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Habitat suitability model for banteng (*Bos javanicus*) in Meru Betiri National Park, Indonesia

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Abstract. *Siddiq AM, Kholiq N, Subchan W, Maulahila HI. 2023. Habitat suitability model for banteng (*Bos javanicus*) in Meru Betiri National Park, Indonesia. Biodiversitas 24: 1296-1302.* In Indonesia, the population of banteng (*Bos javanicus*) has drastically dropped. The last line of defense against the continued existence of this species is provided by conservation areas like Meru Betiri National Park (MBNP). The purpose of this study was to evaluate the banteng's habitat suitability in the MBNP region. The occurrence statistics from 2019 to 2020 collected by MBNP were sent to us. Three categories, i.e., direct encounter, footprint and dung encounter, and camera trap encounter are used to categorize the occurrence data. Eight environmental factors that we thought would affect the appropriateness of habitats and the distribution of banteng were incorporated into our modeling (land cover, altitude, slope, annual temperature range, annual precipitation amount, distance to the river and coastline, and distance to the nearest settlement). Utilizing MaxEnt v.3.4.4, the Habitat Suitability Model (HSM) was produced. In general, four environmental factors have a substantial impact, including; altitude, annual temperature range, distance from the nearest settlement, and the coastline distance to the settlement, distance to the coastline, altitude, and annual temperature range were the most significant variables according to permutation importance (PI) (35.1%, 22.2%, 11.8%, and 11.6%, respectively). According to our final HSM, the MBNP includes 33,891 Ha (65%) of inappropriate habitat and 17,985 Ha (35%) of habitat suitable for banteng. Finally, implementing habitat and population management for banteng in MBNP can use these results as guidance.

Keywords: Banteng, habitat suitability, Meru Betiri National Park

INTRODUCTION

Banteng (*Bos javanicus*) is one of the largest mammals in Indonesia that is under threat of significant population decline (Gardner et al. 2016). Several factors, including hunting, natural predators, competition, disease, and habitat degradation, can threaten this species (Timmins et al. 2008; Gardner et al. 2016; Radcliffe 2016; Rahman et al. 2019; Gardner et al. 2021). The IUCN Red List of Threatened Species includes this animal in the endangered species category (Gardner et al. 2016). The Indonesian Government also, in its regulations, includes this animal in a protected status (MenLHK 2018) and designates this species as a priority for the conservation strategy.

In Indonesia, banteng is divided into two subspecies, and it is distributed in the forests of Borneo (*B. javanicus* subsp. *lowi*), Java, and Bali (*B. javanicus* subsp. *javanicus*) (Timmins et al. 2008; Gardner et al. 2014). In Java Island, banteng occupies several habitats, such as coastal, lowland, and highland forests up to 2000 m above sea level (masl) (Gardner et al. 2014). Currently, the habitat of banteng in Java Island found in conservation areas such as Ujung Kulon National Park (UKNP), Baluran National Park (BNP), Alas Purwo National Park (APNP), and Meru Betiri National Park (MBNP) (Gardner et al. 2014; Hakim et al. 2015; Imron et al. 2016; Rahman 2020). However, the scientific reports on banteng distribution and their habitat in MBNP are partially (Garsetiasih and Heriyanto 2014; Garsetiasih and Alikodra 2015; Siddiq et al. 2022) and certainly do not describe them thoroughly.

The MBNP is a conservation area in East Java that includes the banteng as a priority animal to be protected along with the Javan leopard (*Panthera pardus melas*), Javan Hawk-Eagle (*Nisaetus bartelsi*), and sea turtles (four species were identified in Sukamade, Banyuwangi, East Java, Indonesia). This conservation area has a five ecosystems type (Syarief 2018), and banteng can be found in natural habitats (coastal forests, lowland rainforests) and artificial habitats (feeding ground areas and plantations) (Garsetiasih and Heriyanto 2014; Siddiq et al. 2022). The existence of banteng outside their natural habitat, such as plantation areas, can cause conflict between animals and the resident. Reports regarding the banteng population in MBNP are still very limited a decline was reported from 2000 to 2002 (Timmins et al. 2008).

The effort to monitor banteng populations by MBNP staff has been carried out regularly through direct observation and camera traps and began intensively in

2014-2021. The monitoring data found the banteng presence distribution in their habitat ranging from an altitude of 2 to >600 masl. The presence of data on each species in their habitat is very important for predicting the distribution, preference, or habitat suitability level (Hirzel and Lay 2008; Bradley et al. 2012; Kwon et al. 2016), one of which is banteng in MBNP. Therefore, this study will construct a prediction model of habitat suitability for banteng in MBNP. Determination of habitat suitability is based on ecological factors that affect the existence of species in nature (Ellith et al. 2011; Hansen et al. 2020). Furthermore, referring to the previous study on predicting the suitability habitat of banteng in APNP (Imron et al. 2016) and UKNP (Rahman et al. 2019; Rahman 2020), this study uses nine environmental variables, including land cover, altitude, slope, annual temperature range, annual precipitation amount, distance to the river, distance to the coastline, distance to the road, and distance to the settlement. These variables represent the habitat characteristics and suitability of banteng, including biological resources and physical and anthropogenic variables. Based on this study, it is expected that it will be able to explain the suitability habitat of banteng in MBNP, which has not been fully reported so far. Furthermore, this research can be used as a scientific reference for managing banteng conservation policies, especially its habitat in the MBNP.

MATERIALS AND METHODS

Study area

The Meru Betiri National Park (MBNP) is a conservation area in Jember, East Java, Indonesia with an area of 52,626.04 ha (Figure 1). Geographically, this conservation area is located at 113º27'23"-113º58'11" East and 8º20'31"-8º35'09" South, while administratively covering two districts, i.e., Jember and Banyuwangi and divided into three management sectors, e.g., Ambulu, Kalibaru, and Sarongan sectors. There are five ecosystem types in MBNP, e.g., coastal forest, brackish forest, lowland rainforest, swamp forest, and rheopyhtes (Syarief 2018). MBNP has a climate in type B based on Schmidt and Ferguson, with annual precipitation of about 1300-4000 mm. The topography is varied from flat to steep, with an altitude range of about 0-1100 masl.

Occurrence data

From MBNP, we were able to get 536 instances of banteng that were recorded between 2019 and 2020. Three categories direct encounter, footprint and dung encounter, and camera trap encounter, are used to categorize the occurrence data. Both camera traps and patrol tracking lanes used by police across all sectors were used to acquire the data. Moreover, to reduce the bias of occurrence, the coordinate data were also processed with resampling and rarefying.

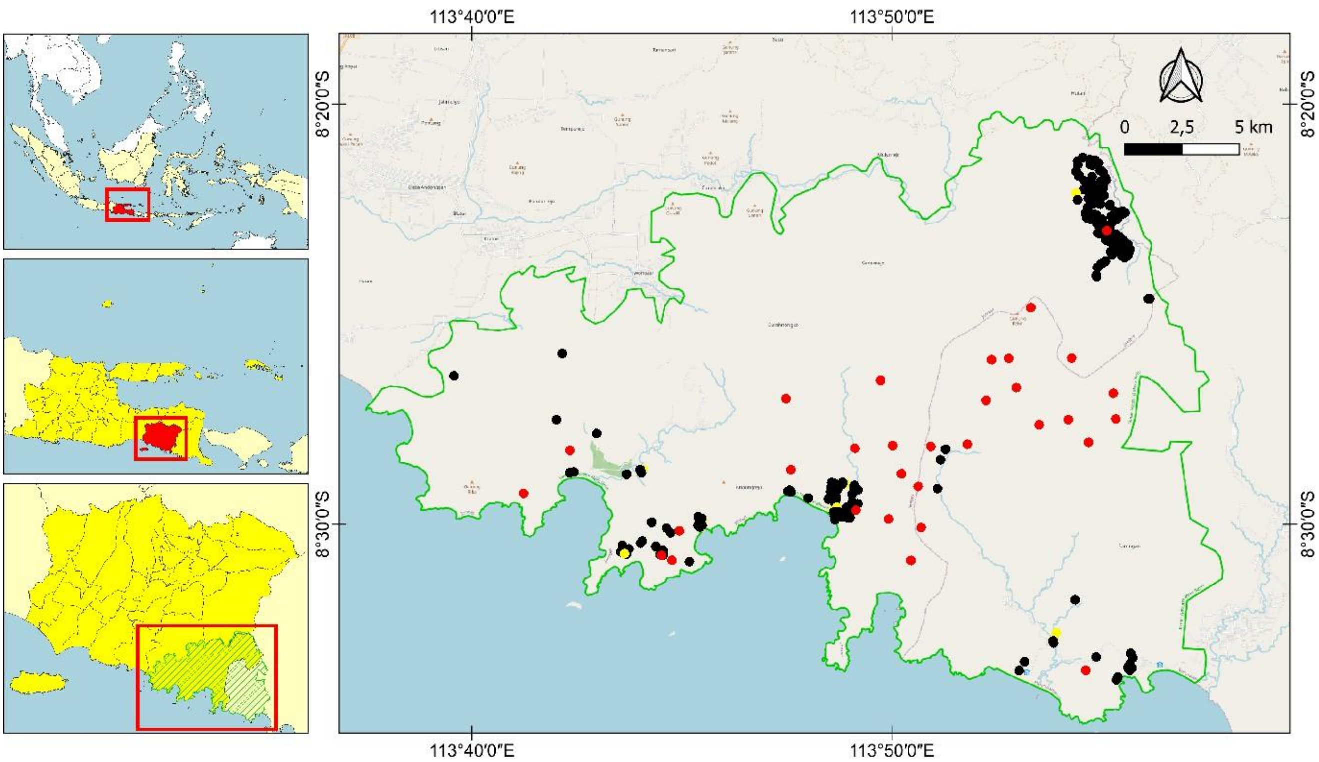

Figure 1. The study area map and the distribution of banteng occurrence in all sectors of Meru Betiri National Park (MBNP), Jember, East Java, Indonesia. Yellow dots represent direct encounters, black dots represent footprint & dung encounters, and red dots represent camera trap encounters. Maps were generated using ArcGIS software 10.7.1 by ESRI with data from MBNP

Environmental variable data

Nine environmental variables considered to affect the habitat of banteng were used to construct the model. These variables were classified into three classes based on previous studies; (i) resource variables, i.e., land cover; (ii) physical variables, i.e., altitude, slope, annual temperature range, annual precipitation amount, and distance to the river and coastline, and (iii) anthropogenic variables, i.e., distance to the nearest settlement, distance to the nearest road (Imron et al. 2016; Rahman et al. 2019; Lim et al. 2021).

The land cover variable was obtained from esa-worldcover.org (Zanaga et al. 2022). The elevation and slope data were downloaded from Sentinel-2 (usgs.gov), which was generated using contour and slope tools. The annual range temperature and precipitation amount variables were obtained from chelsa-climate.org (Karger et al. 2017). Moreover, distance data to the river, coastline, road, and settlement were downloaded from Peta Rupa Bumi Indonesia (basemap.big.go.id) and generated using Euclidean Distance. Finally, all the variable data were converted into a raster layer with resampling to a 30 m cell size grid and mask into the MBNP boundaries park with ArcGis 10.7.1 (Young et al. 2011).

Furthermore, the environmental variable was filtered using the Pearson test to avoid the multicollinearity between variables affecting the habitat suitability model (Feng et al. 2019). The environmental variables with |r| > 0.7 will be removed from the model (Dormann et al. 2012). Finally, there are eight environmental variables (i.e., land cover, altitude, slope, annual temperature range, annual precipitation amount, distance to the river and coastline, and settlement) were used to generate the habitat suitability model.

Habitat suitability model

The Habitat Suitability Model (HSM) was generated using MaxEnt v.3.4.4 (Phillips et al. 2017a) with the following setting in this program: regularization multiplier at unity, maximum of 5000 iterations, 10 replicates, and convergence threshold of 10 percentile. The output format was also set to the logistic format, and the program was run with the auto feature (Young et al. 2011). In addition, the accuracy of the model was measured using the Area Under the Curve (AUC) with values ≥0.8-0.9 that represented a model with a good fit until excellent (Manel et al. 2001). Based on the model output, we also assess the contribution of the environmental variable to the habitat suitability of banteng using the Jackknife test (Phillips 2017b).

RESULTS AND DISCUSSION

Model Evaluation

The Area Under the Curve (AUC) value obtained from the Maxent running replication is 0.809 with a standard deviation of ±0.045. This value indicates that the model built has good accuracy. Therefore, the model can predict the habitat suitability of banteng in MBNP.

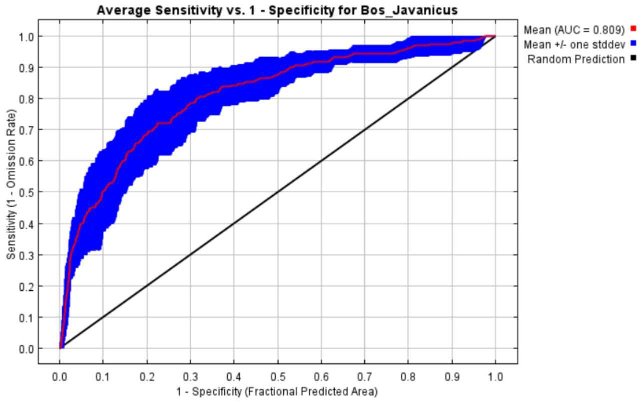

Figure 2. The Receiver Operating Characteristic (ROC) and the average Area Under Curve (AUC) of banteng HSM in MBNP, Jember, Indonesia

Environmental variables contribution

The maxent output shows the contribution of environmental variables for the habitat suitability model of banteng in MBNP. Generally, four environmental variables have significant contributions, e.g., distance from the settlement, distance from the coastline, altitude, and annual temperature range. Based on permutation importance (PI), distance to the settlement was the most significant variable, followed by distance to the coastline, altitude, and annual mean temperature (35.1%, 22.2%, 11.8%, and 11.6%, respectively) (Table 1). Meanwhile, the jackknife test in the model revealed the highest gain when the distance from the coastline was used alone, followed by annual mean temperature, altitude, and distance to the settlement (Figure 3).

The spatial distribution of banteng in environmental variables was mapped and followed by the response curve (Figures 4A-I). Four environmental variables with high contribution (e.g., distance from the settlement, distance from the coastline, altitude, and annual temperature range) show a different pattern (Figures 4A, 4B, 4E, 4G, and 4I). Banteng in MBNP tends to avoid settlement (>2000 m), distributed at a low altitude (<200 masl), and close to the coastline (<5000 m) although it has a small probability to be still found at 0-1000 m from the settlement, at ±600 masl, and >5000 m from the coastline. Meanwhile, banteng has an annual temperature range toleration from 5.6-7.3℃ with the maximum probability distribution at ±6.5℃.

Table 1. The permutation importance of environmental variables in habitat suitability of Banteng in MBNP, Jember, Indonesia

Environmental variables	Permutation importance (%)
Altitude	11.8
Distance to coastline	22.2
Annual precipitation amount	5.6
Distance to river	5.8
Distance to settlement	35.1
Slope	5.8
Annual temperature range	11.6
Land cover	2.1

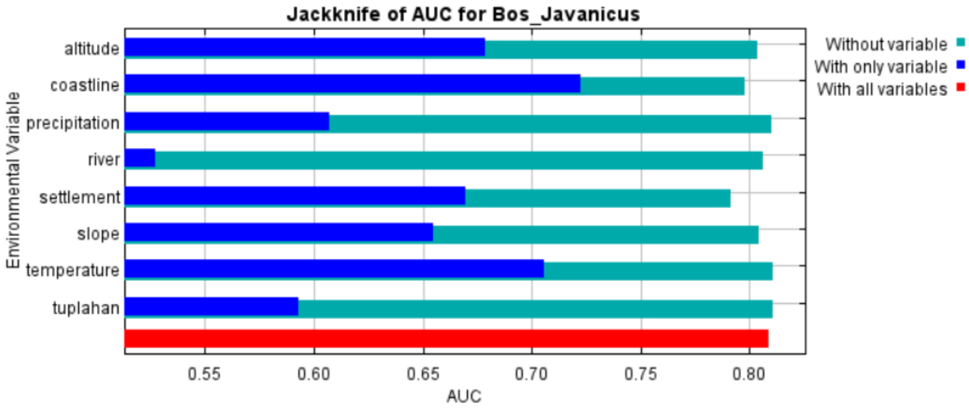

Figure 3. The results of the jackknife test for environmental variables contribution of the banteng habitat suitability model in MBNP, Jember, Indonesia. The environmental variables comprise altitude, the distance from the coastline, the annual precipitation amount, the distance from the river, the distance from the settlement, the slope, the temperature is annual temperature range, and *tuplahan* is representative of the land cover

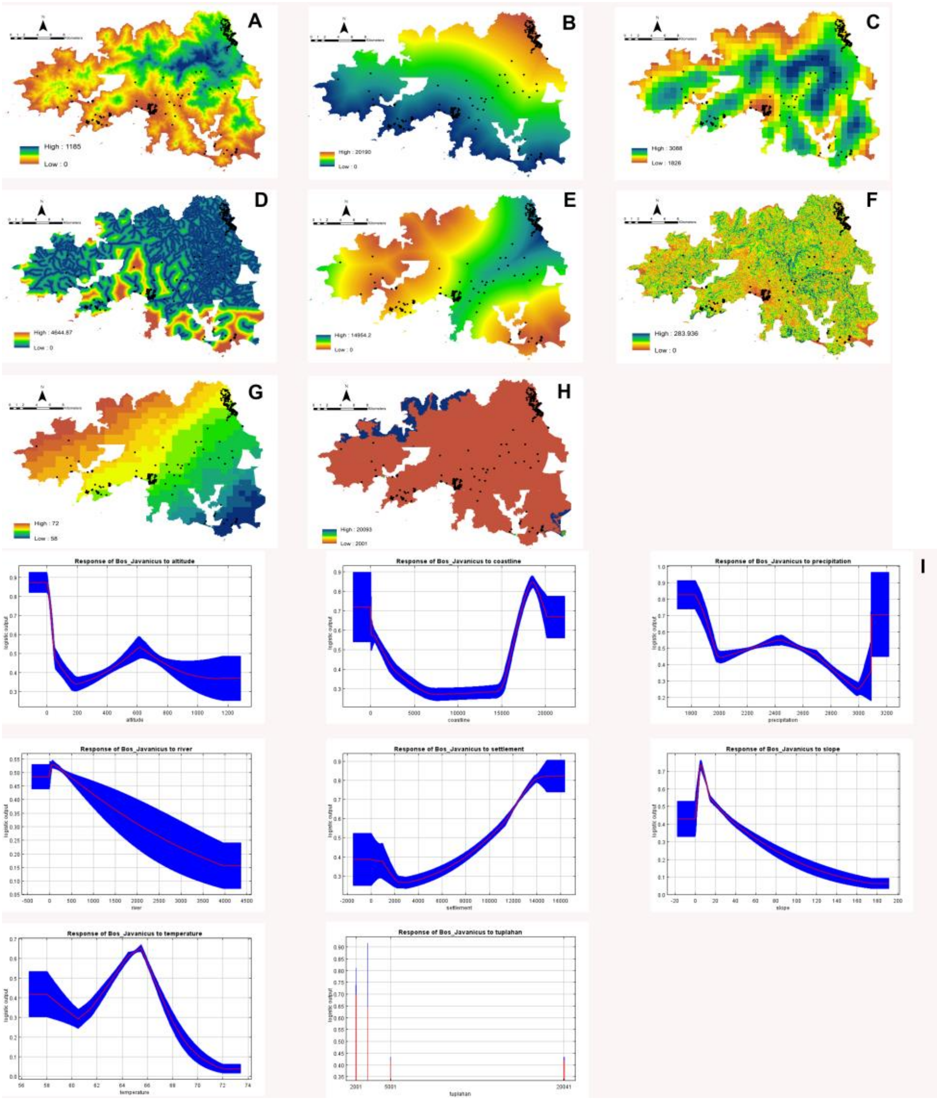

Figure 4. Environmental variables map of banteng habitat (A-H), altitude (A), distance to the coastline (B), Annual precipitation amount (C), distance to river (D), distance to the settlement (E), slope (F), Annual temperature range (G), and Land cover (H). The model also shows the response curve between the probability of presence and environmental variables (I). Altitude is masl, the coastline is the distance from the coastline (m), the precipitation is annual precipitation amount (kg/m^2), the river is the distance from the river (m), settlement is the distance from the settlement (m), the slope is the percentage of slope (%), the temperature is the annual temperature range (℃, scale 0.1). *Tuplahan* is representative of the land cover

Furthermore, the response curve from the distance to the river and the slope percentage show a negative correlation. The presence probability of banteng decreased as the distance to the river and slope percentage increased (Figures 4D, 4F, and 4I). It is revealed that banteng in MBNP tends to be distributed in flat areas and close to the river. The output response of annual precipitation amount revealed that banteng has a bimodal curve; it tends to distribute from ±1800-3200 kg/m^2 (Figures 4C and 4I). The output model also shows that the banteng tends to distribute in an area with high tree cover compared to shrubland (Figures 4H and 4I). However, the landcover variable has the smallest contribution in this model.

Habitat suitability model of banteng

Using 10 percentile training presence as a threshold, the MBNP is classified as an unsuitable and suitable habitat for banteng (Table 2). Generally, the suitable area is distributed at the north and the south part of MBNP (Figure 5). The suitable north areas are in parts of Baban, Malangsari, and Sumberpacet Resort. This suitable area is also connected to Bandealit Resort in the southern part. Moreover, the suitable area for banteng in the southern part of the MBNP extends with patch conditions from Wonoasri to Rajegwesi Resort, concentrated around the coast.

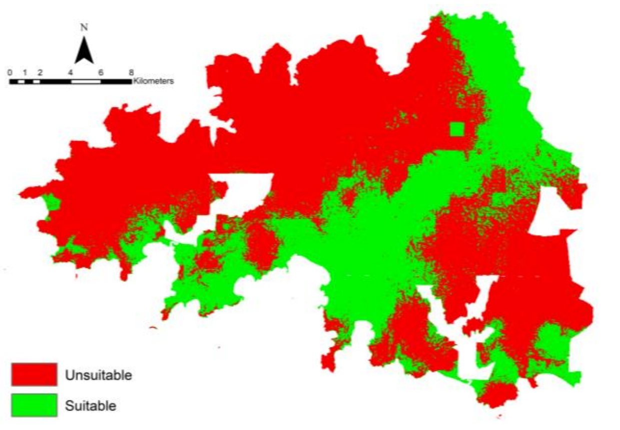

Figure 5. The final HSM of banteng output shows the distribution of habitat suitability in MBNP, Jember, Indonesia. The maps build under Maxent v.3.3.4 with modification in ArcGIS software 10.7.1 by ESRI

Table 2. The area of habitat suitability model for banteng in MBNP, Jember, Indonesia

Suitability	Area (ha)	Proportion (%)
Unsuitable	34,641.04	65.82
Suitable	17,985	34.18

Discussion

This study showed the prediction models of habitat suitability for banteng based on the updated occurrence of banteng in the MBNP area. Moreover, this study also answers the big question of the habitat characteristics and suitability of banteng in this conservation area. The HSM analysis showed that MBNP has 17,985 ha of suitable habitat for banteng or 34.18% of the 52,626.04 ha total area. This is nearly similar to the modeling by Imron et al. (2016) on Alas Purwo National Park (APNP), which reported that APNP has suitable habitat for banteng below 50%, appropriately 31.03% (13,789.23 ha). These two studies show slight differences based on the variables or predictors, especially the physical factors. Our research adds the annual temperature range and precipitation amount to provide complexity in the HSM analysis. However, in general, the prediction of HSM can provide essential information regarding habitat suitability and the most influencing factors on the distribution of banteng.

Based on the jackknife test and permutation importance results, it shows that four variables (the distance from the settlement, the distance from the coastline, altitude, and annual temperature range) have a high contribution to building HSM of banteng in MBNP (Figures 4A, 4B, 4E, 4G, and 4I). The presence of banteng in MBNP was found to increase at distances away from settlements (>2000 m). This indicates that banteng prefers habitats that are far from human activities. But other facts show that banteng in MBNP is also found very close to settlements (0-1000 m), yet it is rarely common. This is possible because of the plantations (Bandealit, Sukamade, and Baban) around the settlement attracting banteng to come closer. One example is Bandealit plantations which provide feed for bantengs such as *Hierochloe horsfieldii*, *Andropogon pertutus*, *A. aciculatus*, and *Paspalum conjugatum* (Garsetiasih et al. 2012). Although habitat conditions differ, banteng in Khao Khieo-Khao Chomphu Wildlife Sanctuary Thailand also tends to occupy an agricultural area (Chairayat et al. 2019). This condition can certainly trigger conflict between the residents (local people) and banteng. Garsetiasih and Alikodra (2015) state that this conflict can be indicated by an increase in poaching, as has happened in the Bandealit plantation area, where within four years, there were six cases of banteng deaths due to poaching. Besides, also suspect the movement of banteng to plantation areas due to reduced food availability in their natural habitat during the dry season. That was reported by Chairayat et al. (2019) that the reintroduced banteng in the Salakphra Wildlife Sanctuary, Thailand, used a wider range of habitats in the dry than in the wet season. However, this assumption needs to be proven by scientific analysis related to the home range of banteng in MBNP. According to Prayurasithi (1997), banteng has a home range of about 20.0-44.0 km^2 in the dry season and 30.0-44.8 km^2 in the wet season.

The occurrence of banteng in MBNP is also more commonly found at low altitudes (<200 masl), especially in the Sarongan and Ambulu Section areas. These two areas are located west, south, and southeast of MBNP. Banteng was found in groups using a flat area like a feeding ground for grazing. That is quite similar to the banteng found in

APNP (Imron et al. 2016), in which the banteng in this park is also found mostly in low altitudes at lowland forests. Gardner (2014) states that banteng in Java has an altitudinal range of coastal, lowland, and highland forests up to 2000 masl. It is very interesting because banteng on Java Island has a varied habitat distribution, even up to the highlands (Gardner et al. 2014). Moreover, in this study banteng in MBNP also found up to a height of 1065 masl, especially in the Kalibaru section.

Furthermore, the distance of the coastline also contributes to the modeling of the banteng HSM at MBNP. The coastline is one of the important areas for several wildlife habitats as a reservoir of minerals. The occurrence of banteng in MBNP is close to the coastline (<5000 m), but it has a small probability of still being found at >5000 m from the coastline. Periodically, banteng will come to the coastline for salting activities (Santosa and Delfiandi 2007). This activity is needed by banteng to completely mineral salts in the body. At Bandealit Beach, a group of banteng was observed resting under the coastal forest vegetation and was suspected of carrying out salting activities. Based on the direct encounters with MBNP staff, banteng in Bandealit periodically come over to the coastal forest under the canopy of *Barringtonia* formation. This is often also confirmed by discovering several dungs in this location. Banteng needs salt to help their digestion, so banteng usually comes to the coastline to completely salt by drinking seawater (Santosa and Delfiandi 2007).

Another physical factor that contributes greatly to the habitat suitability and distribution of banteng is the annual temperature range. Sunday et al. (2012) stated that air temperature determines the distribution of animals and will also affect the population of these animal species. Banteng in MBNP has an annual temperature range of tolerance from 5.6-7.3℃ with the maximum probability distribution at ±6.5℃. That shows the banteng in the MBNP is more widely distributed in temperatures with a moderate range. The foraging activities of banteng in the open areas at Bandealit and Sukamade are mostly carried out in the morning and evening. It is suspected that this period has a moderate temperature or is still tolerated by the banteng. Meanwhile, during the noon and afternoon, banteng reduces activity and enters the deep forest with a dense canopy. Rahman et al. (2019) also reported a fairly similar pattern in Ujung Kulon National Park, that banteng tends to be more active at dusk (mean activity time between 17:00-19:00).

Furthermore, the variables of distance from the rivers, slopes, annual precipitation amount, and land cover has low contributions to modeling the HSM of banteng in MBNP. Banteng in this area is found in habitats close to rivers (Figures 4D and 4I). One of the data came from Bandealit Resort's Sumbergede Block, where a banteng group was discovered just 0-10 meters from the river. Water is one of the crucial necessities of the banteng's ecological activity, claim Garsetiasih et al. (2016). Therefore, the survival river, especially the river that flows all year round, becomes crucial to the existence of the banteng. Many springs in the MBNP flow through various river systems, particularly in Bandealit, Sukamade, and Trebasala. Additionally, banteng in MBNP has been discovered to select habitats that are typically flat; it can be observed that the higher the slope of an area, the fewer the banteng are located. Based on Figure 4F, the slopes in MBNP vary widely (0-190%) and tend to be dominated by high slopes. That also makes the habitat characteristics in MBNP quite unique and different from other National Parks in East Java. Furthermore, banteng in MBNP also has the potential to forage in hilly habitats or move across hills.

On the other hand, this study's description of feed and shelter availability for banteng has not been explained in detail. But indirectly, the land cover variable can also provide an overview of the shelter characteristics and feed chosen by banteng. Indeed, comprehensive research is needed on the feed and shelter availability of banteng in MBNP; as reported by Siddiq et al. (2022), there are four feed types of banteng in Pringtali Feeding ground, i.e., *Mikania scandens*, *Desmodium pulchellum*, *Panicum muticum*, and *Eulalia amaura*. Based on the land cover value, banteng in MBNP more occupy habitats with high tree cover characteristics than shrubland (Figures 4H and 4I). This tends to be unique because banteng in Baluran, East Java, Indonesia (Hakim et al. 2015) and Alas Purwo (Purnomo and Pudyatmoko 2011; Imron et al. 2016) occupy more open habitats. That also describes banteng in MBNP as having a habitat preference in forest areas and are slightly different from other parks in East Java. However, we must underline that the landcover variable has the smallest contribution in MBNP. The dominant tree canopy structure may attract several ungulate species (Garcia-Marmolejo et al. 2015). Banteng also utilizes food, e.g., bamboo, fruits, and leaves (Chairayat et al. 2020). In addition, this dense vegetation gives an advantage in camouflage from both natural predators and hunters (Gardner et al. 2018). Finally, these results can be used as a reference in implementing banteng conservation at MBNP, such as establishing priority areas for banteng habitat based on this habitat suitability model.

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