LAND USE/COVER CHANGE ON POTENTIAL LOSS OF SUMATRAN TIGERS IN KERINCI SEBLAT NATIONAL PARK BASED ON REMOTE SENSING DATA

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Received: 12.08.2022; Revised: 26.08.2022; Approved: 29.08.2022

Abstract. The Sumatran tiger is an animal whose life is threatened due to land use changes and human activities. Based on remote sensing data, this study described the correlations between land use/cover (LULC) changes and the potential loss of Sumatran tigers in Kerinci Seblat National Park (KSNP) based on remote sensing data. Remote sensing technology was used due to the good historical data, and it can be used for LULC changes analysis. The results of the analysis of the LULC changes can be used to analyze the changes in the suitability level of the Sumatran tiger habitat. The analysis of LULC changes in 2000 and 2020 has been carried out from Landsat-5 dan Landsat-8 data using the random forest classification method, and then we examined the changes in the level of suitability of the Sumatran Tiger habitat. The results of the analysis of LULC changes showed a significant reduction in primary forests at 282.58 km^2, while the increase in plantations and secondary forests was 186.52 km^2 and 101.68 km^2. This change affects the suitability level of the Sumatran tiger habitat from a highly suitable level to a suitable and not suitable class, approximately about 164.42 km^2. The declining suitability level class indicated the potential loss of Sumatran tigers in the Kerinci Seblat National Park. The increasing of plantation and settlement areas will increase the activity of humans. The conflict of human activity with Sumatran tigers' life will impact the loss of Sumatran Tigers in KSNP.

Keywords: *Sumatran Tigers, land use/cover (LULC) change, habitat suitability level, Kerinci Seblat National Park*

1 INTRODUCTION

Sumatran Tigers (Panthera Tigris Sumatra) are Indonesian endemic animals that are protected by law and classified as Critically Endangered on the IUCN 2006 Red List of Threatened Animals and as Appendix I under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (Suyadi *et al.* 2012). The threat to the life of the Sumatran tiger continues due to human activities such as forest/land clearing and hunting. The dominant forest/land clearing that disturbs the life of their habitat is the establishment of plantations (Patana *et al.* 2021), Hadadi et al. 2015, and Suyadi *et al.* 2012). This disturbance can be continued, and finally, the Sumatra tigers are extinct. Research related to the potential disturbance to the Sumatran Tiger's habitats needs to be carried out, then it can be used in policy-making to prevent extinction. Remote sensing is one potential technology to use in the spatial distribution of potential loss of certain habitats (Rudiansyah *et al.* 2007). The advantages of using remote sensing are related to the historical data. It can provide data for several years and makes it easy to analyze the environmental changes in certain areas (Chulafak *et al.* 2022).

The potential for the use of remote sensing technology for monitoring the sustainability of flora and fauna is very high. The use of remote sensing technology for plant monitoring is currently growing rapidly. The utilization of remote sensing satellite imagery can be used to analyze habitat suitability and the distribution of a species (He *et al.* 2011). Based on (Valderrama-Landeros *et al.* 2018), multispectral satellite imagery can be used to distinguish mangrove species. Remote sensing technology can also work well to detect land cover/use changes (Berhane *et al.* 2020; Srichaichana *et al.* 2019). Based on the development of existing methods, remote sensing data can be used to project changes in land use/cover that may occur in the future (Daba & You 2022).

Usually, to analyze the disturbance of habitat to land use/land cover (LULC) change, it used direct measurements in the field using a camera trap so that the presence of the animal (Ariyanto *et al.* 2021). Spatial models are also widely developed to see the suitability of certain habitats and the suitability of their environment (Sulistiyono *et al.* 2020). However, research linking changes in land cover/use with the level of habitat suitability is still rarely carried out. Decreases in suitability levels due to land changes can occur and can be described as potential disturbances to the Sumatran Tiger habitat. Besides the habitat suitability level, the hunting of the Sumatran tiger is the most disturbance of habitat loss. This study examines the potential disturbance of the Sumatran Tiger's habitat due to the land use/cover change. Remote sensing is the main technology in this research activity.

2 MATERIALS AND METHODOLOGY

2.1 Studi Area

This research was conducted in the Kerinci Seblat National Park (KSNP) area, as shown in Figures 2-1. The KSNP area covers 4 provinces on Sumatra Island, namely West Sumatra, Jambi, Bengkulu, and South Sumatra (Simarmata 2019). KSNP is a habitat for various types of endemic flora and fauna in Indonesia. Some of them are endemic flora and fauna species.

2.2 Data Availability

This study used several types of data as input to model the level of suitability of the Sumatran Tigers' habitat. These data can be grouped into two categories: remote sensing data and its modeling and non-remote sensing data. Remote sensing data used in this study include Landsat-8 OLI TIRS images, Landsat-5 TM images, Land Surface Temperature (LST) modelling images, and The Moderate Resolution Imaging Spectroradiometer (MODIS), Famine Early Warning Systems Network (FEWS Net) images. Land Data Assimilation System (FLDAS), OpenLandMap Soil modelling images, and Digital Elevation Model (DEM) images of The Shuttle Radar Topography Mission (SRTM). The complete availability of data used in this study is shown in Table 2-1. The non-remote sensing data used in this study was the vector of the river network in the KSNP area.

2.3 Methods

Landuse/cover Classification

Land cover parameters were obtained from Landsat-5 imagery (mosaic from 1998 to 2002) and Landsat-8 imagery (mosaic from 2018 to 30 April 2022) using supervised classification. Before being used as input for the LULC classification of Landsat-5 and Landsat-8 images, a geometric, radiometric, atmospheric, and cloud masking correction process were conducted to obtain a cloud-free image and a mosaic process using the median value of each data pixel. The classification algorithm used was Random Forest because this algorithm can provide good classification accuracy (Orieschnig *et al.* 2021; Tavares *et al.* 2019; Yulianto *et al.* 2021). The LULC used in this study consisted of 9 classes: primary forest, secondary forest, fields/moorlands, rice fields, built-up land, open land, plantations, shrubs, and bodies of water. Besides being used as input for the LULC classification, Landsat-5 and Landsat-8 images were used to determine the canopy density parameter.

Sumatran Tigers suitability classification

Based on research by Rudiansyah (2007) and Rambe (2020), the habitat of Sumatran Tigers is influenced by the environment's physical, biological, and food conditions. Several parameters of physical environmental conditions that can affect the Sumatran Tigers' life are slope, altitude, vegetation index, distance from waters, and canopy density. In addition to the physical environment, another factor that significantly affects Sumatran Tigers is human activity, which is indicated by land use/cover. The existence of human activities can change the structure of the vegetation in the natural habitat of Sumatran Tigers. As an example of the conversion of land from forest to roads or other built-up lands could disturb the modeling of the Sumatran Tigers' habitat in this study was derived from these life of the Sumatran Tigers's habitat. The parameters by using Weighting Linear Combination (WLC) (Malczewski, 2000).

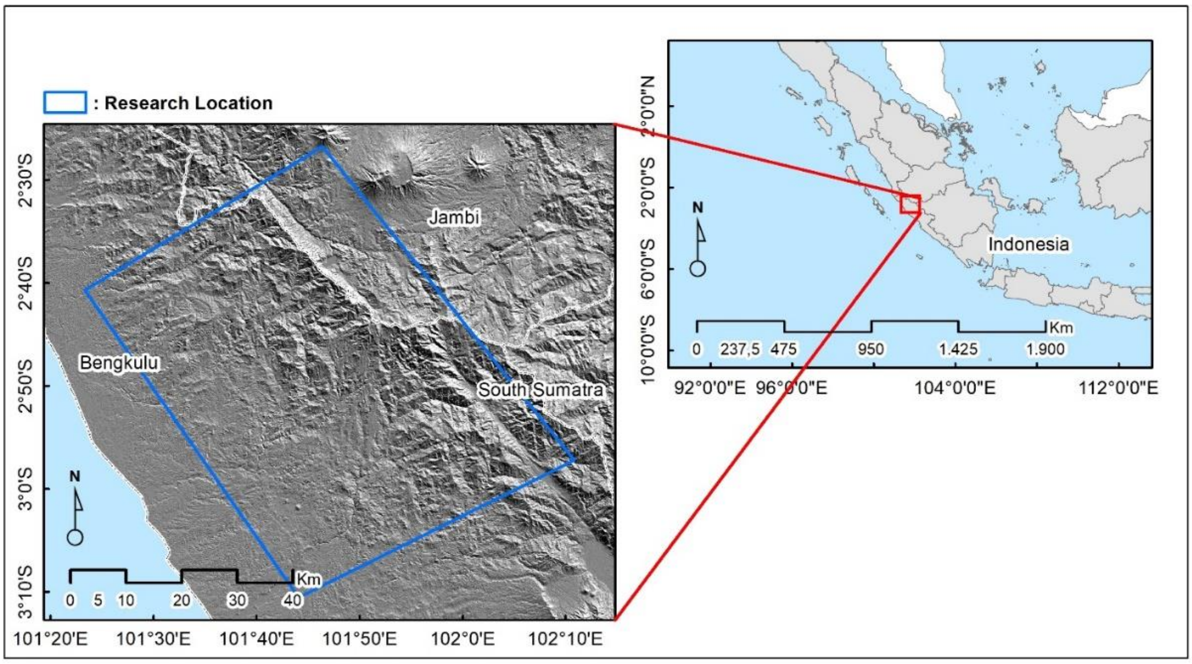

Figure 2-1. Study area: Kerinci Seblat National Park in Sumatra Island.

Table 2-1. Availability of remote sensing data used in research

Images	Bands	Purpose	Sources
Landsat-8 OLI TIRS	Red, Green, Blue, NIR, SWIR-1, SWIR-2	LULC classification, Leaf Area Index (LAI) parameter calculation	NASA and USGS in GEE
Landsat-5 TM	Red, Green, Blue, NIR, SWIR-1, SWIR-2	LULC classification, Leaf Area Index (LAI) parameter calculation	NASA and USGS in GEE
LST MODIS	LST_Day_1km	Humidity parameter calculation	LP DAAC in GEE
FLDAS	Tair_f_tavg	Calculation of air temperature parameters	GES DISC in GEE
OpenLandMap Soil	b0	Calculation of parameters of soil acidity level (pH)	Creative Commons Attribution-Share Alike 4.0 International in GEE
DEM	elevation	Calculation of elevation and slope parameters	NASA JPL in GEE

In general, the classification of the level of suitability of the Sumatran Tigers' habitat is carried out in 4 stages (Figure 2-2) i.e.: 1) preparation of input parameters. 2) classification of input parameters using the logic function method. 3) calculate the habitat suitability model for Sumatran Tigers. The last stage, 4) is the classification of the level of suitability of the Sumatran Tigers' habitat.

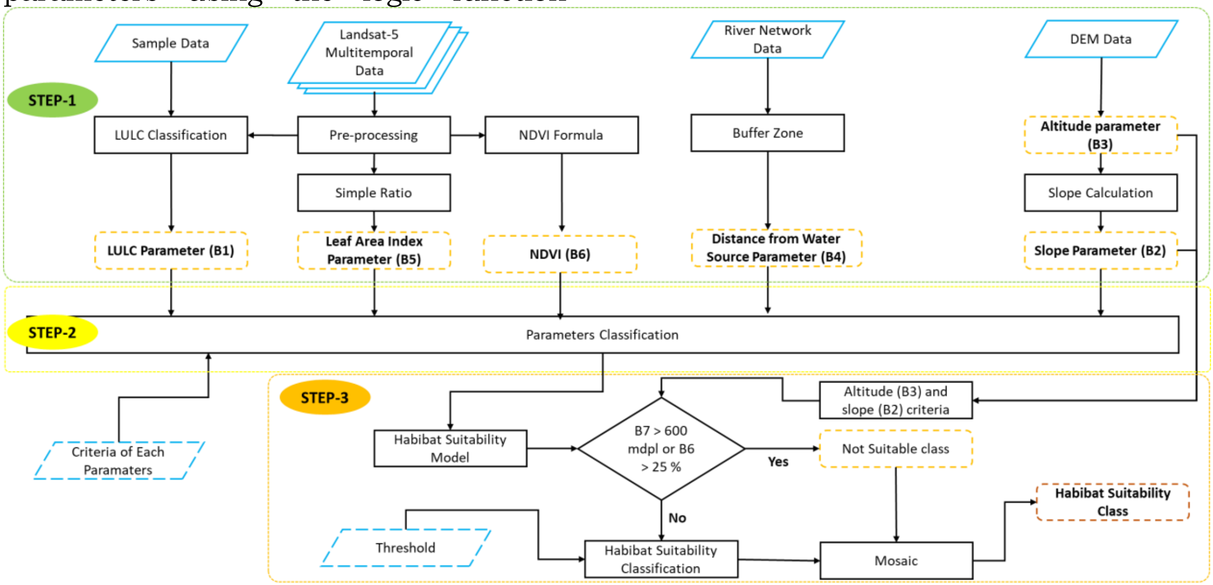

Figure 2-2. Flowchart of the classification process for the level of suitability of the Sumatran Tigers' habitat in general

Stage-1 preparation of input parameters: at the input preparation stage, each input parameter is calculated using remote sensing images and their derivatives. The crown density was estimated using the Leaf Area Index (LAI). The LAI estimation from satellite imagery is shown by the following equation 2 (Flores et al., 2006):

$$SR = \frac{NIR}{Red} \quad (1)$$

$$LAI = 0.56SR - 0.83 \quad (2)$$

Where SR is the vegetation index using a simple ratio (Blinn et al., 2019), NIR and Red are the NIR band and the red band of Landsat images, respectively. The air temperature parameter is obtained from the FLDAS image using the Tair_f_tavg band. The band contains temperature values near the surface (McNally et al., 2017). The acidity parameter was obtained from the OpenLandMap Soil image using the b0 band. Band b0 contains the value of soil acidity at a depth of 0 meters. The height and slope parameters were obtained from the SRTM DEM image. The image is an elevation modelling image that has a resolution of about 30 m (Hennig et al., 2001). The distance parameter from the river was obtained from the vector data of the river network. The vector of the river network is then buffered with a distance of 100 m and 400 m. The air humidity parameter was estimated using LST MODIS and DEM data.

$$NDVI = \frac{NIR - Red}{NIR + Red} \quad (3)$$

Stage-2 input parameter classification: classification of input parameters is done by using a threshold. The classification method using threshold has been widely applied for various purposes such as flood detection, detection of residential areas, bodies of water on land, and vegetation mapping (Feyisa et al., 2014; Lu et al., 2008; Pangali Sharma et al., 2019). Input parameters are classified into three classes, namely not support, support, and very supportive. Equation 6 is used to classify the input parameters of air temperature, canopy density, humidity, soil acidity, humidity, and altitude. The distance parameter from the river is classified using equation 7.

$$C_{ik} = \begin{cases} 1, & B_i > Th_2 \\ 2, & B_i < Th_1 \\ 3, & Th_1 \leq B_i \leq Th_2 \end{cases} \quad (4)$$

$$C_{ik} = \begin{cases} 1, & B_i > Th_2 \\ 2, & Th_1 \leq B_i \leq Th_2 \\ 3, & B_i < Th_1 \end{cases} \quad (5)$$

where X_{ik} is the input parameter class (1: not supported, 2: supported, and 3: strongly supported), B_i is the input parameter value, Th_1 and Th_2 are threshold-1 and threshold-2 for each input parameter. The threshold for each class for each input parameter is more fully shown in Table 2. Specifically, for the LULC parameter, the class division is determined as follows: LULC in the form of primary forest and shrubs is classified as a very supportive class ($C_{ik} = 3$). LULC, in the form of mangroves, rice fields, bodies of water, and secondary forests, was classified as a supportive class ($C_{ik} = 2$). Fields/moorlands, open land, built-up land, ponds, and plantations are classified as unsupportive classes ($C_{ik} = 1$).

Table 2-2. Threshold and weighting of each input parameter of the Sumatran Tigers habitat suitability model.

Code	Parameter	Threshold Th1	Threshold Th2	Weight (%)
B1	LULC	-	-	30
B2	slope	15 %	25 %	20
B3	elevation	300 masl	600 masl	20
B4	distance from water source	400 m	1200 m	10
B5	Leaf Area Index (LAI)	1	2.29	10
B6	NDVI	0.5	0.8	10

Stage 3 stratified classification of habitat suitability of Sumatran Tigers: the habitat suitability model of Sumatran Tigers was determined from the input parameter values and their weighting. The habitat suitability model for Sumatran Tigers is shown by equation 8 below:

$$SRAHM = \sum_{i=1}^{n} x_i B_i \quad (8)$$

Where SRAHM is the habitat suitability model for Sumatran Tigers, i is the parameter index, n is the number of parameters, Bi is the i-th parameter, and xi is the i-th parameter weighting (table 2). The stratified classification method was applied to determine the three levels of the suitability of the Sumatran Tigers' habitat, namely not suitable, suitable, and highly suitable. The parameters of the height and slope of the slope are first used to obtain the non-conforming class. Pixels that have a height value of more than 550 masl or a slope of more than 45 % were classified as unsuitable classes. Then the other pixels will be classified using the following equation 9:

$$CM = \begin{cases} 1, & mod \leq 1 \\ 2, & 1 < mod \leq 2 \\ 3, & 2 < mod \end{cases} \quad (9)$$

where CM is the level of suitability of the Sumatran Tigers habitat and the mod is the pixel value of the Sumatran Tigers habitat suitability model.

3 RESULTS AND DISCUSSION

3.1 Dynamic Land Use Land Cover Map

The results of LULC classification in the KSNP area using the Random Forest algorithm are shown in Figure 3. There was a change in land cover in the KSNP area and its surroundings from 2000 to 2020. Primary forest experienced a significant reduction in the area at about 282.58 km² from 3,184.12 km² in 2000 to 2,901 km² in 2020. The increase in plantations and secondary forests is 186.52 km² and 101.68 km². From 2000 to 2020, the plantation area increased from 182.42 km² to 284.11 km². Meanwhile, the area of the secondary forest increased from 182.42 km² to 284.11 km² in 2020. Meanwhile, although the other LULC objects changed, the changes were not significant with changes in fewer than 10 km². In more detail, the area of LULC in 2000, and 2020, and their differences are shown in Table 3-1.

3.2 Sumatran Tigers Habitat Suitability

This research found the differences in habitat suitability maps in the years 2000 and 2020. In 20 years of data, this research found the decreasing of the highly suitable environment to suitable around 164.42 km^2. It influenced the increasing suitable class around 160.49 Km^2 from 2000 until 2020. For not suitable level was not significant changes, although it increased 3.93 Km^2. The result of habitat suitability of the Sumatran Tigers map is shown in Figures 3-2. The complete area calculation is also shown in Table 3-2.

3.3 Discussion

Based on the result of the study, it can be discussed that the environment of Kerinci Seblat National Park (KSNP) supports the life of Sumatran Tigers, although there is LULC change in those areas. It is shown by the large area of a highly suitable and suitable area in the study area of KSNP. Almost 50% of the study area supports the life of Sumatran Tigers.

Referring to the effect of LULC change on the potential loss of Sumatran Tigers, this research shows the significance of the potential loss of Sumatran Tigers. It proved by the decreasing of highly suitable to a suitable level of Sumatran Tigers' habitat. The increasing of plantation and settlement areas will increase the activity of humans. The conflict between human activity and with Sumatran Tigers' life will impact the loss of Sumatran Tigers in KSNP (Nyhus and Tilson, 2004).

This study shows that the use of remote sensing data has a very high potential to analyze the potential loss of biodiversity, such as the Sumatran tiger, through mapping the level of suitability of its habitat. The difference and medium level in the spatial resolution of the input data used in the research when making the mapping results is less detailed. The use of data with higher spatial resolution and automatic classification methods that are more adaptive to input parameters can be developed for future research.

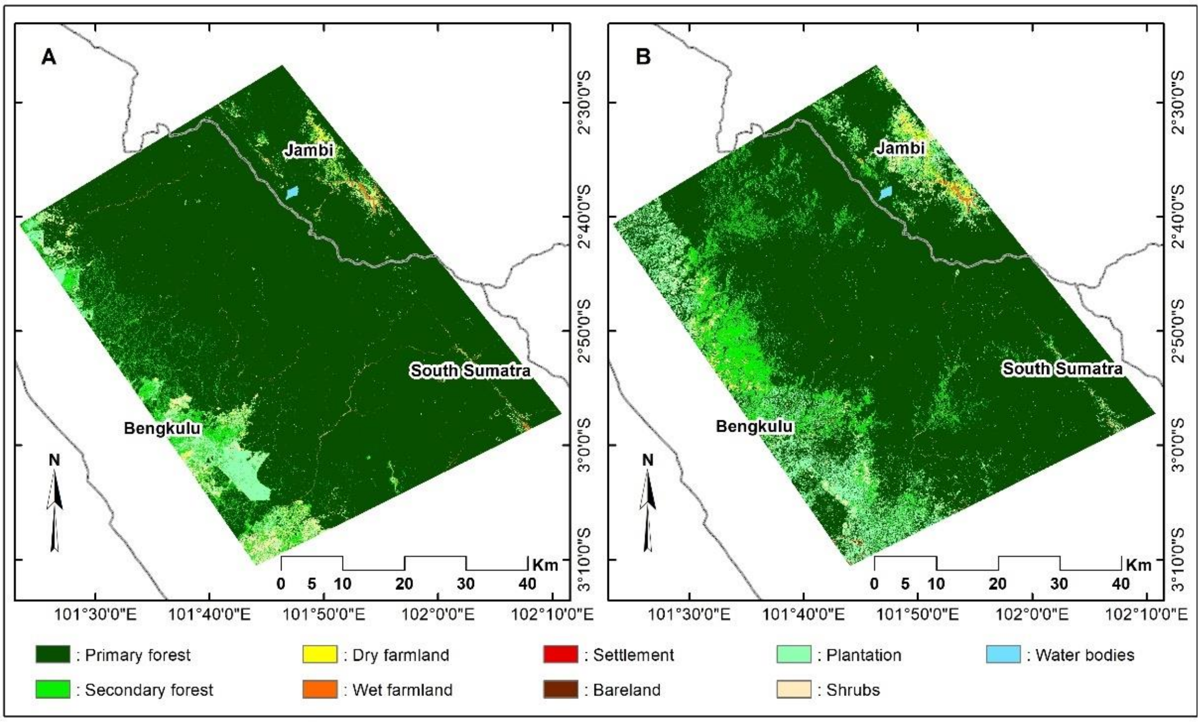

Figure 3-1. Land cover use in KSNP using the Random Forest algorithm. (a) 2000 land cover use; (b) land cover use in 2020.

Table 3-1. LULC in 2000, 2020, and its changes

LULC Classes	Area (km^2)		
	2000	2020	Gap
Primary forest	3.184,12	2.901,54	-282,58
Secondary forest	182,42	284,11	101,68
Dry farmland	22,79	27,88	5,09
Wet farmland	20,33	11,98	-8,36
Settlement	0,65	1,50	0,86
Bare land	1,28	1,59	0,31
Plantation	132,59	319,11	186,52
Shrubs	78,25	72,01	-6,24
Water bodies	4,80	7,52	2,72

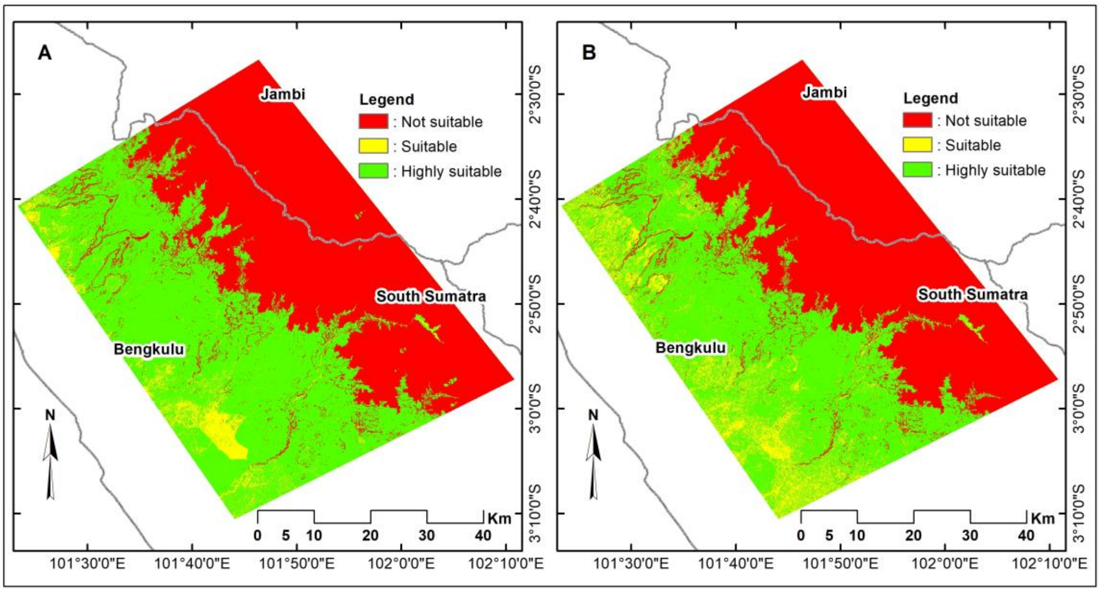

Figure 3-2. Habitat suitability map of Sumatran Tigers. (a) Habitat suitability 2000; (b) Habitat suitability 2020.

Table 3-2. The area calculation of every suitability class for Sumatran Tigers Habitat

Suitability Classes	Area (km^2)		
	2000	2020	Gap
Not suitable	1,782.57	1,786.51	3.93
Suitable	145.79	306.28	160.49
Highly suitable	1,698.86	1,534.43	- 164.42

4 CONCLUSIONS

This research concluded that remote sensing plays an important role in showing the land use/cover change and described the Sumatran Tigers' habitat suitability. However, the research has shown that the environmental condition of KSNP supports the life of Sumatran tigers. The decreasing suitability level shows that the potential loss of Sumatran tigers can happen. The increasing of plantation and settlement areas will increase the activity of humans. The conflict of human activity with Sumatran tigers' life will impact the loss of Sumatran Tigers in KSNP. The automatic habitat suitability classification method can be developed using machine learning or deep learning to get more appropriate mapping results.

ACKNOWLEDGEMENTS
This research was conducted using funds from the Program House for the Biological Research Organization, the National Research and Innovation Agency for the 2022 fiscal year, with the activity code RP1WBS4-010. The authors are grateful to BIG, NASA, USGS, LP DAAC, GES DISC, NASA JPL, and Creative Commons Attribution-Share Alike 4.0 International for providing free remote sensing data and data processing platform for this research.

CONFLICTS OF INTEREST:
The authors declare no conflict of interest.

CONTRIBUTORS:
All authors of this paper contributed equally as the main contributors

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