

MODELLING FUTURE DISTRIBUTION AND HABITAT SUITABILITY OF IVORY CANE PALM [*Pinanga coronata* (Blume) Blume] – A CULTURALLY IMPORTANT PALM IN A FAST-CHANGING WORLD

Saniyatun Mar'atus SOLIHAN^{1,3,*}, Mega ATRIA¹, Joko Ridho WITONO², Chris J. THOROGOOD⁴

¹ Biology Department, Faculty of Mathematics and Natural Sciences, Universitas Indonesia, Depok, Indonesia

² Research Center for Biosystematics and Evolution, National Research and Innovation Agency
Republic of Indonesia, Cibinong, Indonesia

³ Conservation Department, Mitra Natura Raya, Bogor Botanical Garden, Bogor, Indonesia

⁴ Department of Biology, University of Oxford, Oxford OX1 3SZ, United Kingdom

Abstract

Indonesia is an international center of diversity for palms. One of the most widely distributed palms in Indonesia is the ivory cane palm (*Pinanga coronata*). This culturally important plant is wild-harvested for various traditional uses – a trend that appears to be increasing. Here we examine the spatial distribution and habitat suitability for *P. coronata* to assess conservation priorities. Species occurrence data were obtained from living collections, herbaria, and databases. The data were analyzed using the maximum entropy (MaxEnt) model. The model prediction from MaxEnt for *P. coronata* under two climate scenarios gave AUC values of 0.890 (current climate scenario), 0.889 (future climate scenario ssp126), and 0.886 (ssp585). The AUC value is >0.70, indicating the model is sufficient to quantify the occurrence of *P. coronata*; we identify high-priority areas across the region. The most important environmental factors contributing to habitat suitability were found to be annual rainfall and temperature. Most suitable habitats for *P. coronata* are predicted to fall outside protected areas, calling for urgent conservation intervention. We discuss our findings in the broader context of policy-setting and conservation, and call for further work in quantifying the distributions of species under threat

Keywords: Conservation; Habitat suitability; Ivory cane palm; Maxent; *Pinanga coronata*

Introduction

Indonesia is an international center of diversity for palms and home to about 20% of all species (570 of 2600 species) [1], [2]. Various palm life histories exist in the country, ranging from solitary to clumping, as well as shrubs, trees, and lianas [3]. One of the most widespread clumping palms, which occurs across the archipelago, is *Pinanga coronata* [4]. This palm species is native to Sumatra, Java, and the Lesser Sunda Islands (Indonesia) and occurs on steep hillsides, mountain forests, and lowland forests at altitudes to 1800 m above sea level [5-10].

Pinanga coronata is a distinctive species with clustered, upright stems to 10 m high and a crownshaft of up to 1 m across (Fig. 1). Across Indonesia, local communities use *Pinanga coronata* for various purposes, and it can be thought of as a 'multi-purpose tree'. People in

* Corresponding author: sani.ms54@gmail.com

Sumatra and the Lesser Sunda Islands use the palm's seeds as a substitute for areca nut (*Areca catechu*) for chewing and traditional medicine; the leaves are used as roofs for huts, the hard outer part of the stem is used for blades, and the inside of the stem is used as a traditional herbal asthma medicine by heating the stem pith on open hot ashes, leaving it overnight, after which it is eaten [11], [12]. Around the Mount Gede Pangrango National Park, Java, the plant is used as an ornamental, and its shoots are for food [13]. The people of West Nusa Tenggara use *P. coronata* as an ornamental plant indoors and outdoors, such as in parks [14]. Taken together, the plant has significant ornamental and cultural value across its range.

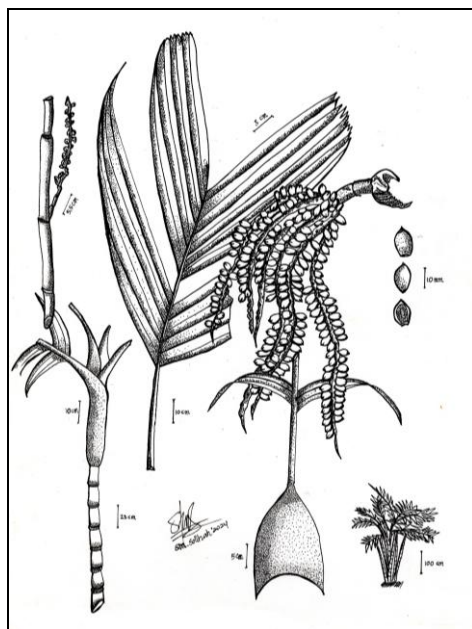


Fig. 1. Morphological characteristics of *P. coronata*.

Pinanga coronata is not yet listed by the International Union for Conservation of Nature (IUCN Red List) and is widespread [15]. However, considering its extensive use coupled with a pattern of growing land conversion activities in Indonesia [17], this plant is under threat. Effective conservation intervention will require basic information such as spatial distribution and habitat suitability data, which are currently missing. Habitat suitability maps can be created through spatial modeling of habitat suitability, which can be carried out using a Geographic Information System (GIS)-based model approach based on remote sensing data [18]. Remote sensing is now established as a useful tool for mapping [19]; statistical techniques coupled with machine learning can be used to better understand and model the habitat requirements of a given plant species [20], [21]. To understand habitat suitability predictions, species distribution models (SDMs) are commonly used to combine species occurrence data and environmental variables [22-25]. Among distribution modeling methods, Maximum Entropy (MaxEnt) is considered very powerful and outperforms other tools when predicting species with narrow habitat ranges [24-28]. This method opens up opportunities for identifying potential new subpopulations of palm in surveyed areas of Sumatra, Java, and the Lesser Sunda Islands. Ecological data for *P. coronata* in its natural habitat are scant, and spatial distribution and

habitat suitability of *P. coronata*, in particular, have never been studied. Here we analyze the spatial distribution and predict suitable habitats for *P. coronata* to inform conservation outcomes for a plant that has a long and important history of cultural use and that may be threatened by major global change.

Materials and methods

Research sites

Records of the presence of *P. coronata* were obtained from collection data in six Indonesian botanical gardens: the Bogor Botanical Garden (BG), Cibodas BG, Purwodadi BG, ‘Eka Karya’ Bali BG, Cibinong BG, and Baturraden BG (39 records). Occurrence data were obtained from Herbarium Bogoriense (BO) (48 records), and the Global Biodiversity Information Facility (GBIF) (63 records). Records of the distribution of *P. coronata* at various altitudes considered to fall in Indonesia (from Sumatra and Java to the Lesser Sunda Islands) were extracted from plant inventory records and scientific articles [14], [29], [30], [31]. Total occurrences of *P. coronata* comprised 150 records. The points of occurrence are presented in figure 2.

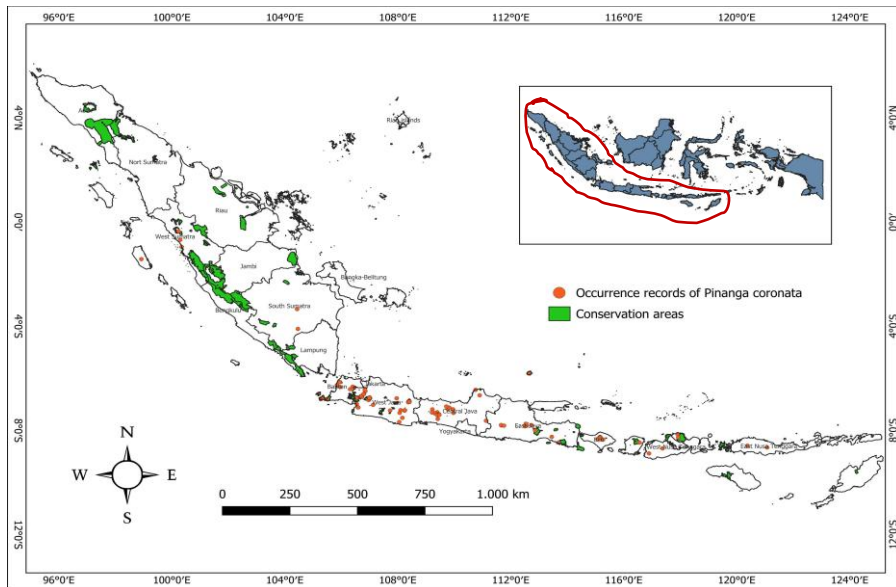


Fig. 2. The occurrence records of *Pinanga coronata* in Malesia

Spatial distribution

Spatial distribution data were obtained from field research results and previous research and downloaded from various online resources (listed below). These data include species coordinate points, global climate data (mean annual temperature and annual rainfall), elevation, and soil data. Species coordinate points were obtained from the Global Biodiversity Information Facility (GBIF) website (www.gbif.org) [10]. All coordinate points were entered into Microsoft Excel in CSV format. Global climate data in mean annual temperature and annual rainfall were extracted from WorldClim version 2.1. These variables represent averages for the years 1970–2000, with a spatial resolution of 30 seconds (approximately 1 km²) [32] (www.worldclim.org) [33], which serve as environmental variables. The climate data comprised 19 climate variables.

The climate data comprised two types of climate, namely the current scenario and the future climate scenario (2081-2100) using the Global Climate Model (GCMs) in the form of MIROC6 with climate scenarios ssp126 and ssp585 [24], [32], [33]. Bioclimatic variables (Bio1-Bio19) were separated in the ssp126 and ssp585 climate scenarios using RStudio [33], [34]. Elevation data with a resolution of 30 seconds (1 km²) was obtained from the Shuttle Radar Topography Mission (SRTM) Digital Elevation Model Data [24], [35], [36], as well as elevation and administrative areas of Indonesia from DIVA-GIS as input for mapping the spatial distribution of diversity and endemism (diva-gis.org) [37]. Soil data, such as soil pH, nitrogen, and soil organic carbon (SOC), were obtained from SoilGrids (mapped global soil information) (soilgrids.org) [24]. These data are available at a spatial resolution of 250 m [38]. The creation of base maps for all maps in this study, including clipping of the Malesia area map and the *P. coronata* distribution map based on elevation, used QGIS 3.38 Grenoble (qgis.org) [39].

Habitat suitability

The habitat suitability of *P. coronata* was modeled using Maxent software version 3.4.4 by applying a machine learning technique called Maximum Entropy (MaxEnt) [40]. This algorithm is considered the best method compared to similar models. The general equation of the MaxEnt algorithm is as follows:

$$H(\pi) = -\sum_{x \in X} \pi(x) \ln \pi(x)$$

information:

π = unknown probability distribution

x = individual elements of the species' presence coordinates

In conducting the MaxEnt analysis, we used the default settings of the MaxEnt Java program, but for the assessment of models with multiple sites, a jackknife (or 'leave-one-out') procedure was applied. Models were built using the remaining n-1 sites. Therefore, for species with observed sites, n separate models were built for testing [27]. For the MaxEnt settings: percentage of random trials 30, regularization multiplier 1, number of background points 750 (5 × the number of coordinate points), replication test type (cross-validation), maximum iteration 500, convergence threshold 10⁻⁵, and default prevalence value 0.5. Predicted suitable habitats for *P. coronata* were crossed with each other to create areas. These areas were then overlaid with conservation areas to identify highly suitable habitats within conservation areas. Four classes of potential habitat were grouped into unsuitable (≤0.10), low potential (0.11–0.30), medium potential (0.31–0.70), and high potential (≥0.71) [24], [41], [42], [43].

Results and discussion

Spatial distribution

The predicted maximum entropy habitat model of *P. coronata* can be evaluated using the area under the curve (AUC) value; this value represents the model's prediction skill on a 0–1 basis. The prediction of the *P. coronata* model using the current climate scenario has an AUC value of 0.890, while using the future climate scenario ssp126 has a value of 0.889 and ssp585 has a value of 0.886. The AUC value greatly determines the success of the model. If the AUC testing value is closer to 1, the more sensitive and descriptive the model is good [44]. The results showed that the habitat suitability prediction model for *P. coronata* has an AUC value > 0.80, which indicates that the model has good performance or is included in the good category

[24], [45], [46]. AUC values range from 0 to 1 [47]. An AUC value of 0.50 indicates that the model does not perform better than random, while a value of 1.0 indicates perfect discrimination [48]. Habitat suitability maps are generated based on model predictions, and the AUC value represents the predictive model's performance. Models with AUCs in the range of 0.9–1 (very good), 0.8–0.9 (good), 0.7–0.8 (adequate), 0.6–0.7 (poor), and 0.5–0.6 (failure) [49]. The probability values are classified into four classes of habitat suitability, namely, unsuitable (0–0.2), low (0.2–0.4), moderate (0.4–0.6), and high suitability areas (0.6–1) [50], [51], [52], [53]. Predictive habitat suitability models with AUC values in the range of 0.7–0.8 are considered acceptable, and 0.8–0.9 are considered very good [54]. Based on the highest AUC test value, the data with five times the number of background points used as the visualization determinant produced a habitat suitability map model for *P. coronata* in the Malesia region using two climate scenarios (Fig. 3).

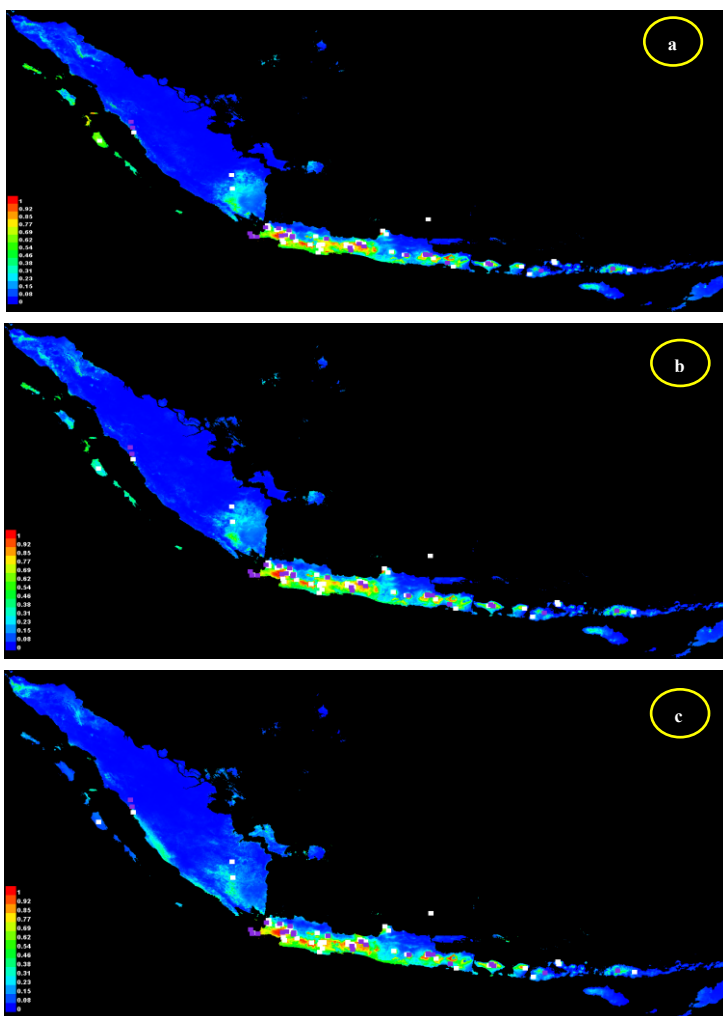


Fig. 3. The predicted suitable habitats of *P. coronata* provided by MaxEnt Models. A) Current climate scenarios, B) future climate scenarios (ssp126), and C) future climate scenarios (ssp585). Areas with grid cells that have a value > 0.5 indicate more suitable, while areas with grid cell values < 0.5 indicate less suitable.

MaxEnt modeling allows for identifying the relative influence of environmental variables on habitat suitability. The results of using the jackknife procedure (or ‘leave-one-out’) using two climate scenarios obtained important variables that affect the habitat suitability of *P. coronata* (Fig. 4). The results of the current climate analysis obtained the three most important variables, namely Precipitation of Coldest Quarter (bio19), Precipitation of Wettest Quarter (bio16), and Mean Temperature of Driest Quarter (bio9). The future climate with the ssp126 scenario obtained the three most important variables, namely Mean Temperature of Driest Quarter (bio9), Precipitation of Warmest Quarter (bio18), and Mean Temperature of Warmest Quarter (bio10), while the ssp585 scenario obtained the three most important variables, namely Precipitation of Warmest Quarter (bio18), Precipitation of Wettest Quarter (bio16), and Mean Temperature of Warmest Quarter (bio10). Variable data for habitat suitability comprise environmental conditions, including annual average temperature, annual rainfall, altitude, soil data, and land cover [24]. The process of selecting meaningful environmental variables in determining occurrence records, as well as choosing the right predictors, is important in determining the suitability of a species' habitat [54], [55], [56]. The growth and reproduction of *P. coronata* from juvenile to adult levels are greatly influenced by topography and water availability (rainfall) [57].

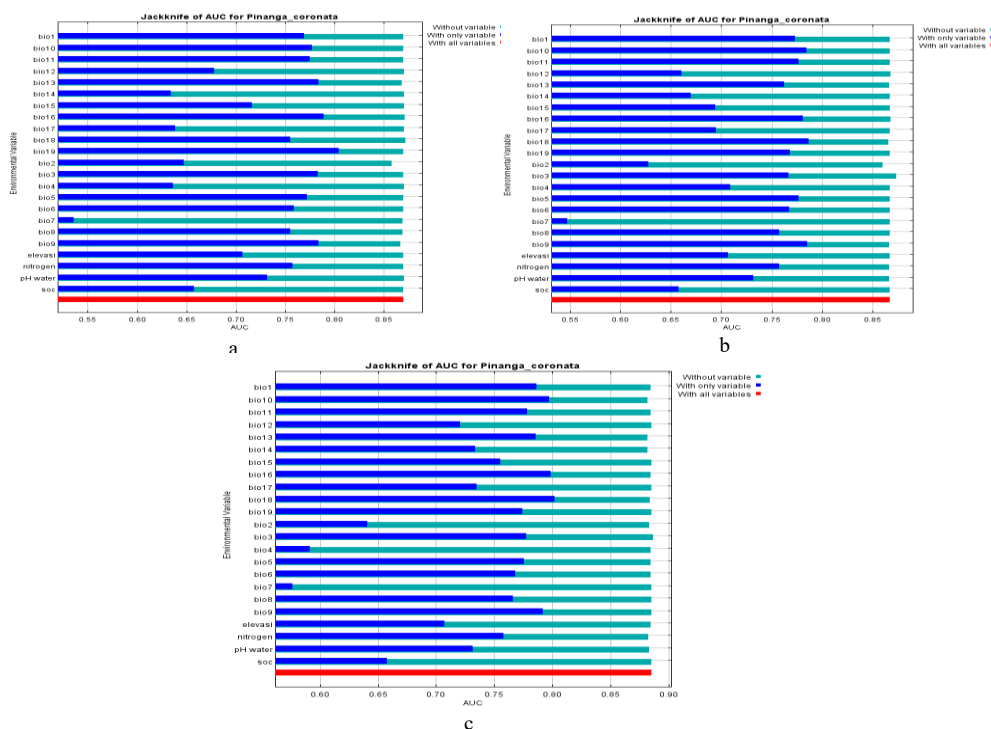


Fig. 4. The importance variables that affect *P. coronata* using the jackknife procedure: a) current climate scenario, b) future climate with the ssp126 scenario, c) future climate with the ssp585 scenario

To build the prediction of this model, there are three predictors (topography, soil, and climate) used as input. We consider these variables to be significant in determining the habitat suitability of *P. coronata*. The jackknife (or ‘leave-one-out’) procedure was applied to model the species. The application of the jackknife test to the MaxEnt model resulted in a high success

rate and statistical significance obtained with a small sample size as low as five [24], [27]. A critical difficulty in this study is the limited location records of *P. coronata* from the few available studies and herbarium specimen data, especially records from Sumatra and the Lesser Sunda Islands. To obtain a more reliable model for *P. coronata*, additional occurrence records from Sumatra and the Lesser Sunda Islands should be obtained. Several previous studies have used MaxEnt modeling to predict the potential distribution of endemic or rare species with a small number of records, such as *Rafflesia arnoldii* in Sumatra with 28 occurrence points [24] and *Vanda bicolor* with 10 occurrence points [58].

Habitat suitability

Based on the prediction of the influence of current climate on the suitability of the distribution of *P. coronata* found in Malesia, it shows 49,663,371 ha (73.65%) is unsuitable, 9,669,251.40 ha (14.34%) is less suitable or low potential, 5,685,874 ha (8.43%) is suitable (moderate potential), and 2,416,391.30 ha (3.58%) is highly suitable (high potential) (Fig. 5).

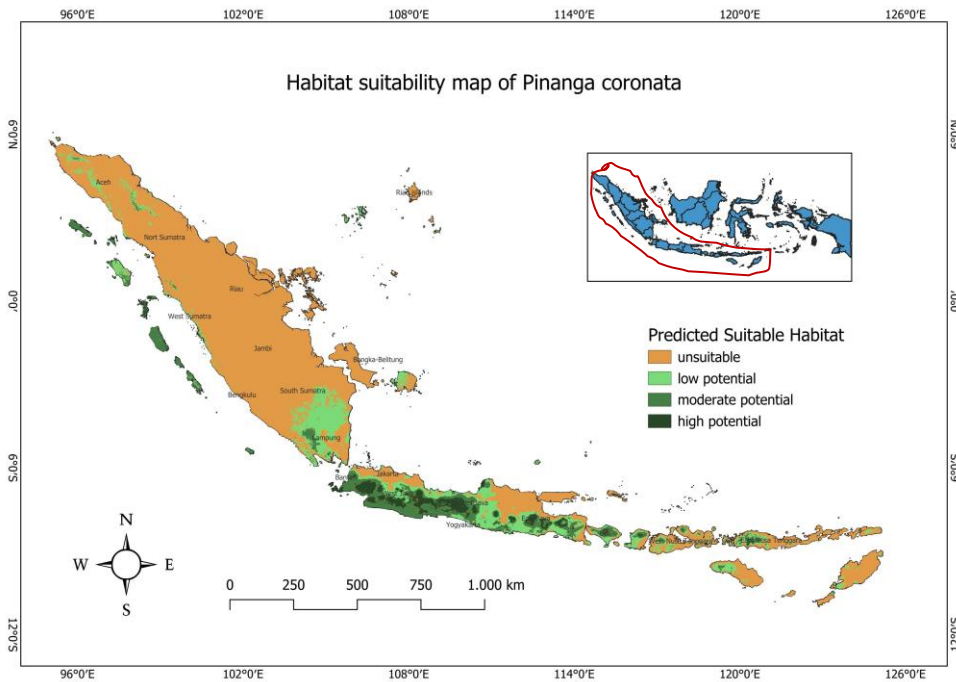


Fig. 5. Predictable suitable habitat of *P. coronata* in Malesian region (current scenario)

Habitats predicted to be highly suitable based on the distribution area of *P. coronata* are mostly located outside conservation areas (Fig. 1). There are 133 conservation areas identified as having high habitat suitability for *P. coronata* (Sumatra 33 areas, Java 82 areas, and Lesser Sunda Island 18 areas) (Table 1).

Table 1. Identified conservation areas that are suitable habitats of the *P. coronata* in Malaysia

Location	Conservation areas
Sumatra	1) Gunung Leuser, 2) Gunung Leuser National Park, 3) Kepulauan Banyak, 4) Lingga Isaq, 5) Pulau Bengkaru, 6) Pulau Weh, 7) Bukit Barisan Selatan, 8) Gumai Pasemah, 9) Isau-isau Pasemah, 10) Kerinci Seblat, 11) Berbak, 12) Batang Pangean I, 13) Hutan Bakau Pantai Timur, 14) Bentayan, 15) Gunung Raya, 16) Batang Palupuh, 17) Lembah Anai, 18) Lembah Harau, 19) Malampah Alahan Panjang, 20) Maninjau, 21) Singgalang Tandikat, 22) Gunung Sago Malintang, 23) Pulau Berkeh, 24) Bukit Rimbang Bukit Baling, 25) Giam Siak Kecil, 26) Bukit Batu, 27) Tasik Tanjung Padang, 28) Tasik Besar-Tasik Metas, 29) Dolok Surungan, 30) Sibolangit, 31) Sibolangit, 32) Tinggi Raja, 33) Karang Gading dan Langkat Timur Laut
Java	1) Alas Purwo, Rawa Dano, 2) Gunung Halimun – Salak, 3) Muara Angke, 4) Ujung Kulon, 5) Pulau Bokor, 6) Pulau Rambut, 7) Yan Lapa, 8) Dungus Iwul, 9) Sukawayana, 10) Banten, 11) Gunung Tukung Gede, 12) Kepulauan Seribu, 13) Leuwang Sancang, 14) Gunung Tangkuban Parahu, 15) Gunung Tilu, 16) Cikepuh, 17) Gunung Gede – Pangrango, 18) Telaga Warna Cibanteng, 19) Takokak, 20) Telaga Patengan, 21) Cigenteng Cipanji, 22) Gunung Jagat, 23) Papandayan Nature Recreation Park, 24) Papandayan Nature Reserve, 25) Talaga Bodas Nature Reserve, 26) Talaga Bodas Nature Recreation Park, 27) Nusa Gede Panjalu, 28) Pananjung Pangandaran, 29) Linggarjati Gunung Masigit Kareumbi, 30) Cimanggu, 31) Gunung Simpang, 32) Gunung Sawal, 33) Gunung Tampomas, 34) Kawah Kamojang, 35) Gunung Burangrang, 36) Ir. H. Juanda, 37) Gunung Ciremai, 38) Gunung Celering, 39) Wijaya Kusuma, 40) Telaga Ranjeng, 41) Guci, 42) Telogo Warno Pengilon, 43) Telogo Sumurup, 44) Telogo, 45) Dringo, 46) Peson Subah I, II, 47) Kecubung Ulolanang, 48) Pagerwunung Darupono, 49) Keling II/III, 50) Gebugan, 51) Sepakung, 52) Pringamba I/II (Pringamba), 53) Sub Vak 18c 19b Jatinegara, 54) Vak 55 Bantarbolang, 55) Grojogan Sewu, 56) Gunung Butak, 57) Gunung Selok, 58) Bekutuk, 59) Kepulauan Karimun Jawa, 60) Sigogor, 61) Nusakambangan Timur, 62) Bromo Tengger Semeru, 63) Kawah Ijen, 64) Meru Betiri, 65) Pulau Nusa Barung, 66) Dataran Tinggi, 67) Yang, 68) Baluran, 69) P. Bawean, 70) Gua Nglirip, 71) Besowo Gadungan, 72) Manggis, 73) Gadungan, 74) Pulau Sempu, 75) Gunung Baung, 76) Pancur Ijen I/II, 77) Curah Manis Sempolan I – VIII, 78) Tretes, 79) Suranadi, 80) Gunung Kijang, 81) Pulau Pasir Panjang, 82) Mega Mendung
Lesser Sunda Islands	1) Bali Barat, 2) Batukahu I-II-III, 3) Pangelokan, 4) Pulau Dana, 5) Gunung Rinjani, 6) Pulau Moyo, 7) Komodo National Park, 8) Komodo UNESCO-MAB Biosphere Reserve, 9) Gunung Tambora Selatan Game Reserve, 10) Gunung Tambora Selatan Wildlife Reserve, 11) Manupeu Tanadaru, 12) Dataran Bena, 13) Tuti Adagac/ KH Gunung Besar, 14) Gunung Mutis, 15) Pulau Rusa, 16) KH Egon Ilewekoh Lewotobi, 17) Teluk Pelikan, 18) Kerumutan

Based on the observed occurrence records, *P. coronata* is predicted to occur on the entire western side of Sumatra along the Bukit Barisan Mountains from Lampung to Aceh, then widely from Java Island through Bali to East Nusa Tenggara. Referring to the results of the potential habitat prediction map and identification of conservation areas, the suitability of *P. coronata* habitat is high on the western and southern to central sides of Java, from Banten to East Java. This is in accordance with the environmental conditions in the area, such as Ujung Kulon National Park, which has an average temperature of 26.6–28.9°C and an average monthly air humidity ranging from 85 to 90% [59]; Mount Gede Pangrango National Park, which always has rainfall above 200 mm/month (high throughout the year), surplus water availability, and an average annual temperature of 25.3°C [60]; the Mount Slamet area with annual rainfall reaching a range of 2,750–6,500 mm and air temperatures ranging from 20 to 30°C [61]; Bromo Tengger Semeru National Park with an average annual rainfall of 6,600 mm/year [62]; and in Alas Purwo National Park, the average air humidity is 75.2% and the average annual air temperature is 27.9°C [63]. Meanwhile, there are only a few records of occurrences in Sumatra due to the difficulty of identification in the wild, especially when still seedlings, because they are similar to *Areca catechu* seedlings and the lack of literature

reporting *P. coronata* occurrences in Sumatra. Presence data reliability may be influenced by sampling techniques and species identification [64].

The most extensive suitable habitat of *P. coronata* is predicted to reside in Java. The area ranges from the coast and lowlands to mountains. The lowlands in Ujung Kulon National Park, which are the result of the eruption of Mount Krakatoa in 1883 [65], and the mountains on the central side of Java, consisting of stratovolcanoes, some of which are still active today, such as Mount Slamet, Mount Merapi, Mount Semeru, and Mount Bromo; these are covered by dense forests with higher slopes [66], [67]. Based on observation records, *P. coronata* is found throughout Java. Northern Java is predicted as a less suitable habitat represented by the orange color (Fig. 5) because the northern part of Java comprises an alluvial plain [68], [69].

While the highest habitat suitability lies in Java, the highest habitat change is also on this island, due to land conversion and volcanic activity. These changes have an impact on ecosystems, animals, and landscapes and may be exacerbated by climate change. Central Java Province has lost 446,561.09 ha, or 88%, of its natural dryland forests over 16 years (1990-2006) [70], and this trend is still increasing. Forest fragmentation in Java is a consequence of various human activities such as urbanization, rural settlements, agricultural land expansion, infrastructure development, legal and illegal logging, economic crisis, the COVID-19 pandemic, and a limited understanding of its impacts [71]. Java Island, as the main rice producer in Indonesia, has maximized its agricultural expansion and opened up new land for food production [72]; government-led agricultural expansion through forest conversion has resulted in deforestation, biodiversity loss, and increased greenhouse gas emissions [71]. Land conversion for agriculture other than rice; forest plantations; settlements; and infrastructure-related development, such as arterial roads, toll roads, and high-voltage electricity networks, is also a major challenge [70].

The habitat suitability map of *P. coronata* generated from this study may not accurately predict the current location of the species because it relies on biophysical variables, including altitude, water pH, nitrogen, and soil organic carbon. Other factors, such as human management and site history, may also be important [24]. Although the predicted habitat suitability of a site may be high, there are many reasons why the species may not be found there. These may be biotic, such as seed dispersal limitations, or unidentified interactions that hinder recruitment or survival [24]. It is possible that the species formerly occurred in a predicted habitat but has since become extinct there. For example, based on occurrence records from the Herbarium Bogoriense, *P. coronata* was once found on the west side of Java, precisely in Depok. This record is the result of a herbarium collection collected by C.A. Backer on October 27, 1818, with collection number 26279; S.H. Koorders on April 18, 1903, with collection number 40192B; and Dr. C.G.G.C. van Steenis on May 28, 1939, with collection number 11237. However, after we conducted an exploration in Depok in 2024, precisely in the Pancoran Mas Nature Reserve (now the Pancoran Mas Forest Park), *P. coronata* had disappeared. The Pancoran Mas Forest Park is the oldest nature reserve in Indonesia and a highly important reservoir for biodiversity [73], [74]. The habitat suitability map model identifies Depok as an area of high habitat suitability: it is clear that human activity has driven the demise of the palm at this location. This forest, which lies in a densely populated settlement, has decreased in area and functionality. Initially it comprised an area of 150 ha [75]; however, with an increasing population in Depok City, this has diminished to just 6 ha [74].

Conservation implications

The tide of modernization as a result of a rapidly changing world has not eliminated traditional cultural practices passed down through generations. Several species of palms, including *P. coronata*, have played a significant role in the daily lives of Indonesian peoples, mainly in Java. *P. coronata* can be considered a ‘multi-purpose’ palm that is valued by the community for food, medicine, construction, and as an ornamental plant [13], [76], [77], [78], so it is worthy of research attention. To improve conservation-based management, the integration of in situ and ex situ conservation is necessary [79]. Referring to the BRIN online database "Makoyana" [80], several botanical gardens in Indonesia have collected *P. coronata*, such as Batam BG (Riau Isl. Province), Bogor BG, Cibodas BG, Kuningan BG (West Java Province), Baturraden BG (Central Java Province), Purwodadi BG (East Java Province), Eka Karya Bali BG, Gianyar BG (Bali Province), and Lombok BG (West Nusa Tenggara Province). Several in situ conservation areas are located within or adjacent to botanical gardens, such as Gede Pangrango National Park and Cibodas BG [13], Mount Slamet Protected Areas and Baturraden BG [79], and Batukaru Nature Reserve and Eka Karya Bali BG. It means that *P. coronata* grows both in the wild and in cultivated conditions. With in situ conservation conditions, *P. coronata* can be protected in its natural habitat and maintained ecological interactions, while ex situ conservation is crucial to conserve *P. coronata* and use it for research and educational purposes. Therefore, both in situ and ex situ conservation play a crucial role in maintaining the sustainability of plant biodiversity in Indonesia, particularly *P. coronata*. Integration of these two strategies is the main foundation of a modern conservation system that is oriented towards long-term preservation and is in line with efforts to achieve Sustainable Development Goals (SDG) 15, namely Life on Land [81].

Cultivation of *P. coronata* in botanical gardens, nurseries, and local communities is an important action for conservation and sustainable use of *P. coronata* in the future. The species is easily propagated by seeds, since it has a clustered habit and produces fruit every year. Propagation of *P. coronata* and other palm species has been successfully conducted in several local communities in Java, such as local communities around Baturraden BG, which cultivate *P. coronata* in their home gardens or community gardens for ornamental plant and consumption purposes [79]. Cultivation of *P. javana*, an endemic palm to Java, has also been conducted in Pronojowo village in Lumajang District (East Java) for consumption purposes. Therefore, we recommend that the results of this study be used to inform policy, to determine protected areas, and to improve conservation-based management.

Conclusions

We demonstrate the value of a modeling-based approach for predicting the distribution of a culturally important and potentially threatened palm in a megadiverse region. The spatial distribution prediction of *P. coronata* with two climate scenarios has an AUC value of >0.70 (approaching 1), indicating that the model is useful for quantifying the occurrence of *P. coronata*—and potentially other palms in the future. The environmental factors that contribute most to the suitability of *P. coronata* habitat are annual rainfall and average temperature. The most suitable habitat for *P. coronata* is predicted to be outside conservation areas. There are 133 conservation areas predicted to be suitable habitats for *P. coronata*. Our approach could be

extended to other species at risk of land conversion and local use over broad geographic areas that may be difficult to sample extensively on the ground. We hope this work will spur further research to inform policy and conservation practice.

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