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INNSPUB

Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 14, No. 6, p. 126-135, 2019
http://www.innspub.net

RESEARCH PAPER OPEN ACCESS

Orangutan (*Pongo pygmaeus*) habitat suitability mapping based on remote sensing imagery in forest area, Hulu Sungai Utara Regency, South Kalimantan Province, Indonesia

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Article published on June 30, 2019

Key words: Orangutan (*Pongo pygmaeus*), Habitat suitability mapping, Remote sensing, South kalimantan

Abstract

This study aims to map and analyze the habitat suitability of orangutan species based on remote sensing image technology, in the forest area of Hulu Sungai Utara Regency, South Kalimantan Province, Indonesia. The total area suitable for orangutan habitat in the forest area of Hulu Sungai Utara Regency is 4,950 hectares. Based on the results of the field survey and analysis of Citra Sentinel-2, the location of suitable habitat for orangutans is visually located within peatswamp forests or peatswamp shrub and bushes. The use of the thresholding method for quantitative parameters of habitat, from the results of this study, can be seen to be quite efficient in mapping areas suitable for orangutan habitat. However, to improve the accuracy of the mapping, in the future it is necessary to consider conducting a prior statistical analysis before thresholding. For example data normality test, data homogeneity test, and data correlation test.

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Introduction

According to Van Schaik (2006), orangutans are the only great apes in Asia, that can only be found in the interior forests of the island of Borneo and the island of Sumatra. Rapid human growth and development had caused the existence of orangutans to be increasingly depressed, and its spread is currently limited to only those two large islands (Rijksen and Meijaard, 1999, Singleton *et al*, 2004), and both are declared separate species, namely *Pongo abelii* in Sumatra and *Pongo pygmaeus* in Borneo (Groves, 2001). Orangutans in Kalimantan are spread in West Kalimantan, Central Kalimantan and East Kalimantan. Until now there is no scientific data that states that orangutans also live and develop in South Kalimantan. A large decrease in population causes orangutans to be included in protected animals, and since 2000 IUCN Red List of Threatened Species had categorized Bornean orangutans as Endangered and Sumatran orangutan groups as Critically Endangered (IUCN 2013, Ancrenaz, *et al*., 2008).

The distribution of orangutans is highly affected by the quality and quantity of the components of the habitats. In their natural habitat, orangutans are wild animals with opportunistic type of feed gathering and collecting (which eat anything they find). The distribution of amount and quality of feed, especially fruits as the orangutans staple highly influences their movement behavior, population density, and social organization (Singleton & van Schaik, 2001; Meijaard *et al*., 2001).

The distribution of orangutan habitat is completely inseparable from the biophysical, climatic, and human activities aspects. The biophysical aspects include the availability of tree vegetation for nests and feed, and the availability of water for drinking. Climatic aspects include temperature, humidity, intensity of irradiation, and so on. While human activity in general is a limiting factor for orangutan habitat. Because orangutans tend to avoid contact with humans.

Biophysical aspects such as the availability of trees/vegetation and the body of water can be easily extracted through satellite imagery. Parameters that are rather difficult to extract directly from satellite images are human activities. However, spatially human activities can be represented as the proximity of a location to the type of land use or certain land cover that has massive human activity. In this case, what is meant is settlement and road network. So that the existence of these settlements and roads can be extracted from satellite images.

Climate aspects such as temperature, humidity and intensity of irradiation are generally obtained from meteoclimatology data from the Meteorology, Climatology and Geophysics Agency (BMKG). However, this climatic parameter can be illustrated by the condition of vegetation canopy covering. Air temperature, irradiation intensity, and air humidity, correlate with moisture or water content in the vegetation canopy. The higher the intensity of irradiation, the higher the temperature, and the lower the water content in the canopy. So far, the water content in the vegetation canopy can be extracted from optical satellite images, such as Landsat 8 Operational Land Imager (OLI) or Sentinel-2 Multispectral Instrument (MSI) imagery.

Air temperature, especially forests (places that are relatively far from human activities), is generally determined by the intensity of solar radiation and the elevation of the place above sea level. Especially for the Hulu Sungai Utara Regency which became the location of this study, elevation can be ignored. Because the condition of elevation is relatively the same for all regions. Almost all research areas are located in wetlands with flat topography, and are only a few meters above sea level. In short, simply by using remote sensing image technology, we can extract biophysical, climatic, and human activity parameters, all of which are aspects that can characterize the suitability of wildlife habitats, especially orangutans.

The purpose of this study is to map the habitat suitability of orangutan species based on remote sensing image technology, in the forest area of Hulu Sungai Utara Regency, South Kalimantan Province, Indonesia. From the results of this study, it is expected to obtain a simple and efficient method for predicting areas suitable for orangutan habitat.

Materials and methods

Materials

This research took place in the forest area of the Hulu Sungai Utara Regency, South Kalimantan Province. The forest area is taken from the Appendix of the Decree of the Minister of Environment and Forestry of the Republic of Indonesia, Number: SK.2308 /MENLHK-PKTL/KUH/PLA.2/4/2017, concerning the Map of the Development of Forest Zone Inauguration in South Kalimantan Province until 2016. Where according to this Decree, the entire forest area in the North Hulu Sungai Regency area is included in the Conversion Production Forest (Fig.1).

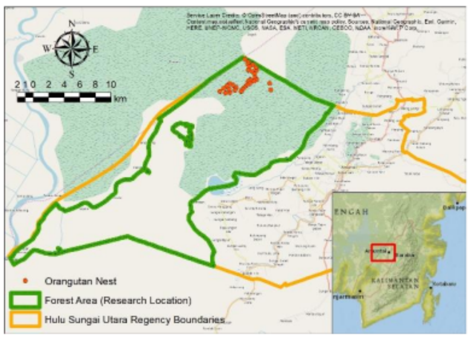

Fig. 1. Research location and orangutan nest.

Methods

The method of mapping the suitability of orangutan habitat used in this study is by analyzing the similarity of orangutan living places (nest locations) found directly in the field, with all the areas studied. In other words, if in an area within the scope of this research area, the characters are the similar to the location of the orangutan nest, then the area is said to be suitable for orangutan habitat. The characters in question are vegetation density, humidity of vegetation canopy, health of vegetation, distance of place with body of water, and distance of place with human activity.

The location of orangutan nests is obtained directly through surveys to the field. The sampling method used was accidental sampling. Based on the results of the field survey, a total of 32 points were found to be the location of orangutan nests. The location of all orangutan nests is then analyzed for the character of the vegetation density, the canopy moisture, the health of the vegetation, and the distance from the water body and the place of human activity (Fig. 2).

Fig. 2. Orangutan nest from field survey.

In this study, vegetation density was represented by the Leaf Area Index (LAI) and Fraction of Vegetation Cover (FVC) parameters. Canopy moisture is expressed by the parameter Canopy Water Content (CWC). The health of vegetation which is the source of orangutan food is represented by the Canopy Chlorophyll Content (CCC) parameter and the Fraction of Absorbed Photosynthetically Active Radiation (fAPAR). While the distance from the body of the water and the place of human activity are calculated using the Euclidean method Distance from the water body and settlements and road networks.The overall parameters in this study were extracted from Sentinel-2B imagery recorded on May 6 2018 (S2B_MSIL1C_20180506T022549_N0206_R046_T50MKC_20180508T021713). Before the extraction process of all parameters was carried out, Sentinel-2B imagery level 1C used in this study was atmospherically and topographically corrected first, using the Sen2Cor tool from ESA SNAP 6.0 software, so as to produce Level 2A (Bottom of Atmosphere reflectance) Image Sentinel. Then all Sentinel-2 channels that differ in spatial resolution, are sampled to 10 meters (Fig. 3).

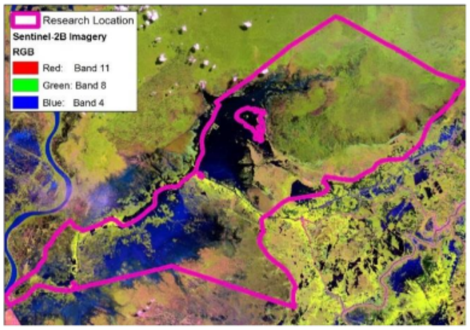

Fig. 3. Sentinel-2B imagery composite 11,8,4.

LAI, FVC, CWC, CCC, and FAPAR are extracted automatically using the Biophysical Processor tool from ESA SNAP 6.0 software. LAI is defined as the area of leaves on one side per land surface area. The FVC is related to the fraction of the gap between the leaves of the tree from the nadir direction. Processes in energy balance processes, including temperature and evapotranspiration (Weiss, 2016).

FARES corresponds to the fraction of photosynthetically active radiation absorbed by the canopy (Weiss, 2016). fAPAR and CCC can be considered as parameters that represent plant health, because these two parameters describe vegetation photosynthetic activity. While CWC illustrates climatic factors. Because CWC depends on the intensity of radiation, air temperature, air humidity, and rainfall (Fig. 4).

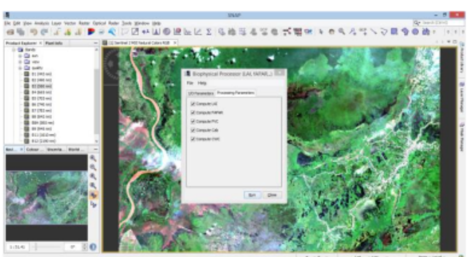
Fig. 4. ESA SNAP Biophysical Processor.

The body of water is extracted using the Modified Normalized Difference Water Index (MNDWI) transformation method (Xu, 2006). While the place of human activity, namely urban (settlement and road network) is extracted using the Urban Index (UI) method (Kawamura *et al.*, 1996).

MNDWI was formulated by Xu (2006) as follows:

$$\mathrm{MNDWI} = \frac{\rho_g - \rho_{swir1}}{\rho_g + \rho_{swir1}}$$

While UI was formulated by Kawamura *et al.* (1996) as follows:

$$\mathrm{UI} = \frac{\rho_{swir2} - \rho_{nir}}{\rho_{swir2} + \rho_{nir}}$$

ρ_g = *green band (Sentinel-2 band 3)*

ρ_{nir} = *near infrared band (Sentinel-2 band 8)*

ρ_{swir1} = *shortwave infrared 1 band (Sentinel-2 band 11)*

ρ_{swir2} = *shortwave infrared 2 band (Sentinel-2 band 12)*

According to Xu (2006), water bodies are extracted using a threshold value> 0 in MNDWI. While urban extracted using threshold value> -0.22 at UI. The UI -0.22 threhold value was obtained by the Triangle threshold method using ImageJ software (Schneider *et al.*, 2012; Schindelin *et al.*, 2015). The reason for using the Triangle threshold method is because for the case of this research area, the urban location of the UI is most accurately extracted using this Triangle method. This is after going through visual analysis and comparing it with other threshold methods. After the location of the water and urban bodies is found, then an Euclidean Distance analysis is performed to measure Distance from Water (DW) and Distance from Urban (DU). DW and DU are calculated using the Euclidean Distance tool from ESRI ArcGIS 10.4 software.

After all the parameters are extracted, the coordinates of the location of the orangutan nests obtained from the field are stacked with the seven parameters, namely LAI, FVC, CWC, CCC, FAPAR, DW, and DU. This is to obtain the values of the seven parameters at each orangutan nest point. In this study, the minimum and maximum values of each parameter in all orangutan nest points were justified as limiting values for orangutan habitat. Thus, the suitability of orangutan habitat in this study is formulated as follows:

$$\mathrm{Suitability} = ((LAI >= LAI_{min})\&(LAI <= LAI_{max}))x((FVC >= FVC_{min})\&(FVC <= FVC_{max}))x((CWC >= CWC_{min})\&(CWC <= CWC_{max}))x((CCC >= CCC_{min})\&(CCC <= CCC_{max}))x((fAPAR >= fAPAR_{min})\&(fAPAR <= fAPAR_{max}))x(DW <= DW_{max})x(DU >= DU_{min})$$

The minimum and maximum values in the formula above, namely LAImin, LAImax, FVCmin, FVCmax, CWCmin, CWCmax, CCCmin, CCCmax, fAPARmin, fAPARmax, DWmax, and DUmin, are determined from the minimum and maximum values of each parameter, at the location point the discovery of orangutan nests. Specifically for the DW parameter the minimum limit is not specified, and for the DU parameter the maximum limit is not specified. Because it is assumed that there is no limit to the minimum distance of orangutan habitat to the body of the water. Likewise there is no limit on the maximum distance of orangutan habitat to urban areas.

The suitability formula above is implemented using the Raster Calculator in ESRI ArcGIS software. This suitability formula will produce a binary image. Where the value of pixel 1 means suitable for orangutan habitat, while the pixel value of 0 means that it is not suitable for orangutan habitat.

Results and discussions

In general, spatial modeling of wildlife habitat suitability, such as orangutans, is carried out using a multiparameter approach. Such as elevation, slope, slope direction, type of land cover, distance from the center of human activity, and climatic parameters such as air temperature and humidity. Some of these parameters are measured directly in the field, some are extracted from satellite images, some are obtained through processing climate data from BMKG.

In this study, we tried to develop a methodology for mapping the suitability of wildlife habitats, especially orangutans, more efficiently. That was only using optical satellite imagery, in this case Sentinel-2 MSI imagery. Where this image has a high spatial resolution, and can be downloaded for free.

The basic idea is that the characteristics of orangutan habitat are limited by certain quantitative parameter values. Such as the distance limits from settlements or roads, limits on distance from water bodies, vegetation density range, vegetation health range, and so on. By analyzing the limitations of these quantitative parameters using orangutan nest locations found directly in the field, it can be predicted which areas are suitable for orangutan habitat. Interestingly, the parameters assumed to be the limiting factor for the orangutan habitat mentioned above, as a whole can be extracted from optical satellite images, such as Sentinel-2 MSI (Fig. 5).

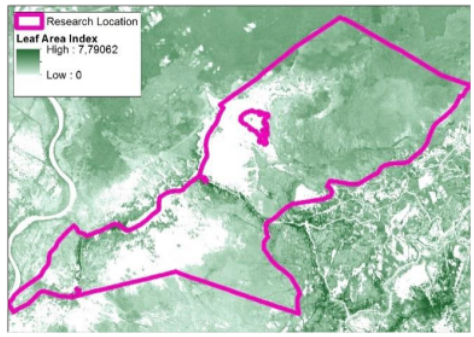

Fig. 5. LAI imagery.

Orangutans need vegetation as a place to live and feed sources. So the vegetation requirements for orangutan habitat are the availability of dense vegetation (trees) as well as healthy vegetation (Fig. 6). In this study, vegetation density was measured using LAI and FVC. While the health of vegetation is represented by CCC data and photosynthetic activity (fAPAR). Where the healthier the vegetation, the CCC and fAPAR will be higher (Fig. 7). LAI states the extent of one side of the leaf (facing upwards) per surface area of a particular land. Of course, LAI directly represents vegetation density. Where this parameter is very important influence on the existence of orangutan nests. While the FVC, as mentioned earlier, is associated with a fraction of the gap between tree leaves. FVC is used to separate vegetation and soil in energy balance processes, including temperature and evapotranspiration (Weiss, 2016). From Fig. 5 and Fig. 6, it is evident that the location of orangutan nests is indeed in a tightly vegetated area.

CCC is the content or concentration of chlorophyll in the leaves per particular canopy area. The CCC has a unit of mass per area, generally expressed by g/cm^2. The chlorophyll concentration in the leaves direcly correlates with the health of vegetation. Healthy vegetation will be rich in chlorophyll, making it ideal for orangutans feeding. The health of vegetation can also be seen from its photosynthetic activity, which is reflected through the fAPAR parameter. fAPAR is very useful as input to the number of primary productivity models based on simple efficiency considerations (Prince 1991). fAPAR also depends on the intensity of solar radiation, so that the fAPAR parameter can represent some of the climatic aspects in determining orangutan habitat (Fig. 8).

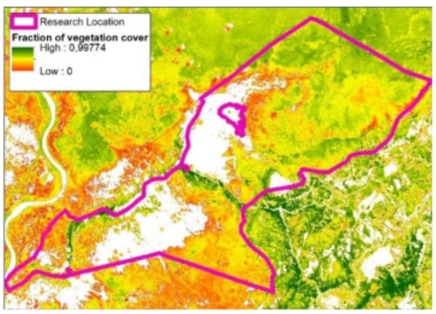

Fig. 6. FVC imagery.

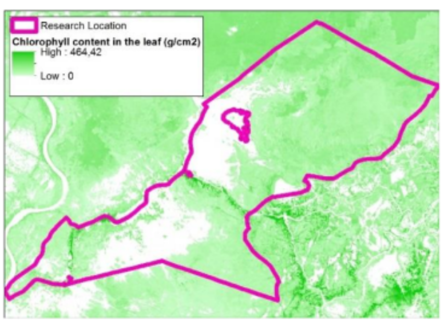

Fig. 7. CCC imagery.

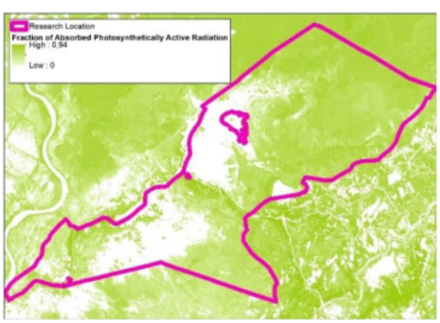

Fig. 8. fAPAR imagery.

If fAPAR represents the climatic parameters of the intensity of solar radiation, CWC represents the climatic parameters of the intensity of solar radiation, temperature, humidity, and rainfall. If the value of CWC is increasing, a number of possibilities can be predicted (Fig. 9). There is a possibility that the rainfall is high, or the radiation intensity is low, or the air temperature is low. From Fig. 9 it can be seen that the location of orangutan nests is found in areas with high water content in the canopy.

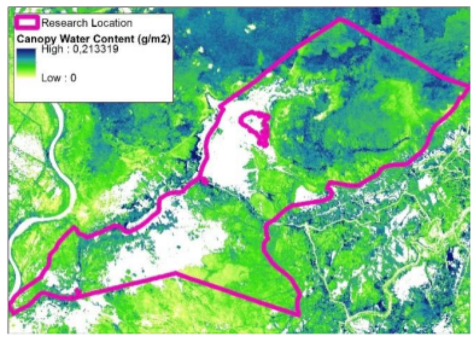

Fig. 9. CWC imagery.

Proximity to the body of the water also greatly determines the suitability of wildlife habitats such as orangutans. Because orangutans need water to drink. In this case, we can assume that orangutan habitat will not be too far from the body of the water (Fig. 10). In this study, by measuring each distance of orangutan nests from the body of water (DW), the furthest distance limit (DWmax) can be determined which is suitable for orangutan habitat from the water body. From Table 1 it is known that the maximum distance of orangutan habitat from the body of water (DWmax) is around 3,464 meters (Fig. 11). If the proximity of the body of the water is a life-supporting parameter for orangutans, the proximity of the distance from urban areas (settlements and road networks) is a limiting factor for orangutan habitat. This is because orangutans generally avoid the presence of humans (Fig. 12).

By measuring the distance of each orangutan's nest from urban areas (DU), the closest distance (DUmin) limits can be determined which are suitable for orangutan habitat (Fig. 13). From Table 1, it is known that the minimum distance of urban orangutan (DUmin) habitat is around 1,152 meters.

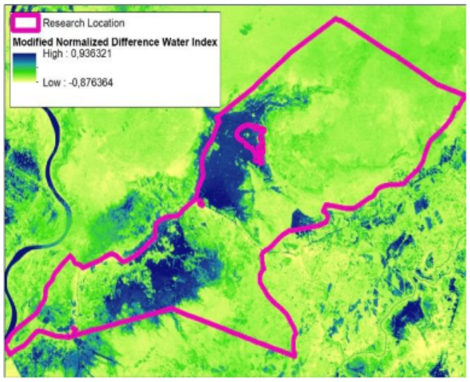

Fig. 10. MNDWI imagery.

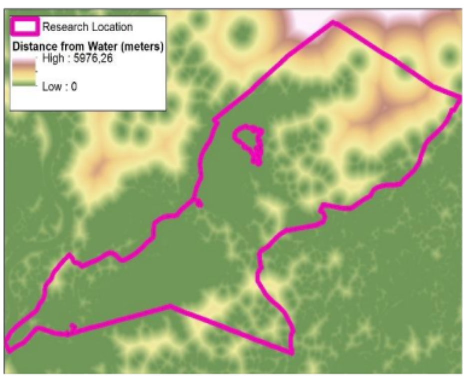

Fig. 11. Distance from water (DW).

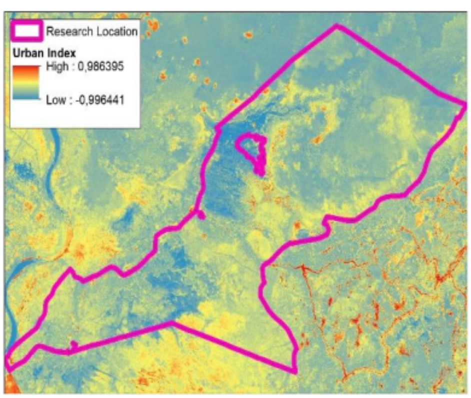

Fig. 12. Urban Index imagery.

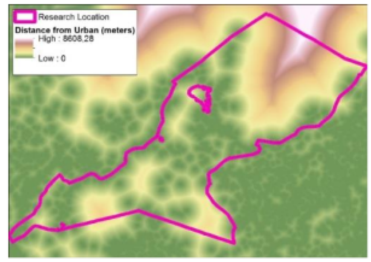

Fig. 13. Distance from urban (DU).

Based on the minimum and maximum values of all parameters in Table 1, the suitability of orangutan habitat is expressed by the following formula:

(DU >= 1152.47998)x(DW <= 3464.169922)x((LAI >= 2.07508)&(LAI <= 3.15649))x((CCC >= 78.799797)&(CCC <= 174.899994))x((CWC >= 0.070729)&(CWC <= 0.10374))x((FVC >= 0.533385)&(FVC <= 0.759371))x((fAPAR>= 0.620597)&(fAPAR <= 0.780749))

From the results of the above formula, we obtained a suitability map of orangutan habitat in the study area, as shown in Fig. 14. From the results of this spatial modeling, it was found that the total area suitable for orangutan habitat was 4,950 hectares (Fig. 14).

Table 1. Statistical summary of all parameter at each orangutan nest location.

Parameters	Min	Max	Mean	SD
Distance from Urban	1.152,480	7.093,260	3.880,619	1.387,431
Distance from Water	502,195	3.464,170	1.513,519	681,986
LAI	2,075	3,156	2,788	0,219
Chlorophyll content in the leaf (gr/cm2)	78,800	174,900	130,115	19,746
Canopy Water Content (gr/m2)	0,071	0,104	0,089	0,007
Fraction of vegetation cover (FVC)	0,533	0,759	0,667	0,044
Fraction of Absorbed Photosynthetically Active Radiation (fAPAR)	0,621	0,781	0,737	0,031

Table 2. Orangutan Nest Coordinate and Values of Each Geospatial Parameters.

No	Nest Coordinate (WGS 1984 UTM Zone 50M)		DU (meters)	DW (meters)	LAI	CCC (gr/cm2)	CWC (gr/m2)	FVC	fAPAR
	X	Y							
1	293956	9744820	5120,71	1534,44	2,796	142,775	0,088	0,647	0,743
2	293848	9745230	5073,59	1958,8	2,631	135,829	0,081	0,605	0,720
3	293457	9745564	4770,54	2401,6	2,764	143,267	0,084	0,642	0,737
4	292891	9745892	4347,16	2949,85	2,639	131,399	0,085	0,622	0,722
5	292457	9746225	4090,2	3464,17	2,826	150,607	0,081	0,656	0,745
6	292838	9745574	4180,55	2713,3	2,506	123,403	0,078	0,590	0,701
7	293044	9745267	4297,95	2338,93	3,115	170,649	0,091	0,700	0,777
8	292912	9744828	4088,53	2085,98	2,904	154,242	0,084	0,676	0,755
9	293383	9744664	4537,66	1654,15	3,156	174,900	0,093	0,705	0,781
10	293695	9744378	4831,25	1237,09	3,131	169,257	0,093	0,696	0,778
11	290497	9743108	1974,74	1972,31	3,010	139,587	0,095	0,724	0,767
12	290933	9742923	2442,29	1793,54	2,837	125,811	0,099	0,678	0,743
13	291343	9742632	2943,64	1617,71	2,818	121,434	0,088	0,695	0,743
14	291171	9742274	3017,83	1220,04	2,834	119,232	0,091	0,695	0,744
15	290536	9741930	2439,71	810,247	2,821	127,852	0,089	0,673	0,741
16	289954	9741904	1883,22	832,166	2,630	119,178	0,083	0,629	0,718
17	289253	9742116	1152,48	1034,46	3,006	137,173	0,091	0,718	0,765
18	289743	9742512	1602,53	1447,79	2,925	129,867	0,092	0,717	0,757
19	290153	9742817	1902,24	1759,32	2,728	112,682	0,093	0,676	0,731
20	290430	9742380	2290,35	1271,22	2,753	118,405	0,089	0,686	0,736
21	293740	9743933	4889,21	871,149	2,881	138,095	0,095	0,682	0,751
22	293987	9743648	5153,88	502,195	2,610	109,878	0,088	0,651	0,715
23	293621	9743417	4830,11	772,334	2,451	97,220	0,084	0,620	0,692
24	293153	9743648	4330,38	1273,46	2,755	124,151	0,095	0,658	0,732
25	292923	9743417	4141,98	1233,69	2,934	134,741	0,096	0,696	0,755
26	293105	9743116	4385,43	892,861	3,118	127,027	0,104	0,759	0,780
27	292724	9742917	4079,34	900,278	2,702	115,951	0,091	0,659	0,726
28	292415	9742624	3894,87	980,867	2,815	125,688	0,094	0,674	0,740
29	292169	9742386	3777,37	1014,15	2,723	117,108	0,083	0,675	0,731
30	291955	9742124	3733,15	1008,46	2,823	134,638	0,089	0,677	0,742
31	295666	9743168	6883,67	1213,42	2,512	112,838	0,080	0,617	0,700
32	295774	9742306	7093,26	1672,63	2,075	78,800	0,071	0,533	0,621

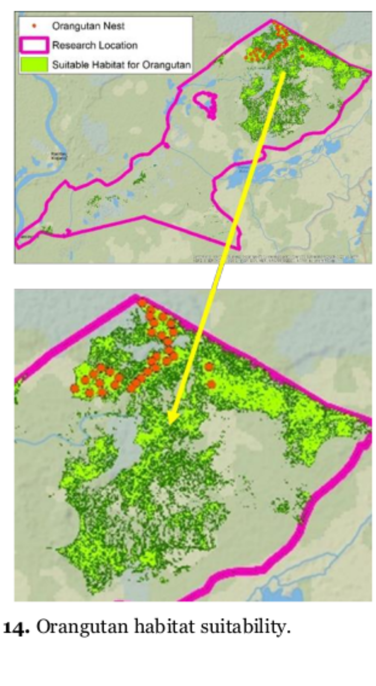

Fig. 14. Orangutan habitat suitability.

Orangutans inhabit various types of habitats including lowland tropical rainforests, peat swamp forests, lowland riverbank forests, and freshwater swamp forests (Ancrenaz *et al.*, 2004; Russon *et al.*, 2001). This causes orangutans to have different behaviors between habitat types. Manduell *et al.* (2012) states that orangutans living in Ketambe, Sumatra with mixed dry forest types tend to use lianas> 4cm in diameter to support arboreal activity. In contrast, orangutans in Sebangau, Central Kalimantan, characterized by peat swamp forests choose to avoid lianas with that diameter. One of the differences in behavior between habitat types is influenced by the characteristics of the constituent vegetation including the composition and structure of vegetation (Manduell *et al.*, 2012).

Preferred habitat selection is an action taken by wildlife in order to obtain a series of conditions that are favorable for reproductive success and survival (Bolen & Robinson 1995). The preferred habitat must be able to provide all the necessities of life for orangutans consisting of food, water, shelter, place to play and place to breed. To ensure the sustainability of the orangutan population, the preferred habitat must have good quality and sufficient area size.

The use of the thresholding method of quantitative parameters of habitat, from the results of this study, looks quite efficient in mapping the areas suitable as orangutan habitat. Although this method still contains several weaknesses. Among them is data distribution, whether normal or not, homogeneous or not. If the data turns out to be not normal, then extraction of quantitative parameters of habitat could be a coincidence.

In addition, in this study there was also no real correlation between quantitative parameters used as the basis for limiting habitat suitability, and the location of the nest or the intensity of the presence of orangutans. So that there may be certain parameters chosen in this study, which in fact have no correlation whatsoever with orangutan habitat. However, from the beginning this study was aimed at the efficiency of predicting habitat suitability. For purposes of accuracy, it is better to do some prior statistical tests, before doing thresholding quantitative parameters of habitat. From the results of the placement of suitable habitat locations for orangutans in this study with Sentinel-2 imagery, it was visually seen that the entire habitat suitable for orangutans was located in peatswamp forests or peatswamp shrub and bushes.

Conclusions

Based on the results of this study, it was found that the total area suitable for orangutan habitat in the forest area of Hulu Sungai Utara Regency was 4,950 hectares. From the results of the placement of suitable habitat locations for orangutans in this study with Sentinel-2 imagery, it was visually seen that the entire habitat suitable for orangutans was located in peatswamp forests or peatswamp shrub and bushes.

The use of the thresholding method for quantitative parameters of habitat, from the results of this study, can be seen to be quite efficient in mapping areas suitable for orangutan habitat. However, to improve the accuracy of the mapping, in the future it is necessary to consider conducting a statistical analysis first before thresholding. For example data normality test, data homogeneity test, and data correlation test.

Acknowledgment

Our thanks to the Research and Community Service Institution for providing funding support in this study. Also to the European Space Agency (ESA) which has provided Sentinel-2 imagery for free. As well as ESRI Indonesia, which has provided an academic license for ArcGIS for Desktop 10.4 software used in this study.

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