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Spatial Modeling for Assessing Extended Potential Habitat of Javan Rhino (*Rhinoceros sondaicus*) in Ujung Kulon National Park, Indonesia

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Abstract. Ujung Kulon National Park (UKNP) is a protected area and also the sole habitat for Javan rhino. In UKNP, Peninsula and Mount Honje area have unique geomorphic characteristics. Distribution of the Javan rhino is found in Ujung Kulon Peninsula only. Therefore, this study aims to produce a potential habitat suitability model and to understand the contribution of each habitat variable to the presence of Javan rhinos in the extended area outside the Ujung Kulon Peninsula. The method used in this research is field observation of the rhino's signs and monitoring through camera traps deployed in those two areas. The presence of Javan rhino in 2017-2018 is monitored. Five variables of habitat fitness are used to produce a spatial habitat suitability model of Javan rhino. Those variables were slope, flow accumulation, potential forage, Normalized Difference Vegetation Index (NDVI), and distance from the stream. Remote sensing and Geographic Information System (GIS) analysis are used to prepare all variables and produce the model. The habitat suitability model is produced by using Maximum Entropy (MaxEnt) software. This model produced a potential habitat suitability map of Javan rhino with mapping accuracy AUC value is 0.695, that is fair performance. The results from this study are the prediction of habitat suitability is 29,1738.05 hectares (60.66%) inside the national park. The suitable area dominated in Ujung Kulon Peninsula and fragmented in Mount Honje, due to the slope factor and followed with potential forage availability. The model shows the highest to the lowest percent contribution variables i.e. slope, potential forage, NDVI, distance from the stream, and flow accumulation. Javan rhino preferred lowland than highland areas, also inhabits in area rumpangs and shurbs because of highly potential forage availability. This model can be used to provide a baseline map and recommendation for the next monitoring design for updating the distribution of Javan rhinos in potential extended habitat within the Ujung Kulon National Park. Prediction of the potential habitat is essential in managing conservation area and also an effort to maintain the existence of Javan rhino.

INTRODUCTION

Javan Rhino (*Rhinoceros sondaicus*) solely found in Ujung Kulon National Park (UKNP). Historically, Javan Rhino distribution covering the eastern area of India, Bangladesh, to Southeast Asia (Myanmar, Cambodia, Thailand, Vietnam, Malaysia, and Indonesia) [1]. In Vietnam, Javan Rhino could be found in Cat Loc, Cat Tien National Park. However, in 2010 Javan rhino in Vietnam is declared extinct [2]. Nowadays Javan Rhino only can be found in UKNP, the west tip of Java Island, Indonesia [1,3,4]. Conservation status of the Javan Rhino is critically endangered (CR) based on the International Union for Conservation of Nature (IUCN) criteria [5]. Due to its distinct characteristics and the only habitat for Javan Rhino, UNESCO declares UKNP as the World Heritage site on February 1st, 1992 [6].

UKNP area that consists of Peninsula and Mount Honje Area have unique and distinct landscape and geomorphology characteristics. In Ujung Kulon Peninsula, the slope is slightly low (structural plane) while in Mount

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Honje has hilly terrain (structural hills). Distribution of the Javan rhino is found in Ujung Kulon Peninsula only. However, there are not many intensive studies about the suitability of Mount Honje as the potential location for Javan Rhino habitat. A comparative overview of the prevailing conditions in UKNP and other potential relocation sites in Java, but did not include an ecological survey of Mount Honje and related environments in UKNP [7]. For these past 10 years, the Javan Rhino study only focusing on the UKNP Peninsula area [8,9]. The old research is no longer relevant with current habitat condition [10–14]. A study stated that another option for the future Javan rhino habitat could be in Cikepuh Nature Reserve [15]. Javan Rhino second habitat report stated that Mount Honje Area only surveyed twice in the southern part [16]. Mount Honje still having potential as the Javan Rhino habitat, but need to study the area and how suitable Mount Honje as the Javan Rhino habitat [17]. The understanding of the Javan Rhino habitat suitability and potential is very important for the area management strategy and as the effort to maintain the existence of the Javan Rhino. A better understanding of Javan rhino habitat suitability is pivotal, both for assessing an appropriate density of the source population at which rhinos can be removed and suitable areas which to translocate [18].

Javan rhino as one of the wildlife priority in Indonesia, need to be managed optimally and effectively according to the document of conservation action strategic plan of Javan rhino or Strategi Rencana Aksi Konservasi (SRAK) Badak Jawa. Nowadays, the population of the Javan rhino in UKNP is 72 individuals where distribution is only in Ujung Kulon peninsula [19]. Poaching of rhinos for their horn continues to be a major threat [20], moreover, the last individual from Vietnam in 2010 died because of the poaching [2]. Reflecting on the eruption of Mount Krakatau and the tsunami in 1883 which destroyed vegetation and wild animals [20–23], it becomes a concern that the Javan rhino habitat will be threatened by these natural disasters [24,25] such as earthquakes and Mount Anak Krakatau activities that triggered a tsunami [21,26]. Another threat to the Javan Rhino is disease transmission from livestock [27], especially anthrax and reduction of food-plant resources due to forest closure arenga palm (*Arenga obtusifolia*) invasion [16,25]. Due to those threats, the study of Javan Rhino habitat especially the habitat potential mapping is urgently needed before those threats strike the last hope of Javan rhino population. The habitat potential availability outside UKNP also needs to be studied for the survival and thriving Javan rhino future population. The area prediction needs to be intensively studied by the experts especially in predicting the Javan Rhino habitat suitability outside the UKNP peninsula area.

This study aims to produce a potential habitat suitability model and to understand the contribution of each habitat variable to the presence of Javan rhinos in expand area outside Ujung Kulon Peninsula. This study presents a habitat suitability model for Javan rhinos in a protected area, UKNP. The model prediction could be used for the management strategy reference in Mount Honje so that the Javan Rhino no longer isolated within the Peninsula Area. This model is a step towards a better understanding of the requirements of Javan rhino under similar condition between the peninsula and Mount Honje [18].

MATERIALS AND METHODS

Study Area

The study area is a protected area, Ujung Kulon National Park (UKNP), Banten Province. Javan rhinos exist only in this protected are in Java. UKNP is designated as a national based on Minister of Forestry Decree No. 284/Kpts-II/1992 on Februari 26, 1992, with a total area is 120,551 ha (76,214 ha land area and 44,337 ha sea waters) covering Ujung Kulon Peninsula, Panaitan Island, Peucang Island, Handeuleum Island, and Mount Honje. Geographically located at 06°30’43” to 06°52’17” S and 105°02’32” to 105°37’37” E (Figure 1). Administratively is located in the Cimanggu and Sumur District, Pandeglang Region, Banten Province [29]. Due to Ujung Kulon has unique landscape phenomenon, the largest lowland tropical forest in Java, and the only Javan rhino habitat, making UKNP designated as The Natural World Heritage Site by the UNESCO World Natural Heritage Commission (United Nations of Educational, Scientific, and Cultural Organization) with Decree No. SC/Eco/5867.2.409 in 1992. Also stated in the vision of UKNP become the Center of Excellence for the conservation of Javan Rhinos in the World [31]. The area of Ujung Kulon Peninsula is ± 38,000 ha, while Mount Honje is ± 19,500 ha and surrounded by 19 buffer villages, both bordering directly and indirectly. In part of the UKNP, there is a sanctuary designated as in-situ conservation, called the Javan Rhino Study and Conservation Area (JRSCA) for intensive management based on Minister of Forestry Regulation No. 43/Menhut-II/2007 about Strategi Rencana Aksi Konservasi Badak in Indonesia in 2007-2017 as a first step in the development of the second habitat for Javan Rhinos.

The park contains vegetation types i.e. coastal forest, mangrove, swamp forest, lowland tropical rain forest, and grassland [29]. UKNP landscape is composed of several types of ecoregions, i.e. fluvial plains (plains near the coast), structural plains (Ujung Kulon Peninsula), structural hills (Mount Honje and Mount Payung) [33]. UKNP land area altitudes range from 0 to 254 m above sea level. The climate is subtropical to tropical with average annual precipitation of 298.32 mm (standard deviation ± 64.45 mm) which rain from November to April [34]. Various types of wildlife inhabiting Ujung Kulon forest i.e. 35 species of mammals, 5 species of primates, 240 species of birds, 59 species of reptiles, 22 species of amphibians, 142 species of fish [29]. The park has a number of herbivores but has potentially ecological competition between Javan rhino and banteng (*Bos javanicus*) [35,36].

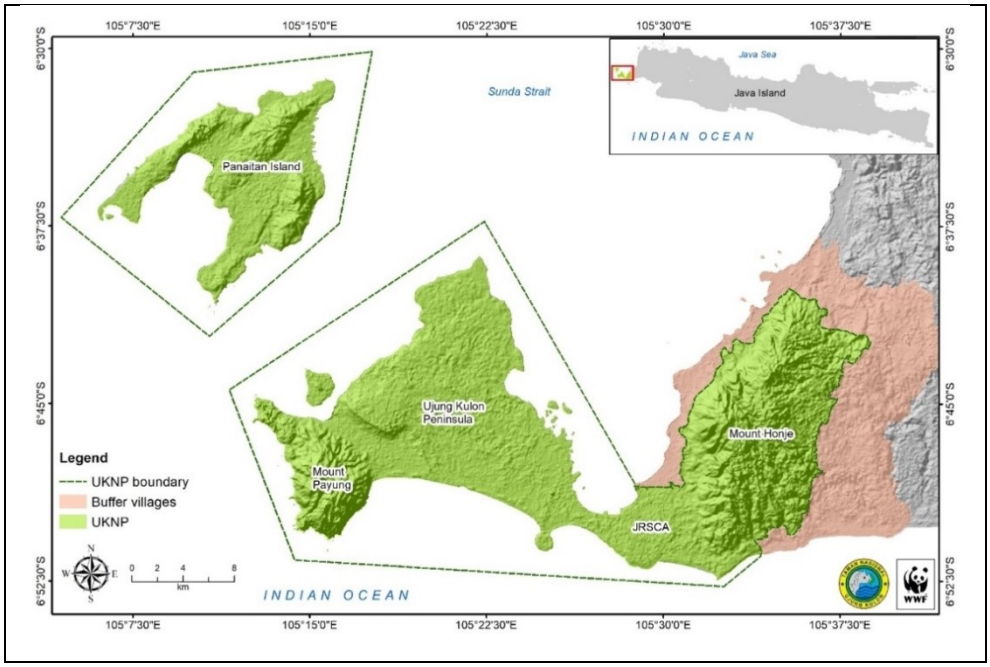

FIGURE 1. Ujung Kulon National Park.

Presence of Javan Rhino

Data collection of Javan rhino distribution through field observation and camera traps. The observed camera trap records are from 2017 to 2018. We deployed 130 units camera traps in Ujung Kulon Peninsula and Mount Honje in different locations. The presence of Javan rhinos is collected by using active and passive methods. The active method means indirect encounters of the Javan rhino signs such as trail marks, faecal, and feed marks. The passive method is by using camera traps in 2 km grids, with 1 km sub-grids inside. The monitoring data in 2017 to 2018 is used to process the models.

Variables of Habitat Fitness

Environmental data processing is prepared before doing the habitat modeling process. Environmental variables have been used to modeling rhino's habitat in the previous study [9,16,18,37]. Based on the literature, we filtered variables and used five environmental variables of habitat fitness to produce a spatial habitat suitability model of Javan rhino. Those variables were slope, flow accumulation, potential forage availability, Normalized Difference Vegetation Index (NDVI), and distance from the stream. We avoid anthropogenic disturbance due to looking for habitat potential outside of Ujung Kulon Peninsula. Remote sensing and Geographic Information System (GIS) analysis are used to prepare all variables and produce the model. Geospatial data processing is used with software ENVI and ArcGIS.

Remote sensing data for extraction NDVI by Landsat-8 OLI acquired on 27 August 2017 path/row 123/065 is obtained from the United States Geological Survey (USGS). Algorithm of NDVI is (NIR-R)/(NIR+R) [38], where

NIR is near-infrared and R is red. We modified land-use and/or land-cover (LU/LC) classification to approaching potential forage availability in UKNP. We used geospatial data to extract environment variables, i.e. slope and flow accumulation. Those variables are processed from Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Global Digital Elevation Model (DEM) downloaded through USGS. Stream network is derived from digital map Peta Rupabumi Indonesia (RBI) i.e. 1109-132 Tanjunglayar, 1109-141 Pulau Peucang, 1109-142 Tanjung Balagadigi, 1109-231 Sumur, 1109-114 Sang Hiang Sirah, 1109-123 Gunung Payung, 1109-124 Cikawung Sebrang, 1109-213 Tamanjaya. Stream network data is processed through spatial analysis using cost distance.

Spatial Habitat Modeling

Environmental data processing is prepared before doing the habitat modeling process. Environmental variables have been used to modeling rhino's habitat in the previous study [9,16,18,37]. Based on the literature, we filtered variables and used five environmental variables of habitat fitness to produce a spatial habitat suitability model of Javan rhino. Those variables were slope, flow accumulation, potential forage availability, Normalized Difference Vegetation Index (NDVI), and distance from the stream. We avoid anthropogenic disturbance due to looking for habitat potential outside of Ujung Kulon Peninsula. Remote sensing and Geographic Information System (GIS) analysis are used to prepare all variables and produce the model. Flow chart of Javan rhino habitat suitability model show in Figure 2. Geospatial data processing is used with software ENVI and ArcGIS. We used model evaluation [39] based on area under the curve (AUC) value from MaxEnt result (Table 1).

TABLE 1. Model evaluation area under the curve (AUC).

AUC value	Model evaluation
0.5 – 0.6	Poor
0.6 – 0.7	Fair
0.7 – 0.8	Good
0.8 – 0.9	Very good
0.9 – 1.0	Excellent

Source: Duan et al. (2014)

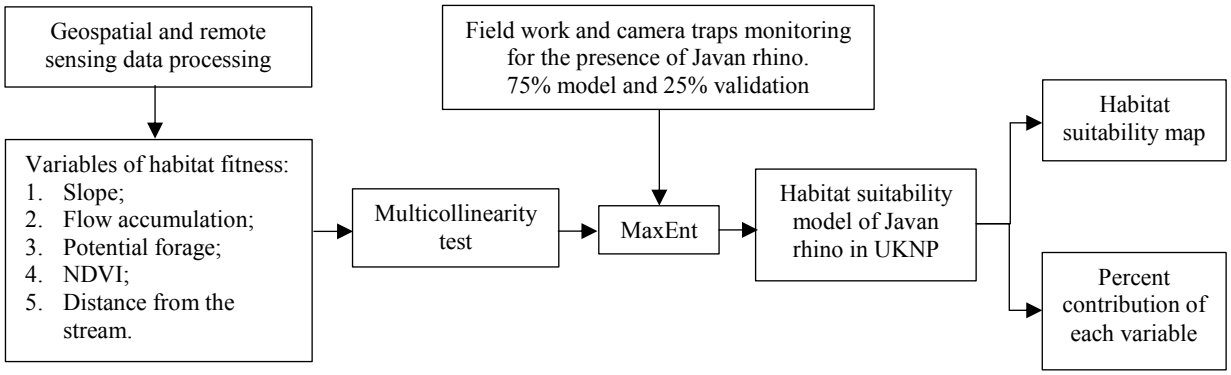

FIGURE 2. Flow chart of Javan rhino habitat suitability model.

RESULTS AND DISCUSSION

The Habitat Fitness Variables

Geospatial and remote sensing data are used for extraction habitat fitness variables as environmental variables for the modeling process. We modified habitat fitness variables form the previous study on rhino habitat modeling [9,16,18,37]. Habitat requirements of the Javan rhino focused on accessibility, availability of drinking water, and availability of forage. For other requirements, such as the need for salt, mud-wallowing, and bathing. Assumed that

these habitat requirements do not provide a problem for the rhinos living in any part of Ujung Kulon [10]. Habitat fitness variables that we used for modeling are slope, flow accumulation, potential forage availability, NDVI, and distance from the stream (Figure 3).

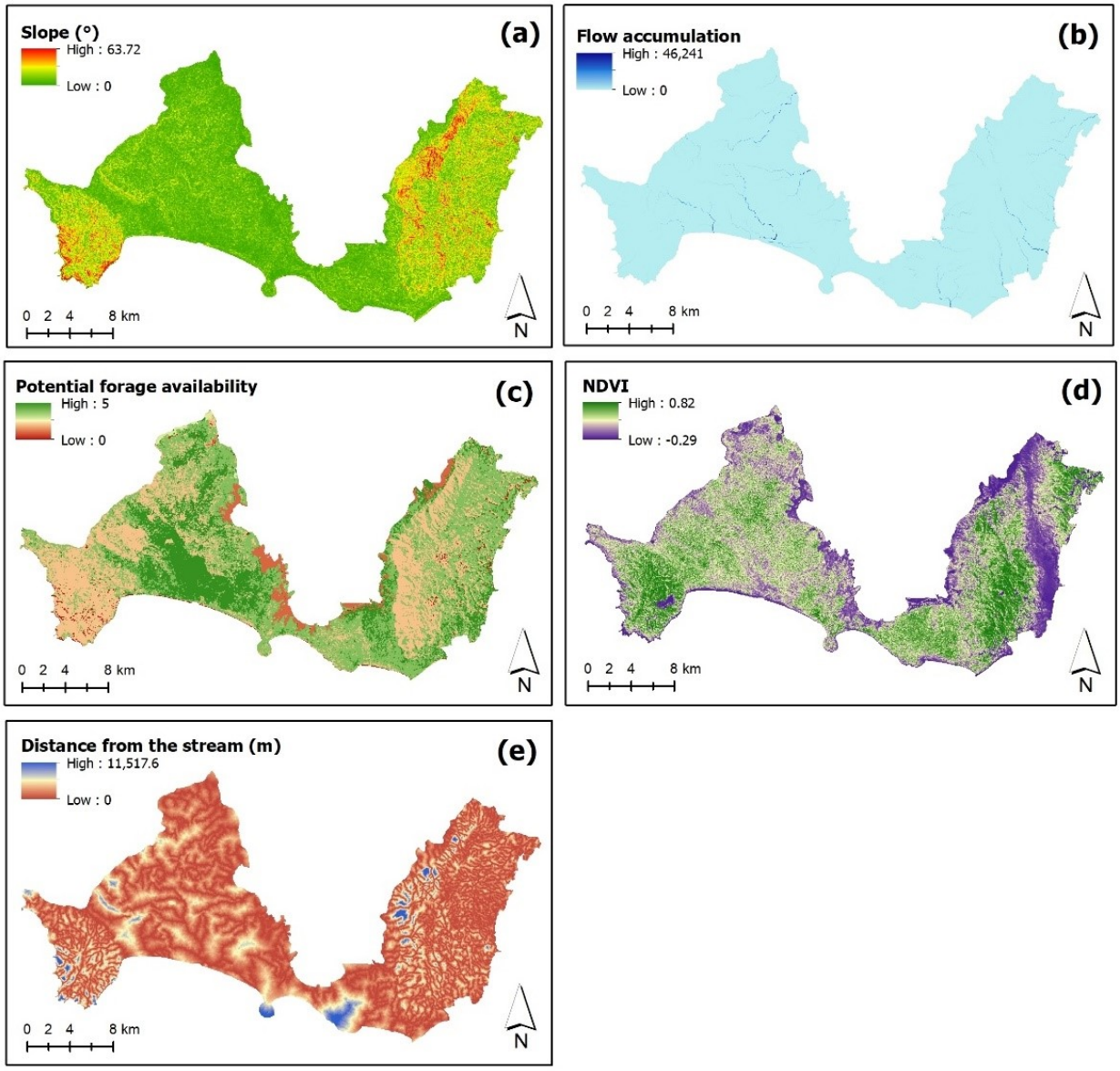

FIGURE 3. Habitat fitness variable maps: a) slope; b) flow accumulation; c) potential forage availability; d) NDVI; e) distance from the stream.

In the study area, the slope range is between 0° to 63.72° (Figure 3a). In UKNP, the slope variation is from flat low land in the peninsula to mountain areas (Mount Payung and Mount Honje). In mountain area slope is higher than the area peninsula. The use of slope in modeling process is due to a slope as an approach to accessibility for easy access for Javan rhino. We assume that in areas that tend to be flat will make it easier and less effort for wildlife to cross rather than a high slope.

Flow accumulation range is 0 to 46,241 (Figure 3b). Flow accumulation is the approach to mud wallowing and drinking water. Mud wallows are critical for rhino's thermoregulation, as well as to avoid and remove ectoparasites, protect their skin, and for engaging in social chemical communication or access to mineral salt sources [3,12,14,16]. Flow accumulation with higher values is an area that has potential to continue the flow of water. At higher values,

there is an area surrounded by a higher elevation around it. Conversely, the value of flow accumulation approaches 0 is describe that the potential for water flow is lower. In the UKNP, high flow accumulation tends to be spreadly enough on flat area and mountains area.

Potential forage availability is modified based on LU/LC classification by the Landsat-8 image (Figure 3c). The result of the LU/LC classifications in UKNP are consist of several classes i.e. building, primary forest, secondary forest, coastal forest, mangrove, shrubs, grassland, bareland, paddy fields, mix cultivation, waterbody, and ponds. Based on field observations and literature studies, we classify the LU/LC through the assumption of a potential forage availability approach. The value of potential forage availability is 0 to 5 (Table 2). Land-use that does not allow the existence of Javan rhino's forage then given value 0. If the potential forage is very low then given value 1, low potential given value 2, the moderate potential is given value 3, a high potential is given value 4, and very high potential given value 5. The availability of potential forage availability based on land-use and/or land-cover shows in Table 2. Javan rhino in Ujung Kulon is often found in rumpangs or with land-cover shrubs. The land-cover shrubs, primary forest, and secondary forest are located in most of the peninsula area.

The refuge area is represented through NDVI value. The NDVI results have pixel value ranges from -0.29 to 0.82 (Figure 3d). Javan rhino refuge area is in an area with a high density of forest canopy. From the NDVI, the value getting closer to 1 is a good condition and tight forest canopy, so the wildlife can take as refuge under the canopy. NDVI with a value close to 0 is the lower forest canopy or can be grassland or bareland. NDVI values less than 0 or negative do not as vegetation, but waters. The distribution of NDVI values in the UKNP is spread enough, both in the peninsula and mountains area.

Distance from the stream approach to water needed, with the result has a pixel value range between 0 to 11,517.6 m (Figure 3e). The closer distance from the water source, the easier it will obtain water availability. In UKNP, almost all of the area can be reached because of the proximity of water sources tend to be close. The waters in Ujung Kulon can still be found at a distance that can be reached, so the Javan rhino has easily in getting water needs.

TABLE 2. The availability of potential forage availability based on land-use and/or land-cover.

Potential forage availability	Land-use and/or land-cover	Value
No forage available	Bareland, ponds, building, waterbody	0
Very low	Mangrove, paddy fields	1
Low	Grassland	2
Moderate	Coastal forest, mix cultivation	3
High	Primary forest, secondary forest	4
Very high	Shrubs	5

We used the multicollinearity test for each variable before running the model. The test result shows that all variables were not collinear each other. The results are shown with the variance inflation factor (VIF) value of less than 10 (Figure 4). Based on test results, we can use five variables for preparation the model.

```
var               vif
dist.stream       1.18213799114922
elevation         1.49659983658786
flowacc           1.11369319783214
slope             1.56056035820874
potentialforage   1.19270053318064
ndvi              1.1793267731198

All variables have VIF < 10, max VIF 1.56
```

FIGURE 4. Multicollinearity test of five variables.

The Habitat Suitability Model

We used five habitat variables i.e. slope, flow accumulation, potential forage, Normalized Difference Vegetation Index (NDVI), and distance from the stream (Figure 3) for running the model through MaxEnt software. The presence of Javan Rhino is used in modeling by 75% and for model evaluation by 25%. Based on the MaxEnt result,

the pixel value representing the suitability is about 0 to 0.89 (Figure 5). The pixel value is less suitable if closer to 0 and more suitable if closer to 1 [40,41]. MaxEnt results show that in Ujung Kulon Peninsula are many suitable habitats than the area Mount Payung and Mount Honje.

Geophysical condition of the Javan rhino habitat in the peninsula is flatter and there are still many potential land-cover as a source of their food than Mount Honje and Mount Payung. In the peninsula, there are still many shrubs that have very high potential forage for their daily needs. Based on altitude, Javan rhino preferred lowland than highland areas, particularly when the slope to the highland was steep but never found on high flatlands. Javan rhino occupied in greater lowland areas due to larger food and water availability. Altitude was not a limiting factor for Javan rhino utilization distribution. This was evident by the findings of Javan rhinos previously in Mount Slamet in 1867, Mount Tangkuban Perahu in 1870, Mount Gede Pangrango in 1880, Mount Papandayan on 1881, and Mount Ciremai on 1897 [8,11].

The average result of the AUC test for the replicate runs is 0.695, and the standard deviation is 0.007 (Figure 6). According to the AUC result in model evaluation [39], the value indicates that the model result is fair performance. We used the logistic 10 percentile training presence threshold to produce a classification habitat suitability map of Javan rhino (Figure 7). Habitat suitability map classified as suitable and unsuitable. In the study area, the suitable habitat of Javan rhino is 60.66% and unsuitable habitat is 39.34%. The suitable area dominated in Peninsula and fragmented in Mount Honje. The area of habitat suitability is shown in Table 3. In Mount Honje, the suitable habitat of Javan rhino is fragmented in the mountain peak area. This is possible because there is still potential availability of forage for them. Shrubs, with have very high potential forage, are distributed less frequently and are spread over a smaller area. While the primary and are still founded.

The results of this model have limitations. Based on the model, Mount Honje and Mount Payung are many unsuitable areas, because there are fewer presence samples than the Ujung Kulon Peninsula. Overall sample points to produce the model, the percentage points between Peninsula Ujung Kulon, Mount Payung, and Mount Honje respectively are 96% (770 points), 3.75% (30 points), and 0.25% (2 points). Because of model limitations, the results can be input for the next monitoring strategy. Therefore, a suitable habitat for Javan rhino in areas outside the peninsula needs to monitor intensively.

TABLE 3. Total area habitat suitability of Javan rhino.

Suitability	Total area (ha)	Percent (%)
Suitable	29,173.05	60.66
Unsuitable	18,920.61	39.34

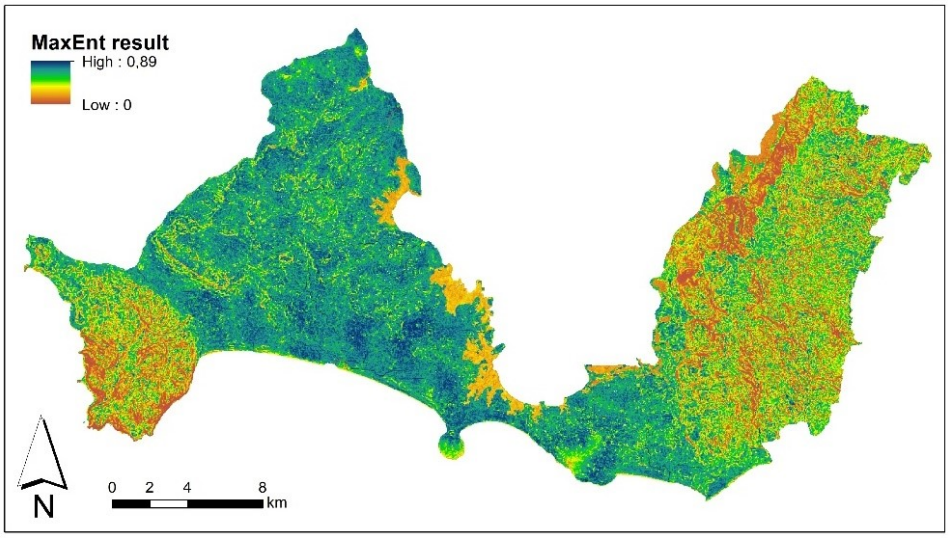

FIGURE 5. Map of Javan rhino habitat suitability model in UKNP produced by MaxEnt (value min. 0 to max. 1).

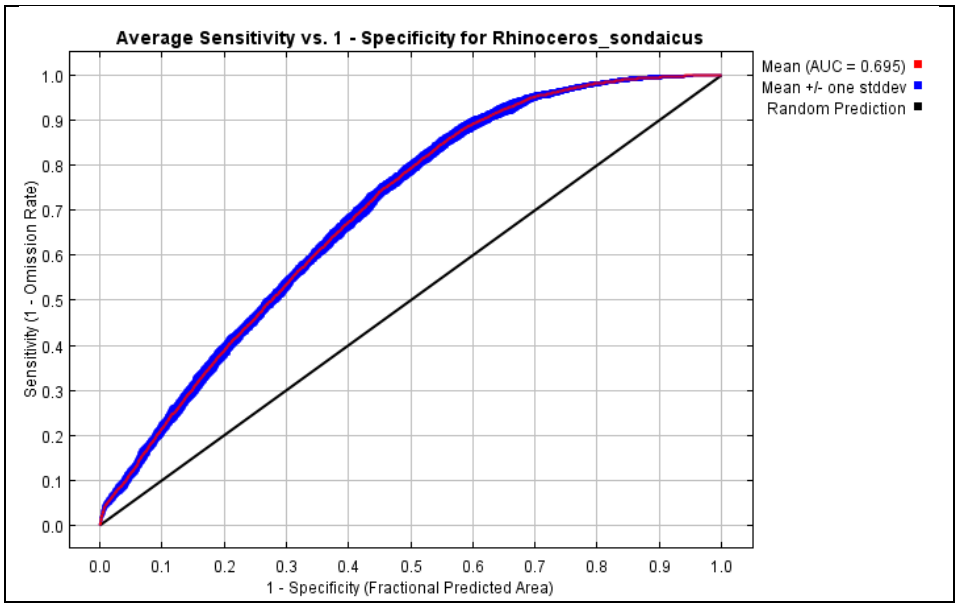

FIGURE 6. AUC graphic produced by MaxEnt.

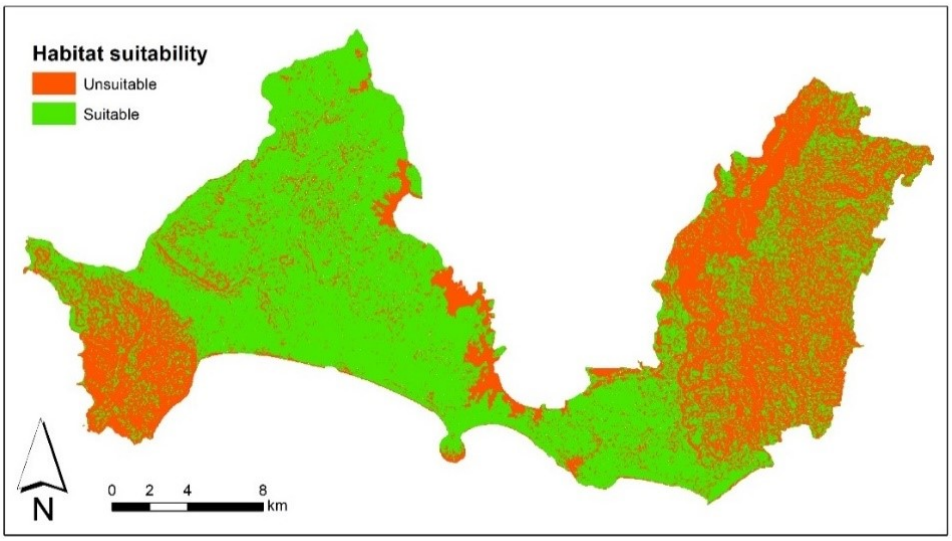

FIGURE 7. Javan rhino Habitat suitability map in UKNP.

Contribution of Each Variable

From five variables of habitat fitness, according to the resulting model, we get percent contribution (Table 4) and a response graph for each variable (Figure 8). The slope was the most important variable in the model, which is 71.4%, but with a negative contribution. Slopes between 0 to 10° are higher suitability than steeper. The results showed that Javan rhino habitat has suitable on areas with flat to rather a steep slope area, which is similar to results obtained in a previous study [8,9,25,42]. Javan rhino used flat to slightly sloping areas to fulfill all its necessary survival needs of food, drink, and wallow. Javan rhino's big posture would make it difficult for the animal to reach steep slope areas [8].

Variable potential forage availability was the second most important variable is 12%. Forage is one important habitat component for wildlife. In an area with higher potential forage availability still has a higher possibility of higher habitat suitability. Potential forage is obtained from the land-cover approach because it is assumed that land-cover can illustrate the potential forage for Javan rhino. Potential forage availability is a positive correlation. If the

potential forage value is higher, the suitability habitat is higher as well. As a browser, Javan rhino required plants shoots. Plants shoots were more abundant in secondary forest and more open areas such as shrubs and rumpangs rather than in primary forest. Shrubs and swampy shrubs provided Javan rhino with various undergrowth and seedlings. Field observation indicated that Javan rhino feeds more undergrowth such as areuy-areuyan [8,43]. In general, Javan rhino often carried out its activities on relatively open areas, which was not grassland. These relatively open areas were used more frequently as a foraging area (rumpangs). Such rumpangs provided an abundant food source for the rhinos, such as tepus, cente, sulangkar, segel, ciciap, bisoro, rattan, areuy palungpung, areuy kuku heulang, areuy jeunjing kulit, areuy capituher, and areuy leuksa. More than 75% of Javan rhinos used areas with dense crown cover to perform specific activities such as wallowing, bathing, and defecating. Defecating, bathing, and wallowing activities were more frequently carried out by Javan rhino in relatively sheltered areas, such as under vegetation of langkap, salak, cangkeuteuk, and kaman [8,42,44]. NDVI variable has small contribution ranging is about 5%. However, that does not mean there is no effect to the model, but a little contribution to the preparation of the model.

TABLE 4. Percent contribution of each variable.

Environmental variable	Percent contribution (%)
Slope	71.4
Potential forage availability	12.0
NDVI	5.9
Distance from the stream	5.4
Flow accumulation	5.3

Percent contribution of the variable distance from the stream was 5.4% contribution in this model. Distribution of water availability in the Ujung Kulon Peninsula was indicative that water was not a critical limiting factor for Javan rhino survival, although it is an important component. Javan rhino use water for drinking, bathing, and wallowing [8,11,12,25,44].

Percent contribution of variable low accumulation was 5.3%. Wallow for Javan rhino could also be functioned as a cleaning agent from dirt and illness, to neutralize body temperature, and to rest. The main function of wallowing is to maintain skin moisture, regulate body temperature, and reduce parasites infection rates. Wallowing activities of Javan rhino is depended on water availability, hence is influenced by seasons [14]. During rainy seasons, water is filling in almost all wallowing places. During the dry season, when there was limited water availability and many wallows were dry, Javan rhino would increase bathing activities in large rivers [8]. Javan rhino preferred areas closed to rivers wallows, and rumpangs as its niche since the advantage of inhabiting such areas would be higher than the loss [45]. The results of the study were similar to previous works [11,12,14,44,8].

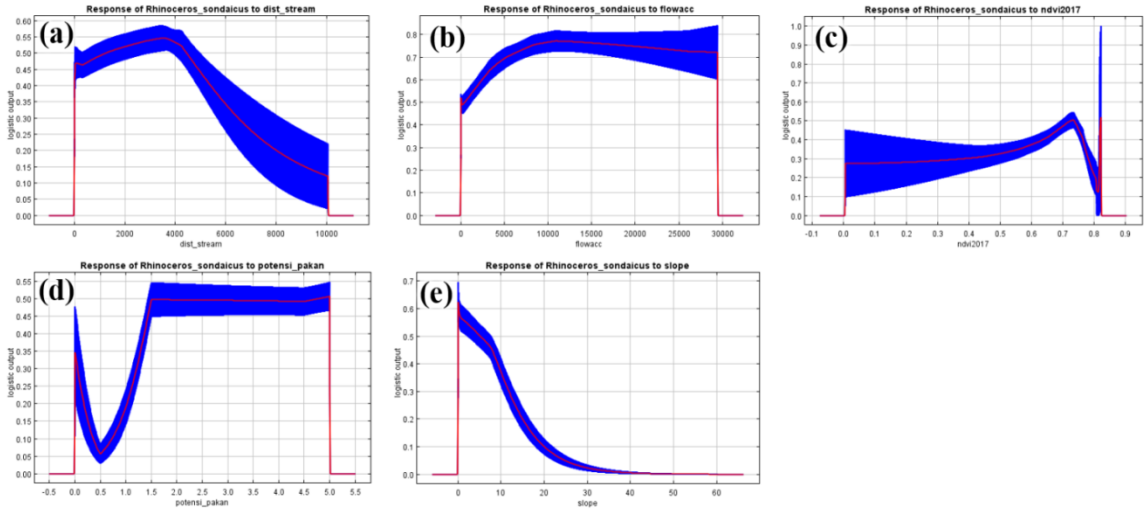

FIGURE 8. Graph of response for each variable: a) distance from the stream; b) flow accumulation; c) NDVI; d) potential forage availability; e) slope.

CONCLUSION

From this study, the prediction of habitat suitability is 29,1738.05 hectares (60.66%) inside the national park, with Ujung Kulon Peninsula are many suitable habitats than area Mount Payung and Mount Honje. The mapping accuracy is fair (AUC value = 0.695 and the standard deviation is ± 0.007). The suitable area dominated in Ujung Kulon Peninsula and fragmented in Mount Honje, due to the slope factor and followed with potential forage availability. Javan rhino preferred lowland than highland areas, also inhabits in area rumpangs and shurbs because of highly potential forage availability. This model can be used to provide a baseline map and recommendation for the next monitoring design for updating the distribution of Javan rhinos in potential extended habitat within the Ujung Kulon National Park, also can be used as a reference to determine the program for community conservation management strategy. Prediction of the potential habitat is essential in managing the conservation area and also an effort to maintain the existence of Javan rhino and improve rhino's habitat management.

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REFERENCES

1. C. P. Groves and D. M. Leslie, Mamm. Species **43**, 190 (2011).
2. S. M. Brook, N. Dudley, S. P. Mahood, G. Polet, A. C. Williams, J. W. Duckworth, T. Van Ngoc and B. Long, Biol. Conserv. **174**, 21 (2014).
3. D. Murphy, *The Status and Conservation of Javan Rhinoceros, Siamese, Crocodile, Phasianidae, and Gaur in Cat Tien National Park, Vietnam* (Cat Tien National Park Conservation Project, 2004).
4. World Conservation Monitoring Centre, *Ujung Kulon National Park & Krakatau Nature Reserve, Java, Indonesia* (New York, 2005).
5. R. van Strien, JOTT Commun. **2**, 633 (2010).
6. UNESCO World Heritage Centre, Ujung Kulon National Park (1991).
7. Sectionov, *Desk Study of Second Habitat Assessment Javan Rhino* (Bogor, 2009).
8. Y. Santosa, U. M. Rahmat, L. B. Prasetyo and A. P. Kartono, J. Manaj. Hutan Trop. **XIX**, 31 (2013).
9. U. M. Rahmat, Y. Santosa, L. B. Prasetyo and P. Kartono, J. Manaj. Hutan Trop. **XVIII**, 129 (2012).
10. P. W. F. M. Hommel, *Landscape-Ecology of Ujung Kulon (West Java, Indonesia)* (Soil Survey Institute, Wageningen, 1987).
11. A. Hoogerwerf, *The Land of the Last Javan Rhinoceros, Ujong Kulon* (E.J. Brill, Leiden, 1970).
12. R. Schenkel and L. Schenkel-Hulliger, Zool. Ansalt Der Univ. Basel **XXVI**, 97 (1969).
13. R. Schenkel, L. Schenkel-Hulliger and S. R. Widodo, Malayan Nat. J. **31**, 253 (1978).
14. H. Amman, Contributions to the Ecology and Sociology of the Javan Rhinoceros (Rhinoceros Sondaicus Desm.), der Universitat Basel, 1985.
15. Ribai, H. S. Alikodra, B. Mas'ud and U. M. Rahmat, Media Konserv. **20**, 108 (2015).
16. W. Ramono, M. W. M. Isnan, H. R. Sadjudin, H. Gunawan, E. N. Dahlan, Sectinov, Pairah, A. R. Hariyadi, M. Syamsudin, B. K. Talukdar and A. N. Gillison, *Report on a Second Habitat Assessment for the Javan Rhinoceros* (Yulee, Florida, 2009).
17. M. Haryono, "Analisis Kesesuaian Kawasan Gunung Honje Sebagai Habitat Badak Jawa (Rhinoceros Sondaicus Desmarest), " Master thesis, Agricultural Institute of Bogor (IPB), 1996.
18. K. G. Buk and M. H. Knight, South African J. Wildl. Res. **42**, 82 (2012).
19. Balai Taman Nasional Ujung Kulon, https://www.ujungkulon.org (2019).

20. N. J. van Strien, R. Steinmetz, B. Manullang, Sectionov, K. H. Han, W. Isnan, K. Rookmaaker, E. Sumardja, M. K. M. Khan and S. Ellis, IUCN Red List **8235**, 1-10 (2008).
21. T. Giachetti, R. Paris, K. Kelfoun and B. Ontowirjo, Geol. Soc. London **361**, 79 (2012).
22. R. Paris, P. Wassmer, F. Lavigne, A. Belousov and N. Mazzoni, Bull Volcanol **76**, 814 (2014).
23. F. Løvholt, N. J. Setiadi, J. Birkmann, C. B. Harbitz, C. Bach, N. Fernando, G. Kaiser and F. Nadim, Int. J. Disaster Risk Reduct. **10**, 127 (2014).
24. R. Setiawan, B. D. Gerber, U. M. Rahmat, D. Daryan, A. Y. Firdaus, M. Haryono, K. O. Khairani, Y. Kurniawan, B. Long, A. Lyet, M. Muhiban, R. Mahmud, A. Muhtarom, E. Purastuti, W. S. Ramono, D. Subrata and S. Sunarto, Conserv. Lett. **11**, 1 (2018).
25. E. K. S. H. Muntasib, "Penggunaan Ruang Habitat Oleh Badak Jawa (Rhinoceros Sondaicus Desmarest 1822) Di Taman Nasional Ujung Kulon," Dissertation, Bogor Agricultural University, 2002.
26. S. Bronto, O. K. Suganda and S. Hamidi, "Pemetaan daerah bahaya gunung api dengan studi kasus Gunung Krakatau" in *Pros. PIT XIX IAGI* (Bandung, 1990).
27. R. Tiuria, A. Primawidyawan, J. Pangihutan, J. Warsito, A. R. S. Hariyadi and B. P. Handayani, S. U. Priosoeryanto, "Identification of endoparasites from faeces of Javan rhino (Rhinoceros sondaicus) in Ujung Kulon National Park, Indonesia" in *Proc. AZWMP* (Chulalongkam University, Bangkok, 2006).
28. Menteri Kehutanan Republik Indonesia, SK Menhut No. 284/Kpts-II/1992 (1992).
29. Balai Taman Nasional Ujung Kulon, *Profil Taman Nasional Ujung Kulon* (Pandeglang, 2016).
30. United Nations of Educational Scientific and Cultural Organization (UNESCO), SK No. SC/Eco/5867.2.409 (1992).
31. Balai Taman Nasional Ujung Kulon (2015). <https://www.ujungkulon.org>.
32. Menteri Kehutanan Republik Indonesia, Permenhut No. 43/Menhut-II/2007 (Kementerian Kehutanan, Jakarta, 2007).
33. PT. Sigma Karya Desin and Badan Lingkungan Hidup Daerah Provinsi Banten, *Kajian Penetapan Ekoregion Provinsi Banten [Banten Ecoregion Determination Study]* (Serang, 2015).
34. Badan Pusat Statistik Kabupaten Pandeglang, *Statistik Dasar Kabupaten Pandeglang [Basic Statistics of Pandeglang Regency]* (2017).
35. Yayasan Mitra Rhino, *Studi Persaingan Ekologi Badak Jawa (Rhinoceros Sondaicus) Dan Banteng (Bos Javanicus) Di Taman Nasional Ujung Kulon [Study of the Ecological Competition of Javan Rhinoceros (Rhinoceros Sondaicus) and Bull (Javanicus Boss) in Ujung Kulon National Park]* (Yayasan Mitra Rhino, Bogor, 2002).
36. E. Harjanto, Commun. Biomath. Sci. **1**, 46 (2017).
37. W. Pusparini, P. R. Sievert, T. K. Fuller, T. O. Randhir and N. Andayani, PLoS One **10**, 1 (2015).
38. J. W. Rouse, R. H. Haas, J. A. Schell, D. W. Deering and J. C. Harlan, NASA/GSFC, Final Report, Greenbelt, MD, USA 1 (1974).
39. R. Y. Duan, X. Q. Kong, M. Y. Huang, W. Y. Fan and Z. G. Wang, PLoS One **9**, 11 (2014).
40. S. J. Phillips, M. Dudik and R. E. Schapire, "A Maximum Entropy Approach to Species Distribution Modeling" in *Proc. Twenty-First Int. Conf. Mach. Learn.* (Banff, 2004), pp. 655–662.
41. S. J. Phillips and M. Dudik, Ecography (Cop.). **31**, 161-175 (2008).
42. Chandradewi, "Perilaku Berkubang Dan Tipologi Kubangan Badak Jawa (*Rhinoceros sondaicus*) Di Taman Nasional Ujung Kulon [Wallowing Behavior and Puddle Typology of Javan Rhinoceros (Rhinoceros sondaicus) in Ujung Kulon National Park]," Master thesis, Bogor Agricultural University, 2011.
43. U. M. Rahmat, Y. Santosa and A. P. Kartono, J. Manaj. Hutan Trop. **XIV**, 115-124 (2008).
44. U. M. Rahmat, "Analisis Tipologi Habitat Preferensial Badak Jawa (*Rhinoceros sondaicus*, Dermarest 1822) Di Taman Nasional Ujung Kulon [Typological Analysis of Preferential Habitats of Javan Rhinos (Rhinoceros sondaicus, Dermarest 1822) in Ujung Kulon National Park]," Master thesis, Institut Pertanian Bogor, 2007.
45. E. P. Odum, *Dasar-Dasar Ekologi [Fundamentals of Ecology]*, Edisi Ketiga (Gadjah Mada University Press, Yogyakarta, 1993).