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Article

Modelling the habitat suitability of rattan (*Calamus zollingeri*) in Lore Lindu National Park, Central Sulawesi

Fadjri Maarif[1]*, Muh. Darmawan Basoka[1], Aji Rachmat Santoso[1], Richo Nandhito Sitinjak[1]

[1] Lore Lindu National Park, Ministry of Environment and Forestry, Jalan Prof. Moh. Yamin No. 53, Palu, 94111, Indonesia
* Correspondence: maariffadjri@gmail.com

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Abstract. *Calamus zollingeri* is a potential rattan species that is widely used by the community and is found in the Sulawesi region. As one of the potential non-timber forest products, habitat suitability modelling is needed to determine the distribution and prediction of *C. zollingeri* distribution in Lore Lindu National Park (LLNP), Central Sulawesi. This study used a species distribution modelling approach with the Maximum Entrophy method. *C. zollingeri* encounter data were obtained through data collected in the Lore Lindu Management Information System (SIMRELI) from 2019 to 2023. Environmental variables used in the modelling included NDVI, altitude, slope, land cover and distance from river. The modelling results show that 40% of the total LLNP area is highly suitable for *C. zollingeri* habitat, 20% of the total LLNP area is suitable for *C. zollingeri* habitat, and 40% of the total LLNP area is unsuitable/insufficient data. This study is important as a reference material for the management of LLNP, especially in structuring the management zone of LLNP.

Keywords: Calamus zollingeri, Central Sulawesi, Lore Lindu, Maximum Entropy (MaxEnt), Rattan

INTRODUCTION

Rattan (Calamoidea) is a spiny plant species that climbs on tree hosts (Henderson & Pitopang, 2018). Rattan can grow in the tropics, including in Indonesia. Rattan can grow in primary and secondary forests (Telu, 2006), with altitudes reaching 1,500 alt.

Calamus is one of the genera of the tribe Calamoidea and the Arecaceae tribe. Calamus is the clan with the largest number of species in the Arecaceae tribe (Rustiami & Henderson, 2017). Calamus is widespread throughout the tropics, from West Africa to Fiji, in tropical Asia the genus is very diverse, especially in lowland and mountain rainforests in Indo-Burma, Sundaland, Wallacea, and the Sahul region (Rustiami & Henderson, 2017). In Indonesia, Calamus is distributed in Java, Sumatra, Kalimantan, Sulawesi and Papua (Syam et al., 2016). Sulawesi is a location with a large diameter rattan source that is widely utilized (Kalima & Prameswari, 2018).

One species of rattan that is widely utilised is *Calamus zollingeri* (Kalima & Jasni, 2015). *C. zollingeri* in Indonesia is only found in Sulawesi, Maluku, and Papua. In Central Sulawesi, *C. zollingeri* is known by the local name rattan batang (Rustiami, 2011). *C. zollingeri* is one of the large-diameter rattan species that has a long-lasting carrying capacity for furniture frames (Abdurachman et al., 2017). *C. zollingeri* is used by the community as food, medicine, and crafts, such as chairs, tables, baskets, and other household tools (Maarif et al., 2021). Rattan can be found in almost all forest areas in Central Sulawesi (Rachman et al., 2021).

C. zollingeri lives in clusters, growing on creepers and climbing the trunks of neighbouring trees (Kunut et al., 2014). The shape of the stem is round and brushy, the colour of the stem is green and becomes brown when it is old, wrapped by spiny leaf midribs, the diameter of the stem reaches 5 cm, and the length can reach 14 m. The leaves are green in colour, have leaflets, and have spiny cirrus on each leaf. It has compound flowers, the fruit is generally one-seeded, oval-shaped, and covered by scales (Sarwiana et al., 2016).

Lore Lindu National Park (LLNP) is a conservation area located in Sigi and Poso Regencies, Central Sulawesi Province. With an area of 215,733 ha, the LLNP area is at an altitude of around 200 to 2,357 m alt. The LLNP area has a high diversity of flora species. The LLNP area is one of the 10 unique biodiversity hotspots in the world. Rattan is one of the important non-timber forest products for the people living around the LLNP area. Utilisation of non-timber forest products has been regulated in the Regulation of the Minister of Environment and Forestry of the Republic of Indonesia Number P.78/MENLHK/SEKJEN/KUM.1/10/2019 concerning Administration of Non-Timber Forest Products Originating from State Forests. The management of potential non-timber forest products in the LLNP area needs to be carried out sustainably so that non-timber forest products can provide benefits to the community and maintain ecological balance. The utilisation of rattan by the community has an impact on the community's economic sector where the community can utilise rattan as one of their creative economic products. However, ecological sustainability also needs to be considered and go hand in hand so that the principle of economic and ecological benefits is maintained.

Research on modelling the suitability of *C. zollingeri* rattan habitat in Indonesia or the LLNP area has never been conducted. This study will have an important impact on new information related to rattan habitat suitability modelling in Indonesia or in the LLNP. Therefore, this study needs to be conducted to determine the suitability of rattan habitat modelling in the LLNP area in order to become a recommendation material for the Lore Lindu National Park Office in managing conservation areas and biodiversity in them in a sustainable manner.

MATERIAL AND METHODS

Study Site

This research was conducted from October to December 2023. The research site is located in the Lore Lindu National Park with an area of 215,733 ha (Figure 1). Lore Lindu National Park is located in two districts, Sigi and Poso, Central Sulawesi Province.

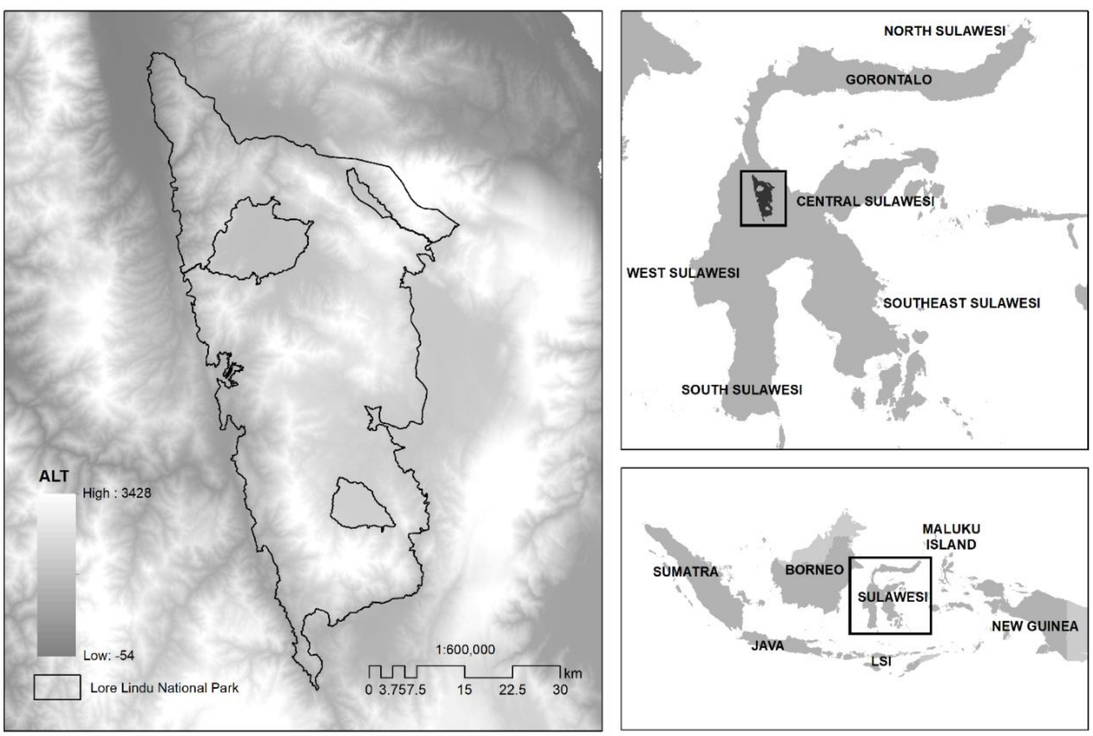

Figure 1. Map of Lore Lindu National Park, Central Sulawesi

Research Materials

The tools used in this research are a laptop with Maximum Entropy Species Distribution Modelling software version 3.4.1, ArcMap version 10.8, and Microsoft excel. The material used in this study is rattan plant encounter data in the LLNP area from 2019 to 2023 with a total of 1,252 encounter points.

Data collection of *C. zollingeri* encounter points was carried out by collecting data on coordinate points and documentation scattered in the LLNP area. *C. zollingeri* encounter points are the results of SMART patrol data from 2019 to 2023 stored in the Lore Lindu Management Information System (SIMRELI) application. The data used is data that has been verified for the suitability of the species name and its documentation.

Environmental variable data used are elevation and slope data sourced from the Digital Elevation Model (DEM) was obtained through the Geospatial Information Agency website which was built from several data sources including IFSAR, TERRASAR-X and ALOS PALSAR, distance from rivers, land cover of the Lore Lindu National Park area in 2022, and Normalised Difference Vegetation Index (NDVI) obtained through Google Earth Engine (GEE) using Sentinel-2 imagery. Environmental variable data comes from primary and secondary data from third parties that have been further processed. Environmental variable data used based on literature studies conducted in previous research on *C. zollingeri* habitat, including Siebert (1993), Rustiami & Henderson (2017), Kalima & Prameswari (2018), and Witno et al. (2022).

Data Analysis

C. zollingeri encounter point data were saved into comma delimited (csv) format via Microsoft Excel application. The environmental variable data used had to be further processed to adjust the projection and coordinate system, cell size, and outer boundary of the analysed area. The environmental variable data used must be converted into ascii format through ArcMap 10.8 application (Figure 2).

Habitat suitability modelling was conducted through the Maximum Entropy version 3.4.1 application by combining *C. zollingeri* encounter data with environmental variable data. Environmental variable data in the form of land cover is classified into categorical data types, while data on altitude, slope, distance from rivers, and Normalised Difference Vegetation Index (NDVI) are classified into continuous data types. This is because the land cover environmental variable data is non-numeric data in the form of categories/levels while the continuous data type is numeric data whose values may be unlimited. The environmental variable data has been selected based on the highest percent contribution, where the variables used in the selection include soil type, rainfall, landscape, distance from roads, and distance from settlements. Of the total *C. zollingeri* encounter data, 25% was used as a test and the other 75% to build the model (Latifiana & Kp, 2019; Phillips & Dudík, 2008; Qin et al., 2017; Zhang et al., 2019).

The modelling results will be validated through the Area Under Curve (AUC) value. AUC is a method to determine the accuracy of model prediction (Lobo et al., 2008). If the AUC value is below 0.5 then the modelling is not acceptable. According to Swets (1988), the AUC value in the range of 0.5 - 0.7 indicates a low category, 0.7 - 0.9 indicates a medium category, and above 0.9 indicates a high accuracy value.

The results of habitat suitability modelling are divided into three class ranges, namely very suitable, suitable, and unsuitable/insufficient data. The range of suitability values can be seen through the following equation (Supranto, 2000):

$$C = \frac{Xn - X1}{K}$$

where C = Estimated range size, Xn = Highest habitat suitability value, $X1$ = Lowest habitat suitability value, and K = Number of habitat suitability classes.

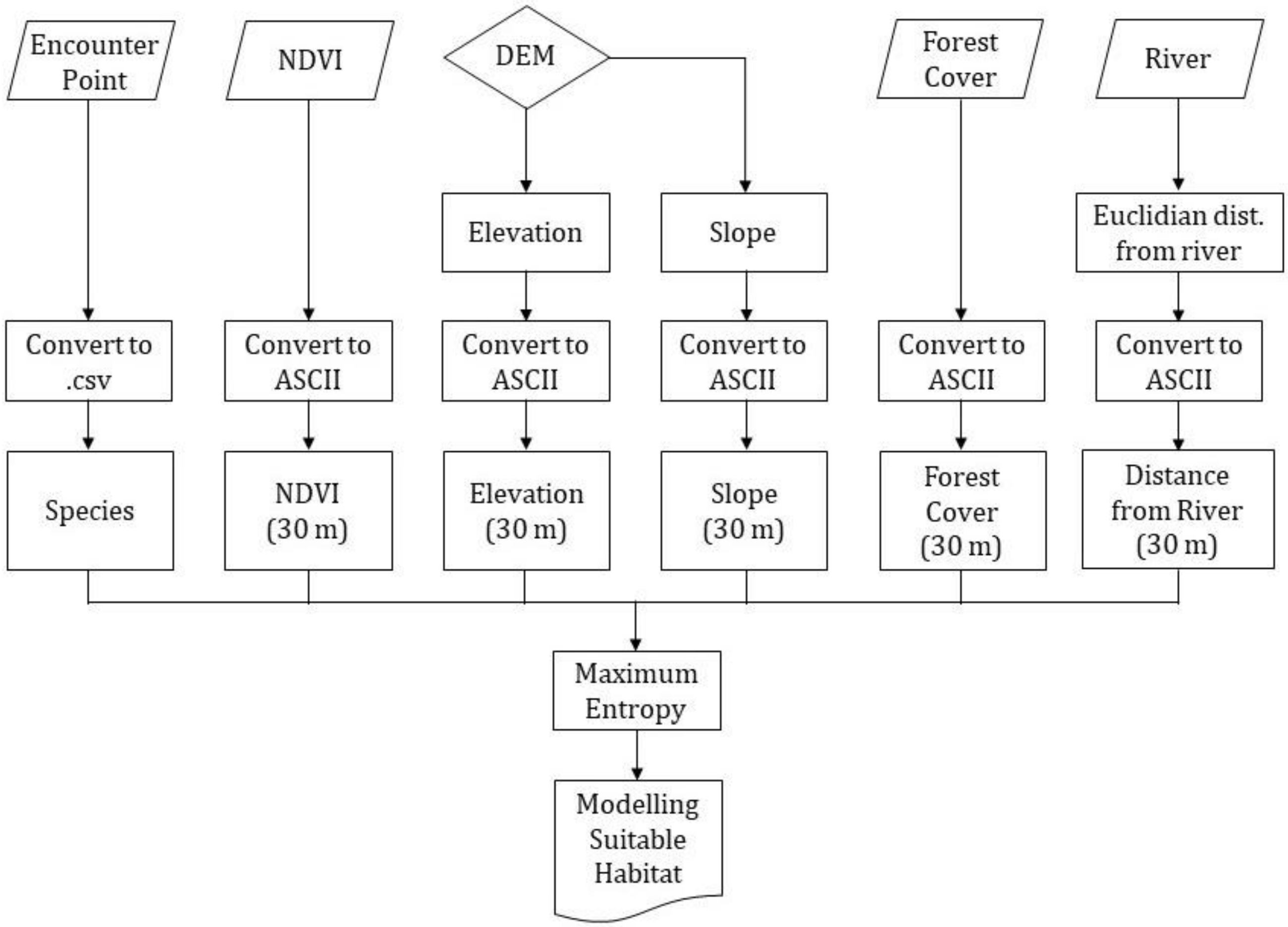

Figure 2. Data processing flowchart

RESULTS

Modelling the suitability of *C. zollingeri* habitat in Lore Lindu National Park based on plant encounter data for five environmental variables resulted in a moderate/fair model performance with an AUC value of 0.777. Araujo et al. (2005), classified model performance into four categories: very good (AUC > 0.9), good (0.8 > AUC ≥ 0.7), fair (0.7 > AUC ≥ 0.6), less (0.6 > AUC ≥ 0.5), and very less (AUC ≤ 0.5) (Phillips et al., 2006). The suitability of the modeled habitat is evaluated through the obtained AUC values, with a value closer to 1 signifying better performance. To classify *C. zollingeri* habitat suitability, we used a 10-percentile training presence logistic threshold of 0.314. This value serves as the minimum threshold, meaning areas with values below 0.314 are categorized as unsuitable for *C. zollingeri* habitat.

The Jackknife test evaluates the influence of environmental variables on modelling. Results of the Jackknife analysis performed on *C. zollingeri* habitat suitability modelling indicate that each variable has a varying degree of influence (Figure 3). These results further show that all environmental variables used in the modelling have an AUC value above 0.7, indicating they are 'quite good' predictors. Normalized Difference Vegetation Index (NDVI) emerged as the variable with the highest AUC, while the distance from the river had the lowest AUC. As noted by Lobo et al. (2008) in Nugroho et al. (2022), a higher AUC value signifies that the model can effectively differentiate between known species encounter locations and potential, untested sites.

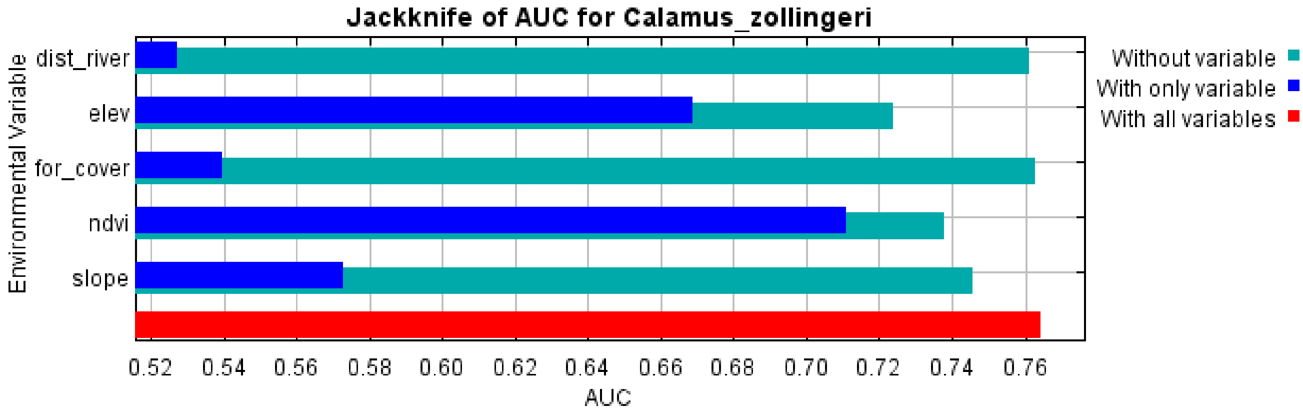

Figure 3. An AUC value for environment variable

Analysis of the contribution of environmental variables to the modelling shows that the Normalized Difference Vegetation Index (NDVI) is the most influential environmental variable which contributes 44.8%. Apart from NDVI, another environmental variable that influences modelling is height data with a contribution percentage of 31.2. The slope environmental variable has an influence of 18.7 on the model. The last two variables, land cover and distance from the river, had the lowest percent contribution to the modelling with 3.9% and 1.4%, respectively. The percentage contribution of environmental variables to the development of a habitat suitability model can be seen in Table 1 According to Aryanti et al. (2021), the environmental variables are deemed to have good contribution if it generates above 10%. The higher the contribution percentage value, the more significant the environmental variable is in modelling the habitat suitability of the species being modelled (Giri et al., 2023). Based on this analysis, environmental variables that contribute quite a lot in building a suitability model for *C. zollingeri* habitat are NDVI, height, and slope**.**

Table 1. Proportion of environmental variables to habitat suitability modelling

Variable	Contribution percentage
NDVI	44,8
Elevation	31,2
Slope	18,7
Forest cover	3,9
Distance from the river	1,4

DISCUSSION

Based on the modelling results, the Normalized Difference Vegetation Index (NDVI) emerged as the environmental variable with the greatest contribution to model development. NDVI serves as an index for quantifying vegetation density within an area (Purwanto, 2015). High NDVI values typically correspond to areas with dense vegetation cover, leading to lower surface temperatures due to the presence of oxygen within the vegetation itself (Innadya et al., 2022). Nurwiyoto (2021) emphasized the influence of sunlight intensity on rattan growth, with optimal conditions found within habitats receiving 50-60% sunlight penetration.

Similar to NDVI, altitude contributes significantly to the model and influences the presence of *C. zollingeri*. This species is typically found in lowland habitats, as evidenced by its distribution within the LLNP area. Encounter data reveal that *C. zollingeri* were found at lower (<1,000 masl) and mid-elevations (1,000-2,000 masl) in significantly higher numbers (722 individuals at <1,000 masl and 506 individuals at 1,000-2,000 masl) compared to higher elevations (>2,000 masl, with only 24 individuals), supporting the trend of decreasing presence with increasing altitude. This observation aligns with findings by Rustiami & Henderson (2017), who reported *C. zollingeri* distribution in lowland habitats ranging from 10 to 1,434 meters above sea level.

The slope of the land significantly impacts vegetation growth within an ecosystem due to its influence on soil properties. As reported by Septianugraha & Suriadikusumah (2014), steeper slopes are more susceptible to erosion, leading to the displacement of essential nutrients like C-organic content by surface water flows to flatter areas. This depletion of nutrients creates conditions unfavorable for most vegetation, resulting in sparse plant growth on land with steeper inclines.

Analysis of land cover data reveals that *C. zollingeri* was primarily found in secondary dry land forest (1,008 encounters, 80.5%), followed by plantations (210 encounters, 16.77%). Additionally, the species was found in lower frequencies within shrubs (14 encounters, 1.11%) and other land cover types (less than 1% combined). Notably, secondary dry land forests, as defined by (Savitri & Pramono, 2017), are areas with past logging or human activity but are not categorized as agricultural land or plantations.

While distance from the river contributes minimally to the model, *C. zollingeri* exhibits the ability to grow in both close and distant proximity to water sources. However, closer proximity to rivers or other water bodies is generally associated with increased soil fertility, as documented by Kalima (2022). This suggests that *C. zollingeri* might potentially thrive better in habitats with higher soil moisture content, which is often found near water sources.

Within the LLNP area, *C. zollingeri* encounters are more frequent at lower elevations and within secondary dry land forest, suggesting a potential association with specific vegetation communities and aligning with the documented preference for lowland habitats (Figure 4). Interestingly, modelling indicates a higher likelihood of finding *C. zollingeri* near the LLNP area's edges compared to the center, possibly due to the presence of more favorable environmental conditions in these peripheral areas. Vegetation conditions at the edge of the area are less dense than vegetation conditions in the middle of the area, this causes sunlight intensity to be more suitable for the needs of *C. zollingeri*. Environmental conditions at the edge of the area are dominated by low altitude compared to the centre of the area, where these conditions are suitable for *C. zollingeri* habitat. Altitude correlates with temperature in the field, the higher the surface, the lower the temperature and the lower the temperature, the less *C. zollingeri* is found. The area around the area is also an area with a gentle slope/not too steep. This slope condition is one of the environmental factors that also affects the habitat suitability of *C. zollingeri*. The habitat of *C. zollingeri* in LLNP is generally in the traditional zone and jungle zone.

The existence of non-timber forest products in the traditional zone allows the community to utilise these non-timber forest products through a cooperation mechanism/conservation partnership with the Lore Lindu National Park Office. Factors that could threaten the rattan habitat are land conversion and natural disasters. Land conversion can cause a shift in the function of rattan habitat into land for community activities. This condition needs to be considered and socialised to the community regarding the sustainable use of rattan so that its sustainability can be maintained. Strengthening human resources through conservation partnerships in providing access to the utilisation of non-timber forest products needs to be emphasised in terms of its ecological aspects (Yulianto et al., 2019). Utilisation of non-timber forest products should be an alternative for the community to minimise logging in conservation areas, but the ecological aspects also need to be considered.

The utilization of rattan as a non-timber forest product around the LLNP area has been widely practiced by LLNP buffer village communities. The utilization of rattan as a non-timber forest product is carried out through a conservation partnership between the Lore Lindu National Park Office and local community groups. The utilization of rattan by the community is carried out to increase community productivity in managing non-timber forest product resources in a sustainable manner that can improve the community's economy. Based on the results of analysis through modelling, the location of habitat suitability is in a location that is not too far from community settlements so that accessibility is not too difficult. The results of this modelling can be used as a reference in structuring LLNP management zones in determining zoning in accordance with conditions and needs at the site level.

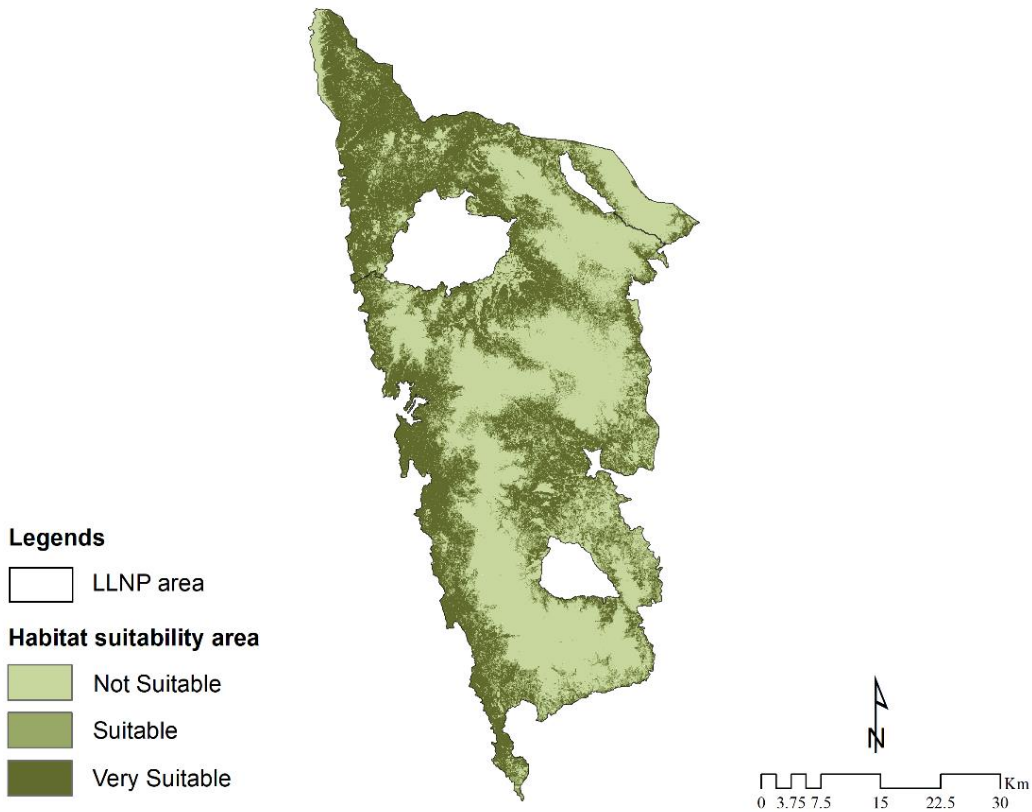

Figure 4. Map of the Habitat Suitability of *C. zollingeri*

CONCLUSION

The results of *C. zollingeri* habitat suitability modelling show that the LLNP area supports the habitat of *C. zollingeri*. The existence of this species in the LLNP area is supported by suitable environmental factors so that this species is found in the LLNP area. Environmental factors that become *C. zollingeri* habitat in this modelling include NDVI, altitude, slope, land cover, and distance from the river. The results of this habitat suitability modelling can also be used as a recommendation for the Lore Lindu National Park Office in managing the LLNP area, especially in structuring the LLNP management zone. The existence of *C. zollingeri* in LLNP can also be used as a potential non-timber forest product that can be utilised by the community in a sustainable manner and still pay attention to ecological balance.

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AUTHOR CONTRIBUTIONS

FM: research conceptualization, analysing data, map making, writing the manuscript; MDB: analysing data, research implementer; ARS: map making and interpretation; RNS: interpretation.

CONFLICTS OF INTEREST

The authors declare there is no conflict of interest related to financial funding and authorship order for this article.

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