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# SPATIAL ANALYSIS ON THE ECOLOGICAL IMPACTS OF **ROAD DEVELOPMENT** IN THE HEART OF BORNEO



WORKING  
TOGETHER  
TO SAVE  
THE HEART  
OF BORNEO



**Authors:** Dicky Sucipto, Gemasakti Adzan, Zahra Z Mutiara

**Contributors:**

WWF-Indonesia & WWF-Malaysia

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**WWF-Indonesia**

Gedung Graha Simatupang  
Tower 2 Unit C 4<sup>th</sup> Floor  
Jln Letjen TB Simatupang, Kav 38  
Jakarta Selatan 12540  
<http://www.wwf.or.id/>

**WWF-Malaysia**

No. 1 Jalan PJS 5/28A,  
Petaling Jaya Commercial Centre (PJCC),  
46150 Petaling Jaya, Selangor, Malaysia  
<http://www.wwf.org.my/>

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# 1. INTRODUCTION

Indonesian Government through (draft) Presidential Decree on Spatial Planning of the Heart of Borneo National Strategic Area (KSN) is trying to control the pressure of development rate. Reflecting on deforestation rate in this area, which covers an area of 600 thousand hectares during 2000 – 2015, the issuance of the Heart of Borneo Spatial Planning is expected to ensure that sustainable development principle is carried out, in order to reduce the environmental degradation rate.

The spatial planning is expected to maintain the ecological function of KSN in the Heart of Borneo as catchment area, as biodiversity protection, and as life support for the traditional community in Borneo. The Presidential Decree on Spatial KSN in the Heart of Borneo will become reference for spatial revision process for province, as well as districts and cities in Kalimantan (Ichwan Susanto 2018).

On the other side, currently the Government of Indonesia and Government of Malaysia focus their investment substantially on infrastructural development.

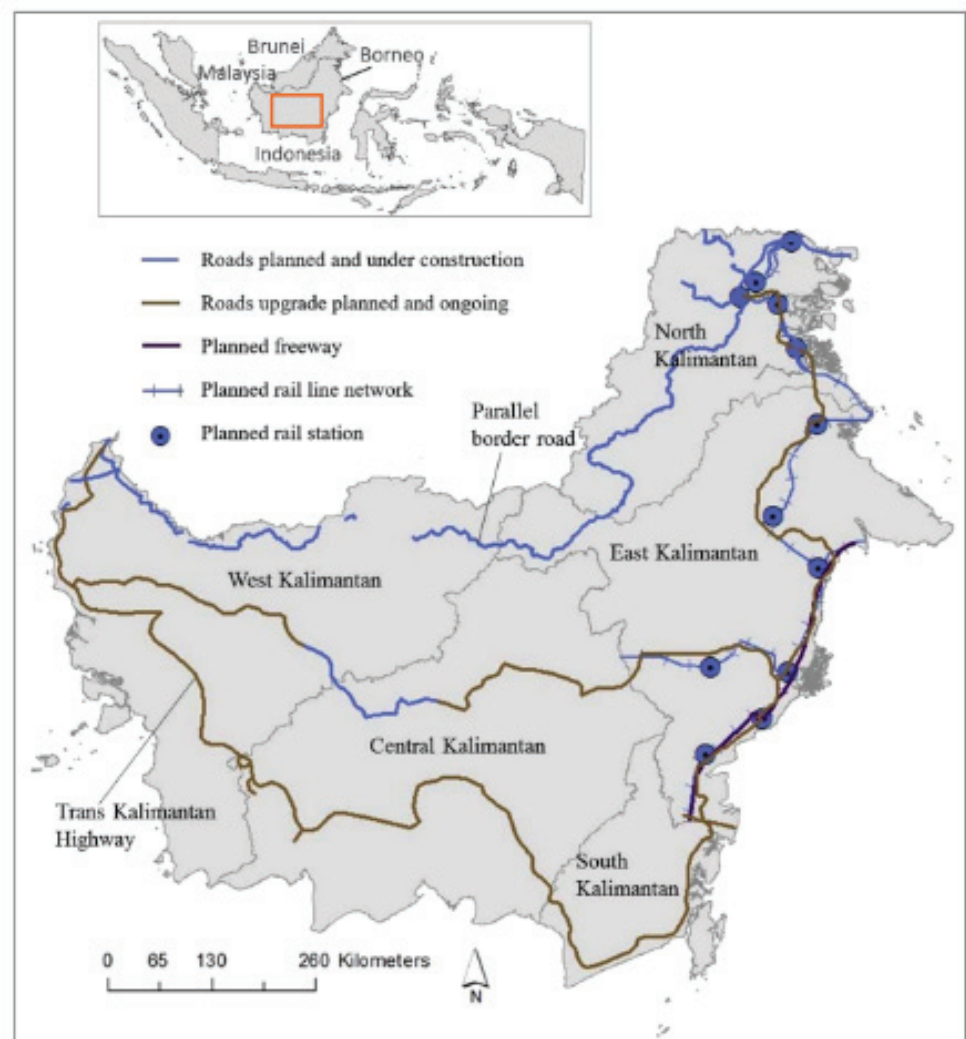


Figure 1 National Road Development Plan in Kalimantan (Alamgir et al. 2019)



In Kalimantan alone, Indonesian Government has compiled the infrastructural development plan on National Road which parallels to the border between Indonesia and Malaysia. However, up until today, many of linear infrastructural developments have always been blind to the need of the conservation and maintainance of environmental carrying capacities.

New road infrastructure development tends to give both direct or indirect good impact on a big scale land clearing, followed by land plantation and agricultural development which reflected in the increase of carbon emission and climate change (Perz et al. 2008, Mena et al. 2017), habitat fragmentation and the extinction of many types of flora and fauna (Mark L. Watson 2005, Miriam Goosem 2007, Gaveau et al. 2009, Marcantonio et al. 2013, Sharma et al. 2018, Alamgir et al. 2019). For Kalimantan itself, road infrastructure development plan and rail line plan are estimated to have an impact up to 34% on landscape fragmentation (Alamgir et al. 2019).

Change on landcover and land use spatial modeling is a good instrument to see interactions of various causing factors of land change and as one of the basic to evaluate policies for land use. The simulation of change on landcover and land use can indicate the explanatory factors affecting the landscape. Based on that, it is possible to model various scenarios on land change that might happen in the future (Han et al. 2015). The changes of landcover and land use are strongly related to the environmental quality. Therefore, the various scenarios of change on landcover and land use in the future are expected to support the sustainable land management (Gibson et al. 2018).

This report depicts the result of spatial modeling study on various scenarios of changes on landcover and land use as an impact of space structure development plan, in a form of road infrastructure and space allocation plan in Indonesia that are assigned in the (draft) Presidential Decree on Spatial in the Heart of Borneo Year 2017-2037. There are at least four scenarios of changes on landcover and land use within this study: (1) Business as Usual Scenario; (2) Based on road development plan scenario; (3) Based on Spatial Plan Scenario; and (4) Combination between road development and Spatial Plan in the Heart of Borneo Scenario. The study also delves into further potential environmental impact on landcover and land-use by using ecosystem services approach. Special highlights are made on the possible impact to the habitats of Orang Utans (in Kalimantan, Indonesia) and Elephant (in Sabah, Malaysia).

## 2. INDONESIA

### 2.1 LAND COVER CHANGE DURING 2006-2017

Within this study, the four scenarios of land change modeling are analyzed using Land Change Modeller (LCM) in the IDRISI software. Landuse/cover map in 2006 and 2017 (source: Ministry of Environment and Forestry Republic of Indonesia 2017) is used as foundation to establish trends in land change which happened in the Heart of Borneo area. The land change analysis 2006-2017 is done throughout Kalimantan area, with the assumption that land change process could not be separated from the land management. As stated in area development plan (RTRW) for every region or province, demands of land change in the Heart of Borneo cannot be separated from the other area in Kalimantan.

Around 40 types of changes or transition on landcover and land use have happened during 2006-2017, which then categorized into various simpler classes. The main category is based on a similarity of the explanatory factor of the changes happen in each of those transition categories (Gibson et al. 2018)

Table 1 Landcover Change Category

No	Change submodel	Description
1.	Abandonment	Plantation and agricultural areas converted to grassland and bare areas
2.	Dry agriculture intensification	Agricultural activities substitute previous land cover
3.	Land clearing	Natural forest converted into shrubs or bare area
4.	Industrial tree plant intensification	Forest plantation substitutes previous land covers
5.	Plantation intensification	Plantation substitute previous land covers
6.	Urban intensification	Urban area substitutes previous land covers
7.	Wet agriculture intensification	Agricultural (rice field) activities substitute previous land cover

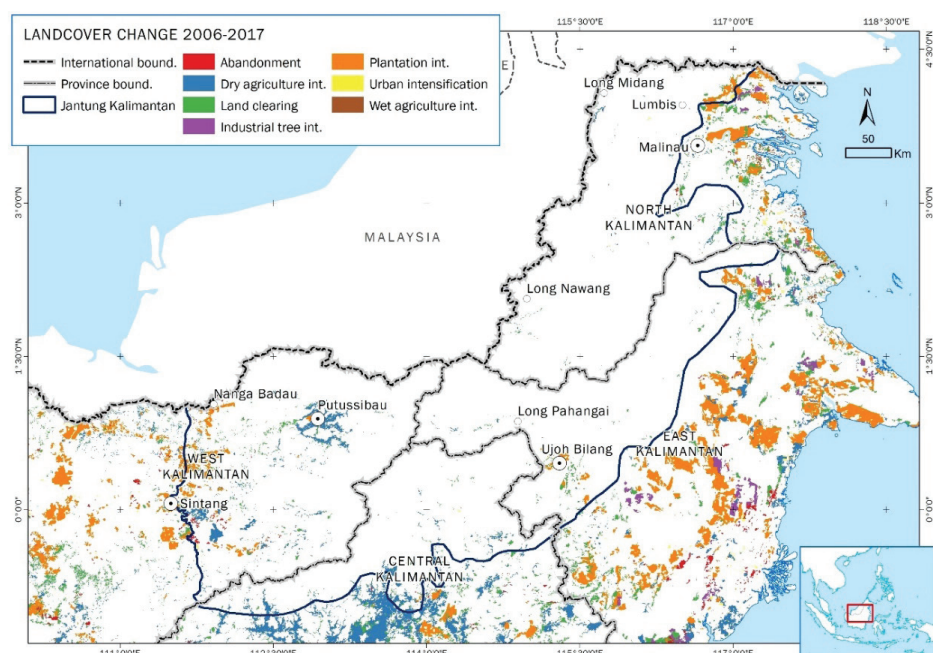


Figure 2 Landcover change during the period of 2006-2017



In the scope of the whole island of Kalimantan, intensification of land as plantation appears to be the biggest form or pattern of land change, with the area of more than 2.5 million Hectares. Deforestation rates that refer to the conversion of natural forest to (land) plantation have become relatively very high compared to deforestation to agriculture area and forestry plantation. However, deforestation in a form of land clearing converted into shrubs or bare area still become the most common change, which reach an area of 2 million Hectares or around 200 thousand Hectares each year.

The land change transition pattern trends in the scope of Kalimantan area seem to be different with what happen in the Heart of Borneo area. In the scope of Heart of Borneo area, intensification of land as agricultural land is the most dominant land change patterns happened during 2006 – 2017, with almost 2 million hectares change. Deforestation to shrubs or bare area as an effort of land clearing become the next dominant type with an area of more than 1.25 million Hectares.

## 2.2 METHOD & DATA: EXPLANATORY FACTORS

Land Change Modeller (LCM) and most of the land change modeling are using inductive approach to see the correlation between various explanatory factors towards existing land change tendencies. Spatial explanatory factors mean a spatial set of data based on biophysics as well as social economy criteria which represent explanatory or other factors of a specific land change. Some of the spatial explanatory factors are often used in land change modeling such as slope, elevation, distance between road and developed land, distance to the river (Gibson et al. 2018).

Statistically the strength level of explanatory factors is also affecting the validity of existing land change modeling. The strength of the factors indicates that variable is better in describing the existing land change transition. In LCM, Cramer's V is used to test the strength of spatial explanatory factors, that is to measure the relationship of a variable with the existing land change tendency, scoring between the point of 0.0 (no correlation) to 1.0 (perfect correlation). Cramer's V scoring range that is higher than 0.15, is a minimum indication that the variable can be used as explanatory variables. While scoring above 0.4 shows that the variable is very good to use as explanatory variables (Eastman 2012). Besides Cramer's V scoring reference, the spatial explanatory factors determined within this study is also considering several references (Gaveau et al. 2009, Uryu et al. 2010).

Table 2 Spatial explanatory variables used in developing the land change model scenario

No.	Variable	Source
1.	Distance to level 1 road	Arterial road network and collector; map of Rupa Bumi Indonesia (RBI) scale 1: 50,000 (Geospatial Information Agency of Indonesia)
2.	Distance to level 2 road	Local road network; map of Rupa Bumi Indonesia (RBI) scale 1: 50,000 (Geospatial Information Agency of Indonesia)
3.	Distance to level 3 road	Other road network; map of Rupa Bumi Indonesia (RBI) scale 1: 50,000 (Geospatial Information Agency of Indonesia)
4.	Distance to level 4 road	Footpath network; map of Rupa Bumi Indonesia (RBI) scale 1: 50,000 (Geospatial Information Agency of Indonesia)
5.	Elevation	Elevation digital model Global ALOS 30 meter (©JAXA)
6.	Slope	Elevation digital model data derivation Global ALOS 30 meter (©JAXA)

## 2.3 LANDCOVER AND LAND USE MODELING SCENARIO

There are two kinds of land changes modeling scenario within LCM, i.e. soft prediction and hard prediction. Soft prediction can be seen as possible potential of land change, which is an accumulation of transition potential in every change submodel, and can show the gradient possibility of a location (in this context, the smallest mapping unit is grid raster), whether it will change or not. Soft prediction does not describe the indication of landcover and land use type, only what might come from the change (Gibson et al. 2018).

Meanwhile, hard production is produced from multi objectives land allocation (MOLA) module, which is taking the maximum point from aggregation of various land change potential as well as land conformity factor. The amounts of land change that will happen are based on probability matrix built upon land change analysis 2006-2017 using Markov chain approach (Gibson et al. 2018).

In LCM, it is possible to integrate amongst land change potential, land conformity, infrastructure development plan, including constraint factor as a consideration in a land change allocation. Within this study, the approach is used to accommodate basic assumptions of developing scenarios. Road constructions plan, which becomes the basic of scenarios 2 and 4 can be accommodated with infrastructure development plan feature, while spatial plan in scenario 3 and 4 will become a boundary factor using the constraint factors featured.

### SCENARIO 1: BUSINESS AS USUAL (BAU)

BAU's landcover and land use change scenario is based on the assumption that landcover and land use change which will happen in the future will follow the landcover and land use change trends that happened previously, without policy change in the development plan. In the context of development plan process in Indonesia, the non-existence of effective development plan is making BAU's scenario becomes relevant enough in doing the landcover and land use change projection study (Sharma et al. 2018).

In BAU scenario, landcover and land use change tendency is based on the amount of change during the previous two periods of time. Several similar studies have been done to model the land change scenario with BAU assumption. Sharma et al. (2018) used land-

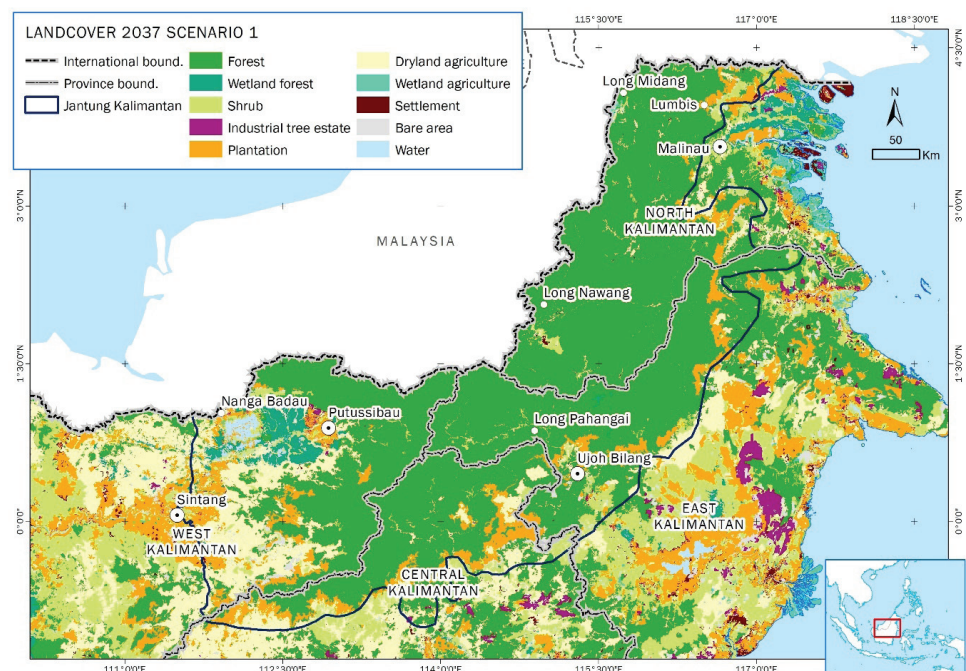


Figure 3 Landcover year 2037 as a result of Scenario 1 Simulation



cover data derived from citra Landsat year 2006 and year 2015 to build BAU scenario in Central Kalimantan. On the other hand, Adrian and Ariastita (2019) used land usage data 2009-2017 for the palm plantation development in East Kalimantan in modeling the BAU scenario. In this study, the land change tendency is built from the land change analysis during the period of 2006-2017 controlled by spatial explanatory variables.

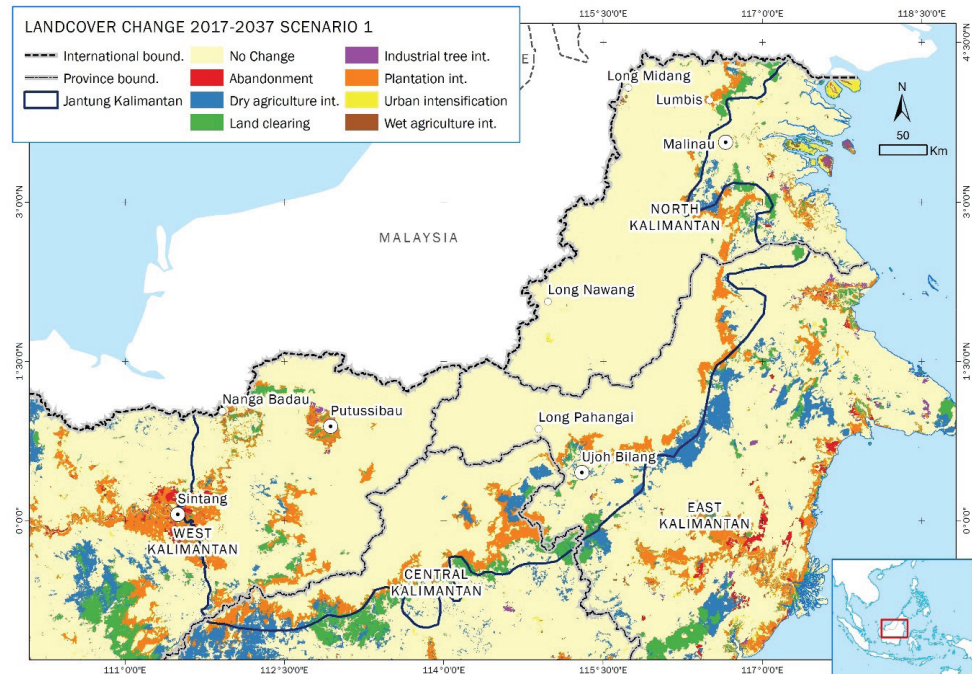


Figure 4 Landcover change during the period of 2017 – 2037 based on Scenario 1

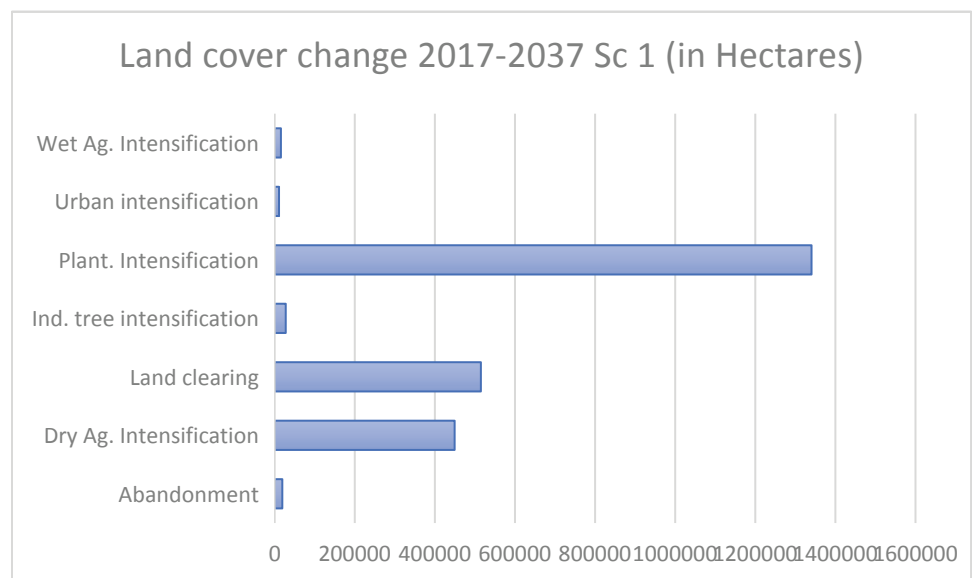


Chart 1 Land change area during the period of 2017 – 2037 Scenario 1 within the Heart of Borneo area.

The results of land change Scenario 1 simulation show the dominance of land plantation intensification and deforestation to more than 1.2 million Hectares in the Heart of Borneo area. Mainly, these changes can be found at the regional development centers in Sintang (most extensive), Putussibau, and Nanga Badau (West Kalimantan Province); Ujoh Bilang (Central Kalimantan); and Lumbis (North Kalimantan). The pattern of land change is evidently extending parallel to the southern side of the Heart of Borneo area which is estimated mainly because it is a flat area which becomes the main land compatibility for the (land) plantation and agriculture area allocation.

## SCENARIO 2: ROAD INFRASTRUCTURE DEVELOPMENT PLAN

Scenario 2 is built under the assumption that the new road infrastructure development plan in the Heart of Borneo will be involved as explanatory factors in event of the land-cover/land use change in the year 2037. (Bird 2010) revealed various ecological impacts which might happen as the results of road constructions:

1. Habitat loss – Forest encroachment is causing an increase in the disturbance and has the potential in inhibit the movement of wildlife due to the disconnection of habitat connectivity;
2. Disturbance – various disturbances from traffic might occur such as air and noise pollutions, which after a certain amount of time might influence wildlife or plants behaviours within the habitat;
3. Mortality – traffic accidents often become the causes of animals' mortality;
4. Barrier – road infrastructure can become a barrier in animals movement that encourage the population isolation. It will surely be dangerous as it becomes one of the factors that cause the local extinction of a spesies.

Road infrastructure development can also cause a long-term impact in the form of land encroachment that follows existing road network approximation. Several results on land change projection model study indicate how the new road infrastructure development plan can become real explanatory factors, which in the end can change an ecosystem condition.

Mena et al. (2017) is modeling projection of deforestation that has an occuring potential as the consequences of road development in area development plan for oil and gas exploration within the Amazon landscape, Ecuador. The study result indicates that the road infrastructure development plan has the potential to encourage deforestation around the road network, which cut 27% of natural forest cover, and have an occurance impact of around 284 million tons of carbon dioxide emission. Road development will also cause habitat fragmentation and inhibit the wild animals' movement.

Amor and Christensen (2015) predict the deforestation that will happen as an impact of road investment plan in some part of Mayans Tribe forest area in Mexico, Belize, and Guatemala. The study reveals several things related to the correlation of road development plan with potentials of deforestation, i.e. (1) the deforestation potential is bigger as it is closer to road segment, however (2) the probability of deforestation occurring in the road development area (near to the other existing road) tends to be higher, compared to road development in an area that is relatively undeveloped (far from other road network).

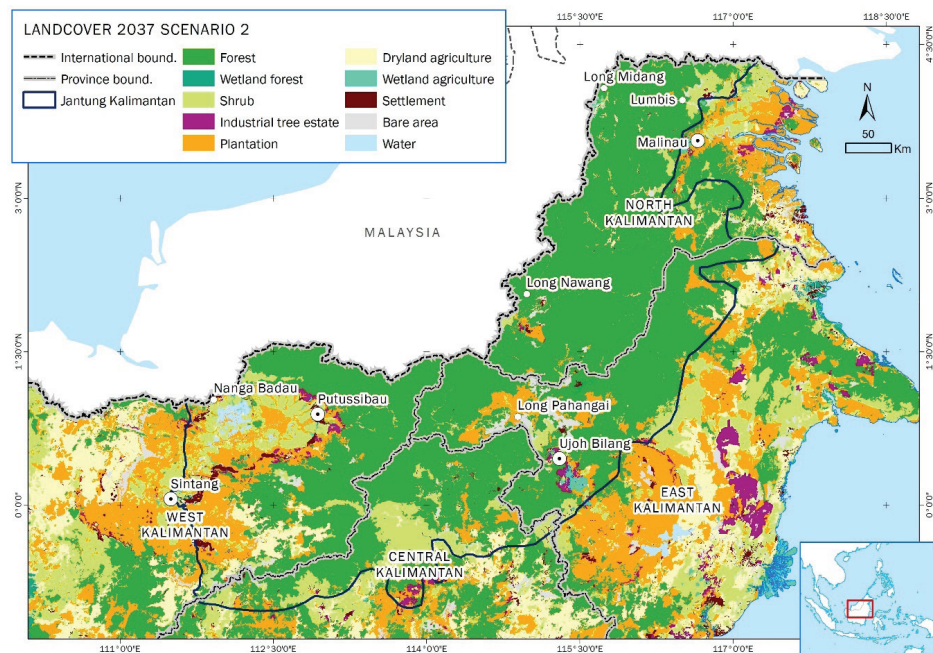


Figure 5 Landcover year 2037 as a result of Scenario 2 simulation

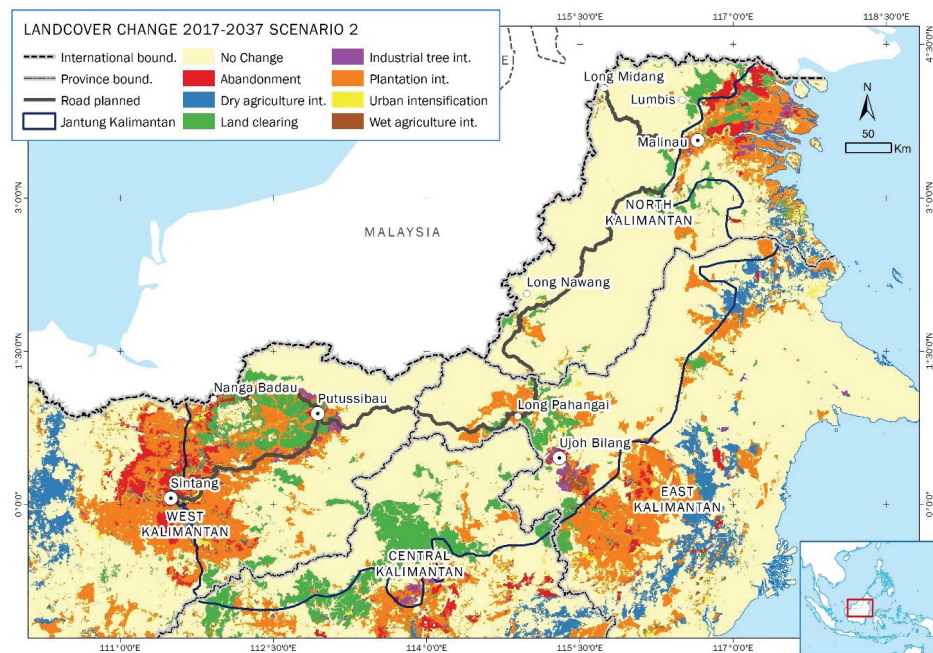


Figure 6 Land cover change during the period of 2017-2037 based on Scenario 2



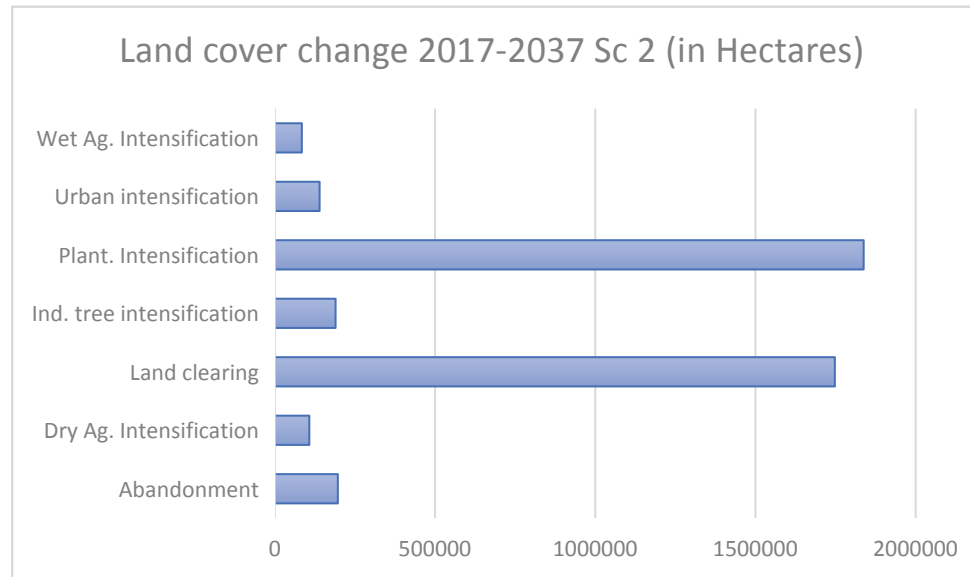


Chart 2 Land change area during the period of 2017-2037  
Scenario 2 within the Heart of Borneo

Landcover and land use change simulation in Scenario 2 as in the road development plan in the Heart of Borneo area shows the tendency of deforestation where its distribution is associated with road development plan segment. Plantation intensification became the dominant land change in the Heart of Borneo area based on Scenario 2 simulation, followed by land clearing with an area of more than 1.5 million Hectares. This change occurred in the Sintang-Putussibau-Nanga Badau road corridor and the Long Pahangai-Ujoh Bilang corridor. New residential areas are also developing along the Badau Sintang-Putussibau-Nanga corridor road. This shows a road development plan will give a significant impact on area developments especially to the regional development centers.

This is in accordance with the result of a study by Amor and Christensen (2015), the deforestation potential is bigger as it is closer to road segment. Another interesting example which amplify this can be seen in land encroachment along the right and the left side of Bukit Batabuh road crossing (Taluk Kuantan-Kiliran Jao section), located in part of the central area of Sumatera (Hadian and Haryono 2015). Road capacity development carried out from footpath to paved roads during the period of 1994-2013, proved to encourage deforestation along the right and left side of the road, eventhough it is a protected forest area.

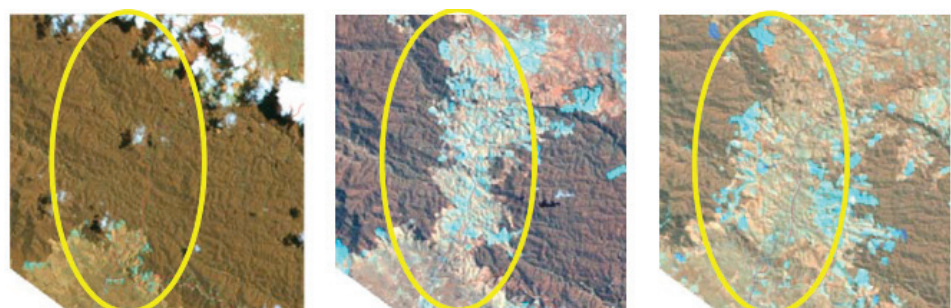


Figure 7. An overview of deforestation process along Bukit Batabuh road crossing, based on citra Landsat 5 TM year 1994, Landsat 7 ETM+ Th. 2002, dan Landsat 8 OLI Th. 2013 (Hadian and Haryono 2015).

### SCENARIO 3: THE HEART OF BORNEO SPATIAL PLANNING (RTR)

Scenario 3 is built with the assumption that landcover/land use change will be according to the directional spatial pattern in the Heart of Borneo RTR. In another word, the assumption built is really being applied to as a development plan instrument within the Heart of Borneo area.

Within LCM, the use of RTR layer can be accommodated through the use of constraint feature. It means that every area or spatial pattern polygon plan has a range of points. It limits whether or not changes in a certain type of landcover or land use happen. The ranging point is from 0-1, where as it gets closer to 1, the possibility of changing is higher. On the contrary, as it gets closer to 0, the restriction gets higher and makes it more impossible for land change to happen in that area.

The determination of constraint value is done qualitatively with a consideration that conservation and protection areas have the highest constraint value (point close to 0) whilst at the other land use area every type of land change can be accommodated (Hadian and Adzan 2017). At the area of production forest, the preference of land change approval is forestry plantation area. Whereas the priorities of land change and plantation intensification approval is allocated in agriculture/plantation area.

The program indications in the form of (land) plantation intensification found in the Heart of Borneo RTR based on Scenario 3, the distribution are mainly located on the southern side of the Heart of Borneo region and at the development center of the Sintang region (West Kalimantan) with a total area of more than 1.2 million Hectares. The intensity of land change in the central development corridor of the Sintang-Putussibau-Nanga Badau area is not as big as what happened in the simulation results of Scenario 2. This is because Scenario 3 applies constraints namely the existence of conservation areas, especially wildlife corridors and protection of peat ecosystems within the area.

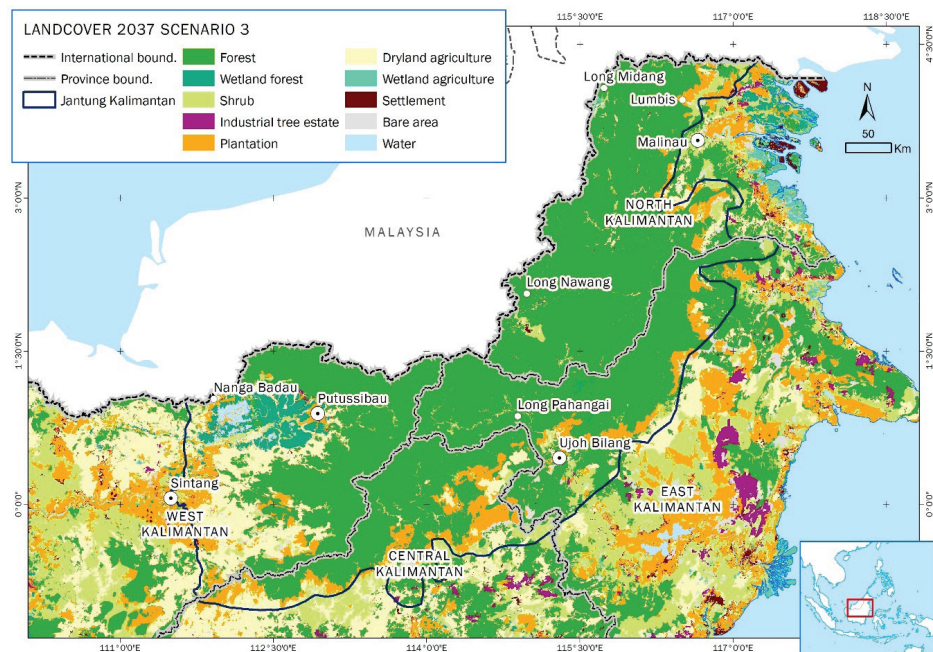


Figure 8 Land cover year 2037 as a result of Scenario 3 simulation

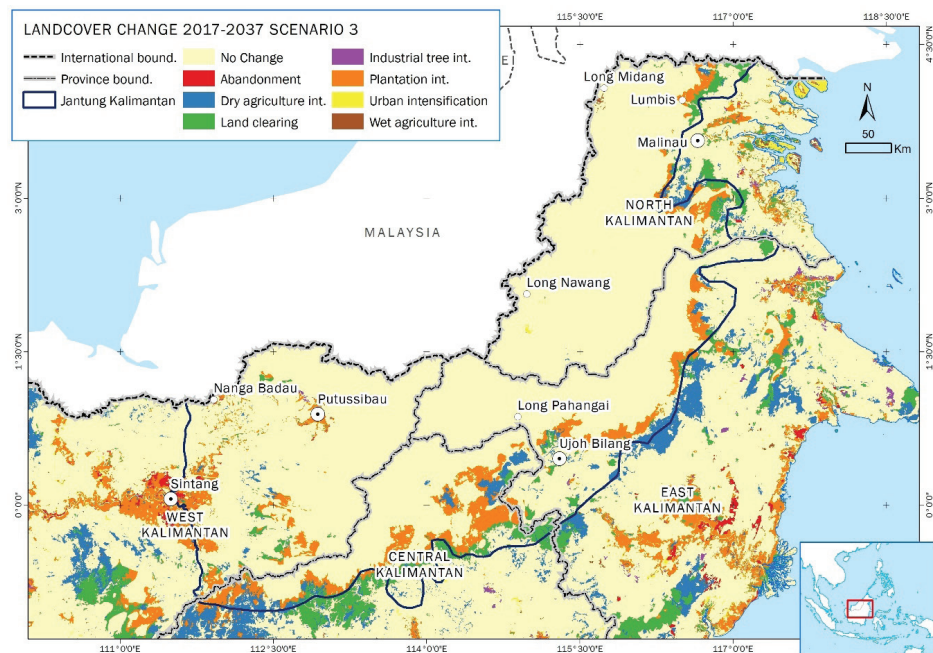


Figure10 Land cover change during the period of 2017-2037 based on Scenario 3

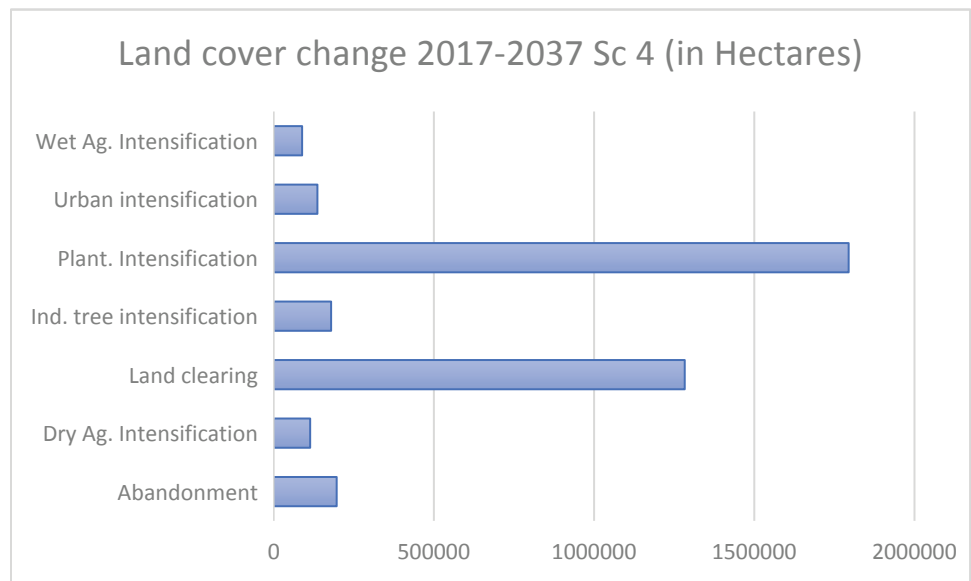


Chart 3 Land change area during the period of 2017-2037 Scenario 3 within the Heart of Borneo area.



## SCENARIO 4: ROAD DEVELOPMENT PLAN + THE HEART OF BORNEO RTR

Scenario 4 is built by combining two explanatory factors i.e. road development plan and the Heart of Borneo RTR. Basically the road development plan is one of the program indication listed in the Heart of Borneo RTRW document. Therefore, the application of the Heart of Borneo RTRW as assumed in Scenario 4 is not only on its spatial pattern (as in Scenario 3) but also involving the road network infrastructure development plan. The road infrastructure development plan application in LCM is accommodated by applying infrastructure change feature, while the application of RTR area is accommodated by constraint feature (Eastman 2012).

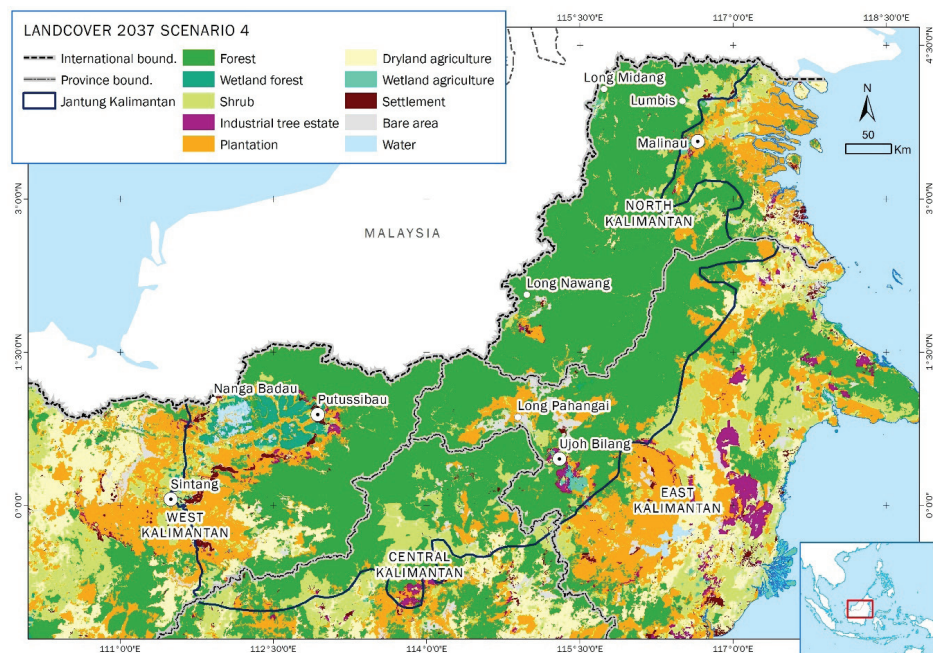


Figure 11 Land cover year 2037 as a result of Scenario 4 simulation

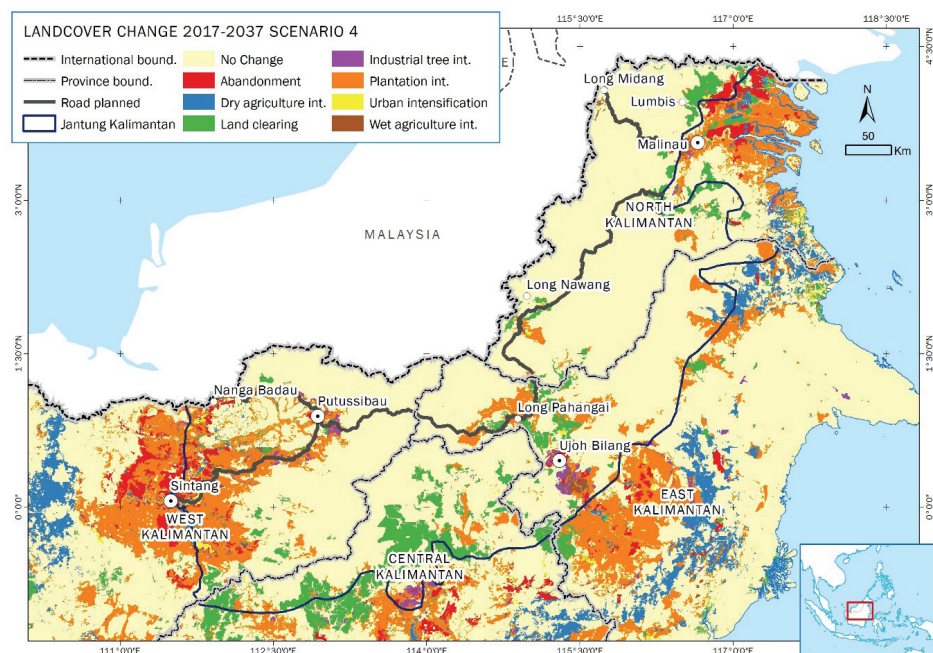


Figure 12 Land cover change during the period of 2017-2037 based on Scenario 4

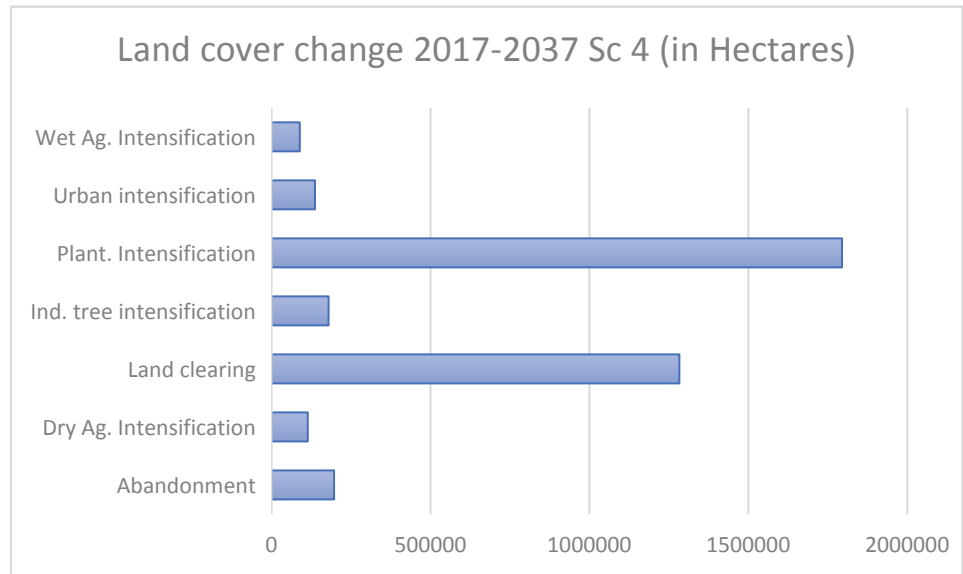


Chart 4 Land change area during the period of 2017-2037  
Scenario 4 within the Heart of Borneo area

The results of the land change simulation using Scenario 4 appear to have the same change area tendency as in the results of Scenario 2, but with a smaller value. The limiting factor in the form of implementation of wildlife corridor areas and the protection of peat ecosystems can primarily reduce the intensity of land changes, especially intensification of (land) plantation that happens in the corridors of Sintang-Putussibau-Nanga Badau development center and land clearing on the southern side of the Heart of Borneo.

## RESULTS: LAND CHANGE SCENARIO SIMULATION

Table 3 Landcover area based on each scenario

	Area in Hectares (percentage change)				
	2017	2037			
	Baseline	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Bare area	77,399	222,151 (187%)	361,722 (367%)	213,906 (176%)	358,397 (363%)
Dryland agriculture	1,447,110	1,725,548 (19%)	545,507 (-62%)	1,728,947 (19%)	551,801 (-62%)
Forest	13,993,027	12,157,365 (-13%)	11,776,454 (-16%)	12,053,981 (-14%)	11,922,310 (-15%)
Industrial tree estate	4,088	32,290 (690%)	189,793 (4543%)	22,441 (449%)	179,285 (4286%)
Plantation	174,451	1,504,308 (762%)	1,838,686 (954%)	1,523,508 (773%)	1,795,516 (929%)
Settlement	10,087	20,977 (108%)	149,768 (1385%)	20,887 (107%)	146,627 (1354%)
Shrub	583,164	719,602 (23%)	1,768,724 (203%)	753,115 (29%)	1,306,712 (124%)
Water	142,655	141,630 (-1%)	141,630 (-1%)	141,630 (-1%)	141,630 (-1%)



	Area in Hectares (percentage change)				
	2017	2037			
	Baseline	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Wetland agriculture	2,905	18,065 (522%)	86,742 (2886%)	9,255 (219%)	91,297 (3043%)
Wetland forest	432,610	325,560 (-25%)	8,470 (-98%)	399,826 (-8%)	373,921 (-14%)

The four land change simulations scenarios in the Heart of Borneo area show the dominance of land change in the form of (land) plantation intensification. The types of landcover of industrial forest plantations, settlements, shrubs, and rice fields are also consistently increasing in each scenario's area. However, generally the highest intensity of change is found in Scenario 2, which is based on the road infrastructure development. This proves that the road infrastructure development can become an explanatory factor for a tangible regional development in the Heart of Borneo area. The scenario 2 simulation results also show the highest potential for deforestation compared to the other three scenarios.

Scenario 3, based on the implementation of the Heart of Borneo RTR, has a relatively small intensity of land change compared to the other scenarios types. This is driven by the existence of a barrier, namely the protection area for peat ecosystems and wildlife corridors, so that forest cover conversion is not permitted in the area. The implementation of protected areas to protect peat ecosystems and wildlife corridors has also proven to have reduced the intensity of land change that can be observed in the Scenario 4 simulation results.

## DISCUSSIONS: ECOLOGICAL IMPACTS DUE TO LAND COVER CHANGE SCENARIOS

Ecosystem service approach is used to see the ecological impacts of each land change scenario simulation result. The grading of ecosystem service is conducted by using InVEST (Integrated Valuation of Ecosystem Services and Trade-Offs) software. InVEST is a measurement tool used in measuring natural resources potential and ecosystem service spatially. By using spatial based approach, this tool has an advantage in giving more comprehensive illustration on biophysics condition of an area. As a result, it simplifies the decision making process related to an area management policy (Sharp et al. 2018).

InVEST uses landcover type as its main proxy in the ecosystem service grading. Biophysics characteristic is guarded based on landcover type, not only for field measurement but also certain guidance references. The information then combined with other physics parameter in relation to the thematic ecosystem service analyzed. Habitat Quality, Water Yield, dan Carbon Stock and Sequestration are some thematic ecosystem services used to assess the ecological impact within this study.

## THE IMPACT OF LAND CHANGE TOWARDS ORANGUTAN HABITAT

One of the causes of habitat damage is the change of Landcover/land use; habitat fragmentation at one time will cause an extinction of certain species. Until the end of the 21st century, the change in landcover/ land use will always become the main factor affecting biodiversity, especially terrestrial ecosystem. Land change and its correlated impact in the form of land encroachment from the road infrastructure development will cause habitat fragmentation, which means that the originally wide and unfragmented habitats are now fragmented into several fragments (Primack 2004).

One of the impacts caused by habitat fragmentation is increasing edge effect, where there is a change on the condition at the edge of a habitat. For example, the orangutan habitat fragmentation caused by road infrastructure development, at the moment the edge of the habitat area along the road corridor can become an entrance for its abuser, especially orangutan hunter as well as land clearing activities. Primack (2014) stated that hunters

are the main predators in many places around the world. When roads divide habitats, making it possible for the intensive hunting to be done in the fragmented habitat and it can even reach the hinterland. The animals will lose their hiding places and the population will decrease.

Gaveau et al. (2009) conducted a study that illustrates that road infrastructure development can spur deforestation which threaten the existence of primary tropical forest as the orangutan habitat. Land change modeling done at Ulu Masen Landscape, Aceh, shows that road development also become the trigger of deforestation, as wide as 9,226 Km<sup>2</sup>. The loss of the forest is estimated to give an impact on the declining number of orangutan population as many as >1,384 individuals.

The study done at Heart of Borneo indicates that land change based on land change simulation scenario are proven to pose a threat for the disappearance habitat of Orangutan. Two types of disturbance that have predominant potential occurrence in orangutan habitat are land clearing and plantation intensification. In general, Scenario 2 simulation shows that a long term road infrastructure development has the potential to encourage the area development that can affect up to 29% of the total habitat of orangutans in the Heart of Borneo. This number is the highest compared to the potential disturbance generated by the other three types of scenarios. The implementation of protected areas and wildlife corridors in Scenario 4 is included within the Heart of Borneo area RTR can reduce the potential degradation of these habitats by up to 8%.

Table 4 Types of disturbance and their areas on Orangutan habitat within the Heart of Borneo area

	Type of disturbance on orangutan habitat	Area in Hectares			
		Scenario 1	Scenario 2	Scenario 3	Scenario 4
1.	Dry Ag. Intensification	194,581	5,427	1,893,94	8,212
2.	Land clearing	327,863	1,205,901	304,814	767,715
3.	Ind. tree intensification	16,893	112,807	6,655	104,775
4.	Plant. Intensification	792,374	303,430	782,017	271,320
5.	Urban intensification	448	3,915	409	3,877
6.	Wet Ag. Intensification	4,997	3,002	586	7,185
	Total area (percentage of total habitat)	1,337,156 (24%)	1,634,482 (29%)	1,283,875 (23%)	1,163,084 (21%)



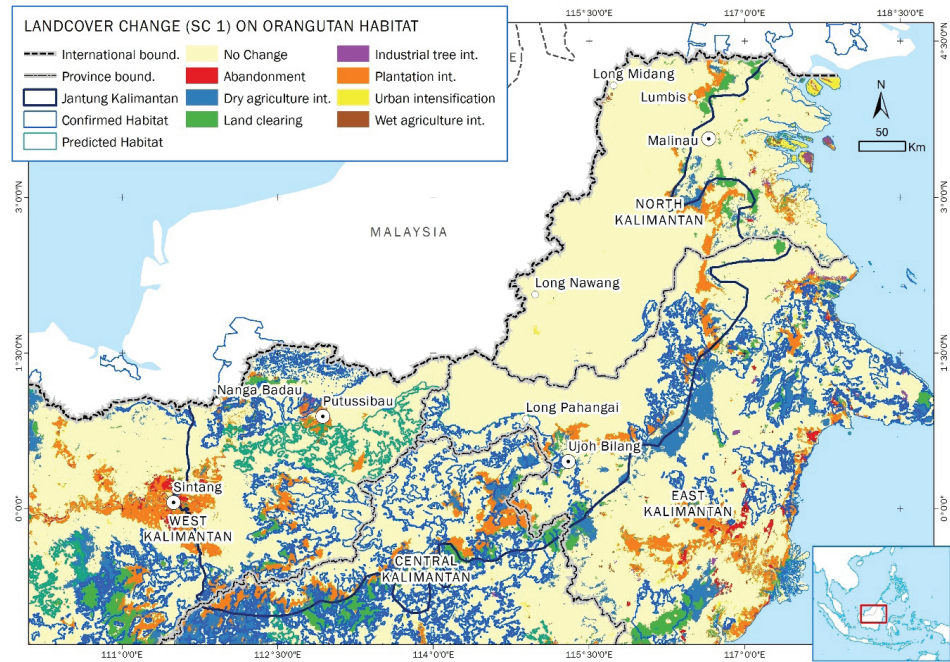


Figure 13 Area change on Orangutan habitat based on Scenario 1 simulation

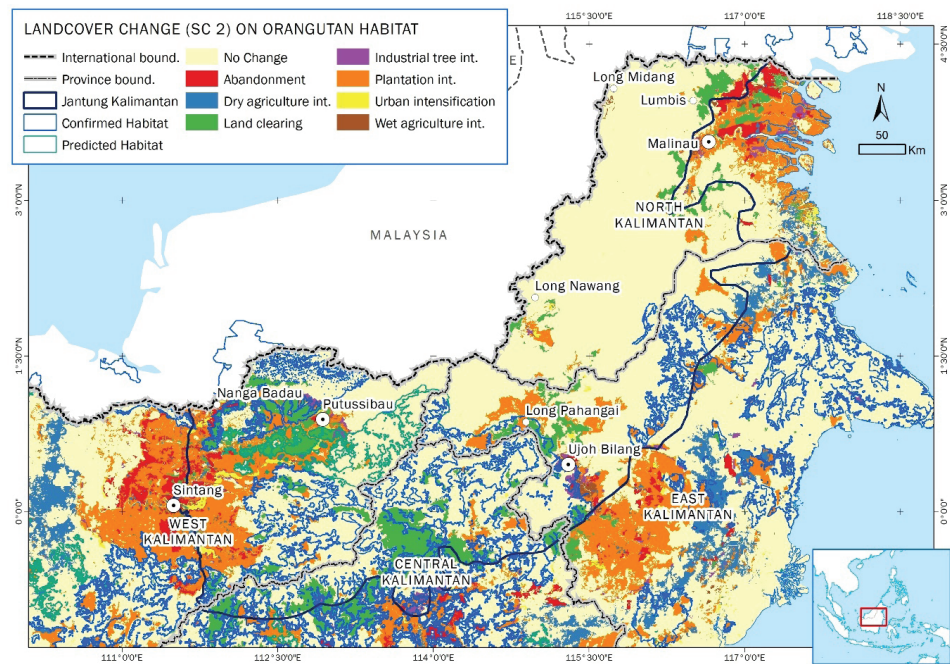


Figure 14 Area change on Orangutan habitat based on Scenario 2 simulation

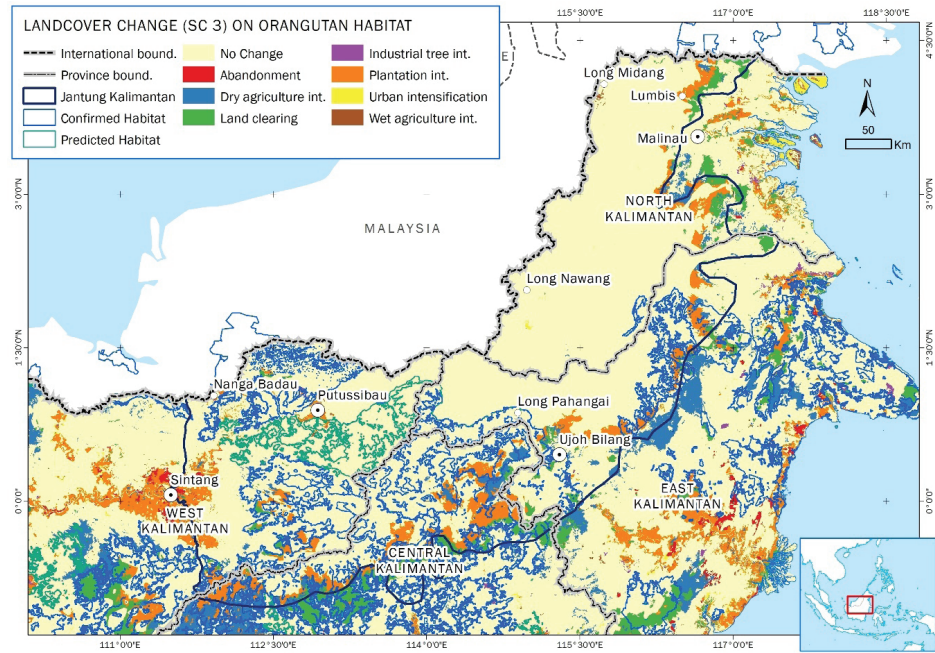


Figure 15 Area change on Orangutan habitat based on Scenario 3 simulation

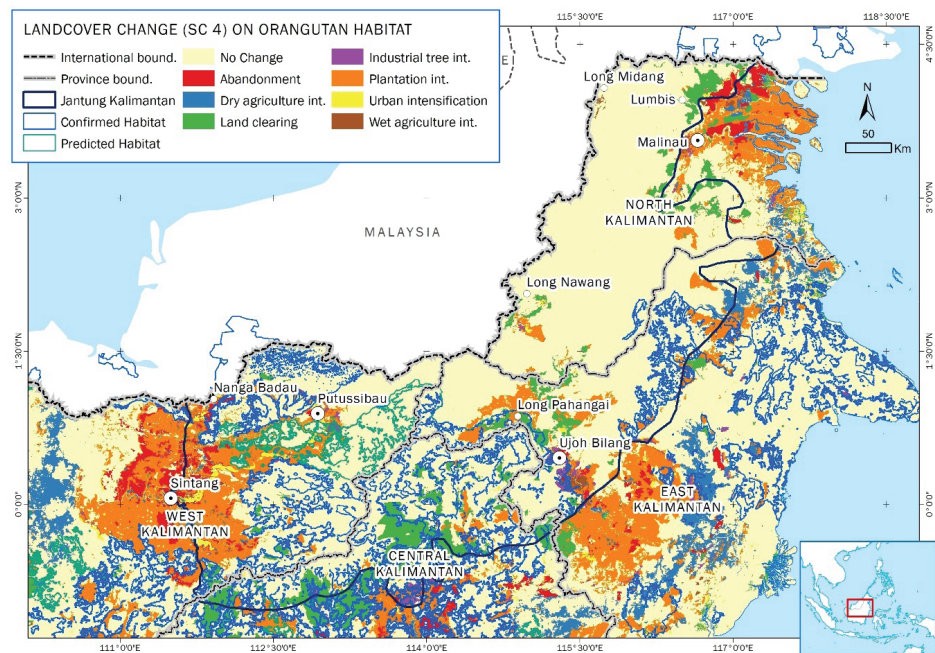


Figure 16 Area change on Orangutan habitat based on Scenario 4 simulation



## THE IMPACT TOWARDS CARBON DEPOSIT POTENTIAL

The calculation of potential carbon deposit in the Heart of Borneo area is done using InVEST tool based on 4 carbon pools informations, they are aboveground biomass, belowground biomass, leaf litter biomass and soil biomass. Those 4 carbon pools are measured using the reference value from various literature which refers to landcover and land use type.

Several limitations in this carbon modeling are as follow (Hadian and Adzan 2017):

1. This modeling simplified the carbon cycle, some contributors in this carbon circulation process are not used (such as: landcover history, landcover management);
2. Changes in carbon value only stem from the type of change in landcover, therefore the result of carbon value accuration will be influenced by the detailed level of landcover classification;
3. This model does not measure the carbon movement between pools. For instance, on dead tree, there is carbon movement from above ground biomass to carbon on dead organic material. Taking this modeling into assumption, only in every deforestation process or tree disappearance, the carbon value will directly evaporate to the atmosphere.

Table 5 Carbon sequestration on each land change scenario within the Heart of Borneo area

Year	Total Carbon Value (Tons)	Carbon sequestration (Tons)
2017	3,201,831,928	-
2037 Sc1	2,907,733,850	-294,098,078
2037 Sc2	2,809,466,136	-392,365,792
2037 Sc3	2,879,675,413	-322,156,515
2037 Sc4	2,886,311,339	-315,520,589

Sequestration in the form of loss of carbon deposits in modeling carried out in the Heart of Borneo area mainly comes from deforestation into various types of land cover. While the addition of potential carbon stocks is contributed by plantation intensification, which previously in the form of bare area or lower biomass agriculture area. The carbon sequestration model produced a similar intensity of land change that occurred in the previous analysis. The landcover Scenario 2 simulation is resulting the biggest carbon loss potential, which is based on the road infrastructure development. Implementation of protected areas for peat ecosystems and wildlife corridors in Scenario 4 can then slightly reduce the potential for carbon loss.

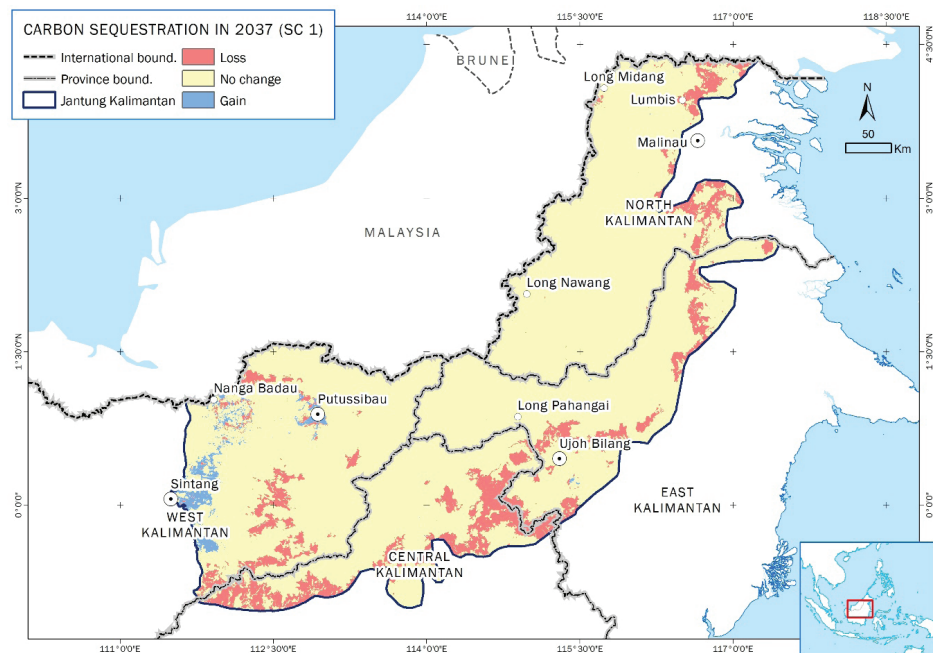


Figure 17 Carbon sequestration within the Heart of Borneo based on Scenario 1

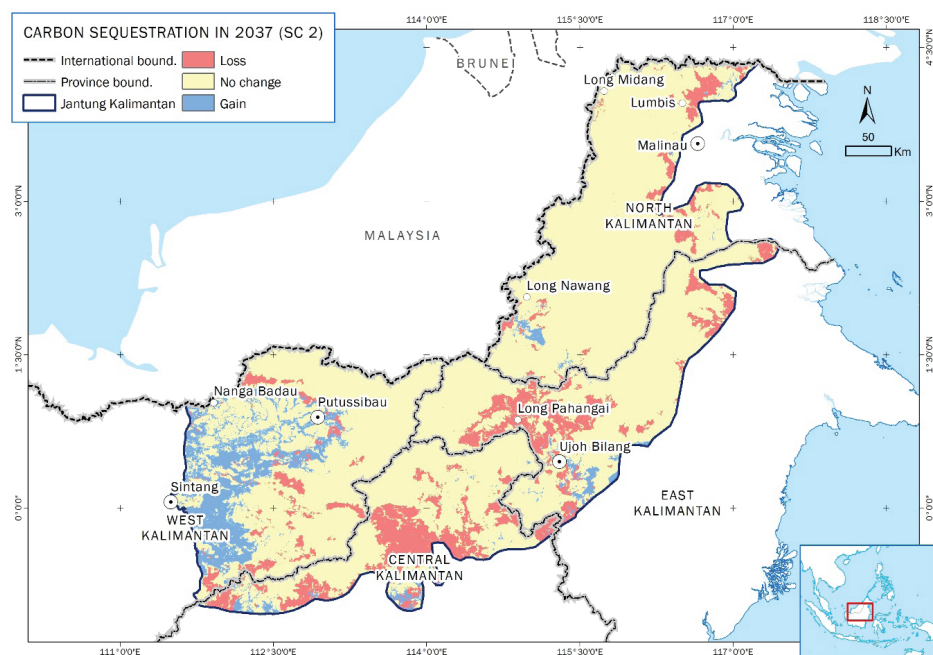


Figure 18 Carbon sequestration within the Heart of Borneo based on Scenario 2

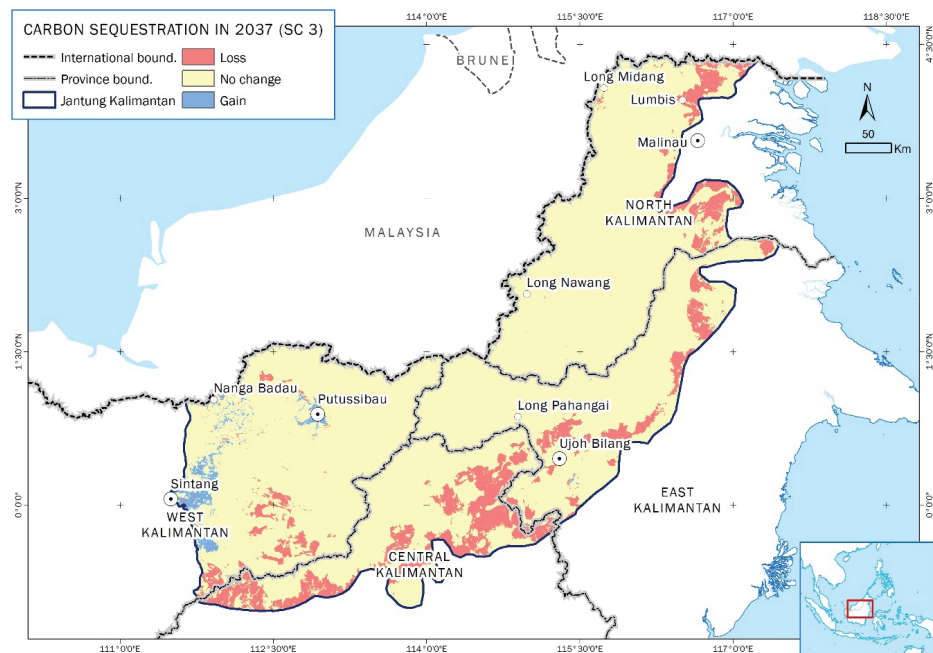


Figure 19 Carbon sequestration within the Heart of Borneo based on Scenario 3

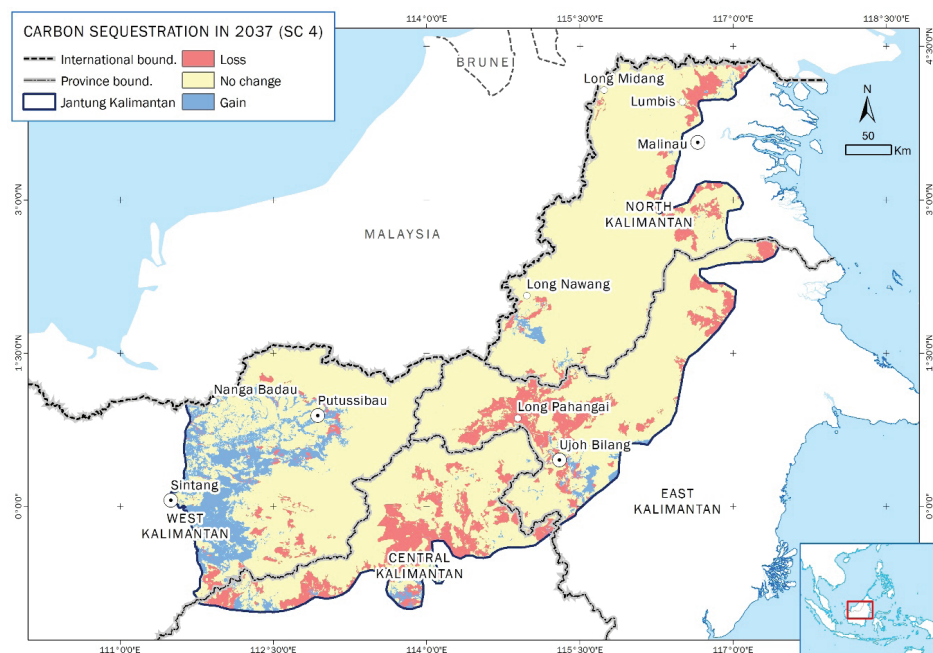


Figure 20 Carbon sequestration within the Heart of Borneo based on Scenario 4



# 3. MALAYSIA

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## 3.1 ELEPHANT HABITAT PREFERENCE AND POTENTIAL IMPACTED AREAS

Road infrastructure has been widely known to have a negative impact to the wild-life of both plants and animals. The road infrastructure development can cause habitat loss both directly when land clearing is done to build roads, and indirectly when habitat quality declines due to the exposure of various road traffic pollution (Forman and Alexander 1998, Jaeger et al. 2005, Miriam Goosem 2007, Barber et al. 2014). The development of road infrastructure imposes habitat fragmentation which will then cause large populations to split into small populations. This is very dangerous because small populations will increase competition in the population, decrease the ability of migration, and encourage close marriage which can cause the loss of genetical diversity (Forman and Alexander 1998, Mark L. Watson 2005, Goossens et al. 2016).

The side effect caused by habitat fragmentation of road construction is an increase in illegal hunting because of the access through the road side (Indrawan et al. 2007, Laurance et al. 2009). The number of human-wildlife conflicts will also increase, especially in agricultural area and settlements (Sukmantoro et al. 2019). In addition, it is common to find cases of animal's death, due to hit and run by vehicles, when they were road crossing (Forman and Alexander 1998, Laurance et al. 2009).

These negative impacts, both directly and indirectly, are particularly felt by various types of large mammals; who generally have a wide home range. Habitat fragmentation followed by forest encroachment and conversion of lowland forest are the main causes of the continuous declining number of Asian elephant populations (Alfred et al. 2011, Sitompul et al. 2013, Goossens et al. 2016). The conflict escalation between humans and elephants continues to increase where 300-500 hectares of oil palm plantations area in Sabah are "destroyed" annually by elephant herds and at least 10-16 elephants and 1-2 people die each year (Alfred et al. 2011).

The ecological behavior of elephants in response to road infrastructure is actually very complex. Elephants are known to have adaptability skill in various habitat types. In areas with massive developments of land use activities, such as in several areas in Sumatra, elephants tend to avoid road infrastructure that has the potential to cause conflicts with humans (Sitompul et al. 2013, Sukmantoro et al. 2019). On the contrary, in the Malaysia Peninsula area, road infrastructure has become an attraction for the elephants. The elephants' population concentration in open areas along the side of the road is quite high because there are more food sources in the area. The post-land clearing succession along the road encourages the growth of shrub vegetation, that is very favored by elephants (Wadey et al. 2018).

By looking at the description above, elephant habitat management needs to pay attention to the habitat preference patterns and elephant behavioral responses toward road infrastructure; so that appropriate and effective interventions can be done in the purpose of conserving elephant habitat. This study aims to reveal Asian elephant habitat preferences and the tendency of responses to road infrastructure in some parts of Sabah area, especially in the Sapulut Forest Reserve non-conservation area. This study is expected to provide consideration in response to the road widening plan within the area.

## 3.2 METHOD AND DATA

### STUDY AREA

Study area in this study is the road corridor between Matiku-Simpangan Mailau, especially in Asian elephant distribution area in Sapulut Forest Reserve (FR) Commercial Forest region and around.

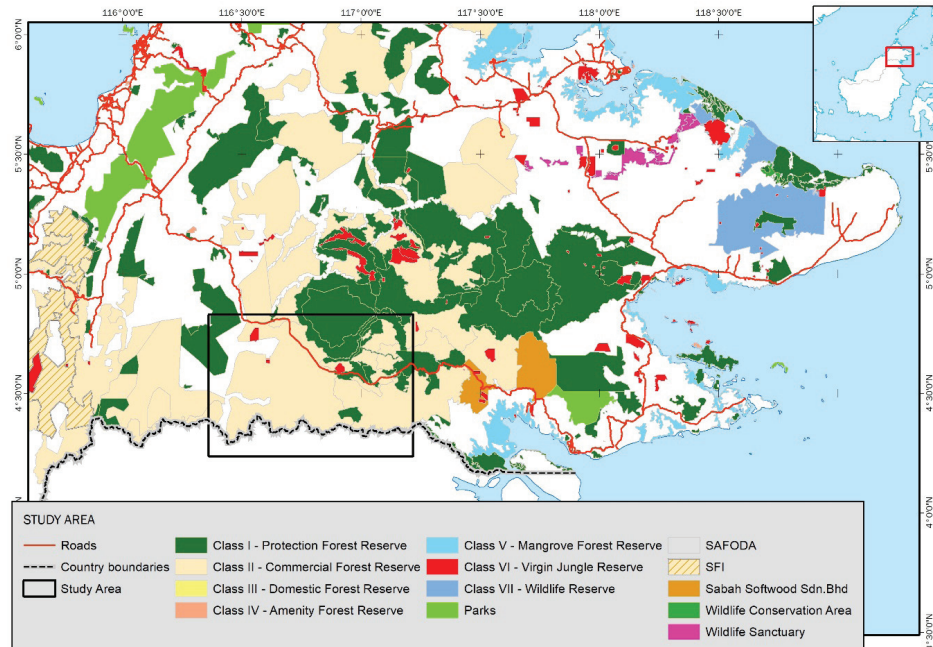


Figure 21 Study area: Sapulut FR

### DATA USED

Elephant habitat preference in this study is built through Maxent modeling (Phillips et al. n.d.), based on the elephant's point of existence and several environmental factors, which become the determination, through the maximum entropy approach. The elephant's existence data is received from the mapping of GPS Collar result and field survey conducted during the period of 2014-2016 by WWF Sabah.

Environmental factors used in building the elephant habitat modeling in this study, refers to the elephant habitat study conducted in Malaysia Peninsula (Wadey et al. 2018), those are slope, wetness index, and distance to road. Slope is derived from digital elevation model from ALOS Global DSM 30 meter (©JAXA). Wetness index is generated from the transformation in the six channels of multispectral citra Landsat 8 OLI of composite acquisition year 2016-2019. Road network information is interpreted visually in the panchromatic Landsat 8 OLI channel. All data (ALOS Global DSM and Landsat 8 OLI imageries) are downloaded through Google Earth Engine platform.

## 3.3 RESULTS AND DISCUSSIONS

### ELEPHANT HABITAT PREFERENCE

#### *Distance to road*

Result of habitat modeling with Maxent shows strong spatial relation between elephant distribution and habitat distance to road, especially the main road. Distance to road has become the dominant factor (70%), compared to the other two factors in influencing elephant habitat preference in Sapulut FR. Elephant distribution seems to overlap with the perimeter of main roads, logging roads and local roads.

With the main road as the largest concentration, elephant distribution can be found on the south and north side of the road, with the tendency of larger population on the south side. Further study is needed to reveal whether elephant herds in Sapulut FR area has the tendency to do road crossing, or if the separated herds show two isolated populations blocked by road infrastructure. If in fact both are isolated populations, then the road has become an obstacle for elephant herds to migrate. If not, then it means the elephants have the tendency to do road crossing despite the high risks of getting hit by vehicle.

This result is in line with the elephant behaviour research in Malaysia Peninsula, which tends to concentrate on the road side (Wadey et al. 2018). From the research, it is known that elephant has a preference to road crossing (with 2-3 lanes, road width is around 25 meters). The main factor influencing the road crossing behaviour is assumed the busy road traffic. Elephant in Malaysia Peninsula is more often to cross the road at night, when the road traffic is less busy.

Referring to wildlife vulnerability to road category (Jaeger et al. 2005), then elephant in Sapulut FR area can be assumed as animals with low roads and high car avoidance. Low roads avoidance shows that elephant in Sapulut FR has the tendency to approach the roads, yet on the other side, high car avoidance shows that elephant has awareness towards busy road traffic when it is road crossing. Keeping in mind, both populations in the northern and southern side of the roads in Sapulut FR are the same herds with the tendency to do road crossings.

### ***Wetness Index***

One of the environmental factors known as elephant habitat preference is vegetation cover. Elephant tends to choose tight vegetation as its main habitat, yet elephant also likes bare area and secondary forest as they provide more food sources than primary forest (Sitompul et al. 2013, Sukmantoro et al. 2019). In this study, the wetness index is extracted from Landsat 8 OLI, and then used as an approach in scoring the vegetation gradient. With the assumption, the higher the wetness index, the higher the humidity and it reflects the tightness of the vegetation condition. On the other hand, lower wetness index shows loose vegetation condition.

Maxent modeling result shows that elephant distribution in Sapulut FR tends to be in the loose vegetation, indicated by the low wetness index point. Referring to the forest cover map (Figure 2), it shows that the elephant distribution is associated with bare area, logging forest, palm plantation and acacia plantation. This result is in line with the research of elephant habitat preference in Malaysia Peninsula (Wadey et al. 2018), which also shows elephant tends to choose bare area (indicated by low wetness index) as it provides more food sources.

### ***Slope***

Maxent modeling result shows that elephant distribution in Sapulut FR tends to choose slope with flat or even condition, and avoids steep slope. This is in sync with several other experiments which also shows elephant habitat preferences to avoid steep slope (Alfred et al. 2010, Sitompul et al. 2013, Wadey et al. 2018).

The result of elephant habitat modeling in Sapulut FR, considering the three factors above, is shown in Figure 3. High habitat compatibility is described with redder colour, where as low habitat compatibility is described with bluer colour.



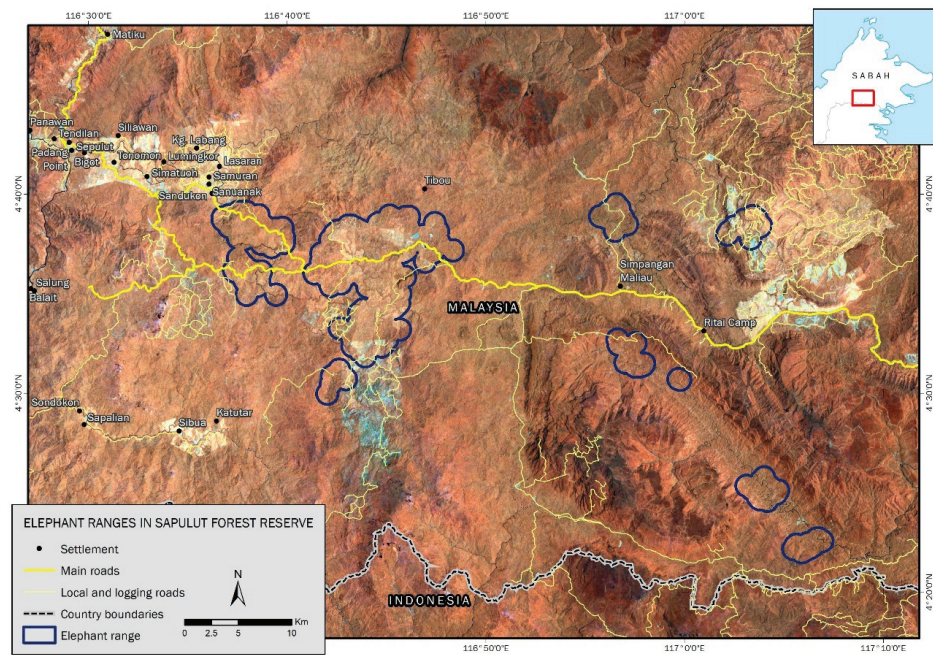


Figure 22 Elephant distribution Sapulut FR

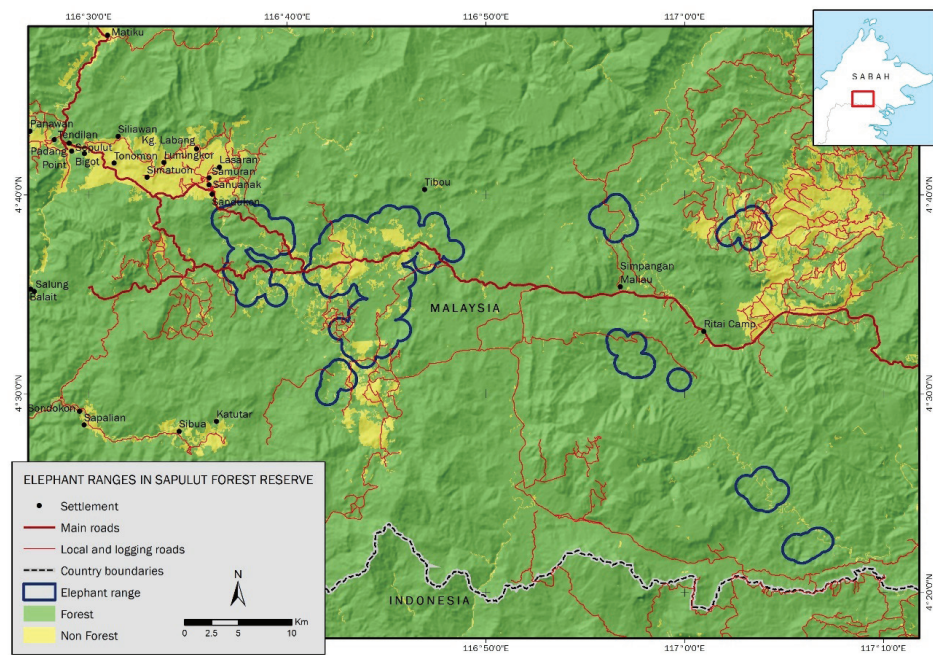


Figure 23 Elephant distribution in forest and non-forest mosaic in Sapulut FR.

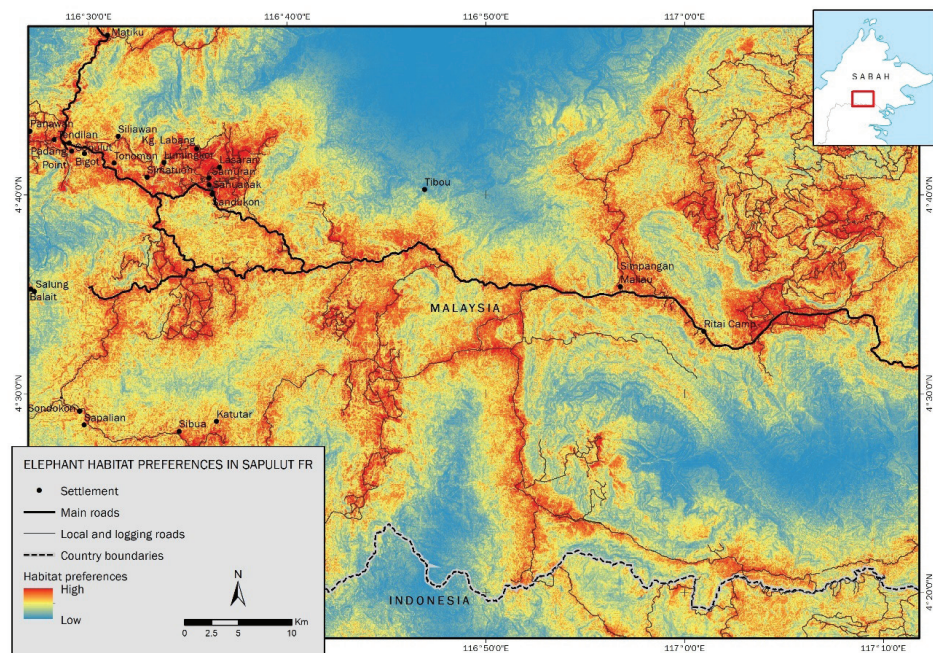


Figure 24 Elephant habitat preferences in Sapulut FR as a result of Maxent's modeling with consideration of distance to road, slope, and index of wetness, showing vegetation growth gradient.

## ESTIMATED ECOLOGICAL IMPACTS

### *Forest degradation potential*

Road widening activities are often accompanied by many land openings on the forested areas. The ecological impacts on the landscape, whether it is change in vegetation structure to potential display of air pollution, noise, and light from a variety of road widening and road infrastructure development, are starting from 300 m to 5 Km from the expanded road (Barber et al. 2014). In this study, with the assumption that the ecological impact caused from the road widening plan in the study area, is as far as 1 Km from the side road. Forest degradation risk is modeled considering the distance to road and slope. Assuming forest degradation risk will get higher as it gets closer to road and flat slope.

Road widening plan in the study area is estimated to create ecological impact on forest degradation as wide as 41 thousand hectares. The degradation can be in the form of losing some forest vegetation or changes in vegetation structure due to the unveiling of forest area, in the road widening activities. When bare areas on the side of the road turn to be an access for forest encroachment, degraded forest will eventually become deforested. Such forest degradation is estimated to cause loss as in carbon emission as big as 8.3 million Tons.



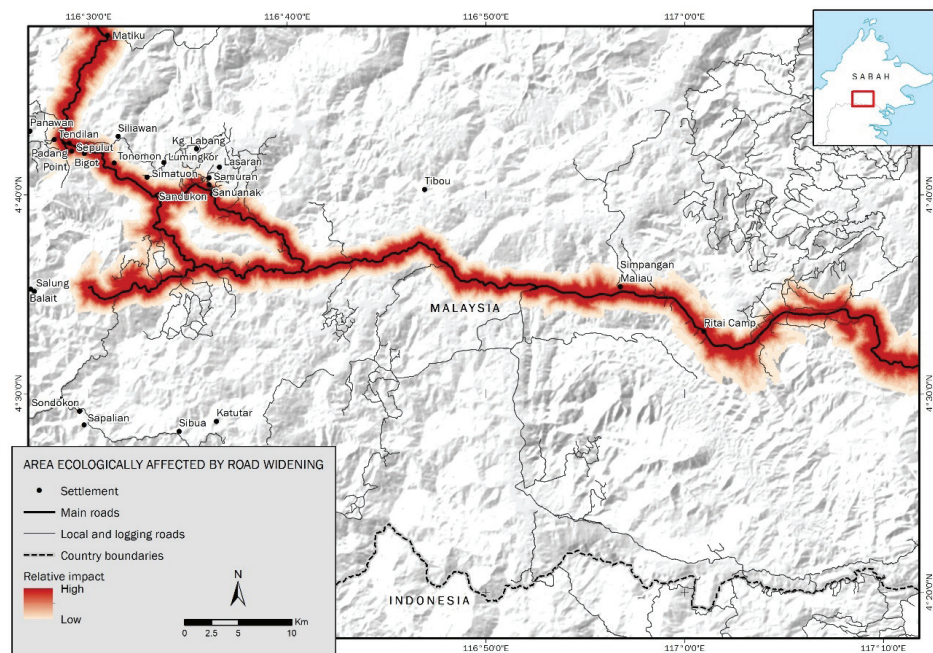


Figure 25 Relative impact on road corridors based on road widening plan

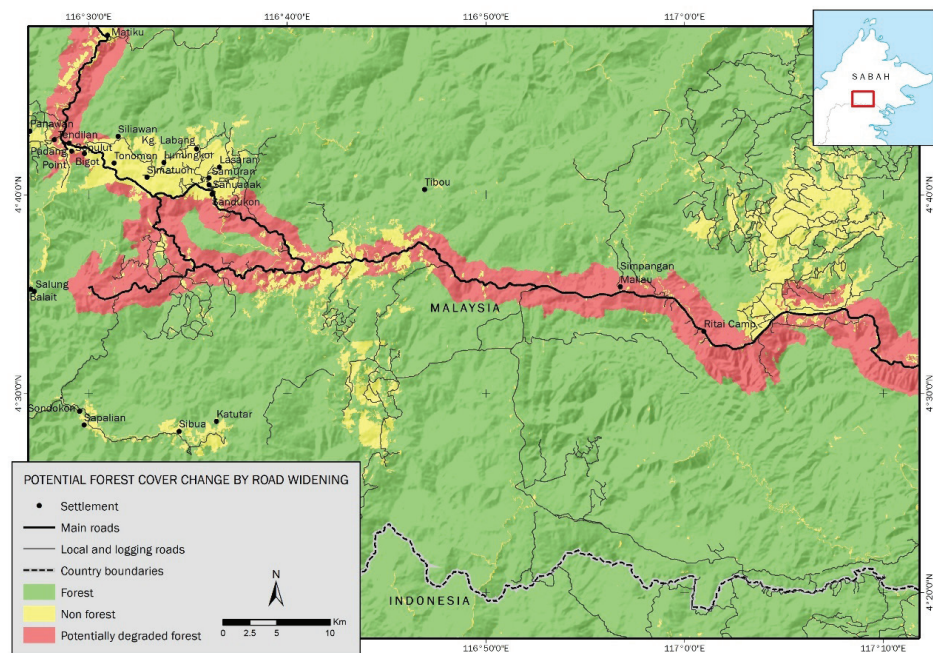


Figure 25 Deforestation potential affected by road widening plan



### ***Impact towards elephant habitat***

Based on the modeling result above about elephant habitat preferences and behaviours, in respond to road infrastructure as well as forest degradation potential caused; road widening plan from 2 lanes to 4 lanes, needs to be considered. Road widening will cause new sink, as more bare areas are attracting more elephant herds to approach the roads. Bare area with succession vegetation such as grass and shrubs are well-liked by elephants, causing elephant concentration in that area. This is very dangerous as the risk of elephant death will get higher due to road traffic accidents; as road widening will encourage higher road traffic. This also will facilitate elephant tusk hunter in illegal hunting, and will raise the conflicts between humans and elephants.

The status of Sapulut FR region alone, as it is a commercial forest, has a high tendency of land use change. Management of the area is needed, such as long-term reforestation activities on the road corridors to avoid being elephant concentration point; corridors development for elephant habitat connectivity; bridges development, viaduct, and other green infrastructures to accommodate elephants in road crossing migration; as well as reinforcing the anti elephant hunting along the roads.

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# BORNEO FOREST FACTS

PAPER FROM  
RESPONSIBLE  
SOURCES

## FORESTS LOSS

About half of Borneo's natural forests have been lost and losses continue at a rapid pace.

## 3<sup>rd</sup> LARGEST

Borneo is the third largest island on the planet.



## 850,000

Between 1985 and 2005 Borneo lost an average of 850,000 hectares of forest every year. If this trend continues, forest cover will drop to less than a third by 2020.

## 75.5 MILLION

East Kalimantan alone is believed to lose over €75.5 million a year in business tax revenue due to illegal logging and illegal timber processing.



### Why we are here

To stop the degradation of the planet's natural environment and to build a future in which humans live in harmony with nature.

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