

Spatial Assessment of Sumatran Tiger-Human Conflict in South Tapanuli Regency, North Sumatera

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Abstract: According to the International Union for Conservation of Nature (IUCN) red list, the Sumatran tiger is classified as one of the critically endangered animals. The problems related to the conflicts between animals and humans very often occurred in the wildlife. The presence of the Sumatran tiger's natural habitat close to the active human area can trigger the increasing conflict vulnerability between both. The Natural Resources Conservation Agency (Balai Konservasi Sumberdaya Alam/BKSDA), has recorded at least 16 incidents of conflict between Sumatran tigers and humans in the South Tapanuli Regency, North Sumatera Province since 2018. By using geospatial modeling, this study aims to describe the potential conflict between Sumatran tigers and humans by using a random forest algorithm, natural algorithm, and deep learning to model the conflict potential also with a maximum entropy algorithm. The tools that were used to analyze this research are cloud computing mapping using Google Earth Engine (GEE), geospatial information system application (ArcGIS and QGIS), and also Maximum Entropy (Maxent). The results of this study indicate the influence of the distribution of each variable that has been used with the statistical model spread over the research area. The average value of AUC prediction in this model is at the number of 0.882 and with a standard deviation of 0.043. The biggest contribution variable is the fragmented habitat as much as 49.5%, followed by the contribution of the forest edge as much as 32.7%, and elevation as much as 6.5%. Angkola Timur sub-district is the area with the highest level of conflict vulnerability in 49.9% of its total area, followed by Hutaimbaru sub-district in 48.06%, and Angkola Barat sub-district in 44.99%.

Keywords: Conflict; conservation; Sumatran tiger; maximum entropy; wildlife.

Introduction

South Tapanuli is a regency located in the province of North Sumatera, crossed by the Bukit Barisan mountains so that the entire area can be seen with the view of hills lined up with each other. The area of South Tapanuli reaches 43,553,500 hectares with an altitude ranging from 0-1,985 meters above sea level. South Tapanuli still has an unquestionable diversity of biodiversity, including rare species, such as the Sumatran tiger.

The Sumatran tiger (*Panthera tigris sumatrae*) is one of the endemic animals on the island of Sumatra. Sumatran tigers live in fragmented habitats and are isolated from one another, this sub-species has the smallest average body size among the other tiger subspecies that exist today

(Kitchener, 1999). The male Sumatran tiger has an average length from head to tail of 240 cm and weighs 120 kg. While the female has an average length from head to tail of 220 cm and weighs 90 kg. The Sumatran tiger required the roaming area between 180 km² are usually located in the altitude range between 100-600 meters above sea level (masl.), 274 km² at an altitude range of 600-1700 masl, and 380 km² at an altitude above 1,700 masl (Soehartono et al, 2007) in lowland tropical forests up to the mountains.

The population of Sumatran tigers is currently very critical and is categorized as a protected species, The World Wide Fund for Nature (WWF) of Indonesia states that the current population of Sumatran tigers is only around less than 400 is left

in blocks of lowland forest, peatlands, and mountain rainforests, therefore the International Union for Conservation of Nature (IUCN) states that Sumatran tiger has reached the CR status (Critically Endangered) which means very threatened.

The reduction in tiger population is usually associated with the reduction of their habitat, which leads to an increase in the potential conflict with humans. This is one of the impacts of the increasing number of human populations which leads to the expansion of development to forest areas, both for plantations and settlements, causing conflict between the two. Conflicts between humans and wildlife generally occurred as the result of the number of negative interactions, either directly or indirectly, including in this case regarding the Sumatran tiger. The emergence of the Sumatran tiger conflict occurs due to the disconnection of habitat connectivity and forest fragmentation in tiger habitat, such as uncontrolled land expansion due to the pressure of land needs that can change land cover conditions as the human population increases (Rahman et al. 2019). Based on data and reports from The Natural Resources Conservation Agency (Balai Konservasi Sumberdaya Alam/BKSDA), on average, conflicts occurred not far from human activity areas, where they are not in their supposed natural habitat. These conflicts include sightings of tigers directly, tigers preying on livestock, finding traces of tigers, and even tiger attacks on humans.

Rapid technology developments in this era, especially in the use of Geographic Information Systems (GIS) and Remote Sensing make it easier to obtain, record, collect and analyze spatial data. Along with the advancement of GIS and Remote Sensing technology, the development of the use of spatial data to generate information from the cases continues to increase. To find out the potential distribution of conflict between the Sumatran tiger and humans, it is necessary to process spatial data because the existence of this conflict cannot be separated from the scope of space and geographical conditions of an area where the Sumatran tiger lives. The combination of remote sensing data and geographic information systems is widely used to identify areas prone to animal

conflict. In this case, the use of spatial technology is very helpful in analyzing and identifying animal conflicts, where this study uses spatial aspects such as the distance between habitat fragments, elevation, slopes, forest edges, rivers, plantations, settlements, and the coordinates of conflict events to obtain regional information with the vulnerability of conflict between Sumatran tigers and humans in the selected area of interest.

Materials and Methods

Study area

This research was conducted in South Tapanuli Regency, North Sumatra Province which is geographically located at $0^{\circ}58'35''$ - $2^{\circ}07'33''$ North Latitude and $98^{\circ}42'50''$ - $99^{\circ}34'16''$ East Longitude. The study area also includes the Padangsidimpuan city area which is located right in the middle of this regency.

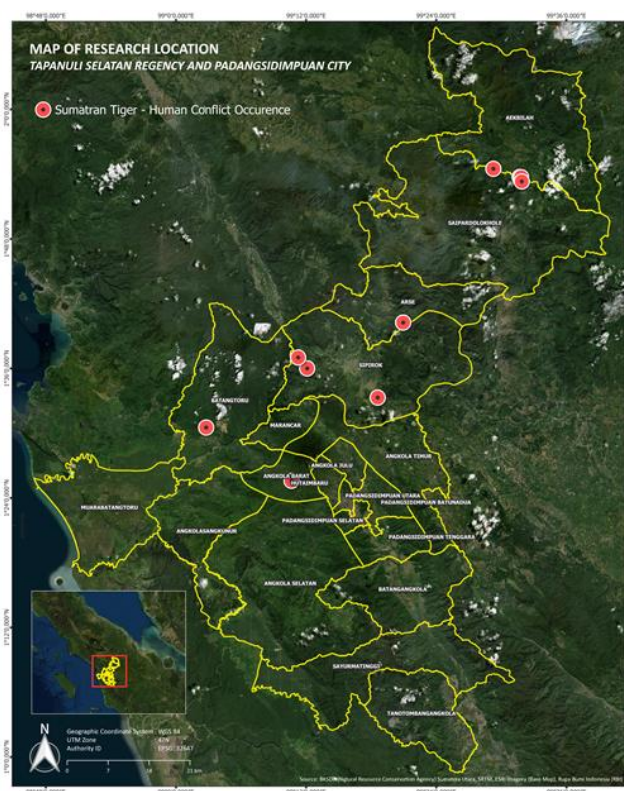


Figure 1. Map of Research Location.

Procedures

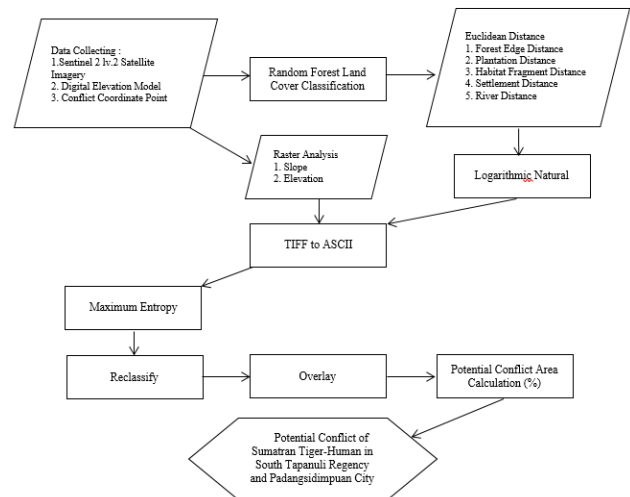
The data used in this research are categorized as secondary data. Secondary data is data obtained by researchers not directly from the subject or object under study but through other parties such as related agencies or institutions, libraries, archives, individuals, and so on. The data used in this study can be seen in table 1 below.

Table 1. The Data and Sources.

Data	Source	Type
Satellite Imagery (Sentinel 2 level 2)	European Space Agency	Ratio
Digital Elevation Model Information (DEM)	Indonesia Geospatial Portal	Ratio
River Line Vector	Indonesia Geospatial Portal	Ratio
Conflict Coordinates Land Cover	BKSDA Satellite image processing result by random forest algorithm – Google Earth Engine	- Ratio

The data processing flow is carried out sequentially starting with the collecting of all basic data consisting of Digital Elevation Model data, Sentinel 2 Level 2 satellite imagery data, and Sumatran Tiger Conflict Coordinate Point data collected from the Natural Resources Conservation Center of North Sumatra province.

The satellite image data obtained were then classified using the random forest algorithm so that the land cover data was found in the form of water bodies, rice fields and plantations, forests, swamps, shrubs, bare land, and settlements. From the land cover data, the variables used were determined, namely forest edge distance, plantation distance, habitat fragment distance, settlement distance, and river distance which were processed using Euclidean distance tools. All these environmental variables were then formatted from TIFF to ASCII to be processed with the maximum entropy algorithm so that data on potential conflicts between Sumatran tigers and humans was obtained. To be able to see the data processing procedure can be seen in Flow Chart 1.



Flow Chart 1. Sumatran tiger-human conflict analysis data processing

Data analysis

Random Forest Classification

Is an ensemble method, which is a way to increase the accuracy of classification by combining classification methods (Han, 2012). Random Forest is categorized as a supervised classification. Which creates classified areas with the number of samples taken. Random Forest is a classifier consisting of a structured collection of tree classifiers where each tree casts a voting unit for the most popular class in input x (Breiman, 2001). The formula can be seen as follows:

$$MSE = 1/N \sum_{i=1}^n (f_i - y_i)^2$$

Where N is the number of data points, f_i is the value returned by the model, and y_i is the actual value for data point i . After the process, then training samples will be tested using accuracy assessment with Confusion Matrix.

Euclidean Distance

Euclidean distance is a tool in geographic information system applications that are used to calculate the distance to the nearest source for each cell. Euclidean Distance is one of the distance calculation methods used to measure the distance from 2 (two) points in Euclidean space (covering two-dimensional, three-dimensional, or even more Euclidean planes).

The Euclidean Distance method is a method of classifying its closest neighbors by calculating the distance between 2 (two) objects, this method is

also called the Euclidean distance (Pablo Navarrete and Javier Ruizdel-Solar, 2003: 6-7).

Euclidean distance is formulated as follows:

$$d = \sqrt{(x1 - x2)^2 + (y1 - y2)^2}$$

Whereas:

d = euclidean distance in degrees

x1= latitude of starting location

x2= latitude of the destination

y1=longitude of starting location

y2= longitude of the destination

Within the scope of spatial analysis, euclidean distance is used to calculate or measure the distance of each environmental variable that will be used in maxent modeling (Hadjeres Nielsen, 2020). In our study, we use a slight difference in the standardization of the value of the Euclidean distance with the logarithmic natural (ln). This is because the consideration of the benchmark value of the center of the variable object in the Euclidean distance is getting further away from the object's nub, the value will be getting weaker (Hanif et al. 2020). So the variables that estimate the distance need to be considered in line with the natural effects around the ecosystem which are not so influential so that the results of the distance values of each variable are further refined by the logarithmic natural. So the equation formula used is as follows:

$$e^{d/n} = (Max e^d + 1) - e^d$$

$$e^d = \ln(l + d)$$

Whereas :

d = euclidean distance parameter

ln = logarithmic natural

e^d = the output of ed

Max e^d = maximum raster value of e^d

e^di = euclidean distance parameter transformation

Maximum Entropy

The maximum Entropy Method is a program used to estimate the probability distribution of encounters of a species determined by existing environmental variables (Philips et al., 2006). The MaxEnt distribution model only uses attendance data in its analysis, which is then sampled from the research area including environmental variables in it to estimate the probability value of the

distribution around it (Phillips et al., 2004). MaxEnt calculations provide an overview of habitat suitability as indicated by a vulnerable value between 0 to 1 (Phillips & Dudik, 2008). The output of this processing is called the AUC or the area under the curve where when it approaches the value 1, the model performance is getting better.

RESULTS AND DISCUSSION

The focus of this research is to look at the distribution of the potential conflicts between Sumatran tigers and humans by modeling their distribution mapping and interpreting them in an area of interest study using case studies of conflicts that have occurred over the last three years. It is important to ensure the selection of habitats to be studied for use and to optimize scale as in the modeling process, the probability of tiger occurrence is very close to the scale of the research conducted. (Eric Ash. et al 2020)

The role of Maxent in this research is to obtain various information about a tiger-human conflict potential in our region of interest. However, the process before running this algorithm is completely essential because input parameters must be chosen carefully, especially in choosing environmental variables. To decide the parameters used, we need to investigate what causes the conflict between the Sumatran tiger human human using the spatapproachsoach, such as tiger's food sources, water availability, topographic variations, and anthropogenic factors. Land use, as well as land cover, determines the quantity and quality of suitable habitat and specifically for the existence of the tiger themselves (Seidensticker et al, 1999). So, we chose spatial datasets related to topography and landcover. As environment variables mentioned before, variables extracted from land cover data (Patches, settlement, river, Plantation, and forest edge) were analyzed using the Euclidean Distance method and then to conditioning the result to natural effect by calculating the result with logarithmic natural (ln) function. Whereas topographic data for elevation was not modified and the slope was obtained from slope analysis using GIS software.

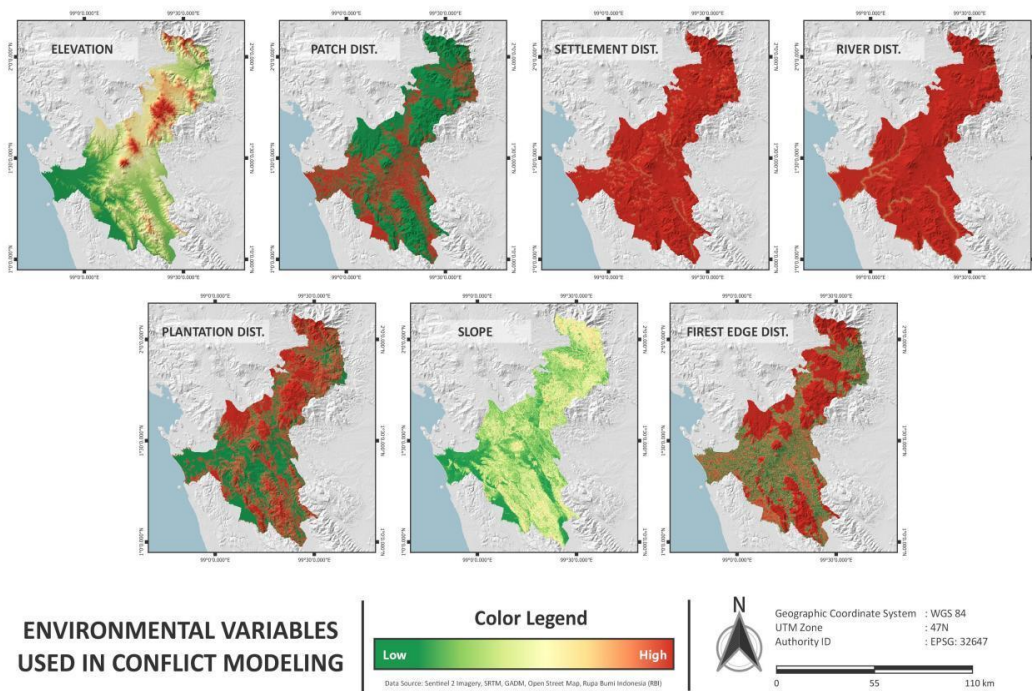


Figure 2. Map of Environmental Variables Used as The Input for Modeling The Sumatran Tiger-Human Conflict Potential.

Entire input variables were set as continuous data and no data reclassified. The consideration of this data set is to let the stretch of values in the result naturally change to a different value, so the transition of pixel value has detail change and visually to keep the model look gradients. but for the final result in the further analysis classified to count the percentage of conflict potential. Those variables are then put into parameters in Maxent to obtain the map of conflict potential between the Sumatran tiger and humans. Some important input parameters after environmental variables to set the number for the algorithm such as using 25% of a random seed, 25 replicates, using Bootstrap replicated run type, and 5000 maximum iteration. Those parameters are processed by Maxent as a machine learning tool in obtaining the result of our analysis.

The output of this analysis obtained pixel values within the range between 0 (no potential) and 1 (highly potential). The model shown in the figure below is the maximum count of the final spatial outputs. This map has a various and maximum stretch of pixel values ranging from 0,332 to 0,967. We divide the conflict potential into 3 classes: low, moderate, and high with the natural breaks method to get the potential zone proportion. We

found 134375,167 ha of conflict potential zone covered our region of interest, we revealed that the conflict potential which in the low potential by 52%, moderate potential by 19%, and high potential by 29%.

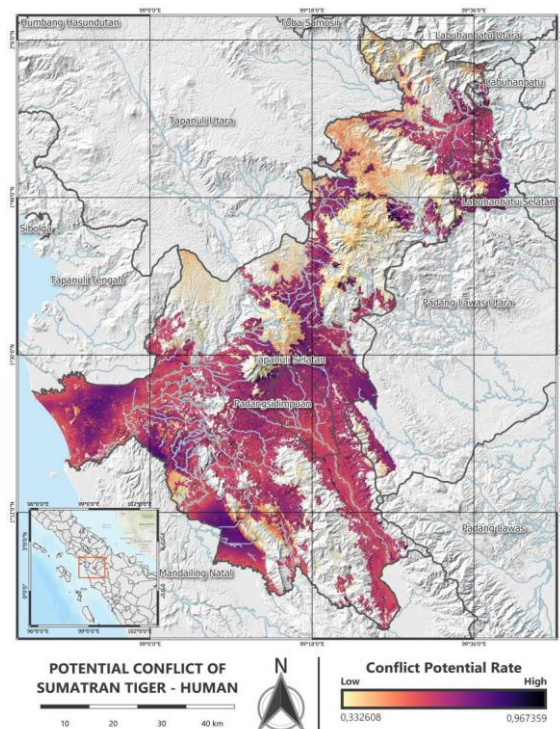


Figure 3. Map of Conflict Potential of Sumatran Tiger-Human in South Tapanuli Regency and Padangsidimpuan City.

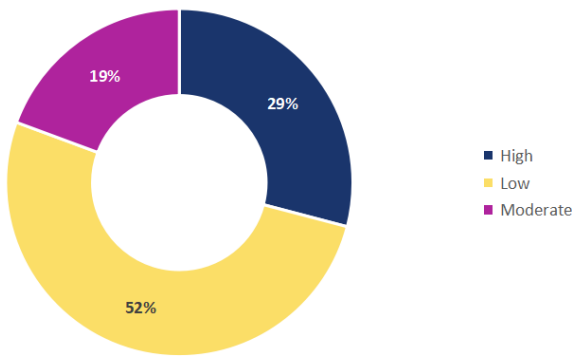


Figure 4. Chart of Conflict Potential Percentage in South Tapanuli Regency.

Overall, our research location was covered by conflict potential zone mostly located in low potential, but followed by the high potential in some locations. Our research location consists of some sub regency. So, to sharpen this analysis, we divide the conflict potential by overlaying with sub regency boundary for detailed information.

Table 2. Conflict Level in Every Sub-Regency.

Sub Regency	Conflict Potential Level (%)		
	High	Moderate	Low
Aekbilah	27.04016337	32.35776534	40.60207129
Angkola Barat	44.99398465	41.83096708	13.17504827
Angkola Julu	44.80615676	48.68049915	6.513344092
Angkola Selatan	37.53752234	49.03934565	13.42313201
Angkola Timur	49.90621649	27.82886372	22.2649198
Angkolasangkunur	30.6689122	53.72219502	15.60889278
Arse	19.59504362	19.17398833	61.23096805
Batangangkola	29.85610195	56.19362014	13.95027791
Batangtoru	12.94665657	5.561687881	31.43646462
Hutaimbaru	48.06073059	48.21889354	3.720375877
Marancar	30.87700089	44.96879463	24.15420447
Muarabatangtoru	40.9916579	54.74265778	4.265684315
Padangsidimpuan Batunadua	26.42215511	72.31433643	1.263508454
Padangsidimpuan Selatan	19.9741041	79.63409777	0.39179813
Padangsidimpuan Tenggara	25.16319966	72.67692573	2.159874617
Padangsidimpuan Utara	24.02317283	75.12021841	0.856608761
Saipardolokhole	25.85126411	19.48599564	54.66274025
Sayurmatangi	25.99930587	61.75751575	12.24317838
Sipirok	31.28568728	24.81483154	43.89948118
Tanotombangangkola	20.8367895	65.56700017	13.59621034

Source: Own Analysis

Angkola Barat, Aek Julu, and Aek Bilah are in alarming condition as the top 3 percentage of the tiger - human conflict in high potential, in successive percentage by 47,95%, 43,11%, and 40,77%. The high level which almost half of this area covered by high potential by 47,95%, but this area also covered by the high percentage of low potential by 46,4%. Batang Toru has the highest percentage in moderate potential level by 46,28%. The sub regency which is the most minimum of conflict potential is Padangsidimpuan Utara covered by 73,88% of low conflict potential.

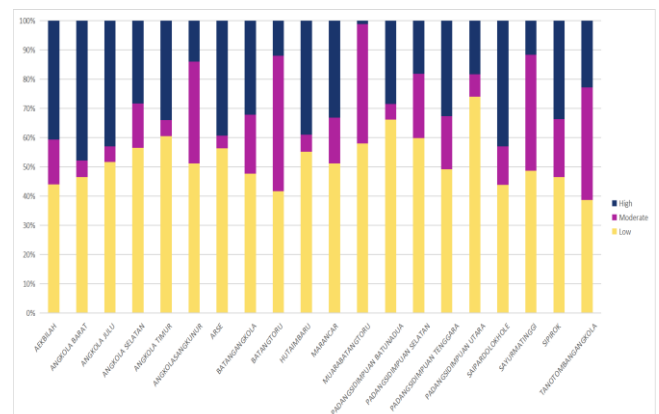


Figure 5. Chart of Percentage of Potential Conflict in Each Sub-District

Maxent processing results receiver operating characteristic (ROC) curve for the same data, averaged over the runs of replicate. According to the data we use in the analysis, the mean AUC in this analysis is 0,882 with a standard deviation is 0,043 which means the final result is satisfactory because the value approaches 1 and low standard deviation. If visualized with a curve, the better result has the larger area under the mean value

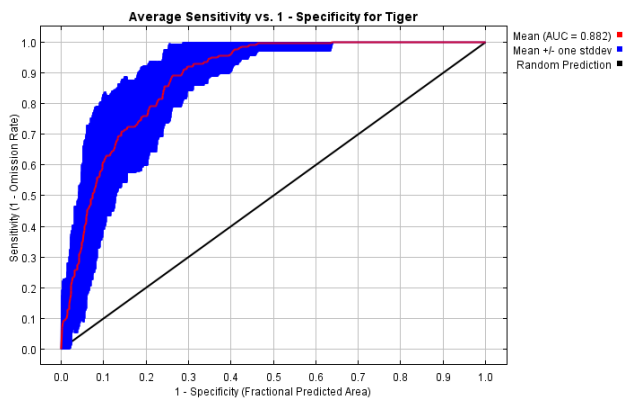


Figure 6. Area Under Curve (AUC) Output.

Maxent processing results receiver operating characteristic (ROC) curve for the same data, averaged over the runs of replicate. According to the data we use in the analysis, the mean AUC in this analysis is 0,882 with a standard deviation is 0,043 which means the final result is satisfactory because the value approaches 1 and low standard deviation. If visualized with a curve, the better result has the larger area under the mean value. Based on the AUC value, the best prediction of the distribution based on the assessment of the relative importance of each parameter is best made based on the ecological relevance of the species because the type of habitat is most likely to have significance for the ecology of the species (Matyukhina et al. 2014). The best predictor of the distribution of tiger conflict vulnerability is Habitat Patch, this is reasonable because tigers inhabit various types of habitats with different compositions of prey species.

Each variable has its influence on the result, the Maxent result revealed the variable contribution in percent as in this following table.

Table 3. The Variable Influence on The Model.

Variable	Percent Contribution
Habitat Patch	49,5
Forest Edge	32,7
Elevation	6,5
River	4,9
Plantation	3,1
Slope	1,7
Settlement	1,7

Source: Own Analysis

Habitat patch, forest edge, and elevation are the top contributors. Habitat patch which affects the model by 49,5% shows that the Sumatran tiger-human conflict potentially occurred in a certain distance of forest area or around patches of forest. Patch could be formed by human intervention such as deforestation and land clearing. habitat patch as the transition between tiger habitat and non-habitat, which could be the left of deforestation, human activity area, or herbs. Tiger conflict occurs because there is a negative interaction between the tiger and human in any specific geographical position such as forest edge which affects 32,7% of the model. When tigers migration over the forest edge to find new food resources or territory area, they tend to meet with an anthropogenic landscape which is highly potential to occur conflict.

The presence of tigers is also positively related to the abundance of prey, young tigers are more likely to cross the Forest Edge to look for livestock that is suitable for them as targets for weak prey and suitable as a medium for learning to hunt. Moreover, elevation is also the third too contributor but not significant, this variable contribution reveals some conflicts potentially occurred in a similar level of elevation because our research location is dominated by hilly topography. Elevation can also be associated with the presence of several other parameters that can affect the distribution of tigers as predators in nature. Assessment of elevation parameters is very relative because elevation usually affects the type of habitat for tigers. The following curves show the variables that interact with the replicated Maxent model.

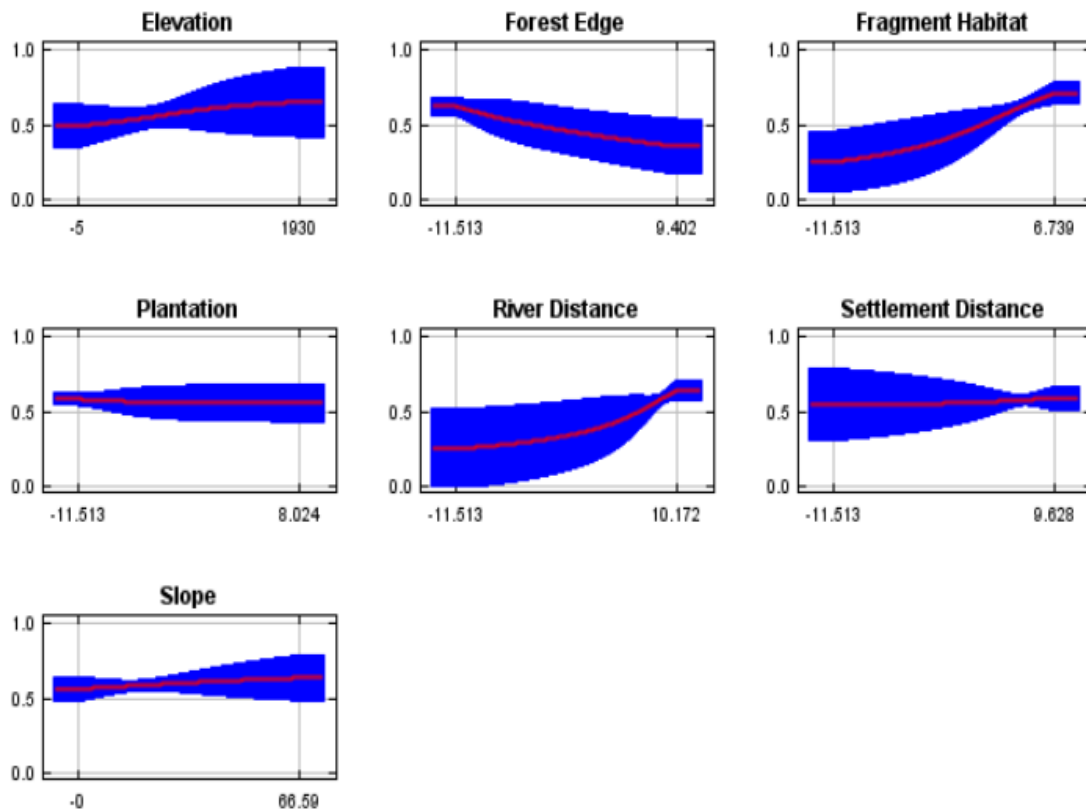


Figure 7. The Curve of Interaction Between The Model and Variables

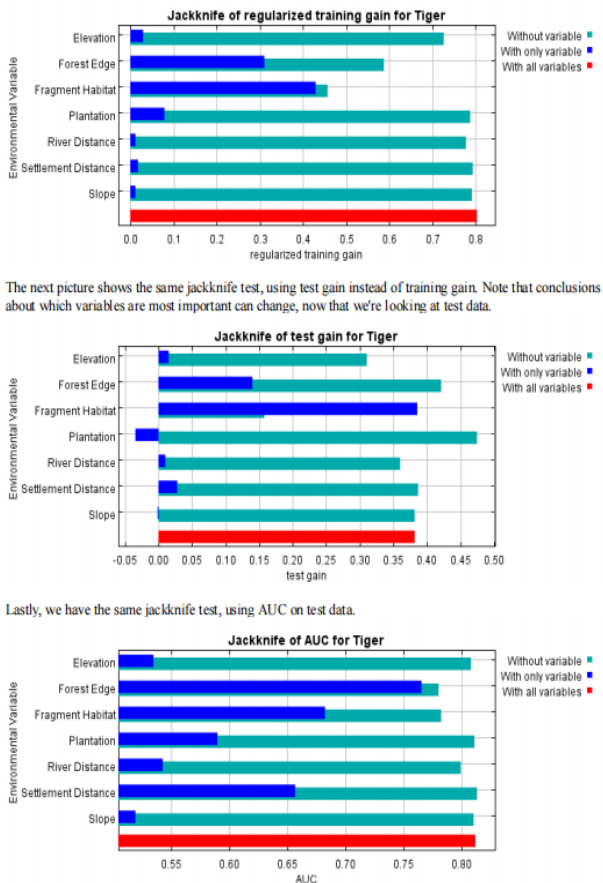


Figure 8. Jackknife Test Result.

To validate the variable contribution of each variable to the model, the data processing produced the Jackknife test. This is useful to reveal the most important information by the presence of a particular variable.

The high gain of environmental variable used in isolation is the fragmented habitat (patch), which appears to have the most useful information by itself. The variable which decreases the grain for the most if this is omitted is habitat fragment (patch), which hence appears to have the most information that does not exist in other variables.

Conclusions

The problems related to the conflicts between animals and humans often occur in the wildlife. The presence of the Sumatran tiger's natural habitat close to the active human area can trigger the increasing conflict between both. The Natural Resources Conservation Agency (BKSDA) has recorded at least 16 incidents of conflict between Sumatran tigers and humans in South Tapanuli

Regency, North Sumatra Province since 2018. By using geospatial modeling, this study aims to describe the potential conflicts between Sumatran tigers and humans by using a random forest algorithm and deep learning to model the conflict potential with the Maxent algorithm. The average value of the AUC prediction in this model is several 0.882. The biggest contribution variable is the fragmented habitat as much as 49.5%, followed by the contribution of the forest edge as much as 32.7%, and elevation as much as 6.5%. Angkola Timur sub-district is the area with the highest level of conflict vulnerability in 49.9% of its total area, followed by Hutaimbaru sub-district in 48.06%, and Angkola Barat sub-district in 44.99%.

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References

- Dutta, T., Sharma, S., McRae, B. H., Roy, P. S., & DeFries, R. 2016. Connecting the dots: mapping habitat connectivity for tigers in central India. *Regional Environmental Change*, 16(1), 53-67.
- Dwi Cahya, Suryani. Analisis Sosial Konflik Manusia Dengan Harimau Sumatera (*Panthera tigris sumatrae*) di Kecamatan Bahorok, Kabupaten Langkat, Sumatera Utara. Skripsi. Medan. Universitas Sumatera Utara
- Ellen, A., Nasihin, L., & Supartono, T. 2019. Pemetaan Kesesuaian Habitat *Rafflesia* (*Rafflesia arnoldii* R. Br) di Taman Nasional Bukit Barisan Selatan. *Konservasi untuk Kesejahteraan Masyarakat* I, 174-183.
- "Ganesa, Ari. 2012. Perilaku Harian Harimau Sumatera *Panthera tigris sumatrae* dalam Konservasi Ex-Situ Kebun Binatang Surabaya. *Jurnal Sains Dan Seni*. Its. Vol 1 No 1. Fmipa. Institut Teknologi Sepuluh November. Surabaya. "
- Hanif, M., Rahman, H., Hidayat, R. A., & Wibisono, H. T. 2020. Spatial Assessment of Potential Conflict of Sun Bear-Human Based on Landscape Ecology in Pasaman.
- Haristu, R. A. 2019. Penerapan Metode Random Forest untuk Prediksi *Win Ratio* Pemain Player Unknown Battleground. Yogyakarta: Repository Universitas Sanata Dharma.
- Hadjeres Gaetan and Nielsen Frank. 2020. Schoenberg- Rao distances: Entropy-based and geometry-aware statistical Hilbert distances. arXiv:2002.08345v1 [cs.LG] 19 Feb. DOI: 10.13140/RG.2.2.27923.63527.
- Matyukhina, D. S., Miquelle, D. G., Murzin, A. A., Pikunov, D. G., Fomenko, P. V., Aramilev, V. V., ... & Marino, J. (2014). Assessing the influence of environmental parameters on Amur Tiger distribution in the Russian Far East Using a MaxEnt modeling approach. *Achievements in the Life Sciences*, 8(2), 95-100.
- Nishom, M. 2019. Perbandingan Akurasi Euclidean Distance, Minkowski Distance, dan Manhattan Distance pada Algoritma K-Means Clustering berbasis Chi-Square. *Jurnal Informatika: Jurnal Pengembangan IT (JPIT)*, Vol.04, No.01, 20-24.
- Putri, A., Kusriani, M. D., & Prasetyo, L. B. 2019. Pemodelan Kesesuaian Habitat Katak Serasah (*Leptobrachium Hasseltii* Tschudi 1838) dengan Sistem Informasi Geografis di Pulau Jawa. *Journal of Natural Resources and Environmental Management*, 12-24.
- Rahman, H., Nizam, K., & Putra, B. G. Identifikasi Dinamika Tutupan Lahan Dan Zonasi Rawan Konflik Harimau Sumatera *Panthera tigris sumatrae* di Kawasan Regional Pesisir Selatan. *PROSIDING*, 47.
- Samuel, E. A. D. W. M., Noochdumrong, A. C. A., & Kaszta, T. R. Z. 2021. Optimization of spatial scale, but not functional shape, affects the performance of habitat suitability models: a case study of tigers (*Panthera tigris*) in Thailand. *Landscape Ecol*, 36, 455-474.
- Sinamo, L. K., Pemetaan Daerah Rawan Konflik Manusia – Harimau Sumatera (*Panthera tigris sumatrae*) di Sekitar Wilayah KPH VI Kabupaten Aceh Selatan Provinsi Aceh. [Thesis]. Universitas Sumatera Utara, Medan [Indonesia].
- Soehartono. 2007. Strategi Dan Rencana Aksi Konservasi Harimau Sumatera Tahun 2007-2017. Departemen Kehutanan. Bogor.
- Wulanningrum, R., & Rachmad, A. 2012. Pengenalan Rumput Laut Menggunakan Euclidean Distance Berbasis Ekstraksi Fitur. *Seminar Nasional Aplikasi Teknologi Informasi 2012 (SNATI 2012)*.