Harnessing Remote Sensed and Cloud-Based Data to Improve The Management of Conservation and Biodiversity in Indonesia

by

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Abstract

Indonesia is one of the most biodiverse countries on Earth. Conservation management in such an environment relies on an integration between technology and local knowledge and wide stakeholder participation. This research presents a novel approach to processing satellite remote sensing scenes of the Indonesian archipelago, to provide the longest ever record of land use change as baseline data for conservation activities. 144,438 individual Landsat scenes covering 222 spatial tiles comprising the entire country were used to map spatial and temporal patterns in deforestation over the 43 years between 1972 and 2016. The processing stream comprised an innovative machine-learning algorithm utilising matrix completion and wavelet analysis to improve the annual resolution of imagery and to reduce the occurrence of cloud-affected pixels. The analysis improves upon both the spatial and temporal resolution of space-based deforestation mapping and shows that total rate of Indonesian deforestation surpassed that of Brazil in 2009. Deforestation trends are also linked to a range of land-use changes, for example the conversion of forested land into agricultural areas. More than 150,000 km^2 of the country are now occupied by palm oil plantations, of which $\sim 30,000$ km^2 are within forested areas designated as protected land. Furthermore, 42% of the remaining forested land in Indonesia are classified as degraded land, reducing the quality of the remnant forest cover with important impacts for sustainable land management and biodiversity. The outcomes of this novel deforestation and land-use mapping approach led to the development of an Information Technology framework for use by the Indonesian government to aid data collection in conservation management. This information collection complies with global meta data structures to contribute to conservation and biodiversity management. The framework employed incorporates cloud-based biodiversity data based on standard formats for use in further research. Finally, a mobile application was developed to assist forest rangers to collect data in remote areas. Preliminary usage showed that implementation of the mobile application helped to record fauna movement patterns and forest structure information. The mobile application and web GIS are well used by forest practitioners, with 66% of forest rangers using the approach. These results demonstrate the importance of remote-sensing based mapping and of technology integration in biodiversity and conservation management efforts in Indonesia.

Dedication

I dedicated my thesis to my family:

My Beloved Ibu dan Ayah
The only reason that makes me feels lucky even in a very low conditions of my life because of their do'a

My Children
They who already dedicated their life, living in a totally different life, to accompany me to accomplish my dream. I hope you proud of me.

My Husband
Thank you for your understanding, your love, and your patient of being smart team-mate in our beautiful journey.

My Sisters
Who are always supporting and being my best friend since the beginning of my life

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Chapter 1

Introduction

With an area of 192.257 km^2 and an archipelago comprising 13466 islands (Geospatial Information Agency of Indonesia 2017) (Figure 1.1), Indonesia supports the World's second highest level of biodiversity (after Brazil) (FAO 2005). Its geographic location, positioned between Asia and Australasia, means that Indonesia has an unique mixture of species of flora and fauna from two of the world's bio-geographical zones. According to the Indonesian Institute of Sciences (LIPI), Indonesia has more than 38,000 species of plants, of which 55% are native. Forest habitat comprises 60% of its land area, which makes it the third largest area of tropical rain forest in the world. The forest is important not only for the national economy and local livelihoods, but also for the global environment (Ministry of Forestry of the Republic of Indonesia 2008). Indonesian rain forests are also among the world's richest in terms of biodiversity, and encompass a significant proportion of the planet's tropical deep peat.

Indonesia is home to two of the global hotpots (Sundaland and Wallacea) (Myers et al. 2000), each characterized by a unique biodiversity that needs protection and careful management. Both have a rich and varied mega fauna that is either vulnerable to or 'at threat from' extinction according to the IUCN. Important species include: Indonesian elephant (*Elephas maximus sumatranus*), Indonesian Rhino (*Rhinoceros sondaicus*), Sumatran orangutan (*Pongo abelii*), and Siamang (*Hylobates syndactylus*) in Sundaland and Indonesia Lowland Anoa (*Bubalus depressicornis*), Indonesia green sea turtle (*Chelonia mydas*), and Indonesia Maleo (*Macrocephalon maleo*) in Wallacea. Furthermore, data

Figure 1.1: Indonesia Map

show that the remaining primary vegetation is only 7.8% and 15% of its original extent for Sundaland and Wallacea respectively.

Habitat loss is one of the uninviting signatures of the twentieth century (Guisan & Zimmermann 2000) and Indonesia is facing significant environmental problems resulting from rapid population growth, urbanization and extensive land use changes. According to data from the National Body of Natural Disaster Management, Indonesia reached a new high rate of species losses in 2016, increasing by 35% since 2015 and resulting from poor management and conservation and forest areas (Information Geospatial Body of Indonesia, 2015). This has been exacerbated by landslides, flooding, and widespread forest fires (Information Geospatial Body Indonesia, 2015).

Over the last four decades Indonesia has been subjected to widespread deforestation of its primary forests. Deforestation occurred at a rate of 1.8 mHa per year between 1990 to 2000 (Potapov et al. 2008) and although this has reduced by a half between 2000-2012, it is still higher than many other countries with large tropical forest stocks. Indeed, Indonesia became the world leader for forest loss in 2012 (Margono et al. 2014), surpassing Brazil. Although Indonesia instigated a moratorium on forest loss on 1st January 2011, the trend is still increasing leading to large scale land use changes and significant levels of habitat loss.

There are many reasons for this biodiversity loss and land degradation. The key factors include climate changes (Parmesan & Yohe 2003), increasing populations and resources usage (Balmford 2002, Terlizzi et al. 2005, Díaz et al. 2006), habitat destruction (Potapov et al. 2012, Hudson et al. 2014, Pawson et al. 2013), agriculture (Henle et al. 2008, Hidayat et al. 2017, Keenan et al. 2015), and pollution (Tilman & Downing 1994, Cohen et al. 1993, Tian et al. 2015). New coalitions among disciplines are required to solve the problem. There is a growing gap between the sophistication of those involved in the illegal capture and trade of wildlife, and the number, skill levels and motivation of the personnel committed to enforcing anti-poaching and other environmental laws in many places in many biodiverse areas of the world.

Research indicates that biodiversity is supported by management, increased human appreciation of the importance of the resource and technology. First, from a management perspective, research is needed to help maintain the rain forest biodiversity using resources in sustainable ways, rather than clear fell logging (Bawa & Reinmar 1998). Secondly, there is a need to capture the societal consequences of biodiversity loss and integrate aims to understanding of the ecological processes connected to ecosystem functions and services, helping to secure it for future generations. Lastly, an important and often overlooked element, is the limited use of technology in applied conservation activity (Myers et al. 2000). Technological advances have provided a range of tools have been created to help people capture data to enhance our understanding of the importance of biodiversity (Hardisty & Roberts 2013, Pimm et al. 2015).

1.1 Conservation and Biodiversity Management

Before focusing on the development of a new system to help manage conservation in Indonesia one first needs to examine the existing system.

1.1.1 Conservation targets and legislation

Indonesian law number 32/2009 emphasises the need for environmental management and protection. Clause 1 point 18 defined the conservation as "the management natural resources to ensure prudent utilization and continued availability while maintaining and improving quality levels and diversity". In Indonesia, conservation activity is managed by the Indonesian Ministry of Environment and Forestry, although numerous independent groups support conservation activity in the region aimed at protecting, understanding and enhancing biodiversity (e.g. Operation Wallacea). Indonesian law, however, requires this type of conservation activity to be carried out jointly by the government and the community (including public, private, NGO organizations), universities, and other interested parties. The national conservation strategy has been formulated around three goals:

1. Protection of life support systems
    (a) Creation of protected areas.
    (b) Training of conservation workers (e.g. forest rangers).
    (c) Controlling the use and management of land in protected area.
    (d) Controlling the maximum utilization in the deep waters protection region.
2. Preserving diversity of plants and animals and their ecosystems
    (a) Preserving the diversity of plants and animals and their ecosystems
    (b) Preservation of plants and animals (in-situ and ex-situ conservation).
3. Sustainable utilization of natural resources and ecosystems.
    (a) Utilization of environmental conditions nature conservation area.
    (b) Utilization of plants and wildlife (in the form of: assessment, research and development, breeding, trading, hunting, demonstrations, exchanges, cultivation).

Conservation activity is authorized by the Indonesian Ministry of Environment and Forestry. The current data flow and work flow in the Indonesian Ministry of Environment and Forestry is depicted in Figure 1.2, which shows a hierarchical system where data moves from the lower authority to the higher authority, while the work flow / policies move in the opposite direction. Data collection takes places at the resort level (the lowest authority in the Indonesian Ministry of Environment and Forestry). After processing and analysis at the section level, the data are combined and reviewed by the Bureau to generate conservation policy.

1.1.2 Data standards, capture and quality

At present data on plant and animals, land use, land use change and so on are manually assessed by field researchers using handheld GPS units using paper reporting forms. The

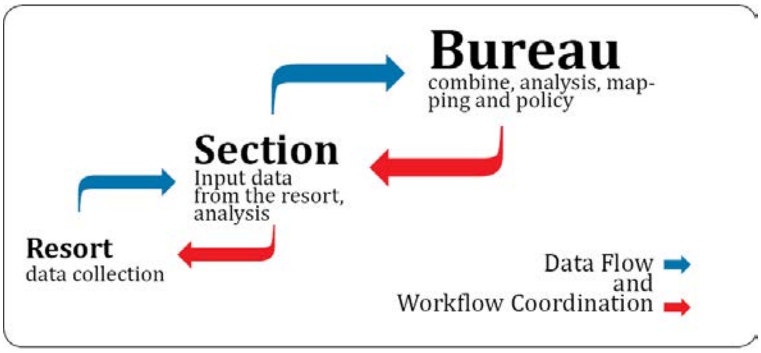


Figure 1.2: Data and Work Flow Diagram (MoEF,2015)

results of each survey event are reported to the central conservation authority by mail; a process that can carries a high risk of data loss and frequent duplication. As a result, data flows are frequently too slow and the data poorly integrated impairing conservation activity. Better baseline, current and/or real time (best case scenario) data are needed to keep pace with rapid environmental degradation Indonesian habitats are subjected to. Moreover, the responsibility for conservation activity is locally managed; many of these areas have different data standards. There is a clear need for data to be harmonised against international standards used at a global level, such as those maintained by the IUCN. This needs to be complemented by new standardised procedures that aid data capture, storage and usage.

As a developing country, many conservation areas in Indonesia are covered by forest and remote from power sources and communication networks. The ecological conditions of the conservation areas are highly variable and characterised by wide topographic variability ranging from valleys to high mountains which impedes survey effort. Thus, it can be difficult to collect appropriate georeferenced data and determine areas where human management practices are leading to conflict.

It is clear that the resort level plays a central and important role in the system where local information is generated about an area. Crucially, this is also the level at which conservation practitioners interact with local people and where potential conflicts are identified and disputes resolved. Central to the operation of the resorts is the creation of conservation areas (reserves and preserves) with some level of legislative protection.

1.2 Conservation Areas

The establishment of conservation areas in Indonesia is a key of strategy to protect taxa from extinction and important global habitats from destruction. The report from the IUCN Conference on 1994 defined conservation areas are "an area of land and/or sea especially dedicated to the protection of biological diversity, and of natural and associated cultural resources, and managed through legal or other effective means" (Shine & de Klemm 1999 p.10). In 2003, IUCN argued for the management of conservation areas using integrated plans that accommodate many interest groups involved in the area, including local communities. The level of local community support would then be an important component of successful conservation activities (MacKinnon & Derickson 2013) aligning conservation activity with the goals of the community leading to a more sustainable environment.

The IUCN conference in 2000 recommended a core set of the values that would help this process:

1. Conservation areas in Indonesia should be valued by all of the parties inside the country to provide benefit to the environment but also recognizing Indonesia's key role as globally megadiverse country;

2. The existence of local and indigenous groups inhabiting conservation areas should be fully supported and shape co-management of the conservation process;

3. Knowledge, innovation and best practice held by local communities should be valued as an important contribution supporting conservation management;

4. The Government should collaborate with local conservation area managers to implement the wider unified system of controls to manage the land inside conservation areas.

As a result, Indonesia law places conservation activity in a position where it can provide advantages using biodiversity resources but also maintain their stocks, and where

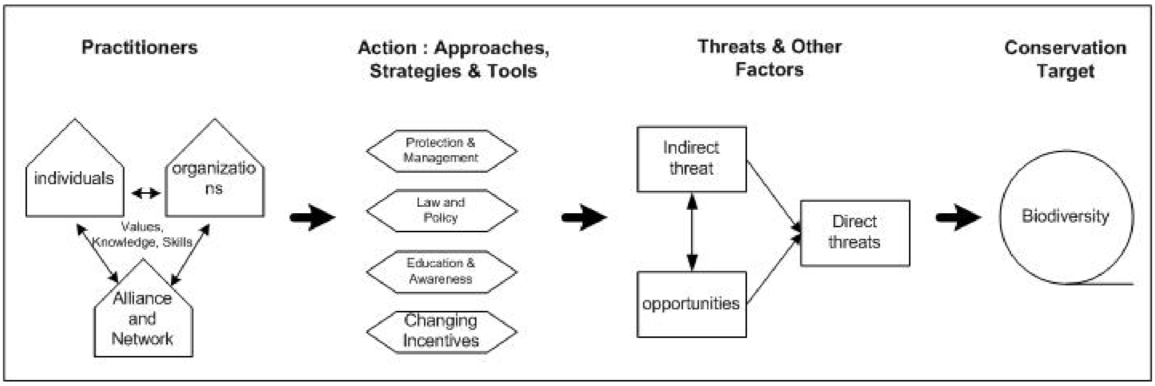


Figure 1.3: A generalized model of a conservation project (Salafsky et al., 2002)

possible improve the quality and value of biodiversity. Nature sanctuaries and wildlife reserves are included in Nature Reserve Areas. National, forest, and tourist parks are included in Nature Preserve Areas. the Indonesian Ministry of Environment and Forestry typically view conservation areas as protected land.

1.3 Working towards a conservation decision support system for Indonesia

This thesis proposes the application of integrated technologies that bridge the gap between human behaviour (Cardinale et al. 2012) and policy implementation (Higgs et al. 2008, Berry et al. 2011) to help conservation work in Indonesia. There is a clear need to bridge the gap between harmonise data, provision capture, to enhance data coverage and accuracy and its use in conservation. Expert systems (Eigaard et al. 2014) have been proposed to help the management of fisheries based on real time operational systems. Social marketing, another form of applied technology, was promoted by Andriamalala et al. (2013) and involves using social media to support the socialization of application in Madagascar to protect fish and other marine species. But a more thematic and joined-up approach is required. Salafsky & Wollenberg (2000) proposed a conceptual framework for integrating human needs and biodiversity in Figure(1.3).

Their framework generalized by Salafsky (2000) emphasized the key elements of a robust and flexible conservation systems. It illustrated the need for good (and baseline) data capture that integrates information from practitioners, landowner, and public bodies that factor in conservation targets and legislation that are biodiversity related.

1.4 Aim and Objectives

The central aim of this thesis is to develop and build a technology that supports the conservation process to achieve the goal of protection biodiversity in Indonesia. This will be achieved through for objectives:

1. Utilized machine learning methodologies to improve data capture, processing and support decision-making in Indonesia;
2. Use remote sensing data to establish a long-term baseline dataset on deforestation in Indonesia;
3. Use remote sensing data to establish a long-term baseline dataset on land use and land compositional change in Indonesia;
4. Create the database of biodiversity that is harmonised against IUCN data structures and capable of real time update on a web portal;
5. Build novel IT framework based to improve the performance of the ministry of the Republic of Indonesia;
6. Implement the framework to provide a new approach in monitoring the conservation activity in Indonesia;
7. Empower forest rangers in Indonesia with novel technology to aid the conservation process in Indonesia;

1.5 Thesis Structure

This chapter has shown that habitat loss in Indonesia represents a significant environmental threat, which due to the country's unique biodiversity, is of global significance and concern. Currently, levels of habitat loss are unsustainable in the long term yet conservation activity is hampered by a hierarchical and fragmented conservation framework/system. The need for a harmonised, web-based database of land use change, to support an enhanced conservation decision support system is clear.

Chapters two and three focus on the provision of an improved baseline data set on land use using all available remote-sensing products. Chapter 2 examines temporal and spatial changes in forest loss in Indonesia using a new and extensive 43-year annually resolved dataset at a high spatial resolution (60x60m for 1972-1990 and 30 x 30m pixel resolution from 1990 onwards). It introduces an innovative matrix completion methodology that segments the images at a pixel level replacing cloudy pixels with the nearest cloud free pixel using the acquisition date of the images, nearest neighbor analysis and machine learning methodologies.

Chapter 3 uses the same images to create a longitudinal analysis of land use change using pixel by pixel depiction of the land use that supplanted primary woodland. Thereafter, the variables driving the land use changes (i.e. Timeseries) are evaluated with Generalised Additive Models (GAMs), using economic and social data as explanatory variables.

Chapters 4 focuses on the design and implementation of an online, mobile web-enabled conservation system for Indonesia. Chapter 4 develops a framework for the integration mobile-web technology for biodiversity and conservation management in Indonesia focused on the smallest conservation unit in the Indonesian system, the resort. The objectives were to review the current status of conservation structures and processes in Indonesia, and design a bespoke system that takes advantage of new and emerging web-based and mobile technologies.

Android-based smartphone mobile application is developed in Chapter 5 and evaluated by conservation officers (Forest Rangers) in Indonesian national parks (within the Resort management units). The thesis concludes with a summary of the key findings and outcomes and identifies areas for further research that further the development of conservation activity in Indonesia.

Chapter 2

Evaluating the Patterns of High and Variable Deforestation in Indonesian Primary Forests

2.1 Summary

Indonesia is the second most biodiverse country on the planet, it contains two global biodiversity island hotspots (Sundaland and Wallacea). The Indonesian archipelago is comprises more than 17,000 islands home to over 1,230 and 16,500 endemic vertebrate and plant species. Since 2000, loss of primary forest cover has accelerated and is now thought to be higher than in Brazil resulting in biodiversity loss, and increased greenhouse gas emissions. However, quantification of deforestation prior to 2000 is unknown and since then it has been confounded by errors due to image cloudiness. This chapter reports on cloud-corrected, spatio temporal trends in Indonesian forest loss for the full satellite observational record (1973-2016). Between 2000-2005 rates of deforestation are 21.24% larger than previous estimates (1.024 x 106 $km^2 y^{r-1}$ +/- 0.028) with stronger inter-island group variability than previously thought. Spatial variability and patterning across island groups revealed large and early contemporary losses of primary forest on Java, and to a lesser extent Sumatra Island. Mitigating conservation policies appear to have had little effect on rates of deforestation. Urgent conservation measures should be focused on the island groups with the greatest remaining proportions of intact forest, where current deforestation is highest (Kalimantan, Sulawesi and Papua).

2.2 Introduction

Although it covers only 1.3% of the world's land surface, Indonesia ranks in the top ten countries (=8th) for its stocks of primary forest (The Indonesian Ministry of Environment and Forestry, 2008). It houses two important biological hotspots (Sundaland and Wallacea) and is home to 11% of the world's plant species, 10% its mammal, and 16% of its bird species (Myers, 2005). Across the Indonesian archipelago, 1,230 and 16,500 species of vertebrates and plants are endemic (5.5% and 4.5% of plants and vertebrates respectively of its total species pool) on its 17,000 islands, including numerous, charismatic and globally significant animals (e.g. Orangutans (*Pongo pygmaeus*), Sumatran tiger (*Panthera tigris sumatrae*), Anoa (*Bubalus depressicornis*)).

In 2005, Indonesia and Brazil were the two countries with the highest rate of forest degradation in the world (FAO 2005), with deforestation rates reaching 3.1 and 1.8 million hectares per year in Brazil and Indonesia respectively. Since 2000 the loss of primary forest has increased alarmingly so that by 2012, Indonesia had the highest rate of forest loss in the world, supplanting Brazil at the top of the list (Margono et al. 2014). Moreover, Sumatra, one of the largest islands in Indonesia, will have lost almost 95% of its natural habitats to land degradation by 2020. If left unchecked, Indonesia is predicted to have lost most of its forest cover by 2030 (UN-REDD, 2010). Not surprisingly, Indonesia is now an extinction hotspot, with the extinction rates running at 2 per 866 known species per year, with almost 295 species of its biota classified as endangered by the International Union for the Conservation of Nature (IUCN). Coupled to projected losses as a result extinction, deforestation leads to carbon losses which are currently estimated to be 1.1 Gt C per year globally (Brinck et al. 2017). Deforestation in Indonesia is a large contributor to these losses and thus the country is a significant emitter of greenhouse gases that contributing to global warming.

The Indonesian government has generated a range of legislation aimed at managing land use, resource usage (e.g. especially its timber reserves), royalties from resource exploitation, planning, emphasising sustainable outcomes. This included ratification of the

Kyoto and Convention of Biodiversity (see Appendix A). It has coupled this with numerous laws and initiatives designed to protect and conserve biodiversity and key habitats, culminating in a country-wide moratorium on logging in 2012. The issues in managing land use change, especially in forested environments is not one of lack of legislation but one of enforcement.

A key element of the land use change story in Indonesia relates to the pattern and spread of deforestation, especially prior to 2000 and post 2012, where little comparable data exist. Although Margono et al. (2014), have examined the period 2000-2012 in some detail, they use a 5-yr sample period. Thus, annual data are missing from the analyses. This chapters thus aims to:

- Create the longest cloud-corrected, annual data series documenting Indonesian forest loss using full satellite observational record (1973-2016);
- Use these data to compare the patterns and rates of loss between Indonesia's five main island groups and relate these patterns to Indonesia's trade and conservation policies;
- Compare the rates of loss to existing audits using similar data sources.

2.3 Method

Measuring deforestation trends from remotely-sensed data in tropical areas is complicated by data losses due to atmospheric processes (e.g. cloud formation), aerosol pollution, wildfires and volcanic plumes (Keenan et al. 2015, Morales-Hidalgo et al. 2015). While considerable progress has been made in generating deforestation datasets over longer timescales (e.g. Margono et al. 2012), a detailed depiction of patterns of change at fine spatial scales, within and between island groups, and over the full satellite observational record pre-dating 2000 has not previously been attempted. Further, while improvements have been made in measuring contemporary forest loss, no analysis yet exists examining the underlying drivers of loss including urbanization and agricultural intensification, with clear linkages to Indonesia's trading policies and economic development (see Chapter 3). These methodological limitations are principally the result of the persistent occurrence of cloud cover over Indonesia and the difficulty observing land cover in cloud-afflicted visible and near infra-red (VNIR) spaceborne imagery. Previous remote sensing-based forest cover change assessments have addressed this issue by selecting only those scenes in which at least 50% of the tile is cloud-free (e.g. Margono et al. 2014, 2012), an approach which may substantially underestimate true rates of loss. A matrix-completion algorithm methodology is presented here to outline annual patterns of forest loss on all Indonesian island groups. The algorithm, described in detail below, creates annual cloud-free mosaicked image composites for the full Landsat satellite record (1972-2016). This comprehensive new dataset permits analysis of the loss of Indonesian primary forest in greater spatial and temporal detail than previously presented. All of the process of this method had been done within 12 months of data process with total images size were 8TB.

2.3.1 Landsat data sources

The NASA / USGS Landsat program provides the longest continuous record of Earth surface observation data in existence (Ma et al. 2015) and has been widely used to document Earth system change, targeting a wide range of environmental issues. While the spatial extent of available data is global, image quality varies depending on coverage and instrument age. Satellite platforms and sensors launched since 1972 have significantly improved both spatial and spectral resolution, permitting the analysis of new and better data with innovative processing solutions (Mather & Koch 2011). The following sections describe the steps taken to process the full Landsat operational image record of Indonesia to produce the longest and most comprehensive time-series of primary forest loss to date.

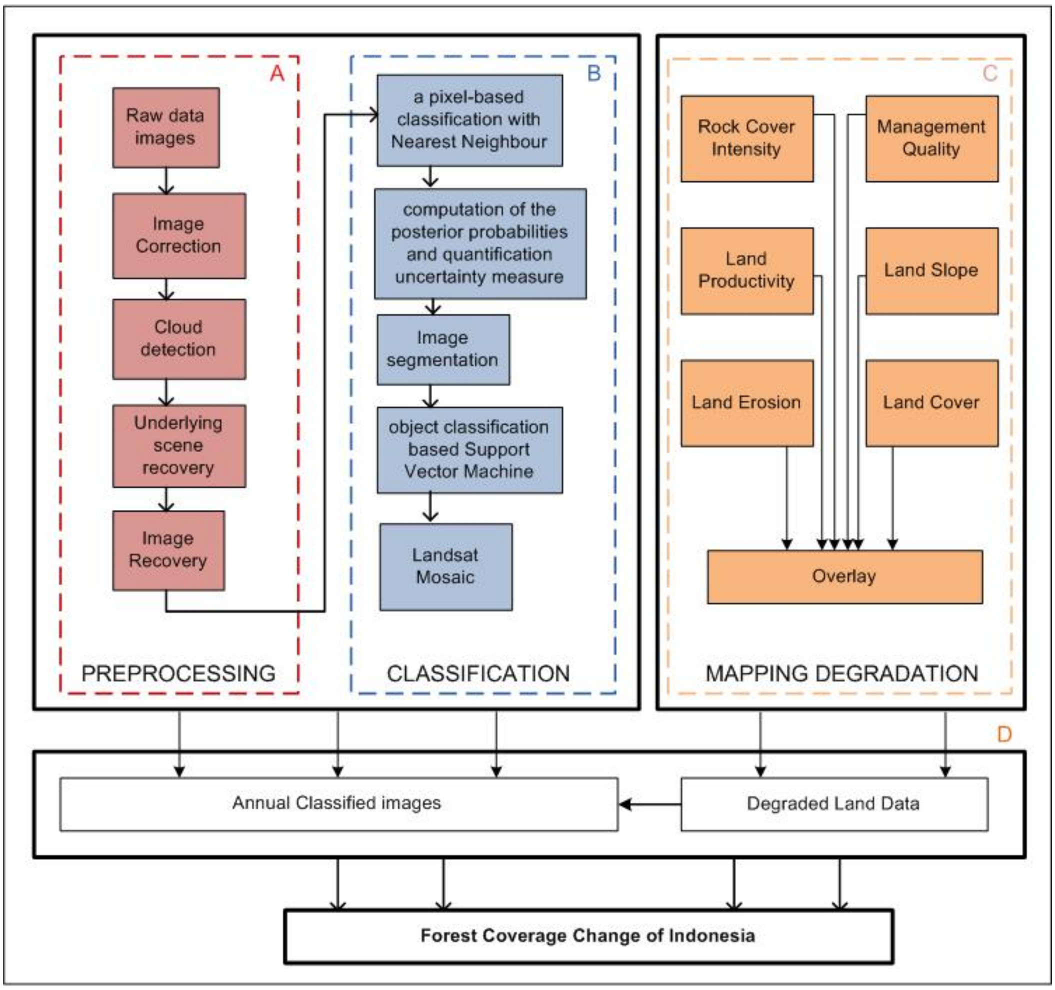


Figure 2.1: Workflow for Landsat image pre-processing, classification and mapping for Indonesian forest cover change assessment.

2.3.2 Raw Image Selection and Processing

Landsat data processing was undertaken in four stages: (1) Pre-processing; (2) classification; forest loss estimation; and, (4) land-use degradation validation. Each are depicted in Figure 2.1.

Pre-processing

Level-1 Landsat data products corrected for geometric, radiometric and terrain effects were accessed for pre-processing from the USGS archives via Earth Explorer (earthexplorer.usgs.gov). Post-download, scenes were grouped by instrument product and organised into a relational database using location and date stamps. All available scenes covering the Indonesian archipelago were downloaded, providing database totals of 23,794 (Landsat 1-5 MSS), 56,899 (Landsat 4-5 TM C1 Level-1), 53,488 (Landsat 7 ETM+ C1 Level-1), and 9,255 scenes (Landsat 8 ORI/TIRS C1 Level-1).

Data from each instrument in the Landsat series has different numbers of spectral bands (Table 2.1) so pre-processing emphasized those bands in each dataset that were suitable for vegetation mapping according to Global Terrestrial Observing System - Global Observation of Forest and Land Cover criteria (GOFC-GOLD, 2017). False-colour image composites were created by combining Band 4 (Green) red, Band 7 (NIR) green, and Band 5 (Red) in the blue channels (Landsat 1-5 MSS). Image composites from the higher spatial resolution Landsat 4-5 (30 m) used the same band combination as previous scenes (Band 1 Green in red, Band 4 NIR in green, and Band 2 Red in blue). Gaps in Landsat 7 ETM+ scenes due to the Scan Line Corrector (SLC) failure were repaired and filled using the ERDAS Imagine engine (ERDAS, 2014; Chen et al., 2014). The band used by Landsat 8 OLI/TIRS to resolve high-level cirrus cloud (Band 8) was also used additionally to segment cloud within the cloud detection protocol outlined below (2.3.2.1). Following image compositing, resampling of Landsat 1-3 scenes to 30 m (for comparison with other instrument scene resolution) and noise reduction was undertaken using a wavelet-based low pass filter (Mallat 1989).

Table 2.1: Overview of Landsat satellite program (1-8) spectral bands, band names and range of wavelengths.

L1-L2 (60x60)	L3 (60x60)	L4-L5(60x60)	μm	L4/L5 TM (30x30)		ETM+ (30x30)		Landsat 8 (30x30)	
				Band	μm	Band	μm	Band	μm
								Band 1 Coastal	0.43-0.45
				Band 1	0.45-0.52	Band 1 Blue	0.45-0.52	Band 2 Blue	0.45-0.51
Band 4	Band 4	Band 1	0.5-0.6	Band 2	0.52-0.6	Band 2 Green	0.52-0.0.6	Band 3 Green	0.53-0.59
Band 5	Band 5	Band 2	0.6-0.7	Band 3	0.63–0.69	Band 3 Red	0.63-0.69	Band 4 Red	0.64 – 0.67
Band 6	Band 6	Band 3	0.7-0.8	Band 4	0.76–0.90	Band 4 NIR	0.77-0.9	Band 5 NIR	0.85 – 0.88
Band 7	Band 7	Band 4	0.8-1.1						
				Band 5	1.55–1.75	Band 5 SWIR 1	1.55-1.75	Band 6 SWIR 1	1.57 – 1.65
				Band 7	2.08-2.35	Band 7 SWIR 2	2.09-2.35	Band 7 SWIR 2	2.11 – 2.29
						Band 8 Pan	0.52-0.0.6	Band 8 Pan	0.50 – 0.68
								Band 9 Cirrus	1.36 – 1.38
	Band 8		10.4-12.6	Band 6	10.41-12.5	Band 6 TIR	10.4-12.5	Band 10 TIRS 1	10.6-11.19
								Band 11 TIRS 2	11.5 – 12.51

Cloud Detection and Image Recovery

Each Landsat scene was processed in sequence using date stamps to produce a final processed image per year with no cloud pixels present. A threshold was first defined to determine the maximum cloud area using a semi-automated training algorithm to identify white pixels from RGB composite images using their position and time stamps. The thresholding process characterized images based on their dark channel from the RGB intensity values contained with the images. The area of cloud were then identified by the consistent value of white areas. Each individual image composite was classified using its RGB value to determine the median pixel value for each cloud-affected pixel. The pixels were then combined into a cloud mask using a k-nearest neighbour algorithm.

As cloud pixels can be assumed to be only those with white values (in a tropical forest area) and must contain more than one matrix value, a loop algorithm was employed to detect and combine the total cloud area per scene. The matrix member is determined by the member of each cloud area by computing the median pixel vector for each matrix value, computing the k-nearest neighbour search of the area from the nearest matrix based on the median computed prior, and the process is then stopped when the cloud area was detected. Areas of cloud in the individual image composites were set to no pixel value before replacement (filling) using cloudless pixels from coincident tiled and time-stamped scenes. This process was then iterated until each pixel in the final image had a non-cloud value using scenes from the same year. As the pixel variance within the same scene can be large, especially in scenes with a lot of cloud, forested composite images were used to help select replacement pixels. Low-rank matrix approximation was used to determine the importance of individual components and to omit those that were either inconsistent or represented noise, thus minimizing the problem of high data dimensionality resulting from the large data files produced by the iteration process. The continuity of matrix completion was optimized based on the distance value between each pixel and the Frobenius norm of the image (square root of the sum of absolute squares of matrix elements) (Keshavan et al. 2009, Hastie et al. 2014). The process was further optimized using Matlab's augmented

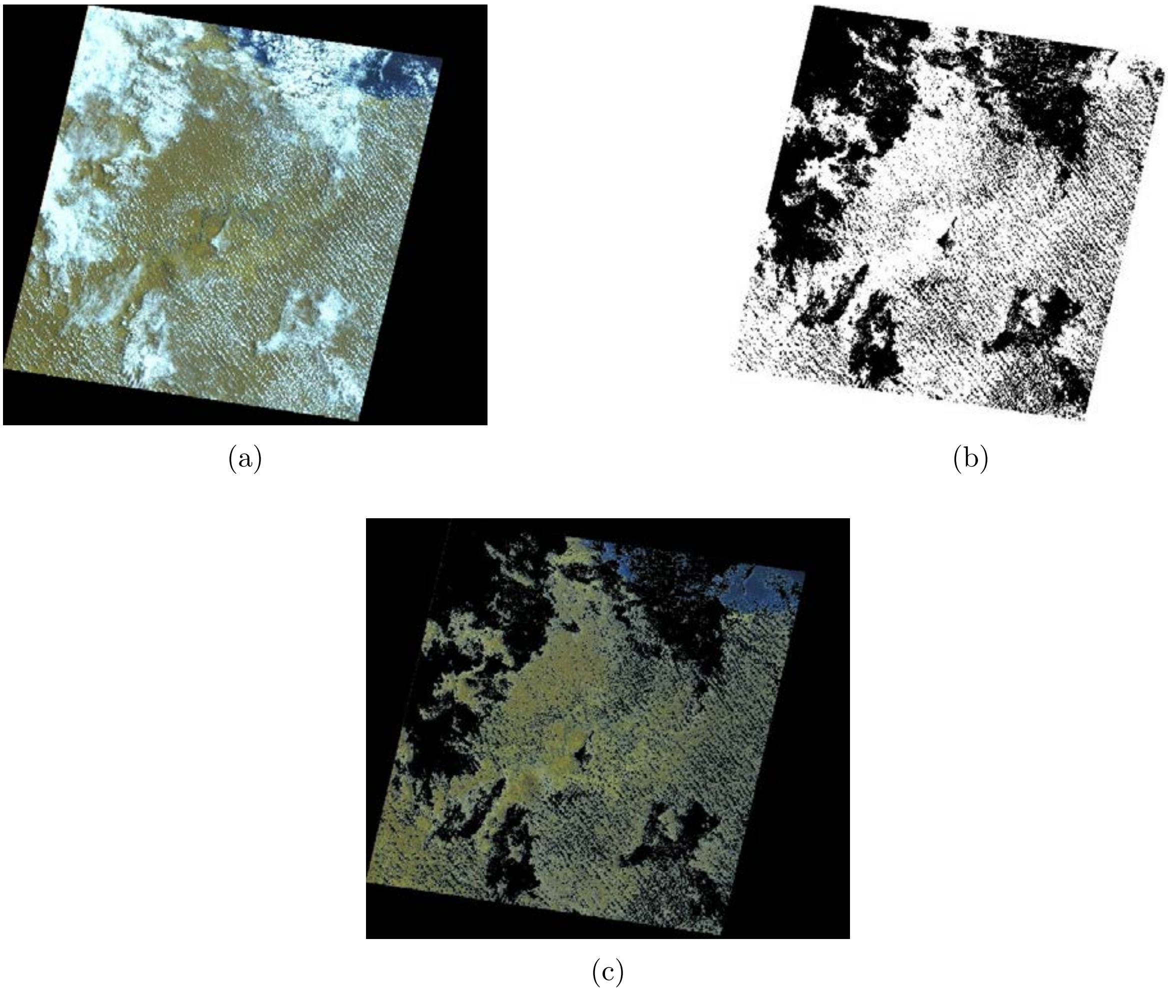
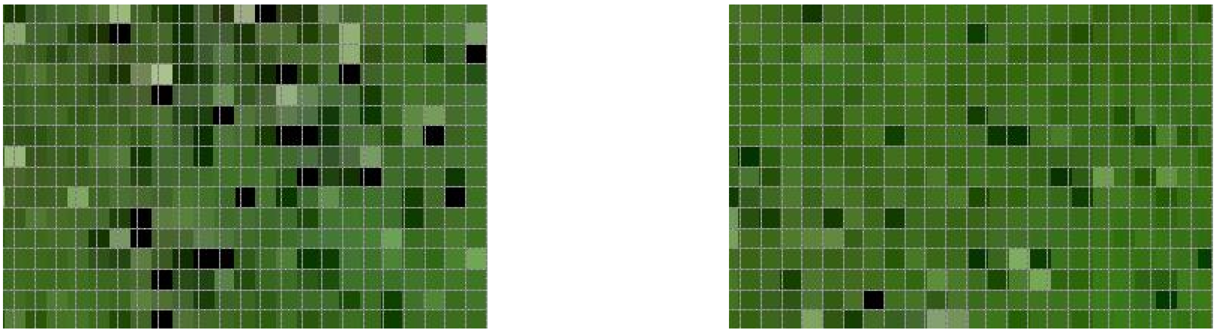


Figure 2.2: Example of cloud pixel detection and replacement. a) clouds are visible as black pixels, and b) following the matrix replacement process, c) cloud pixels are replaced with data from cloud-free scenes of the same year



(a) (b)

Figure 2.3: (a)Pixel appearance of cloud detection inside image where the black color is cloud and the other color is land use (b) The image result from matrix completion process that would complete the empty matrix with the other pixels from available images sequence from certain position

Lagragian[1] method (Li et al. 2013), where default values selected of $\lambda 1 = 20$, $\lambda 2 = 0.5$, step size n = 100 and the threshold value set to 0.6. This final processing step produces a single, complete cloudless scene allocated to one year (Figure 2.2).

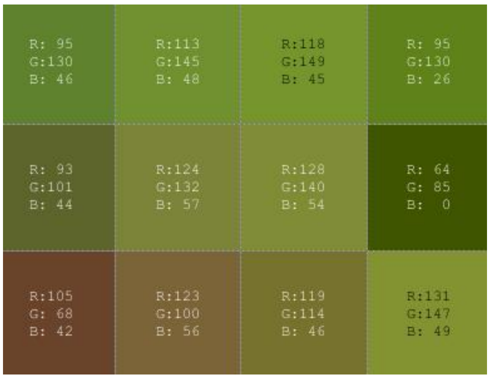
2.3.3 Vegetation Classification

The areal extent of forest vegetation was classified using an innovative combination of traditional pixel based (Chen & Wang 2005, Hussain et al. 2013), object orientated (Blaschke 2010)(Hussain et al. 2013) techniques.

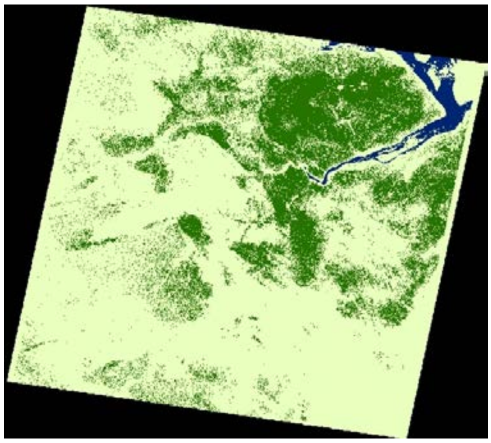
Pixel Based Classification

The cloudless scenes were classified using Bayesian Classifier (Aksoy & Akcay 2005) to determine the probability of each pixel group as forest or non-forest. The hybrid method classified the surface of the image based on objects such as tree crowns and parts of buildings. The definition of the Indonesian Ministry of Environment and Forestry to define forest were used as an evergreen woody group of plants with 5 m minimum estimated height (using NDVI), 30% of crown cover and an aerial extent of more than 25 km^2. All the scenes were set at a pixel size of $512x512$ to aid comparison. The noise inside the

[1] available in: uk.mathworks.com/matlabcentral/fileexchange/41254-augmented-lagrangian?focused=3783128&tab=function& requestedDomain=true# feedbacks



(a)



(b)

Figure 2.4: (a) Examples of pixel combinations used in the classification process to determine the pixel groups forest and non-forest (b) Reclassified RGB colour combinations forest and non-forest class within a scene.

scene (including salt and pepper) was normalised with a Wavelet function (Mallat 1989, 1996, Mountrakis et al. 2011). Forest area cover was defined with the combination of Red, Green and Blue pixels using the following values: Red (0-75), Green (75-150) and Blue (0-75) (2.4a) (Waser et al. 2011).

Pixel classification accuracy was assessed with an error matrix, where the Pi,j entry in the matrix is the estimate, obtained from the data. Accuracy assessment was made with the error matrix, where the $P_{i,j}$ entry in the matrix is the estimation, obtained from the data.

$$P_(i, j) = \frac{(n_{i,j}/n_{it})}{(N_{i,j)}/N_{it})}$$

where $n_{i,j}$ is the number of the data pixel classified as map class i and reference class j;n_{it} is the sample size in class i; N_{it} is the total number of pixels in the map.

Regions of Interest (ROI) for pixels that may appear to be forest (e.g. rice fields) were selected as training sets to define representative classes and assess the levels of misclassification in pixel allocation. The uncertainty process was optimized to assess the quality of classification process using:

$$\Upsilon = 1 - \frac{\max_{i=1,..,n}(P_i) - (\Sigma_{i=1}^{n} P_i)/n}{1 - 1/n}$$

Object Based Classification

To complement the pixel based classification, an object-based classification (Walter 2004, Blaschke 2010) was undertaken. The object class training sample used rice field, agriculture, farm, palm oil and urban land uses.

Image segmentation was used to support the object classification (Shi & Malik 2000) using the Statistical Region Merging (SRM)[2] algorithm (Boltz 2004). The Q parameter of this algorithm determines the type object for segmentation and Region Pixel Minimum the placement of boundaries.

2.3.4 Generating Time Series

The scenes from the classification process were combined to produce annual maps of forest presence in Indonesia and the used these to quantify inter-annual change the using the following rules:

1. $Forest_{t0} \rightarrow Forest_{t1}$ (remained)
2. $Forest_{t0} \rightarrow NonForest_{t1}$ (changed)
3. $NonForest_{t0} \rightarrow NonForest_{t1}$ (remained)
4. $NonForest_{t0} \rightarrow Forest_{t1}$ (changed)

2.3.5 Degraded Land

Previous researchers (e.g. Margono et al. 2014) recognized that defining the extent of forest landscapes using remote sensing data can overestimate the used area of primary

[2]https://uk.mathworks.com/matlabcentral/fileexchange/25619-image-segmentation-using-statistical-region-merging?requestedDomain=true

habitat because of edge effects and the influence of adjacent non-forested habitats. Margono et al. (2014) characterized primary forests primary intact and primary degraded subclasses using the GIS-based buffering approach of the Intact Forest Landscapes (IFL) (Potapov et al. 2008). Their IFL layer buffers were based on the pixel value between intact and degraded forest around roads, settlements and other signs of human landscape adjacent to zones of primary forest cover, see Figure 2.5. Both Matthews et al. (1999) and Potapov et al. (2008), however, agreed this approach could be improved upon by to better utilizing different data supplied by other bodies (e.g. local government). Here, the research adopt such an approach and use technical guidance from Direktorat Jenderal Bina Pengelolaan Daerah Aliran Sungai dan Perhutanan Sosial (2013) to generate a map of degraded forest land in Indonesia (Figure 2.7), to help resolve the existing primary forest reserves. This uses six categories that more reliably generate data determining the level of degradation in the landscape: Land cover of primary forest, levels of erosion, land productivity, rock cover, slope angle and land management.

Land Cover

Land cover was classified using the percentage of canopy cover per pixel as Very High (80% canopy cover), High (61-80% canopy cover), Medium (41-60% canopy cover), Low (26-40% canopy cover) and Very Low (40% canopy cover). Group 1 (Very high) were forested with near intact canopy, group 2 (High), were shrubs and abandoned forest, group 3 (Medium) were occupied by farm and other agricultural land covers, while the fourth group (Low) were field-dominated with limited tree cover (either solitary trees or trees in small groups); the last group (Very Low) were grasslands, open fields, and residential areas.

Soil Erosion

Soil erosion was quantified using Technical guidance from Nature Disaster Management body of Indonesia and is based on the USLE formula described by (Wischmeier & Smith

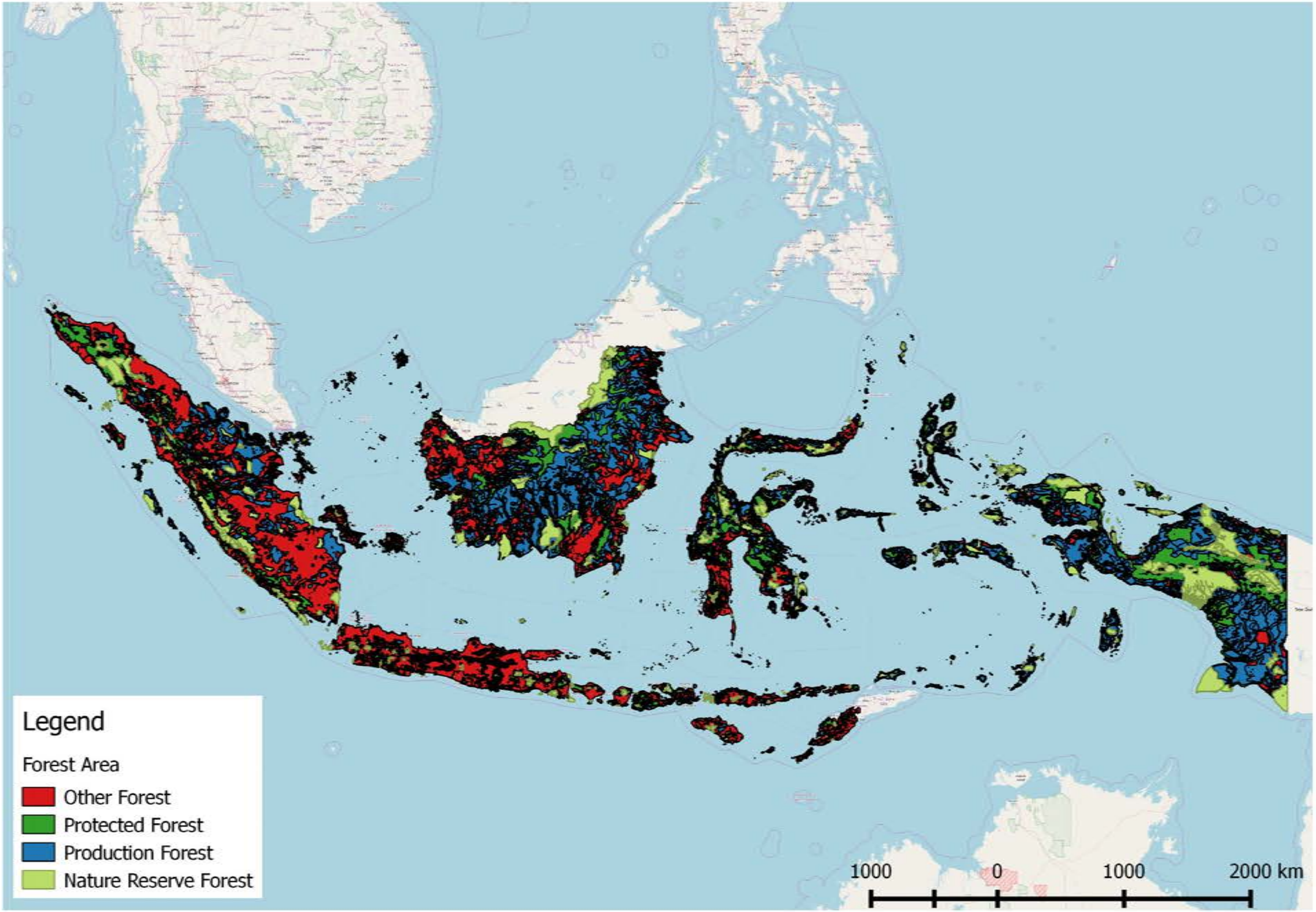


Figure 2.5: The distribution of different forest designations in Indonesia in 2004 (note: other forest is landuse forest of Margono et al. (2014)

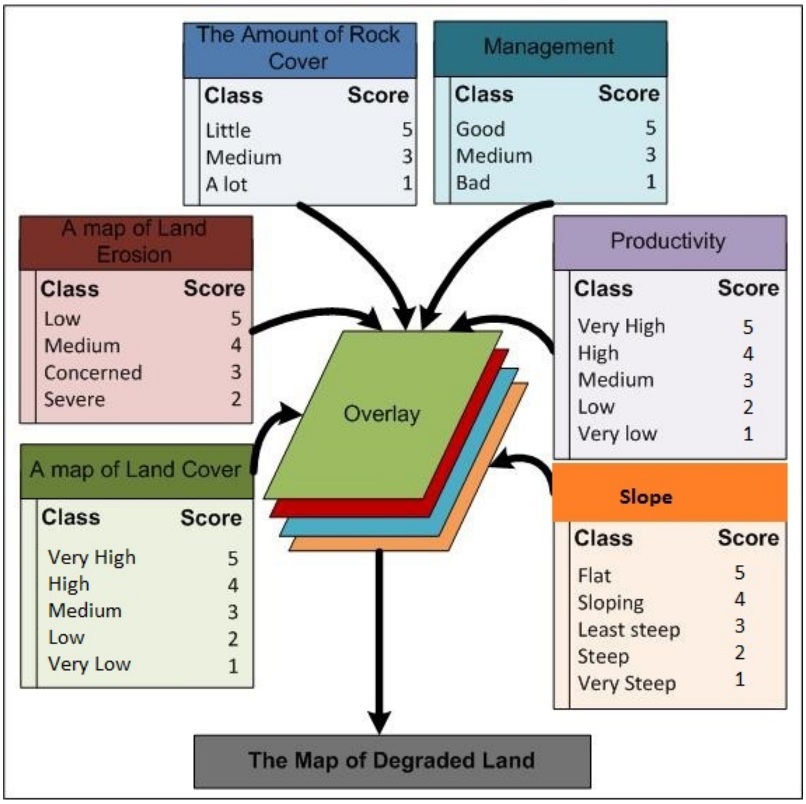


Figure 2.6: Method to Map degraded land in Indonesia

1978):

$$A = RxKxLxSxCxP$$

Where, A is the degree of soil erosion (ton/ha/year), R is a degree of rainfall, K is a degree of soil eroded process, L is the index of slope length, S is the index of slope steepness, C is land cover index, and P is land management, or soil conservation.

Erosion was classified into 4 groups (low, medium, concerned, and severe):

1. Low (5) $\rightarrow >$ Subsoil : reduced less than 25% of its topsoil/ having flow erosion in between 20-50m in distance; Topsoil : reduced less than 25% of its topsoil/ having flow erosion in less than 50m in distance

2. Medium (4) $\rightarrow$ Subsoil : reduced 25-75% of its topsoil/ having flow erosion in less than 20 m in distance; Topsoil : reduced 25-50% of its topsoil/ having flow erosion in 20-25 in distance

3. High (3) $\rightarrow$ Subsoil : reduced more than 75% of its topsoil/ having trench erosion

in 20-50 m in distance; Topsoil : reduced 50-75% of its topsoil

4. Severe (2) →Subsoil : all of subsoil already gone, reduced more than 25% of its subsoil/ having trench erosion with medium deep in 20-50 m in distance; Topsoil : Lost all of its subsoil, most

Land Productivity

Data from National Development Planning of Republic Indonesia was used to estimate the production of rice, fruits, and vegetable (per province) in Indonesia. Land productivity was defined as a ratio of general production to traditional productivity. The approach used to know the degree of land productivity based on Indonesia measurement were using the formula:

$$P_v = \frac{Y}{L_p}$$

where P_v productivity index, Y is annual production (ton), L_p is the plantation area (Ha) To obtain land productivity index, percentage would be used to specify the group of land productivity index, following items were used:

$$LandProductivity = \left(\frac{P_v}{GeneralCommodityRate}\right)x100\%$$

Land productivity that would be classified into 5 classes (very high, high, medium, low, and very low):

1. Very High (5) → > 80% commodity
2. High (4) → 61-80% commodity
3. Medium (3) → 41-60% commodity
4. Low (2) → 26-40% commodity
5. Very Low (1) → < 40% commodity

Rock Cover

Rock cover data were derived from data from The Ministry of Energy and Mineral Resource (2015) detailing exposed mineral and rock cover in Indonesia. This was classified into 3 group: Low ($< 10\%$ area covered by rock), Medium (10-30% area covered by rock), and High ($> 30\%$ area covered by rock).

Slope

The slope of land is a significant contributory factor that leads to land degradation. Land slope was mapped using a Digital Elevation Model with 30x30 m resolution downloaded from USGS[3]. All the DEM scenes were mosaic using slope criteria as follows using ArcMap to generate slope data expressed as percentages: Flat ($< 8\%$), Sloping ($8 - 15\%$), Less Steep ($16 - 25\%$), Steep ($21 - 40\%$), and Very Steep ($> 40\%$).

Land Management

Data on land management was derived from data held by the Indonesian Ministry of Environment and Forestry for conservation units in each province in Indonesia. This was categorized as (Good, Medium, and Bad):

1. Good encapsulated well managed land characterized by high forest cover and natural successional processes. This included forests but also some plantations (mainly tea). We limited the classification of this group based on the characteristic of land management inside the forest and tea plantation farm. Habitats in this group are patrolled and monitored regularly by forest rangers in the area.

2. Medium included the land cover of shrubs, agriculture land (rice farm, field, mixed plantation schemes), with some of residential. It also previously forested areas undergoing regeneration by low vegetation and not maintained in plantation management or land conservation.

[3]available in: https://gdex.cr.usgs.gov/gdex/

Table 2.2: Land use classes and degradation levels

Critical Level	Protected Forest	Cultivated Area and Farm	Protected Area Outside the Forest
Critically Degraded	120-180	115-200	110-200
Degraded	181-270	201-275	201-275
Medium Degraded	271-360	276-350	276-350
Potentially Degraded	361-450	351-425	351-425
Not Degraded	451-500	426-500	426-500

3. Bad included all land use outside of the conservation activities. This included grassland, road, river, and some of residential areas.

Overall score

Before we calculated the final score of degraded land, we grouped the land into 3 groups which were: Forest Area, Cultivated Area/Farm, and Non-Forest protected Area using definitions created by the MoEF. The formula below was then used to calculate a degraded land class total score per pixel:

$$Total_Score = LC + LS + LE + LM + RC$$

where, LC = Land Cover, LS = Land Slope, LE = Land Erosion, LM = Land Management, LP = Land Productivity, RC = Rock Cover.

The score was then mapped as a vector layer on the GIS to identify areas that were critically degraded on a continuum to those that had not been degraded (Table 2.2).

After the calculation of degraded area, the distribution of the area can be seen in Figure 2.7

The final task was to use these vector data to quantify the remaining areas of pristine primary forest at each yearly time step by:

$$PristineForest = Forest - DegradedLand$$

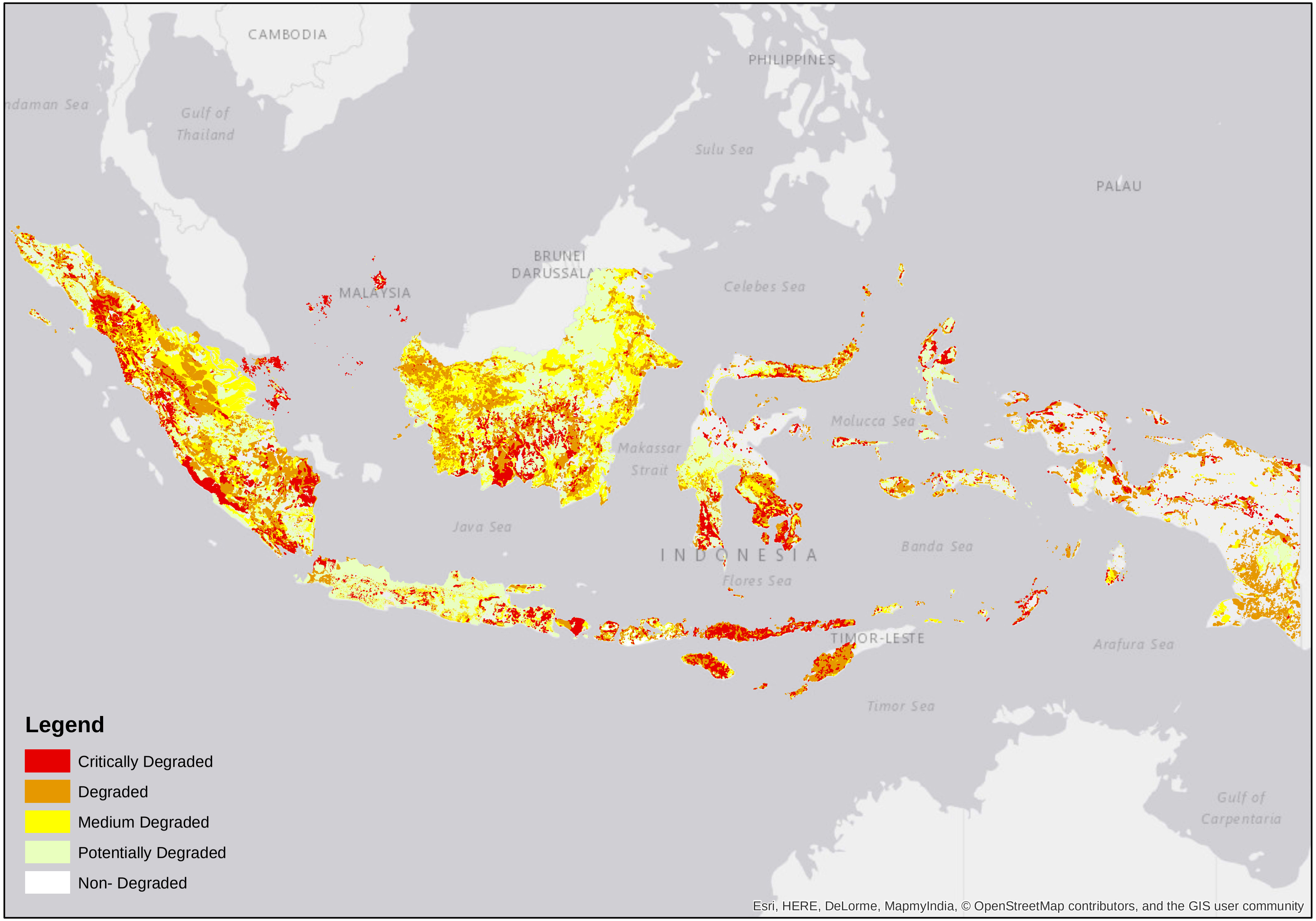


Figure 2.7: The distribution of degraded land in Indonesia based on Chapter 2

Statistical modelling

The rates of change in primary forest loss were modelled to all of Indonesia (Figure 4.10) and the main islands groups (Sumatra, Java and Bali, Kalimantan, Sulawesi, Papua and Maluku; Figure 2.15a) using Generalised Additive Models (GAMs) (Wood 2006). As the focus was in understanding the yearly trends in rates of loss, the fitted models capture temporal variation in the mean of the probability distribution of the response (deforestation in this case). To allow easy interpretation of the fitted trends, periods along the trend, where the slope was statistically significantly different from 0, were identified and alternatively coloured to indicate significant increases in loss and periods where rates of loss dropped significantly. To do this, the first derivatives of the splines were computed using the finite differences methodology following the method outlined by Curtis & Simpson (2014).

2.4 Results

The dataset included all available digital imagery available for Indonesia sampled, or resampled in the case of Landsat 1-3 images, to a 30 x 30m pixel resolution, with a total of 43,386 scenes covering 222 tiles. Although the data cover all islands in the country ($\sim 17,000$), we have grouped these into six island groups to aid the description of the patterns of loss. At 43 years, this is the longest time series capturing data on forest loss in Indonesia ever assembled and it highlights some significant and important patterns in not only total rates of forest loss but also highly variable and hitherto undocumented inter-island differences in the sequencing and rates of loss.

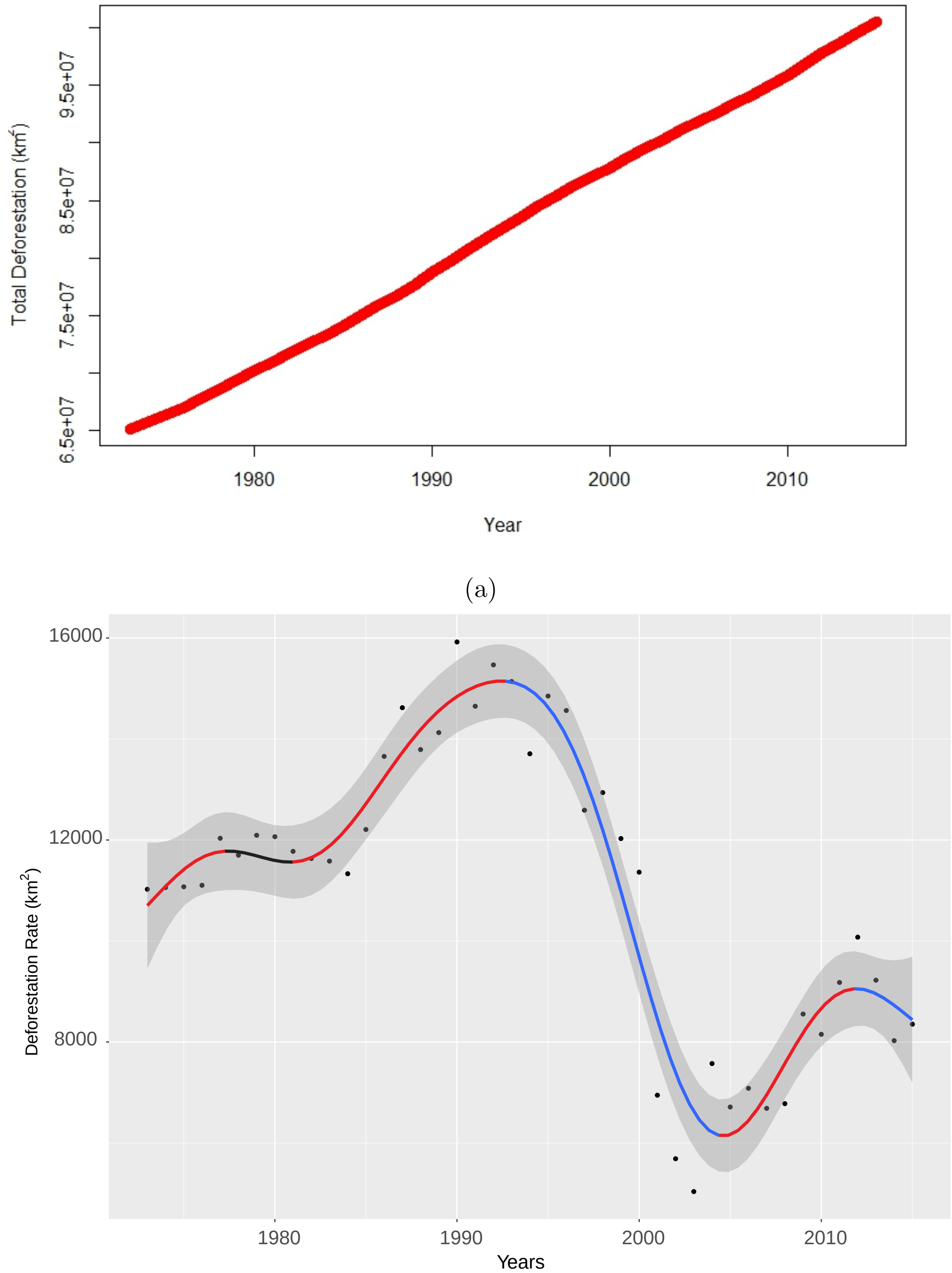
2.4.1 Primary Forest loss and Rates of change

In 1973, 1,294,251 km^2 ($\sim$ 61.7%) of the land surface of Indonesia was forested and by 2015 only 831,108 km^2 remained ($\sim$ 39.6% of the land surface), representing a loss of 463,143 km^2 of primary pristine forest (Table 2.3). The rates of loss for the whole of the country (combining all islands) were modelled using a General Additive Model (GAM)in Figure 2.8. The rates of loss were high (highest rate of 15467.873 km^2yr^{-1}) +/- 0.028), yet variable across the times series and are 21.24% larger than previous estimates (between 2005-2015). There appear to be four phases that are visible in the record: (i) 1972-1992 was characterised by a very high rate of loss, (ii) between 1993-2005, the rates of deforestation decreased substantially but did not return the lower levels witnessed in the mid 1970s, (iii) there was another significant increase in rates of loss between 2006-2012, which almost reached the peak achieved in 1992-3, and (iv) 2013 onwards the rate of loss stabilised at around 9000 km^2yr^{-1}). Cumulative total loss has continued in a linear fashion and is now well in excess of 1 million km^2 (Figure 2.8a).

2.4.2 Island comparisons and temporal change

These headline figures obscure important differences in the temporal patterns of loss between the island groups, especially in relation to more recent changes (since 2005 onwards). Figure 2.9 shows the spatial temporal pattern of loss across the island groups. Table 2.4 illustrates the variability in the 1973 baseline of remaining primary forest (km^2), overall percentage loss of forest, percentage of forest at the beginning (1973) and end of the sequence (2016), all expressed as a proportion of the total land mass of the main islands groups. It is clear that before 1973 a substantial amount of forest has already been lost and that the baseline of primary forest cover across the islands was highly variable. In Java and Bali, only 4.4% of the landmass was forested. Indeed, most of the deforestation occurred before the digital records existed (Figure 2.9). All other island groups were forested at much higher levels (Table 2.3). By 2016 all island groups had been subjected to substantial losses with Sumatra, Kalimantan, and Sulawesi being worst affected. Papau and Malaku retained more of its forests, losing only 4.2 and 7.6 percent respectively. Java was also relatively unimpacted, but it started from a much lower baseline.

The loss of forests on Sumatra and Kalimantan, which are the largest island groups in the country, drive the overall patterns of loss (Figures 2.6-2.9). These two islands showed



(a)

(b)

Figure 2.8: A. Commulative increasein total primary forest loss (in km^2yr^{-1}), B. GAM model of deforestation rates in Indonesia. Black points are annual data points, grey shaded areas are 95% CIs. The red line is the cumulative increase in total primary forest loss (in km^2yr^{-1}).

Table 2.3: Primary forest deforestation in Indonesia (1973-2015). The data show the baseline situation in 1973 when the first Landsat data became available as: (i) the total forest reserve (km2), (ii) the percentage of forest lost, (iii) the percentage of remaining forest at the start (1973) and end (2015) of the time series.

	Sumatra	Kalimantan	Sulawesi	Papua	Java	Malaku
Total loss 1973-2015 (km^2)	188,877	230,989	18,463	17,840	1,316	5,658
% lost 1973-2015	39.9	31.1	10.6	4.2	0.6	7.6
% remaining 1973	61.6	64.3	59.4	83.9	4.4	73.4
% remaining 2015	21.8	33.2	48.9	79.7	3.8	65.8
Total land mass (km^2)	473,481	743,330	174,600	425,297	206,807	74,505

increasing rates of annual loss until 1992 (Sumatra) and 1995 (Kalimantan) when the rates decreased markedly (Figure 2.8-2.9). In 2003, the rates of loss started to increase again. Worryingly, for Sulawesi and Papua, forest loss has continued to rise throughout the time series (Figure 2.9). Moreover, even in the post moratorium period deforestation has continued apace on Kalimantan (average annual rate of 3760 km^2yr^{-1}), Papua ($624km^2yr^{-1}$), Sulawesi ($609km^2yr^{-1}$) and Maluku ($148km^2yr^{-1}$) and only decreased on Sumatra ($3706km^2yr^{-1}$) and remaining relatively stable on Java ($9km^2yr^{-1}$). It is worth emphasising that even on Sumatra, where the rates are reducing, the annual losses remain very high. Importantly, the largest remaining areas of primary forests are on the islands where recent rates are increasing; that is Kalimantan, Sulawesi and Papau (Figure 2.9).

The relationship between legislation, conservation and economic policy is predictably complex but certain patterns emerge (Figure 2.15). Firstly, the plethora of conservation measures generate in the 1970 did not reduce deforestation a great deal, although those grouped in the 1990s and 00s appear to coincide with a marked decrease in deforestation rates. This drop, however, did coincide with a severe economic downturn in Indonesia's economy. Legislative changes geared towards the economy also appear to be linked to deforestation rate variability, although the process links are likely to be complex. These factors were explored in greater detail in Chapter 3, and focus now on forest reserves and the distribution of the remaining forests.

After the analysis of the degraded forest lands, the estimate of the remaining pristine

Table 2.4: The amount of forest that has legislative protection (either protected or conservation forest) and the total remaining primary forest (in 2015) by island group.** Based on Law no. 21 Year 2004

Island	Area(km^2) of Protected/-Conservation Forest**	Remaining Forest in 2015 (km^2)
Sumatra	276,393	100,162
Kalimantan	406,195	242,568
Sulawesi	108,656	846,30
Java, Bali, NT	316,73	78,52
Papua	405,464	338,238
Maluku	714,61	48,879
Indonesia	188,646,7	807,702

(primary) standing forest stock was 807,702 km^2 (Table 2.5), with marked spatial patterning of the remaining resource. The islands of Papau, Kalimantan, Sulawesi and Sumatra have the largest reserves (Figure 2.9). Indonesian law 21 (2004) divided the woodland in Indonesia into four classes (Table 2.6). Two of these, protected forests (forest reserves), and conservation forests (wildlife sanctuaries) are protected from development by law. The remaining forests, categorised as production and land use forests are available for development for raw products (e.g. Timber) but also for agriculture (e.g. rubber and tea plantations) (Table 2.6). On all island groups (and overall at a country level) the remaining primary forest is substantially smaller than the putative areas that are protected, indicating the failure of conservation policies at a national scale.

Analysis of the forest resources (Table 2.6), however, does provide evidence for limited successful conservation outcomes for forests designated as protected and conservation forests; losses here up to 2016 (as a proportion of protected area) are 22% and 29% respectively. In contrast, forest loss in production and land use forests has been large, approximately 62% and 74% respectively.

2.5 Discussion

There are four important outcomes from this work. The steps are: (i) developed a new matrix completion methodology that helps better resolve data capture (i.e. Primary forest

Table 2.5: The designation of forest resources (according to law 21) showing the allocation of area to each class, loss of forest 1973-2015) and remaining forests at 2016 (percentage changes in parentheses)

Forest Type	Area allocated (km^2)	Total Loss (km^2) 2004-2015	Remaining Forest (km^2) 2015
Protected Forest (Reserve)	297,434	65,961 (22)	231,473 (78)
Conservation Forest (Natural Sanctuary)	219,488	63,487 (29)	156,000 (71)
Production Forest	693,328	431,226 (62)	262,102 (38)
Land Use	676,217	503,463 (74)	172,754 (26)
Indonesia	188,646,7	106,413,7	822,329

loss) and cloud removal, (ii) created the longest time series in existence documenting land use change in Indonesia which shows that the scale and rates of primary loss are greater than previously estimated, (iii) shown that inter-island patterns are key to understanding where losses occurred and where the likely greatest impact may occur as we move forward towards 2020, and (vi) illustrate how past patterns in loss are linked correlatively to conservation, legislation and economic processes. It is addressed each in turn.

Methodological advances

Many methods have been applied to quantify the degradation and deforestation in tropical countries (e.g. Broich et al. 2011; Moisen et al. 2016). The two mains areas of concern relate to how to assemble composite images when many scenes are characterised by high levels of cloud cover and how to capture data on primary forests that captures edge effects from adjacent non-forest land uses (e.g. urbanisation and agriculture). Previous researchers have dealt with cloud cover by simply excluding images where cover was > 50

Scales and rates of deforestation

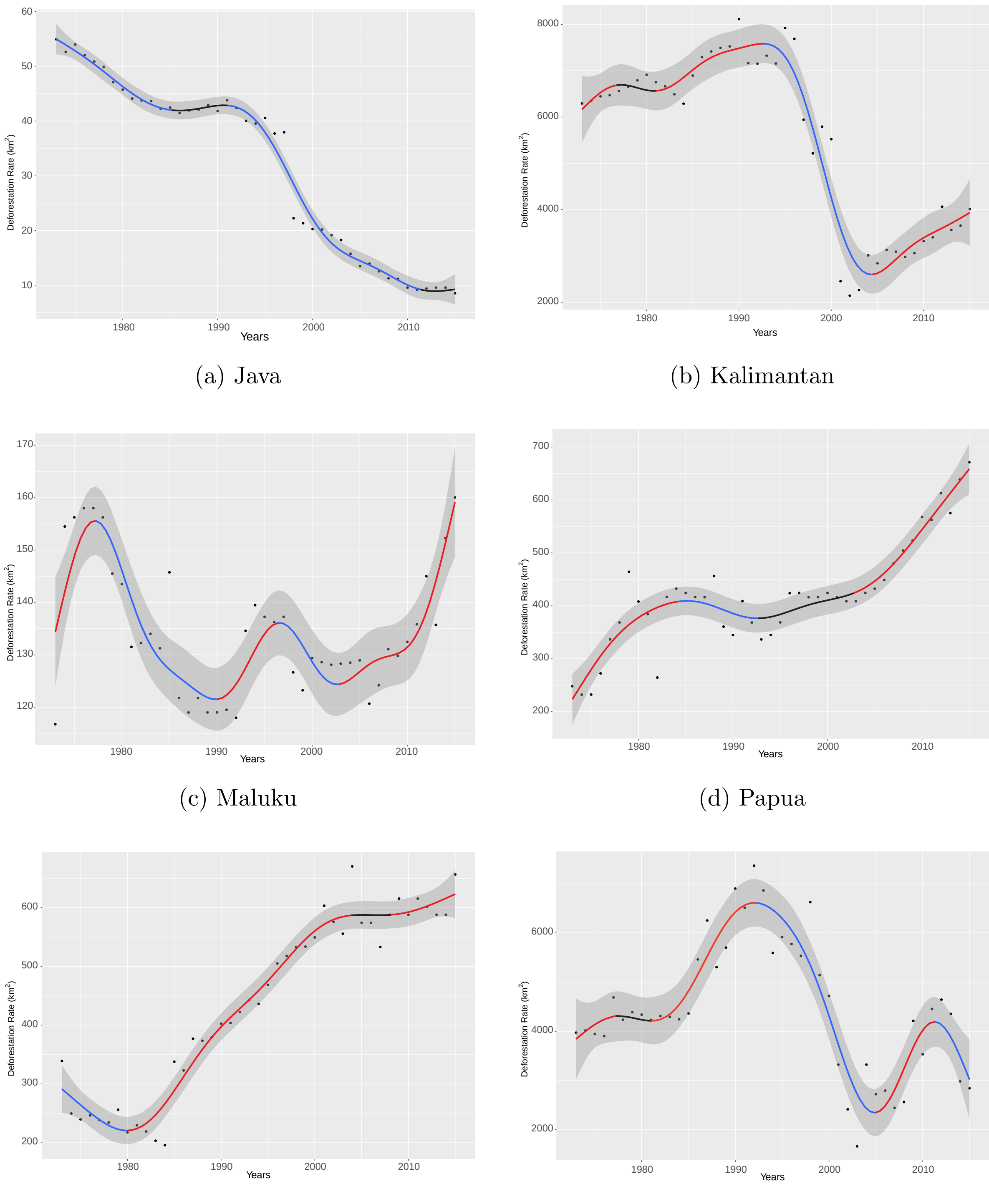
Hansen et al. (2013) used earth observation satellite data to map global forest loss between 2000-2012, identifying the tropics as a ‘cause for concern’ as the only climate domain where forest loss had increased by $\sim 2101\ km^2yr^{-1}$. Subsequent studies, using an extended time series (2000-2014), and focusing on forest loss in Indonesia (Margono et al. 2012; 2014) showed that from 2009 onwards Indonesia was subjected to the highest rate of forest loss than any other country in the world, including Brazil. The extended timescale adopted in this study (43 years) and the different approaches to generating the annual composites have provided new and critical insights onto the forest loss story. It is now clear that highest estimate of rates loss is $\sim$ 21% higher than documented by Margono et al. (2014) for the period of 2005-2010; when the rates were increasing in a linear manner (Figures 2.8a). Moreover, the spatial patterns (Figure 2.8) show not only show that currents rates of loss are highest on the islands where the largest stocks of forests are found, but also, even where rates, are dropping they are still unsustainably high in global terms.

Protected areas and primary forests

Global concern over the loss of primary forests has led to a marked increase the number and area of protected areas (PAs). Between 1990 and 2015 the percentage of forests protected has increased from 7.7% to 16.3%, with tropical regions showing a strong upward trend increasing from 12% in 1990 to 26.3% in 2015 (Morales-Hidalgo et al. 2015). This is extremely positive as recent work has shown that globally biodiversity is higher in protected as opposed to non-protected habitats. Gray et al. (2016) estimated that not is species richness is 10.6% higher but also species abundances are 14.5% higher. Additionally, recent estimates of show substantial reductions in deforestation carbon emissions of around 29% (between 2000 and 2012) in tropical PAs (Bebber and Butt, 2017). Questions remain, however, about whether protection is having the desired effect of halting forest losses within the reserves.

Heino et al. (2015) modelled global forest loss in PAs and in intact forest (ITFs) over the period 2000–2012 and found that "on a global scale 3% of the protected forest, 2.5% of the intact forest, and 1.5% of the protected intact forest were lost during the study period" (p. 7/21). This study has shown that notwithstanding their designation protected forests in Indonesia have been subjected to losses of around one fifth of their stocks. This, coupled to the finding that 42% of the remaining forested land in Indonesia has been classified as degraded, makes for bleak reading. The knock-on carbon storage and biodiversity impacts of this is of considerable concern. While carbon storage and cycling effects can be more readily modelled, biodiversity impacts are more complex due to the roles of disturbance within forest impacting species (without clear felling) (Alroy, 2017), the enhanced timelines due to extinction debt (Chen and Peng, 2017) and that fact likely climate changes will push species out of low-lying reserves (Scriven et al. 2015).

There is an urgent need to focus conservation attention on protected forest areas. Even the countrywide logging moratorium of 2012 failed to halt the forest decline (Margono et al, 2014) in many of the island groups (Papau, Sulawesi, Kalimantan, Maluku), although some islands have showed reduced rates of loss (Sumatra and Java; Figure 2.8). Indonesia does not lack appropriate legislature for this (Appendix A), it lacks the capacity to enforce legislation and at a more basic level monitor change. Importantly, this work also shows that forests subjected to widespread degradation due to land use conflicts, especially where land uses are juxtapositioned and turnover is high, also require attention. The complexity surrounding the policy, economic and social drivers of land use change are addressed in the next chapter (Chapter 3).

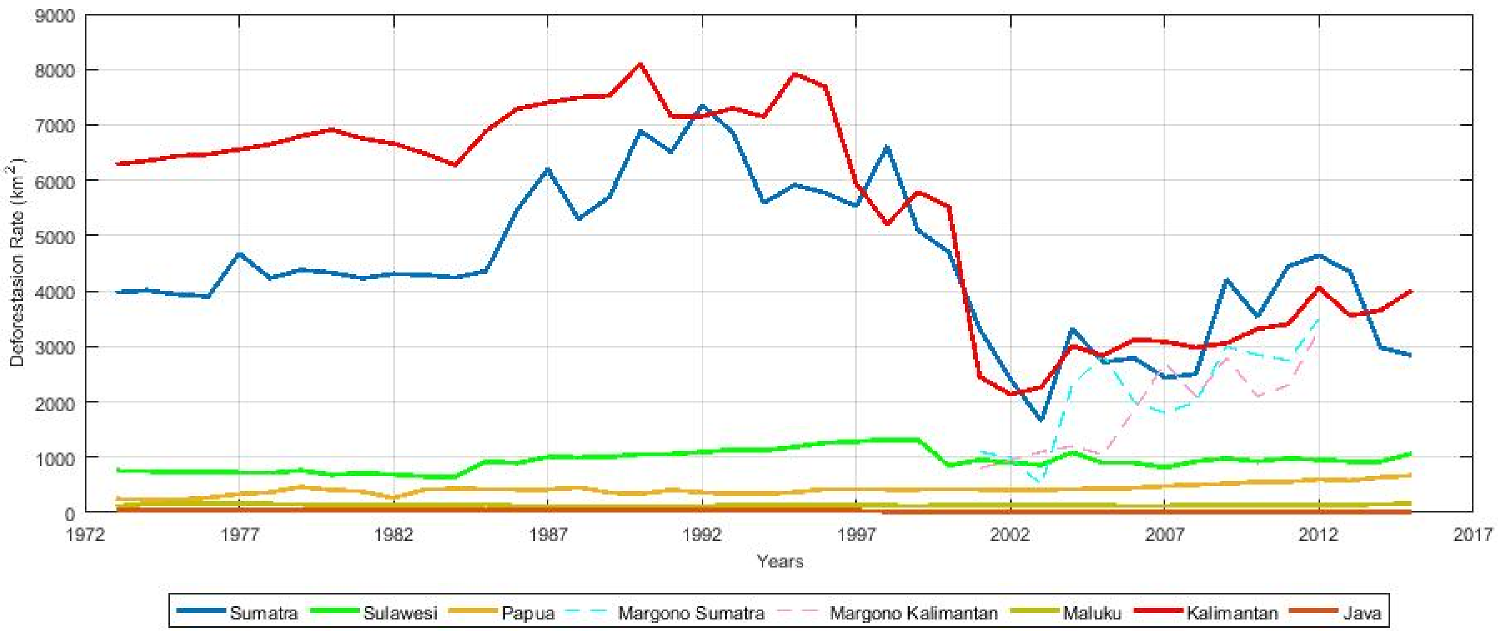


(a) Java (b) Kalimantan

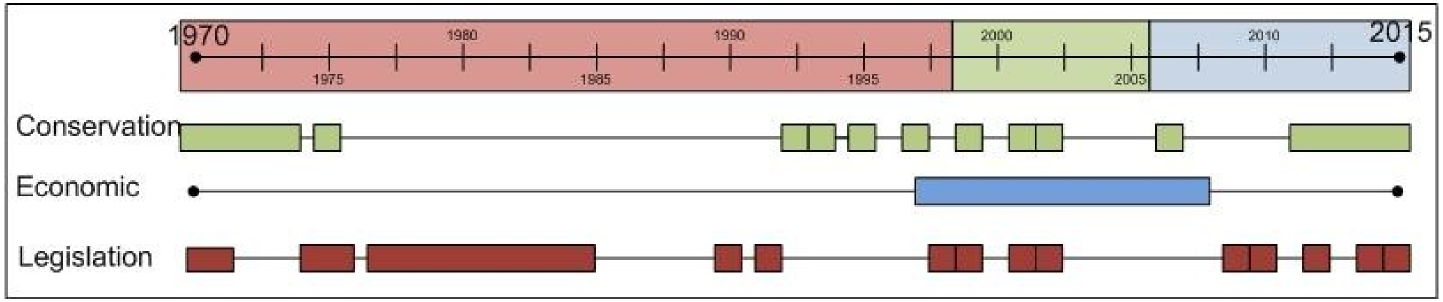
(c) Maluku (d) Papua

(e) Sulawesi (f) Sumatra

Figure 2.14: Time series (1973-2015) of rates of loss (km^2yr^{-1}) for individual island groups. Red lines=significant increased, Blue lines = significant decreased, Black lines=not significant differences



(a)



(b)

Figure 2.15: Deforestation rates by island group and also key elements of conservation law, legislation and economic patterns.

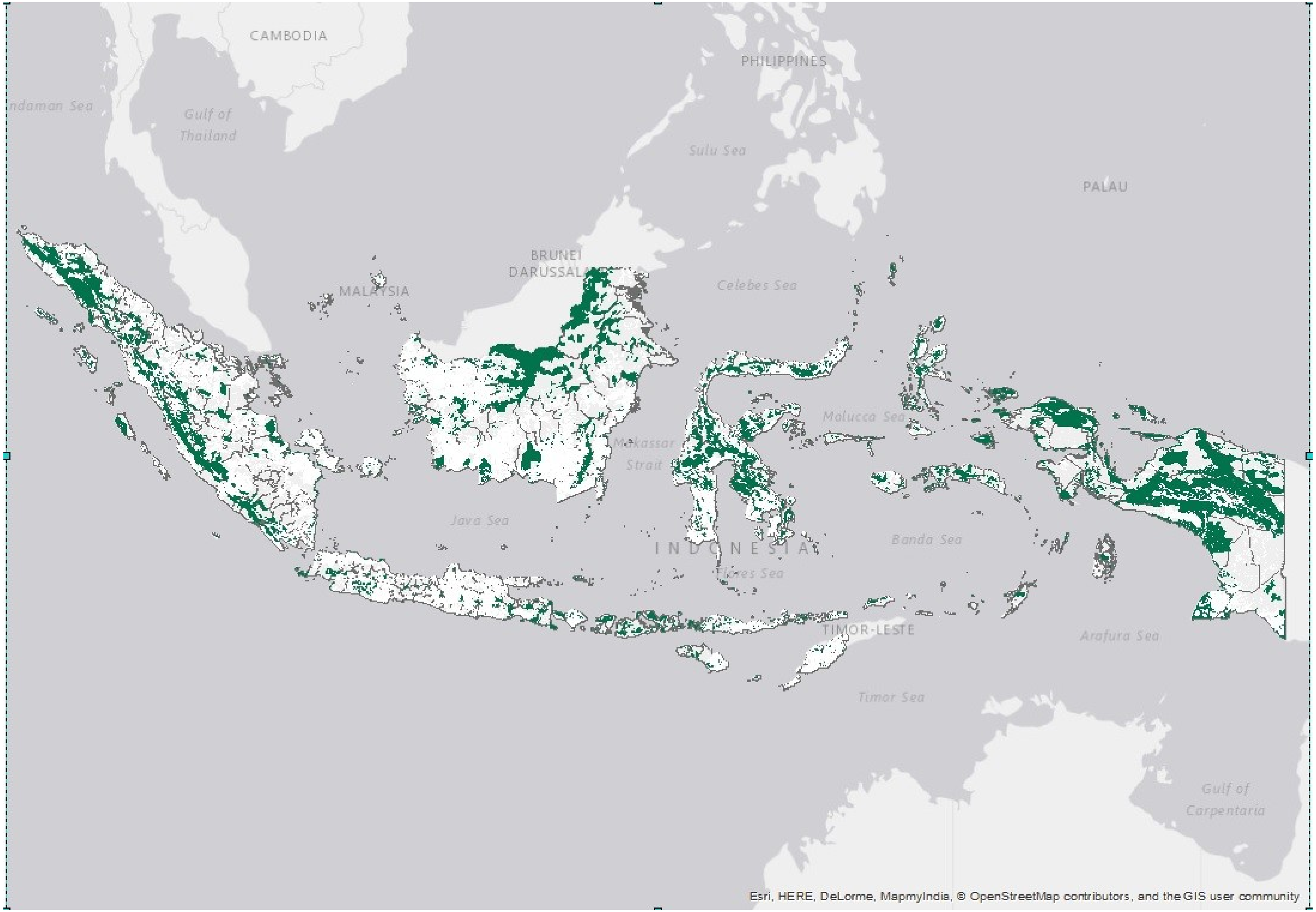


Figure 2.16: Remaining primary (pristine) forest in Indonesia at 2016

Chapter 3

The factors driving Land Use Change in Indonesia

3.1 Summary

Land use change in Indonesia is driven by high rates of deforestation. High demand on food supplies, biofuels and natural resources for exploitation are believed to the main factors for commercialisation of forest stocks and removal of forested land. Some land conversion is believed to be the result of weak management in conservation areas and the economic opportunities promoted by the Indonesian government to increase national income by maximising natural resource exploitation. However, the principal cause of deforestation trends were previously unknown. Here, the modelling land use change shows that the main predictors of change are removal of forested land for replacement by permanent crops, palm oil plantations, other production value lands, arable land, coconut plantations, timber production, rice field and rubber plantations. The main three factors were found to be: arable land production, palm oil plantation, and timber production. All are linked to global commodities markets and an important element of the Indonesian economy.

Table 3.1: Indonesian laws and permits for forest use

Regulation	Purpose
PD No (2004)	Permits or Contract Relating to Mining in Forest Area Ministry of Forestry Regulation (MoFR)
No 19 (2004)	Collaborative Management of Nature and Game Reserves
GR No. 23 (2010)	Implementation of Mineral and Coal Mining Business Activities
MoAR No. 19 (2011)	Guidance for Indonesian Sustainable Palm Oil (ISPO)
No. 7662 (2011)	Resources and the Ministry of Forestry on the Coordination and Acceleration of Permit Issuance for Geothermal Energy Development in Production Forests and Protection Forests. Preparation for Geothermal Utilization in Forest Conservation Areas
MoAR No. 11 (2015)	Certification System for Indonesian Sustainable Palm Oil (ISPO)

3.2 Introduction

Land use changes in Indonesia have been driven by factors including population growth, policy, resettlement, and assorted global environmental factors (Sunderlin & Resosudarmo 1993, Geist & Lambin 2001, Wicke et al. 2011, Prasetyo et al. 2011). Some researchers have suggested that deforestation and subsequent changes in land use in Indonesia are unrelated government policy (Nasendi 2000, Margono et al. 2012). Although many historical policies have been put in place to protect forest resources including the moratorium of 2011 (PI Number 10 by 2011; Margono et al. 2014), other policies have been supportive of land use change through the issuing of permits and licenses for mining, resource usage (e.g. Timber), agricultural activities (e.g. Palm oil production) and geothermal energy production (Table 3.1).

This is supported by evidence of increasing rates of deforestation even in the face of a supposed governmental moratorium on forest conversion (Margono et al. (2014); Chapter 2). Many areas have been deforested to harvest timber resources and to change land use type to palm oil plantations, particularly in Sumatra and Kalimantan (see Chapter 2). These trends in deforestation are coincidently expected to have increased the risk of fire in harvested areas.

Although there was a guidance in policy of the Indonesia Ministry of Environment and Forestry to regrow trees following forest clearance (GR No. 61 in 2012; GR No. 24 in 2010; GR No. 60 in 2012; GR No. 10 in 2010, GR No. 24 in 2010), data suggests that this is not always the case (Margono et al. 2012, see chapter 2). In particular, restrictions on the limit on forest clearing in official policy documents shows no correlation with the remain stocks of primary forest (FAO 2012, Margono et al. 2014, see chapter 2; Table 2.3). Many remote forest areas are beyond the jurisdiction of conservation enforcement and as such have been cleared to change land function to benefit people, industry and government (e.g. palm oil plantations).

The previous chapter showed that only 42% of primary forest remains in Indonesia, while the remaining land area is now classified to other landuses; a substantial proportion of which are classified as degraded land. This raises the question of the future status of Indonesia's forest cover and the threat of future reductions and consequent impacts on human, plant and animal life. Mapping landuse change in biodiverse countries such as Indonesia is significant and pressing issue that goes beyond concerns over the likely increases in extinctions and the loss of endemic biodiversity which is predicted to double in tropical areas Barlow et al. (2016). The role of REDDs (Reducing Emissions from Deforestation and forest Degradation) is reducing carbon emissions is of global importance (Gaveau et al. 2009, Graham et al. 2017), especially as the likely increases in carbon release due to palm oil production are thought to be extremely high (Carlson, Curran, Ratnasari, Pittman, Soares-Filho, Asner, Trigg, Gaveau, Lawrence & Rodrigues 2012, Carlson, Curran, Asner, Pittman, Trigg & Marion Adeney 2012).

In this chapter, the deforestation trends are examined further to investigate concomitant land use changes (i.e. what deforested land was converted to). The aims are to: (i) evaluate the patterns of landuse change and the outcomes of the deforestation process,

(ii) model the landuse change temporally to seek associations between change and forest loss. This understanding will permit the principal causes of the trend to be elucidated with more clarity and will also serve to inform mitigation and conservation policies to halt deforestation trends.

3.3 Method

Landsat ETM+ remote sensing scenes were used from 2014-2015 which are usually used to identified land use with aerial data (Patapov, Belinda). The classification process was undertaken using a semi-automatic (supervised) classification methodolohy (Nooni2014, Southworth2016) using landsat ETM+ with a resolution 30m x 30m. This process uses a machine learning algorithm and has a discrimination accuracy of up to 93%. This classification was carried out by using QGIS plugins[1]. The following procedure was undertaken to select the feature classes and to train the algorithm to ahead of a full classification run.

1. Feature Selection

   An object-based classification based on 100 object (images) per class (Nooni et al. 2014) was used to determine the objects that replaced the deforested pixels generated from classifications outlined in chapter 2. The first step of the process used a supervised classification by identifying the objects into and placing them in predetermined land-use classes. The objects analysed in this chapter are:

   (a) Plantation - Plantation areas are those defined as having more than 20% and less than 30% of tree canopy cover (Wu 2002) which was classified previously as non-forest area (see chapter 2). This class members would also include agricultural area with plantations (crops included coffee, tea, rubber). The spatial resolution of the landsat images is such that further differentiation of crop type was not possible with any degree of accuracy.

[1]available in: https://plugins.qgis.org/plugins/SemiAutomaticClassificationPlugin/

(b) Palm-Oil Plantation – Palm Oil plantation has its own characteristic pattern in terms of plantation structure and planting density which is visible in remote sensing images (Lee et al. 2016, Vijay et al. 2016). Palm oil is usually visible as plantations $\tilde{9}$ m apart from each other and planted in triangular shape. The importance of gain accurate classifications on this crop type mean that ground-truthed data were also collected from known sample points by forest rangers in the field to report some of sample position of images that would classified as palm oil plantation (n = 100). The ground-truthed objects were included as the training dataset for the classification algorithm. A maximum likelihood algorithm was used to classify the objects with 100 iterations.

(c) Savana – Captured objects that did not classified as plantation, viz: with less than 20% of tree canopy cover would be identified into "bushes" class (Wu 2002). The same semi-automatic training algorithm was used with the same size training dataset.

(d) Building – The area occupied by buildings and human activity in urban areas were collected as a sample image to be classified. The sample of image included objects such as roads, paths, house, and other buildings, industrial units were sampled remote sensing imagery cities in each province of Indonesia.

(e) Embankment - Allocated in a buffer zone (of 50 m width) nearby the sea and has some border to see that there is some human activities in the place. For this class, the sample of images were collected from the area where there were known as embankment area in some province in Indonesia.

(f) Rice Field – Rice fields are readily distinguished from Landsat image ETM+ due to its own characteristic their characteristic locations and regular shape. Rice field in Indonesia are located nearby the river in lowland areas where the field are easily flooded and water levels maintained. It is also has a square shape structure identifying it from another areas surrounding them. After deciding the classes that would be involved in classification process, the samples were collected from the images to carry out the classification process.

2. Generalised Additive Model

   Generalised Additive Models (GAMs) was occupied to model the temporal patterns in landuse conversation. The model took the form of:

$$G(m) = \beta_o + f_i X_{i1} + f_2 X_{i2} + \dots.$$

   Where f_1 and f_2 are non parametric smoothing function. Where f1 and f2 are non-parametric smoothing terms.

   GAMs are a particularly useful regression method for time series (Zuur et al. 2009) as they do not force a parametric relationship between the response and predictor, and smoothers can be used to model complex, non-linear relationships that are common in temporal data. GAMs were fitted using version 1.8-12 of the mgcv package for R Wood (2011). An independent data source (Tsujino et al. 2016) were used to examine forest loss/policy interactions in Indonesia, tabulated in the same time range as our 1972-2015 deforestation time series. All variables relating to Indonesian landuse were selected and supplemented with an additional GDP growth index derived from the World Bank[2].

3.4 Results

This section provides data on three elements related to landuse change. First, a spatial depiction of the distribution of the designation of forests introduced was used in chapter 2 (Table 2.5) to illustrate how the use of production and landuse forests have been modified with the consent of government policies. Secondly, a spatial analysis was provided to illustrate the widespread modifications that have taken place in forested areas and elsewhere, supporting this with a model of the distribution of degraded land across

[2]http://databank.worldbank.org/data/home.aspx

the country. Thirdly, secondary data were used to model the patterns in landuse and economic metrics to help disentangle the links between landuse change and deforestation in the country .

3.4.1 Land Degradation and Forest Designition

Indonesian Law no. 21 published in 2004 set out a clear policy to permit the development of primary forest area to assist the economy in the country. The spatial distribution primary forests that are protected (protected or conservation forests) and those that were made available for development (production and landuse forests) is shown in Figure 2.5. The patterning of this shows that protected forests are largely situated to the islands to the east of the country in Sulawesi, Papau and Malaku, with areal reserves extents of 108,656 km^2, 405,464 km^2, and 714,61 km^2 respectively. The larger islands, Sumatra, Kalimantan and Java/Bali have less protected forests (in proportion to non-protected forests): 276,393 km^2, 406,195 km^2, and 316,73 km^2 respectively. In contrast, and probably because the islands to the west were subjected to earlier phases of deforestation (chapter 2), production and landuse forests are more common on Sumatra, Kalimantan and Java/Bali (Table 2.4, chapter 2).

The modelled degraded land (see methods chapter 2) illustrates a similar pattern with levels of degradation across all landuse types being higher in the western islands than those to the East (Figure 2.7), although critical levels of degradation are found in southern Sulawesi. The link between forest designation and landscape degradation is an important one and worthy of further investigation.

3.4.2 Land Use Pattern

Figure 3.3 depicts the completed classification of landuse using space imagery dated to 2015-16. The total area for each landuse class are as follows: Plantation agriculture (excluding palm oil): 668,114 km^2, savanna: 189,519 km^2, palm oil plantation: 187,495 km^2, rice fields: 663,37 km^2 and embankments: 17,500 km^2. Table 3.2 shows data on the areal

Table 3.2: Areal extent of non-forest landuse on Indonesia, 2015-16. Data shown square kilometres.

Classes	Sumatra (km^2)	Kalimantan (km^2)	Java (km^2)	Sulawesi (km^2)	Maluku (km^2)	Papua (km^2)
Palm Oil Plantation	46,900	124,507	5,877	2,019	204	3,409
Rice Field	7,171	425	44,051	13,799	161	362
Building	13,564	2,286	24,098	3,542	419	31
Embankment	437	3,310	851	4,728	3,068	4,816
Plantation	581,241	31,845	41,623	14,164	1,329	12,528
Savana	19.253	11,420	3,337	33,445	10,942	47,910

Table 3.3: The area of land use change after deforestation within 5 years

Replacement Area	1990-1995(km^2)	1995-2000(km^2)	2000-2005(km^2)	2005-2010(km^2)	2010-2015(km^2)
Agriculture	16765.528	9727.326	3092.0418	3886.8825	4433.4133
Building	4513.796	3613.0068	3629.7882	2332.1295	2313.0852
Palm Oil Plantation	6125.866	9449.4024	4167.5346	6063.5367	8481.3124
Savana	3868.968	2779.236	1613.2392	2021.1789	2313.0852
Rice Field	967.242	2223.3888	941.0562	1243.8024	1734.8139
Deforestation Rate	32241.4	27792.36	13443.66	15547.53	19275.71

extent of each landuse type across the island groups. Outside of the forest resources, the landuse on Sumatra and Kalimantan islands is dominated by palm oil and agricultural production (Table 3.2), while on Java Island, urban areas are common, especially around the capital city, Jakata. Java and Bali islands group are almost entirely occupied with agricultural and residential land use types. Palm oil plantations are uncommon in Sulawesi, Maluku, and Papua islands (Table 3.2). Some of the parts of Papua, Maluku, and Sulawesi are occupied by savana and plantations.

Land use change in Indonesia were classified in 5 years group that shows how the forest change after deforestation. The classification process were divided into 5 classes (agriculture, building, palm oil plantation, savanna, and rice field). The result of classification are narrated in table below.

From table 3.3 the percentage of the land that change into agriculture and plantation are the biggest change of the land from deforestation. Agriculture was the most area

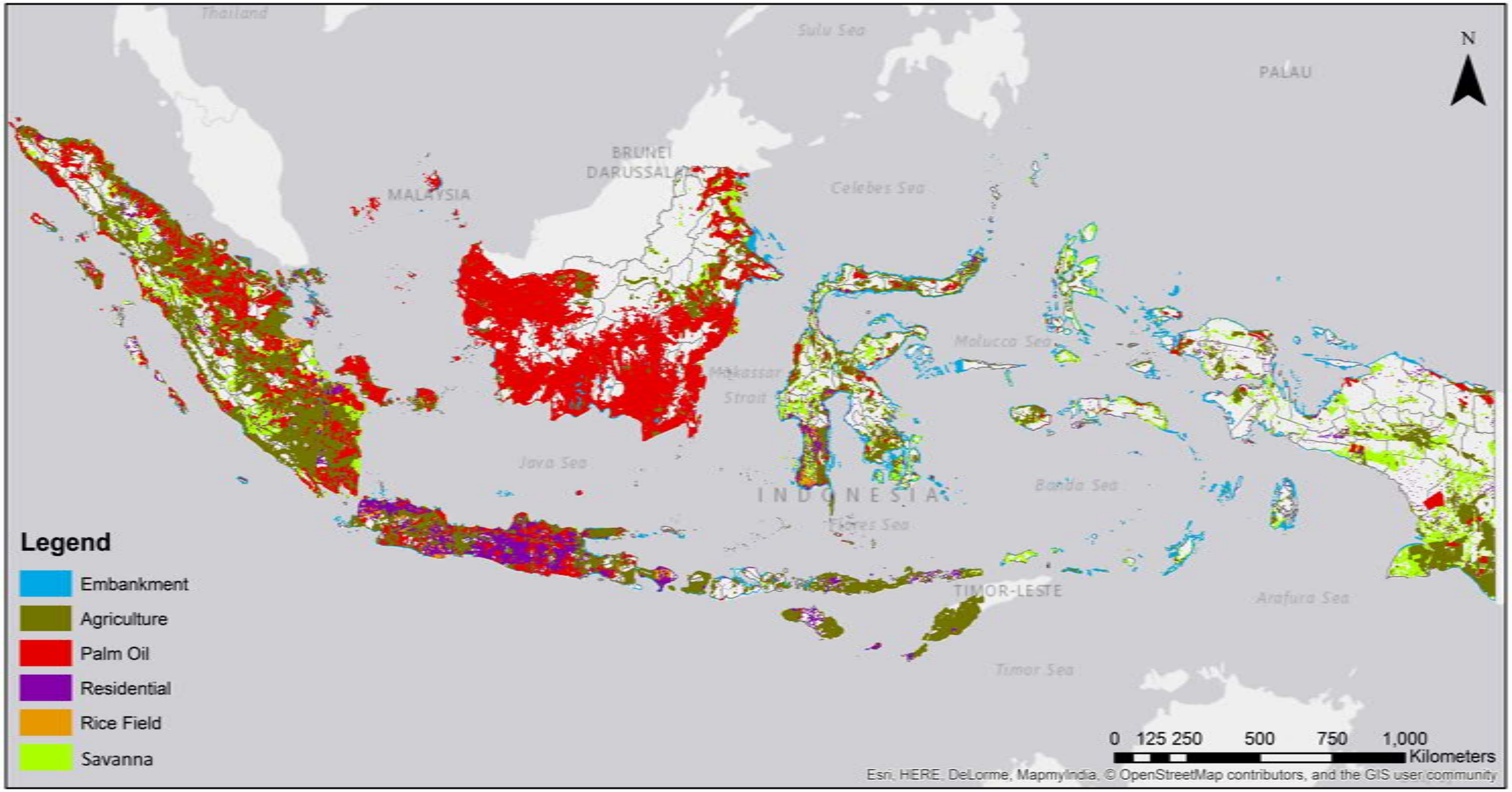


Figure 3.1: Land Use patterns in Indonesia based on remote-sensing image classification (2015-16)

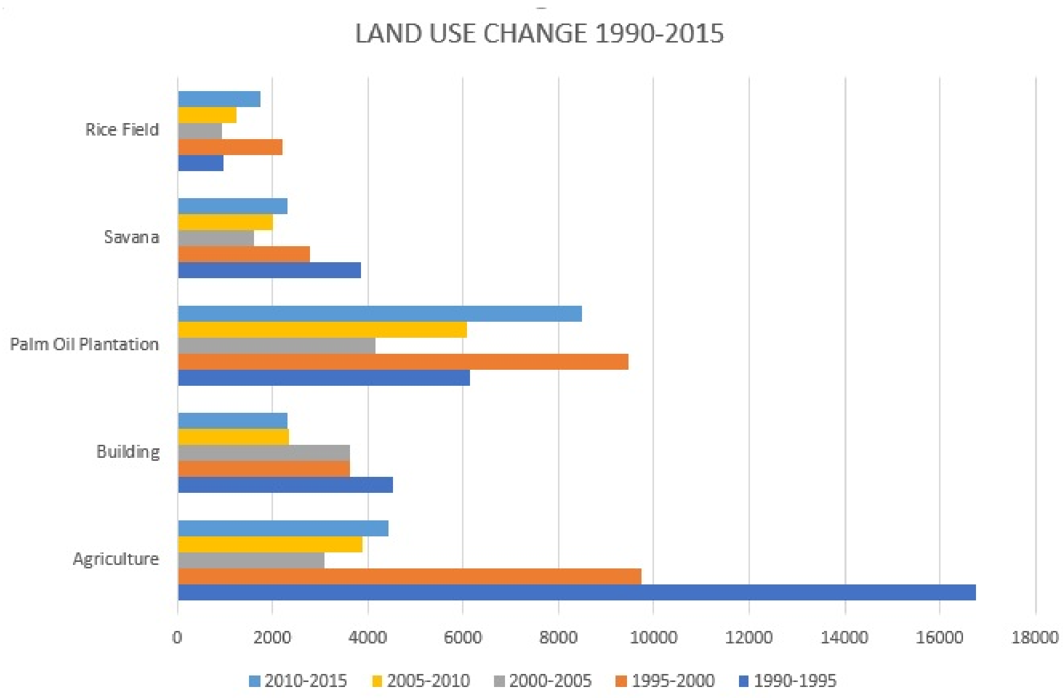


Figure 3.2: Land Use patterns in Indonesia based on remote-sensing image classification (2015-2016)

replaced the forest in 1990-1995 (54%) and palm oil plantation is the most area replaced the forest in 2000-2015 (Figure 3.2).

3.4.3 Palm Oil Explotion

A recent policy in Indonesia lifted the lid on the expansion palm oil plantations in an attempt to generate income for the country (Table 3.1). Forests were (and still are) being extensively burned or clear cut for replacement with palm oil plantation, especially in Kalimantan, but also large swathes of Sumatra. Kalimantan Island has great potential for palm oil plantations because of its topography (see Chapter 2). The previous chapter has shown deforestation rates in Kalimantan were increasing post 2000, and many of these regions have now been replaced by palm oil plantations (Figure 3.3).

Figure 3.3 shows the distribution of palm oil plantations in Indonesia. Almost all of the area of Kalimantan island has now been replaced with palm oil plantations, excluding land set aside as protected and conservation forests. A similar pattern appears to have occurred in Sumatra island, where most of the area that previously had been deforested

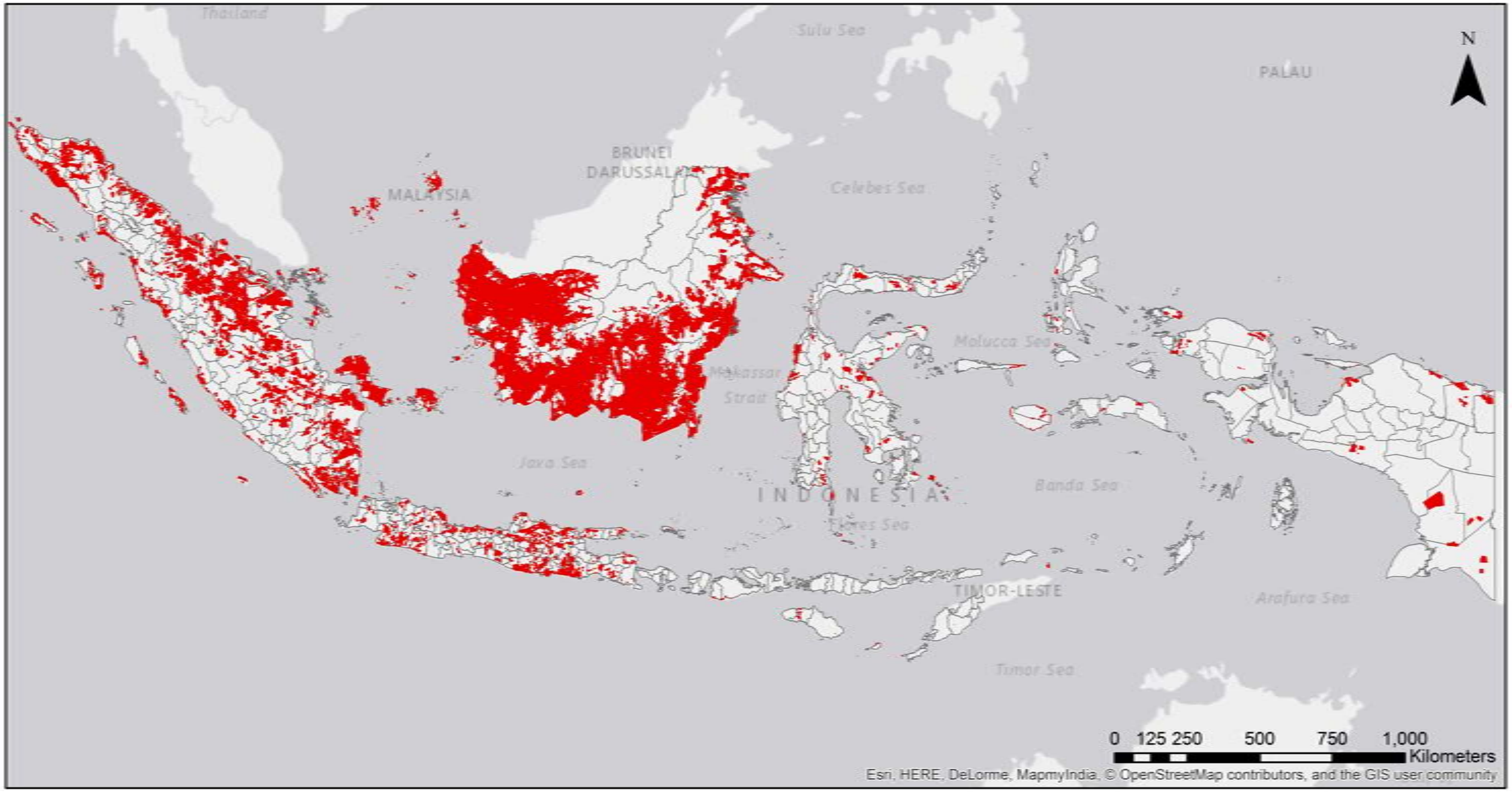


Figure 3.3: Palm Oil Plantation Distribution in Indonesia (2015-16)

is now occupied by palm oil plantation. Plantations are also prevalent in Java island, supplanting its typical crop types such as tea, coffee and chocolate. The area of palm oil plantation per island group is: Sumatra 46,900 km^2; Kalimantan: 124,507 km^2; Java, Bali and Nusa 5,877 km^2; Sulawesi 2,019 km^2; Maluku 204 km^2; Papua 3,409 km^2.

3.4.4 Modelling Land Use Change

Table 3.4: Important economic and landuse metrics (1973-2015) (Data from Tsujino et al. (2016))

Year	Population (million Person)	GDP Value	Forest cover (Mha)	Arable Land	Rice field (Mha)	Rice Production (Mton)	Permanent crops (Mha)	Oil Palm (Mha)	Rubber(Mha)	Coconut(Mha)	Other (Mha)	Timber Production (Mm3)	Indonesia Rate
1973	125	883.479	131.9	14.2	8.4	24	5.8	0.2	2.3	2	29.8	26.3	11024.27
1974	128	926.8856	130.9	14.6	8.5	23.8	6.1	0.2	2.3	2.1	30.3	21.8	11059.02
1975	131	948.7627	129.8	14.9	8.5	23.5	6.2	0.2	2.3	2.2	30.9	16.3	11073.69
1976	134.2	989.2293	128.8	15.2	8.4	23.3	6.5	0.2	2.3	2.3	31.4	22.1	11103.07
1977	137.4	1049.954	127.7	15.5	8.4	23.3	6.7	0.2	2.4	2.4	31.8	25.7	12033.86
1978	140.7	1094.358	126.7	15.9	8.9	25.8	7	0.2	2.4	2.4	32.2	26.4	11698.49
1979	144	1146.892	125.7	16.2	8.8	26.3	7.3	0.2	2.4	2.5	32.6	27.3	12093.49
1980	147.5	1230.84	124.7	16.5	9	29.8	7.6	0.3	2.5	2.6	33	27.9	12065.3
1981	150.4	1297.717	123.6	16.9	9.4	31.6	8	0.3	2.5	2.7	33.3	19.9	11774.86
1982	153.4	1296.577	122.6	17.3	9	33.6	8.3	0.3	2.5	2.8	33.6	19.4	11633.3
1983	156.4	1320.699	121.7	17.6	9.2	35.3	8.7	0.4	2.6	2.9	33.8	20.5	11582.06
1984	159.5	1382.118	120.7	18	9.8	38.1	9.3	0.4	2.7	3	33.8	20.1	11332.2
1985	162.7	1386.483	119.7	19.5	9.9	39	10	0.5	2.8	3	32.6	22.5	12208.02
1986	165.9	1438.391	117.9	20.2	10	39.7	10.5	0.6	2.9	3.1	33.2	32.5	13656.24
1987	169.1	1480.006	116.2	21.2	9.9	40.1	10.2	0.7	2.9	3.1	34.3	43.7	14620.06
1988	172.5	1536.287	114.4	21.2	10.1	41.7	11	0.9	3	3.3	35.2	44.4	13790.47
1989	175.9	1620.903	112.7	20.9	10.5	44.7	10.9	0.8	3	3.3	37.3	37.2	14126.84
1990	179.4	1707.598	111.1	20.3	10.5	45.2	11.6	1.1	3.2	3.4	38.9	37.8	15921.8
1991	182.4	1794.189	109.4	18.1	10.3	44.7	12.1	1.2	3.2	3.6	42.2	36	14648.98
1992	185.4	1878.71	107.8	18.1	11.1	48.2	12.2	1.3	3.2	3.6	43.7	41.7	15467.87
1993	188.5	1968.124	106.2	18.1	11	48.2	12.3	1.4	3.2	3.6	45.2	39	15138.3
1994	191.6	2083.064	104.6	17.1	10.7	46.6	12.1	1.4	3.4	3.7	48	33.8	13707.51
1995	194.8	2219.811	103	17.3	11.4	49.7	12.4	1.7	3.4	3.7	49	36	14850.61
1996	197	2357.959	101.5	17.9	11.6	51.1	12.9	1.9	3.5	3.7	49.5	39.9	14563.99
1997	199.3	2433.341	100	18.5	11.1	49.4	13.5	2.6	3.5	3.7	49.8	38.8	12590.48
1998	201.6	2084.235	99.6	18.7	11.7	49.2	13.5	2.8	3.4	3.7	50	28.9	12938.13
1999	203.9	2071.551	99.1	19.7	12	50.9	13.8	3	3.4	3.7	49.1	27.3	12028.58
2000	206.3	2143.39	98.7	20.5	11.8	51.9	14.9	3.6	3.6	3.7	47.7	20.8	11362.8
2001	209.2	2190.766	98.3	20.2	11.5	50.5	16.1	4.3	3.3	3.9	47.3	13.9	6946.593
2002	212.2	2257.747	97.8	20.1	11.5	51.5	17	5.1	3.3	3.9	46.9	11.3	5688.496

2003	215.2	2333.097	97.4	22.4	11.5	52.1	17.1	5.3	3.3	3.9	44.9	18.3	5038.064
2004	218.3	2416.836	97	24.7	11.9	54.1	17.9	5.7	3.3	3.8	42.3	18.5	7573.337
2005	221.4	2519.51	96.5	21.9	11.8	54.1	18.1	6	3.2	3.8	45.2	38	6712.717
2006	224.6	2621.96	96.1	21.5	11.8	54.5	18.7	6.3	3.3	3.8	45.4	38.6	7083.483
2007	227.8	2750.615	95.7	22	12.1	57.2	19	6.3	3.4	3.8	45.1	36.2	6686.452
2008	231	2876.885	95.3	22.7	12.3	60.3	20	7.3	3.4	3.8	43.8	35.4	6779.165
2009	234.3	2970.044	94.8	23.6	12.9	64.4	21	7.9	3.4	3.8	42.3	38	8553.568
2010	237.6	3113.481	94.4	23.6	13.2	65.2	21.6	8.5	3.4	3.7	42.1	46.3	8152.763
2011	241	3262.749	93.7	23.5	13.2	65.8	21.3	9.1	3.5	3.8	43.2	51.7	9179.486
2012	244.5	3415.351	93	23.5	13.4	69	22.6	9.2	3.5	3.8	42.7	55.5	10075.61
2013	248	3560.107	92.4	23.5	13.8	71.2	23.1	10.1	3.5	3.8	42.8	9224.12	
2014	251.5	3692.943	91.7	23.8	13.9	73.5	24	10.4	3.5	3.8	42.2	8026.66	
2015	255.1	3827.548	91	24.1	14.2	75.8	24.8	11.1	3.6	3.8	42	8352.461	

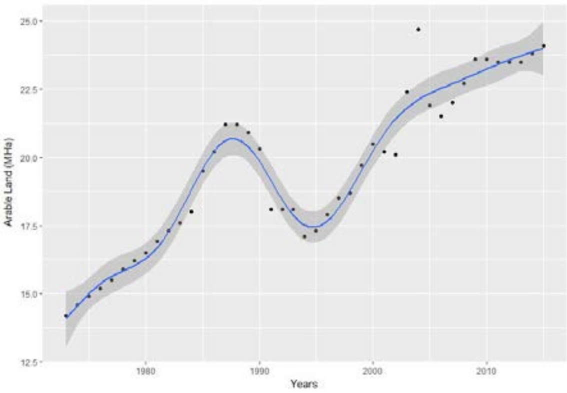
The rates of change of individual (possible) contributory factors was plotted to investigate the drivers of deforestation in Indonesia. Figure 3.4 and 3.4 show that several factors associated with deforestation in Indonesia are well correlated with land use change time-series trends (see Figure 3.4). There are two clear patterns in these GAMs. First, some key commodities (arable, timber and other plantations) mirror the patterns in the countrywide deforestation rate (Figure 3.4c) increasing rapidly until $\sim$ 1990 then decreasing until rising again $\sim$ 2000. Other such as palm oil, rice fields, permanent crop, and rubber show consistent increases since the 1970s. The GAM Model for GDP (Figure 3.4d) also explains some of the deforestation patterns, including the time period during which Indonesia experienced its economic crisis, 1970-2000. This time period appears to affect the rate of change of deforestation where the rate of deforestation in Indonesia decreased significantly (see Figure 3.4c and 3.4d).

3.5 Discussion

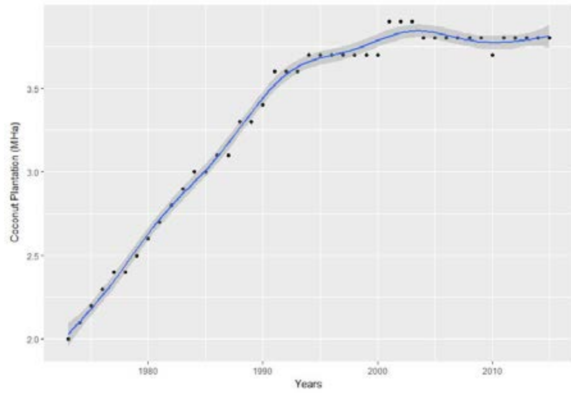
This research has highlighted that Land use change in Indonesia is linked to high rates of deforestation. The principal cause of deforestation trends were not well known (but see Linkie et al. 2010). Here, modelling land use change showed that the main predictors of change are removal of forested land for replacement by permanent crops, palm oil plantations, other plantations and cash crop, arable land, timber production. The main three factors were found to be: palm oil plantation, arable land production, and timber production. All are linked to global commodities markets and an important element of the Indonesian economy. Although an unknown amount of land conversion relates weak management in conservation areas (Chapters 4-5 develop a mobile-GIS web system to address this issue) most is related policies developed by the Indonesian government to enhance economic opportunities.

While the Indonesia government took steps to reduce the rates of deforestation through political means, some of these policies appear to have acted to increase rates of deforestation. The increasing rate of deforestation in Indonesia is also supported by initiatives from government with the goal of self-sufficiency in agriculture. The following temporal patterns are clear (Tsujino et al. 2016). Between 1979 – 1990s deforestation was driven by industrial logging driven by the global commodities market. Increases in rice and plantation cultivation was supported by transmigration and mining during the 1980-90. A large expense of palm oil was begun in 1998 as the country tried to recover from and economic downturn. The Indonesian government committed to an improvement in the production of 'sustainable' palm oil plantation, to improve both the production of the palm oil plantations and to improve the production and export rate of palm oil post 2000. Since then, palm oil plantations have been banned following their replacement of many areas of Indonesian agriculture (see Table 1). Between the mid-1990s and 2015, imbalance between global demand and production of Indonesian timber and oil palm led to illegal or non-sustainable timber harvest and expansion of permanent agricultural areas. The deforestation moratorium initiated in 2011 appears to have relatively limited impact on deforestation.

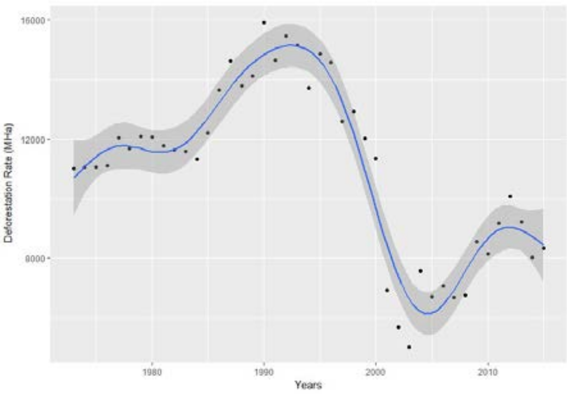
This analysis links the work of Abood et al. 2015 who found that the four industries accounted for $\sim$ 44.7% ($\sim$ 6.6 Mha) of forest loss in Kalimantan, Sumatra, Papua, Sulawesi, and Maluku between 2000 and 2010. Timber plantation and logging concessions accounted for the largest forest loss with oil palm ranking third in the list. This work has shown that currently oil palm is a significant contributor to forest loss, growing in importance since the 1990s. Most the growth in this oil palm plantation has been on Kalimantan and Sumatra. This is a significant issue as these islands were late in the cycle of deforestation and house large reserves of primary forest but also oil palm conversion is a major contributor to carbon emissions (Carlson et al. 2012).



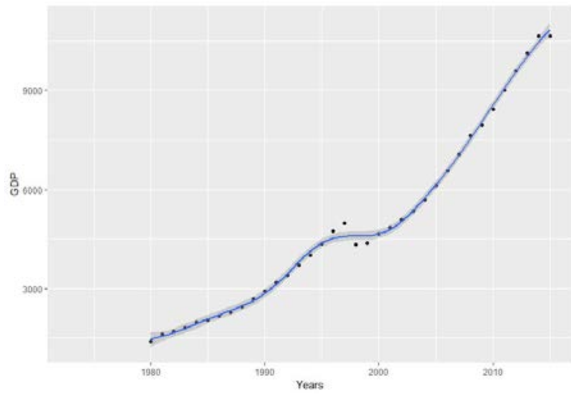
(a) Arable Land Model



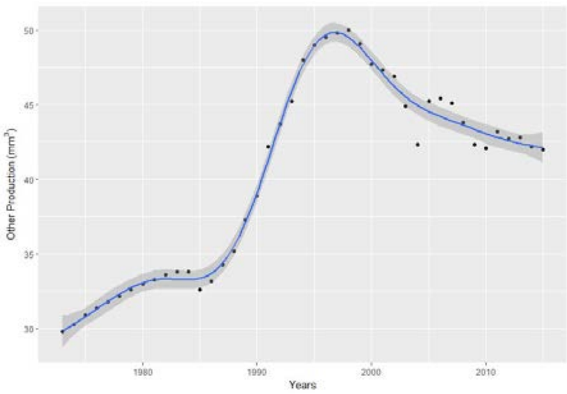
(b) Coconut Plantation Model



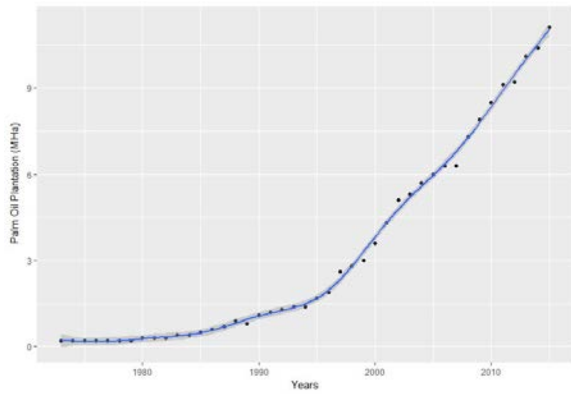
(c) Deforestation Model



(d) GDP Model



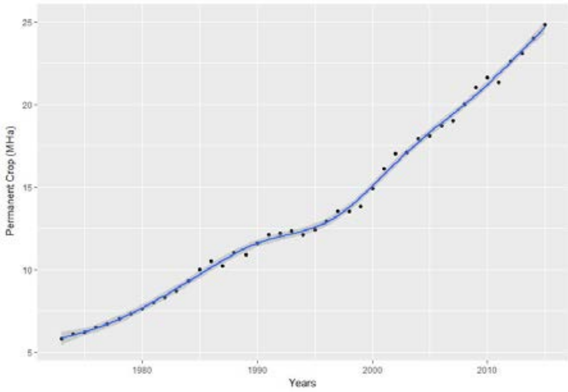
(e) Other Production Model



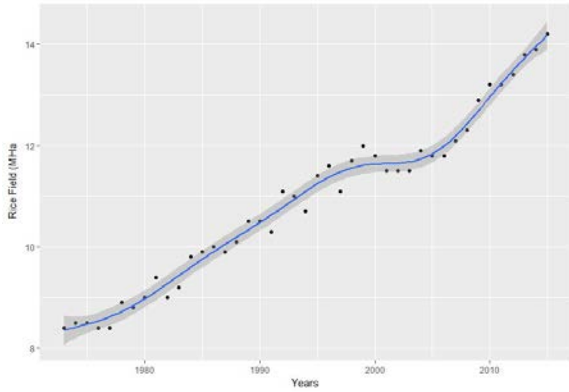
(f) Palm Oil Model

Figure 3.4: Generalised Additive Models for landuse change in Indonesia (1973-2015) (a) Arable Land (b) Coconut Plantation (c) Deforestation (d) GDP (e) Other Production (f) Palm Oil. GAMs were all significant to P$\leq$ 0.001.

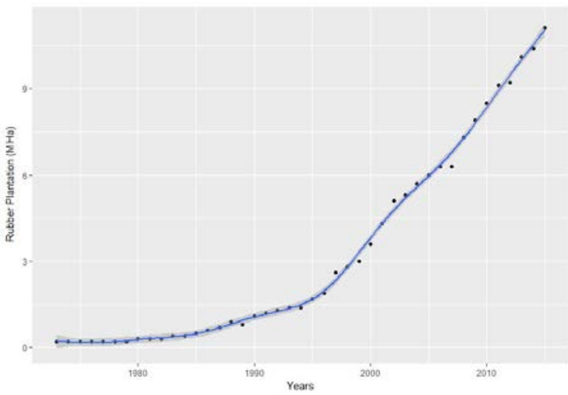
[Please note varying Y axes scales]



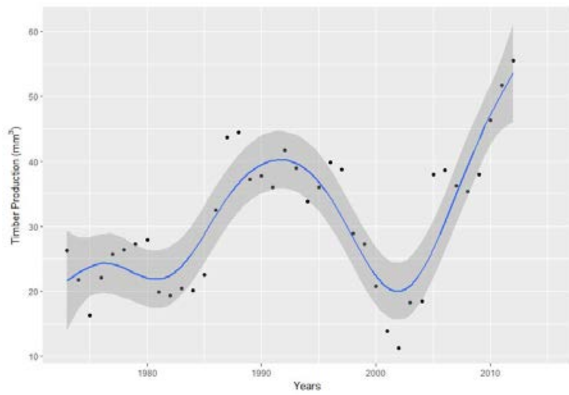
(a) Permanent Crop Model



(b) Rice Field Model



(c) Ruber Plantation Model



(d) Timber Production Model

Figure 3.5: Generalised Additive Models for landuse change in Indonesia (1973-2015) (a) Permanent Crop (b) Rice Field (c) Rubber Plantation (d) Timber Production. GAMs were all significant to P $\leq$ 0.001.

[Please note varying Y axes scales]

Chapter 4

WEB-GIS for Conservation Monitoring Activity

4.1 Summary

Biodiversity loss is a global issue and is especially of pressing concern in mega diverse countries, such as Indonesia. The Ministry of Forestry and Environment of Republic of Indonesia has been promoting a resort-based management to maximize the performance of its conservation activity. Lack of data standardization, conservation system structures, and political fragmentation presents significant conservation management problems for archipelagic country comprising 17,504 islands with no technology provision in most of them. In this chapter a framework was developed to integrate mobile-web technologies to help manage data pertaining to biodiversity and conservation in Indonesia. This prototype system is currently being implemented within the country in Bengkulu province where the system was tested and data were collected.

4.2 Introduction

There are three current challenges which need resolving to enable more effective capture of biodiversity and environment data in tropical areas. The first challenge is the provision of sufficient high quality data, derived from the numerous resources that are available to ecologists and conservationists, allowing them generate evidence-based research that supports conservation policies and strategies. This will only happen when there is agreement on data standards and meta data protocols that support open systems which are operationalised at appropriate large spatial and temporal scales (Roberts & Hardisty 2012). The second challenge sits with information scientists to develop frameworks and algorithms to help the conservationist access and analyse the data (Kissling et al. 2015). Lastly, there is a need to close the governance gap, whereby local communities are distanced from setting and agreeing conservation goals (Bennett & Dearden 2014). Indeed, Muhumuza & Balkwill (2013) showed that 66% of successful and 55% of unsuccessful conservation interventions in African game parks were related to local factors that were socio-economic and/or cultural in nature. This has led to calls for models of conservation that are multi-layered, emphasising local governance structures based on long-term partnerships between legislative and monitoring bodies, communities, and NGOs (Kelman 2013). Such an approach needs to consider the landscape as multifunctional where different land uses can be valued and assessed focusing on their spatial interactions (Santika et al. 2010).

In developing, biodiverse countries, such as Indonesia, which are not only physically diverse (in terms of habitat and landscape diversity), but also culturally and politically diverse, this tension is heightened where the need to grow the economy frequently takes precedence over all other national issues and where timber production and agricultural production of cash crops, such as palm oil are key resources for global markets (Tsujino et al. 2016). As a result, policy pressures can lead to undesirable outcomes. Gaveau et al. (2013) have shown, for example, that 25% of land allocated for timber harvesting in Indonesia between 2000-2010 was reclassified from reserves to production forest (industrial plantation).

In chapter 2, It was shown that considerable pressure has occurred over the past 4 decades in forest ecosystems in Indonesia and that the losses of forest resource have remained unsustainably high until 2015. The conservation structures in place in Indonesia were briefly outlined in chapter one of this thesis, emphasising a clear need for open, real time systems that adhere to global data standards. This chapter focuses on the design of such a system that capitalises on new technologies for capturing environmental data that link national datasets with local conservation activities. While it is acknowledged that effective conservation management systems also require revised local, regional and national governance systems (Bennett & Dearden 2014), the contention is that they cannot be revised effectively in the absence of high quality and accurate information concerning the status of Indonesia's natural resources. Moreover, recent legal and administrative decisions in Indonesia have created an environment where the management of forests is being handed to local communities. Boedhihartono (2017) has reviewed the biodiversity knowledges and values held by people residing in community-managed forests and concluded that biodiversity values need to be monitored, maintained and enhanced at that spatial scale.

Arts et al. (2015) reviewed the potential and pitfalls of the use of smart and digital technologies in conservation science. They identify the potential benefits as the: *"promise [of] more data, faster processing, better information access and connectivity, new communication routes, exciting visual representations and empowering decision-making support systems"* (p.1). Indeed, these kind of benefits are discussed by Bartlett et al. (2015) and Jaguey et al. (2015) in relation to agriculture, and soil science, suggesting improvement in data capture and increased uptake. Smart, mobile and web-based technologies are gradually gaining a foothold in conservation science but their application to areas of the developing world is somewhat limited.

This aim of this chapter is to develop a framework for the integration mobile-web technology for biodiversity and conservation management in Indonesia[1] focused on the

[1]Elements of this chapter have been published in the following journal article: Vatresia et al. (2017a) Resort Based Management Web GIS Towards Cyber Conservation in Indonesia. Sustinere: Journal of

smallest conservation unit in the Indonesian system, the Resort. The objectives were to review the current status of conservation structures and processes in Indonesia, and design a bespoke system that takes advantage of new and emerging web-based and mobile technologies.

4.3 Framing the problem: Conservation in Indonesia

Based on law number P.10/KSDAE/SET/KSA.0/9/2016, The Minister of The Ministry of Environmental and Forestry emphasised the need for conservation technology to help in decision making processes supporting sustainable forest development while minimising the impact of national development schemes. The conservation system in Indonesia has to support a wide range of management units and individual conservation activities (or tasks). Currently, the effectiveness of the system is reduced by the speed at which senior conservation managers and scientists can access current information about the condition habitats and species in Indonesia.

Only limited technology is available to support the maintenance of forest resources and conservation (Regulation of the Minister of Forestry Number P. 81/Menhut-ll/2014), but Indonesia has made a commitment to improving the performance by adopting new approaches emphasising digital and mobile technologies. Despite this there is insufficient emphasis on unified data and web standards and guidance, which means that the amount usable data is reduced and a significant proportion of it is unavailable. Cognizant of this, the Indonesia government have supported the development of applications and websites that have been launched to help the management of biodiversity and conservation activity[2]. Although some of them have an interactive interface to help data collection on Indonesian biodiversity and environment, they are essentially just web portals that lack

Environment and Sustainability, 3(1), p. 10-20. doi: https://doi.org/10.22515/sustinere.jes.v1i1.3.

[2]For example: http://webgis.dephut.go.id:8080/kemenhut/index.php/id/, https://www.kehati.or.id/peta/

open, accessible biodiversity data, so cannot be used in daily conservation task activities.

The important task of monitoring deforestation, forest management, and conservation activity in Indonesia is centralised in The Ministry of Environment and Forestry of Indonesia. The latest management system places the Resort as the central tenet of the activity of conservation in Indonesia (Chapter 1). This body is the outward face of the Ministry that interacts with the people within the area. The Ministry has staffed and resourced the Resorts to monitor biodiversity and land use change and also identify areas of conflict related to illegal wildlife trafficking, poaching and deforestation. The rationale for this is clear; Indonesia is a maritime country spanning some 5000 km from west to east and comprising $17,000$ islands. Accordingly, any conservation system must cover the need of real time data availability from every remote area in Indonesia, cutting across different layers of bureaucracy without increased data redundancy creeping in from varying data standards, manual input of records and so on. It is a complex, challenging but very necessary task.

4.4 Method and Framework Development

The context for the framework is captured by the five domains for effective digital conservation outlined by Arts et al. (2015) (Figure 4.1). Clearly, as a central core, we need data on nature (e.g. biodiversity and habitats), which in a rapidly changing digital environment is being derived from apps (Teacher et al. 2013), UAVs, dedicated global biodiversity networks, all supported by an increasing active citizen science movement (Chandler et al. 2017), but importantly this must also be matched with data on people. New approaches such as 'experience sampling' (Arts et al. op cit) use sensors (e.g. in smartphones and fitness equipment) to track people, providing important information on how, where and when they use natural environments (e.g. parks and other greenspaces) (Doherty et al.

Figure 4.1: The five domains to enhance digital conservation activity (Arts et al. 2015).

2014). As important data from camera traps, nestbox traps, GPS tags, drones and satellites are available to target illegal activities such as wood logging, trapping, hunting and so on.

The growth of web-based Kim et al. (2014) and social media data (e.g. Roberts et al. 2017) also provides opportunity to generate information on how people view, discuss communicate and experience nature, perhaps providing platforms for e-governance structures (e.g. mobile phone networks to reduce human-elephant conflicts – Graham et al. (2017)). Once assembled these data need integration, ahead of analysis. New global biodiversity networks are at a vanguard of this activity pooling scientists, data and driving forward global standards for data quality, such as The Global Biodiversity Information Facility (GBIF) , the IUCN and the Map of Life[3].

In this chapter, the cycle of the Design Science Research (DSR) method was used to evaluate the domains that are current within the present Indonesian conservation system

[3]https://www.gbif.org;https://mol.org

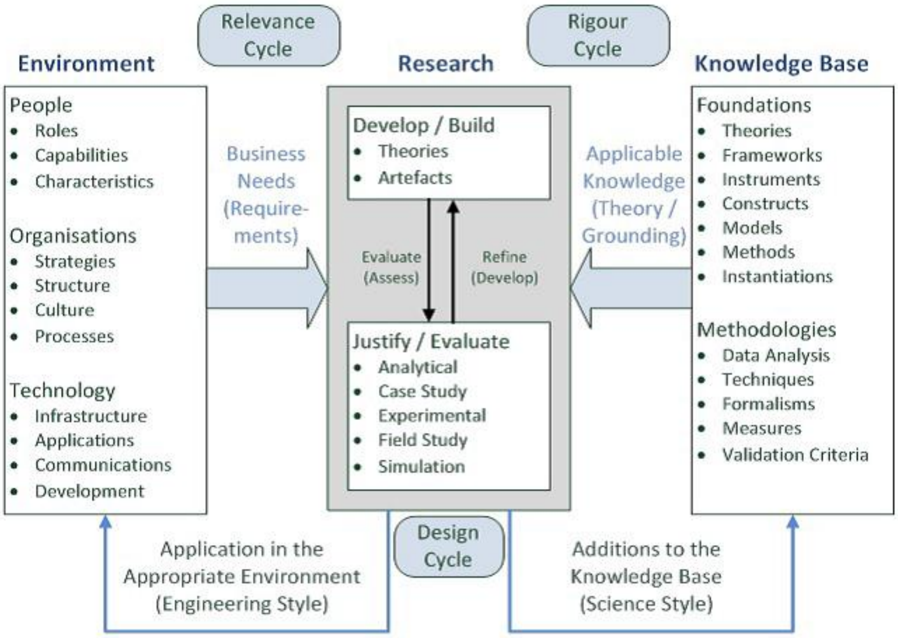


Figure 4.2: The Design Science Research process (Hevner 2007)

to provide a new framework for the process of information collection and storage and ultimate the creation of a web-based application. The Design Science Research (DSR) methodology is based on a problem-solving rather than problem-understanding paradigm. It is commonly used to develop the theories and artefact is based on the problem occurrence in the organization. The processes in Figure 4.2 are designed to align user (business) needs with the current knowledge base and involves iterative design cycles, that systematic optimise the system. This method was developed to bring people, organizations, and technology together needs can be better assessed supporting the design of a framework with greater end user relevance. It contains three cycles that help the developer of the system create optimised algorithms that suits the needs of the organization. The relevance cycle is the process to appoint the requirements from the organization to provide the design and implementation of in- formation system to be develop. IT rigour cycle process confirms that innovation advances and matches the fundamental knowledge that already exists within the organization. The design cycle iterates the main cycles to provide an application that more effectively fits user needs.

The design analysis was supported by utilising the Management Effectiveness Track-

Elements of evaluation	Explanation	Criteria that are assessed	Focus of evaluation
Context	***Where are we now?*** Assessment of importance, threats and policy environment	- Significance - Threats - Vulnerability - National context - Partners	Status
Planning	***Where do we want to be?*** Assessment of protected area design and planning	- Protected area legislation and policy - Protected area system design - Reserve design - Management planning	Appropriateness
Inputs	***What do we need?*** Assessment of resources needed to carry out management	- Resourcing of agency - Resourcing of site	Resources
Processes	***How do we go about it?*** Assessment of the way in which management is conducted	- Suitability of management processes	Efficiency and appropriateness
Outputs	***What were the results?*** Assessment of the implementation of management programmes and actions; delivery of products and services	- Results of management actions - Services and products	Effectiveness
Outcomes	***What did we achieve?*** Assessment of the outcomes and the extent to which they achieved objectives	- Impacts: effects of management in relation to objectives	Effectiveness and appropriateness

Figure 4.3: Management Effectiveness Tracking Tool graph World Wildlife Fund (2007)

ing Tool (METT) method as advocated by World Wildlife Fund (2007) Figure 4.3. This method has been adopted by a number of global conservation organisations to help scope, plan and evaluate their conservation activities. It was produced by analysing the strengths, weaknesses, opportunities, and threats to protected area.

4.5 Results

4.5.1 Evaluation of system needs

Although Resort Based Management was introduced by The Ministry in its strategic planning 2010-2014), the implementation of this still limited in some of the national parks and standard research infrastructure in these areas is still insufficient. Considering these problems, Kissling et al. (2015) suggest that to enable effective information processing, certain requirements must be met:

1. Secure and reliable and open data should be provided as the baseline. Open access should not come at the expense of data security, it should be protected and authorised by administrators. The data should also be validated and screen before upload.

2. Data access and information processing needs to be available to a wider group of stakeholders, in a readily usable but understandable form supported by clear metadata standards that enhance data integration. The metadata generated by the system needs to be relevant the organizations/stakeholders.

3. Core data productions examining biodiversity and habitat changes need to connect through the multiple levels of the conservation system.

4. Enhanced system optimisation. Roberts & Hardisty (2012) suggested that the core of Research Infrastructure (RI) for biodiversity should be elastic and fault tolerant so enhancing its ease use and maximising the user experience. Moreover, the data should be easily optimised to meet the user requirements.

Using the approaches outlined above in section 4.3, first the limitations and challenges were mapped faced by the conservation researchers and practitioners in Indonesia, and secondly, we analysed and reviewed the business processes in the Ministry of Environmental and Forestry of Indonesia. This exercise resulted the identification of the following key issues in relation to conservation practice and management:

1. Data sources harmonisation. It became apparent that in the case of biodiversity and conservation, there are many sources of data, stored in various places (databases) both national but also global, in various formats with inconsistent levels of metadata support.

2. Political domains. There are 50 of national parks in Indonesia which are managed by differently by Provinces. Each national park in Indonesia is unique with a historically wide range of management structures that are as culturally diverse as they are biologically rich. Nonetheless, all are now subject to a local resort-based management system, which requires standardised data structures and processes to operate effectively.

3. Different Information Infrastructures. Although some of the National parks in Indonesia introduced the register system as outlined by the newly merged The Ministry of Environment and Forestry (see Presidential Regulation No. 16 of 2015), other national parks still retain their own versions which were formulated by the bureaus.

4.5.2 Design and Development

To address the shortcomings identified above, a notional data management framework for conservation and biodiversity in Indonesia is depicted in Figure 4.4. The framework details the key processes of a conservation system from data collection, management, analysis to conservation plan creation (left hand side processes) to validation, policy creation and implementation (right hand side processes) that emphasise pre-processing needs, knowledge discovery and finally management processes.

Suryadi (2014) internal review of conservation activities in Indonesia established how conservation knowledges were maintained within the bureaus. 26% of the information was in paper form, 20% are in the electronic documents, and 12% are in electronic knowledge. The remaining 42% is thought to be a consolidated with the human system. Based on this it was clear that human participation was needed to create a system that will gain traction. During this phase, a prototype of the system was developed for IT value assessment and additional specification for a human resource as part of the organisation. Feedback and observation from the various organisational levels within The Ministry of Environmental and Forestry helped to conceptualise the key terms related to IT infrastructure, service, and business processes using an Ontology of Engineering process to unpick the existing

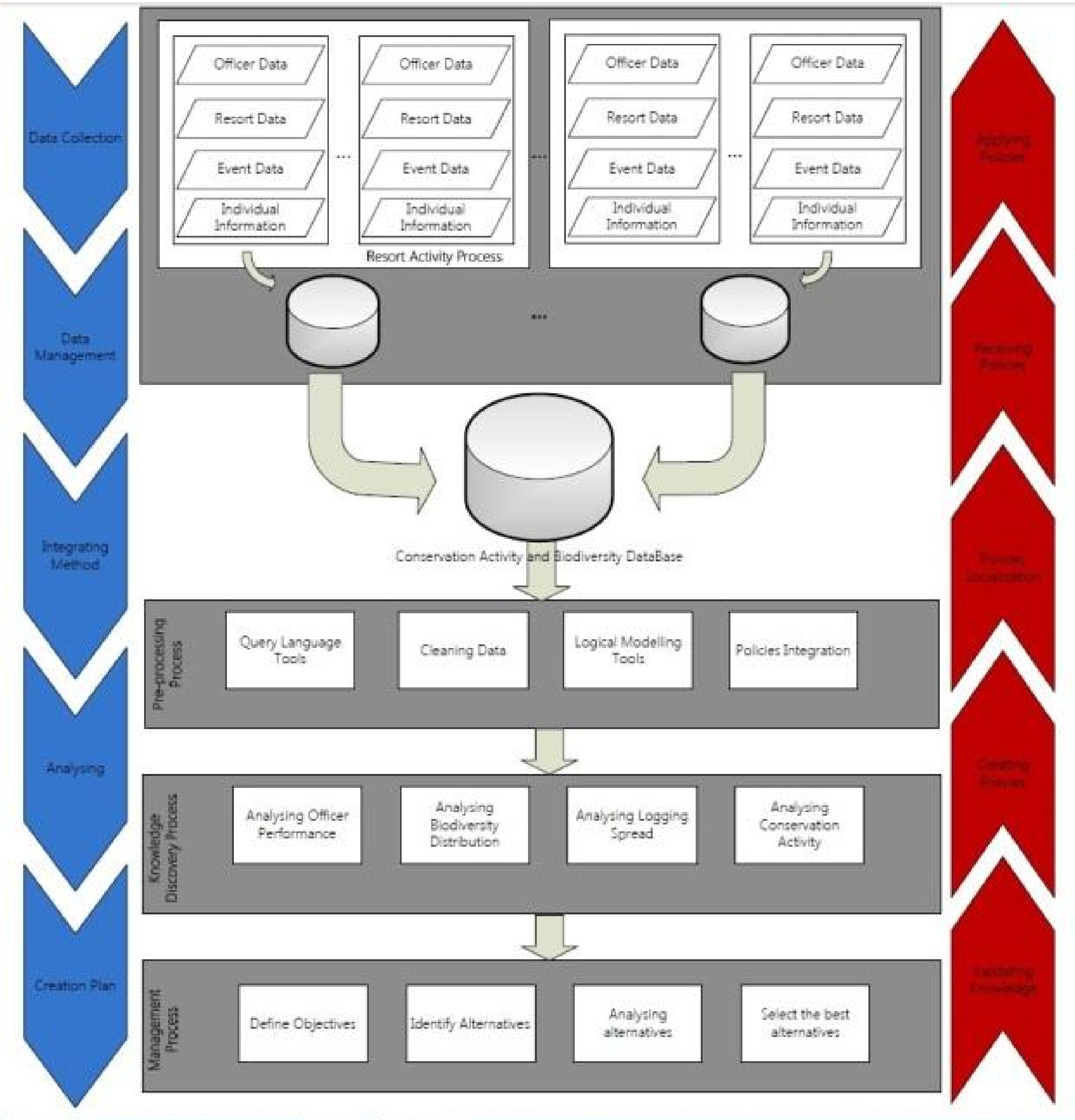


Figure 4.4: Conservation and biodiversity framework for conservation in Indonesia

taxonomy (e.g. COBIT or ITIL).

The remaining two design tasks relate to mapping the client / user domains and then a detail activity map, which are needed to maintain the change in conservation area in real time. This also help the higher position to implement the policy that needed by the country. This process also support the program of social forestry that would involve the people surround the conservation area to take care the existence conservation area. They also would contribute to monitor the area that makes the process of conservation would much more efficient.

The system has two components, the web portal and a mobile application created to assist park rangers in their daily resort-based tasks. The design was outlined, implementation of the mobile client in chapter 5 so focus here on the web portal. Client access to the system is shown in Figure 4.5. All stakeholders have a role to play: resort rangers, administrators, the local population and ultimately decision makers. The key roles of each group are visualised in the map (Figure 4.8).

The activity map conceptualises how the various users interact with the elements of the system in terms of access rights, privileges, queries, and validation routines (Figure 4.6).

4.5.3 Implementation and Evaluation

- **Implementation**

  Environment; Expository the Ministry of Environmental and Forestry of Indonesia through the representation of sample process and consistency check.

  Knowledge Base; this is need the semantic a method for consistency checks and validation of applicability of core concept of the system. The Ontology and stratification was made in implementation phase to initiate the instantiate.

- **Evaluation**

  Environment; Formal grounding of the system and real life application to observe the use of the prototype and interviews the end user. Evaluate the usefulness of the

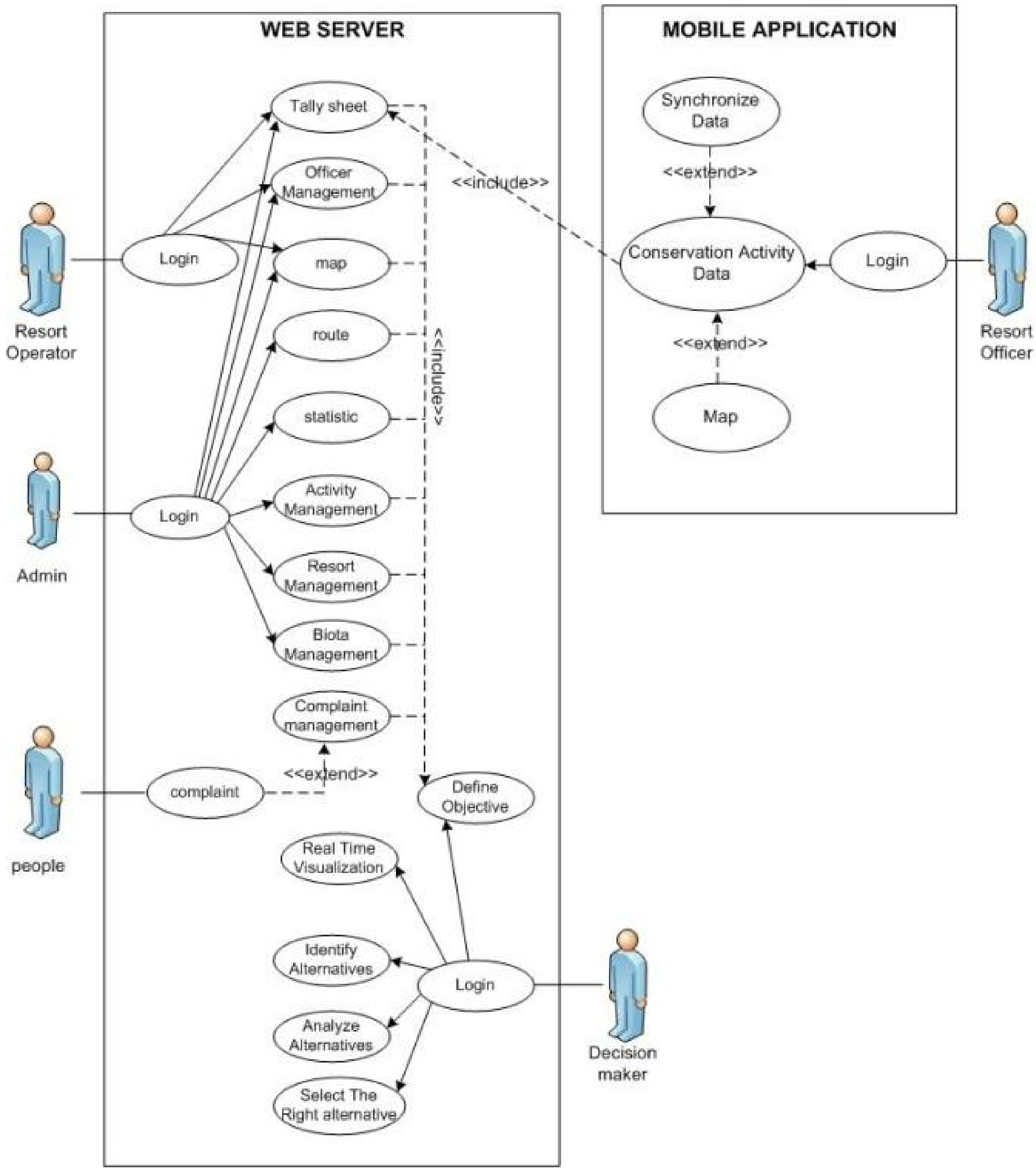


Figure 4.5: Use Case Diagram

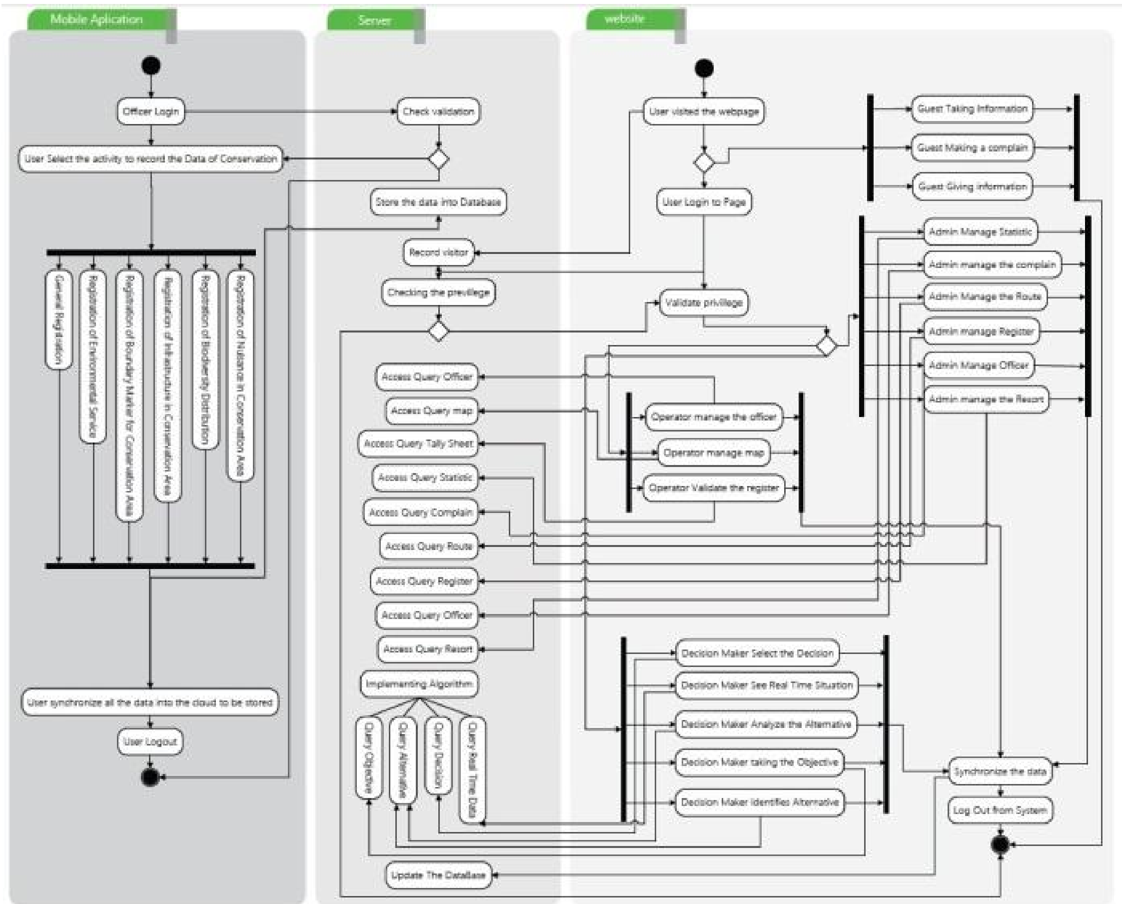


Figure 4.6: Activity diagram

business problem of assessing the business value of IT for the system.

Knowledge Base; the knowledge of this phase would be the real world semantic of Web- GIS concept in the Ministry of Environmental and Forestry in Indonesia. It proves the usefulness of Web-GIS inside the organisation. It would define the truthfulness, the clarity, and expressiveness of the performance of Web-GIS in this system.

4.5.4 Discovering Process

Environment; It involves the identifying of IT service, calculating IT service costs, tracking the business process of IT service requirements to IT infrastructure elements

Knowledge Base; This phase contains the design principle of an ontology for supporting the planning and control of living IT infrastructure to measure the value of IT value. The phases of implementation and evaluation are the looping stage that repeatedly be used to achieve the optimised system implementation on the real world.

1. **Context**

   In this evaluation element, the Ministry as the central of management biodiversity and conservation activity in Indonesia must honestly address the problem that appeared inside the organisation and the organisations surrounding that has overlap interest. By knowing the condition, the Ministry should be able to move forward to gain the solution of the addressed problem. Based on the problem addressed by the Ministry, the context of this process should be corresponded to the law and policy in Indonesia. Because of the main responsible of The Ministry of Environmental and Forestry in Indonesia is to maintain the sustainable environment in Indonesia, the context of the process must include the technical of how to manage the forest, how to manage the area, how to protect islands and how to protect biodiversity.

   By knowing and completing this evaluation, the ministry must have a map of partner and threat organisation that influences the process of the system, including the organisations, non-government organisation, pulp companies, wood companies, palm oil companies, and all of related company that mainly uses the resource of Indonesia forests. By managing this process the Ministry could focused and make some priority scales about how vulnerable the land to be modified.

2. **Planning**

   The aim of the conservation in Indonesia to achieve the global goal of managing forest and biodiversity in Indonesia to reduce the green-house effect and minimize carbon emission to make the earth a better place to live. By knowing the status of the land and make the status of the land and forest become clearer, the Ministry needs to involve the people of Indonesia, making them aware of the importance of the plan and to achieve the goal that already defined. Furthermore, the Ministry should also give a clear guidance on the protected area design and implement the recent policy of Resort Based Management.

3. **Input**

   Resort Based Management System is formulated needed to supporting in application of the policy. The inputs are:

   A – Area Description; The input about area description referred to the official publication from WWF as describe in chapter 2. As the Ministry already defined its own registered the register combined with the suggestion from the Ministry of Environmental and Forestry of Republic of Indonesia.

   B – Animal and Plant Distribution; The animal and plant distribution information in this stage contains information about the location where the animal and plant in Indonesia was found and maintained. Other metadata include details on the site where the organism was seen.

   All of the information needed by the ministry should be provided by the internal member of ministry or protected area staff due to the basic idea of resort based management policy. If the Ministry find the sharing data could help the input process, some additional data could be obtained by trusted organisation that has the same aim and vision to protect the process from misleading process outcomes.

4. **Process**

   The process of the evaluated value is by doing the process based on the framework that already build as a standard process. It has to involve the three cycles of the method that already implemented on the system framework that we built. By following the step of the framework, the process of managing the biodiversity and conservation activity.

5. **Output**

   The output of the process should be measured by the decreasing rate of deforestation, decreasing value of carbon emission, and maintain the richness level of biodiversity and increasing number of animal sanctuary and protected area to achieve the land stability. The output could be also by implementing relevant policy to be accepted easily by the people and corresponded to the need of the problem in Indonesia. For example, there is a constraint to maintain the forest in Indonesia due to the increasing rate of population in Indonesia. By implementing the framework, Indonesia could finalize the policy to keep maintain the forest area and also stabilized the need of housing and income rate so the people doesn't need to degraded land by shifting cultivation nor planting palm oil as an income.

6. **Testing**

   The software was tested by officers in Bengkulu, one of province in Indonesia that contains of 9 resorts and 2 patrol groups. Province of Bengkulu lies in Sundaland-biogeographic province which has initially 9.1% of totalprimary vegetation and has been degraded by 7.8% from its original size. It is also a home of 15,000 endemic plants (5%) and 701 (2.6%) endemics vertebrates (Myers et al. 2000). This province is one of the 34 of Indonesia placed adjacently with Lampung to the south-east, Jambi to the northeast, South Sumatra (Sumatra Selatan) to the east, West Sumatra (Sumatra Barat) to the north, and India Ocean to the west, south-west and

Figure 4.7: Main Interface in the website

south. The province also includes Mega Island and Enggano Island. Its topography has the long coast line of 525 kilometres adjacent to the Indian Ocean on its western side. It is spread from Dusun Baru Pelokan in Muko-Muko Regency to Tebing Nasal in Kaur Regency.

4.6 Web-GIS Implementation

Once the framework was established, the web-gis was implemented and harmonised with the Ministry of Environment and Forestry. The system itself can be seen in `http://webgis.dephut.go.id`, see figure 4.7.

This web GIS contains numerous menu and interactive data layers describe in detailed in Table 4.1:

Table 4.1: Web-GIS Interface

Layers Name	Functionality
IUUPHHK	This menu brings a layer showing the area that defined as the area for business of mining production (see Figure 4.8). There are 3 main type of IUUPHHK defined by MoEF, described in points bellow:

Business Permit for Timber Forest Product Utilization – Nature Forest [IUPHHK-HA]	Previously called HPH, now known as IUPHHK-HA, is a business permit issued to utilize forest product like timber within nature forest in production forest through activities such as harvesting or logging, enrichment, maintenance and marketing. By 2007, there were already 320 Units of IUPHHK-HA/HPH covering forest area of 27.5 million ha.
Business Permit for Timber Forest Product Utilization – Plantation Forest [IUPHHK-HT]	Business License for Utilization of Timber Forest Products in Industrial Plantation Forests in the Forest Plants in Production Forests hereinafter abbreviated as IUPHHK-HTI previously called Plantation Forest Concession Rights (HPHT) or Concession Rights Industrial Plantation Forest (HPHTI) or Business Permit for Utilization of Timber Forest Products at Plantation Forest (IUPHHK-HTI) is a business permit to build plantation forests in production forests built by industrial groups to improve the potential and quality of production forests in order to meet the needs of raw materials industry. (Permen RI Number: P.50/Menhut-II/2010)

Business Permit for Timber Forest Product Utilization – Ecosystem Restoration [IUPHHK-RE]	Business Permit for Utilization of Timber Forest Products Ecosystem Restoration in natural forests hereinafter abbreviated as IUPHHK-RE is a business permit granted to build areas in natural forests in production forests that have important ecosystems so that their function and representation can be maintained through activities maintenance, protection and restoration of forest ecosystems including planting, enrichment, thinning, captivity of animals, release of flora and fauna for restore biological elements (flora and fauna) and non-biological elements (soil, climate and topography) in an area to the original type, so that balance is reached biodiversity and its ecosystem (Permen RI Number : P.50/Menhut-II/2010)
Peat Land	The Peat Hydrological Unit is an Ecosystem Peat which is located between two rivers, on between river and sea and/or on swamps. (PP RI Number 57 year 2016)

management rights for village forest	Village Forests are state forests that have not been impacted with permits/rights, and are managed by the village and used for village welfare. Village forest management rights (HPHD) are rights granted to village institutions to manage state forests within a certain time limit and area. Business license for utilization of timber forest products (IUPHHK) in village forest, hereinafter referred to as IUPHHK-HD, is a permit granted to cooperatives or other legal entities formed by village institutions to utilize forest products in the village forest in production forests through planting, maintenance, harvesting and marketing activities (Permen RI number p.89/menhut-ii/2014 article 12,13,14)
Community Forest	Community Forestry (HKm) is a state forest whose main use is intended to empower local community (Permen RI Number p.88/menhut-ii/2014)
Community Plantation Forest	Community Plantation Forest (HTR) is plantations in production forests built by community groups to increase the potential and quality of production forests by applying silviculture in order to ensure the sustainability of forest resources
REDD Area for Measurement	The next Performance Measurement Area abbreviated as WPK is an area for the implementation of actions mitigating climate change under the REDD + and is a unit to be measured, reported, and verified. This area can bee seen in Figure 4.9
Area of Forest Fire 2016-2017	The area of forest fire maps the area which already gone because of the forest fire appearance of hotspot.

Area of Forest Released for Farming Allocation	This layer showed the area of forest that has been released by government for farming allocation to empower the people around the forest area.
Area of Forest Released for Transmigration Allocation	Maps the area that has been allocated for transmigration program in Indonesia to spread the people from Java island into several islands in Indonesia.
Forest for Special Allocation	The Special Purpose Forest Area (KHDTK) is a forest area designated by the government for public purposes such as research and development, education and training, and religion and culture.
Area of Forest Leasing	The license to borrow and use the forest area is a permit given to use forest areas for development purposes outside of forestry activities without changing the function and designation of forest areas.
Utilisation Direction for Production Forest	This layer maps the direction of forest allocation for production forest from the Ministry of Environment and Forestry; this layer is the new direction of distribution in 2017.
Indicative Area for Community Forest II	This layer maps the change of forest area that is being used by the community.
Indicative Area for Postponed of a new revision of the permit	This layer is one of the real-time layers that shows the status of permit demand from the community to use the forest. Some of the areas are rejected to be used and should be maintained.
Ecological Function for Peatland	This layer shows the area of functioning of peatland in Indonesia.
Ecoregion in Land and Water	This layer shows the ecoregion in land and water all over Indonesia region to maintain the essential ecology

Fire 2014-2016	These layers are showing the spread of hot spot area based on the satellite data correspondent.
Watershed Border	This layer shows the border for the area around the river and water surface.
Mangrove	This layer shows mangrove cover in Indonesia.
Deforestation	This layer shows the deforestation area for each year to know the forest that include in deforestation, see Figure 4.10.
Forest and land rehabilitation	According to the Law of the Republic of Indonesia Number 41 of 1999, Forest and Land Rehabilitation is intended to restore, maintain and improve the function of forests and land so that their carrying capacity, productivity and role in supporting livelihood systems are maintained. Forest and Land Rehabilitation activities are carried out through Reforestation, Reforestation, Maintenance, Planting, or Application of vegetative soil conservation techniques and technical civilization on critical land and unproductive. Reforestation and reforestation activities are generally carried out on critical land and former logging areas. Both activities require large quantities of seeds and good quality. This area can be seen in Figure 4.11.
Forest cover	This layer showed the forest cover all around indonesia.

4.7 Conclusion

Suryadi (2014) internal audit of the conservation information flows within the Ministry of Forestry and Environment showed that almost a fifth of the information was still held in paper format, with a staggering 42% held by people within the system (i.e. rangers and managers). This is a long way from addressing the core attributes that of an informa-

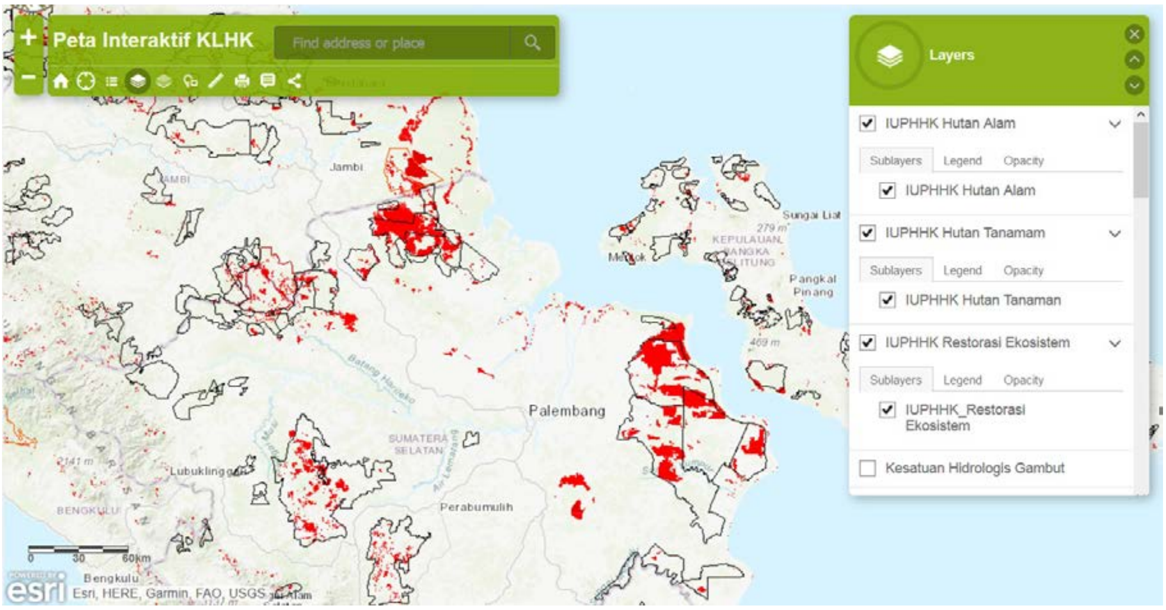


Figure 4.8: IUPHHK Deforestation interface in the website

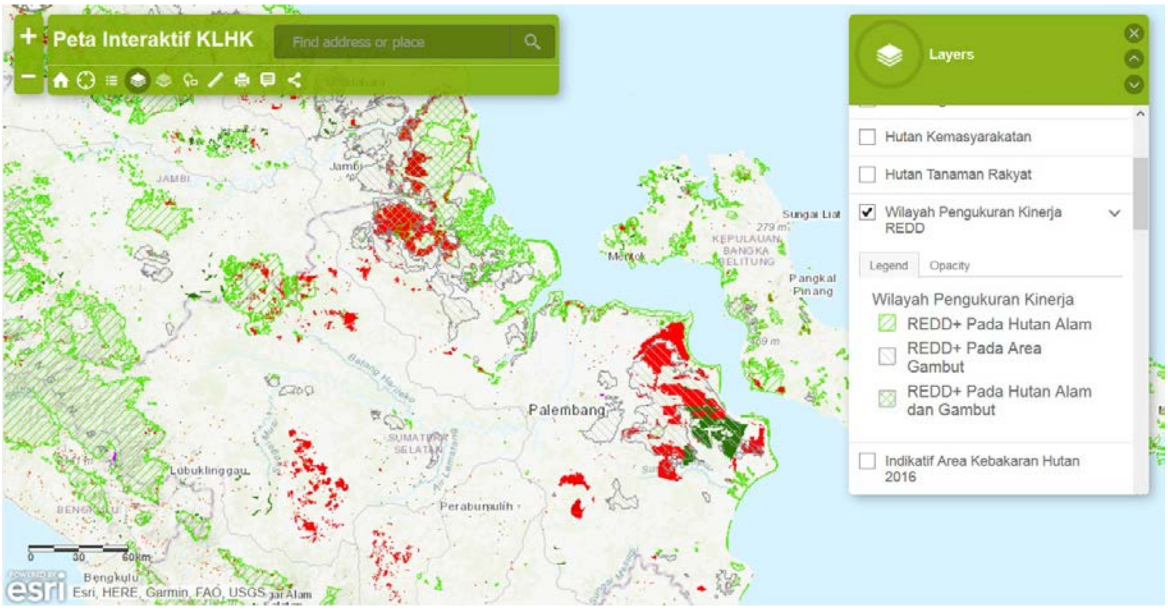


Figure 4.9: Interface of REDD Area of measurement

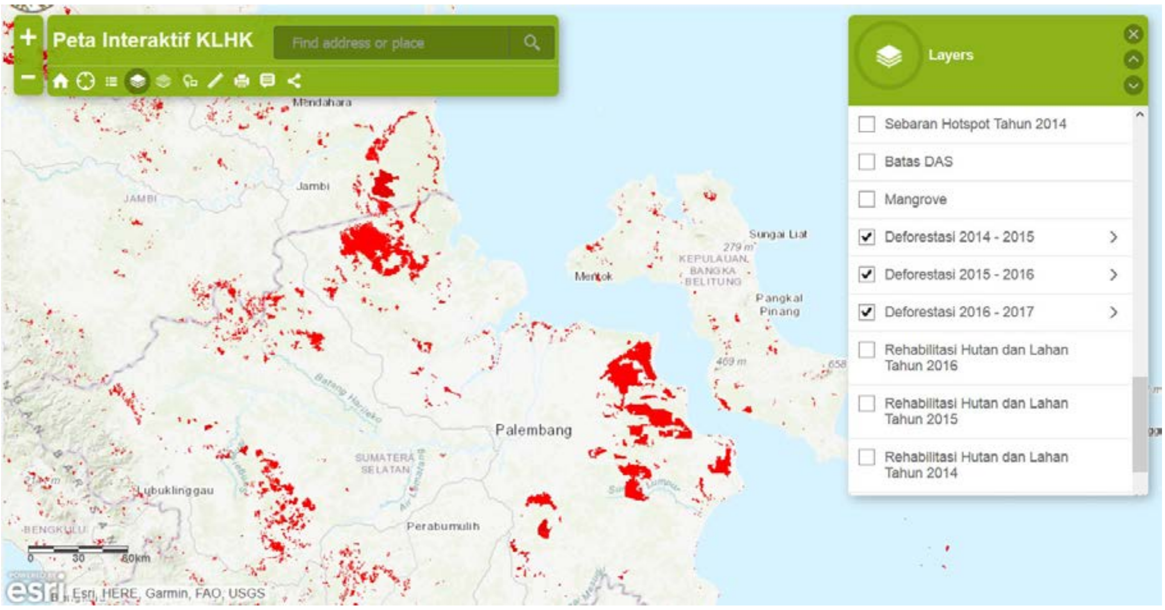


Figure 4.10: Interface of Deforestation

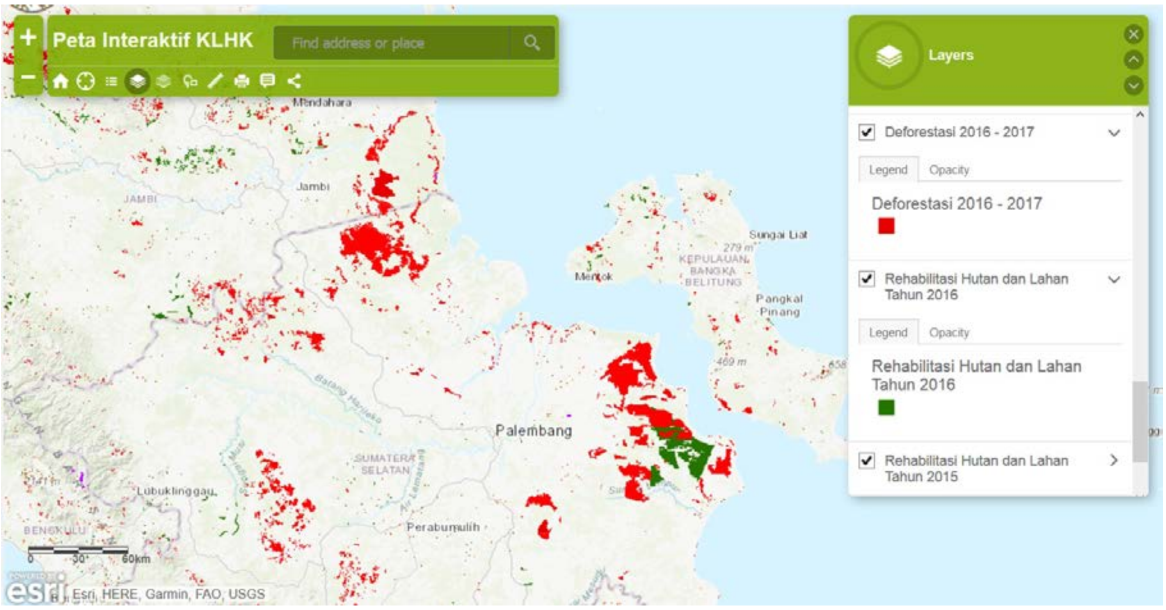


Figure 4.11: Interface of Rehabilitation Area

tion system outlined by Kissling, Hardisty, García, Santamaria, De Leo, Pesole, Freyhof, Manset, Wissel, Konijn & Los (2015) as being secure and reliable with open access, inclusive of a wider group of stakeholders, connecting all elements of biodiversity monitoring system together via enhanced system optimisation. This chapter has outlined the scoping, design and implementation of a Web-enable GIS conservation system to help manage data pertaining to biodiversity and conservation in Indonesia. The prototype is currently being implemented within the country in Bengkulu province where the system were tested and data were collected. The system was based around the five domains aimed at enhancing digital conservation activity (Arts et al. 2015) using data structures adopted The Global Biodiversity Information Facility (GBIF) , the IUCN and the Map of Life. The design was generated using the best practice Design Science Research (DSR) methodology and included open, accessible data structures, with mobile app links to enhance end user engagement by the professional, regulatory and, crucially, public stakeholders as emphasised by Muhumuza & Balkwill (2013).

Chapter 5

The Development of Mobile Application for Conservation Activity and Wildlife in Indonesia[1]

5.1 Summary

As a maritime country comprising 17,504 islands, data collection and the lack central monitoring programmes and procedures for wildlife and biodiversity is a pressing concern in Indonesia. An efficient data collection process is needed to provide decision makers with accurate data; this the key to better informed decisions and the creation of evidenced-based policy in the future. With the advent of cheap and GPS-enabled smartphone technologies it is now possible to create an app that support realtime, field-based observations that can be rolled out to the forest ranger service in Indonesia. In this chapter, I develop such an application permitting forest rangers to capture the data on biodiversity in realtime in a field situation in Indonesia. The app development was driven by the new laws and policy in Indonesia which requires the performance of conservation activity to monitored. It was developed by using Java and the System Development Life Cycling (SDLC) and Unified Modelling Language (UML) 2.0 design models. The application was tested by using both black box and white box methodologies.

[1]This chapter is based on the following publication:Vatresia, A. et al., 2017b. The development of mobile application for conservation activity and wildlife in Indonesia. In Proceedings - 2016 24th International Conference on Geoinformatics Y1 - 14-20 Aug. Galway, 2016, pp. 1-6. doi: 10.1109/GEOINFORMATICS.2016.7578977.

5.2 Introduction

As a maritime country with a large number of threatened forests and numerous plants and animals at risk of extinction (Myers et al. 2000, Jepson et al. 2001, von Rintelen et al. 2017) Indonesia needs to generate new approaches and actions to address these pressing issues. The Ministry of Environment and Forestry in response to this crisis proposed the method of Resort based management to improve the performance of conservation activity in Indonesia (Wiratno 2012, 2013). This hierarchical structure was put in place to maximise the contribution of Forest Rangers who operate across the 50 national parks in Indonesia. Each national park is divided into several resorts depending on its size. The resorts are the smallest management unit where the performance of recent conservation measures are assessed and where the rapidly changing habitats and biodiversity are monitored. The lack of systematic data capture and the remote nature of landscapes in Indonesia make this process problematic.

Table 5.1: Indonesia Regulation Related to Information System and Spatial Planning

Law Number	Description
Regulation from Minister of Environmental and Forestry Number. P.43 / Menlhk / Setjen / 2017	Community Empowerment around conservation area
Regulation from Minister of Environmental and Forestry Number P.83/2016	Social Forestry
Government Regulation No. 25 of 2012	Information System on Land for Sustainable Food Crops
PR No. 3 of 2012	Kalimantan Spatial Planning
PR No. 13 of 2012	Sumatra Spatial Planning
PR No. 17 of 2015	Ministry of Agrarian and Spatial Planning

In applied geographical research, the incorporation of technology in conservation and agriculture has led to many recent innovations, such as irrigation (Bartlett et al. 2015), soil science (Gómez-Robledo et al. 2013), and plant science (Intaravanne & Sumriddetchkajorn 2015). Perhaps unsurprisingly, there has been a concomitant increase in conservation-based applications driven by a plethora of apps created for capturing biodiversity records of particular groups of plants and animals (Teacher et al. 2013). However, apps that focus on tropical and biodiverse nations such as Indonesia are conspicuously absent. Moreover, as conservation science covers more than just the capture of biological data, there is a need for an application that captures a wider range of data including, nuisance activities (e.g. illegal hunting, habitat clearance), boundary disputes and so on.

In this chapter, I develop an app system aimed at improving field data collection of data on species and also habitat condition for forest rangers working in the Resorts. The system was tested using a field trial with forest rangers in Bengkulu province, Indonesia. Bengkulu province has 9 resorts and is characterised by a variety landscapes, including mountains, valleys, and hills and a wealth of different habitat types (e.g. forest, wetland, peatland) and species (e.g. Sumatran tiger). It is also home to Bukit Barisan National Park, which is currently subjected to one of the highest rate of deforestation in the country (Margono et al. 2012, 2014),(Chapter 2).

5.3 Method

The Ministry of Forestry has placed the resort as the central tenet of the activity of conservation in Indonesia. It is the outward facing element that interacts with the people within the area. The aim was to develop a simple, usable app that can be used by forest rangers to provide data to the local community and also identify points of conflict where illegal activities might be taking place.

The development employed the System Development Life Cycle (SDLC) to ensure the needs of the end users were satisfied. It originally followed the guidelines of a 'waterfall' which was initially proposed Royce (1970) (Isaias & Issa 2015) and subsequently modified to be 'the Ripple methodology' by (O'docherty 2005). This approach has numerous benefits including object-oriented coding and strong combinations of the iterative, spiral, and incremental structures (O'docherty 2005). It uses Unified Modelling Language (UML) as the standard notation. The development of the system also involved coding with Java programming tools within IDE Eclipse Indigo (Platform Version 3.7), which was integrated with the Android Software Development Kit (Android SDK) and Android Development Tools (ADT) to make it portable on a wide range of smartphones.

Testing included investigating the software activities to examine the gap between the system requirements and system function (Bruegge & Dutoit 2004). The testing activities involves the full gamete of functional, performance, pilot, acceptance, and installation testing. White box and black box methodology were be used to measure the performance of the system (Bruegge & Dutoit 2004, O'docherty 2005). In white box testing, the internal structure/ design/ implementation of the items are known to the tester. In black box testing the software is evaluated by end users without knowledge of the processes inside the system.

5.4 Design and Analysis

5.4.1 Background

As outlined in chapter 1, the method used to collect the data from the resort is manual and based on paper forms and written summary reports sent to the section. As a result, data processing is slow and this coupled with the lack of analytical capability and data visualisation and synthesis means there is a knock-on impact on the speed and effectiveness of decision-making that undermines the performance of conservation activity. There is currently no digitally-based technology to enhance the data collection in Indonesia. Due to its central role in the conservation system, Resort management has recently become a top priority for the development of and application of new data collection technologies (Wiratno 2013), afforded by smart-phone and related technologies. The resort spatial scale was targeted because it is the level at which biodiversity data are captured and managed (Wiratno 2012, 2013).

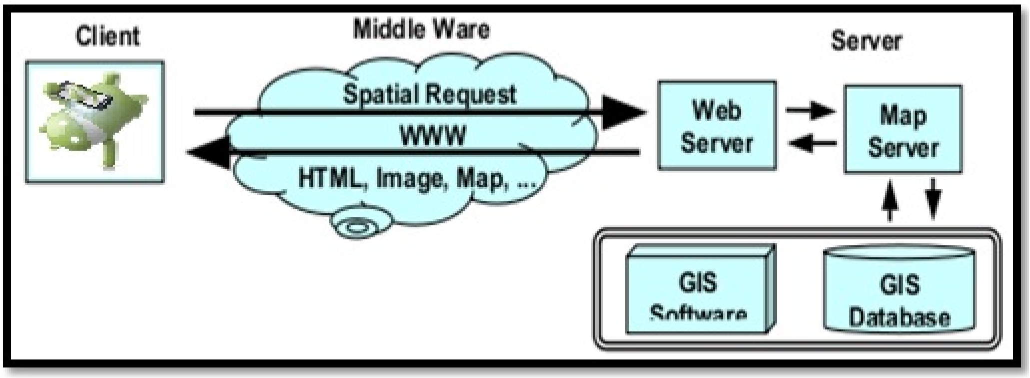


Figure 5.1: Architecture of Android with Web Integration

It is an urgent issue because many of the resorts have been poorly policed and monitored since their inception. In particular, the resorts have become isolated due to the centralised management that is not only remote locationally but lacks on-the-ground expertise. They are managed by groups of people who are focused on landscapes as resources for agriculture, forestry, who sell plots without knowledge conservation laws. The conservation area has the potential power to be used. The resource can be wood, non-wood, nature resort that can be elaborated by the officer and the instructor because they have profound knowledge in that area.

The application was based on a mobile application to help forest rangers working in remote locations. Importantly, it can be used without network and mobile data coverage, as the captured data are saved directly on the mobile sent to the cloud once the device connected to the network. The application was designed to be integrated IUCN metadata structures to make it globally available (see Figure 5.1).

The software development with GIS based is different than just connecting software and hardware inside the CPU. Some of strategies were proposed to give an successful implementation (Neil Smyth 2015). In this research, we modify the waterfall cycle of software development that already tested before to cover the minimum time and cost in implementation. Figure 5.2 is presented the development cycle of WEB-GIS.

This network model is well known and widely used by many organisations, where servers host numerous remote clients. In this system the server hosts the privileges which

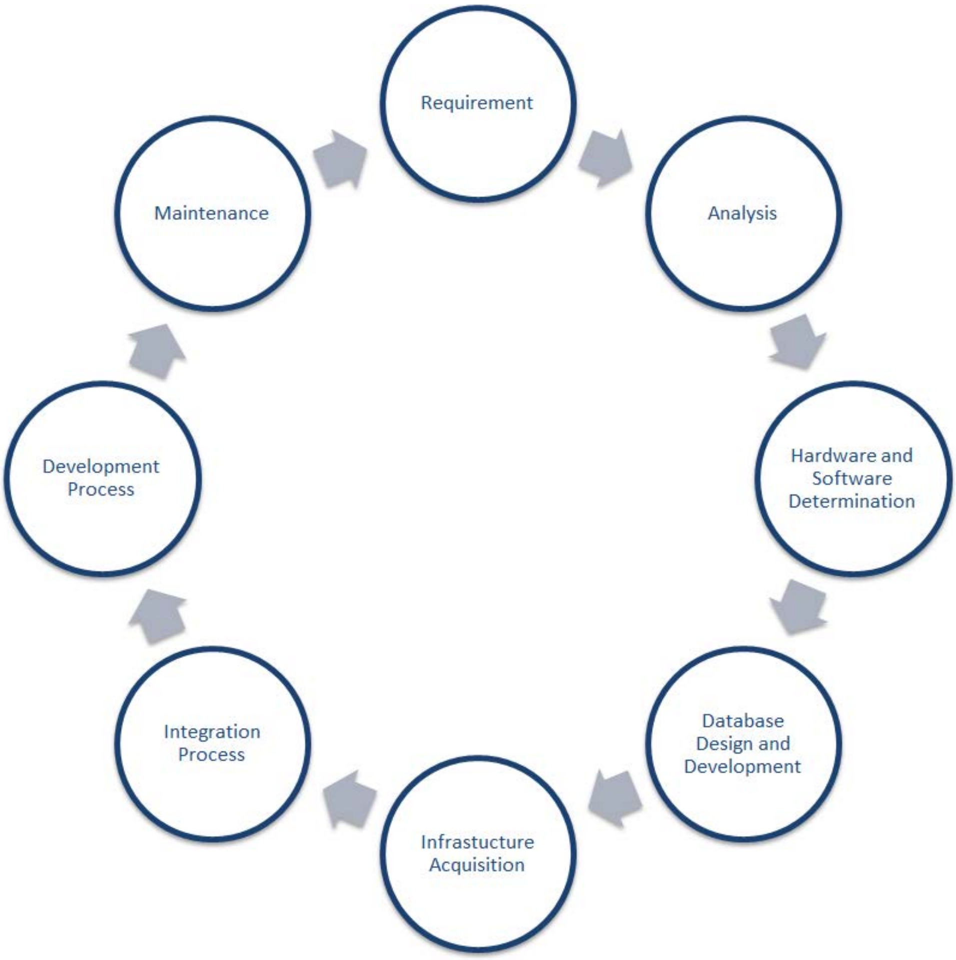


Figure 5.2: Web-GIS Software Development Cycles

are used to process the application and add host the interface on the client side, while middleware placed on server side connects the clients and server. In the first phase of cycle, the developer determines the aim of the system. The output of this stage are the functions needed by the organisation and an understanding of the type of geographic data needed to fulfil the functions. Once this has been defined then the functions for object identification, spatial queries and so on are coded.

In the first phase of cycle, the developer should determine the aim of the system that need to be developed. The output of this stage was the functions needed by the organisation and geographic data that were related each other to provide the result that need to be produced. The functions result from this stage has become object identification, spatial query, or shortest distances.

5.4.2 Requirements

System and Organition Requirements

System requirements were developed with the clients through the a review of Ministry documentation and interviews with end-users. The MoEF employed two forest rangers to support the development of the system and initiate data input. After collecting this information, the system needs are defined as a sequence of problems and solutions:

1. Problem: Indonesia has 34 provinces, 50 national parks, 74 technical implementation units, and 8000 forest rangers(Ministry of Forestry of the Republic of Indonesia 2008); a highly distributed model. Solution: Integration of technology supporting geographic information capture (using GPS data) and functions that can be used in all of the area in Indonesia. The technology needs to be centrally monitored by the government bodies in Indonesia.

2. Problem: Forest rangers need to spend more time in the field monitoring the land in protected areas, including all elements of the resorts (e.g. biodiversity, habitat condition, illegal activities). Solution: The software should records the movement of forest ranger around conservation area so it can detect the working coverage of monitoring conservation area. The software needs to be installed into the light and very portable hardware (e.g. mobile technologies), so forest rangers use it easily in the field. The additional data like image was also be helpful to collect the real conditions in the check points where the forest ranger collect the data. Technologies that used image capture is also desirable as a means of evidencing habitat conditions, species identifications and illegal activities (e.g. logging etc).

3. Problem: Currently, Indonesia has the highest number of extinctions for its important mammal fauna, but the issue is a much wider one and numerous species are classified as endangered, vulnerable or at risk of extinction in the IUCN lists. Solution: Enhanced biodiversity data capture based on global objectives and using existing IUCN global data standards.

4. Problem: A lack of knowledge about the law and conservation activity within the local communities that inhabit protected lands makes the law enforcement more problematic that it should be. Solution: A key and under-utilised role of forest ranger is be interact with the local community in their working area. They need to be able to document this interaction and map it so the information can be distributed for widely across the community. As noted by Muhumuza and Balkwill (2013) community engagement is a key requisite for successful conservation interventions.

User Requirements

The needs of the user are an important component of system design optimisation. In this study, the users of the system are fourfold:

1. Application User (Resort Officers); who can track the information related to the conservation activity, resort map, conservation activity map, the activity gallery, and ground check in resort conservation.

2. Admin and Web Operators who manage the resorts, its officers, and conservation activity. This user should be able to see and manage all data related to conservation activities with map, route, and images, as well as information on public opinion and public reports. The reporting options will be flexible and supported by data housed in a database amenable to SQL querying.

3. Decision Makers; who have a overseeing role and able to query data at all levels to generate evidenced-based decision that should be take based on the conditions around the organisation and community.

4. General User; Local community and citizens who wish to engage with the system. The general user can also place reports and complaints about the conditions around the conservation area.

The application was designed for use by forest rangers in Indonesia and can be accessed easily by downloading from the online Play Store. It is a secure app that can only be

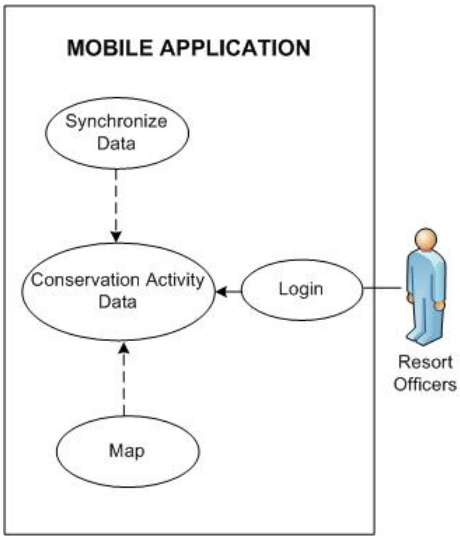


Figure 5.3: Use Case Diagram for Mobile Application

accessed by registered users (forest rangers) using a username and password supplied by the Ministry of Environment and Forestry. Use case diagram (Fig 5.3) shows the interaction between actors and the system. The users will be presented with a real-time map of the area where s/he can insert data that will automatically synchronise with the cloud if within a region where there is mobile data cover. The activity diagram (Fig. 5.4) represents the system work flow. It shows what the application allows the user to interact with and the tasks that are available to them. This includes a wide range of conservation data such as nuisance activity, biodiversity records, boundary conflicts, requests for environmental services.

The analysis phase outlines the requirements of user using both class and communication diagrams. The class diagram is a narration of the likely activities undertaken by forest rangers while they undertake their daily survey work (Fig. 5.5). The register of activities was fixed by the Ministry of Environment at only six linked in conservation activity, but this subsequently increased to 16 when the Ministries of Environment and Forestry merged (In 23 Januari 2015) (Table 5.2). To avoid redundant data, several registers were merged where they shared the same attributes.

The actions of to the users are captured in the communication diagram. It consists of 25 descriptions of the communication between the user and the system (one diagram per

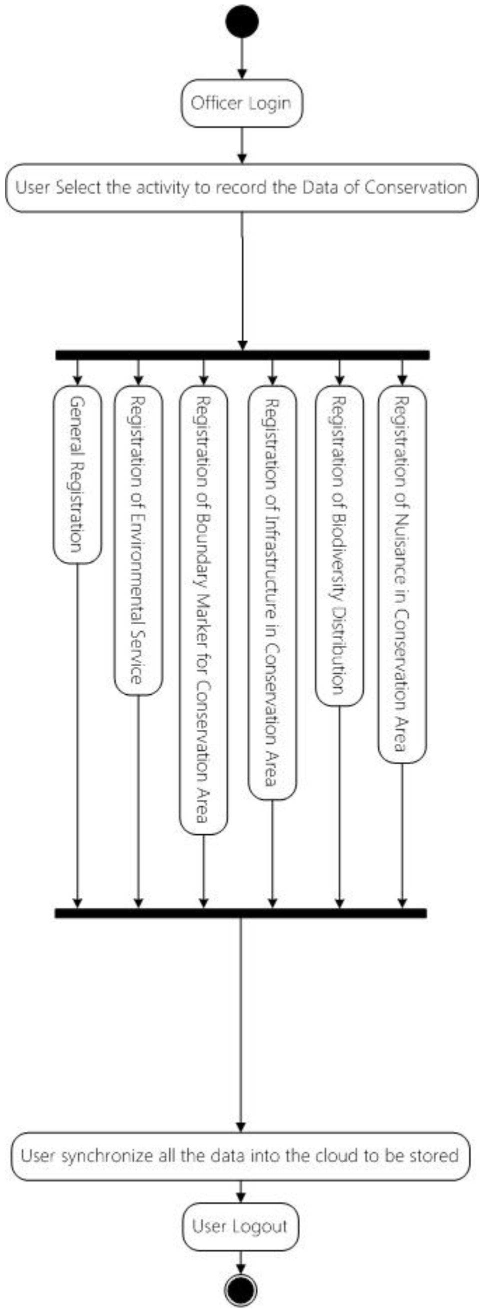


Figure 5.4: Activity Diagram for Mobile Application

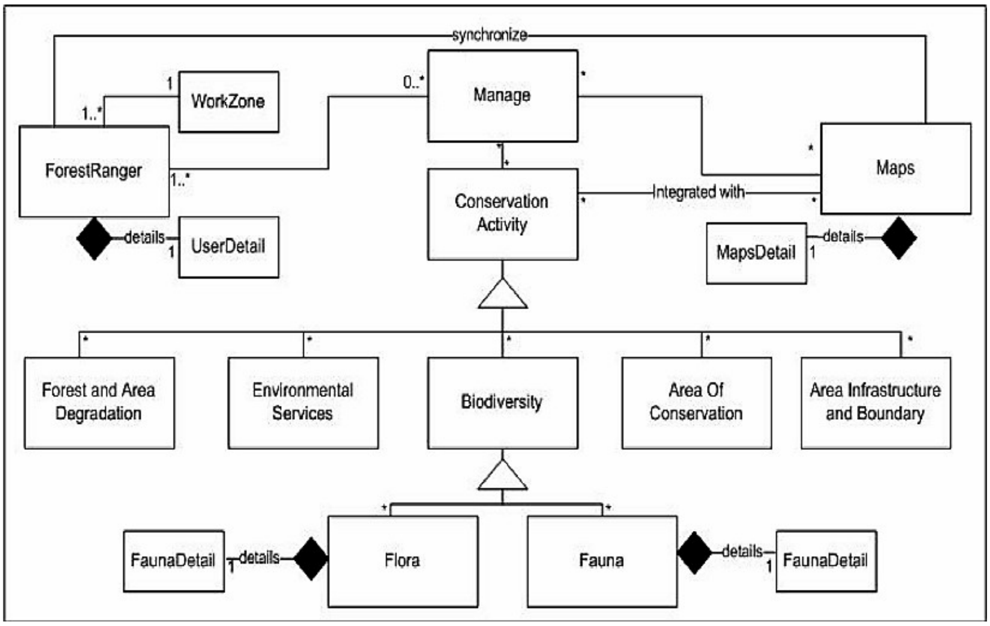


Figure 5.5: Class Diagram for Mobile Application

Table 5.2: List of Registers and its Descriptions

Register Name	Description
Register A	Forest degradation due to illegal logging
Register B	Forest Degradation and fallen tree due to nature catastrophe
Register C	Animal Hunting
Register D	Lost and Died Animal
Register E	Animal Distribution
Register F	Water Resource
Register G	Mooring
Register H	Infringement
Register I	Area Infrastructure
Register J	Entering License for Conservation Area
Register K	Loggers Data
Register L	Area Disturbance
Register M	Animal Observation
Register N	Tourist Attraction and Environmental Service
Register 0	Boundary Mark
Register P	Information on Spot diving, coral destruction, fishing boat, mangrove destruction, seaweed, and water pollution

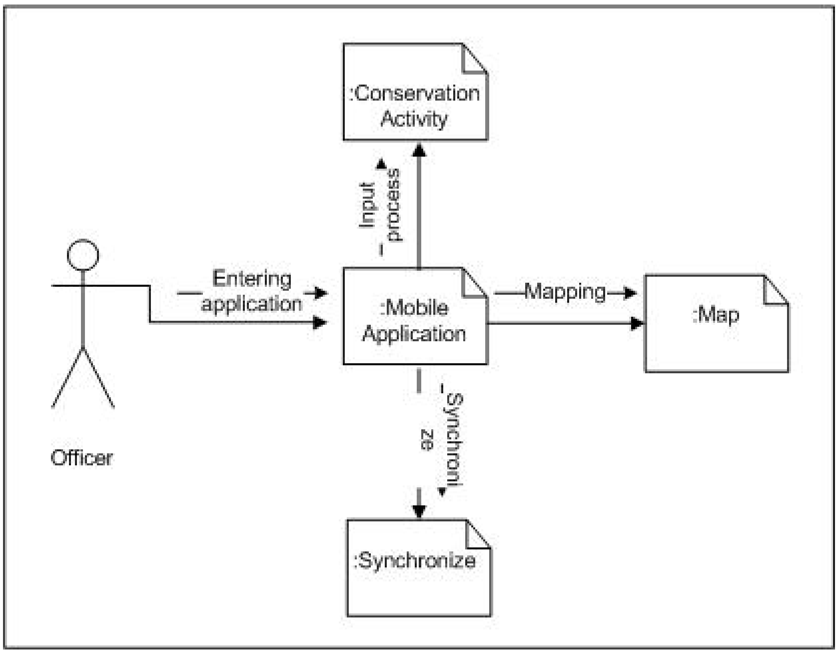


Figure 5.6: Communication Diagram for Mobile Application

action). Figure 5.6 shows an example of a communication diagram where a forest ranger connects and interact with the map inside the application as part of conservation activity. The user also can synchronize the data on the map with database to store the data inside the central system so it can be communicated with another user. Another communications diagram was also involved another actor that can interact with the system.

5.4.3 System and Software Design

The system and the software design can be represented by Entity Relationship diagram for structural design. Since this research is based on Object oriented design, it was suitable when the connectivity between object inside the system were represented by UML. UML *(Unified Modelling Language)* is a standard language in many industry for visualizing, designing and documenting software system. UML offered the visual language to analyze and design the system with object oriented approach (Bennett & McRobb, SteveFarmer 2005). Basically, UML diagram is organized into two groups. The first one is a Behaviour Diagram that describes how the system works and how objects interact with each other in the functions inside the system. It consists of multiple diagrams; namely, Activity, Sequence, Use case, State, Communication, Interaction overview iagram, and Timing diagrams. Secondly a Structural diagram that visualises technical terms and processes in the system which is the basis of the code generated in the software development. It contains Class, Package, Object, Component, Composite structure, Deployment diagrams.

5.4.4 Database

The main purpose of this step is to determine how Web GIS tailored with the needs of organisation. Database design involved the step of how to identify the interpretation of graphic inside the system, including the shape of graphic, the scale, and interface symbol and color. Some activity that might be included in this steps are choose the resource of the data, managing data base physically and logically, determine procedures to convert data from the source into database, and state the procedure to manage and maintenance database. Based on the need of the system and the interaction design that already seen in previous chapter, the database connectivity separated into 13 main tables that interacted inside the query in the system to show the information about the activity.

5.4.5 Hardware and Software

A database was concurrently designed using relational data principles than minimise data redundancy (Figure 5.7). Procedural design of the database needs to be linked to the software and hardware of GIS once the system has been designed. The next important step was thus the selection of the software platform.

Android is an operating system for mobile software based on linux that includes information systems, middleware, and applications. it is an open source platform that is easily developed. It also allows user oriented development with a wide range of available libraries and tools that easy readily modified and developed; it also has a large and active user base.

Android has access to numerous network tools and phone networks, making it ideal to host a WEB-GIS system to solve the conservation activity problems in Indonesia. More-

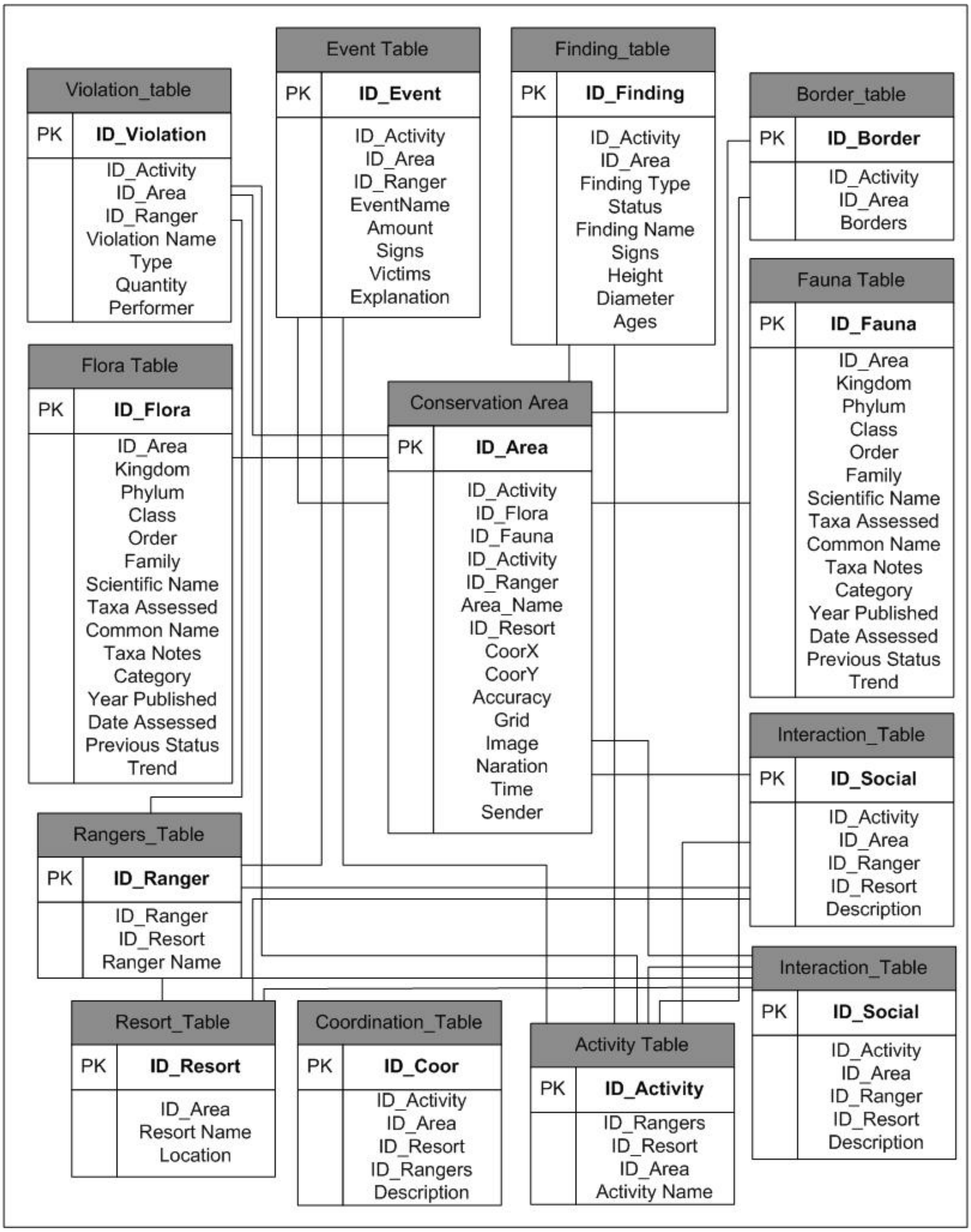


Figure 5.7: Database Design

over, Android phones are widely used in the region because of pricing of the smartphones. Aside from the MoEF program to facilitate forest ranger with smart phone, the development of certain software helped the rangers collect data easily inside the conservation area.

5.5 Results and Discussion

1. **System Integration**

   The code was written with tools IDE Eclipse Luna that is integrated with Android Software development Kit (Android SDK) and Android Development Tools (ADT). The website was written with web programming language PHP (Hypertext Preprocessor). The code was divided into two parts which are class based in Java and interface design with XML extension that were integrated into android. Figure 5.8-5.19 show a sequence of the menu screens on a smartphone.

2. **Development** Development process is the process to develop the application from system integration process. User conveniences, user friendly, and data transfer process was the focus of the development process.

   (a) Login and Password

      To protect the privilege of the software, the user will have to enter the password and user name that is already registered within the system. To protect the privileges of the software, the application is password protected (and data encrypted). Permissions are granted by the Ministry of Forestry and Environment.

   (b) Main Menu

      The main menu The main activity on mobile phone can be seen that in figure 3. The menu are (in order) conservation activity, map, synchronize, about, and Log Out.

Figure 5.8: Authentification Page in Mobile Application (AVD)

Figure 5.9: Main Menu in Mobile Application (AVD)

Figure 5.10: Conservation Activity Page in Mobile Application (AVD)

Figure 5.11: Exploration Option on Conservation Activity in Mobile Application (AVD)

(c) Conservation Activity

These activities were based on the registers provided by the Ministry. From this I developed eight submenus to capture information on patrol activities to public services that are involved in the data collection process. The patrol menu is divided into four submenus (Exploration, Trespass, Event, and Borders); the public service menu is divided into four submenus (Counselling, Socialization, Coordination, and Boundary Border).

(d) Exploration

This menu is focused on monitoring of biodiversity (either animals and plants)

Figure 5.12: Trespass Finding Option for Conservation Activity in Mobile Application (AVD)

in the conservation area. It automatically categorises the record as using IUCN statuses (e.g. least concern, near threatened, vulnerable, endangered, critically endangered, extinct in the wild, or extinct). The species are checked against the web-based dictionary database (Chapter 4) using the AutoCompleteTextView function. If it returns a null response then it will return it as a new species for Indonesia. The position and the location will be automatically added based on the real-time application. This menu also provides the option of capturing a picture of the individual to support record validation by taxonomic experts.

(e) Trespass

This menu option has the following levels: Illegal logging, Encroachment, Hunting, Destruction, and Ownership. The field entry for this sub menu is similar to the Exploration menu insofar as it automatically captures position of the smartphone using either the cellular network or GPS. There is also the option of taking and storing a picture as evidence of the activity.

(f) Event In the sub menu Event, two object-cases are available. They are Fauna Conflict and Hot Spot (Fire). This sub-menu will automatically fill the latitude and longitude field based on the smart-phone and provide the option to taking the picture to see the event.

Figure 5.13: Event Finding Option on Conservation Activity in Mobile Application (AVD)

Figure 5.14: Boundary Border Finding Option on Conservation Activity in Mobile Application (AVD)

(g) Boundary Border sub-menu aims to collect data on the borders around the conservation area. The boundary is dictated by the Indonesia government based on a natural feature (e.g. rivers) or artificial markers (e.g. signposts). It also permits the ranger to define the length of the border and can be supports photographic evidence

(h) Counselling Activity The counselling activity involves a person or organisation as the object. The option permits officers to provide information to the groups or individual about conservation activity in their region. In short it documents encounters between the rangers and people and records the nature of that

Figure 5.15: Couceling Activity for Conservation Activity For Mobile Application (AVD)

Figure 5.16: Socialization Interface for Conservation Activity in Mobile Application (AVD)

interaction.

(i) Socialization Activity Interaction with the community is one of the duties of forest ranger when discussing conservation and wildlife issues. Socialisation activity sub menu in the mobile application aims to concentrate all social interactions into one database.

(j) Coordination The coordination activity emphasises the connectivity between resort and individuals in the conservation area. It users point and place markers to remind officers of interactions.

Figure 5.17: Coordination for Conservation Activity in Mobile Application (AVD)

Figure 5.18: Warning Board Option on Conservation Activity in Mobile Application (AVD)

(k) Warning Board Warning board is a sign that usually installed in conservation area as an information for people that accessed the area. Warning board menu is the menu to input the data about the existence of warning board that found and installed by the officer in certain area. This menu also communicates with map.

(l) Synchronize The synchronization sub menu is used for the officers to send the data into central data base. The database is connected with web system that stores the data inside the central database

Figure 5.19: Synchronization activity to the web application in Mobile Application (AVD)

3. **Maintenance** Maintenance System allows maintenance of mobile Web-GIS. Due to the dynamics of the policy landscape and dynamic organizational behaviour, the system needs to be flexible. This step can be supported by:

   - Services and support to user where the system implemented, in this case, the services used by the forest rangers and staff members of MoEF in Indonesia.
   - Maintenance system involved database system, hardware, and software to make the system can always be update and give advantages for organisation, MoEF.

5.6 Case Study: Testing Application

The mapping capabilities of the app was tested forest rangers while on patrol in Bengkulu. The Province of Bengkulu (Fig.5.20) lies in Sundaland biogeographic province. It is home to 15,000 species endemic plants (5%) and 701 endemics species of vertebrates (Myers et al. 2000). The province had 9.1% of its land area as primary vegetation in 1972 but this had been degraded by 7.8% from its original size by 2015. This province is one of 34 of Indonesia adjacent to Lampung to the south-east, Jambi to the northeast, South Sumatra (Sumatra Selatan) to the east, West Sumatra (Sumatra Barat) to the north, and India Ocean to the west, south-west and south. The province also includes Mega Island

Figure 5.20: Bengkulu Province

and Enggano Island. It has a 525-kilometre coastline adjacent to the Indian Ocean on its western edge. Between 1st February-30 March 2016, a total of 3 rangers tested the application in the field. We did the map testing with officers in Indonesia when they go to patrol in one of the conservation area in Indonesia. The testing result will be shown in figure 5.21.

Figure 5.22 shows a records of important fauna sighting captured as tracks as the rangers undertook their daily recording activities.

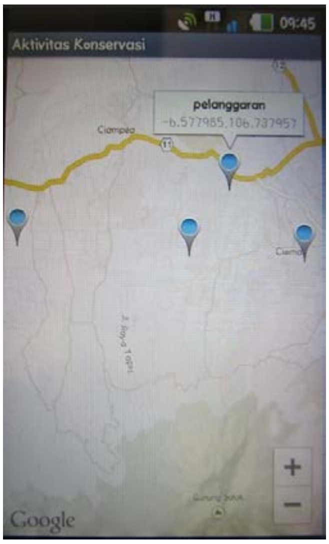


Figure 5.21: Testing Result in Conservation Activity in Mobile Application

(c) Hornbill

(d) Gobbin

Figure 5.22: Fauna Sighting by Forest Ranger when they testing the system

5.7 Application Evaluation

5.7.1 Development Questionnaire

A development questionnaire had been created to evaluate how the application was viewed by conservation professionals working in the Ministry. The questionnaire was given to 200 respondents, who had experience of either using the application directly or were rangers policing conservation activities in the country. The questionnaire used Likert scale (C.-J. et al. 2017) to demonstrate the degree of system performance, based on five levels: Excellent (5), Very Good (4), Good (3), Fair (2), and Poor (1).

The questionnaire was given to respondent with purposive sampling based on certain criteria which is 10 Police Ranger in Ministry of Forestry of Indonesia. We found out the interval with this equation before we did the calculation in Likert scale.

$$i = \frac{m - n}{k}$$

where i is class interval, m is the highest score, n is the smallest score and k is the amount of class. In this case, we had i equals to 0.8 where $m = 5$, $n = 1$, and $k = 5$ with provision of the smallest scale is 1.00, then we can get the categorized table as below:

We used Likert scale to demonstrate the degree of system performance to help the conservation activity in a conservation area. The level consists of 5 degrees; they are Excellent (5), Very Good (4), Good (3), Fair (2), and Poor (1).The questionnaire was given to respondent with purposive sampling based on certain criteria which are 100 Police Ranger in Ministry of Forestry of Indonesia. We found out the interval with this equation before we did the calculation in Likert scale.

$$i = \frac{m - n}{k}$$

where i is class interval, m is the highest score, n is the smallest score and k is the amount of class. In this case, we had i equals to 0.8 where $m = 5$, $n = 1$, and $k = 5$ with provision of the smallest scale is 1.00, then we can get the categorized table as below:

Table 5.3: Result of Interval and Category

Interval	**Category**
4.25 – 5.00	Excellent
3.43 – 4.23	Very Good
2.62 – 3.42	Good
1.81 – 2.61	Fair
1.00 – 1.80	Poor

The testing result we found that the system was categorised as GOOD in interface variable with the average value of 3.80 which inside of the interval 3.43-4.23. In variable Interaction, the system also within the range 3.43-4.23 with mean value 3.6 which is categorised as GOOD. In the variable test of performance of the system, it also has the value of 3.7 that is categorised as GOOD. The table of the questionnaire can be seen in Tables III, IV, and V.

The testing result state that the system was categorized as GOOD in interface variable with the average value of 3.80 which inside of the interval 3.43-4.23. In variable Interaction, the system also within interval 3.43-4.23 with average value 3.6 which are categorized as GOOD. In variable performances of the system, it also has the value of 3.7 that is categorized as GOOD. The table of the questionnaire can be seen in table.

The testing result we found that the system was categorized as GOOD in interface variable with the average value of 3.80 which inside of the interval $3.43 - 4.23$. In variable Interaction, the system also within interval $3.43 - 4.23$ with average value 3.6 which is categorized as GOOD. In variable performance of the system, it also has the value of 3.7 that is categorized as GOOD. The table of the questionnaire can be seen in table iii,iv, and v.

From the testing result we can see that the system working good to help the officers to collect the data in conservation area. Next milestones for this project is to connect the mobile system into the web technology that will help the decision maker to take

Table 5.4: System Interface Testing

	Interface	M	Answer Frequency				
			E	VG	G	F	P
1	Color Composition	3.7	1	5	4	0	0
2	Fonts Readability in the System	3.8	1	6	3	0	0
3	System Layout	4.0	2	6	2	0	0
4	System Interface and Variation	3.6	0	6	4	0	0
5	Interface Quality	3.9	1	7	2	0	0
	Total Frequency		5	30	15	0	0
	Average		10%	60%	30%	0%	0%
	Total of Average		3.8				
	Category		GOOD				

Table 5.5: System Simplicity Testing

	Simplicity	M	Answer Frequency				
			E	VG	G	F	P
1	Simplicity of System Instruction	3.5	0	5	5	0	0
2	Easy to Use	3.5	0	5	5	0	0
3	Information Accessibility	3.6	0	6	4	0	0
4	Easy to Install	3.8	1	6	3	0	0
	Total Frequency		1	22	17	0	0
	Average		2.5%	55%	42.5%	0%	0%
	Total of Average		3.6				
	Category		GOOD				

Table 5.6: System Performance Testing

	Performance	M	Answer Frequency				
			E	VG	G	F	P
1	The Fitness of System Purpose	3.8	1	6	3	0	0
2	Menu Sequencing in the System	3.9	1	7	2	0	0
3	System Feature and Facilities	3.1	1	6	3	0	0
4	System Speed	3.7	0	7	3	0	0
5	Data Processing Time	3.6	0	6	4	0	0
6	System Accuracy	3.6	0	6	4	0	0
7	System Fitness to the Need of the User	3.8	0	8	2	0	0
	Total Frequency		3	46	21	0	0
	Average		4.29%	65.71%	30%	0%	0%
	Total of Average		3.7				
	Category		GOOD				

decision for conservation problem. Furthermore, we will also integrated the technology with machine learning algorithm to make the process effective and efficient.

Although only 12% of the respondents completed the questionnaire, they provide some useful and positive information concerning the utility of the system people. Overall the results indicated that users thought that the application was GOOD for quality of the interface (Table 5.4), system simplicity (Table 5.5), and system performance (Table 5.6). The average scores were 3.7, 3.8 and 3.6 respectively. The questionnaires indicate high levels of satisfaction with the system from the operatives but the low response rate means that further evaluation is needed as the system moves towards national implementation.

5.8 Conclusions

The design and development of this application were tailored to the requirement of current conservation policies in Indonesia. The results from both the field testing and also the questionnaire suggest that the mobile system is of considerable utility. The next milestones for this project are to:

1. connect the mobile system into the web technology to created an integrated decision

support system for the Ministry.

2. integrate the technology with machine learning algorithms to make the informed decision trees on the basis of the data, which can be used by conservation officers to support in conservation activities.

Chapter 6

Conclusions

This research has generated a new digital dataset and an online (and mobile) decision support system to support conservation in Indonesia, addressing a number of key hypotheses (Figure 6.1). A new long-term baseline dataset on land use and land compositional change in Indonesia data series was created using remote sensing data. This work has offered a new approach to documenting tropical deforestation rates, integrating machine learning to improve the analysis of remote-sensed imagery captured over Indonesia, one of the world's few megadiverse countries. The methodology used all available Landsat images in an innovative manner, combining matrix completion, wavelet analysis, machine-learning and bayesian classifiers to generate the longest time series of deforestation (1973-2015) ever created for a tropical nation. Using this time-series it has been possible to show that the loss of primary forest cover has accelerated since 2000 and is now thought to be higher than in Brazil with the attendant implications for biodiversity loss, and increased greenhouse gas emissions. Between 2000-2005 the maximum rates of deforestation are 21.24% larger than previous estimates (1.024 x 106 km^2 yr^{-1} +/- 0.028) with stronger inter-island group variability that previously thought. Spatial variability and patterning across island groups revealed large and early contemporary losses of primary forest on Java, and to a lesser extent Sumatra Island. Mitigating conservation policies appear to have had little effect on rates of deforestation and losses remain high, even within protected areas on islands such as Kalimantan, Sulawesi and Malaku. This product provides a significant baseline data source from which to evaluate the success of conservation policies and to help design new ones.

Chapter 3 showed that land use change in Indonesia is linked to high rates of deforestation. The exploitation of natural resources, high demand on food supplies, and the production of biofuels (i.e. oil palm) the main factors driving the commercialisation of forest stocks and removal of forested land. By modelling land use change it was possible to show that the main predictors of change are removal of forested land for replacement by permanent crops, palm oil plantations, other production value lands, and arable land. The main three factors were found to be: arable land production, palm oil plantation, and timber production. All are linked to global commodities markets and an important element of the Indonesian economy.

Widespread land use changes, population growth and urbanization have all increased forest fragmentation and led to worrying increases in land degradation, which is reaching critical levels on Kalimantan, Sumatra and Sulawesi. Although Indonesia has been proactive in generating appropriate conservation policies, enforcement remains a significant problem. Lack of data standardization, conservation system structures, and political fragmentation is a key issue for conservation managers; this is magnified in an archipelagic country comprising 17,504 islands with no technology provision in most of them. An efficient data collection process was needed to provide decision makers with accurate data; this the key to better informed decisions and the creation of evidenced-based policy in the future. In Chapter 4, framework had been developed a to integrate mobile-web technologies to help manage biodiversity and conservation data in Indonesia. This prototype system is currently being implemented within the country. This including the development of a webgis decision support system that will improve data capture, coverage, access, and use machine learning methodologies to improve data capture, processing and support decision-making.

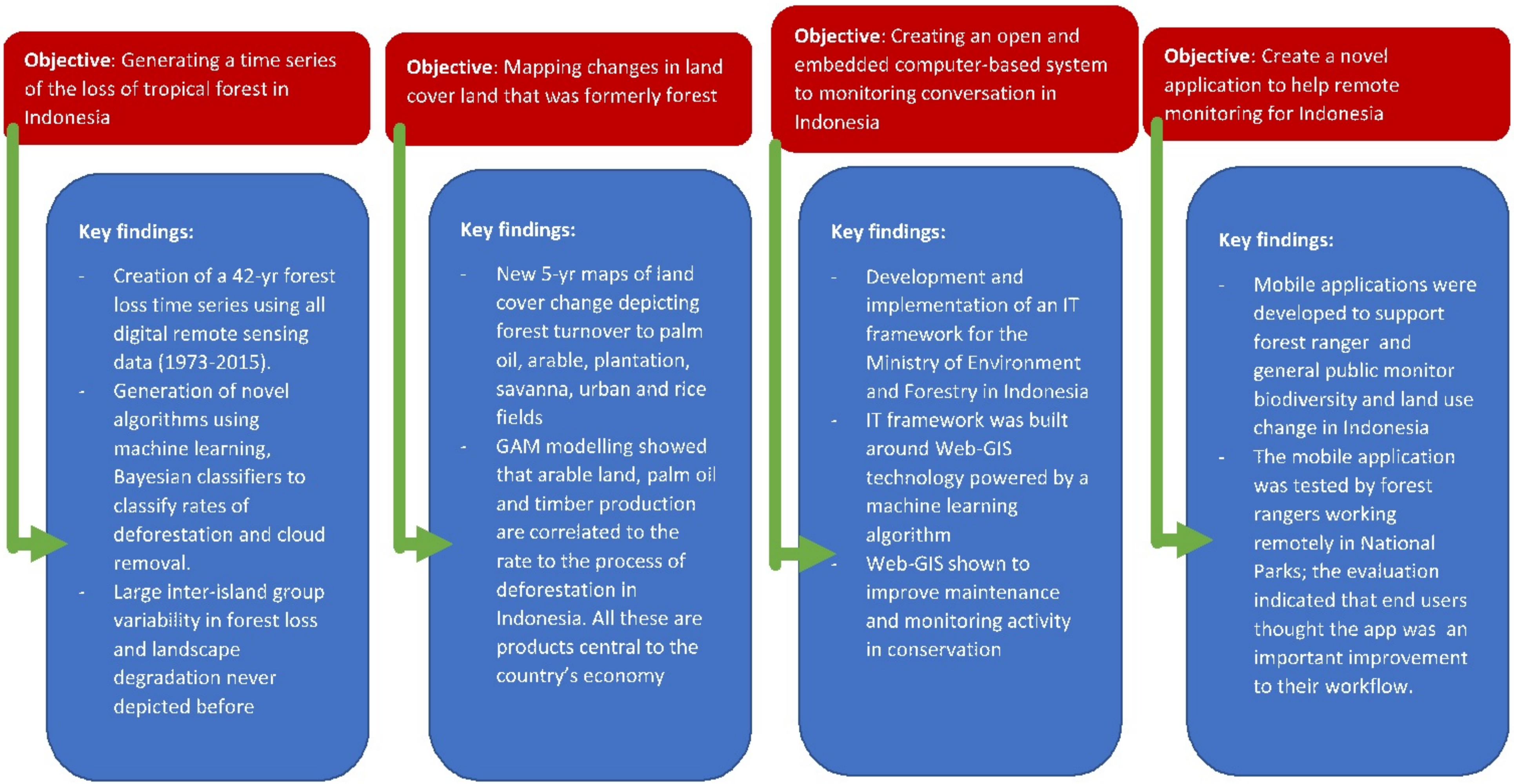


Figure 6.1: Key Hypothesis of the Thesis

In chapter 4, framework was developed to integrate mobile-web technologies to help manage biodiversity and conservation data in Indonesia. This prototype system is currently being implemented within the country. This including the development of a Web GIS decision support system that will improve data capture, coverage, access, and use machine learning methodologies to improve data capture, processing and support decision-making. In the Web GIS application, the forests are displayed in real time depicting current land cover.

With the advent of cheap and GPS-enabled smartphone technologies it was possible to create an app that supports real-time, field-based observations that can be rolled out to the forest ranger service in Indonesia (see chapter 5), linked to the Web GIS. Forest rangers were empowered with novel technology to aid the conservation process in Indonesia by using a smartphone application. Such an application permitting forest rangers to capture the data on biodiversity in real time in a field situation in Indonesia is the last key contribution of this research. It was developed by using Java and the System Development Life Cycling (SDLC) and Unified Modelling Language (UML) 2.0 design models.

6.1 Further Research

Earth observation science is far from a static science and technological developments in sensor technologies and new satellites mean that images will increase in quality, permitting greater resolution and more detailed depiction of environmental variability at the land surface. Methodological advancement in big data science (Pijanowski et al. 2014) data are being generated at exponential rates (Engemann et al. 2015). Optimised data processing algorithms are becoming widespread (Peterson et al. 2010). With a high computation tools improvement, larger size of data can be process faster than before. Earth observation is part of this rapid development, with new algorithms being developed frequently to deal with noise removal, removal of cloudy pixels, pixel comparisons, matrix completion and so on (e.g. Foga et al. (2017)). These development will increase the quality and accuracy of the final images, although with older data products (Landsat 1-5), sensor quality and resolution will limit their application, without elegant re-sampling methodologies. Notwithstanding the data products developed here are of global significance and provide baseline data that can be utilised to create fuller understanding of the links between land use change and ecological and ecosystem processes. There are three areas where these data could profitably be employed:

1. Using fine spatial and temporal resolution (at near pixel scale) to elucidate biodiversity impacts due to the roles of disturbance within forest impacting species (without clear felling) (Alroy 2017), the enhanced time lines due to extinction debt (Chen & Peng 2017) and that fact likely climate changes will push species out of low-lying reserves (Scriven et al. 2015).

2. The examination of carbon flux and carbon stock models across Indonesia, especially in relation to the loss of forests and their replacement by cash crops and bio-fuels. These data provide the opportunity to help resolve global scale carbon models were forest loss and land use data are poorly resolved (e.g. Arneth et al. 2017; Pugh et al. 2015).

3. An assessment of the value and importance of protected areas in tropical regions for the protection of biodiversity and also carbon fluxes.

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Appendices

.A Legalisation from Indonesia about Conservation and Forestry

1957	Law No.1 of 1957 on Regional Governance
	Government Regulation no. 64 year 1957 Granting Some of the Central Government's authority in Fisheries, Forestry and Community Rubber Sectors to First level Regional Government
1959	Presidential Decree (PD) no. 6 year 1959 on Regional Government
1960	Law N0. 5 Year 1960 on Basic Agrarian Principle
	Government Regulation in Lieu Law No. 56 year 1960 on Stipulation of the size of Agricultural land
1961	Law no.20 year 1961 on Revocation of Rights to Land and the Objects Thereon
1967	Law No. 6 of 1967 on the Provisions for Livestock and Animal Health
	GR no 22 of 1967 on Forest Concession License Fees and Royalties
1968	GR No. 6 of 1968 on withdrawing control over matters related to forestry from district forestry to provincial forestry in eastern indonesia
1970	GR No. 21 of 1970 on Forest exploitation Rights and forest product harvesting right
	GR No. 33 of 1970 on Forest Planning
1973	GR No. 39 of 1973 on the procedure for compensation resulting from the revocation of rights to land and the objects thereon
1974	Law Number 5 year 1974 on Regional Governance
1975	GR No. 18 year 1975 on revision of article 9 of GR no. 21 of 1970 on forest exploitation rights and forest harvesting rights
1981	Law number 8 year 1981 on the criminal procedure code
1985	law no.14 year 1985 on supreme court
	GR no. 28 of 1985 on Forest protection
1988	PD No. 26 year 1988 on the national land Agency
1990	Law No. 5 year 1990 on the conservation of biodiversity and ecosystems
	GR no 7 year 1990 on Industrial timber plantation
	PD no 30 year 1990 on the imposition, collection, and distribution of forest royalties
	PD no 32 year 1990 on protected area management
1991	PD No. 29 year 1991 on revision of PD 30 of 1990 on the imposition, collection and distribution of Forest royalties
1992	Law no 12 of 1992 on plant cultivation system
	GR no. 79 year 1992 on the revision of PD no.30 of GR no.32 of 1969 on the implementation of law no.11 of 1967 on mining principles
1993	PD no.41 year 1993 on the revision of PD no.30 of 1990 on the imposition, collection, and distribution of Forest Royalties as Royalties as previously revised by PD No.29 year 1991
	PD no. 55 year 1993 on Coordination for national spatial planning
	Minister of Agrarian affair/Head of National Land Agency Regulation (HoBPNR) No. 2 year 1993 on the procedure for obtaining location permit for investor
1994	Law no.6 Year 1994 on the ratification of the United Nations Framework Convention on Climate Change(UNFCCC)

	PD no 25 year 1994 on coordination in the implementation of resettlement and the settlement of forest squatters
1995	PD No. 22 year 1995 on the establishment of and integrated forest safeguardian team PD no 82 year 1995 on the development of peatland areas for food crops in central kalimantan PD no 83 year 1995 on the eastablishment of a presidential fund to support the development of peatland areasin central kalimantan
1996	GR No.40 of 1996 on the right of exploitation, right of building and tight of the land
	GR No. 69 of 1996 on the implementation of rights and duties and the procedure for public participation in spatial planning
	PD No. 75 year 1996 on basic regulation on work contracts in coal mining activities
1997	GR No.24 year 1997 on land registration
	GR No. 47 year 1997 on National Spatial Planning
1998	MPR-RI Decree (MD) No.XV year 1998 on regional autonomy, just and equitable use of the nation's resources, and fiscal balance between the central government and regional government
	GR No. 36 of 1998 on the control and use of abandoned land
	GR no. 51 year 1998 on forest resource rent provision
	GR No 58 year 1998 on the service tariff for non-tax state revenue valid at the ministry of mining and energy in the general mining sector
	GR No 58 year 1998 on the service tariff for non-tax state revenue valid at the ministry of forestry and plantation
	GR No. 62 year 1998 on the granting to local government of some the central government's authority over matters concerning forestry
	GR No 68 year 1998 on nature reserve and nature conservation forests
	PD No.33 year 1998 on management of the Leuser ecosystem area
	PD no.67 year 1998 on the revision of PD no. 30 of 1990 on the imposition, collection, and distribution of Forest Royalties, as previously revised by PD no. 41 year 1993
	PD no.74 year 1998 on the revision of PD no.82 of 1995 on the development of peat-land areas for food crops in central Kalimantan
	PD No. 133 of 1998 on the revision of PD No.82 of 1995 on the development of Peatland areas for food crops in central kalimantan, as previously revised by PD no. 74 year 1998
	Presidential Instruction (PI) No. 6 year 1998 on foreign direct investment in Palm Oil Plantations
1999	Law No 22 year 1999 on regional governance
	Law no 25 year 1999 on central and local fiscal balance
	law no 28 year 1999 on the state organizer that is clean and free from corruption, collusion and nepotism
	law no 31 year 1999 on the eradication of the criminal act of corruption
	law no. 41 year 1999 about forestry
	law no 43 year 1999 on the civil service
	GR no 6 year 1999 on forest utilization and forest product collection/harvesting in forest production
	GR no 27 year 1999 on environmental impact assessment
	GR no.74 year 1999 on revision of GR no.59 year 1998 on the service tariff for non tax state revenue valid at the Ministry of Forestry and Plantation

	GR No 92 year 1999 on the second revision of GR no 59 year 1998 on the service tariff for non tax state revenue valid at the ministry of Forestry and Plantation PD No 80 year 1999 on general guidance for Planning and Managing Ex-Mega Rice Peat-land Project Areas in Central Kalimantan PD No 154 of 1999 on the revision of PD No 26 of 1998 on the National Land Agency HoBPNR No 2 year 1999 on Location Permits
2000	The 1945 constitution of the Republic of Indonesia (as amanded by the second amandement of 2000) MD No. iiii of 2000 on the sources of law and the hierarchy of laws and regulations MD No. IV of 2000 on policy recommendation for implementing regional autonomy GR No. 25 of 2000 on the authority between the central government and the provincial government as an autonomous region GR no. 150 year 2000 on mitigation of soil degradation from Biomass Production PD No 80 year 2000 on Interdepartmental Forestry Committees PD No 95 year 2000 on the National Land Agency
2001	MD No. IX of 2001 on agrarian reforms and Natural resource Management Law No 20 year 2001 on the revision of law no 31 year 1999 on the eradication of the criminal act of corruption Law No 22 year 2001 on the second revision of GR No 32 year 1969 on the implementation of Law no. 11 of 1967 on mining principles PD No. 10 year 2001 on the implementation of regional autonomy in the land sector PD No 25 year 2001 on the coordination team for eradication of Illegal Mining, fuel smuggling and electricity theft PD No 62 year 2001 on the revision of PD No 166 year 2000 on the position, roles, functions, authority and structure of non departmental agencies, as previously revised by PD no 42 year 2001 PD No 81 year 2001 on the committee on policy for the acceleration of Infrastructure Development PD No. 103 year 2001 on the structure, functions, and authority of non-ministerial agencies PI No 5 year 20001 on Eliminating Illegal Logging and Illegal Timber Trade in the Leuser Ecosystem and Tanjung Putting National Park Ministry of Forestry Decree (MoFD) No 32 year 2001 on the criteria and standard for forest area gazettement West Java Provincial Regulation No 19 year 2001 on forest management in West Java Magelang District Regulation no. 23 year 20001 on mining permits
2002	The 1945 constitution of the Republic of Indonesia (as amanded by the fourth amandement of 2000) Law No 30 year 2002 on the corruption eradication commission GR No 34 of 2002 on forest planning and the formulation of forest Management and Utilization Plan GR No. 35 year 2002 on the reforestation fund GR No 63 year 2002 on Urban Forests GR No 68 year 2002 on Food security
2003	Law no 17 year 2003 on State Finance Law No 24 year 2003 on the constitutional Court

	Law no 27 year 2003 on geothermal
	PD no 34 year 2003 on National Policy in the land sector
	Bontang city regulation no 7 year 2003 on mangrove forest protection
2004	Law no 1 year 2004 on the state treasury
	Law No 7 year 2004 on water resource
	Law no 10 year 2004 on the formulation of law and regulations
	Law No 15 year 2004 on auditing the management and accountability of State Finance
	Law No 17 year 2004 on Ratification of The Kyoto Protocol to the UNFCCC
	Law No 18 year 2004 on plantation (Estate Crops)
	Law No 19 year 2004 on the revision of law no 41 year 1999 about forestry
	Law no 25 of 2004 on the national development planning system
	Law no 31 year 2004 on fishery
	Law no 32 year 2004 on Regional Governance
	Law No 33 year 2004 on Fiscal Balance between the central and regional governments
	GR No 16 year 2004 on Land Management
	GR no 44 year 2004 on Forest Planning
	GR no 45 year 2004 on Forest Protection
	PD No 4 year 2004 about Permits or Contract Relating to Mining in Forest Area
	Ministry of Forestry Regulation (MoFR) No 19 year 2004 on Collaborative Management of Nature and Game Reserves
2005	GR No. 63 year 2005 on the human resource management system in the corruption eradication commission
	Presidential Regulation (PR) No 36 year 2005 on Land Procurement for the implementation of development for the public interest
	PR No. 42 of 2005 on the Committee on Policy for the Acceleration of Infrastructure Provision
	PR No. 64 of 2005 on the Sixth Revision of PD No. 103 of 2001 on the Structure, Functions and Authority of Non-Ministerial Agencies
	PI No. 4 of 2005 on the Eradication of Illegal Logging in Forest Areas and Distribution throughout the Territory of the Republic of Indonesia
	MoFR No. 31 of 2005 on the Release of Forest Areas for Plantation Development
2006	Law No. 15 of 2006 on the Revision of Law No. 5 of 1973 on the State Audit Board
	PR No. 5 of 2006 on the National Energy Policy
	PR No. 10 of 2006 on the National Land Agency
	PR No. 65 of 2006 on the Revision of PR No. 36 of 2005 on Land Procurement for the Implementation of Development for the Public Interest
	PI No. 1 of 2006 on the Supply and Use of Bio-fuel as an Alternative Fuel
	PI No. 2 of 2006 on the Supply and Use of Liquid Coal as an Alternative Fuel
2007	Law No. 17 of 2007 on National Long-Term Development Planning 2005-2025
	Law No. 26 of 2007 on Spatial Planning
	Law No. 27 of 2007 on Coastal and Small Island Management
	Law No. 30 of 2007 on Energy
	GR No. 6 of 2007 on Forest Planning and the Formulation of Forest Management and Utilization Plans
	GR No. 59 of 2007 on Geothermal Business Activities

	PR No. 89 of 2007 on the National Movement for Forest and Land Rehabilitation
	PI No. 2 of 2007 on the Acceleration of the Rehabilitation and Revitalization of Ex-Mega Rice Peatland Project Areas in Central Kalimantan
	Ministry of Agriculture Regulation (MoAR) No. 26 of 2007 on Guidance on Permit Issuance for Plantation Companies
	Minister of Public Works Regulation (MoPWR) No. 41 of 2007 on Technical Guidelines on the Criteria for Cultivated Areas Kepahiang District Regulation No. 1 of 2007 on the Prohibition of Fishing Using Bombs, Electrocution and Poison
2008	Law No. 39 of 2008 on State Ministries
	GR No. 2 of 2008 on the Type of and Tariffs on Non-tax State Revenue from the Use of Forest Areas for Non-Forest Development Activities Valid at the Ministry of Forestry
	GR No. 3 of 2008 on the Revision of GR No. 6 of 2007 on Forest Planning and the Formulation of Forest Management and Utilization Plans
	GR No. 7 of 2008 on Deconcentration and Assistance
	GR No. 26 of 2008 on National Spatial Planning
	GR No. 76 of 2008 on Forest Rehabilitation and Reclamation
	PR No. 26 of 2008 on the Establishment of the National Energy Council and the Selection of its Members
	PR No. 46 of 2008 on the National Council on Climate Change
	MoFR No. 35 of 2008 on Permits for Primary Forest Industrial Activity
	MoFR No. 61 of 2008 on the Procedures for Obtaining Permits for the Utilization of Timber Products in Ecosystem Restoration Activities in Production Forests
2009	Law No. 4 of 2009 on the Mining of Mineral Resources and Coal
	Law No. 32 of 2009 on Environmental Protection and Management
	Law No. 41 of 2009 on the Protection of Land for Sustainable Food Crops
	GR No. 31 of 2009 on the Protection of Areas Producing Specific Estate Crop Produce
	GR No. 60 of 2009 on the Revision of GR No. 45 of 2004 on Forest Protection
	PR No. 54 of 2009 on the Presidential Unit for Development Monitoring and Oversight
	MoAR No. 14 of 2009 on Guidance for the Utilization of Peatlands for Oil Palm Cultivation
	MoPWR No. 15 of 2009 on Guidance on Formulating Provincial Spatial Planning
	MoFR No. 50 of 2009 on the Confirmation of the Status and Function of Forest Areas
2010	Law No. 8 of 2010 on Anti-Money Laundering
	GR No. 10 of 2010 on the Procedure for Changing the Status and Functions of Forest Areas
	GR No. 11 of 2010 on the Control and Use of Abandoned Land
	GR No. 15 of 2010 on Spatial Planning Implementation
	GR No. 22 of 2010 on Mining Areas
	GR No. 23 of 2010 on the Implementation of Mineral and Coal Mining Business Activities
	GR No. 24 of 2010 on the Utilization of Forest Areas

GR No. 55 of 2010 on the Supervision and Control of Mineral and Coal Mining Business Activities
GR No. 68 of 2010 on the Procedure for Public Participation in Spatial Planning
GR No. 70 of 2010 on the Revision of GR No. 59 of 2007 on Geothermal Business Activities
GR No. 72 of 2010 on State-Owned Forestry Companies
GR No. 78 of 2010 on Reclamation and Post-Mining Activities
PR No. 5 of 2010 on the Medium-Term National Development Plan 2010-2014
PR No. 24 of 2010 on the Hierarchy, Duties and Functions of State Ministries
PR No. 78 of 2010 on Guaranteeing Infrastructure in Government Cooperation Projects with Business Entities Done through the Infrastructure Guarantee Agency
PI No. 1 of 2010 on the Acceleration of the Implementation of National Development Priorities in 2010
PD No. 19 of 2010 on the Task Force for Preparation of the REDD+ Agency
MoFR No. 50 of 2010 on Granting Licenses for Timber Production in Natural Production Forests
Letter of Intent (LoI) between the Government of the Kingdom of Norway and the Government of the Republic of Indonesia on Cooperation on Reducing Greenhouse Gas Emissions from Deforestation and Forest Degradation
Law No. 4 of 2011 on Geospatial Information
Law No. 12 of 2011 on the Formulation of Laws and Regulations
MK Decision (MKD) No. 45 of 2011 on the Judicial Review of Law No. 41 of 1999 on Forestry, as Revised by Law No. 19 of 2004 [Paragraph 1(3)]
GR No. 1 of 2011 on the Gazettement and Conversion of Functions of Land for Sustainable Food Crops
GR No. 28 of 2011 on the Management of Game and Nature Reserves
PR No. 10 of 2011 on the National Coordination Board for Agriculture, Fishery and Forestry Extension Services
PR No. 12 of 2011 on the Revision of PR No. 42 of 2005 on the Committee on Policy for the Acceleration of Infrastructure Provision
PR No. 28 of 2011 on the Use of Protection Forests for Underground Mining Activities
PR No. 32 of 2011 on the Master Plan for the Acceleration and Expansion of Indonesia's Economy 2011-2025
PR No. 61 of 2011 on the National Action Plan for the Reduction of Greenhouse Gas Emissions
PR No. 71 of 2011 on the Implementation of the National Greenhouse Gas Inventory
PR No. 80 of 2011 on Trust Funds
PR No. 92 of 2011 on the Second Revision of PR No. 24 of 2010 on the Hierarchy, Duties and Functions of State Ministries
PI No. 5 of 2011 on Safeguarding National Rice Security in Extreme Climate Conditions
PI No. 10 of 2011 on Suspension of the Granting of New Licenses and Improvement of the Governance of Natural Primary Forests and Peatlands
PD No. 25 of 2011 on the Task Force for Preparation of the REDD+ Agency

	MoFR No. 47 of 2011 on a Partial Transfer of Authority on Forestry Governance from the MoF to the Bupatis of Berau, Malinau and Kapuas Hulu under the Framework of REDD+ Demonstration Activities
	MoAR No. 19 of 2011 on Guidance for Indonesian Sustainable Palm Oil (ISPO)
	Memorandum of Understanding (MoU) between the Ministry of Energy and Mineral Resources and the Ministry of Forestry No. 7662 of 2011 on the Coordination and Acceleration of Permit Issuance for Geothermal Energy Development in Production Forests and Protection Forests, and Preparation for Geothermal Utilization in Forest Conservation Areas
2012	Law No. 2 of 2012 on Land Procurement for the Public Interest (Land Acquisition Law)
	Law No. 7 of 2012 on the Resolution of Social Conflicts
	Law No. 18 of 2012 on Food
	MKD No. 35 of 2012 on the Judicial Review of Law No. 41 of 1999 on Forestry (Paragraphs 1(6), 4(3), 5(1)-(4), and Article 67)
	GR No. 24 of 2012 on the Revision of GR No. 23 of 2010 on the Implementation of Mineral and Coal Mining Business Activities
	GR No. 25 of 2012 on the Information System on Land for Sustainable Food Crops
	GR No. 27 of 2012 on Environmental Licenses
	GR No. 30 of 2012 on Financing the Protection of Land for Sustainable Food Crops
	GR No. 37 of 2012 on River Basin (Watershed Area) Management
	GR No. 60 of 2012 on the Revision of GR No. 10 of 2010 on the Procedure for Changing the Status and Functions of Forest Areas
	GR No. 61 of 2012 on the Revision of GR No. 24 of 2010 on the Utilization of Forest Areas
	GR No. 103 of 2012 on the Revision of GR No. 63 of 2005 on the Human Resource Management System in the Corruption Eradication Commission
	PR No. 3 of 2012 on Kalimantan Spatial Planning
	PR No. 13 of 2012 on Sumatra Spatial Planning
	PR No. 71 of 2012 on Land Procurement for the Implementation of Development for the Public Interest
	PR No. 73 of 2012 on the National Strategy on Mangrove Ecosystem Management
	PR No. 121 of 2012 on the Rehabilitation of Coastal Zones and Small Islands
	PR No. 122 of 2012 on the Reclamation of Coastal Zones and Small Islands
	MoFR No. 20 of 2012 on Forest Carbon Implementation
	MoFR No. 22 of 2012 on Guidance on Environmental Service Tourism Activities in Protection Forests
	MoFR No. 31 of 2012 on Conservation Organizations
	Jambi Provincial Regulation No. 6 of 2012 on Environmental Management in Jambi
2013	Law No. 11 of 2013 on Ratification of the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization to the Convention on Biological Diversity
	Law No. 18 of 2013 on the Prevention and Eradication of Forest Degradation
	Law No. 19 of 2013 on the Protection and Empowerment of Farmers
	GR No. 73 of 2013 on Swamps
	GR No. 79 of 2013 on Traffic, Roads and Transportation Networks

	PR No. 62 of 2013 on the REDD+ Agency
	PR No. 63 of 2013 on the National Land Agency
	PI No. 6 of 2013 on the Suspension of New Licenses and Improving the Forest Governance of Primary Forests and Peat-lands
	MoAR No. 98 of 2013 on Guidance on Permit Issuance for Plantation Companies
	MoFD No. 2796 of 2013 on the Indonesia Moratorium Map
2014	Law No. 1 of 2014 on the Revision of Law No. 27 of 2007 on Coastal and Small Island Management
	Law No. 6 of 2014 on Villages
	Law No. 22 of 2014 on the Election of Governors, Bupatis and Mayors
	Law No. 23 of 2014 on Regional Governance
	GR in Lieu of Law No. 1 of 2014 on the Election of Governors, Bupatis and Mayors
	GR No. 1 of 2014 on the Second Revision of GR No. 23 of 2010 on the Implementation of Mineral and Coal Mining Business Activities
	GR No. 12 of 2014 on the Service Tariff for Non-Tax State Revenue Valid at the Ministry of Forestry
	PR No. 135 of 2014 on the Seventh Revision of PR No. 24 of 2010 on the Hierarchy, Duties and Functions of State Ministries; and the Hierarchy, Duties and Functions of 1st-Echelon State Ministries
	PR No. 165 of 2014 on the Arrangement of Duties and Functions of the Presidential Cabinet
2015	PR No. 16 of 2015 on the Ministry of the Environment and Forestry
	PR No. 17 of 2015 on the Ministry of Agrarian and Spatial Planning
	PR No. 20 of 2015 on the National Land Agency
	PR No. 26 of 2015 on the Office of Presidential Staff
	PD No. 38 of 2015 on the Appointment of the Presidential Special Envoy on Climate Change Mitigation
	PI No. 8 of 2015 on Suspension of the Granting of New Licenses and Improvement of the Governance of Natural Primary Forests and Peatlands
	MoAR No. 11 of 2015 on the Certification System for Indonesian Sustainable Palm Oil (ISPO)

Table 1: Legalisation From Indonesia Government

.B Code

```
import arcpy, os
...
... arcpy.env.workspace = r'C:\Users\ava330\Downloads\JavaImage\1990'
... outws = r'C:\Users\ava330\Downloads\HasilProses'
...
... # list all folders in a directory
...
... folders = arcpy.ListWorkspaces()
...
... for folder in folders:
            arcpy.env.workspace = folder
            rasters = arcpy.ListRasters("*","tif")
            tilename = folder
            out_raster = "\\"+tilename+"img"
            fcs = [fc for fc in rasters if os.path.splitext(fc)[0].endswith
               ('B5') or os.path.splitext(fc)[0].endswith('B4')or os.path.
               splitext(fc)[0].endswith('B3')]
            #print(out_raster)
            arcpy.CompositeBands_management(fcs, out_raster)
print "Processing complete"

==========================================================================================

#the code for mosaic the raster data
#MosaicToNewRaster_management (input_rasters, output_location,
   raster_dataset_name_with_extension, {coordinate_system_for_the_raster}, {
   pixel_type}, {cellsize}, number_of_bands, {mosaic_method}, {
   mosaic_colormap_mode})

# Mosaic.py
# Created on: 2013-03-02 17:51:39.00000
# Description:
## ---------------------------------------------------------------------------
import arcpy, os
Fn=''
rasts = []
try:
    workspace = arcpy.env.workspace = r"M:\BD_MODIS_NDVI\PROJ_TIF\Test"
    rasterList = arcpy.ListRasters("*","TIF")
    for raster in rasterList:
        ## grabs the filename before first "." which is J year and appends to
           the list "rasts"
        rasts.append(raster.split(".")[0])
        del raster
    ## make a set so unique (no duplicates) - result of one entry for each
       julian year
    rastSet = set(rasts)
```

```
    ##iterate through set
    for r in rastSet:
        newList = []
        ## iterate through list of rasters again, and those that start with our
             value for r are appended to NewList.
        for raster in rasterList:
            if raster.startswith(r):
                newList.append(raster)
                for raster in newList:
                   Fn= raster[0:7] # file names
                arcpy.MosaicToNewRaster_management(newList,workspace, Fn+".tif
                    ","", "16_BIT_SIGNED", "", "1", "LAST", "FIRST")
                ## use this newList as you raster list for mosaic tool
        # want to do the mosaic at this indentation level so it only does it
           for r = singlevalue
        del raster
        del newList

except:
    print "Mosaic failed."
    print arcpy.GetMessages()

#  Mosaic : Date 02, January, 2001

import arcpy, os

rasts = []
try:
    workspace = arcpy.env.workspace = r"L:/MODIS_NDVI/TIF_files/2001"
    rasterList = arcpy.ListRasters("*","TIF")
    for raster in rasterList:
        rasts.append(raster.split(".")[0]) ## grabs the filename before first
           "." which is J year and appends to the list "rasts"
        del raster
    rastSet = set(rasts)         ## make a set so unique (no duplicates) -
        result of one entry for each julian year
    for r in rastSet:               ##iterate through set
        newList = []
        for raster in rasterList:      ## iterate through list of rasters again
            , and those that start with our value for r are appended to NewList
            .
            if raster.startswith(r):
                newList.append(raster) ## use this newList as you raster list
                    for mosaic tool
        want to do the mosaic at this indentation level so it only does it for
           r = singlevalue
        del raster
        del newList
```

```
except:
    print "Mosiac failed."
    print arcpy.GetMessages()
==========================================================================================

#!classification with python but the range of the image should be carefully
   picked

##Change the value with your raster filename here
raster_file = 'w001001.adf'
output_file = 'classified.tiff'

classification_values = [0,500,1000,1500,2000,2500,3000,3500,4000] ##The
   interval values to classify
classification_output_values = [10,20,30,40,50,60,70,80,90] ##The value
   assigned to each interval

from osgeo import gdal
from osgeo.gdalconst import *
import numpy
import struct

#Opening the raster file
dataset = gdal.Open(raster_file, GA_ReadOnly )
band = dataset.GetRasterBand(1)
#Reading the raster properties
projectionfrom = dataset.GetProjection()
geotransform = dataset.GetGeoTransform()
xsize = band.XSize
ysize = band.YSize
datatype = band.DataType

##Reading the raster values
values = band.ReadRaster( 0, 0, xsize, ysize, xsize, ysize, datatype )
##Conversion between GDAL types and python pack types (Can't use complex
   integer or float!!)
data_types ={'Byte':'B','UInt16':'H','Int16':'h','UInt32':'I','Int32':'i','
   Float32':'f','Float64':'d'}
values = struct.unpack(data_types[gdal.GetDataTypeName(band.DataType)]*xsize*
   ysize,values)

##Now that the raster is into an array, let's classify it#
out_str = ''
for value in values:
    index = 0
    for cl_value in classification_values:
        if value <= cl_value:
            out_str = out_str + struct.pack('B',classification_output_values[
```

```
                index])
            break
        index = index + 1
##Once classified, write the output raster
##In the example, it's not possible to use the same output format than the
    input file, because GDAL is not able to write this file format. Geotiff
    will be used instead
gtiff = gdal.GetDriverByName('GTiff')
output_dataset = gtiff.Create(output_file, xsize, ysize, 4)
output_dataset.SetProjection(projectionfrom)
output_dataset.SetGeoTransform(geotransform)

output_dataset.GetRasterBand(1).WriteRaster( 0, 0, xsize, ysize, out_str )
output_dataset = None
==========================================================================================

import arcpy,
inRaster = r"C:\test.gdb\myRaster"
# Build attribute table if needed
#
arcpy.BuildRasterAttributeTable_management(inRaster, "OVERWRITE")
# Create a search cursor for desired raster
VALUE sCur = arcpy.SearchCursor(inRaster, '"VALUE" = 1')
for row in sCur:
cellCount = row.getValue("COUNT")
print cellCount

==========================================================================================

Mosaic the Raster

import arcpy
from arcpy import env
env.workspace = "c:/data"
arcpy.MosaicToNewRaster_management("land1.tif;land2.tif", "Mosaic2New", "
    landnew.tif", "World_Mercator.prj","8_BIT_UNSIGNED", "40", "1", "LAST","
    FIRST")

=================================
# Name: DeleteIdentical_Example2.py
# Description: Delete identical features in a dataset based on Shape (geometry)
     and a TEXT field.


# Import system modules
import arcpy
from arcpy import env

env.overwriteOutput = True
```

```
# Set workspace environment
env.workspace = "C:/data/sbfire.gdb"

# Set input feature class
in_dataset = "fireincidents"

# Set the field upon which the identicals are found
fields = ["Shape", "INTENSITY"]

# Set the XY tolerance within which to identical records to be deleted
xy_tol = "0.02 Miles"

# Set the Z tolerance to default
z_tol = ""

# Execute Delete Identical
arcpy.DeleteIdentical_management(in_dataset, fields, xy_tol, z_tol)
==========================
import arcpy, os
...
... arcpy.env.workspace = r'C:\Users\ava330\Downloads\JavaImage\1990'
... outws = r'C:\Users\ava330\Downloads\HasilProses'
... path_images = "C:\Users\ava330\Downloads\JavaImage\1990" #arcpy.
    GetParameterAsText(0)
...
... # list all folders in a directory
...
... folders = arcpy.ListWorkspaces()
...
for folder in folders:
        #mendefiniskan working environment dari raster image
        arcpy.env.workspace = folder
        #menselect semua data yang berextension tif di
    rasters = arcpy.ListRasters("*","tif")
        #tilename = rasters[0:-7]
        out_raster = folder + "\\.img"
        #out_raster=[]
        #untuk memfilter bands
        fcs = [fc for fc in rasters if os.path.splitext(fc)[0].endswith('B5')
            or os.path.splitext(fc)[0].endswith('B4')or os.path.splitext(fc)[0].
            endswith('B3')]
        #untuk composite the image
        arcpy.CompositeBands_management(fcs, out_raster)
        #list_raster = arcpy.ListRasters(fcs)
    #print(fcs)
print "Processing complete"
=========================================================================================
```

```
#coding ini sudah berhasil memanggil image raster yang ada pada folder tertentu
#cari perintah untuk mengkopmposit band tertentu dalam folder
import arcpy, os
arcpy.env.workspace = r'C:\Users\ava330\Downloads\JavaImage\1990'
outws = r'C:\Users\ava330\Downloads\HasilProses'
# list all folders in a directory
folders = arcpy.ListWorkspaces()
for folder in folders:
               arcpy.env.workspace = folder
               rasters = arcpy.ListRasters("*.tif)

               for fc in rasters:
               # Test each value to see if it meets the filtering criteria
               if "_1_" not in fc and "_2_" not in fc:
       # If it does then append it onto the filtered list
       filteredFCs.append(fc)
               # Print out the filtered list
               print filteredFCs
               #arcpy.CompositeBands_management(rasters
               #print(rasters)

print "Processing complete"
#end of the code

==========================================================================================

#another code to seperate the band
import arcpy
image_names=["img" + str(s) for s in range(1,143)]
wd="C:\Users\ava330\Downloads\JavaImage\1990" #have this as your directory
   where all rasters are located
arcpy.env.workspace = wd
for image_name in image_names:
   print image_name
   raster_list=arcpy.ListRasters(image_name+"-*", "tif")
   import os
   outws = "C:\Users\ava330\Downloads\HasilProses"
   os.makedirs(outws)
   arcpy.CompositeBands_management(raster_list, outws + image_name+ "
      _stacked_img.tif")
==========================================================================================

#coding ini sudah berhasil menyaring band yang akan diolah dengan composite
#sekarang cari bagaimana mengkomposit setiap image
import arcpy, os
...
... arcpy.env.workspace = r'C:\Users\ava330\Downloads\JavaImage\1990'
... outws = r'C:\Users\ava330\Downloads\HasilProses'
... path_images = "C:\Users\ava330\Downloads\JavaImage\1990" #arcpy.
```

```
   GetParameterAsText(0)
...
... # list all folders in a directory
...
... folders = arcpy.ListWorkspaces()
...
... for folder in folders:
              #mendefiniskan working environment dari raster image
...    arcpy.env.workspace = folder
              #menselect semua data yang berextension tif di
...    rasters = arcpy.ListRasters("*","tif")
              tilename = folder[0:-7]
              out_raster = path_images + "\\" + tilename + ".img"
...    #untuk memfilter bands
...    fcs = [fc for fc in rasters if os.path.splitext(fc)[0].endswith('B5')
   or os.path.splitext(fc)[0].endswith('B4')or os.path.splitext(fc)[0].
   endswith('B3')]
...    #untuk composite the image
...    arcpy.CompositeBands_management(fcs, out_raster)
              #list_raster = arcpy.ListRasters(fcs)
...    #print(fcs)
... print "Processing complete"

==============================================================================

#originalcode
import arcpy, os
...
... arcpy.env.workspace = r'C:\Users\ava330\Downloads\JavaImage\1990'
... outws = r'C:\Users\ava330\Downloads\HasilProses'
...
... # list all folders in a directory
...
... folders = arcpy.ListWorkspaces()
...
... for folder in folders:
              arcpy.env.workspace = folder
              rasters = arcpy.ListRasters("*","tif")
              tilename = folder
              out_raster = "\\"+tilename+"img"
              fcs = [fc for fc in rasters if os.path.splitext(fc)[0].endswith
                 ('B5') or os.path.splitext(fc)[0].endswith('B4')or os.path.
                 splitext(fc)[0].endswith('B3')]
              #print(out_raster)
              arcpy.CompositeBands_management(fcs, out_raster)
print "Processing complete"
```

.C Published Papers

.D Questionnaires

Name :

1. Please make sure that you already download and install the app from playstore
2. Please make sure you already use the application and its feature

Number	Question	Score				
		1	2	3	4	5
1	How was the colour composition on the app?	o	o	o	o	o
2	Was the font readable in the app?	o	o	o	o	o
3	Was the layout interesting?	o	o	o	o	o
4	How was the variation style and interface on the app?	o	o	o	o	o
5	How do you measure the quality of interface on the app?	o	o	o	o	o
		o	o	o	o	o
1	Were the instructions simple to understand?	o	o	o	o	o
2	Was the app easy to be used?	o	o	o	o	o
3	Was the information on the app can be accessed easily?	o	o	o	o	o
4	Was the app was easy to install?	o	o	o	o	o
		o	o	o	o	o
1	Was the app suit to the purposes of the development?	o	o	o	o	o
2	How was the sequence of the menu in the app?	o	o	o	o	o
3	How was the feature and facilities on the app?	o	o	o	o	o
4	Did the app was fast enough to be used?	o	o	o	o	o
5	How was the processing time on the app?	o	o	o	o	o
6	How was the accuracy of the app?	o	o	o	o	o
7	How was the functionality of the app?	o	o	o	o	o

Number	Question	Score Amount				
		1	2	3	4	5
1	How was the colour composition on the app?	0	0	80	100	20
2	Was the font readable in the app?	0	0	60	120	20
3	Was the layout interesting?	0	0	40	120	40
4	How was the variation style and interface on the app?	0	0	80	120	0
5	How do you measure the quality of interface on the app?	0	0	40	140	20
1	Were the instructions simple to understand?	0	0	100	100	0
2	Was the app easy to be used?	0	0	100	100	0
3	Was the information on the app can be accessed easily?	0	0	120	80	0
4	Was the app was easy to install?	0	0	60	120	20
1	Was the app suit to the purposes of the development?	0	0	60	120	20
2	How was the sequence of the menu in the app?	0	0	40	140	20
3	How was the feature and facilities on the app?	0	0	60	120	20
4	Did the app was fast enough to be used?	0	0	60	140	0
5	How was the processing time on the app?	0	0	80	120	0
6	How was the accuracy of the app?	0	0	80	120	0
7	How was the functionality of the app?	0	0	40	160	0