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Habitat Suitability Model to Determine a Suitable Area for Translocation of Sumatran Tiger (*Panthera tigris sumatrae* Pocock, 1929)

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ABSTRACT

Translocation has been used in human-tiger conflict mitigation for more than 5 decades, but the records show the success rate still relatively low. A comprehensive study is needed to determine the ideal and suitable area for tiger translocation within one landscape. Beside the physical characteristic habitat (such as the adequacy of forested areas, topography, as well as availability of ecotone and clean water), potential threats and the history of human-tiger conflict factors, it is very important to consider the factors of wild local tigers presence and their prey in the areas for the future translocation, so that the activities of tiger translocation can be more effective and the success rate will also be increased. In this study we developed a habitat suitability model of translocated tiger, and determined the areas that suitable for the location of tiger translocation in Ulu Masen Landscape. In 2008 we captured an adult female conflict tiger and translocated her 70 km from capture sites in Northern Sumatra. The tiger was fitted with global positioning system (GPS) collars. The collars were set to fix 48 location coordinates per day, and collected 6,680 points of tiger positions during 213 days of observation. Based on the habitat suitability model, 95% of the Ulu Masen forest landscape (approximately 7,500 km2) has the criteria of suitable and most suitable as habitat of Sumatran tigers (*Panthera tigris sumatrae* Pocock, 1929). Suitable location for Sumatran tigers translocation is a landscape where there is a mosaic of lowland forest with schrubs vegetation, has a flat to sloping topography, and elevation below 1,000 meters above sea level. The area should also be free from poaching and encroachment, as well as far away from villages. Predicted that there is a 388.10 km2 (5.2% of the total area) of area that most suitable, and a 2,135.67 km2 (28.5%) area that suitable for the location of Sumatran tiger translocation. Despite being preliminary the finding of this study highlight the conservation value of tiger translocation and have provide valuable information for improving future management of conflict tigers.

Key words: GPS collars, habitat suitability model, spatial model, Sumatran tiger, translocation, Ulu Masen Landscape, Aceh, Indonesia

INTRODUCTION

The International Union for Conservation of Nature (IUCN) defines translocation as a deliberate movement of an individual or wild population from its home range to form a new home range in a new teritory. Translocation in wildlife conservation means capturing and transporting wildlife from one location, and releasing it back in another location (Griffith *et al.,* 1989).

In the last decades, translocation has been used as a method in human-wildlife conflict, such as brown bears (*Ursus arctos*) and black bears (*U. americama*) (Armistead *et al.,* 1994; Blanchard & Knight,1995), wolves (Fritts *et al.,* 1984; Bangs *et al.,* 1999), and large cats (Rabinowitz, 1986; Stander, 1990; Ruth *et al.,* 1998) including tigers (Seidensticker *et al.,* 1976, Nowell & Jackson, 1996, Goodrich & Miquelle 2005, Priatna *et al.,* 2012a).

Griffith *et al.,* (1989) and Wolf *et al.* (1997) stated that translocation in large carnivores is a conflict mitigation tool that can reduce the risk of death for animals that involved in conflict, and as additional individual of wildlife in rebuilding their wild populations.

However, in the case of wildlife conflict mitigation, translocation is usually considered as the last choice like euthanasia (Treves & Karanth, 2003). Nevertheless, translocation for conflict mitigation purposes will continuosly be used, because according to the perception of communities translocation is a non-lethal method of conflict mitigation so that it becomes popular tool of conflict management (Craven *et al.,* 1998), especially for the rare or endangered species (Linnell *et al.,* 1997).

According to Linnell *et al.* (1997), in general carnivores that are translocated as a result of conflict, has a tendency to repeat the livestocks depredation in their new location. Besides, the mortality rate of translocated individual was also high (Craven *et al.,* 1998). At least 11 individuals of conflict tigers were captured, rehabilitated and translocated in Sumatra in the period 2003-2010 (Priatna 2012), six of them were translocated and fitted with GPS collars (Global Positioning System Collars) to monitor their post-release activities (Priatna *et al.,* 2012a, Priatna *et al.,* 2012b). GPS Collars getting popular to be used in studies of habitat selection and wildlife movements (Edwards *et al.,* 2001; Coelho *et al.,* 2008), because

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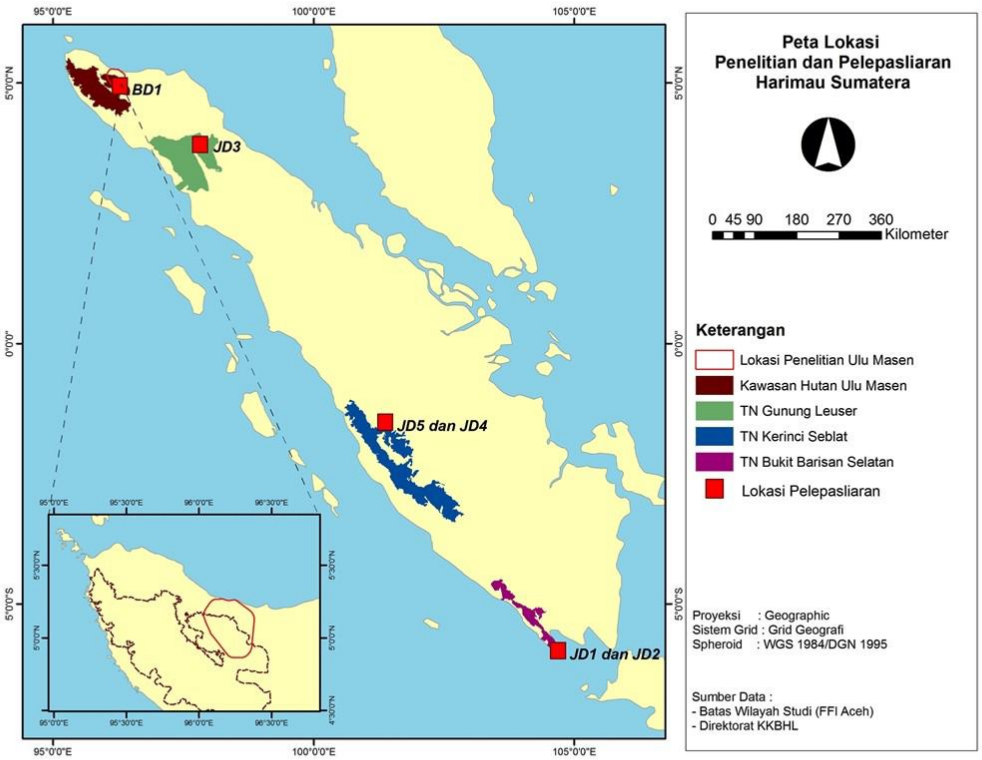

Figure 1. Map of study site in Ulu Masen Landscape, Northern Sumatra, Indonesia.

the device can provide the information of wildlife location precisely under various conditios (Hebblewhite *et al.,* 2007).

Suitable habitat is a place that able to provide conditions needed by the animals for their survival and breeding in a long period. Therefore, habitat suitability model can be defined as a model that can show the ability of a habitat to support the survival of wildlife (Nursal 2007).

The objective of a model is as a guideline in management decision making (Shenk & Franklin 2001 in: Nursal 2007). Habitat suitability model can be used for determining conservation priority (Margules & Austin 1994 in: Guisan & Zimmermann 2000), as well as can generate a biological knowledge for explaining the distribution of a species and evaluating the land activity.

Box (1976 in: ver Hoef *et al.,* 2001) stated that all ecological model which was developed will always not precise as all models contain errors. Constanza & Sklar (1985 in: Sklar & Hunsaker 2001) explained that getting complex of a model then will be getting bigger the observation and simulation data needed. As the result, the model will be getting less accurate or getting uncertainty.

Taking the lesson from experiences of tiger translocations that have been conducted, that mostly the successful rate still relatively low (Seidensticker *et al.,* 1976; Nowell & Jackson, 1996; Goodrich & Miquelle, 2005), including in Sumatran tigers (Priatna *et al.,* 2012a; Priatna *et al.,* 2012b), then the study regarding spatial model of habitat suitability as well as the study for determining the ideal location for translocation is getting important to be done, so that the consideration in selecting the location for tiger traslocation in the future is getting better.

MATERIALS AND METHODS

Study Site

The study was conducted within two phases in between 2008 and 2010. First, obtaining position data coordinates of GPS collars that fitted to a translocated female tiger, which was released in a forest area of Ulu Masen Landscape, Aceh, Nothern Sumatra, Indonesia, conducted from December 2008 to July 2009. Second, field observation to ghather some supporting data that needed in constructing a model of tiger suitability habitat, done from November 2009 to June 2010 within the home range of this translocated tiger (Figure 1).

GPS Collar Data

After having an 18 days of recovery period, an adult female conflict tiger (prey on livestocks in villages) was translocated to a forest area in Ulu Masen Landscape, Aceh, at about 70 km from the area where she was captured. A GPS collar (Televilt, Lindesberg, Sweden) fitted the female tiger before she released back to the wild. Tiger positions data of the released tiger were transmitted periodically everyday through the sattelite to a server, then directly sent to predetermined email address.

Transect Survey

A transect survey was conducted to determine relative abundance of local wild tigers and their main preys (wild pig, muntjac deer, and sambar deer). Every direct sightings and indirect encounters such as footprints, scratchs, dung piles, and other identified signs along surveyed transects were recorded (Dinata & Sugardjito 2008). All signs of tigers and their main preys found within 1 km segment counted as one finding (Wibisono *et al.,* 2011).

Table 1. Ecological components that used for prediction variables of translocated Sumatran tiger's habitat suitability.

Variables	Symbol	Unit	Representation	Source
Elevation	X_1	Meter asl	Physical component, affects movement and exploration	Aster map GDEM
Slope	X_2	(%)	Physical component, affects movement and exploration	Aster map GDEM
Distance from river	X_3	Meter	Physical component, affects the in fulfillment of water and foraging needs	RBI map (river sistem)
Distance from settlements	X_4	Meter	Physical component, affects the pattern of habitat space use	RBI map (location of villages)
Distance from road	X_5	Meter	Physical component, affects the pattern of habitat space use	RBI map (road network)
Distance from forest edge	X_6	Meter	Physical component, affects the search of prey	Map of forest and non-forest cover
NDVI	X_7	-	Biotic component, affects the need of shelter or cover	Landsat 5-TM image

A set of transect survey data used in this study, which collected between August 2008 and June 2009, were obtained from FFI Indonesia (Aceh Programme).

Data Analysis

Determination of presence and pseudo-absence

Determination of presence and pseudo-absence points of tiger locations were used to construct a translocated tiger's habitat suitability model. Habitat modeling conducted based on locations data received from the GPS collar. 6,680 positions data collected was filtered so that ghathered a 6,116 of high accuracy of positions data. 50% of these data was used for determining presence area, and another 50% was used for validating the model. Pseudo-absence points determined with randomizing the points of positions data, employing Hawthstool extension in ArcGIS 9.3, in the outside of translocated tiger's home range polygon as large as the size of translocated tiger's home range.

Components of Sumatran tiger's habitat

In the spatial model of suitability habitat, choosing ecological variables is extremely depend on availability of spatial data. All observed variables in this study is presented at Table 1.

Relative abundance of local tigers and their preys

Data of wild local tigers and their preys collected through transect surveys were calculated with Encounter Rate (ER) approach (Lancia *et al.,* 1994, Dinata & Sugardjito 2008) as follows:

$$ER = N/km$$

Where:
N= number of encounter with footprints or signs
Km= length of transect in kilometers

Analysis of habitat modeling

Multi-collinearity test

A method to detect any multi-collinearity is with checking of VIF (Variance Inflation Factor) and Tolerance values in the regression model (Pratisto, 2010). If one of free variable has a Tolerance value >0.1 or VIF value <10, mean that this variable is not occurring a multi-collinearity. VIF value >10 means that occur a multi-collinearity. In this study, all free variables were tested using multiple linear regression to obtain their VIF value and eliminated every variable that occur a multi-collinearity.

Analysis of logistic regression

The form of logistic regression that used to analyze habitat suitability of tiger translocation is a binary logistic regression.

All statistical analysis conducted through Enter method of SPSS 17. This method was used as it is not consider the size of the effect of the independent variable on the dependent variable. Model of parameter predicted using the rule of "maximum likelyhood method" (Pratisto 2010):

$$Z = a + b_1X_1 + b_2X_2 + b_3X_3 + ... + B_nX_n$$
$$\text{and} \quad P = 1/(1+e^{-z})$$

Where: Z= model of logistic regression; P= chance of tiger presence;
X= free variable (covariates); a= contant; e= (2.7182818)

Level of habitat suitability is determined based on three categories: "less suitable", "suitable" and "most suitable". Treshold of each category refered to Supranto (2000):

$$\text{Interval distance} = \frac{P_{max} - P_{min}}{\text{N of category}}$$

Spatial model of habitat suitability

Spatial model was constructed from the value of chance that resulted from the calculation of logistic regression. Map of habitat suitability produced using ArcGIS 9.3. ArcGIS combined all available information (environmental variables that have a real impact) into a map of suitability with function of logistic regression. Raster calculator was used to obtain a suitability value of translocation location. The value was then classified through the process of reclassify in ArcGIS 9.3. Map of suitability that interpreted was the map with 30 meter resolution.

Feasibility test of logistic regression model

Hosmer-Lemeshow test was used to test the model feasibility (Hosmer & Lemeshow 2000). In this research, feasibility of developed logistic regression model can be seen from the impairment of -2 *log likelihood* as well as Hosmer-Lemeshow test that generated from data analysis using SPSS 17. The model is feasible if significance of impairment of -2 log likelihood less than 0.05.

Hosmer-Lemeshow test is used to see the fitness of predictor variables with developed model. Predictor variables is fit with the model if significance of Hosmer-Lemeshow test >0.05. Coefficient of determination (R^2) is determined by the model of Nagelkerke R^2 that analog with R^2 within least square method for the function of multiple linear regression (Piorecky & Prescott 2006). Nagelkerke R^2 shows how important the independent variable predicts dependent variable.

Validation of the model

Validation of the model of tiger habitat suitability's logistic regression is done at the same location with the location of data collection of tiger's position that used for model development. Technically, validation of the model conducted using 50% of tiger's position data collected through GPS collar. The validation was done to minimizing the error in future utilization of the model. The value of model validation is showed by Kappa index of selected model.

Then, the validation of the model was conducted to the result of spatially model extrapolation in the study area. The level of model validation was seen from percent of presence point data that overlapped with suitable area for tiger habitat.

$$\text{VALIDATION (V)} = n/N \times 100\%$$

Where:

n = number of coordinate points of translocated tiger within one of suitability classification

N = total number of coordinate points of translocated tiger that collected by GPS collar (50%)

V = percent of confidence

Extrapolation of model

Extrapolation of the model was conducted within all area of Ulu Masen Landscape to give the picture about parts of landscape that suits for tiger habitat. The process of extrapolation was done by entering the equation of formed logistic regression model through raster calculator in ArcGIS 9.3. The percent of the size of area was predicted for each classification (less suitable, suitable, and most suitable).

Analysis of translocation location suitability

Some steps should be done to determine a suitability map of tiger translocation location. First, mapping the value of relative abundance of wild local tigers and their preys intersect method in ArcGIS 9.3. Then, those relative abundance values were categorized into "low suitability", "intermediate suitability" and "high suitability". Interval of category determined based on the lowest and the highest of relative abundance values. The higher of local tiger's relative abundance value in an area, means that the lower suitability for tiger translocation. But, the higher of prey species relative abundance value in an area, means that the higher suitability for tiger translocation. To predict suitable areas for future tiger translocation activity in Ulu Mase Landscape, then overlay and intersect conducted between map of translocation location suitability produced based on relative abundance of local tigers and their prey with the map of tiger habitat suitability that resulted from extrapolation within the landscape.

RESULTS AND DISCUSSION

Habitat Suitability Model

Determination of presence and pseudo-absence points

Total number of 6,880 coordinate position points collected (presence points) from GPS collar that fitted to a female translocated tiger. But, only 6,116 poits considered as the points that have high accuracy. 50% of presence position points (3,058 points) were used to develop a model, and another 50% used for validation of the model (Figure 2).

The development of binary logistic regression model requires position points of tiger presence (presence = 1) and the location points of predicted tiger absence (pseudo-absence = 0). Determination of pseudo -absence points for the development or validation of models was conducted randomly through a 30m x 30m grids, in the outside of the border of Ulu Masen Landscape polygon, and in the outside of translocated tiger's buffered home range poygon. Putri (2010) explained that giving a buffer to the forest boundaries in determining pseudo-absence points conducted to avoid of including areas outside the forest which also still used by tigers.

Multicollinearity Test

In regression analysis, values of Variance Inflation Factor (VIF) from tested independent variables is one of method to see the presence or absence of multicollenearity (Table 2).

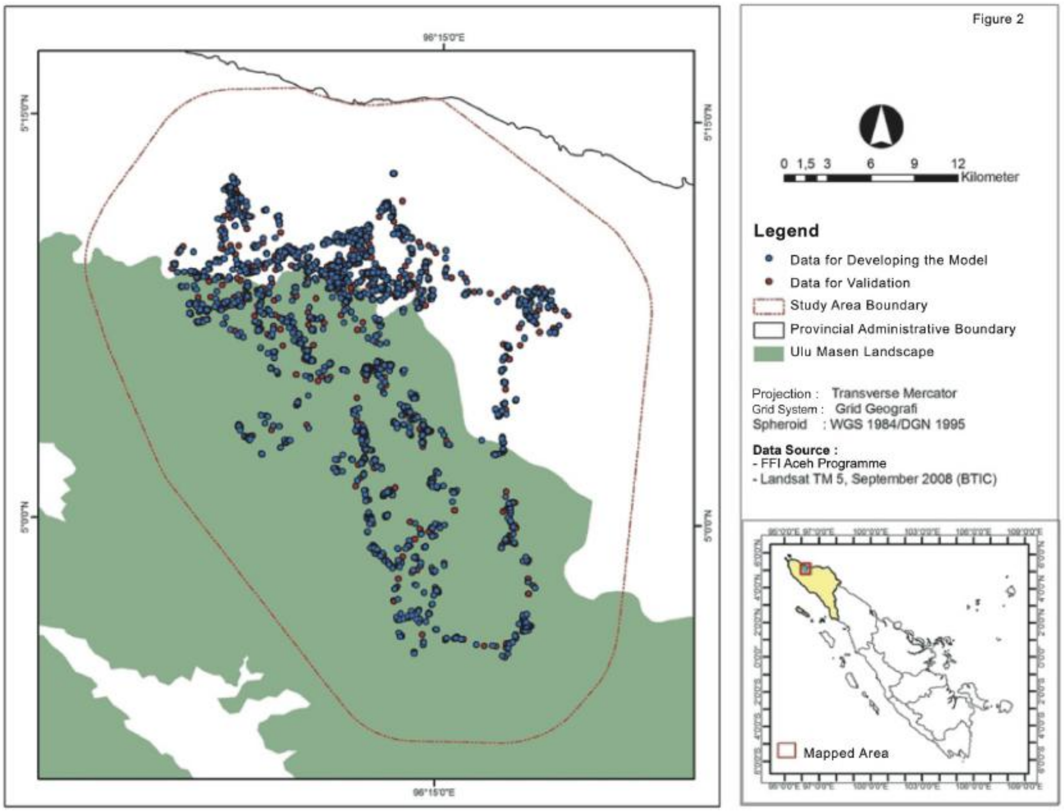

Figure 2. Map of presence points distribution of translocated tiger that used for development and validation of the models.

The result of test shows that there are two independent variables which have tolerance value <0.1 and VIF value >10 i.e. "distance to road" (TOL=0.052; VIF=19.064) as well as "distance to village" (TOL=0.042; VIF=23.807). This give us a figure that there is a multicollenearity between those independent variables and the other independent variables. The problem of multicollenearity (connectedness) among independent variables must be addressed before data analysis can be proceeded.

Table 2. Result of multicollenearity test of independent variables using VIF.

Model	Collinearity Statistics	
	Tolerance (TOL)	VIF
1 (Constant)		
Elevation	0.116	8.587
Distance from road	0.052	19.064
Distance from settlement	0.042	23.807
Distance from river	0.903	1.107
Distance from forest edge	0.701	1.426
NDVI	0.886	1.129
Slope	0.713	1.402

Multicollenearity can be addressed trough various ways such as using assumption information, principle component analysis, factor analysis, data addition, and elimination procedure of independent variables elimination that have double collinear. In this study we employed elimination procedure (Ambagau 2010). Based on this procedure, there were two independent variables that must be taken out i.e. "distance to road" and "distance to village". Thus, only five independent variables that can further be analysed to obtain a habitat suitability model of translocated tiger based on the equation of logistic regression. Those independent variables are elevation, distance to river, distance to forest edge, NDVI and slope.

Analysis of logistic regression

Independent variables that used to develop logistic regression model were five independent variables that have no double collenearity based on the values of tolerace and VIF, i.e. are elevation, distance to river, distance to forest edge, NDVI and slope. Result of binary logistic regression analysis of Enter method in SPSS 17 with confidence level 95% is presented on Table 3.

In Table 3 showed that all those five analyzed independent variables have statistically significant level (Sig <0.05). Based on the calculation can be seen the values as follows:

Constant = -1.149
Constant of elevation variable (elv) = -1.563
Constant of distance to river variable (jsg) = -0.205
Constant of distance to forest edge (jth) = -1.021
Constant of NDVI variable (ndvi)= 3.724

Table 3. Result of binary logistic regression analysis is using Enter method to all independent variables.

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1(a)	Elevation	-1.563	0.064	595.028	1	0.000	.210
	River	-.205	0.010	435.361	1	0.000	.815
	Edge	-1.021	0.178	32.947	1	0.000	.360
	NDVI	3.724	0.277	181.124	1	0.000	41.437
	Slope	.062	0.004	285.582	1	0.000	1.064
	Constant	-1.149	0.171	45.010	1	0.000	.317

Constant of slope variable (slp) = 0.062

The equation of logistic regression for habitat suitability of translocated tiger is as follows:

$$Z = -1.149 - (1.563*elv)-(0.205*riv)-(1.021*jth)+(3.724*ndv)+(0.062*slp)$$

Then, presence of translocated tiger within study area can be predicted through the following equation:

$$P = \frac{1}{1 + e^{(-1.149 - (1.563*elv)-(0.205*riv)-(1.021*edg)+(3.724*ndv)+(0.062*slp))}}$$

Where: P= probability; e is natural number = 2.7182818

In general, result of analysis which presented in Table 3 shows that variables of elevation, distance from river and distance from edge have given a negative influence to the developed regression model. The higher a place from sea level, farther from a river, and farther a place from the edge of the forest, so it is more unsuitable for tiger habitat. Meanwhile, NDVI and slope variables have given a positive influence to the model. More dense a vegetation (more forested) and the steeper a location is, so the more suitable a location for tiger habitat. Through the value of its regression coefficient, can be determined that NDVI is the most influential environment variable on the model. Meanwhile, slope is the variable that gives smallest influence on the model.

Study area in Blangraweu forest, Ulu Masen, is a combination of lowland, hilly and mountainous areas with elevation between 0 and 2,771 meters above sea level (asl) (Appendix 1). From Table 3 can be seen that the regression coefficient value of elevation is -1.563. This means that the higher a location, the less likely it is to have a tiger presence. A modeling conducted by Wibisono *et al.,* (2011) shows that Sumatran tigers are generally found in lowland areas. Elevation is one of the environmental factors that influence the distribution and form of plants that live in mountainous areas (Jin *et al.,* 2008). The difference in altitude causes climate variations that affect the diversity of plant species. Lowland forest areas have higher plant diversity compared to upland areas. The diversity of plant species in an area affects the diversity of animal species that live in it. The main tiger prey species are herbivores that need plants as a food sources. Putri (2010) stated that altitude was not a limiting factor for Sumatran tigers to choose their habitat, but Santiapillai & Ramono (1993) explained that Sumatran tigers tend to prefer lowland forest as their habitat because this forest can support the biomass of large ungulates, such as wild pig (*Sus scrofa*), sambar deer (*Rusa unicolor*), and barking deer (*Muntiacus muntjak*), all of which are the main prey species of Sumatran tiger (Dinata & Sugardjito 2008). Griffiths (1994) stated that the diversity and abundance of tiger prey species in the forest with altitude of 100-600 meters asl is more compared to the forest with altitude of 900-1,700 meters asl.

Wild animals is utilizing water for drinking and wallowing (Alikodra 1990). The availability of water sources is also one of the basic needs for tiger survival (Sunquist & Sunquist 1989). *Euclidean distance* analysis shows that the distance of transloced tiger presence from the river varies between 0 - 16,364 meters. Regression coefficient value of distance from river is -0.205 (Tabel 3), this means that the further a place is from the river, the less suitable it is for tiger habitat. This is similar with the finding of Imam *et al.,* (2009) dan Putri (2010) which states that the closer an area is to a water source, the more suitable it is for tiger habitat.

Dinata & Sugardjito (2008) also stated the same thing that there is a strong correlation between the suitability of Sumatran tiger habitat with the distance to the river. According to them, Sumatran tigers in Kerinci Seblat National Park like the areas near the river streams. The area near the river is the area most used by wildlife, including ungulates, which are the main prey of tigers, because besides being a water source, the area near the river is also an alluvial area that is rich of nutrients. The predator strategy is always looking for places where prey animals gather to make catching easy. Prey animals usually gather in places where abundant food sources, where the river banks are very fertile areas for the growth of vegetation that is the source for the food of tiger prey. Tigers prefer areas close to rivers to make them easier to ambush prey animals. Places around the river banks usually have a dense vegetation cover, so it is very beneficial for tigers to hunt their prey by sudden attack or ambush.

Forest edges is an one of important areas within Sumatran tiger home range. Transition areas between forest vegetation and open areas (ecotone) is the most preferred by ungulates for their foraging. Distance from the presence of translocated tiger to forest edge varies between 0 –1,600 meters. Variable of distance from forest edge in the developed logistic regression model shows a negative correlation that is equal to -1.021 (Tabel 3). This means that the further away an area is from the edge of the forest, the area is increasingly unsuitable for tiger habitat. The Presence of translocated tiger in the area of forest edges is strongly correlated with the effort of tiger to hunt the prey. Nahlik *et al* (2009) reported that red deer (*Cervus elaphus*) utilizes open areas within their home range as place for finding food, while the forest is used as cover from predators. At the same time, the forest also provides cover for deer from hot during day time. Some studies reported that open areas and forest edges are the places where mostly chosen by ungulates (tiger prey), while forest vegetation has function as cover for protection (Williamson & Hirth 1985). Masse & Cote (2009) stated that deer forages in the edges of the forest where predators also occur.

The result of analysis shows that NDVI value in study area is between -0.467 - 0.802. NDVI relates with the degree of greenness and the relative biomass content of a vegetation. This provides figure that the study site is mostly forested forest with some small open areas (agriculture and settlement) within Ulu Masen Landscape. Research result of Syartinilia & Tsuyuki (2008) shows that forested vegetation has NDVI value between 0.1 – 0.7. NDVI that has value close to 0 usually related with cloud cover, where NDVI value less than 0 usually relates with water body or areas without vegetation (Justice *et al.,* 1985 in: Roger *et al.,* 2007).

The value of NDVI regression coefficient 3.724 (Tabel 3) gives positive correlation to the developed regression model. This means that the further high of relative biomass contetnt or the further high the greeness degree of a vegetation (forested), thus increasingly suitable for tiger habitat. Previous researchs reported that NDVI possititively correlated and significantly affect to suitability of tiger habitat (Caroll & Larson 2008, Imam *et al.,* 2009, Singh *et al.,* 2009). Tigers need vegetation with a dense tree crown as a place for covering them from heat of the sun, rest, and as a place for hiding when they stalk their prey.

Variation of slope degree in study area is between 0% (flat) and 79.4% (very steep) (Appendix 5). Analysis of binary logistic regression shows that the level of translocated tiger presence is increased along with the increasing the value of the slope. But, with regression coefficient value 0.062 (Tabel 3) can be explained that the slope vaiable gives a very little effect to the formed logistic regression model. This research result is supported by several previous studies which stated that slope is not significantly affects to the tiger habitat suitability, either in Sumatra or India (Endri 2006, Imam *et al.,* 2009, Singh *et al.,* 2009).

Research of Putri (2010) in Bukit Tigapuluh NP shows a different result, where she found that tiger habitat is increasingly unsuitable with the increasing of slope value of an area. The difference can be caused by the difference of collecting data method. Sumatran tiger presence data used by Putri (2010) was secondary data, such as camera trapping sites that record tiger pictures, sites of tiger scat and scratches found. Determining the locations of tiger presence using this method is very biased, because probably the tiger presence data collected only represent flat areas. Meanwhile, areas with steep and very steep slopes that are very difficult to reach but still used by the tiger are not represented. Sumatran tiger presence data in this study was determined based on primary data directly taken from a tiger through a GPS collar, so that it has a much higher level of accuracy. However, the presence of tiger in this study was collected from a Sumatran tiger which were translocated to an area dominated by steep and very steep slopes, so that it could not represent whole of Sumatran tigers. Seidensticker *et al.,* (1999) stated that tigers tend to prefer a flat and undulated areas.

Spatial model of habitat suitability

All thematic maps of independent variables that develop a logistic regression model (elevation, distance from river, distance from forest edge, NDVI and slope) are presented in Appendix 1-5. A map of translocated tiger habitat suitability in study area, which resulted from applying a developed logistic regression model, through *raster calculator* in ArcGIS 9.3, can be seen at Figure 3.

In Figure 3 can be seen that the size of the area which used as study area in Ulu Masen Landscape is 1,278.05 km^2. Based on the developed model, known that the size of area which identified as “less suitable” class is 112.9 km^2 (8.84%), “suitable” class is 566.39 km^2 (44.32%) and “most suitable” area as Sumatran tiger habitat is 598.76 km^2 (46.85%). In the produced map can also be seen that the size of “less suitable” area supposed to be smaller than interpreted area in this study, because “cloud cover” in the satellite imagery was also interpreted as “less suitable area. Less suitable areas for Sumatran tigers habitat generally is human settlements. Areas that interpreted as suitable areas for Sumatran tigers habitat are mostly located in forested areas inside Ulu Masen Landscape, and some other areas located in forested and schrubs in the outside of the boundary of Ulu Masen Landscape. Meanwhile, the most suitable areas are almost all located within Ulu Masen Landscape.

Feasibility test of logistic regression model

Feasibility test of logistic regression model employing *Hosmer-Lemeshow* test shows that the developed model is feasible with significance value 0.233 (> 0.05). The value of *Nagelkerke* R^2 is 0.302. This value gives a figure that 30.2% of independent variables in the model explain the variability of translocated tiger habitat suitability (Appendix 6). Meanwhile, another 69.8% of independent variables in the model is explained by other factors or other variables which are not include in the developed model.

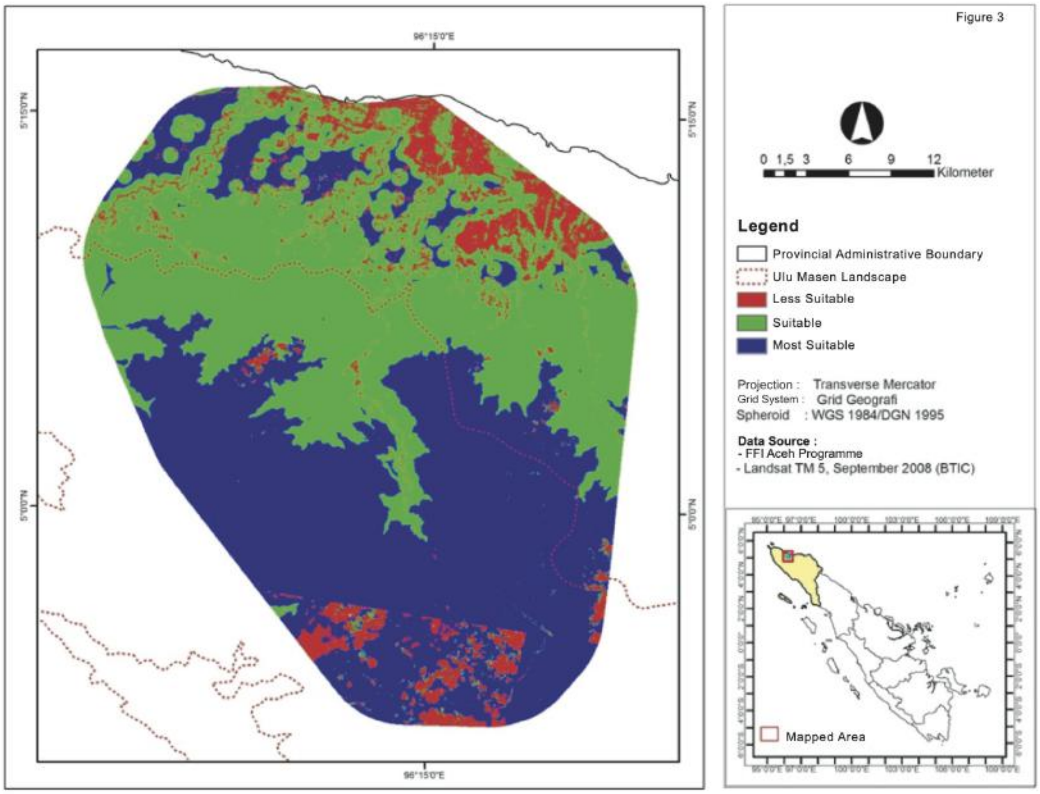

Figure 3. Map of traslocated tiger habitat suitability in study area.

The other environmental factors that may take effect to the tiger habitat suitability, but are not included in the development of this logistic regression model such as density of main prey, degree of human disturbance to the area, and landscape structure. Sunquist (2010) stated that the majority of tiger activity time is spent for foraging. In his modeling, Rajapandian (2009) found that there is a strong relationship between the density of prey and tiger presence in an area. Rajapandian (2009) and Wibisono *et al.* (2011) reported that the most preferred habitat by the tigers either in Sumatra and Terai Arc Landscape, are the areas that close to forest patches and the areas that have less disturbance from encroachment.

Model validation

Result from model validation shows that the value of accuration kappa is 46.6%. This value illustrates that the level of accuracy of the model is not good. Landis & Koch (1977) explained that a good or accurate model is a model that has a value of accuration kappa between 60 – 80%, because those values have high accuration (satisfactory).

Model validation test shows that there is an error in the model in predicting an area that less suitable for tiger habitat, where actually the tiger can probably found within those areas (*omission error*) is 53.5%. This error was happened when determining the tiger *pseudo-absence* points, where the areas that actually still tiger habitat were used as randomization area to determine the *pesudo-absence* points. It seems that prediction the suitability of tiger habitat employing the point approach turned out to be inappropriate, because tiger has very large home range and it can be found in various habitat with very diverse conditions. This can cause difficulties in determining the *pseudo-absence* points which can represent a habitat that is less suitable for tigers. Another error is the moldel's error in predicting an area as suitable habitat, but actually there has never been reported the presence of Sumatran tiger in the area (*commission error*) is 38.7% (Appendix 7). But, the validation conducted on the result of extrapolation of the model using 50% of *presence* data points show that the validity level is 98.0%.

Model extrapolation

The level of model accuracy based on accuration kappa shows that the model can be applied in the other area. Ulu Masen Landscape as one ecosystem unit with the study area, can be considered to have conditions that are similar to the conditions af the study area. Thus, the model can be applied or extrapolated to all area of Ulu Masen Landscape (Figure 4). Based on the polygon of the map of area boundary, the size of Ulu Masen Landscape is 7,496.86 km^2. Based on the result of extrapolation, identified that "less suitable" area for Sumatran tiger habitat is 376.89 km^2 (5.0% of total area of the landscape), while "suitable" area is 5,360.55 km^2 (71.5% of total area of the landscape), and the size of "most suitable" area for tiger habitat is 1,759.42 km^2 (23.5% of total area of the landscape).

Habitat suitability model in perspective of ecology

Analysis using SPSS 17 shows that from the seven independent variables observed, only five variables could further be analyzed to develop a Sumatran tiger habitat suitability model in Ulu Masen Landscape. Those

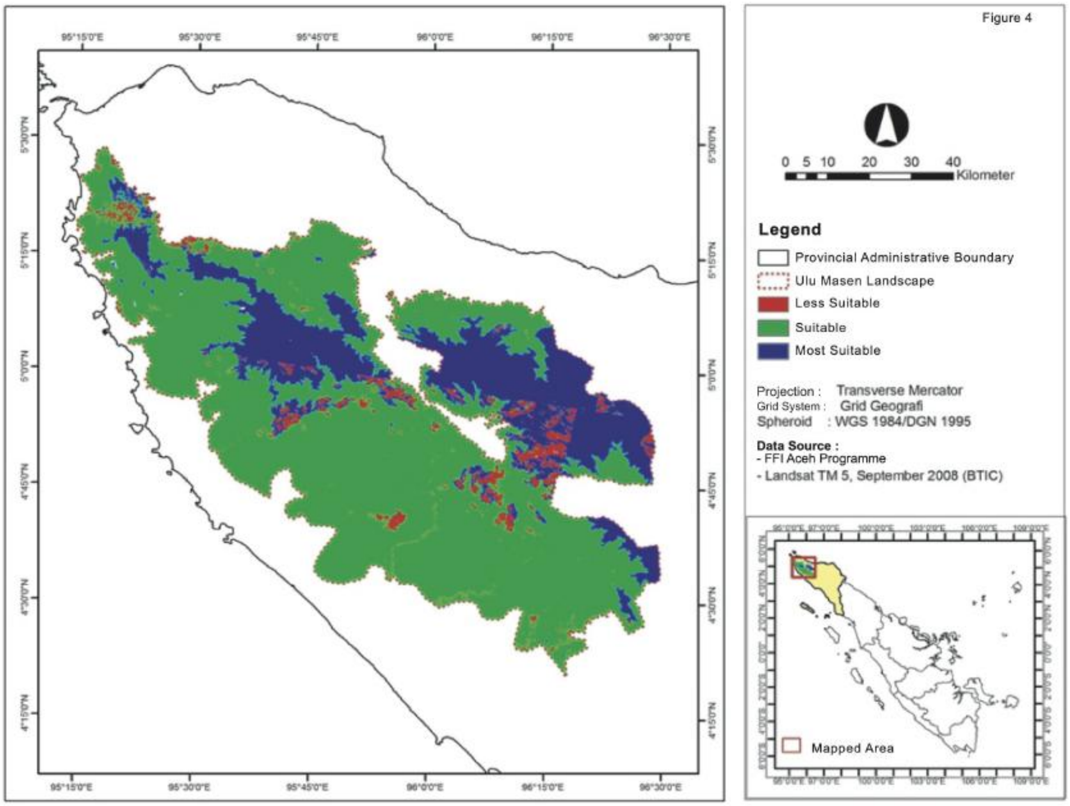

Figure 4. Map of habitat suitability of translocated Sumatran tiger resulted from extrapolation in all areas within Ulu Masen Landscape.

independent variables are elevation, distance from river, distance from forest edge, NDVI, and slope. Those all five independent variables have significantly affected the suitability of translocated tiger habitat (sig. <0.05). This result is similar with the study of Putri (2010) in Bukit Tigapuluh NP, which reported that the physical factors of an area, such as elevation, slope, distance from river, and vegetation cover, provide a significant effect to habitat suitability of Sumatran tiger. But, Putri (2010) didn’t include distance from forest edge in her study. In this research, distance from forest edge is one of factor that provide significant effect to habitat suitability model. Wibisono *et al* (2011) stated in their modeling that the tigers in Sumatra mostly found in the areas that adjacent with forest patches. Border areas between open areas and forests are the area most pavored by many ungulates as the pace for feeding. Williamson & Hirth (1985) explained that the places choosen by ungulates (which are main tiger prey) are open areas and forest’s edges. For ungulates, areas with forested vegetation has function as cover for protecting them either from predator or from heat. Naturally, open areas that adjacent to forests are rich in lower level vegetation which is food for ungulates. Besides, those areas is also ideal areas for tigers to lurk and ambush their prey.

Box (1976 in: ver Hoef *et al.,* 2001) stated that no ecological models that has been that is truly precise, because all models contain errors. A model, whether developed using few or many variables, all will still contain error. The more complexity of a model (the bigger observation data and simulation data needed), then the model will be even less accurate or increasingly uncertain (Constanza & Sklar 1985 in: Sklar & Hunsaker 2001). A model with low complexity (that developed using few variables), Model dengan kompleksitas yang rendah (yang disusun dengan sedikit variabel), could achieve higher accuracy because it could explain many things from something few. The effectiveness of real model is how much the model can try to explain (the complexity) and how well the model can explain what is observed (Sklar & Hunsaker 2001).

The developed habitat suitability model shows that Sumatran translocated tiger in Ulu Masen Landscape is significantly affected by five environmental variables, that are elevation, distance from river, distance from forest edge, NDVI, and slope. Meanwhile, Bailey (1984) dan Alikodra (1990) stated that the factors which influence the presence of animal in a particular habitat are combination between physical and biotic components. Likewise, the carnivorous and solitary of Sumatran tigers, their presence in a habitat is also determined by the existence of a complex interaction among various physical and biotic components. There are several components of habitat or other limiting factors that are suspected to strongly influence the presence of translocated tiger in a habitat, but they are not included the model that developed due to limitation of supporting data and resources. These factors/variables such as avaibility of main prey (deer, barking deer, and wild pig), the presence of local tigers in the area, and disturbance factor or human presence in the area of tiger habitat.

As a carnivorous and top predator, Sumatran tigers need 5-6 kg of meat everyday (Sunquist 1981).

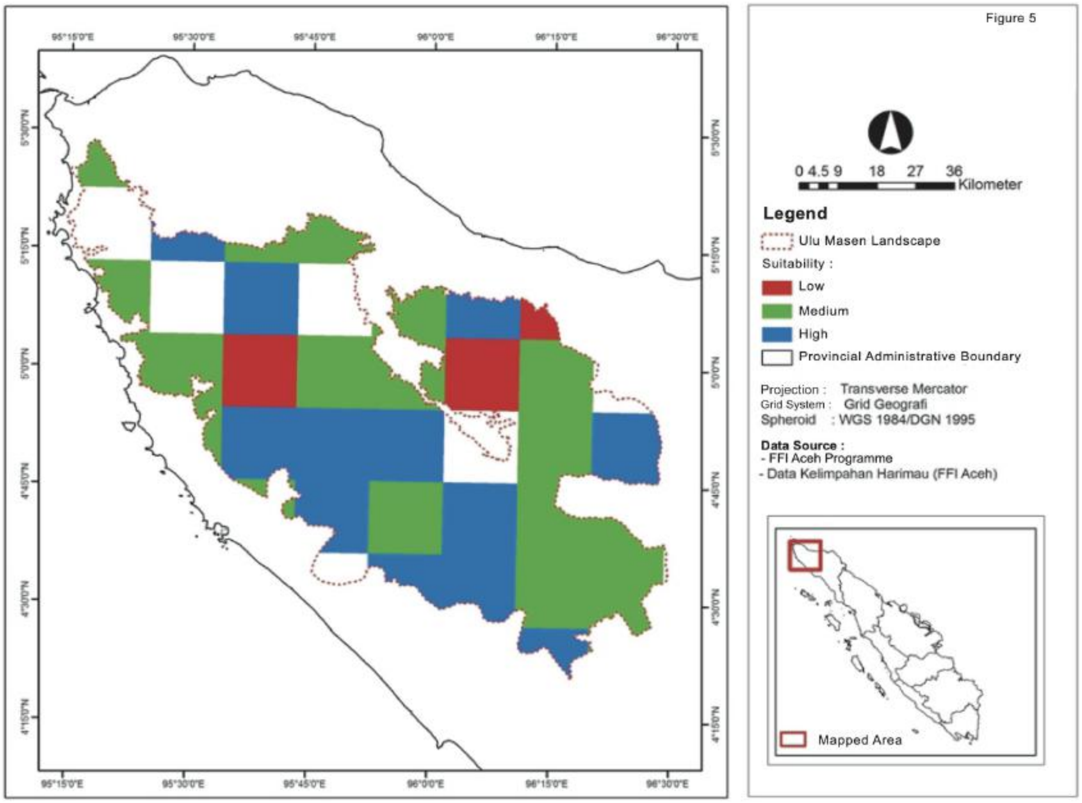

Figure 5. Prediction map of translocation location suitability based on availability of prey and the presence of local tiger in Ulu Masen Landscape

A tiger can hunt a 20 kg of barking deer every three days or a deer with weight of 200 kg in every several weeks (Sunquist *et al.,* 1999). Although sometime a tiger found hunt a smaller size prey, such as mouse deer, pig-tailed macaque, porcupine, pangolin, and great argus (Soehartono *et al.,* 2007), but there is a tendency that there is a preference to hunt a large weight prey (Bagchi *el al.* 2003). Thus, strongly predicted that the presence of tigers in a forest area is affected by availability of prey in the area. Modeling constructed by Rajapandian (2009) shows that availability of ungulates (deer and barking deer) positively affect the tiger distribution.

Tigers is a solitary, secretive, and territorial species, although their home range is not exclusive. Social interaction is only happened between female tigers with her cubs. Male tiger is intolerant to the presence of other male in his territorial range. In the presence of these properties, it is certain that the presence of other tiger that translocated to the area will have a major impact on the demographic structure of tigers that already exist in the area. Two scenarios can occur. Local tiger will leave it home range if it loose in the competition, or translocated tiger will be eliminated and become a *floater/transient* if unable to compete with local tiger. Thus, the factor of local tiger presence/abundance at the translocation site is one of the important variable that need to be considered in developing a habitat suitability model of translocated tiger.

With its secretive and avoid interaction with humans, making Sumatran tigers very sensitive to human presence in their habitat. Various activities that are increasingly out of control carried out by humans in the forest areas (encroachment, illegal logging, hunting on tiger prey etc.), has directly or indirectly been able to reduce the density of tigers in the area. Therefore, the factor of human disturbance intensity in the forest area (which is the tiger habitat) is also an important variable that must be considered in developing a habitat suitability model. Result of modeling in Terai Arc Landscape, India, which was carried out by Rajapandian (2009) shows that the existence of agricultural lands and the presence of human within the tiger habitat have a negative influence on the distribution of tigers.

Determination of Translocation Location

Relative abundance data of local tiger and prey species that generated from transect *sign* survey in Ulu Masen Landscape is presented in Appendix 8. Maps of the prediction of relative abundance of local tiger and prey species resulted from spatial analysis are presented in Appendix 9 and 10.

After *intersect* between map of perediction of translocation location suitability based on the presence of local tiger and prey was conducted, then a predicted map of the suitability of the translocation location in Ulu Masen Landscape is produced, based on relative abundance of tiger and its main prey (Figure 5). From this spatial analysis known that in Ulu Masen Landscape there is area which identified as "highly suitable" area for translocation location based on the abundance of local tiger and its prey with the size of 2,632.43 km^2 (35.1% of total area of the landscape). The size of area with criteria as "moderately suitable" area is 3,068.85 km^2 (40.9% of total area of the

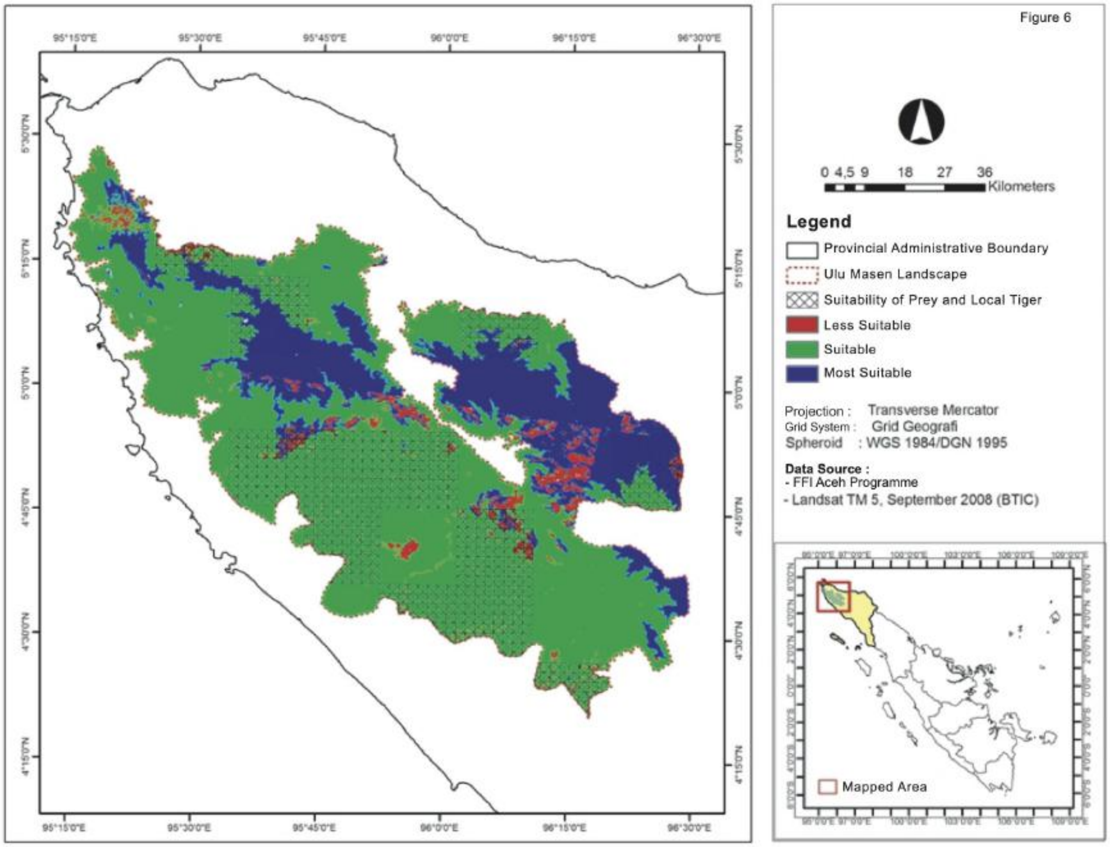

Figure 6. Prediction map of suitable location for tiger translocation Ulu Masen Landscape.

landscape), and the area that identified as "less suitable" area is 640.21 km^2 (8.5% of total area of the landscape). Another 15% of the area of the landscape could not be identified as there is no data available.

Overlay between habitat suitability map of translocated tiger that resulted from extrapolation and availabitity of prey, producing a map of suitable area for tiger translocation in Ulu Masen Landscape (Figure 6). Overlay was only conducted between map of tiger habitat suitability and the map of highly suitable based on the presence of local tiger and prey, that is the area with a low abundance of local tiger but has a highly abundance of tiger main prey (deer, barking deer, and wild pig).

From the result of spatial analysis that presented in Figure 6, known that there is area with the size of 388.1 km^2 (5.2% of total area of the landscape) which is predicted as highly suitable area to be used for tiger translocation. These areas are areas that has a low abundance of local tigers, high abundance of tiger prey, and are physically "highly suitable" for tiger habitat. These areas can be used as areas with first priority if an area for tiger release is needed in the future. Furthermore, in Ulu Masen Landscape there are also areas that have a low bundance of local tigers, high abundance of prey, and physically are "suitable" as tiger habitat based on spatial interpretation. The size of the areas with this criteria is 2,135.67 km^2 (28.5% of total of the landscape). These areas can be used as areas with second priority for location of tiger translocation in the in the future.

CONCLUSSIONS

Based on habitat suitability model, is known that 95% of Ulu Masen Landscape (around 7,500 km^2) identified as "suitable" and "highly suitable" area as Sumatran tiger habitat. Regression logistic model that developed using the approach of presence points, the result was not satisfactory or less feasible (validity of 46.6%). This model was arranged of environmental variables that can only explain of tiger habitat suitability of 30.2%.

The criteria of good location for Sumatran tiger translocation is a landscape where there is a mosaic of combination between lowland forests and schrubs vegetation (young secondary forests), flat to sloping topographically, and has elevation below 1,000 meters above sea level. The area must also be free from hunting or poaching and encroachment, as well as far away from human settlements. In Ulu Masen Landscape there is areas with the size of 388.1 km2 (5.2% of total of the landscape) that determined as "highly suitable" areas as well as areas of 2,135.67 km2 (28.5% of total of the landscape) that determined as "suitable" areas for the location of Sumatran tiger translocation.

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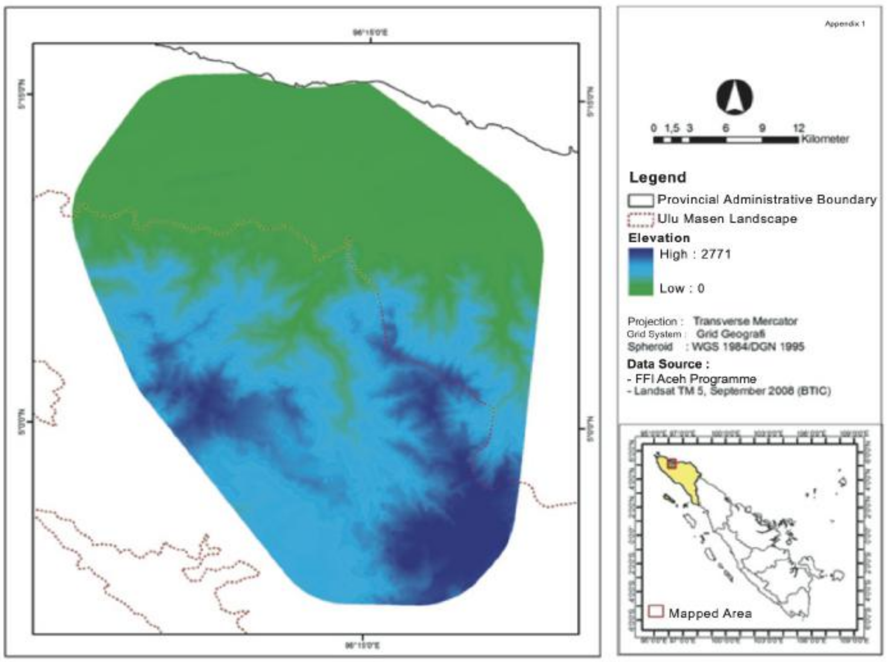
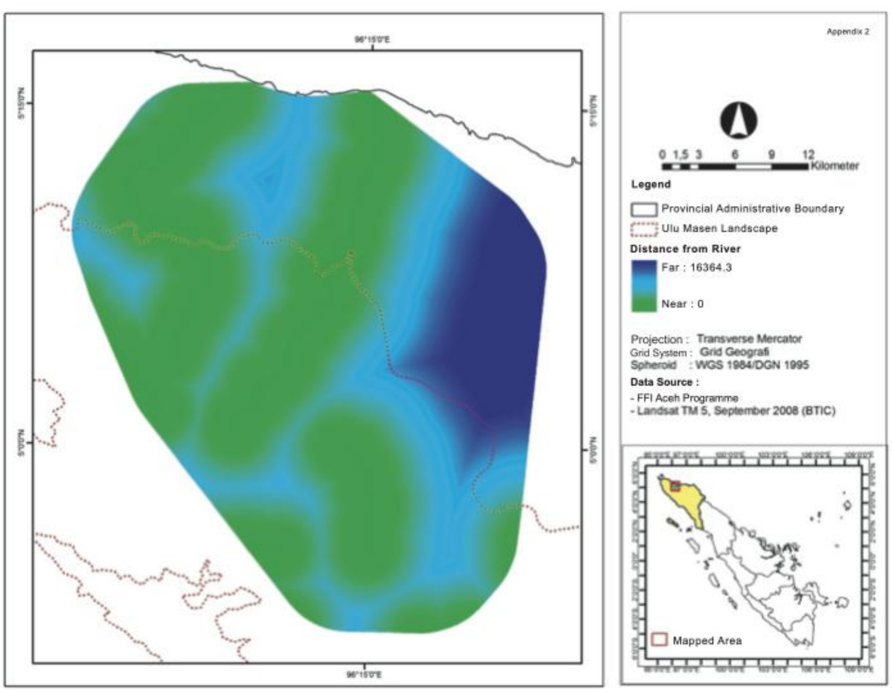
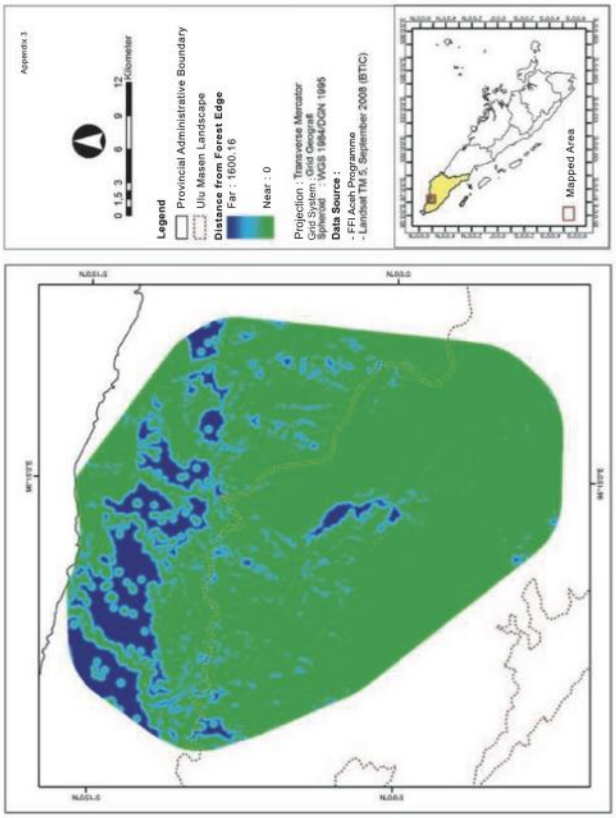
Appendix 1. Map of elevation in the study area.



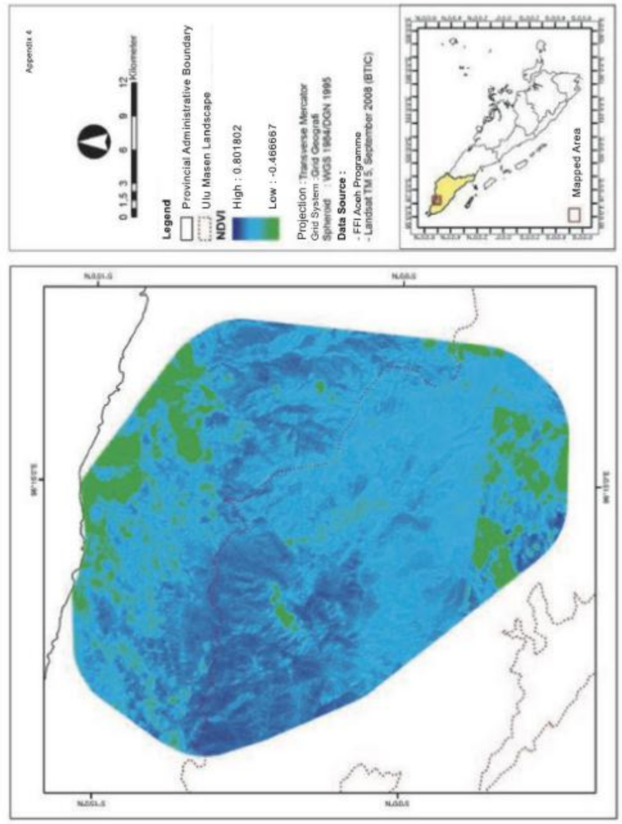
Appendix 2. Map of *euclidean* of distance from river in the study area.



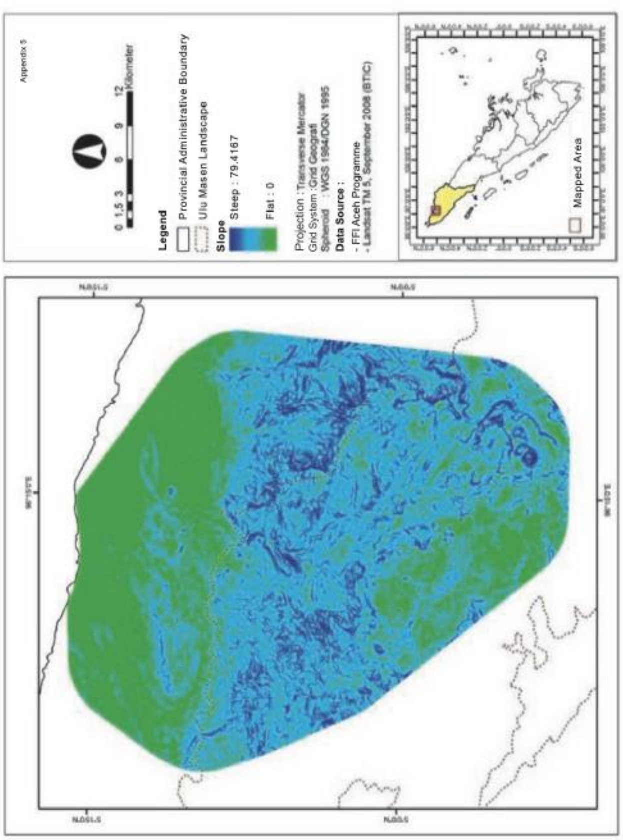
Appendix 3. Map of *euclidean* of distance from forest edge in the study area.



Appendix 4. Map of NDVI in the study area.



Appendix 5. Map of *slope* in the study area.



Appendix 6. Values of Nagelkerke R^2 and Hosmer Lemeshow tests to five independent variables.

A. Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	280.794(a)	0.224	0.302

a Estimation terminated at iteration number 5 because parameter estimates changed by less than 0.001.

B. Hosmer and Lemeshow Test

Step	Chi-square	df	Sig.
1	10.479	8	0.233

Appendix 7. Values of *kappa accuracy, commission error* and *omission error.*

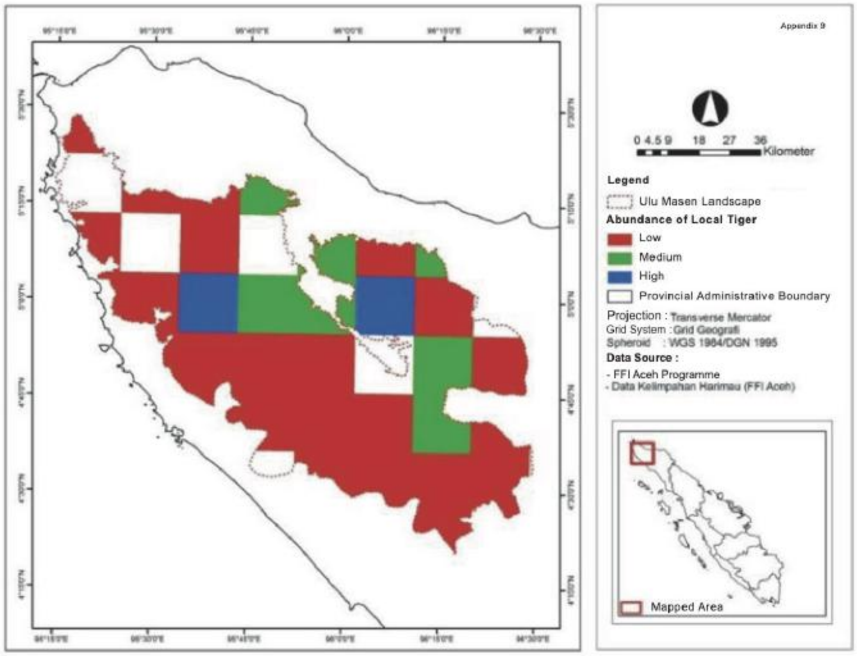
		Procedure				
		Presence (1)	Absence (0)	Total	User accuracy	Comission errors
User	Presence (1)	2988	1552	4540	0.658	0.342
	Absence (0)	70	1478	1548	0.045	0.045
Total		3058	3030	6088		**0.387**
Accuracy procedure		0.977	0.488			
Omission errors		0.023	0.512	**0.535**		

Kappa accuracy = (Oa - Ca) / (1 - Ca)
Observed agreement (Oa) = (2.988 + 1.478) / 6.088 = 0.734
Chance agreement (Ca) = ((3.058 / 6.088) * (4.540/6.088)) + ((3.030 / 6.088) * (1.548 / 6.088)) = 0.501
Kappa accuracy = (0.734 - 0.501) / (1 - 0.501) = 0.466 = **46.6%**
Omission error = (70 / 3.058) + (1.552 / 3.030) =0.535 =**53.5%**
Comission error = (1.552 / 4.540) + (70 / 1.548) = 0.387 =**38.7%**

Appendix 8. Values of relative abundances of local tiger and prey in Ulu Masen.

Location	Transect #	Distance Surveyed (km)	Findings (Tiger)	Tiger ER (sign/km)	Findings (Prey)	Prey ER (Sign/km)
EUM	N29W37	39	1	0.03	9	0.23
EUM	N29W38	30	2	0.07	11	0.37
EUM	N30W36	32	1	0.03	1	0.03
EUM	N30W37	31	0	0.00	2	0.06
EUM	N30W38	48	2	0.04	12	0.25
EUM	N30W39	15	0	0.00	8	0.53
EUM	N30W40	39	2	0.05	20	0.51
EUM	N31W36	26	1	0.04	2	0.08
EUM	N31W37	27	0	0.00	4	0.15
EUM	N31W38	27	2	0.07	13	0.48
EUM	N31W39	26	1	0.04	10	0.38
EUM	N31W40	38	1	0.03	4	0.11
EUM	N31W41	52	3	0.06	16	0.31
EUM	N31W42	28	0	0.00	8	0.29
EUM	N32W36	38	0	0.00	2	0.05
EUM	N32W37	23	1	0.04	19	0.83
EUM	N32W38	25	2	0.08	8	0.32
EUM	N32W40	19	0	0.00	9	0.47
EUM	N32W41	41	0	0.00	17	0.41
EUM	N32W42	22	0	0.00	9	0.41
EUM	N32W43	19	1	0.05	5	0.26
EUM	N33W36	28	1	0.04	3	0.11
EUM	N33W38	33	2	0.06	8	0.24
EUM	N33W39	38	8	0.21	12	0.32
EUM	N33W40	23	2	0.09	10	0.43
EUM	N33W41	28	2	0.07	10	0.36
EUM	N33W42	31	6	0.19	10	0.32
EUM	N33W43	13	0	0.00	2	0.15
EUM	N33W44	37	2	0.05	9	0.24
EUM	N34W37	39	1	0.03	2	0.05
EUM	N34W38	28	2	0.07	2	0.07
EUM	N34W39	30	0	0.00	10	0.33
EUM	N34W40	29	3	0.10	11	0.38
EUM	N34W42	35	2	0.06	11	0.31
EUM	N34W44	21	1	0.05	2	0.10
EUM	N35W41	33	3	0.09	11	0.33
EUM	N35W42	36	2	0.06	3	0.08
EUM	N35W43	33	1	0.03	13	0.39
EUM	N36W41	30	0	0.00	3	0.10
EUM	N36W42	35	0	0.00	3	0.09
EUM	N36W43	23	1	0.04	3	0.13
EUM	N36W44	30	0	0.00	1	0.03
EUM	N34W36	21	0	0.00	2	0.10

Appendix 9. Map of prediction of local tiger relative abundance in Ulu Masen.



Appendix 10. Map of prediction of prey species relative abundance in Ulu Masen.