913 pp. Indian Naturalist, Udupi, India.

Borah M. & Devi A. 2014. Phenology, growth and survival of *Vatica lanceaefolia* Bl.: A critically endangered tree species in moist tropical forest of Northeast India. Trop. Plant Res. 1(3): 1-12.

Curtis J. T. & Mcintosh R. P. 1950. The Interrelations of Certain Analytic and Synthetic Phytosociological Characters. Ecology 31(3): 434-455. https://doi.org/10.2307/1931497

Deepu S., Sanil M. S., Sreekumar, V. B. & Jose P. A. 2021. *Vatica chinensis*. The IUCN red list of threatened species 2021: e.T33030A169589229. Downloaded on 2 October 2021. https://dx.doi.org/10. 2305/IUCN.UK.2021-2.RLTS.T33030A169589229.en.

Elith J., Catherine H. G., Robert P. A., Miroslav D., Simon F., Antoine G., Robert J. H., Huettmann F., John R. L., Anthony L., Jin L., Lohmann L. G., Loiselle B. A., Manion G., Moritz C., Nakamura M., Nakazawa Y., Overton J. M. M., Peterson T., Phillips S. J., Richardson K., Pereira R. S., Schapire R. E., Soberón J., Williams S., Wisz M. S. & Zimmermann N. E. 2006. Novel methods improve prediction of species distribution from occurrence data. Ecography 29(2): 129-151. https://doi.org/10.1111/j.2006.0906-7590.04596.x

Engler R., Guisan A. & Rechsteiner L. 2004. An improved approach for predicting the distribution of rare and endangered species from occurrence and pseudo-absence data. J Appl Ecol 41: 263-274. https://doi.org/10.1111/j.0021-8901.2004.00881.x

Fielding A. H & Bell J. F. 1997. A review of methods for the measurement of prediction errors in conservation presence/absence models. Environ Conserv 24(1): 38-49. https://doi.org/10.1017/S0376892997000088

Hijmans R. J., Cameron S. E., Parra J. L., Jones P. G. & Jarvis A. 2004. The WorldClim interpolated global terrestrial climate surfaces, version 1.3.

Janardhanan K. P. 1993. Dipterocarpaceae. In: B. D. Sharma & M. Sanjappa (eds.). Flora of India, pp. 206-251. Botanical Survey of India, Calcutta.

Kriticos D. J., Webber B. L., Leriche A., Ota N., Macadam I., Bathols J. & Scott J. K. 2012. CliMond: global high resolution historical and future scenario climatic surfaces for bioclimatic modeling. Methods Ecol Evol 3: 53-64. https://doi.org/10.1111/j.2041-210X.2011.00134.x

Mabberley D. J. 2008. Mabberley's plant-book: a portable dictionary of plants, their classification and uses. 4th edition, 1124 pp. Cambridge University Press, Cambridge.

Malik K., Saranya K. R. L., Reddy C. S. & Varghese A. O. 2022. Predicting the habitat suitability of *Dipterocarpus indicus*: an endemic and endangered species in the Western Ghats, India. Spat. Inf. Res. https://doi.org/10.1007/s41324-022-00466-1

Chudnoff M. 1984. Tropical Timbers of the world. Agriculture Handbook No. 607. USDA, forest service, Wisconsin.

Maycock C. R., Khoo E., Kettle C. J., Pereira J. T., Sugau J. B., Nilus R., & Burslem D. F. 2012. Using high-resolution ecological niche models to assess the conservation status of *Dipterocarpus lamellatus* and *Dipterocarpus ochraceus* in Sabah, Malaysia. Journal of Forest and Environmental Science 28: 158-169. http://dx.doi.org/10.7747/JFS.2012.28.3.158

Nayar T. S., Beegam A. R & Sibi M. 2014. Flowering plants of the Western Ghats. Vol. 1. Jawaharlal Nehru Tropical Botanic Garden and Research Institute, Thiruvananthapuram, Kerala, India.

Peterson A. T., Egbert S. L. Sanchez-Cordero V. & Price K. P. 2000. Geographic analysis of conservation priorities using distributional modeling and complementarities: endemic birds and mammals in Veracruz, Mexico. Biol Conserv 93(1): 85-94. https://doi.org/10.1016/S0006-3207(99)00074-9

Peterson A. T., Soberon J. & Sanchez-Cordero V. 1999. Conservatism of ecological niches in evolutionary time. Science 285(5431): 1265-1267. https:// 10.1126/science.285.5431.1265

Phillips S. J., Anderson R. P., Schapire R. E. 2006. Maximum entropy modelling of species geographic distribution. Ecol Model 190(3-4): 231-259. https://doi.org/10.1016/j.ecolmodel.2005.03.026

Potts S. G., Biesmeijer J. C., Kremen C., Neumann P., Schweiger O. & Kuninm W. E. 2010. Global pollinator declines: trends, impacts and drivers. Trends Ecol Evol 25(6): 345-353. https:// doi.org/10.1016/j.tree.2010.01.007

Raxworthy C. J., Martinez-Meyer E., Horning N., Nussbaum R. A., Schneider G. E., Ortega-Huerta M. A., Peterson A. T. 2003. Predicting distributions of known and unknown reptile species in Madagascar. Nature 426: 837-841. https://doi.org/10.1038/nature02205

Robiansyah I. 2017. Predicting habitat distribution of endemic and critically endangered *Dipterocarpus littoralis* in Nusakambangan Indonesia. Reinwardtia 16: 11-18.

Saldanha C. J. 1984. Flora of Karnataka. Vol. 1. Oxford and IBH Publishing Co., New Delhi.

Sasaki S. 1980. Storage and germination of Dipterocarps seeds. Malaysian Forester 43(3): 290-308.

Sasidharan N. 2004. Biodiversity Documentation for Kerala part 6: Flowering Plants of Kerala. 44-46 pp. Kerala Forest Research Institute, Peechi, Thrissur.

Sasidharan N. 2017. A handbook on the red list species and their conservation status in Kerala. 229-235 pp. Kerala Forest Research Institute, Peechi, Thrissur,

Shiva M. P. & Jantan I. 1998. Non-timber forest products from Dipterocarps. In: S. Appanah & J. M. Turnbull (eds.). A Review of Dipterocarps: taxonomy, ecology and silviculture, pp. 187-197. Centre for International Forestry. Research Bogor, Indonesia.

Siqueira M. F., Durigan G., Junior P. M. & Peterson A. T. 2009. Something from nothing: using landscape similarity and ecological niche modeling to find rare plant species. J Nat Conserv 17(1): 25-32. https://doi.org/10.1016/j.jnc.2008.11.001

Sivaram M., Sasidharan N., Shine S., Sreedevi E. P. & Soumya R. 2006. Invent NTFP ver. 1.0. Computer aided inventory analysis for sustainable management of non-timber forest product resources. Kerala Forest Research Institute, Peechi.

Srisawat T., Chumkaew P., Kanokwiroon K., Graidist P. & Sukpondma Y. 2015. *Vatica diospyroides* Symington type is root extract induces antiproliferation of KB, MCF-7 and NCI-H187 cell lines. Trop J Pharm Res 14(6): 961-965. https://doi.org/10.4314/tjpr.v14i6.4

Sukesh & Chandrashekar K. R. 2013. Effect of temperature on viability and biochemical changes during storage of recalcitrant seeds of *Vatica chinensis* L. International Journal of Botany 9(2): 73-79. https://doi.org/10.3923/ijb.2013.73.79

Tewary P. K. 1984. Revision of Indian Dipterocarpaceae. pp. 207. PhD. Thesis, University of Kalyani, West Bengal, India.

Tewary P. K. & Sarkar A. K. 1986. Taxonomic revision of the genus *Vatica* L. (Dipterocarpaceae) in India. J. Econ. Taxon. Bot. 8(2): 419-424.

Thomsan M. B., Mittermeier R. A., Mittermeier C. G., Da-Fonseca G. A. B., Antony B. R., Konstant W. R., Flick P., Pilgrim J., Oldfield S., Magin G. & Hilton-Taylors C. 2002. Habitat loss and extinction in the hotspots of biodiversity. Conserv Biol 16(4): 909-923. https://doi.org/10.1046/j.1523-1739.2002.00530.x

Yap S. K. 1981. Collection, germination and storage of Dipterocarp seeds. Malays. For. 44: 281-300.