Potential habitat of Javan Hawk-Eagle based on multi-scale approach and its implication for conservation

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Abstract. In Indonesia the Javan Hawk-Eagle has been designated as one of the 25 top priority protected species to be increased by 10% of current population number. Lack of suitable habitat is most likely the reason for the decline of the species in landscapes subject to major human modification. Central part of Java Island has suffered the most severe forest damage and fragmentation compared to the western part and eastern part of the island. This study presents the number of predicted suitable habitats for Javan Hawk-Eagle in the central part of Java Island based on habitat probability model. Multi-scale approach was being used to determine the accuracy level of patches reading between different image resolutions. 38 patches were detected at 30 m², 28 patches at 90 m², and 19 patches were detected at 250 m² images resolutions. Higher reading implied more landscape structures within different regions should be considered during management of habitat conservation. Therefore, larger scale of conservation management application should be conducted as well.

1. Introduction

Javan Hawk-Eagle (Nisaetus bartelsi) is an endemic species raptor from Java Island. Its habitats characterized by tropical forest either primary or secondary, and located on steep slopes [1-3]. The home range of this species can reach the area as wide as 3000 ha within fragmented landscape [4]. With its vast home range Javan Hawk-Eagle (JHE) could be an umbrella species which could save the other species within its reach if we apply the right conservation management system [5].

The Indonesian government had been officially announced JHE as one of 25 top priority species to be increased in population by 10% in the period of 2015 until 2019 [6]. Predicted population number of JHE by 2002 was 325 pairs all over Java Island [2]. The rate of land use change and fragmentation in Java Island was so high [7]. The fragmented landscape reduced the ability of animal to disperse and build up new colonies and most likely induced the inbreeding potential [8, 9]. Inbreeding among species will lead to genetic depletion and increase the extinction risk [10-12]. Up until this study started in 2015 there were very limited new information about current JHE’s habitat condition or population. Therefore, this study tried to evaluate the latest condition of JHE’s habitat and determined whether there is any change that happened in the landscape.

Landscape-scale conservation based on remote-sensing sometimes is facing several issues regarding technical obstacles [13]. Due to the limitation on satellite image availability and software’s inability to
previous study was only able to use the coarse resolution in the process of predicting habitat suitability [2]. In regional management planning the coarse resolution might be enough to monitor any ecological change, but not very useful in habitat mapping and change detection for sensitive species or structure at site level [14, 15]. Different resolution will affects the management it needs for different ecosystem services [16]. In this study we try to analyze the result of the use of different image resolutions in data processing and its accuracy in habitat suitability reading. Then we suggested the suitable management conservation program by the result.

2. Method of analysis

2.1. The study area
This study focused on the central part of Java Island. The boundary of Central Java Province including Special Region of Yogyakarta is used as our study area (figure 1). It covers an area of 37,300 km². Central part of Java Island had the least habitat quality compared to eastern part and western part [2]. More than 80% of natural dry land forest had lost due to extensive human activity [7]. There were three protected areas in the central part of Java. Mount Merbabu National Park and Mount Merapi National Park are located inside the study area. Meanwhile, Karimunjawa National Park was located in the Karimunjawa archipelago of Java Sea and excluded from this study.

![Figure 1. Study area: Central part of Java Island (Source: Landsat 8 OLI/TIRS)](image)

2.2. Model update
Logistic regression was used to determine the suitable habitat for JHE on Java Island [16]. The model was built based on presence and pseudo-absence nests located around Gunung Gede-Pangarango National Park in West Java. The environmental variables that being input into regression were terrain factors, vegetation cover, proximity to water source and proximity to human activity. Thus, produced
the environmental variables preferred by JHE as its habitat which are slope, elevation, and vegetation indices. The model equation (1) is as below:

\[ P_i = \frac{1}{1+\exp[-(0.3804 \times SLP + 0.0148 \times ELV - 0.1229 \times NDVI - 19.6518)]} \]  

SLP and ELV derived from the Shuttle Radar Topography Mission (SRTM) 1 Arc-Second Global digital elevation data of 2014. Landsat 8 OLI/TIRS scene (path/row) 119/66, 119/65, 120/65, 121/65 and scene (path/row) 120/64 were used to generate the NDVI value. All environmental variables were on spatial resolution of 30 m\(^2\). Those 30 m\(^2\) then resampled with Resample tool to 90 x 90 meter and 250 x 250 meter resolution to analyze the multi-scale images (table 1).

**Table 1. Multi-scale image resolution visual comparison**

| Map            | Resolution |
|----------------|------------|
|                | 30m  | 90m  | 250m |
| Elevation      | ![Elevation 30m](image) | ![Elevation 90m](image) | ![Elevation 250m](image) |
| Slope          | ![Slope 30m](image)  | ![Slope 90m](image)  | ![Slope 250m](image)  |
| NDVI           | ![NDVI 30m](image)   | ![NDVI 90m](image)   | ![NDVI 250m](image)   |
| Patch habitat  | ![Patch 30m](image)  | ![Patch 90m](image)  | ![Patch 250m](image)  |

Blue=habitat  
Grey=non-habitat

Multi-scales of environmental variables were then being processed in RAMAS GIS using the probability of a habitat suitability model. The threshold value was 0.5 and the result was ranged from Unsuitable to Suitable area (figure 2).
Figure 2. Multi-scale habitat suitability map with probability threshold 0.5 based on JHE probability of habitat suitability model: (a) 30 x30 meter resolution; (b) 90 x 90 meter resolution; (c) 250 x 250 meter resolution. White: unsuitable landscape; green: partly suitable landscape; yellow: suitable landscape; red: highly suitable landscape. The study site boundary shown with red polyline.

3. Result

3.1. Updated JHE habitat distribution

Habitat patch distribution was obtained by selecting the most suitable habitat with minimum size of 4 km² as the minimum home range of JHE [1]. Multi-scale image resolution had a different ability in detecting habitat patches (figure 3). Thirty-eight patches were detected on 30 m² resolution, 28 patches were detected on 90 m² resolution and 19 patches were detected on 250 m² resolution (figure 4).
Figure 3. 2014 multi-scale JHE habitat patches distribution with minimum patch size 4 km²: (a) 30 x 30 meter resolution, (b) 90 x 90 meter resolution and (c) 250 x 250 meter resolution. Green: habitat patches; Grey: non-habitat patches.

Figure 4. Number of predicted suitable habitat patches using different image resolutions of 2014.
On 250 m$^2$ resolution there were 19 habitat patches detected all over the central part of Java with total area of 1427.25 km$^2$ (figure 5). The 8 historical locality records were detected among those patches. The largest patch size was 115.2 km$^2$ and the smallest patch size was 4.5 km$^2$ (table 2). Patch 19 (Mount Lawu) was still considered as one patch and not divided administratively even though it was located between the Central Java province and East Java province.

Evaluation of the suitable habitat changes which happened between 2002 and 2014 was done by comparing between models. We use the 2002 MODIS NDVI 250 m$^2$ resolution model from previous study to compare with the 2014 LANDSAT 8 250 m$^2$ resolution model of this study. The 2002 model predicted 22 patches with a total patch size of 1477.51 km$^2$. Between 2002 model and 2014 model, the patch size only decreased by 3.4% or 50.01 km$^2$, but the number of patches decreased by 13.63%. There were only two protected areas in the study area which located close to each other: Mount Merbabu National Park (57.3 km$^2$) and Mount Merapi National Park (64.1 km$^2$). These protected areas only covers 8.5% of the total patch size.

**Table 2.** 250 m$^2$ resolution suitable habitat patches distribution and size in 2014

| Patch number | Location | Patch size (km$^2$) |
|--------------|----------|--------------------|
| Patch 1      | Mt. Muria* | 46.36              |
| Patch 2      | Mt. Sagara* | 9.00              |
| Patch 3      | Mt. Palasari | 6.61              |
| Patch 4      | Mt. Subang | 23.8              |
| Patch 5      | Mt. Ungaran* | 37.16            |
| Patch 6      | Mt. Imus, Mt. Beser, Mt. Langit, Mt. Igirtipis, Mt. Bongkok, | 22.25 |
| Patch 7      | Mt. Pesanong | 5.19             |
| Patch 8      | Mt. Cupu*, Mt. Kraton, Mt. Jaha | 13.25 |
| Patch 9      | Mt. Beser, Mt. Butak, Mt. Malang, Mt. Tumbang, Mt. Bopong | 6.13 |
| Patch 10     | Mt. Pogong | 5.09              |
| Patch 11     | Mt. Slamet* | 238.2            |
| Patch 12     | Mt. Pandan | 4.50              |
| Patch 13     | Mt. Lumping*, Mt. Lebakbarang*, Mt. Kemulan, Mt. Sindoro | 511.2 |
| Patch 14     | Mt. Telomoyo | 26.3             |
| Patch 15     | Mt. Andong | 5.64              |
| Patch 16     | Mt. Sumbing | 107.6            |
| Patch 17     | Southern hill of Mt. Sumbing | 4.43 |
| Patch 18     | **Mt. Merapi dan Mt. Merbabu** | 160.7 |
| Patch 19     | Mt. Lawu* | 193.8             |

Note:
- Bold names are protected areas
- (*) historical locality record of JHE occurrences [2, 17]
The suitable habitat of JHE in the central part of Java Island had been experienced loss, shrunk and fragmented [18]. There were 2 small patches southern to Patch 13 detected on 2002 model but undetected on 2014 model. On 2014 model, Patch 13 was separated from Patch 16. Meanwhile, on the 2002 model Patch 13 and Patch 16 were on one single patch and not fragmented. Aside from habitat loss and fragmentation there was new suitable habitat detected which is Patch Mount Muria (Patch 1). This patch was detected on the 2014 model, but was not detected on the 2002 model (figure 6).

Figure 5. Javan Hawk-Eagle habitat patches distribution comparison. (a) JHE habitat patches derived from 2014 LANDSAT 8 model; (b) JHE habitat patches derived from 2002 MODIS NDVI model; Blue patch is Mount Merbabu National Park; Purple patch is Mount Merapi National Park.

Figure 6. Number of detected patches and total size comparison between 2002 MODIS NDVI model (250 m² resolution) and 2014 LANDSAT 8 model (250 m² resolution).
Figure 7. Landscape changing process of JHE habitat in the central part of Java between 2002 MODIS NDVI (250 m$^2$ resolution) model and 2014 LANDSAT 8 (250 m$^2$ resolution) model.

Habitat loss or expansion could happen because of land conversion which reduce or add the overall size of native habitat [18]. Habitat fragmentation is happened when a habitat patch is divided into smaller fraction [18, 19]. Habitat fragmentation can also happened as the after effect of human disturbance at larger scale: landuse change from natural forest to production forest, extensive farming practice, illegal logging, edge-effect, settlement development and infrastructure expansion [20-22].

4. Discussion
In understanding the environmental problem and providing adequate conservation measure we should optimize the function of scale [23, 24]. Implementing different scale in habitat monitoring allowed us to configure different variables in modeling habitat suitability [25, 26]. Landscape configuration and composition which determined the predicted distribution pattern of a species may vary between local-scale, patch-scale and landscape-scale [27, 28]. The multi-scale model could provide guidance in conservation management ranging from the territorial area up to national level [29, 30].

This study showed that the finer-resolution of satellite images were able to detect more predicted suitable habitat for the sustainability of Javan Hawk-Eagle than coarse-resolution images (figure 4). The coarse-resolution (Landsat 8 at 250 m$^2$ and 90 m$^2$) resulted by resampling the finer-resolution pixel (Landsat 8 at 30 m$^2$ resolution). This could happen because when resampling the fine-scale image to coarse-scale image there were some information which lost during process [33]. Thus, eliminating potential variable smaller than the resampled pixel size and fewer patch detected (table 1). By analyzing the potential habitat on a multiple scale we could identify the true extent of suitable habitat [24].

Coarse-scale and fine-scale were both important for habitat management conservation. By looking at the coarse-scale model the managers and conservationists will be able to identify all of the hotspots of predictive suitable habitat in general [2], especially the locations where management decisions should take into account the jurisdictional boundaries. Also, the coarse-scale model is able to help in assessing the need of ecological networks through valuing the connectivity between widely scattered fragmented patches [31, 32]. Meanwhile, more specific management conservation guideline can be produced better.
through the use of finer-scale model. By using the fine-scale model we can specify the detailed habitat preferences, ecological needs and even foraging ground location for JHE [15, 30]. With multi-year coarse-scale model we can identify the landscape change in regional scale (figure 5). But, to figure out what causing those changes, the fine-scale is better to determine the landscape configuration [27].

Our study predicted the suitable area for Javan Hawk-Eagle habitat larger than the designated park within a single patch (Figure 6). At coarse-scale, the model was good enough to predict the extended habitat outside the protected area. To apply the management conservation species specific the fine-scale was better in determined the habitat edge delineation.

In conclusion, the logistic-regression model to predict suitable habitat for JHE shows different results for different image resolution. Finer-resolution method and coarse-resolution method were both important for wildlife management depending on the purpose and goal of conservation. Finer-resolution can provide higher accuracy in mapping the forest and predicting nesting site [29, 34]. But to provide the finer-resolution data will result in higher cost in human resources and technology [35, 36]. Therefore, the managers and conservationists can choose the most suitable image scale for managing, planning and monitoring based on the scale of application—site-scale or regional scale.

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