Project Methodology and Results Report

AN APPROACH FOR MAPPING AND ASSESSMENT OF THE KATINGAN CORRIDOR LANDSCAPE FOR ORANGUTAN CONSERVATION

Definition of terms:

1. **Analysis Unit / Area of Interest (AoI)** refers to a square of the coverage area analyses, both inside the Katingan Landscape (the area of Sebangau, Bukit Raya Bukit Baka and connecting area) and outside the Katingan Landscape (Tanjung Puting). The total area is approximately 13 million hectares.

2. **Katingan Landscape** comprises areas of Sebangau National Park (SNP) and Bukit Baka Bukit Raya National Park (BBBRNP), including connecting areas between both SNP and BBBR-NP known as the Katingan Corridor. The total area of Katingan Landscape is approximately 2.3 million hectares.

3. **Katingan Corridor** is the connecting area between Sebangau NP and Bukit Raya Bukit Baka NP, covering a total area of almost 1.5 million hectares.

4. **Critical Linkage Area** is the fragmented area inside the Katingan Corridor due to be divided by linear infrastructure and other land uses, such as designated concessions, as a target to improve the connectivity for accommodating orangutan mobility inside the Katingan Corridor.

5. **Land Use and Land Cover (LULC)**, "land use" means complicated aspect as it involves social sciences and management principles and is defined as the social and economic purposes and contexts for and within which lands are managed. Land cover refers to the physical and biological cover over the surface of land, including water, vegetation, bare soil and/or artificial structures.

6. **KPH, Kesatuan Pengelolaan Hutan (forest management unit)**

7. **KPHP, Kesatuan Pengelolaan Hutan Produksi (production forest management unit)**

8. **KPHL, Kesatuan Pengelolaan Hutan Lindung (protected forest management unit)**

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I. INTRODUCTION

Habitat fragmentation occurs worldwide, affecting tropical forests in locations such as the Amazon, Congo and Borneo. Fragmentation continues due to linear infrastructure development (e.g. roads, drainage, power lines and pipelines), forest conversion, agricultural expansion and other land use (W. F. Laurance 2001; Curran et al. 2004). Infrastructure development accelerates to meet production targets as a response to the demands of economic growth, driven not only by spatial planning policy for regional development, but also by unplanned activities such as private and illegal roads for logging and encroachment. This is different from conservation approaches, which are mostly at the site level and offer a more sectoral approach. Therefore, the regional development plan is less concerned with habitat integrity as a basic requirement to maintain wildlife habitat quality and their spatial range. Hence, site-level conservation approaches are insufficient to maintain the biodiversity outside protected areas and need to move toward using landscape approaches. For example, the landscape corridor can impact species migration and affect seed dispersal by birds from one place to another (Levey et al. 2005).

In Indonesia, the government is currently focusing on infrastructure development to accelerate regional economic development through Presidential Decree No. 58/2017 relating to national strategic projects. Infrastructure is a basic requirement for the generation of sector activities and increased productivity. This policy, of course, has positive and negative effects. On one hand, it improves the conditions needed to provide goods and services, while on the other, it negatively impacts habitat quality and the environment. For example, construction of new roads often results in habitat loss and fragmentation, leading to indirect impacts such as exploitation by encroachers of high conservation value areas by opening access. This often goes unnoticed by the project owner and developer, whose responsibility it is to reduce the negative impacts of infrastructure development in the mitigation plan. Furthermore, regulations such as Presidential Decree No.13/2012 relating to island spatial planning mandates the establishment of functioning ecosystem corridors to maintain high conservation value areas, while simultaneously allowing for land use purposes that accommodate economic activities without strong guidance for controlling the behaviour of the road and land user. However, these regulations are not synchronised or coordinated across other ministries or sectors (e.g., infrastructure construction regulation). Therefore, focusing on economic development without considering its repercussions for the environment can ultimately lead to the degradation of both forest quality and quantity.

Sebangau National Park (SNP) in the Indonesian province of Central Kalimantan is renowned as a natural habitat for the Bornean orangutan (Pongo pygmaeus sp.). Their distribution is within and outside the SNP

boundary, toward Bukit Baka Bukit Raya National Park in an area between two major rivers – the Kahayan and Mendawai - located in the northern section of the park (Figure 1). The area connecting these two national parks is known as the Katingan Corridor.
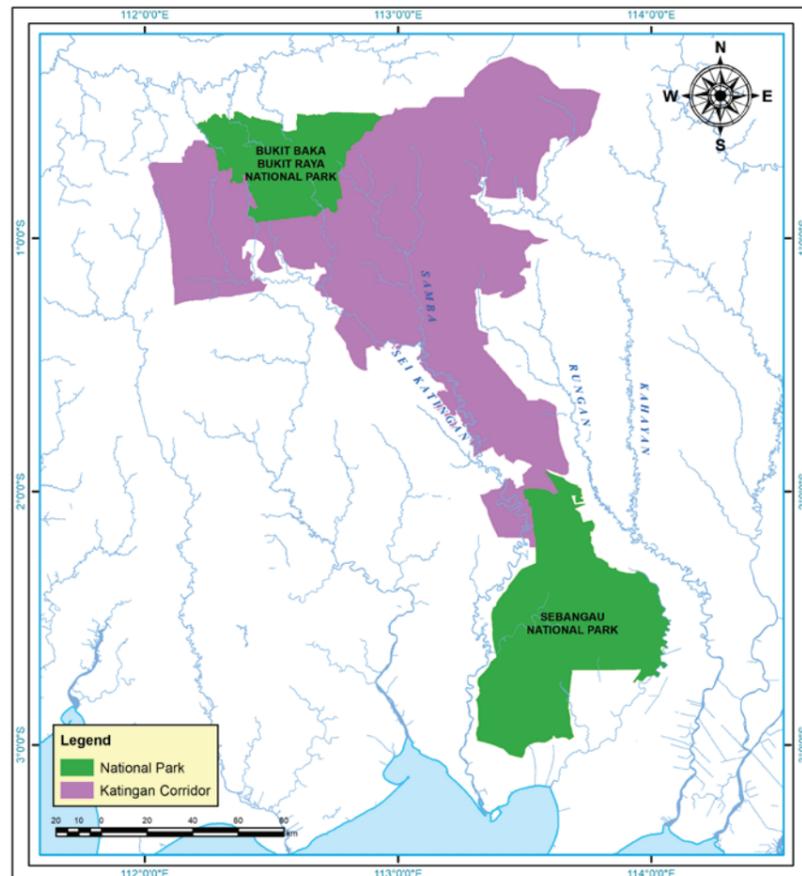
Figure 1. Katingan corridor located between two major rivers: Kahayan and Mendawai

In general, the current portrait of the Katingan Corridor is heavily fragmented by the trans-Kalimantan highway, canals and powerlines. The highway was built to connect Palangkaraya and other cities in Central Kalimantan (such as the capital of Katingan district in Kasongan) to West Kalimantan. Furthermore, some parts of the corridor are degraded and deforested due to illegal mining, intensive agriculture and plantation establishment. Up until 2010, Katingan Corridor was predominantly covered by secondary forest. However, the following year the land started being cleared for oil palm and rubber.

The baseline data of the Katingan Corridor provides limited information relating to necessary management actions. Therefore, further mapping and analyses of the Katingan Corridor are required in order to understand the biophysical context more comprehensively. Mapping of the corridor can be conducted using a combination of visual techniques and automatic delineation through morphological image processing (Vogt et al. 2007). In a similar project, the fragmentation of the RIMBA corridor required delineation for effective management of wildlife and target road segments (Sulistyawan et al. 2017).

This study aims to map and identify priority areas for orangutan movement within Katingan Corridor by using automatic corridor delineation tools based on Land Use and Land Cover (LULC) data from 2005, 2010, 2015 and 2017/2018. A number of methods were used, including remote sensing to generate LULC information, spatial analysis for calculating the forest cover and land use changes and spatial modelling, which created a projection for future conditions and delineated an effective corridor based on orangutan distribution in HCV areas in the corridor buffer. This study will ultimately be used to provide recommendations for management action.

The main contribution of this project is to bring conservation into regional planning and develop a strategy for managing the corridor between two conservation areas. Landscape corridors in Indonesia do not have a single protected status; land with multi-use status (e.g. production forest, production forest conversion, and other land use) poses a challenge, as stakeholders must be convinced of its conservation importance. The goal of this corridor is to establish connectivity for orangutan movement in order to stabilise their habitat, while also facilitating opportunities for economic development and further environmental protection.

II. APPROACHES AND SCOPE OF ASSESSMENT

The Katingan landscape corridor assessment will address several key questions through the multi-pronged approach using both remote sensing and spatial modelling analysis.

The study seeks to provide answers to the following questions:
1. How has LULC changed since 2005?
2. What is the extent of forest degradation in the Katingan Corridor?
3. What is a projection of LULC for 2029/2030 based on its current condition?
4. Where is a Critical Linkage Area for connecting the fragmented habitats?
5. Where does forest connectivity need to be improved and/or protected as part of Forest Landscape Restoration (Integrated Landscape Management)?

There are several definitions related to forest degradation. According to FAO, forest degradation means changes within the forest that negatively affect the structure or function of the stand and site, thereby lowering its capacity to supply products and/or services (FAO, 2002). ITTO defines degradation as changes in forest structure, dynamics and functions, resulting primarily from human-induced causes relative to a preferred condition (ITTO, 2002). According to UNFCCC, forest degradation is defined as 'direct human-induced long-term loss (persisting for X years or more) of at least Y per cent of forest carbon stocks (and forest values) since time (T) and not qualifying as deforestation' (IPCC, 2003a). In order to remain consistent, this study used the FAO definition of forest degradation for conducting analyses, because the previous classification of secondary data already referred to the FAO system.

FOREST DEGRADATION NOT ONLY CONCERNS THE REDUCTION OF WOODLAND, BUT ALSO A DECREASE IN BIOMASS, SPECIES COMPOSITION AND SOIL QUALITY (RESULTING IN SOIL DEGRADATION)

However, the threshold of forest cover in relation to forest degradation is quite different. For example, FAO defines a dense forest as a crown canopy above 40% and open forests between 10-40%. UNFCCC defines as a forest with a crown canopy above 30% and lets each country decide on its own definition for crown canopy between 10-30% (Sasaki and Putz 2009).

To assess forest degradation, it is essential to analyse data covering more than one year, because degradation is about the process of land cover changes. By using remote sensing technology and by conducting repetitive measurements of spectral, temporal and spatial indicators, forest degradation can be accurately identified. Any in-depth understanding of the processes of forest degradation must be based on accurate monitoring of the degradation over large areas, for at least a decade (Lambin, 1999).

By conducting spectral, temporal and spatial indicator measurement in the landscape, it can be determined whether a forest landscape is experiencing degradation or regrowth. The spectral aspect relates to the quality of the forest in terms of density or health, while the temporal aspect provides information on the rate and timing of forest degradation. The spatial aspect provides specific information with regards to locations undergoing degradation.

LULC encompasses two different terms: Land Use and Land Cover. Although similar, there are subtle differences between these two concepts. Land Cover refers to surface cover on the ground, which usually includes vegetation, water, bare soil and infrastructure; Land Use describes how the land is used by people for a specific purpose, such as agriculture or settlements. Land Cover is determined by direct observation of the earth's surface, whereas Land Use is a socioeconomic interpretation of the activities that take place on that surface (Fisher, et al., 2005).

LULC can be divided into three main types (Blaschke & Strobl, 2001):

Table 1. Method of land use landcover interpretation with their pros and cons (Blaschke & Strobl, 2001)

Type	Advantages	Disadvantages
Manual interpretation	Can be fairly accurate	Subjective
	Limited image preparation required	Time consuming
	Commonly used to make resource management maps	Inconsistent among interpreters
	Comprehensive, uses human knowledge to make logical decision	Expensive
	Well-developed discipline (in some regions)	Dependent upon interpreter's experience
		Requires well-trained and experienced interpreters
		Accuracy standards vary widely
Pixel-based classifiers	Systematic	Arbitrary analysis unit (pixel)
	Consistent	Tend to use only spectral information
	Repeatable	Less suited to analysis of high spatial resolution imagery
	Many well-developed and affordable software packages are available	Can produce speckled 'salt and pepper' results
	Pixel-based accuracy assessment techniques are well developed	

Table 1. Continued

Type	Advantages	Disadvantages
Object-based classifiers	Systematic Consistent Repeatable Ability to incorporate multiple scales Better mimics human perception of objects Integrates attributes important to landscape analysis (tone, shape, size, texture, context)	Object creation is difficult and can produce unexpected results Less availability and affordable of software Better suited to high spatial resolution imagery Object-based accuracy assessment procedures less developed

This study used object-based classifiers (object-based image analysis/OBIA), also known as Geographic Object-Based Image Analysis (GeOBIA). This is the latest technique that promises to overcome the significant limitations of previous techniques in its ability to consistently and accurately detect an object. The technique is relatively new, having been first developed in the 2000s, and thus requires time to be widely used.

Land cover projections are developed based on previous examples of land cover, allowing us to accurately estimate and forecast the continuation of current trends (business as usual). With adequate historical data and awareness of future regulations or policies (such as land use planning), we can collate this information and create tools to ascertain a clearer picture of LULC. This method is based on limited development and restricted land zoning (Van Der Laan, 2016).

LULC change is generally based on the fulfilment of basic human needs, i.e., food and housing needs through development. Economic development scenarios represented by changes in LULC are important in anticipating possible impacts in the future. In the context of ecosystem services, the development of scenarios is important when examining potential environmental degradation that may occur due to development processes within a region.

Modelling LULC scenarios is complex, as it involves economic, social and political considerations as driving factors (Lambin and Giest 2001); the integration of these factors themselves is particularly challenging in terms of methodology. Moreover, not all of them can be spatially depicted (Veldkamp and Lambin, 2001). Thus, we can use certain variables as proxies for these factors. These variables would be the actual impact of a driver, such as the distance to the road from the transition of the land cover and the location of land use change taking place.

III. STUDY AREA AND ANALYSIS PHASES

3.1. Study area

a) What is Katingan Corridor?

The Katingan Corridor is a connecting area between two national parks (SNP and BBBRNP). It covers around 1.4 million hectares of land. Administratively, the area covers three districts, namely Katingan District, Gunung Mas District and Palangkaraya City. At a stakeholder meeting held in Kinabalu City in March 2016, the Katingan Corridor was confirmed as a priority landscape of Kalimantan, due to its connectivity between Sebangau peatland forest and the Muller-Schwaner mountain range. The distance between these two areas is 180km. In this corridor, national roads, high voltage electricity networks (SUTET) and canals stretch from west to east, dividing the region into two sections - north and south.

Legend

- District capital
- High Voltage Overhead Power Line Tower
- Arterial road
- Collector road
- Sebangau National Park
- Katingan Corridor
- Forest Cover 2017
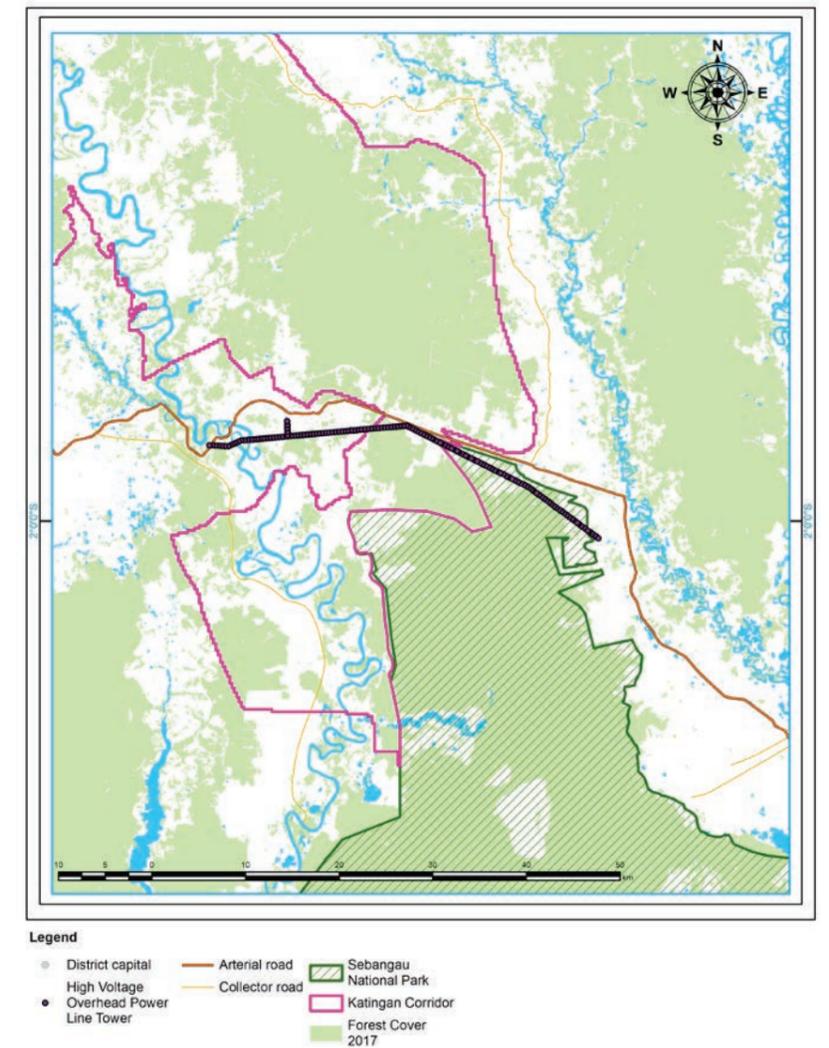
Figure 2. Road and electricity network in Katingan Corridor

The road in this area forms a straight line, approximately six metres in width. The relatively flat topography of the region, combined with the absence of major obstacles along the route, negates the need for bends in the road and allows it to follow a consistently straight trajectory. SUTET in this region consists of towers that connect high-powered cable networks. The distance of these towers to the road body is approximately 1.5-2km . These towers are constructed on land that has forest area status. The canals exist on the roadsides and in plots of land adjacent to the roads; plots that are generally reserved for plantations. These plantations produce commodities such as palm oil (Elaeis guineensis), rubber (Hevea brasiliensis) and jelutung (Dyera spp.) but can also include wild acacia (Acacia denticulosa).
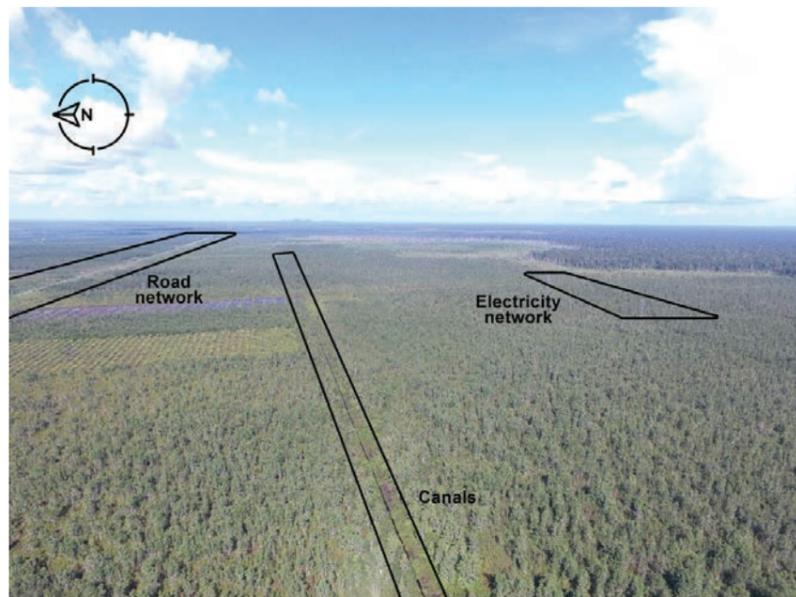
Figure 3. Three linier infrastructures in Katingan Corridor: road, canals, and electricity.
Source: gadzan@wwf.id

Referring to the Decree from the Ministry of Environment and Forestry No. SK. 6025/MENLHK-PKTL/KUH/PLA.2/11/2017 regarding the Development of Central Kalimantan's Forest Establishment, the northern part of this corridor functions predominantly as production forest under the management of Production Forest Management Unit (KPHP) XVII Kalteng - also known as KPHP Katingan Hulu Unit XVII according to SK.2/ MENHUT-II/ 2012/09/11/2016. Further to the north, the corridor joins the Bukit Baka Bukit Raya National Park area. To the south of this corridor, Sebangau National Park is an area of approximately 568,000 hectares.

Figure 4. Katingan corridor as connector between two national parks

b) Why must the Katingan Corridor be protected?

This area connects the main orangutan habitat in Sebangau National Park to the Bukit Baka Bukit Raya National Park, which currently serves as a location for releasing orangutan from the Borneo Orangutan Survival Foundation (BOSF) into the wild. In addition to orangutan, other endangered species are present in this area, including the sempidan Kalimantan (*Lobiophasis bulweri*), binti bird (*Ciconia stormi*) and Bornean tortoise (*Orlitia borneensis*).

The corridor is also significant for socio-economic reasons; it acts as a rainfall catchment area and supplies water for local communities. Many people in the region rely on the forests for their food security and see the corridor as an effective means of reducing human-wildlife conflicts, particularly between people and orangutan (Suryanto, 2017).

3.2 Stages of assessment

WWF activities inside Katingan Landscape were first initiated in 2001 and continue to the present day. In 2001-2002, various economic activities began in the area surrounding Sebangau, including land clearing for plantations. In 2010, similar activities began around Bukit Baka Bukit Raya. In 2012 WWF initiated rattan cultivation activities along the Katingan River as part of efforts to optimise commodities of Non-Timber Forest Products (NTFP) in forested areas.

In 2017, Central Kalimantan Governor Regulation No.10 helped to establish KPH and governance in Central Kalimantan, consisting of 16 KPHPs and two KPHLs with a total of 33 units of land in the area approved. KPHP Katingan Hulu has a management area of 17 units, with more than 711,379 hectares located in Katingan District.

From April to June 2017, the Conservation Science Unit (CSU), together with WWF-Indonesia's Central Kalimantan Programme, conducted a baseline study in the Katingan Corridor. The study (Suryanto, 2017), demonstrated that communities in areas adjacent to the corridor generally agree with plans for its creation. The community has also expressed an interest in the wildlife and its movements, determined through assessments by WWF-Indonesia, as these areas would be potentially designated as community-owned land.

Following up on the previous study, the CSU team and WWF-Indonesia conducted an ecological study in Katingan Corridor using Geographical Information Systems (GIS) and Remote Sensing for analyses of land cover classification, land change modellers, and InVEST Scenario Generator.

These activities were conducted as follows:
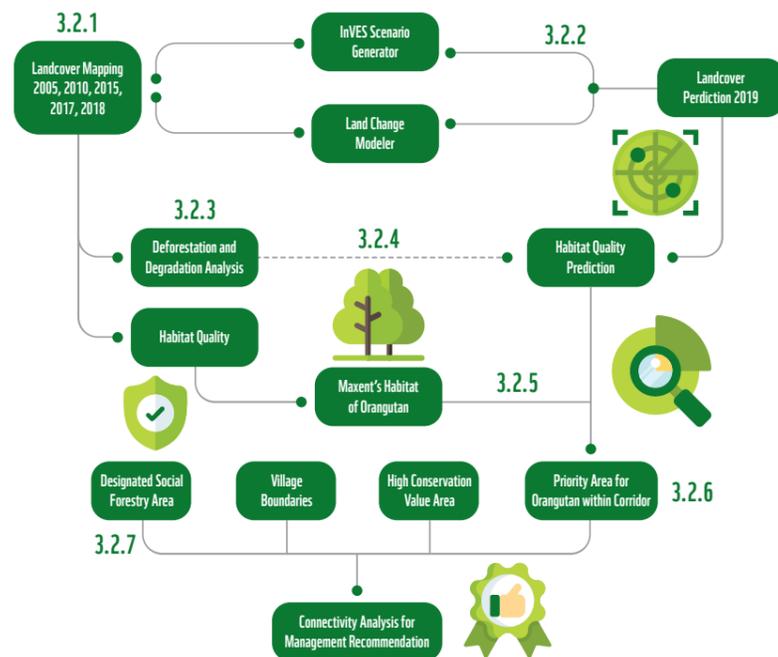
Figure 5. Overall process to define priority area within Katingan Corridor

3.2.1 Mapping land cover using remote sensing and GIS techniques with cloud computing technology
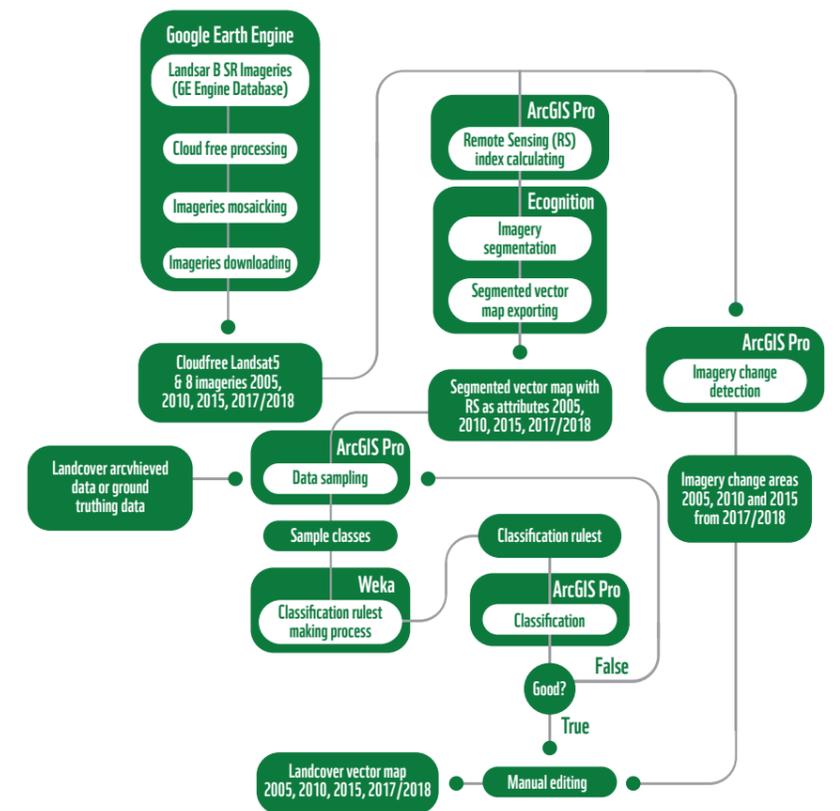
Figure 6. Flowchart of LULC mapping process including deforestation rate analysis

The mapping process begins with the preparation of Landsat 5 & 8 imagery for 2005, 2010, 2015 and 2017. We used Google Earth Engine (GEE) to produce cloud-free images. GEE is a web-based cloud computing platform used for processing earth observation data. GEE provides extensive earth observation data through powerful servers. The Google Earth Engine with code editor can found at https://code.earthengine.google.com/. We used JavaScript to process the imagery.

First, we accessed Landsat 5 & 8 surface reflectance imagery in GEE database ('LANDSAT/LC08/C01/T1_SR' and 'LANDSAT/LC05/C01/T1_SR'). Second, for each selected year of study, we acquired imagery through cloud-free processing for one year before and after the given year (for example, to produce cloud-free images for 2005, we used Landsat images from 2004, 2005 and 2006). Thirdly, we created a mosaic of cloud-free results, composited into one image and downloaded to achieve the desired results.
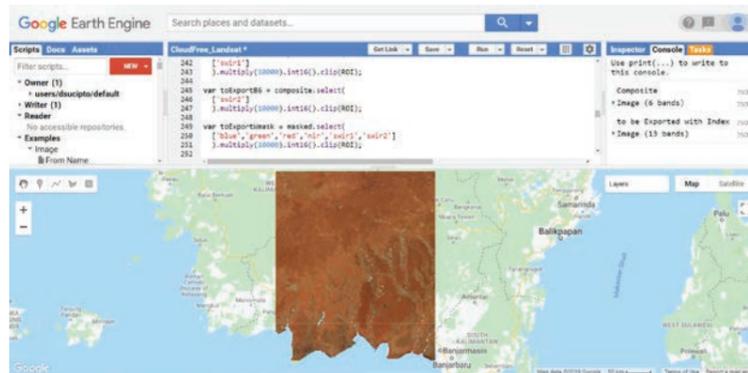
Figure 7. Google Earth Engine (GEE) interface with the main working panels on the top and the mapping panel on the bottom

We used trial Ecognition v.9.1 for the segmentation of images downloaded from GEE. Image segmentation is the process of partitioning a digital image into multiple segments (sets of pixels, also known as super-pixels). The result from Ecognition is a vector map (shapefile) that was then used for data sampling to represent classes of land use in ArcGIS Pro (version 2.2). The result was sample classes.

The sample classes were then analysed using WEKA v.3.8.2 to produce a classification rule set. WEKA (Waikato Environment for Knowledge Analysis) is a workbench for machine learning that is intended to aid in the application of machine learning techniques to a variety of real-world problems (Frank et al. 2005). In WEKA, we used a decision tree algorithm to make the rule set. Decision tree algorithms begin with a set of cases (or examples) and create a tree data structure that can be used to classify new cases (Quinlan 1992). This rule set is used with the segmented vector map in ArcGIS Pro to produce a map for the classification of LULC. A decision tree can be changed to refine the object classifications. The end result is a LULC map of the Katingan Corridor. The process was repeated to develop maps for 2005, 2010, 2015 and 2017/18.

Figure 8. Tree visualization from sample of decision tree

We used two approaches for projections landcover: Land Change Modeller (LCM) and InVEST Scenario Generator. The main difference between the two is the influence of input factors. The LCM uses historical changes to produce input factors and spatial presentation, whereas the InVEST Scenario Generator tool relies on input factors such as expert knowledge and/or stakeholder consultations to predict future land use policy interventions, such as spatial planning.

a. Integrated Valuation of Ecosystem Services and Trade-Offs (InVEST) Scenario Generator
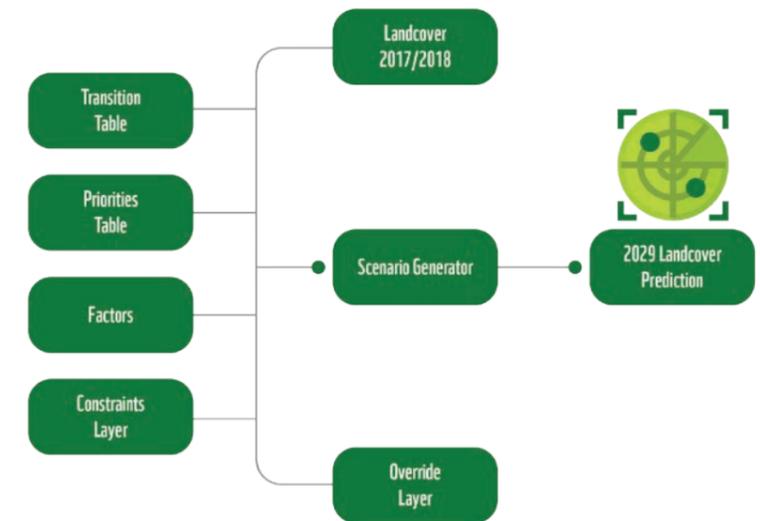
Figure 9. LULC projection using InVEST Scenario Generator

InVEST Scenario Generator assists in the process of allocating LULC changes to other purposes that are essentially multi-criteria analyses, influenced by various factors as drivers. In the process of participatory mapping, these drivers can arise from a variety of relevant stakeholders, who may have interests and objectives that may differ from one to another. On the other hand, land suitability factors can limit the transition to possible LULC changes (e.g. slope, elevation, soil type etc.). Ideally, all information and issues that could potentially affect the prediction are obtained from workshops involving all relevant stakeholders, including government, private sector, academia and society. For this study, input was provided by the WWF-Indonesia team based in Central Kalimantan.

The major components of the input for InVEST Scenario Generator are: i) the transition likelihood, ii) the physical and environmental factors that influence change and iii) the extent of anticipated change in a given scenario.

b. Land Change Modeller (LCM)

The process of LCM covers four steps as described in Figure 10. Land Cover change analyses used for the Katingan Area of Interest are from 2010 and 2017.
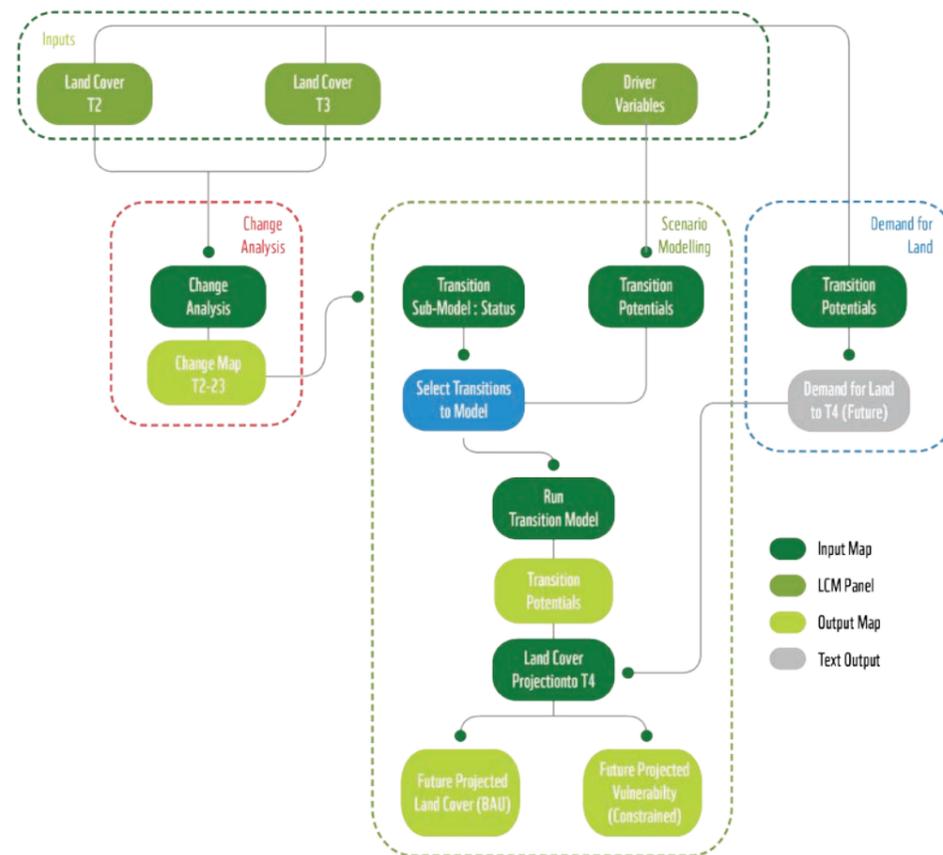
Figure 10. Change Prediction Process Workflow in LCM

The study incorporated two approaches. The first was Business As Usual (BAU), in which changes rely solely on historical data and variables compiled from 2010 to 2017; the second method optimised additional data and spatial planning maps (constrains) to control changes, specifically in relation to forests.

The regulation in question was province-level spatial planning. We used trends in land use change as input data for the creation of projection maps, based on maps from 2005, 2010, 2015 and 2017.

3.2.3 Deforestation Rate and Degradation Analysis

3.2.3.1 Deforestation Rate Calculation

The calculation based on FAO 1995 (Puyravaud, 2002):

$$r= 1/(t_2-t_1) \ln A_2/A_1$$

Where r = deforestation rate, A1 and A2 are the forest cover at time t1 and t2 with unit per year or percentage per year.

3.2.3.2 Forest Degradation Analysis

The analysis using Forest Canopy Density (FCD) Mapper tool, with threshold of forest density as follow:

Table 2. Forest density classification

Class	Forest Cover Density
low dense forest	< 40 %
moderate dense forest	50 - 70 %
high dense forest	> 70 %

In analysing forest degradation over a period, the first thing to determine is which forests are consistent throughout the time period analysed. Cloud cover must also be taken into consideration, as this can be an obstacle to accurate analyses of forest degradation.

3.2.4 Habitat Quality Analysis

After developing LULC data - both current conditions and projections - we can conduct habitat quality analyses by using the data as our main point of reference
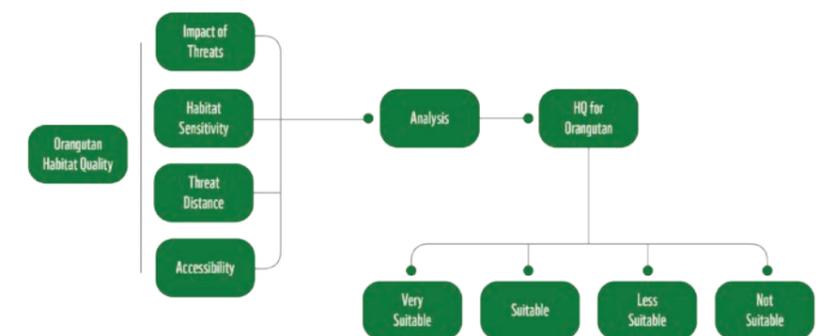
Figure 11. Flow process of habitat quality assessment

Biodiversity in an ecosystem is an indicator of its productivity. When biodiversity conditions are disrupted, the ability of an ecosystem to produce resources will decrease.

InVEST habitat quality modelling analyses biodiversity (habitat and vegetation) in an ecosystem using the relationship between land cover, land use and threats. The main parameters in this modelling are land cover and land use positioned as habitat units, and factors that are considered a threat to the habitat. There are at least four factors used in the habitat quality model: the relative impact of threat variables, habitat sensitivity to various types of threats, distance between habitat and threat source, and degree of protection of a region (spatial regulatory aspects) (WWF ID Conservation Science Unit, unpublished).

Table 3. List of data required for habitat quality analysis with InVEST

| Data	Type	Source
Land use/land cover (LULC)	Map	Landsat 8 OLI Satellite, mosaicking of imageries from January 01, 2017 to June 31, 2018
Threats data	Table	Source of each threats data:
		1. Drinage layer is taken from Topographic Maps in scale 1:50,000 (Peta Rupa Bumi by Badan Informasi Geospasial, 2013)
		2. Roads layer is taken from Topographic Maps in scale 1:50,000 (Peta Rupa Bumi by Badan Informasi Geospasial, 2013)
		3. Settlement area is taken from land cover maps produced in previous steps
		4. Forest concessions layer is collected from Indonesian Ministry of Environment and Forestry, 2017
		5. Palm oil and mining data gathered by Central Kalimantan team
Source of threats	Map	Same as above
Accessibility to sources of degradation	Map	These layers is integration of some layers: the latest issue of forestry area (kawasan hutan) of Central Kalimantan Province, social forestry area, and moratorium of permits in forestry area by Indonesian Ministry of Environment and Forestry
Habitat types and sensitivity of habitat types to each threat	Table	Value given are based on focus group discussion with WWF's Orangutan expert

Maximum Entropy (Maxent) model (Phillips, et al., 2006) was used to validate the result of habitat quality analysis generated by InVEST. This is most widely used as a Species Distribution Model (SDM). It estimates the distribution (geographic range) of a species by finding the distribution that has maximum entropy (i.e. is closest to geographically uniform) with constraints derived from environmental conditions at recorded occurrence locations. Constraints are defined in terms of 'features' and require the mean of each feature to match the sample mean. This formulation is equivalent to maximizing the likelihood of a parametric exponential distribution.

This requires two main inputs (i.e. samples and environmental layers). The samples used were occurrence data from field surveys conducted between 2012 and 2018. We used near infrared, shortwave infrared 1 and shortwave infrared 2 from Landsat 8 satellite imagery, along with elevation and slope from ALOS Global Digital Surface Model (DSM) as environmental layers. Satellite data proved to be useful in gathering evidence relating to the occurrence of nests built upon certain vegetation, or orangutan occurrence on feeding trees, while multispectral image bands were very useful for distinguishing vegetation types.

The results of prediction will be compared with the results of habitat quality analyses based on survey location. These areas are used because they prove the existence of orangutan within the area.

Table 4. List of data required for species prediction with Maxent

Data	Type	Source
Near Infrared (0.851 – 0.879 μm)	Map	Landsat 8 OLI Satellite, mosaicking of imageries from January 01, 2017 to June 31, 2018
Shortwave Infrared 1 (1.566 – 1.651 μm)	Map	
Shortwave Infrared 2 (2.107 – 2.294 μm)	Map	
Orangutan occurrence points	Map	Survey at 2012, 2013, 2015, 2016, 2017, and 2018 conducted by WWF Indonesia
Elevatio	Map	ALOS Global Digital Surface Model
Slope	Map	
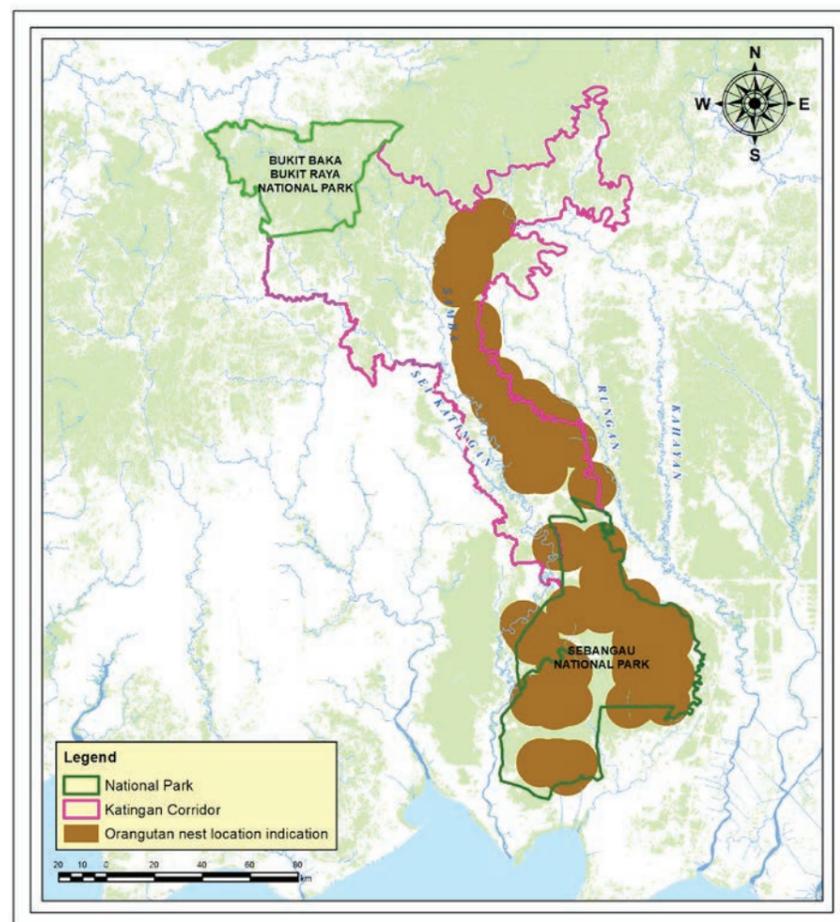
Figure 12. Orangutan nest location(incl. buffer) indication

3.2.6 Identify Critical Linkage Area for Orangutan Movement within Corridor

The main criteria in delineating the Katingan corridor is the connectivity of Orangutan's distribution between Sebangau NP to Bukit Baka Bukit Raya NP. Modelling Orangutan's geographic range from occurrence data has become fundamental.

Identify critical connectivity within Katingan Corridor design for Orangutan's movement is important to determine the minimum width (such as 2 km forest cover) of the Orangutan's pathway, redesign linear infrastructure to improve permeability for crossing, and to inform for applying better practices agriculture practices including the responsible sand mining through restoration post-mining activities.
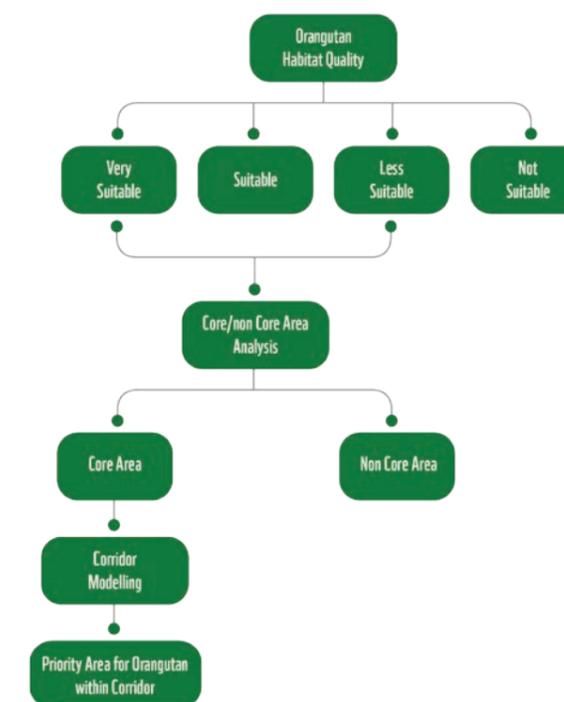
Figure 13. Identification of priority area for Orangutan movement within

For critical orangutan connectivity identification, we use corridor design with a method intended to minimise cost. The main parameters for this purpose are suitability and resistance (Beier, et al., 2008).

The result of habitat quality mapping for orangutan becomes an important basis in determining the form of critical linkage, because the resistance/travel cost map can be created based on this mapping. By adjusting to the behaviour of the animals, core and non-core areas need to be determined (Hadadi, et al., 2016). We can determine these areas by taking the classification from the habitat quality map and accounting for very suitable and suitable classification for the core areas, along with less suitable for non-core habitat areas based on environmental parameters such as the orangutan's preferences for trees, elevation and types of land cover.

Core habitat areas are a priority in determining the starting point of linkage, while non-core habitats are not prioritized. However, there is a possibility of establishing linkage in the area as well. Unsuitable areas for habitat are not considered for linkage. However, this area is considered in terms of its functional suitability as a buffer zone, with which to stabilise land use in the core area through the cooperation of landowner(s) in corridor management and restoration.

3.2.7 Analysis for Management Recommendations

This relates to the collation of results relating to priority areas for orangutan movement, integrated with high conservation value areas, social forestry and village boundaries to develop management recommendations.
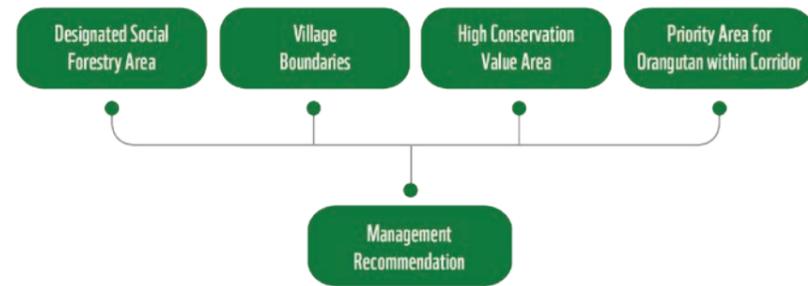
Figure 14. Analysis for Recommendation Management

We used HCVA reports from PILAR (Ibie, et al., 2016) covering the entirety of Central Kalimantan province, then we clipped based on our study area - particularly in Katingan Corridor - focusing primarily between Bukit Baka Bukit Raya NP and Sebangau NP. This is because a national road network that separates this area has a significant impact on orangutan habitat.

IV. RESULTS AND DISCUSSIONS

4.1 Mapping Land Cover

We produced a series of land cover data from 2005, 2010, 2015 and 2017 taken from satellite imagery. Two types of Landsat images were used: Landsat 5 for the land cover of 2005 and 2010 and Landsat 8 for land cover in 2015 and 2017. We avoided using Landsat 7 images due to the stripping problem experienced since 2003 (Figure 15). This problem could potentially reduce the accuracy of the classification process. We did not use Sentinel 2 either, due to the quality of its images in relation to radiometric information; additionally, pre-processing in Google Earth Engine requires a different algorithm from Landsat pre-processing.
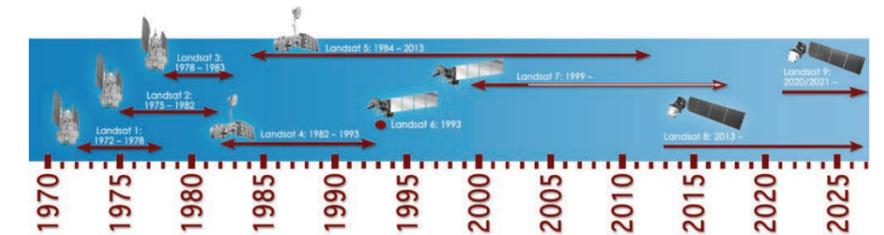
Figure 15. Landsat satellite timeline, source: https://landsat.gsfc.nasa.gov/a-landsat-timeline/

We obtained seven classes of a land cover extracted from the Landsat data (i.e. bare land, forest, forest regrowth, oil palm or rubber plantation, settlement, shrub or mix plantation). The classification process used six bands consisting of Green, Red, Near Infrared (NIR), Infrared (IR), Short Wavelength Infrared 1 (SWIR 1) and Short Wavelength Infrared 2 (SWIR 2). We also used the index to enhance the result of classification: Land and Water Mask (LWM), Normalised Difference Built-Up Index (NDBI), Normalised Difference Vegetation Index (NDVI), Normalised Difference Water Index (NDWI), and Tasselled Cap (brightness index, greenness index and wetness index). Road density, road distance and settlement distance data were also used.

4.1.1 Land Cover 2005 - 2017

Statistical evaluation of each land cover class between 2005 – 2017 within the Katingan Corridor (described in Table 5) indicated the fluctuations of land cover over time.

Table 5. Land cover dynamic 2005-2017 within the Katingan Corridor

Clases	Year (ha)			
	2005	**2010**	**2015**	**2017**
Bare Land	21,131,29	19,438.87	33,206.73	26,802.24
Forest	1,096,214.96	1,037,980.51	1,096,214.96	1,037,980.51
Forest Regrowth	322,046.80	366,442.06	398,978.78	402,433.59
Oil Palm or Rubber Plantation	-	3,941.82	10,195.68	10,379.29
Settlement	49.09	71.25	112.12	128.04
Shurb or Mix Plantatation	32,002.14	43,780.81	42,479.28	54,568.52
Water Bodies	9,031.10	8,820.07	9,772.99	9,504.29
Grand Total	1,480,475.38	1,480,475.38	1,480,475.38	1,480,475.38

In 2005 natural forest cover was approximately 1.096 million hectares. However, this had gradually decreased to 0.976 million hectares by 2017. Forest areas have decreased by an average of 9,962 hectares per year for last 12 years (Figure 16).
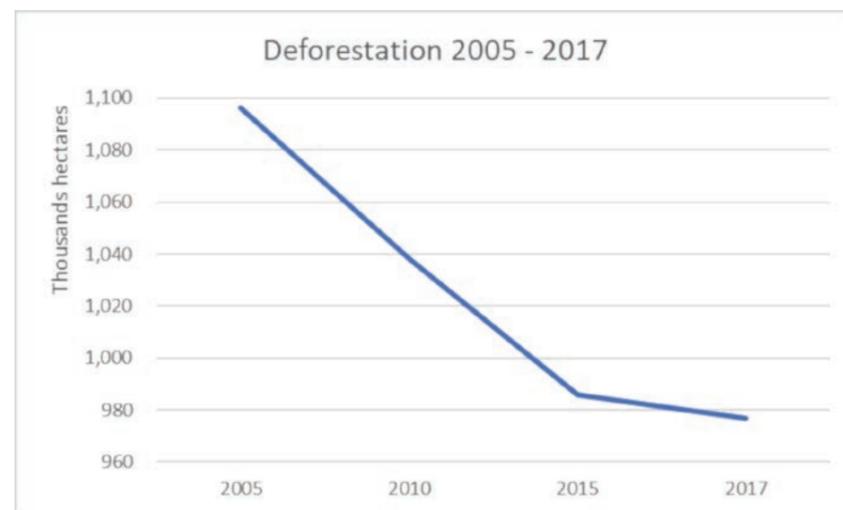
Figure 16. Deforestation between 2005-2017

Forest regrowth increased by 6,698.89 hectares per year over the 12 years of the study (Figure 17), from 322,046.80 hectares in 2005, to 402,433.59 hectares in 2017.
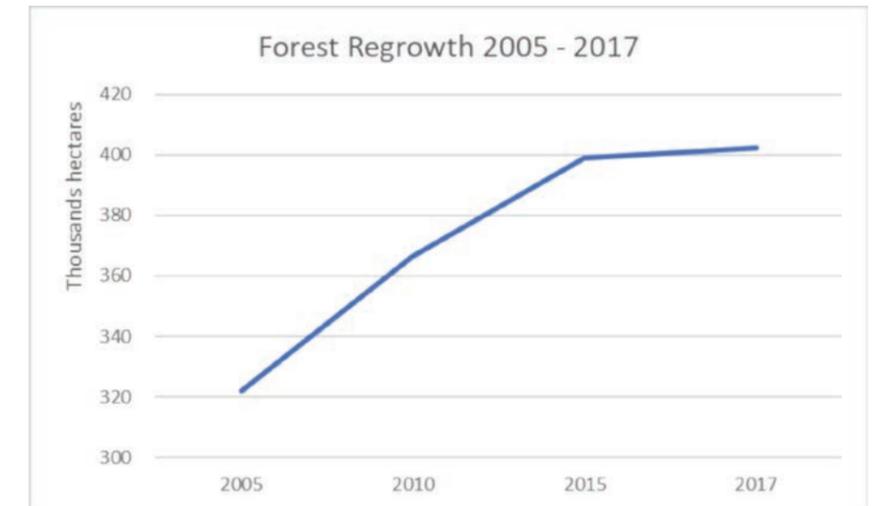
Figure 17. Forest regrowth between 2005-2017

Forest cover quality in between 2005-2017 was not always in the same phase and condition due to forest degradation linked to human interventions such as encroachment, slash and burn and logging. Forest degradation analyses in this report were the only parameter used on forest cover changes (based on canopy density).

(a)   (b)

(c)   (d)
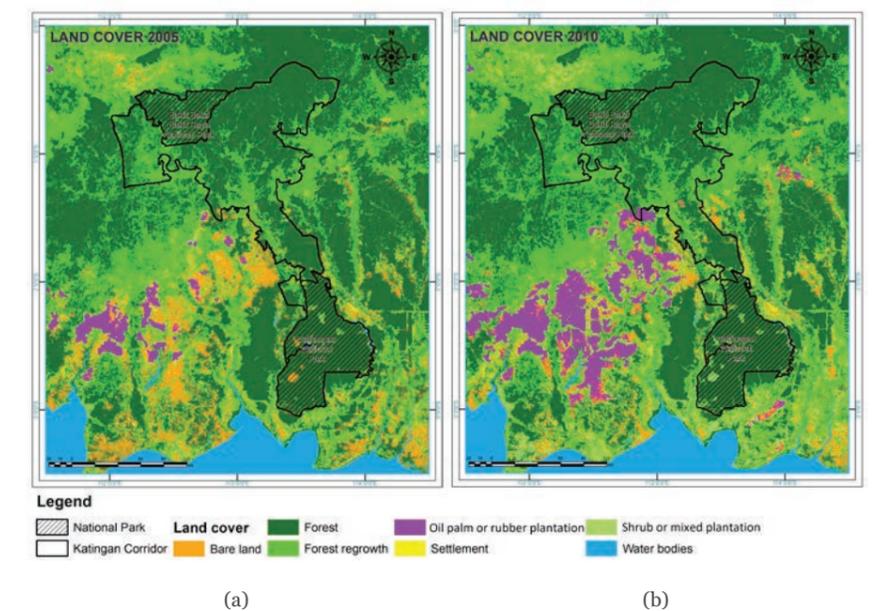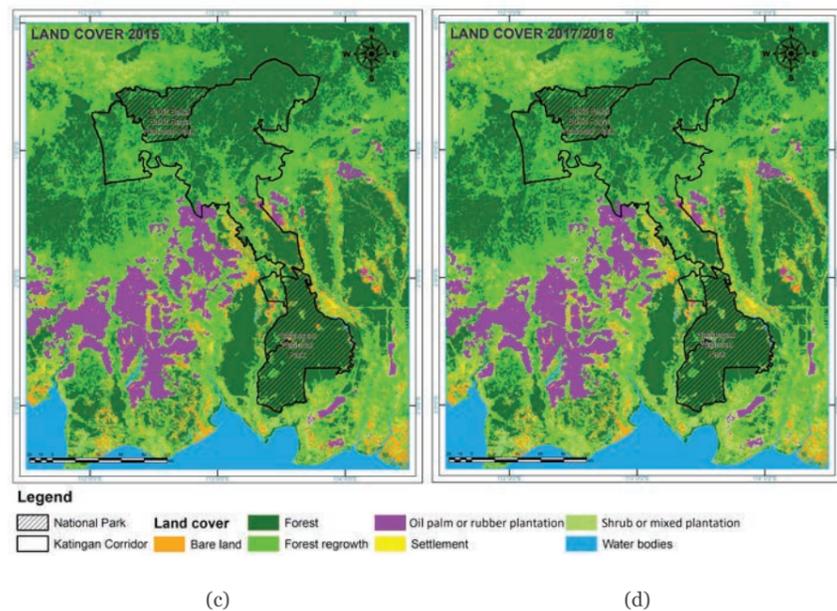
Figure 18. (a) Landcover 2005; (b) Landcover 2010; (c) Landcover 2015; (d) Landcover 2017
in Katingan Area of Interest

4.1.2 Forest Fire Event

We also collated instances of forest and land fire events over a period of 10 years (2007 – 2017) in Sebangau Katingan landscape. The forest and land fire data were overlaid with land cover, then the relationship between fire and land use was analysed with by simply overlaying the hotspot information with confidence level greater than or equal to 60 inside the land cover class (Figure 19).
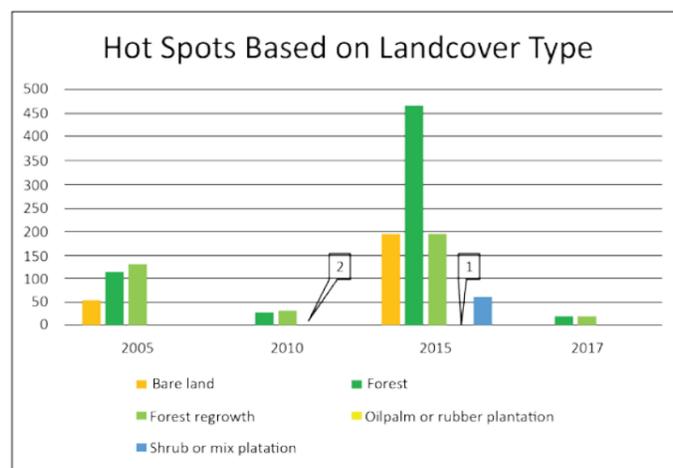
Figure 19. Hot spots based on land cover type, with confidence level ≥ 60 (scale 1 - 100).
Figure 2 and 1 mean there were only two hot spots in 2010 and only one hot spot under oil palm or rubber plantation class.
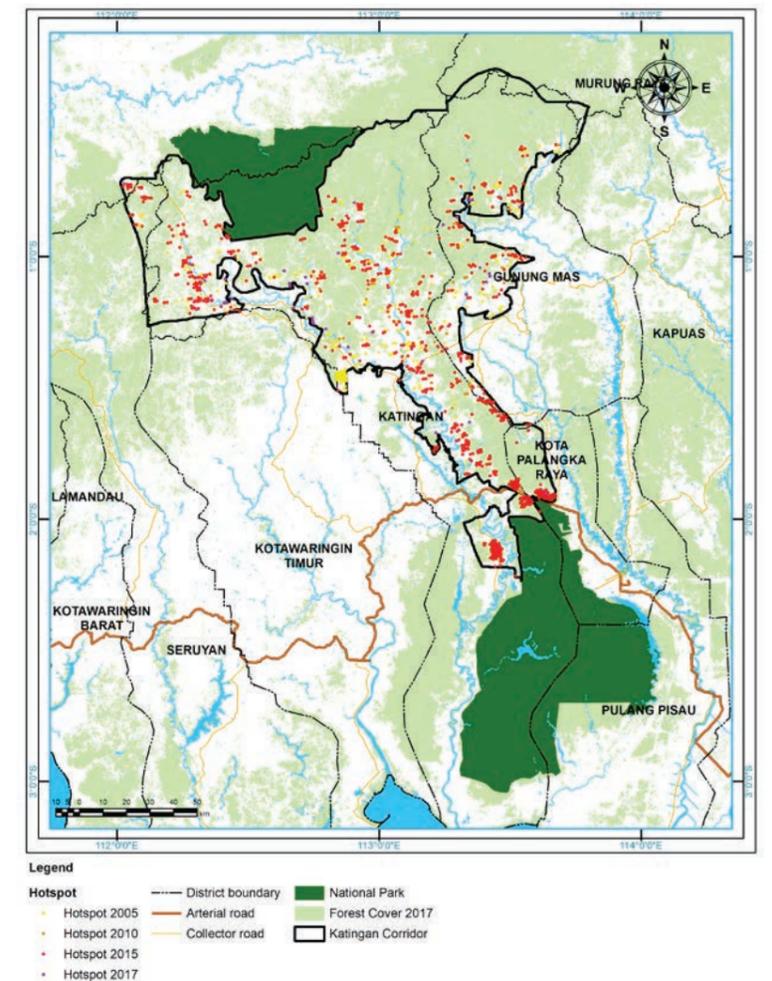
Figure 20. Hot spot distribution in Katingan Corridor 2005 - 2017

4.2 Land Cover Projection

Land cover projection analyses were conducted for a whole Area of Interest (AoI), covering an area comprising 12,924,133.81 hectares.

4.2.1 InVest Scenario Generator

To run this tool, we defined factors such as layers of soil depth, average rainfall, spatial planning, slope and elevation. Constraints were taken from association with the level of accessibility to certain areas, derived from forest areas and several regulations related to their utilization. Transition likelihood was adapted from the proportion of land cover changes in 2005-2017; the greater the changes to certain types of land cover, the greater the transition likelihood value. Defining priority was taken from the extend of a land cover transition; land cover types were tabulated into the matrix table.

We assessed four different scenarios of land cover change projection, based on different variables for each scenario. The first scenario was a simple

analysis base on the transition likelihood matrix. The second and third scenarios used additional variables such as priority matrix (Scenario 2) and land suitability as a controlling factor (Scenario 3). The fourth scenario used a more complex model, incorporating all variables of the InVEST generator, such as transition likelihood, prioritisation, suitability factors and constraint layers (Figure 21).
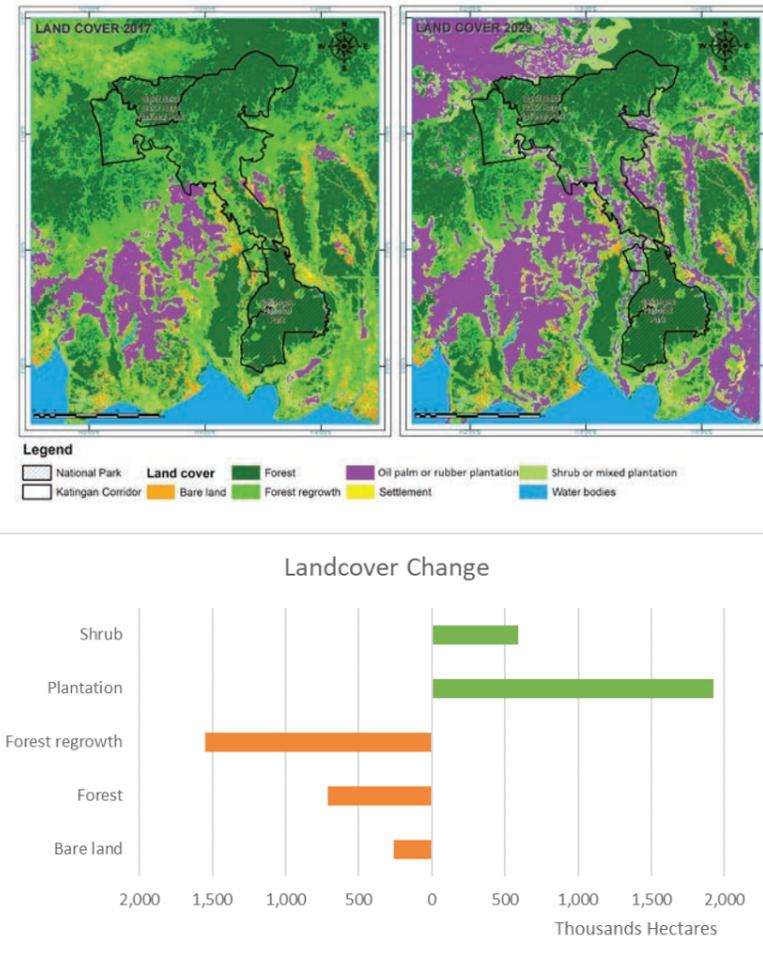
Figure 21. Land cover change projection in ha based on fourth scenario (used all parameters) in Scenario Generator

All land cover change projection scenarios indicated trends of decline in forest area and forest regrowth. Forest regrowth exhibited a relatively large decrease compared to forest class; approximately 30-50% (see figure 22). The land cover change projected for forest class was an approximate 3% decrease in the first to third scenarios, with a more substantial decrease (around 5%) projected in the fourth scenario (see figure 22).
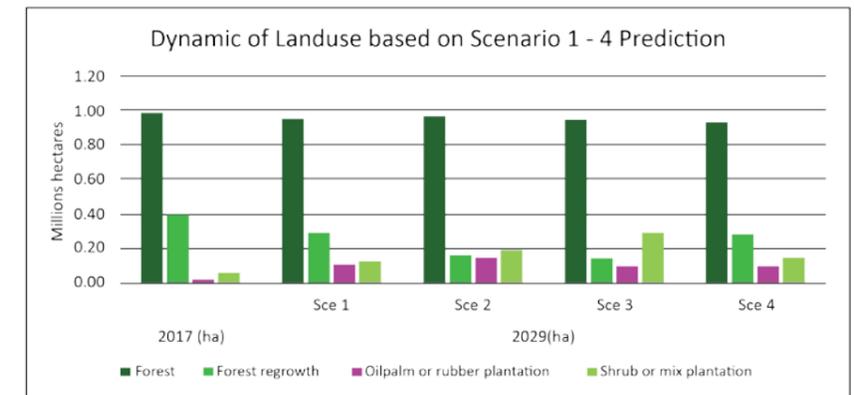
Figure 22. Comparison of land cover predictions in Katingan Corridor

Table 6. Comparison of land cover prediction based on four scenarios in Katingan Corridor

Landcover	2017 (ha)	2029 (ha)			
		Sce 1	Sce 2	Sce 3	Sce 4
Bare Land	26,802.24	-	-	202.77	14,636.95
Forest	976,659.42	952,836.00	965,993.89	942,927.89	926,529.47
Forest Regrowth	402,433.59	289,149.18	164,969.51	143,362.20	286,251.10
Oil Palm or Rubber Plantation	10,379.29	103,254.26	148,226.51	91,632.95	92,409.50
Settlement	128.04	543.31	2,376.12	236.50	175.59
Shurb or Mixed Plantations	54,568.52	124,978.98	188,835.99	292,399.42	150,759.12
Water Bodies	9,504.29	9,713.63	9,713.63	9,713.63	9,713.63

The fourth scenario is considered a more reliable data source, due to its optimal use of all variables as factors in its analyses with the Scenario Generator tool. Hence, the fourth scenario has been used as the main reference in predicting the changes and dynamics of land cover trends.
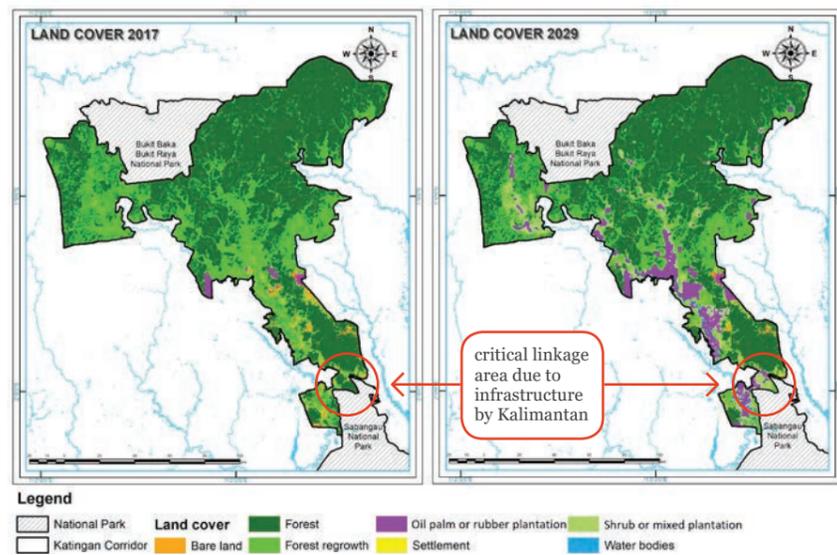
Figure 23. Land cover change projection based on data 2017 to 2029 in Katingan Corridor based on InVEST Scenario Generator

Figure 24. Projected land cover based on Business as Usual (BAU) and based on Spatial Planning (Constraint) in Corridor

4.2.2 Land Change Modeller

The combined prediction results of BAU and Constrained (Spatial Planning) give the same land allocation for each classification in the context of the study area, as described in Figure 24. However, within the Katingan Corridor, there was a significant disparity between forest and forest regrowth: forests appeared to be more intact under BAU compared to Constrained in the northern area. On the other hand, plantation expansion under Constrained also appeared larger when compared to BAU.

Table 7. Comparison of Land Cover Projection Area Type (2029) based on BAU Prediction and Constrained in Katingan Corridor

Category	Legend	2017 (Ha)	2029 (Ha)	
			BAU	Constrained
1	Forest	976,659.42	627,060.87	512,419.59
2	Forest Regrowth	402,433.59	602,277.30	631,628.46
3	Plantation	10,379.29	52,553.79	64,108.26
4	Settlement	128.04	322.02	501.12
5	Shrub	54,568.52	112,562.19	161,301.60
6	Bare Land	26,802.24	39,324.60	64,153.62
7	Water Bodies	9,504.29	10,924.56	10,912.68

4.2.3 Comparison between prediction of Scenario Generator and Land Change Modeller

The results of both Scenario Generator (SG) and Land Change Modeller (LCM) were compared to obtain the best option. The two model results were comparable, because both of them used spatial planning as a parameter (Figure 25). We used a fourth-level scenario generator in this comparison.
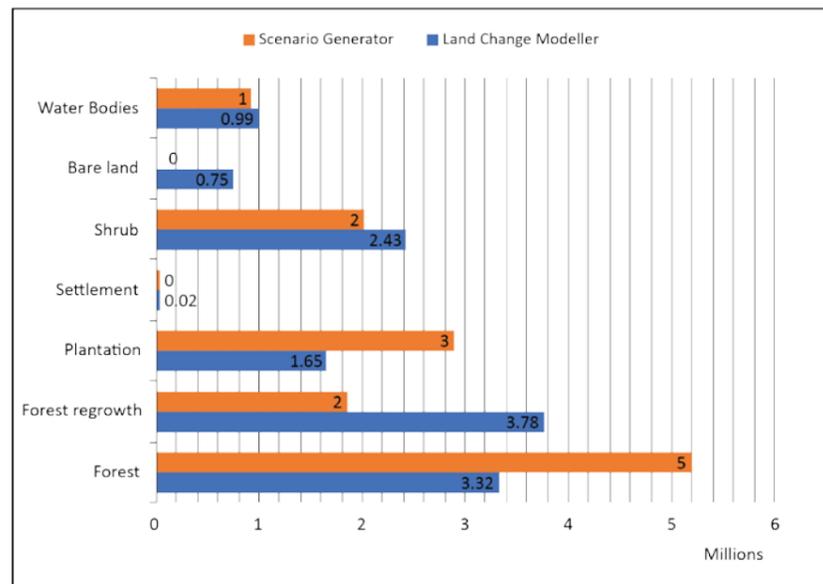
Figure 25. Comparison Scenario Generator (SG) and Land Change Modeller (LCM)

The result showed that there is a significant difference in predicting plantation, forest regrowth, and forest class. SG results tended to be more optimistic when compared to LCM, placing forest regrowth at around 5.2 million hectares. The same situation was present in the plantation class. In the trade-off, forest regrowth under SG has less area then under LCM. Hence, we decided to use SG in our further analyses, as a means to accurately predict future changes to forest cover. These results are an important resource in relation to future spatial planning policy and land use allocation.

4.3 Deforestation Rate and Forest Degradation

4.3.1 Deforestation Rate

We identified deforestation by overlaying all landcover data. On landcover that initially turned from forest into non-forest, we classified this as deforestation. Distribution of deforestation between 2005 – 2017 is described in Figure 26.
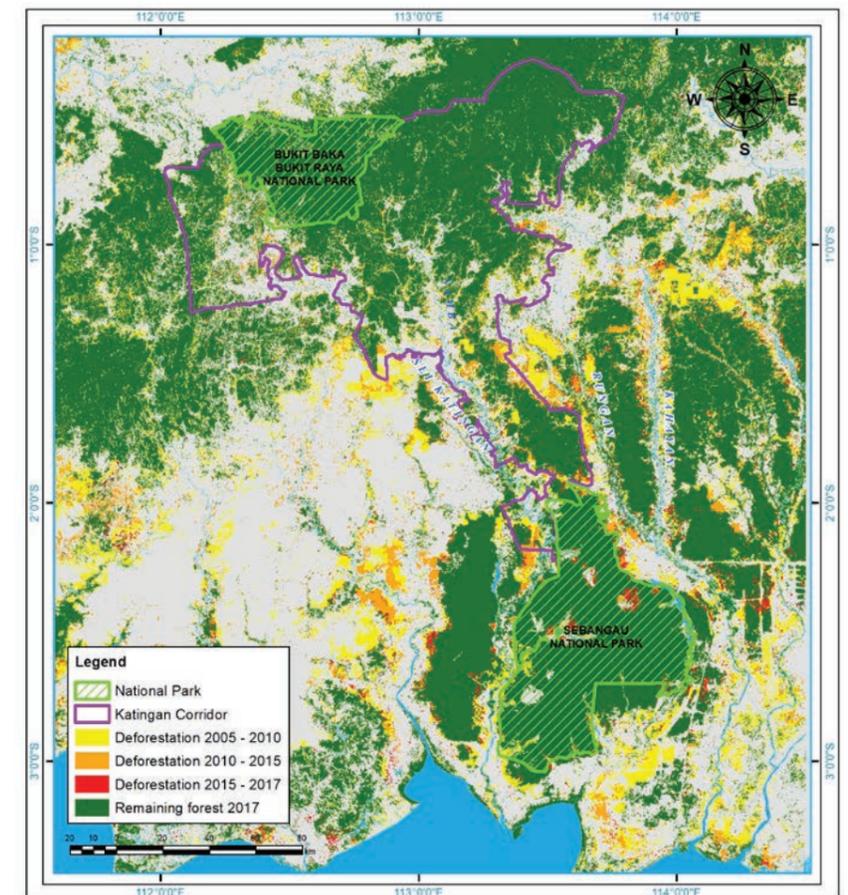
Figure 26. Deforestation in Katingan Corridor and surrounding area 2005 to 2017

Specifically, the total forest loss inside Sebangau Katingan Corridor from 2005-2017 is about 119,550 hectares, with a deforestation rate of 0.96% per year (Table 8). Details for each class can be seen in Table 9. The map of deforestation rates in Sebangau Katingan Corridor are described in Figure 27.

Table 8. Deforestation 2005 - 2017 in Katingan Corridor

Classes	Years				Deforestation Rate
	2005	**2010**	**2015**	**2017**	
Forest	1,096,214.96	1,037,980.51	985,729.80	976,659.42	0.96%
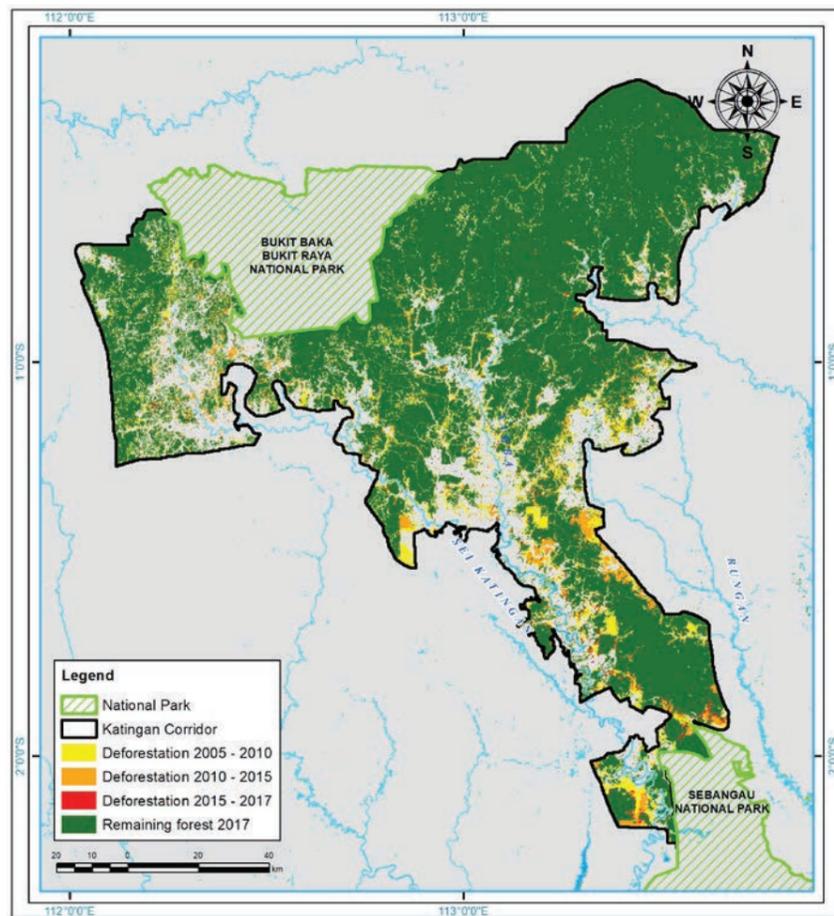
Figure 27. Deforestation in Katingan Corridor 2005-2017

Table 9. Forest conversion to other classes from 2005-2010, 2010-2015, and 2015-2017 in Katingan Corridor

Forest Covert to	2005-2010	%2005-2010	2010-2005	%2010-2005	2015-2017	%2015-2017
Bare Land	8,500.19	10.96%	14,234.86	24.45%	392.39	4.08%
Forest Regrowth	53,429.11	68.90%	35,921.60	61.69%	7,445.38	77.37%
Oil Palm or Rubber Plantation	1,947.31	2.51%	2,297.70	3.95%	-	
Settlement	0.45	0.00%	0.54	0.00%	-	
Shrub or Mix Plantation	13,665.05	17.62%	5,772.80	9.91%	1,785.17	18.55%
Total	77,542.10	100.00%	58,227.50	100.00%	9,622.94	100.00%

We distinguished a process of forest conversion over three separate periods: 2005-2010, 2010-2015, and 2015-2017 (Table 9).

During 2005-2010, total forest conversion was 77,542 hectares, with the biggest change being forest regrowth (68.9%) followed by bare land (10.96%) and mixed plantation (17.62%). Similarly, between 2010-2015, it was still forest regrowth (61.69%), followed by bare land (24.45%), while mixed plantation was 9.91%. In the 2015-2017 period, the biggest changes were in forest regrowth (77.37%) and mixed plantations (18.55%).

A key takeaway from the results is that the change of forest to oil palm and rubber is not as substantial between 2005-2010 (1,947 hectares) and 2010-2015 (2,297 hectares). This is possibly due to this conversion process requiring certain stages and times. When forest use change and processes from 2005 to 2017 are compiled, a significant increase in oil palm or rubber (7,531 hectares) can be noticed, as described in Table 10. The contribution of oil palm or rubber can come from non-forest such as bare land.

Table 10. Forest conversion to other class from 2005 to 2017 in Katingan Corridor

Forest Convert to	Areas (Ha)
	2005-2017
Bare Land	15,397.57
Forest Regrowth	76,635.21
Oil Palm or Rubber Plantation	7,531.09
Settlement	4.03
Shrub or Mixed Plantation	21,226.65
Total	120,794.54

4.3.2 Deforestation Prediction 2029

Prediction of deforestation 2029 is conversion from forest cover 2017 to non-forest 2029. Land cover 2029 is analyzed by the InVEST Scenario Generator. In the 2017-2029 period, the total forest conversion will be 87,652.06 hectares with the biggest change being forest regrowth (56.55%) followed by shrub or mix plantation (38.18%) and Oil palm or rubber plantation (4.06%). This means that the main driver of deforestation will be forest Logging.

The deforestation prediction areas need special attention for avoiding deforestation in 2029. These areas are vulnerable to deforestation. We should plan scenarios for voiding deforestation.

DEFORESTATION PREDICTION 2017 - 2029

BUKIT BAKA
BUKIT RAYA
NATIONAL PARK

SEBANGAU
NATIONAL PARK

Legend
National Park
Katingan Corridor
Deforestation prediction 2017 - 2029
Remaining forest 2029
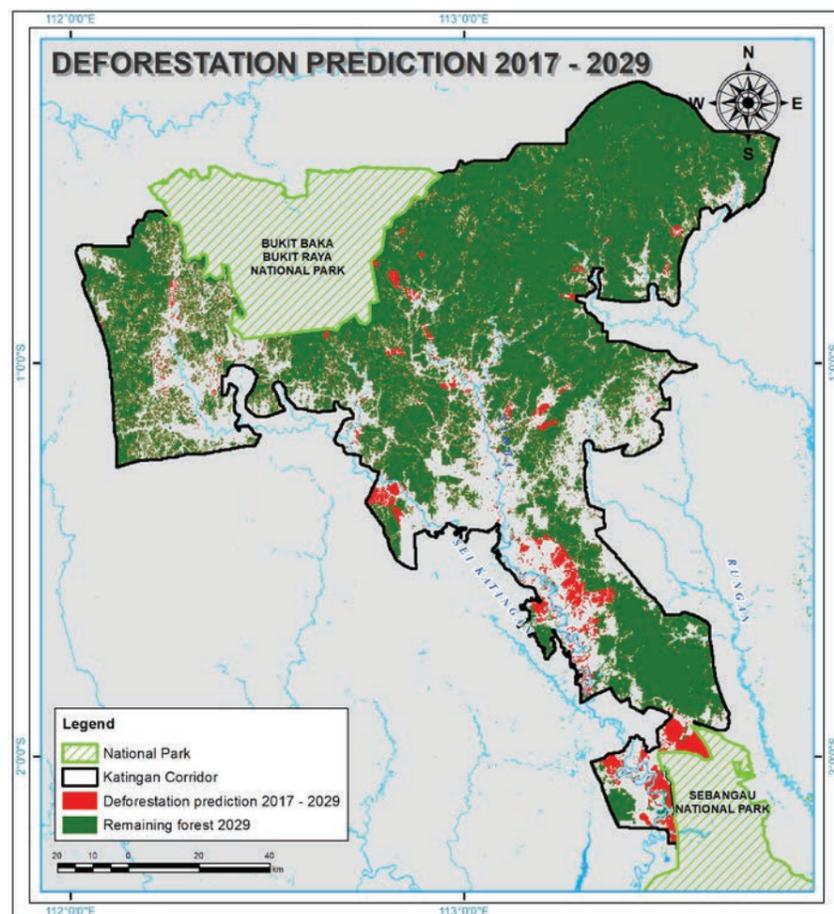
Figure 28 Deforestation Prediction in Katingan Corridor 2017 – 2029

Table 11 Forest conversion to other class from 2017 – 2029 in Katingan Corridor

Forest Convert to	2017-2029	%2018-2029
Bare Land	697.33	0.80%
Forest Regrowth	49,564.45	56.55%
Oil Palm or Rubber Plantation	3,560.51	4.06%
Settlement	2.48	0.00%
Shrub or Mix Plantation	33,465.12	38.18%
Water Bodies	362.17	0.41%
Total	87,652.06	100.00%

4.3.3 Forest Degradation

Degradation analysis using a Forest Cover Density (FCD) mapper tool in Katingan areas of interest resulted in the three results categories: decrease, no change and increase. By calculating the difference, it is possible to identify the full extent of forest degradation.

Legend
National Park   Katingan Corridor   Forest Cover Density   No Data   Decrease   No change   Increase
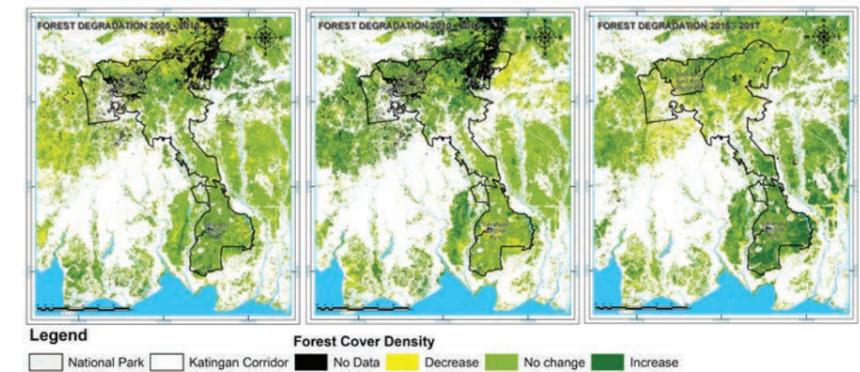
Figure 29. (a) Forest degradation 2005 – 2010; (b) forest degradation 2010 – 2015; (c) forest degradation 2015 - 2017 in Katingan area of interest

The extent of degradation is described in the table as follows:

Table 12. Amount of forest degradation in Katingan area of interest

Forest Convert Density (Ha)	Period (hectare)		
	2015-2010	2010-2015	2015-2017
No Data	476,522.92	429,383.88	81,081.66
Decrease	741,606.25	534,115.39	776,126.55
No Change	3,640,656.27	3,246,644.30	3,073,226.28
Increase	876,512.85	1,237,942.65	1,462,484.80
Total	5,735,298.30	5,448,086.22	5,392,919.30

Analyses of forest degradation were conducted in two steps. First, forest cover density was calculated for each year. Second, forest cover density layers were overlaid to calculate forest density changes. The following table describes the forest objects used in the 2005-2010 period, during 2010-2015, and in the 2015-2017 period. Bold figures relate to forest degradation analysis.

Table 13. Landcover change matrix 2005-2010 in Katingan Corridor. Bold figures indicate values that use forest degradation analysis

Land Cover (Ha)	Year 2005							
	Bare Land	Forest	Forest Regrowth	Oil Palm or Rubber Plantation	Settlement	Shrub or Mixed Plantation	Water Bodies	Grand Total
Bare Land	9,120.02		6,809.06	1,639.73	17.33	3,471.22	73.93	21,131.29
Forest	8,500.19	**1,018,464.19**	53,429.11	1,947.31	0.45	13,665.05	208.68	1,096,214.96
Forest Regrowth	1,208.78	19,516.32	294,112.31	294.76	4.38	6,855.74	54.51	322,046.80
Settlement					49.09			49.09
Shurb or Mixed Plantations	556.22		11,632.96	58.77		19,741.50	12.70	32,002.14
Water Bodies	53.66		458.63	1.25		47.31	8,470.25	9,031.10
Grand Total	19,438.87	1,037,980.51	366,442.06	3,941.82	71.25	43,780.81	8,820.07	1,480,475.38

Table 14. Landcover change matrix 2010-2015 in Katingan Corridor. Bold figure indicated value that use for forest degradation analysis

Land Cover (Ha)	Year 2010							
	Bare Land	Forest	Forest Regrowth	Oil Palm or Rubber Plantation	Settlement	Shrub or Mixed Plantation	Water Bodies	Grand Total
Bare Land	12,574.75		2,375.11	2,690.37	20.84	1,636.63	141.17	19,438.87
Forest	14,234.86	**979,285.90**	35,921.60	2,297.70	0.54	5,772.80	467.11	1,037,980.51
Forest Regrowth	2,085.81	6,111.80	352,020.26	820.32	6.53	4,914.48	482.87	366,442.06
Oil Palm or Rubber Plantation				3,941.82				3,941.82
Settlement					71.25			71.25
Shurb or Mixed Plantations	4,200.57	332.11	8,532.98	445.47	12.97	30,134.63	122.07	43,780.81
Water Bodies	110.73		128.83			20.75	8,559.76	8,820.07
Grand Total	33,206.73	985,729.80	398,978.78	10,195.68	112.12	42,479.28	9,772.99	1,480,475.38

Table 15. Landcover change matrix 2010-2017 in Katingan Corridor. Bold figures indicate values used for forest degradation analysis

| Land Cover (Ha)	Year 2015							
	Bare Land	Forest	Forest Regrowth	Oil Palm or Rubber Plantation	Settlement	Shrub or Mixed Plantation	Water Bodies	Grand Total
Bare Land	24,677.26		2,700.03	183.61	15.12	5,455.70	175.02	33,206.73
Forest	392.39	**976,083.03**	7,445.38			1,785.17	23.84	985,729.80
Forest Regrowth	1,106.76	576.03	390,196.94		0.71	6,973.72	124.62	398,978.78
Oil Palm or Rubber Plantation				10,195.68				10,195.68
Settlement					112.12			112.12
Shurb or Mixed Plantations	154.68	332.11	2,020.86		0.09	40,298.92	4.74	42,479.28
Water Bodies	471.16	0.36	70.39			55.01	9,176.07	9,772.99
Grand Total	26,802.24	976,659.42	402,433.59	10,379.29	128.04	54,568.52	9,504.29	1,480,475.38

(a)   (b)   (c)
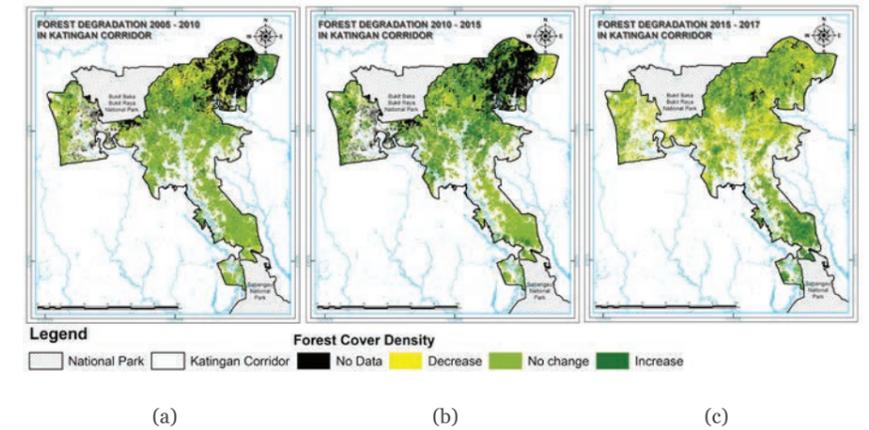
Figure 30. (a) Forest Degradation 2005 – 2010; (b) Forest Degradation 2010 – 2015; (c) Forest Degradation 2015 - 2017 in Katingan Corridor

Table 16. Amount of forest degradation in Katingan Corridor

Forest Cover Density (hectares)	Period (hectare)		
	2015-2010	**2010-2015**	**2015-2017**
No Data	193,353.58	184,865.41	19,085.70
Decrease	106,365.77	79,839.82	233,916.47
No Change	546,611.90	424,598.96	500,958.72
Increase	172,243.51	290,079.08	222,218.41
Total	**1,018,574.76**	**979,383.27**	**976,179.30**

4.4 Priority Area Within The Corridor: Orangutan Connectivity

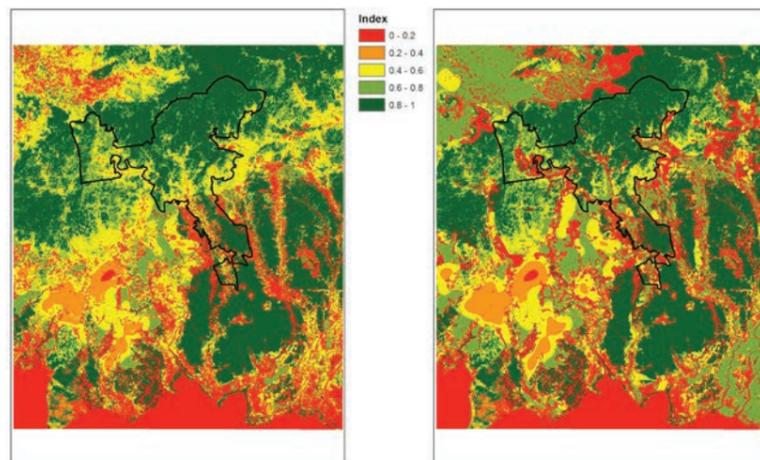### 4.4.1 Habitat Quality Analysis

Figure 31. Orangutan habitat quality map 2017   Figure 32. Orangutan habitat quality map 2029

Two different years of orangutan habitat quality (2017 and 2029) were analysed and projected by the InVEST tool. As arboreal animals, orangutan spend most of their time in trees, only occasionally descending to ground level (Ancrenaz, et al., 2014). Orangutan habitat quality therefore depends on the animals' preferred forest condition and the tree species they favour. Hence, the forest canopy is a very important indicator of orangutan habitat quality, as it includes the resources they require for feeding, nesting and sleeping. Orangutan habitat quality can be divided into four indexes, i.e 0

– 0.4: not suitable habitat; 04 – 0.6: less suitable; 0.6 – 0.8: suitable; and 0.8 – 1.0: very suitable.

This criterion refers to the level of habitat quality in relation to the vegetation and environmental preferences of the orangutan. It does not refer to the occurrence density of the animals themselves. The index simply categorizes forest areas in terms of their fitness for habitation by orangutan; the higher the forest cover and quality of forest, the greater the suitability of habitat.

4.4.2 Orangutan Habitat Prediction with Maxent Analysis

The maxent map was used to strengthen the InVEST habitat quality model. Maxent map showed the orangutan habitat is dominant in the lowland. However, there were some instances of orangutan groups found in highland areas too. Through the comparison of 64 field data points, it was discovered that orangutan nests were predominantly found in suitable and very suitable areas, while only occasionally noticed in less suitable areas (Figure 34).
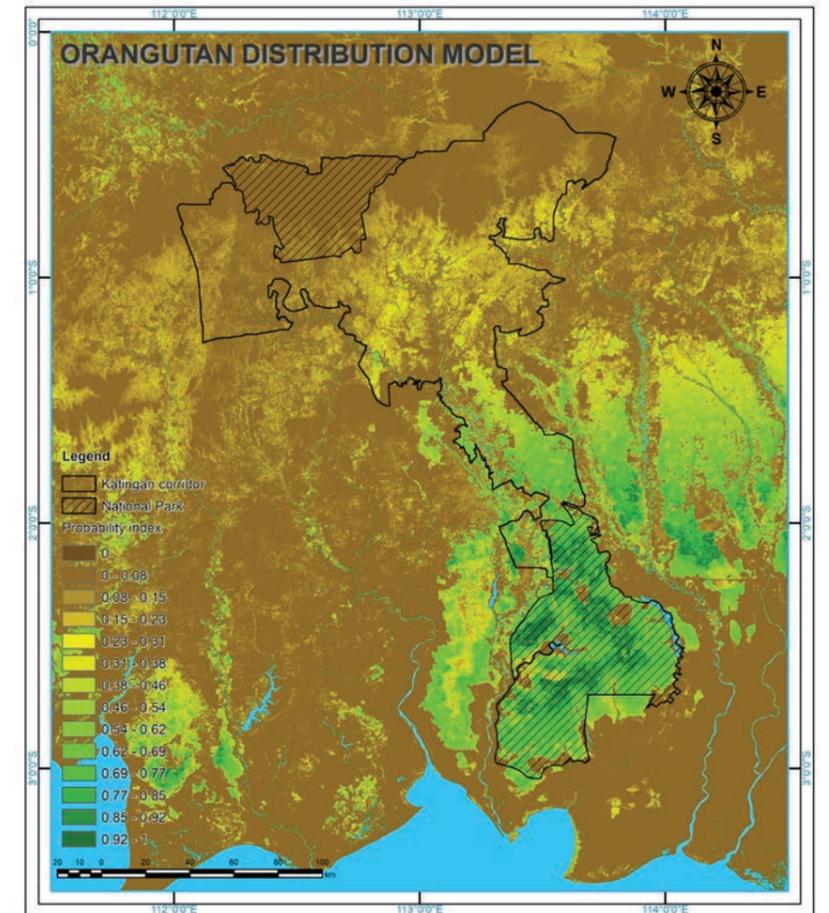

Figure 33 Orangutan Distribution Model Map 2017

Figure 34. Integration maxent and InVEST Habitat Quality with proof of nests of orangutan

### 4.4.3 Orangutan Movement in Critical Linkage Area

The Critical Linkage Area is an area inside the corridor that is fragmented by linear infrastructure such as roads, canals and power lines. To delineate the critical linkage area, the shortest distance of the edge of two core zones must first be defined as a connecting point from two sides. We estimated the minimum width of suitable orangutan habitat, larger than or equal to 2km from the linear infrastructure distance that needed to be restored. The core zone areas for delineating the connectivity are included in Critical Linkage Areas (or fragmented areas), both in the southern and northern parts of Sebangau Katingan landscape. However, the current study is still limited to the southern part; further continuation of the assessment is required for the northern part.

The Corridor Design tool is able to delineate orangutan connectivity pathways in Critical Linkage Areas. The model defines the area as either very suitable, suitable, less suitable or not suitable. Crucially, the results determine which location is most effective as a connectivity pathway for the orangutan. Furthermore, the model is also able to optimize remaining forest cover to reconnect core zone areas that have been fragmented by roads, power lines and canals.

Before analysis begins, the InVEST habitat quality is graded from 0-100 to ascertain habitat suitability in the Corridor Design tool. The map of orangutan connectivity pathways in Critical Linkage Areas can be seen in Figure 33. There are three potential areas in the corridor that could be considered as Critical Linkage Areas.
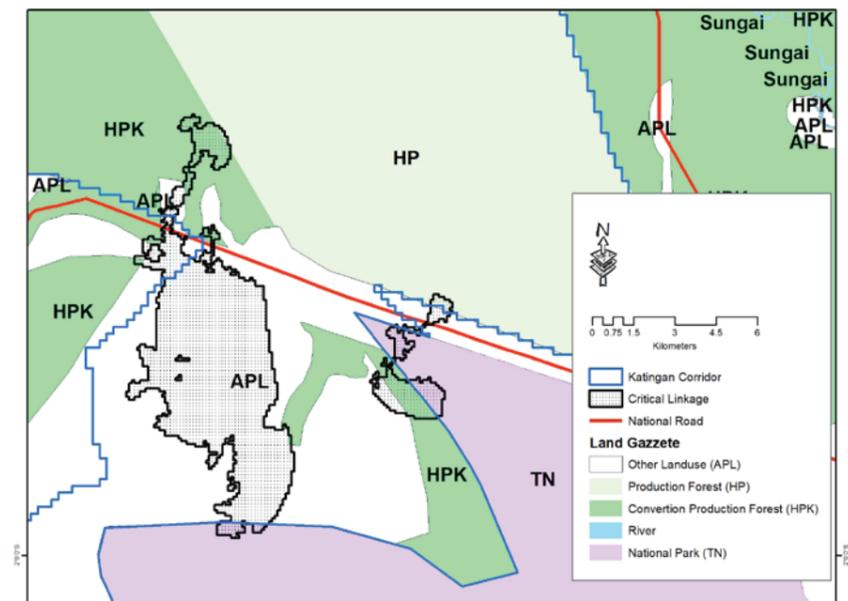
(a)
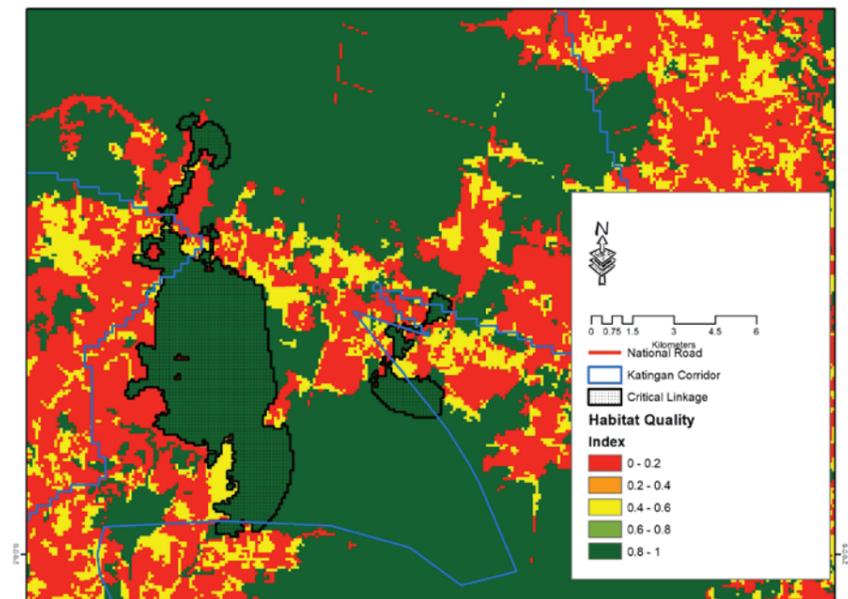
(b)

Figure 35. (a) Indication of sustainable location on Land Gazate map; (b) Indication of sustainable location on Habitat Quality map.

4.5 Intervention and Management

The orangutan habitat in Sebangau Katingan landscape diversifies into different types of land use allocation. Therefore, interventions for securing orangutan habitat should consider multi-policy regulations determined by the land use status.

Management of the orangutan habitats should combine different units, such as national parks, essential ecosystem areas, district and province strategic areas, community conservation areas and forest management unit areas.

We overlapped the Critical Linkage Areas with social forestry maps in Central Kalimantan, village boundaries and high conservation value areas.
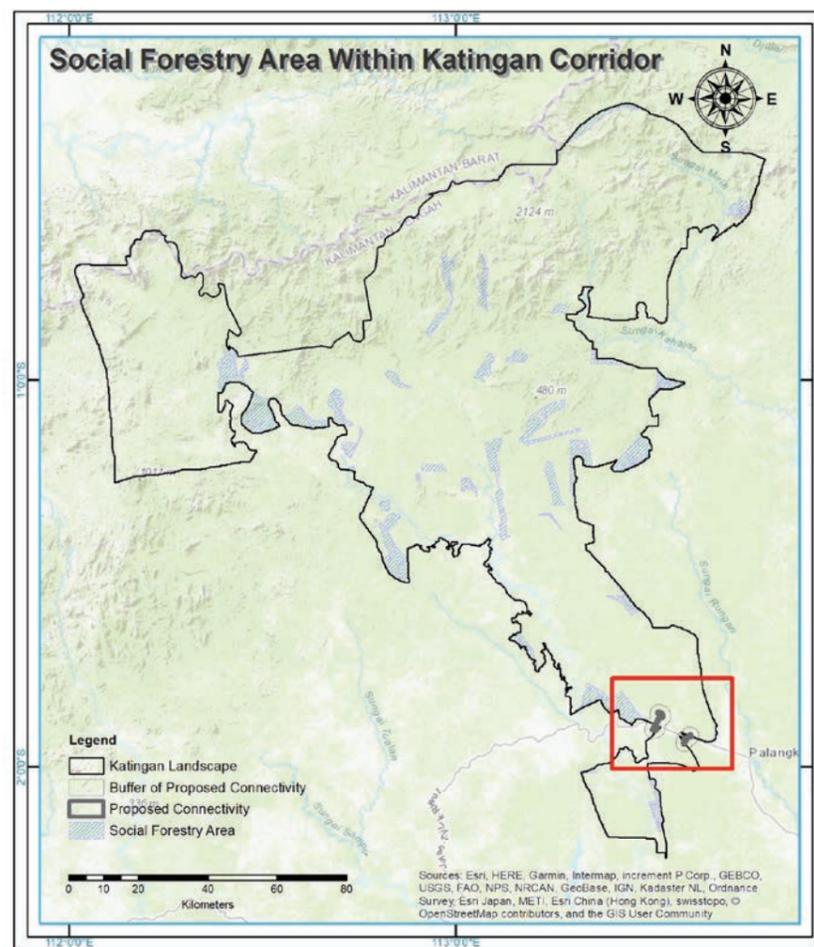
Figure 36. Social Forestry Indicative Area within Katingan Landscape

We found that no social forestry areas overlapped with critical linkage. The closest candidate - Kasongan Lama Village - is located around 2.7 kilometres to the west. This situation is not fixed; corridor rationalisation is advised in the Recommendation chapter, to facilitate greater potential for connectivity in orangutan habitats.

Within the Sebangau Katingan landscape, there are 10 FMU (Table 16) that cover around 1.2 million hectares. From 10 FMU, the area is mostly dominated by FMU III, XV, XVI, and XVII. They do not cover the whole landscape, so it is therefore recommended to use an alternative approach in order to seek sustainable management outside FMU areas.

Figure 37. Forest Management Unit Area within Katingan Landscape

Table 17. FMUs within Katingan landscape

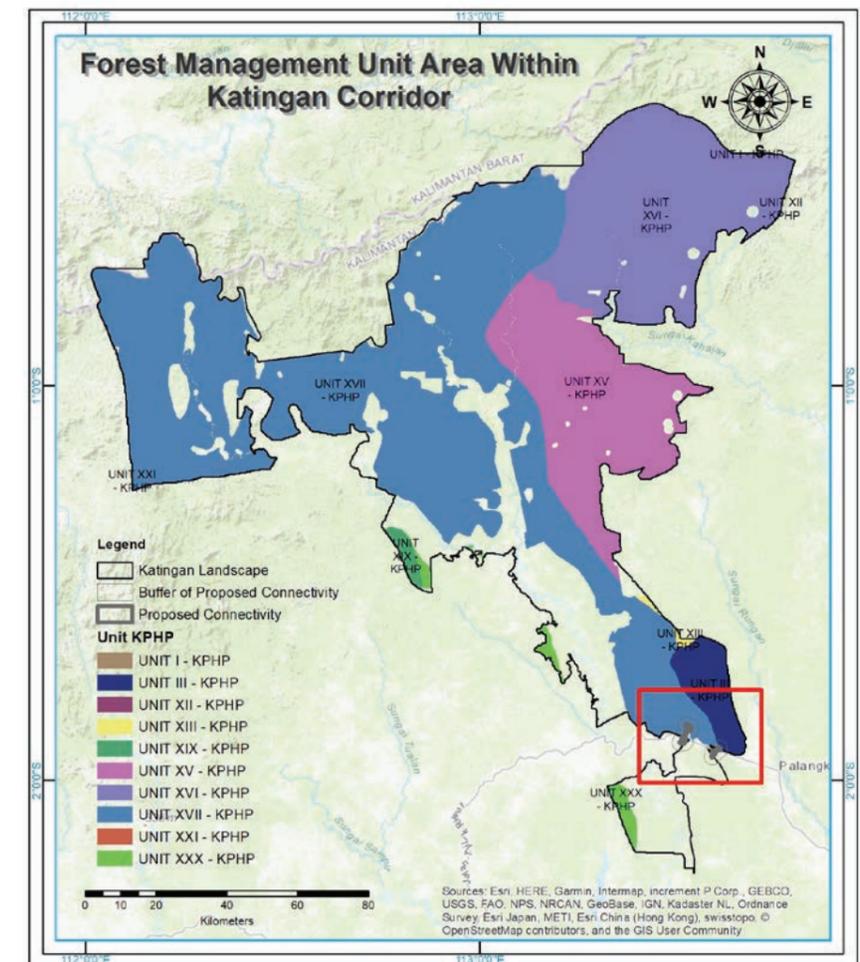| FMU Unit	FMU Name	Area (Ha)
UNIT I - KPHP	UPT KPHP Murung Raya	398.15
UNIT III - KPHP	UPT KPHP Kahayan Tengah	35,531.86
UNIT XII - KPHP	UPT KPHP Kapuas Hulu	93.14
UNIT XIII - KPHP	UPT KPHP Kahayan Tengah	2,428.80
UNIT XIX - KPHP	UPT KPHP Mentaya Hulu - Seruyan Tengah	7,287.58
UNIT XV - KPHP	UPT KPHP Kahayan Hulu	208,018.79
UNIT XVI - KPHP	UPT KPHP Kahayan Hulu	265,528.46
UNIT XVII - KPHP	UPT KPHP Kahayan Hulu	670,406.37
UNIT XXI - KPHP	UPT KPHP Kahayan Hulu	177.75
UNIT XXX - KPHP	UPT KPHP Katingan Hilir	13,295.42
Grand Total		**1,203,166.33**

In terms of high conservation value areas (HCVA) within the landscape, there are several types to consider: HCV 1.1, HCV 2.1, HCV 2.2, HCV 3, and HCV 4.2. These HCVAs cover almost all of Katingan Landscape (1,031,925.41 hectares) with a combination of mostly HCVA 1.1 and HCVA 2.1 (Figure 36).
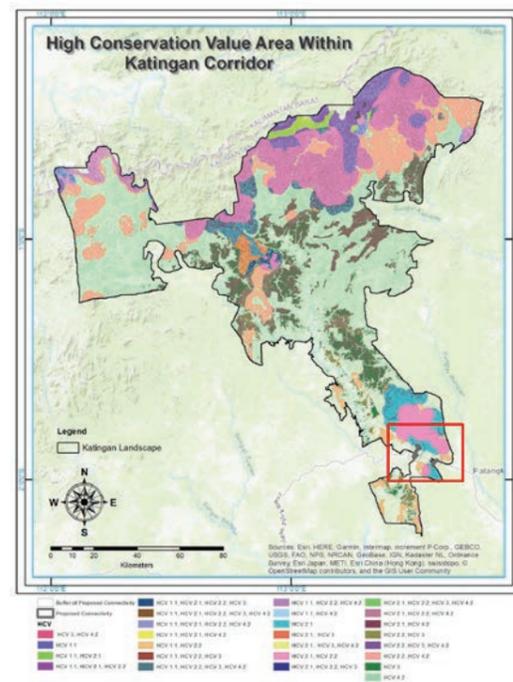

Figure 38. Combination of HCVAs within Katingan Landscape

The areas indicated as HCVAs could be encouraged to become essential ecosystem areas (KEE) to ensure the implementation of sustainable management without having to change the status of the area to be protected. Inside the landscape, there is also a social forestry indicative area, covering about 91,288.92 hectares (Figure 34).

Management interventions can also be focused on areas that are APL in the location of critical linkage sites, because economic activities in this region are legal (Figure 37). The existence of economic activities that have continued there is a challenge, as well as an opportunity to maximize the potential of connectivity for the movement of orangutans. The challenge is how critical existing linkage can truly serve as a medium for the movement of orangutans, even though they are located close to human activities. The opportunity comes from recognising critical linkage as a new source of economic activity in the form of wildlife observation tours.
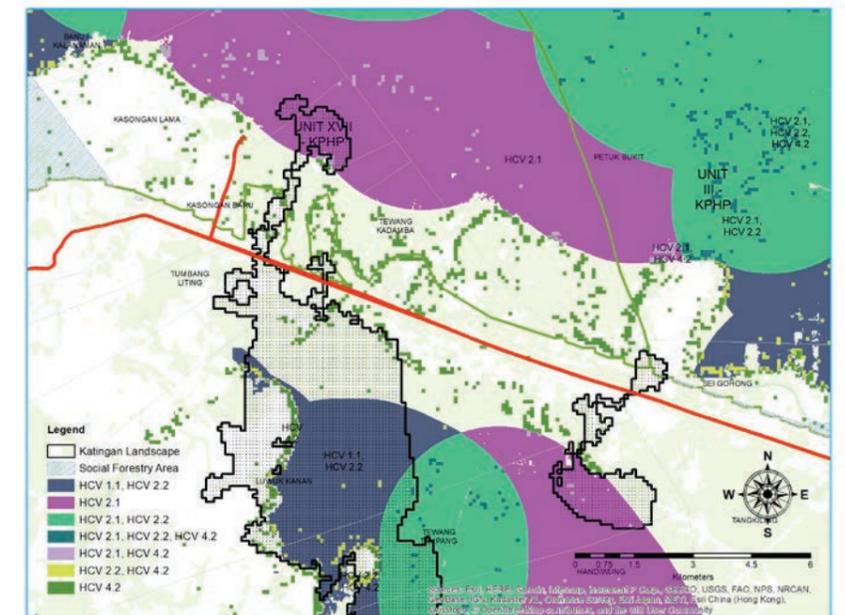
Figure 39. Challenge and opportunity for connecting Orangutan corridor

The projected land cover data for 2029, based on scenario generator (Figure 38), raised some concerns. It can be seen from the resulting data that the location recommended for orangutan connectivity is expected to experience forest loss in the intervening years. Thus, it is essential to ensure the area remains forested. Interventions through various policies, such as essential ecosystem area revision, spatial planning or even a change of status from production forest to protected forest could be viable options going forward.

Figure 40. Projected loss of forest in 2029

V. RECOMMENDATIONS AND CONSERVATION ACTIONS

Activities relating to orangutan conservation in Katingan Landscape can be divided into three areas, separated by roads that intersect the region. It can thereby be determined that the northern region is a production forest area, suited to Non-Timber Forest Products (NTFP) that offer potential for partnerships with several FMUs already operating in the region.

The existence of a national road, used for connecting two major cities in provinces that divide the landscape, makes the area a strategically advantageous location for civil engineering. This existing infrastructure can be used for implementing wildlife corridors in orangutan habitats.

In the southern region of the landscape, which covers the Sebangau National Park, the existing orangutan population needs to be protected, but also developed for special interest tourism. Thus, the conservation function in this region can still provide economic benefits to stakeholders. Going forward, there remains an urgent need to integrate and align conservation efforts with stakeholders' interests. We hereby provide summaries, recommendations and guidance, pertaining to the development of conservation activities in the corridor landscape.

5.1 Recommendations

5.1.1 Corridor Boundary Rationalisation

From the critical linkage analysis, the areas with the greatest potential for connectivity are outside the delineation of Katingan Landscape. Therefore, rationalisation of the corridor's shape is needed, in order to better accommodate orangutan habitat.

Since the main objective of the initiative is to facilitate orangutan movement and protect their habitat, reshaping corridor boundaries is recommended. Based on orangutan habitat modelling and the land cover situation, rationalisation is conducted to optimise the function of the corridor. This study recommends reshaping the corridor according to orangutan habitat prediction analyses, using rivers as natural boundaries for their habitat.
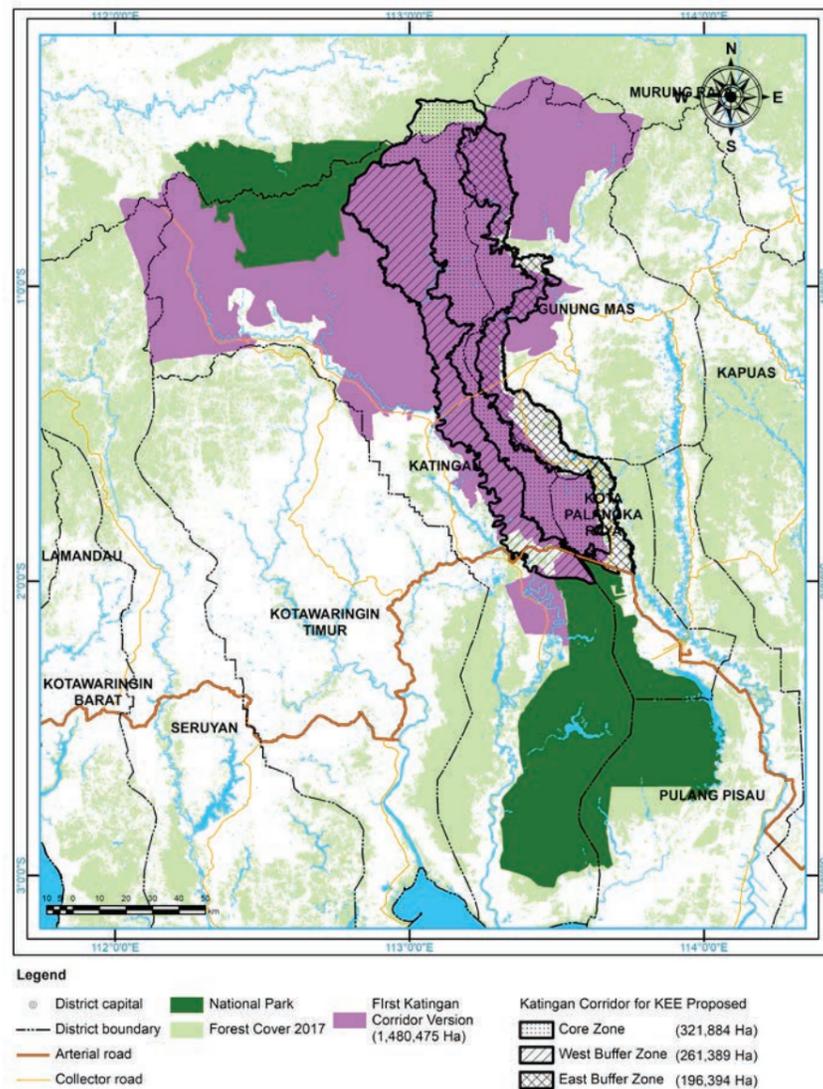
Figure 41. Proposed new boundary of Katingan Landscape

To improve connectivity within the corridor core zone, it is necessary to restore non-forest areas. The analysis of the restoration area was carried out by overlaying between the corridor core zone and the landcover 2017. Restoration is needed in landcover class of the bare land, shrub or mix plantation and forest regrowth. The areas that need to be restored is 31.375 Ha.
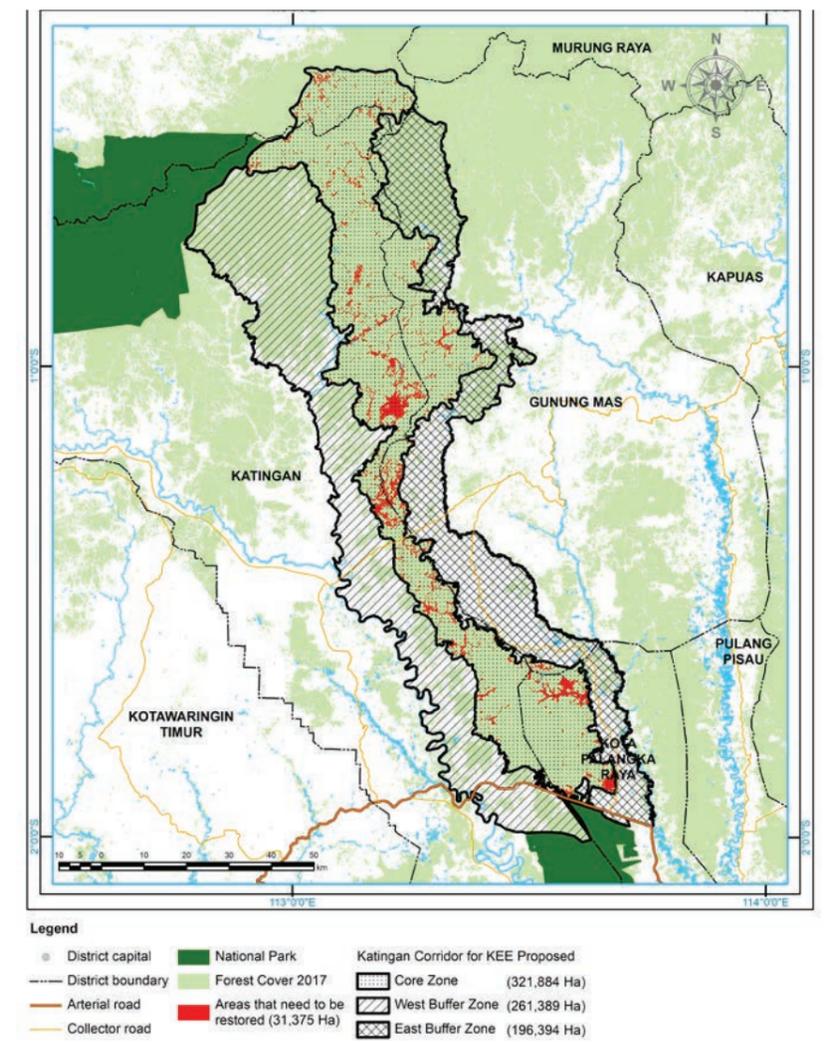
Figure 42 Areas that need to be restored map

5.1.2 Proposed Legal Basis for Management of Katingan Landscape

To ensure that the landscape is secure, this initiative needs to have a legal foundation, providing solid ground for implementation at the site level.

Katingan landscape has fulfilled the criteria in determining essential ecosystem areas; there are wetlands offered by peat lands and the potential to establish wildlife corridors for the movement of orangutans; especially from Bukit Raya National Park, Baka Hill to Sebangau National Park or vice versa.

Another alternative is to develop this landscape to become a strategic provincial area in the interests of high biodiversity. This initiative can be detailed in provincial-level spatial documents, which will then be adopted by the spatial plan below, namely at the district level.

5.1.3 Protect Critical Linkage Area for Orangutan Habitat Connectivity

Based on 2017 data, the Critical Linkage Area is still covered by natural forest (Figure 40). The predicted results of land cover under Scenario Generator and Land Change Modeller show that the forest in the Critical Linkage Area will change to another designation with the dominance of oil palm plantations. Therefore, advocacy is required to ensure that the area is protected, especially through the mechanism of an essential ecosystem area.
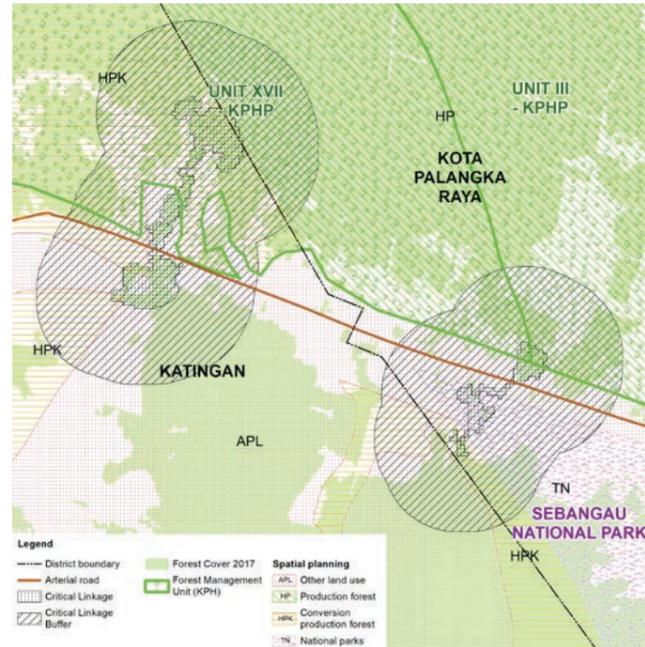

Figure 43. Forest cover situation in 2017 in critical linkage proposed area

The area is also a target for restoration, in order to restore land cover to be conducive to connectivity in orangutan habitats. The results of the HCV and forest cover analyses can form the basis for determining the appropriate location for restoration. Areas that are APL or already licensed recommended to be the location of the HCV.

Based on the 2029 projections of land cover, when some forest areas are expected to be gone, the need for restoration to support connectivity would be 1,822.33 hectares for the west connectivity, and 2,607.28 hectares for the eastern area. From those numbers, 870.81 hectares would be under the jurisdiction of Production FMU Unit XVII and 349.58 hectares would be under Production FMU Unit III. Other challenges would be to address restoration in APL, comprising 1,605.45 hectares in the west and 1,213.51 hectares in the eastern Critical Linkage Area.

Table 18. Restoration requirements in the proposed corridor area

| Managers	Land Status	Landover	Area (ha)
Production FMU (KPHP) Unit XVII	HP	Non-Forest	7.73
	HPK	Non-Forest	701.58
Others	APL	Non-Forest	1,605.45
	HPK	Non-Forest	507.57
West Corridor			**2,822.33**
Production FMU (KPHP) Unit III	HP	Non-Forest	349.58
Production FMU (KPHP) Unit XVII		Non-Forest	161.50
	APL	Non-Forest	1,213.51
Others	HPK	Non-Forest	432.41
	TN	Non-Forest	450.28
East Corridor			**2,607.28**
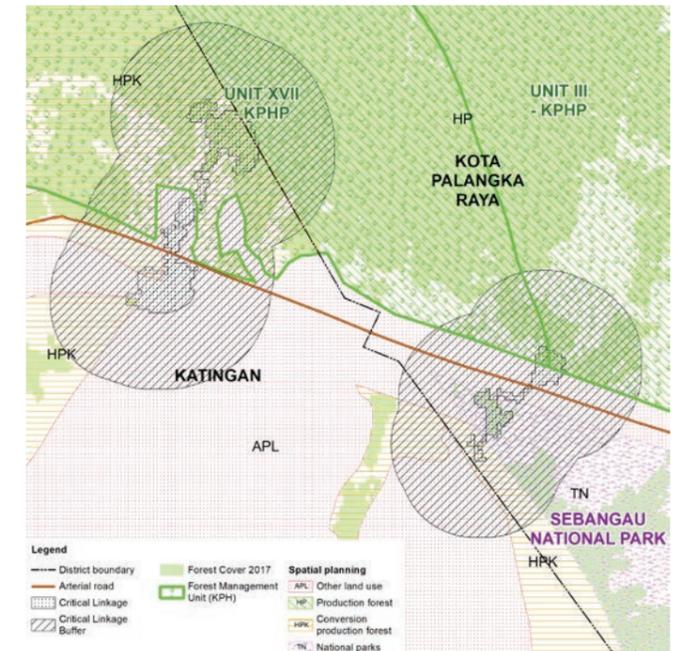
Figure 44. Projection of forest cover situation in 2029 in critical linkage proposed area.

5.1.4 Skateholder and Land Tenure Mapping

Mapping of both stakeholders and land ownership needs to be completed before intervention strategies can be determined or implemented. Based on information extracted from the field, certified land has been found in several locations. Referring to the management of corridors abroad, there is an option to purchase land to be used as a corridor, in order to optimise its management.

5.1.5 Proposal to Establish a Multi-Skateholder Forum

Central to implementation in the field is cooperation and agreement from stakeholders; their attitudes toward the Katingan Landscape initiative will ultimately determine its viability. For this reason, it is necessary to establish a multi-stakeholder forum comprising all parties, especially those with interests around the Critical Linkage Area.

5.1.6 Conduct Scientific Studies Related to The Natural Succession of Vegetation

Based on observations in the field and information that was excavated, several locations damaged by the fires that struck in 2015 have since recovered and demonstrated fairly good regrowth. Those locations recovered naturally, without the need for additional planting.

This condition can be used as a basis in determining appropriate action for burned areas. The process of regenerating vegetation in a location does not depend on human intervention through replanting, but rather securing burned areas so that they are left alone to recover independently. Without human encroachment (such as oil palm plantations), optimal vegetation regrowth will occur naturally.

Figure 45. An area with natural forest regrowth

5.2 Conservation Actions

1. We encourage the improvement of habitat quality and restoration investment in the core zone area of Sebangau Katingan corridor landscape (Figure 41). This will be the natural pathway and home range for orangutan. Furthermore, we recommend promoting the core zone as an essential ecosystem area within production forest areas.

2. The buffer zone area (Figure 42) should be managed through a sustainable scheme such as RSPO/ ISPO and FSC certification systems, to ensure the land users (mixed garden, rubber plantations, oil palm plantations) are aware and cooperative in managing and living within the landscape.

3. To mitigate unnecessary conversion, the spatial function of core and buffer zones in the Sebangau Katingan corridor landscape should be integrated into a district, province and national development plan.

4. Land swap and/or buying back land in the Critical Linkage Area (Figure 41) is crucial to controlling land tenure and reconnecting the block landscape between Sebangau national park in the south, to the production forest in the north. The current land status permits the land tenure to be owned by individual and private corporate entities.

5. This project proposes the design and construction of artificial and natural wildlife pathways, such as eco-roads and canopy bridges for the connection of segments in the Critical Linkage Area, particularly in sections that cross the trans-Kalimantan highway, power lines and drainage canals.

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