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Spatial and Temporal Patterns of Tropical Forest Landscape Prioritization for Conservation Planning: A Case Study in Sultan Adam Forest Park, Indonesia

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Abbreviations and Acronyms

ACCA	:	Automatic Cloud Cover Assessment
AHP	:	Analytic Hierarchy Process
Bakosurtanal	:	Badan Koordinasi Survey dan Pemetaan National (National Mapping and Survey Coordination Agency), former name of BIG
BBSDLP	:	Balai Besar Penelitian dan Pengembangan Sumberdaya Lahan Pertanian (ICALRD, in English)
BIG	:	Badan Informasi Geospasial (Geospatial Information Agency), the later name of Bakosurtanal
BMKG	:	Badan Meteorologi, Klimatologi dan Geofisika (Meteorology, Climatology and Geophysical Agency, Indonesia)
CGIAR	:	Consortium of International Agricultural Research Centers
C&I	:	Criteria and Indicator
DEM	:	Digital Elevation Model
DN	:	Digital Number
FI	:	Fragmentation Index
FMU	:	Forest Management Unit
GIS	:	Geographic Information System
GRASS	:	Geographic Resources Analysis Support System
ICALRD	:	Indonesian Center for Agricultural Land Resources Research and Development (BBSDLP, in bahasa Indonesian)
ITTO	:	International Tropical Timber Organization
KDE	:	Kernel Density Estimation
LULC	:	Land Use and Land Cover

MoF	:	Ministry of Forestry of Indonesia
NASA	:	The National Aeronautics and Space Administration
NDVI	:	Normalized Difference Vegetation Index
NIR	:	Near Infra-Red
NFI	:	Indonesian National Forest Inventory
PIF	:	Pseudo Invariant Feature
PCA/PC	:	Second Principal Component Analysis / Principal Component
QA	:	Quality Assessment
RL	:	Red List criteria
RRN	:	Relative Radiometric Normalization
RS	:	Remote Sensing
SAFP	:	Sultan Adam Forest Park (In some literatures it is also called Sultan Adam Grand Forest Park)
SFM	:	Sustainable Forest Management
SNI	:	Standard Nasional Indonesia (Indonesian National Standard)
SR	:	Species Richness criteria
SRTM	:	Shuttle Radar Topographic Mission
TA	:	Training Area
TOA	:	Top of Atmospheric
USGS	:	United States of Geological Survey
VU	:	Value Use criteria

Abstract

This study was aimed to develop and assess the application of the conservation prioritization, in terms of spatial and temporal patterns, in the area prioritization of the forest landscape for conservation planning with the study site of Sultan Adam Forest Park, Indonesia. It tries to formulate the appropriate prioritization framework, to prepare the biophysical conditions data and assess their spatial and temporal changes, to assess the spatial and temporal patterns of the preservation prioritization, to assess the spatial and temporal patterns of the rehabilitation prioritization, to formulate the proposed contribution of the forest landscape conservation prioritization for forest landscape zonation, and to assess the optimum proportion for conservation priority and to assess the sensitivity of the conservation prioritization framework in forest landscape.

Chapter 1 discussed the background, problem statement, objective and aims, significance, framework, and the study site. Since Indonesian forests have been divided into Forest Management Unit (FMU), forest management practice at the FMU level certainly contributes to the sustainability of the Indonesian forest. Sultan Adam Forest Park (SAFP) was selected as the study site due to its wide ecosystem types and significant size. SAFP is also among few FMUs that have been formally assigned and passed the development phase.

Chapter 2 consisted of the literature review and methodological approaches. The application of the landscape approach was highlighted. The two identified conservation tasks, namely the *preservation* and *rehabilitation*, were used as the main prioritization goal in a GIS-based multi-criteria analysis. The framework for conservation prioritization of the forest landscape was developed. It has multi-criteria of tasks, components, sub-components, and parameters. Management preference were accommodated by weighting techniques using

Analytic Hierarchy Process (AHP) as the weighting method. In addition, other weighting methods were also used for assessing the sensitivity of the developed framework.

Chapter 3 assessed forest landscape biophysical conditions for landscape prioritization. The lowest level criteria are parameters that were estimated from the landscape biophysical conditions. The spatial and temporal analysis were carried out to assess the related parameters on the vegetation, forest fragmentation, species' status, settlement, accessibility, forest fire, soil erosion, topography and land management criteria. An additional of hazard prevention was also included which was used for the sensitivity analysis. The spatial and temporal patterns of the biophysical conditions certainly affect the spatial and temporal patterns of the prioritization.

Chapter 4 analysed the spatial and temporal patterns of the preservation prioritization in tropical forest landscape. The preservation priority area was analysed in two decadal period of analysis. The resultant preservation priority in 1993, 2003 and 2013 were assessed spatially and temporally. The inclusion of the threat component significantly changed the preservation prioritization. It was also found that the changes in the preservation priority area were related to the change of the biophysical conditions. The importance to assess the preservation priority and its spatial and temporal patterns in forest landscape is highlighted.

Chapter 5 analysed the spatial and temporal patterns of the rehabilitation prioritization in tropical forest landscape. The rehabilitation priority area was analysed in two decadal period of analysis. The resultant rehabilitation priority in 1993, 2003 and 2013 were assessed spatially and temporally. It found that the inclusion of the recoverability component significantly changed the resultant priority area. The changes in the rehabilitation priority also linked to the change of the biophysical conditions, spatially and temporally. The resultant rehabilitation priority area is less temporally changed compare to the preservation priority.

The importance of the assessing the spatial and temporal patterns of the rehabilitation priority is underlined.

Chapter 6 formulated the proposed contribution of the forest landscape prioritization for forest planning. The new concept of the prioritization regimes was proposed. It is observed that in the period of 1993-2003 and 2003-2013, conservation and preservation regimes decreased while rehabilitation and enhancement regimes increased. The spatial and temporal patterns in the proposed prioritization regimes are significant. Current zonation in SAFP has a moderate agreement with the proposed prioritization regimes. Further, the proposed prioritization regimes were proposed as one of the considerations for forest landscape zonation. Since the prioritization regime acknowledged the spatial and temporal patterns, its application was recommended in mid-term or short-term forest plans. This chapter shows the functionality of the prioritization regime as the complement of the zonation or special zone assignment in FMU.

Chapter 7 assessed the optimum proportion of the priority area and assessed the sensitivity of the conservation prioritization framework in forest landscape. Even the linear and logarithmic models show their good performances, however, neither one of them was consistently favorable over another. The optimum proportion was also hard to be consistently defined since it depends on the spatial and temporal change of the preservation and rehabilitation prioritizations. Thus, arbitrary proportion for determining priority area in forest landscape still the appropriate option. On the weighting sensitivity, it can be concluded that if the forest manager has sufficient resource, the AHP is the favorable method. Meanwhile, for lacking of prior study and information on decision-making preference, any of equal, proportionally equal and rule-of-weight methods can be used with insignificant differences. This chapter also confirmed that criteria selection has a wide spectrum of choices without significant difference in the result. Since the prioritization or framework could not be evaluated in terms of right or wrong, for this reason, developing the acceptable, repeatable and objective framework is considerably appropriate in conservation prioritization.

Conclusion and recommendation were presented in **Chapter 8**. It shows the general conclusion in the summary of findings, scientific contribution of this study and its limitation. In addition, the recommendation on the basic idea of implementation and the future perspective were discussed.

Chapter 1: General Introduction

1.1. Background

Indonesian forest suffers from deforestation that counts the second highest rate of deforestation among the tropical countries (Margono et al., 2010). The raise of the deforestation rate was started since 1980s with the average of 1 million $ha.yr^{-1}$ (FWI/GFW, 2002). The rate increased into 1.7 million $ha.yr^{-1}$ in 1990s and 2 million $ha.yr^{-1}$ in 1996 (Myers, 1991). Lately, in the period of 2009 – 2010, Indonesian Ministry of Forestry (2012) estimated that the rate of the deforestation was 610,000 $ha.yr^{-1}$. However, the figure ignored the conversion of natural forest to plantation forest and the deforestation outside of the state forestland. Hansen et al. (2013) Estimated that the Indonesian deforestation rate between 2011 and 2012 was above 2 million $ha.yr^{-1}$. The rate of the deforestation is unfortunately projected to increase in the future (Indonesian Ministry of Forestry, 2011).

Beside of deforestation, forest degradation is also a significant issue in Indonesia. Forest fragmentation is one of distinct indicator of forest degradation. Forest fragmentation, which was defined as the process that results in the conversion of continuous forest into patches (Tejaswi, 2007), is also a significant issue in the forest landscape. Forest fragmentation is related to forest as habitat (Wulder et al., 2009), then habitat fragmentation affects abiota and biota (Rutledge, 2003), species abundance and extinction (Arroyo-Rodríguez et al., 2007). Forest fragmentation is, therefore, forest degradation, one of the major threats to biodiversity and species extinction.

The causes of deforestation and forest degradation (or forest fragmentation) can be categorized into two groups; direct causes and underlying causes (Tejaswi, 2007). The landscape level analysis deals with the direct causes of deforestation. Since forest fragmentation is the result of the deforestation (Broadbent et al., 2008), therefore, direct causes of the deforestation can also the direct cause of forest fragmentation. Some significant direct causes of deforestation are logging (Broadbent et al., 2008), conversion of forested lands (Aurambout et al., 2005), cattle raising (Tejaswi, 2007), urbanization (Tigas et al., 2002), road accessibility (Barber et al., 2014), and forest fire (Langner, 2009). However, since it depends on the characteristics of each forest landscape, not all causes are found in every forest landscape.

Deforestation and forest degradation can cause ecological and socioeconomic effects (Alig et al., 2010b). Considering that Indonesia ranks third in tropical forests endowment and posing 10% of world's biodiversity (Myers, 1991; Sunderlin and Resosudarmo, 1996), reducing deforestation and forest fragmentation is necessary. Since the main achievement in managing the forest is Sustainable Forest Management (SFM), therefore developing the strategy to achieve the SFM is indispensable.

Forest Management Unit (FMU) was expected to be the key success in achieving the SFM in Indonesian forest. In the accordance with the issuance of the Forestry Act (Government of the Republic of Indonesia, 1999), it became mandatory that all Indonesian Forests are managed under FMUs. Since there are three main forest functions of Indonesian forests, thus three types of FMU were developed, namely conservation FMU, protection FMU and production FMU. FMJU is the smallest management unit for efficient and sustainable management of the forest (Indonesian Ministry of Forestry, 2011).

However, Kartodihardjo et al. (2011) stated that the mandate was neglected in practice. There are still obstacles to the FMU development, such as legislation, mobilization of resources and FMU organization. Fortunately, the FMU development got more awareness, and then its development was dramatically escalated again since 2009. Until the end of 2013, from the total Indonesian forest of 131 million ha, it had been assigned 79 million ha as FMUs.

In managing FMU, forest managers need conservation planning as the tool for combating deforestation and forest degradation. Incorporating the conservation strategy in forest landscape management, it can be expected that the SFM in forest landscape can be achieved, which in turn, the national level forests are also managed sustainably.

In order to support the forest plan, forest zonation and special zone assignment are the two main practices in forest planning in Indonesian forest (Mulyana et al., 2010). However, zonation and special zone assignment are relatively static in the terms of spatial and temporal dimensions. Moreover, the two are mainly considered as the legal guidance for forest management. Zonation and special zone assignment are likely preceded by a long and detailed study. On the other hand, the forest manager needs a more dynamic tool to support the decision-making in forest planning. Therefore, this study proposed prioritization as the complement of zonation and special zone assignment in forest planning.

Prioritization has been widely practiced in determining the biodiversity preservation. Nevertheless, its application to support site-level management is not explored yet. In addition, the most common perspective in such prioritization is making prioritization on only the targeted species. This perspective has some disadvantages from neglecting other species importance. It is also a costly effort due to narrow focus and long study period. A more general, and consequently, less detail prioritization is needed in FMU management. Thus, a landscape perspective is considered as a more appropriate approach for forest landscape prioritization to support forest planning in FMU.

Landscape perspective underlines that forests landscape prioritization must acknowledge the nature of the forest in FMU as landscapes. It has different characteristic compared to the species-based prioritization. In the landscape ecology discipline, it can be found some landscape characteristics that related to prioritization, namely spatial and temporal. Understanding the application of the landscape perspective in forest landscape prioritization and its spatial and temporal patterns will benefit to forest management. Therefore, the application of landscape approach for Indonesian tropical forest prioritization needs to be studied, especially on how the spatial and temporal patterns of landscape characteristics affect the resultant priority and how the resultant priority spatially and temporally changes.

The summary of the background of this research can be seen in Figure 1-1. It shows that deforestation and forest degradation pressure on the Indonesian forests need to be reduced as the requirement for the SFM. Dividing all Indonesian forests into FMUs is certainly a strategic management to achieve the SFM. One of the indispensable tools for managing FMU is conservation planning that apply to all types of FMU (conservation, protection, and production). The availability of the zonation system and special zonation assignment in the FMU contribute to better forest conservation planning. However, since they are relatively static in terms of spatial and temporal and their function are mostly considered as the legal guidance in the forest planning, another tool is required. Prioritization is therefore proposed to support forest planning as the complement of the zonation or special zone assignment. It has been a useful tool for defining biological preservation area (or conservation FMU). This study tries to extend its function in supporting the conservation planning within FMU.

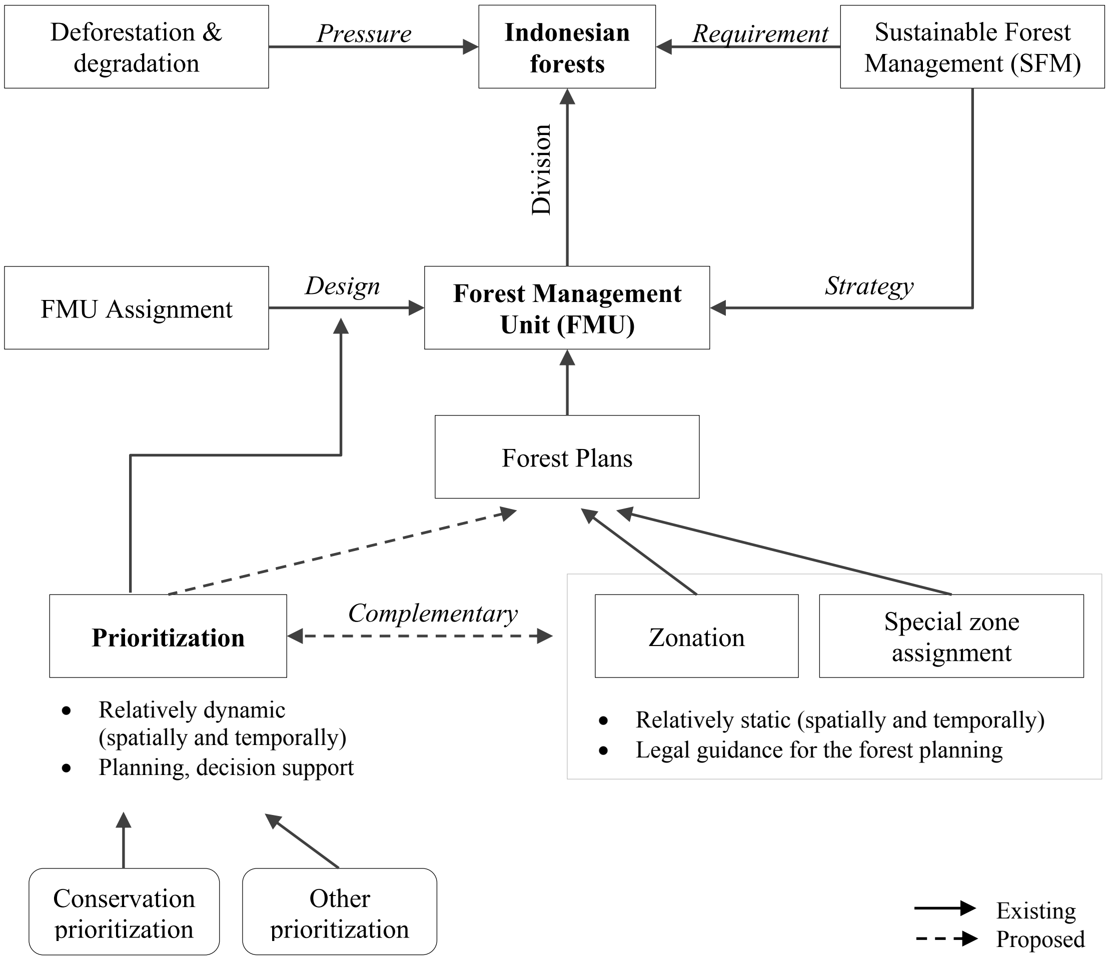


Figure 1-1: The need for prioritization to achieve for SFM in Indonesian FMUs

The introduction of the conservation prioritization in supporting the FMU conservation planning requires the study of its development and application. Conservation prioritization, which is commonly used to determine the area for conservation area (FMU). Literally, prioritization was commonly used in determining the FMU but not in supporting the FMU management yet. Prioritization probably provides beneficiary to support the conservation planning, as the complementary of the existing zonation and special zone assignment.

1.2. Problem statement

FMU as the strategic forest management in Indonesian forest needs the decision tools for managing forest landscape to be complemented with the forest zonation and special zone assignment. The tool should acknowledge the spatial and temporal dynamic in the forest landscape that is not well accommodated in the existing forest zonation and special zone assignment. The introduction of the prioritization method as the proposed tool to support the FMU conservation planning needs its development and application's assessment, spatially and temporally. The appropriate conservation prioritization benefit from the emerging landscape approach, contemporary conservation concept, and criteria definitions. Even though the prioritization has been widely used in the conservation FMU assignment, however, there is no such study on how to use it within FMU to support the forest planning.

1.3. Objective and aims

The main objective of this study is to develop and assess the application of the conservation prioritization, in terms of spatial and temporal patterns, in area prioritization of the forest landscape for conservation planning with the study site of Sultan Adam Forest Park, Indonesia. In order to achieve that main objective, several works have been done with specific objectives as follow.

1. To formulate the framework for tropical forest landscape prioritization in FMU;
2. To prepare the biophysical conditions data and assess their spatial and temporal changes;
3. To assess the spatial and temporal patterns of the preservation prioritization;
4. To assess the spatial and temporal patterns of the rehabilitation prioritization;
5. To formulate the proposed contribution of the forest landscape conservation prioritization for forest landscape zonation within FMU;

6. To assess the optimum proportion for conservation priority and to assess the sensitivity of the conservation prioritization framework in forest landscape.

1.4. Significance of the study

The development and application of the conservation prioritization in the forest landscape contribute to better conservation planning which in turn contribute to achieving the SFM in FMU. There is a need to explore the development and application of the conservation prioritization to support the conservation planning in FMU. One of the main keys to the successful management of FMU is proper forest planning, including the conservation planning. Since all Indonesian forests have been dividing into FMU, the successful FMU management leads to the SFM for Indonesian forests.

1.5. Framework of the study

This study consists of eight Chapters that can be seen in the following figure.

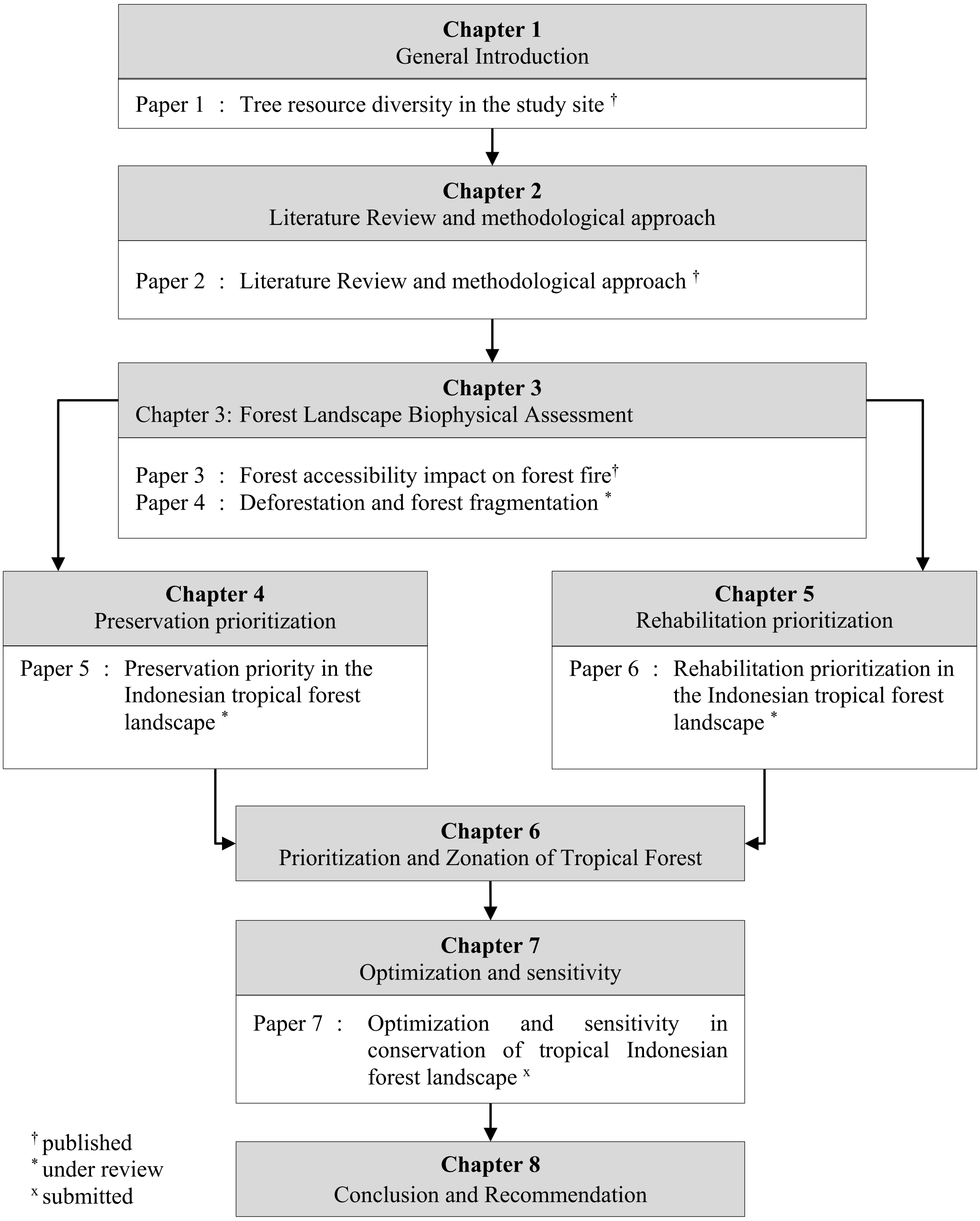


Figure 1-2: Research Framework

1.6. Software

The study used a GIS-based multi-criteria analysis with the input from the biophysical conditions of the study site. Thus, remote sensing and geographic information system software were needed for managing the spatial data and spatial and temporal analysis. In addition, it also needed calculation and statistical analysis software. The software used for entry, data analysis, visualization, and modeling are as follow.

- GRASS GIS 6 (stable) and 7 (SVN)
- ArcGIS Desktop 10
- Microsoft Excel 2013
- R Software, R Studio, and R additional packages (*fitdistrplus*, *survival*, *splines,* and *reshape2*)
- SPSS
- Microsoft Word 2013

1.7. Study site

Sultan Adam Forest Park (SAFP) (Taman Hutan Raya Sultan Adam in Indonesian, often translated into English as the Sultan Adam Grand Forest Park) is managed by South Kalimantan Provincial Government. It is located in South Kalimantan Province and covers about 112,000 ha. In the center of the park, there is an approximately 7,000 ha artificial lake, which was formed after the construction of the Riam Kanan hydropower plant. The lake also supports irrigation and water supply to several cities downstream. This makes the forest park indispensable for the regional development. Within the park, there is one sub-district that consists of 14 villages with 2,261 households and the population of 8,304 (Government of the

Banjar Regency, 2009). The park is managed by a Sultan Adam Forest Office. The map of the SAFP is presented in Figure 1-3.

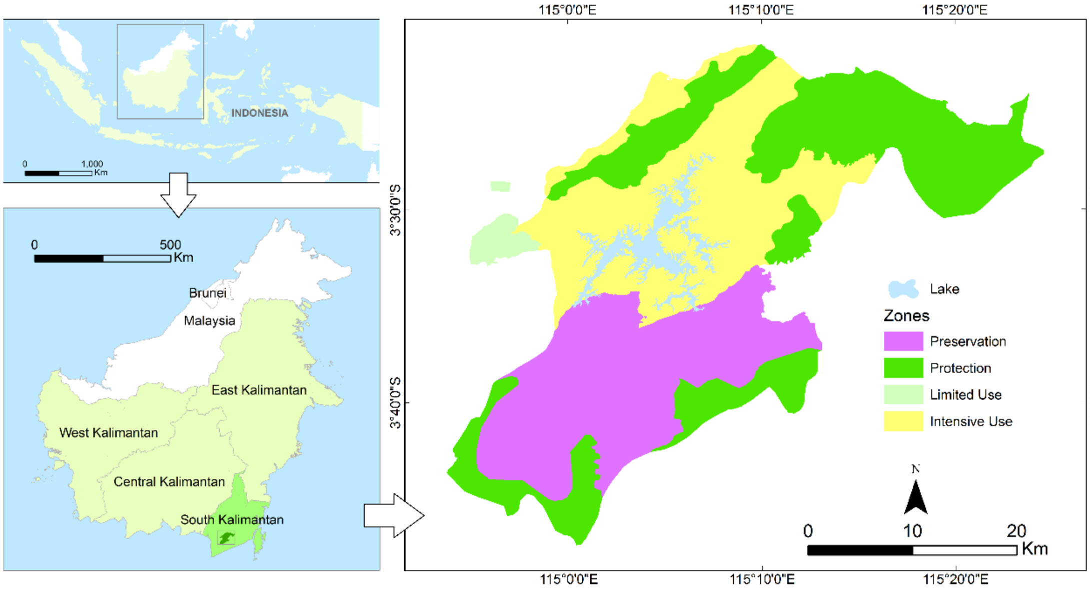


Figure 1-3: Map of Sultan Adam Forest Park, Indonesia

SAFP was established by combining some forest areas. Wild preserve (*suaka margasatwa* in Indonesian) (ca. 36,400 ha), PM Noor Protected Forest (ca. 55,000 ha), Kinain Buak Protected Forest (ca. 13,000 ha), Lambung Mangkurat University Educational Forest (ca. 2,000 ha) and some part of production forest around the Riam Kanan Lake were altogether combined into SAFP (Government of the Republic of Indonesia, 1989).

SAFP was established with several purposes. In Government of the Republic of Indonesia (1989), the purpose of the park establishment was mentioned as follow.

1. Preservation of Bornean flora and fauna genetic resources;
2. Research on Bornean vegetation and fauna of tropical rainforest;
3. Education, training, and extension;
4. Nature recreation;
5. Natural scenery and microclimate;
6. Hydro-orology function.

In order to achieve those purposes and also as one of the forest management tool, SAFP has been divided into four zones in 1989 (Government of the Republic of Indonesia, 1989). Further, the zonation was spatially updated in the Long-Term Planning of SAFP in 2011 (Forestry Service of South Kalimantan Province, 2011). The spatial distribution of the zone has is shown in Figure 1-3 with the size proportion in Figure 1-4

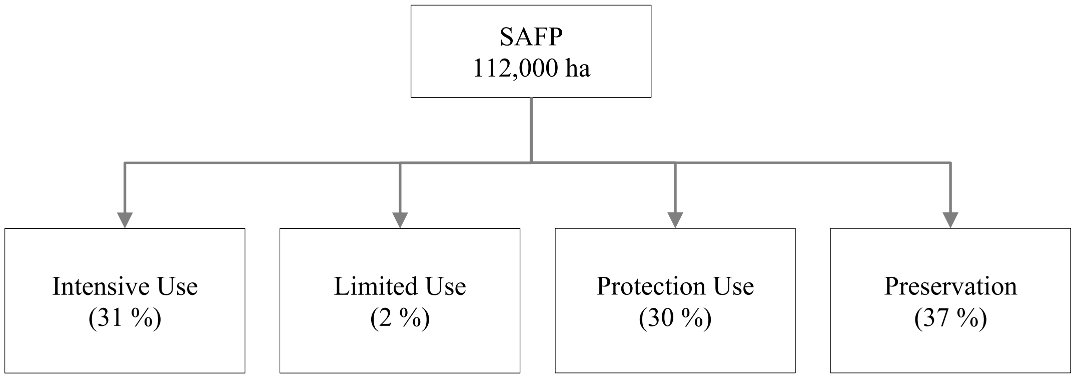


Figure 1-4: Proportion of the Zones in Sultan Adam Forest Park

Zonation in SAFP assures the appropriate activities within each zone. As one of the management tool, zones are used as the legal guidance on what activities are applied in each zone. Each zone in SAFP has a different function as follow (Forestry Service of South Kalimantan Province, 2011). Preservation zone is for biodiversity protection, Protection zone is for soil and water conservation, Limited use zone is for education and research, and Intensive use zone is for ecotourism and socio-economic activities. The management activities for each zone are as shown in the following table.

Table 1-1: Forest management activities within each zone in SAFP

Zones	Activities
Preservation	• Preservation of endemic genetic resources • Research and education • Fauna enrichment • Vegetation and habitat enrichment • Facilities for vegetation and habitat enrichment
Protection	• Research • Protection and patrol facility • Vegetation enrichment • Nature preservation and non-timber cultivation, such as medicine plants, honeybee, mushroom, and orchid
Limited use	• Education, research and vegetation enrichment • Tourism (limited) • Management facility • Fauna enrichment • Habitat enrichment • Outdoor activity • Sport • Landscape viewing • Use of nature service
Intensive use	• Research, education, and tourism • Flora and fauna breeding • Fauna rehabilitation • Nature tourism/recreation • Outdoor activity • Sport; watersport, air sport, camping ground • Tourism facility • Vegetation plantation and enrichment • Use of nature service • Landscape viewing

Adapted from Forestry Service of South Kalimantan Province (2011)

In order to perform the study on the development and application of the conservation prioritization in the forest landscape, it is essential to select a study site that represents the FMUs in Indonesian. Moreover, since not all Indonesian forests must be managed under FMU, therefore, the appropriate progress in the FMU development in the study site was considered in determining the study.

SAFP was selected as the study site due to several considerations regarding its size, ecosystem ranges, development role and the phase of the FMU development that can be further explained as following.

1. SAFP officially has the size of 112,000 hectares (1,120 km^2) that makes the park as the largest forest park in Indonesia. In the term of size representativeness, it is certain that the park is not about the average of the Indonesian forest parks. However, large size of SAFP has benefit due to complete conditions of the park, which in turn, the result of the study will more represent various Indonesian forest conditions.
2. SAFP has a wide range of ecosystems, from grassland to forest, from lowland to mountainous, and from human-influenced to the virgin forests. The wide range of its ecosystem makes the SAFP is appropriate for the study site.
3. SAFP also has a vital role in the regional and national development. It supports electricity, water catchment regulation, drinking water supply, irrigation, and fisheries. Taking SAFP as the study site will contribute to improving its function.
4. SAFP is one of the Indonesian FMU that has just managed under a management body in 2010. Since the FMU mandate has been neglected since the issuance of the Forestry Bill in 1999, FMU issue started to regain its traction in 2009. Only a few forests have been managed under FMU while most forests are now under FMU assignment or FMU developing phase. The FMU development phase of SAFP represents most of the Indonesian forests.

1.8. Publication

Parts of the manuscript have been published, under review, or submitted to several journals as follow.

1. Raharjo, B. and Nakagoshi, N. (2012). *Tree resource diversity in the biological preservation block of the Sultan Adam Forest Park, South Kalimantan*. Hikobia (16):151 – 160. (Published)

2. Raharjo, B. and Nakagoshi, N. (2014). *Stochastic Approach on Forest Fire Spatial Distribution from Forest Accessibility in Forest Management Units, South Kalimantan Province, Indonesia*. Journal of Environmental Protection, 5, 517-529. http://dx.doi.org/10.4236/jep.2014.56055. (Published)
3. Raharjo, B. and Nakagoshi, N. (2014). *Application of prioritization procedure in conservation planning of tropical forests: A case in Sultan Adam Forest Park, Indonesia*. Hikobia Journal (16): 441 – 451. (Published)
4. Raharjo, B., Nakagoshi, N., Firdaus, R. *Deforestation and forest fragmentation patterns in the tropical forest landscape: A case study in Sultan Adam Forest Park, Indonesia*. Journal of Sustainable Forestry. Taylor and Francis. IF 0.55 (Under Review, submitted 01-Oct-2014).
5. Raharjo, B. and Nakagoshi, N. *Developing preservation prioritization for landscape level forest management in Indonesia*. Forest System Journal, Spanish National Institute for Agricultural and Food Research and Technology. IF 0.62 (Under review, submitted 19-October-2014).
6. Raharjo, B. and Nakagoshi, N. *Component and weight changes in the forest rehabilitation prioritization of Sultan Adam Forest Park, Indonesia*. Journal of forestry research. Springer. IF 0.25 (Under Review, submitted 18-Oct-2014).

Chapter 2: Literature Review and Methodological Approach

2.1. Introduction

The world is suffering from biodiversity loss (Brooks, 2006) especially in developing countries of tropics (Pfund et al., 2008). The loss can be in terms of species, ecosystem or economic value of nature. The tropical region also has the fastest rate of degradation (Pawar et al., 2007). Therefore, nature conservation, that is considered as the protection of the natural richness of landscape (Ploeg and Vlijm, 1978), is highly required to stop the loss in the tropical forests resources.

Tropical forests consist of evergreen tropical rainforests, moist deciduous tropical forests and others (FAO, 1998). The evergreen rainfall forests are located in areas with rainfall intensity greater than 2,500 mm/year, mostly in lowland, evergreen, predominantly hardwood, have a complex structure and richness of biodiversity. On the other hand, moist deciduous tropical forests have rainfall intensity of 1,000 – 2,500 mm.yr^{-1}, with fewer species and smaller biological diversity. One of the countries that have rich tropical forests is Indonesia. Since tropical forests have an essential role in human life (FAO, 2012), conserving Indonesian tropical forests is indispensable.

Indonesian forests are also suffering from deforestation and forest degradation with the average of 2 million hectares per year since 1996 (FWI/GFW, 2002). From 2009 to 2010, the Ministry of Forestry estimated that the rate of the forest degradation in the state forest land was about 610,000ha.yr^{-1} (Indonesian Ministry of Forestry, 2011). Since the figure neglected the deforestation outside of the forestland, a different figure was proposed by Hansen et al. (2013) who estimated that the Indonesian deforestation rate between 2011 and 2012 was above 2 million ha.yr^{-1}.

One of the management strategies to combat the biodiversity loss, deforestation and forest degradation on the Indonesian forests is dividing all forests into Forest Management Units (FMUs), which is defined as the smallest management unit for efficient and the Sustainable Forest Management (SFM) (Indonesian Ministry of Forestry, 2011). Proper conservation planning is needed to conserve the forest that evaluates with proper criteria and techniques to prioritize the forest area (Phua and Minowa, 2005). Recent prioritization in conservation studies are focused on the identifying rich biodiversity forest for nature preservation (Carwardine et al., 2008). Literally, the prioritization was focused on determining the FMU rather than supporting the FMU management. In fact, the forest planning within the FMU still needs prioritization to deal with spatial and temporal dynamic in the forest landscape. The application of the conservation prioritization in supporting conservation planning is therefore needed to be studied.

Previous researches have been performed in improving the prioritization procedure. However, the acknowledgment of forest landscape characteristic in forest prioritization is still a niche in prioritization study. In addition, the widely available prioritization procedure needs adjustment on its application in forest landscape within FMU. Appropriate prioritization procedure is crucial for forest conservation planning.

This chapter formulates the framework for the tropical forest landscape prioritization. The expected output is to identify the appropriate perspective, task, criteria (component, sub-component, and parameter), weighting the management preference and analysis for conservation prioritization in SAFP.

2.2. Literature Review

2.2.1. Perspectives on forest landscape prioritization

Conservation is originally aimed to conserve particular important species such as birds (Buchanan et al., 2011), insects (Abellan et al., 2005) or mammals (Cofre and Marquet, 1999; Galetti et al., 2009). Selected species may attract public attention, play important roles in the ecosystem and has symbolic value (Phua and Minowa, 2005). However, the single-species perspective is expensive and inefficient for forest prioritization. Then, conservation shifted from species to landscape perspective (Trombulak and Baldwin, 2010). Landscape prioritization treats the whole ecosystem as the target rather than prioritize particular species. As a consequence, prioritization does not take into account the details of species by species (Valente and Vettorazzi, 2008). It is also in accordance with the forest management goal of sustainable forest ecosystem and landscape (Chen et al., 2008).

Landscape perspective on conservation prioritization gives a better perspective of forest conservation. It provides flexibility in the extent and considers a proper scale (Trombulak and Baldwin, 2010). It also acknowledges wider landscape processes such as the presence of inland water, upstream-downstream linkage (Nislow et al., 2010). Landscape, therefore, is an appropriate perspective for forest conservation prioritization.

2.2.2. Forest conservation tasks

Conservation is very complex with a wide range of activities. Viñas (2005) grouped the conservation into two main tasks, namely (1) preservation and (2) restoration. The concept is relatively new in natural resource management since the typical conservation activities are related to only preservation such as in Geneletti (2004), Nislow et al. (2010), Balaguru et al. (2006), and Soosairaj et al. (2007). Designing the biological preservation is the main focus on the conservation activities (Carwardine et al., 2008). The conservation concept in Viñas (2005) is considerably new, especially in forestry application.

Preservation and restoration have different characteristics and activities in the conservation. *Preservation* means an action taken to keep something as it is. It is the most common practice in conservation. Some studies often refer preservation as the same as conservation. The acknowledgment of preservation task has been accommodated in forest area management. Excluding a forest (or a part of the forest) from disturbance is a simple practice of forest preservation. Meanwhile, *restoration* is the action to alter the process to something like the original form (Viñas, 2005). *Restoration* task has been adopted in Indonesian forest management as *forest and land rehabilitation*. In fact, Roni et al. (2005) stated that restoration and rehabilitation terms have slightly different meaning. Restoration is aimed to achieve the original state. Meanwhile, rehabilitation is to improve some aspects or ecosystems into the functional state. Therefore, in the context of forest conservation planning, the term of *rehabilitation* is considerably more appropriate.

Defining the specific preservation and rehabilitation tasks should consider some externalities. The purpose of the forest assignment is the appropriate consideration for the consideration. Furthermore, in the broader perspective, the established Criteria and Indicator (C&I) for SFM also benefit to the task definition. ITTO (2005), have listed seven C&I for SFM in the tropical forests that can be considered in defining prioritization task. The purpose of the forest assignment and also C&I for SFM are valuable for identifying the conservation tasks in the forest.

2.2.3. Components and sub-components of forest prioritization

2.2.3.1. Value, threat, and priority

Component is the element of the conservation task. Component identification may vary among experts or decision makers. However, since the requirement for the conservation planning is to make the procedure is repeatable (Trombulak et al., 2010), different identified component and sub-component in prioritization may still be appropriate as long as the procedure in selecting them is clearly defined.

Nislow et al. (2010) gave guidance for conservation planning in the three steps: (1) identification of the biological diversity as the conservation targets including the current and desired status; (2) identification of threats that currently or likely to degrade the biological diversity; and (3) development of technique for prioritization. Those steps can be summarized into three keywords for component identification, namely the *value*, *threat,* and *priority*.

2.2.3.2. Value component and its sub-components

Defining the *value* component of the forest resources has not become a consensus among researchers. In fact, it has been debated for years (Secretariat of the Convention on Biological Diversity, 2001). It is caused by non-agreement on defining what can be included as the values and market distortions caused by non-priced goods in forest resources (Krieger, 2001). Value of the forest is commonly estimated in monetary value such as in Costanza et al. (1997). However, in forest prioritization, the precise estimation is not necessary. Only relative value among forest areas (unit analysis) is required.

The *value* component represents the importance of the activity. Biodiversity is the common component representing the value of the forest landscape (Nislow et al., 2010; Phua and Minowa, 2005; Soosairaj et al., 2007). It may be further broken down into sub-component such as forest condition (Valente and Vettorazzi, 2008), and vegetation types (Soosairaj et al., 2007). In addition, cultural and spiritual aspects may be included. However, the trade-off between values and measurability of the value becomes the problem (Secretariat of the Convention on Biological Diversity, 2001).

On the other hand, the value component of the rehabilitation task is considered as the *importance* to rehabilitate the forest ecosystem. Therefore, the appropriate value in rehabilitation is the severity of the forest and land degradation. In this context, the need to conserve the forest and land for soil and water conservation is the appropriate value component for the rehabilitation prioritization. The higher severity of the forest and land degradation counts the higher the value for rehabilitation.

Identification of the sub-component under each of the value component should be based on the prioritization context. Secretariat of the Convention on Biological Diversity (2001) stated the six contexts for determining the forest conservation values, i.e. (1) awareness raising, (2) determining damages for loss of forests, (3) revising the national economic accounts to reflect the values of forest goods and services, (4) land use decision, (5) limiting biological invasions, and (6) encouraging eco-certification. In the forest conservation prioritization, the context of land use decision is the most appropriate for identification of the sub-components.

Components are further detailed into sub-components. One of the relevant concepts to be considered in sub-component identification is High Conservation Value (HCV) or specifically High Conservation Value Forest (HCVF). The Forest Stewardship Council proposed the HCVF in 1999 (Aksenov et al., 2006) as part of the requirement on C&I for SFM (The Consortium for Revision of the HCV Toolkit Indonesia, 2009). The use of HCVF has been adopted in many studies with some adjustments. For example, Aksenov et al. (2006) mapped the HCVF by analysed the less fragmented forest landscape, naturally rare and unique forest communities, known habitat for rare and endangered plant species, and floodplain and bottomland ecosystems of intact river basins as the sub-components. Since different HCVs are often overlapped (Aksenov et al., 2006), few selected HCVs may be appropriate enough to represent the value of the forest landscape.

Consider that there is a wide range of options to identify sub-components in value components, landscape characteristics of the forest being studied should be the main consideration. The sub-components for value components can be extracted from HCVF. However, it must relevant to the forest landscape characteristics.

2.2.3.3. Threat component and its sub-components?

The term *threat* is often interchangeably used with the *hazard*, *disturbance* or *vulnerability*. Threat is considered as the relevant term for prioritization component (Pye and Pacific Northwest Research Station, 2010). Threat can be considered as the factor that potentially reduce the value of the biodiversity or decrease the urgency of the conservation task.

The most relevant threat component for preservation are deforestation and forest degradation which also are related to land use and land cover (LULC) change and forest fragmentation. LULC change is the driving force for threatening the ecosystem (Firdaus et al., 2014) and natural diversity (Alig et al., 2010a). The LULC may also cause forest degradation. Forest degradation is highly related to forest fragmentation since the complexity of the landscape increases due to the fragmentation (Lilieholm et al., 2010) and it causes a huge impact on landscape pattern (Bogaert et al., 2008). Thus, deforestation and forest degradation are the appropriate components as threat in forest preservation task.

In the rehabilitation task, threats are considered as factors that can reduce the importance of the rehabilitation activity. The treat component in rehabilitation task is more appropriately considered as the *urgency* component that put the urgency of the rehabilitation task for each forest area/ analysis unit. Consequently, the self-recovery ability of the forestland is the appropriate threat or urgent component for the rehabilitation task. Forests area that have a good self-recovery condition will have low urgency for rehabilitation task.

2.2.3.4. Forest priority

As the final step in forest conservation, prioritization is development of strategies to deal with both values/importance and threat/urgency (Nislow et al., 2010). In this stage, Multi-criteria Analyses (MCA) and expert judgment are often used (Phua and Minowa, 2005). For simplification, it can be generalized that the priority is the interaction between value/importance and threat/urgency as showed in the following equation:

$$P_i = V_i \times T_i \qquad \text{Eq. 2-1}$$

Where P_i is the priority of the i-th task, V_i is the value/importance component, and T_i is the threat/urgency component. Equation 2-1 specifies that conservation priority is the interaction between value/importance and threat/urgency.

2.2.4. Biophysical parameters for forest landscape prioritization

Parameters are measurable biophysical conditions of the forest landscape to represent the sub-components. Landscape is heterogeneous entities consisting of multiple kinds and spatial arrangements of ecosystems (Chen et al., 2008). Since the landscape is the proper perspective for forest planning (Nakagoshi and Mabuhay, 2014), forest prioritization must acknowledge the importance of landscape concepts on the forest.

Landscape ecology has two emphases on its definition (Turner et al., 2001). It emphasized the spatial configuration for ecological process and the extents which are much larger than those traditionally studied in ecology. Moreover, since the scale refers to physical spatial and temporal dimensions of an object or event (King, 2005), the landscape perspective in conservation prioritization must acknowledge scale, space, and time.

2.2.4.1. Scale

Scale is a fundamental concept in landscape. Forest prioritization can be effective when the selected scale is appropriate for the goal of the conservation (Trombulak and Baldwin, 2010). Landscape is regarded as having relatively large extent or scope compared to species-based perspective, which in turn has higher complexity. The scale must be considered in the prioritization process (Moilanen and Arponen, 2011). Woolmer (2010) proposed that the scale of 1:25,000 – 100,000 for feature and the resolution of 25 – 100 meters are appropriate. Working in higher resolution is rarely required for landscape analysis.

2.2.4.2. Spatial

Conservation planners increasingly acknowledge the importance of the spatial pattern of the forest (Trombulak and Baldwin, 2010) in developing and implementing a conservation plan. Boundary-less of the landscape process and connectivity of the forest landscape are among the reasons why spatial pattern of the forest landscape must be acknowledged (Trombulak and Baldwin, 2010) by the geographic information system (GIS) and other related tools (Geneletti, 2004; Moilanen et al., 2011). The nature of the spatial and temporal patterns in prioritization were discussed in Moilanen et al. (2011) that the spatial pattern influences the identification of the parameters for prioritization. All parameters have spatial dimension or can be derived from spatial data.

2.2.4.3. Temporal

Time aspect is one of the main landscape concepts. It is, therefore, an important aspect in forest landscape prioritization. Since the time is essential to understand the multigenerational connection of the nature (Baldwin and Judd, 2010), it is inevitable to include the temporal pattern in forest prioritization. Most of the temporal patterns of forest landscape are related to human impact because the human footprint on the landscape is transforming. It integrates human access, settlement, land use land cover change, and infrastructure (Trombulak et al., 2010). Change is a recurring theme in the conservation area in respect to human influence (Lilieholm et al., 2010). Acknowledging the temporal aspect improves the prioritization procedure in of the forest landscape.

2.2.5. Forest landscape prioritization in a Forest Management Unit (FMU)

Indonesian forests have three main functions, namely conservation, protection and production as shown in Figure 2-1. The conservation forest, which is defined as forest area with main function to conserve bio-diversity and ecosystem (Indonesian Ministry of Forestry, 2012), was divided into three categories, namely nature reserve area, natural preservation area, and hunting resort. Nature reserve is further divided into National Park, Nature Recreation Park, and Forest Park. One of the forest parks that have significant size and resource is Sultan Adam Forest Park (SAFP) that locates in South Kalimantan Province (Figure 1-3). The SAFP is one of the FMU that has the conservation function. It is managed by the South Kalimantan Provincial Government with the size of 112,000 hectares (Government of the Republic of Indonesia, 1989). The park is the frontier of the region for conservation of a wide variety of natural landscapes which ranging from *Imperata cylindrica* grassland to primary forest.

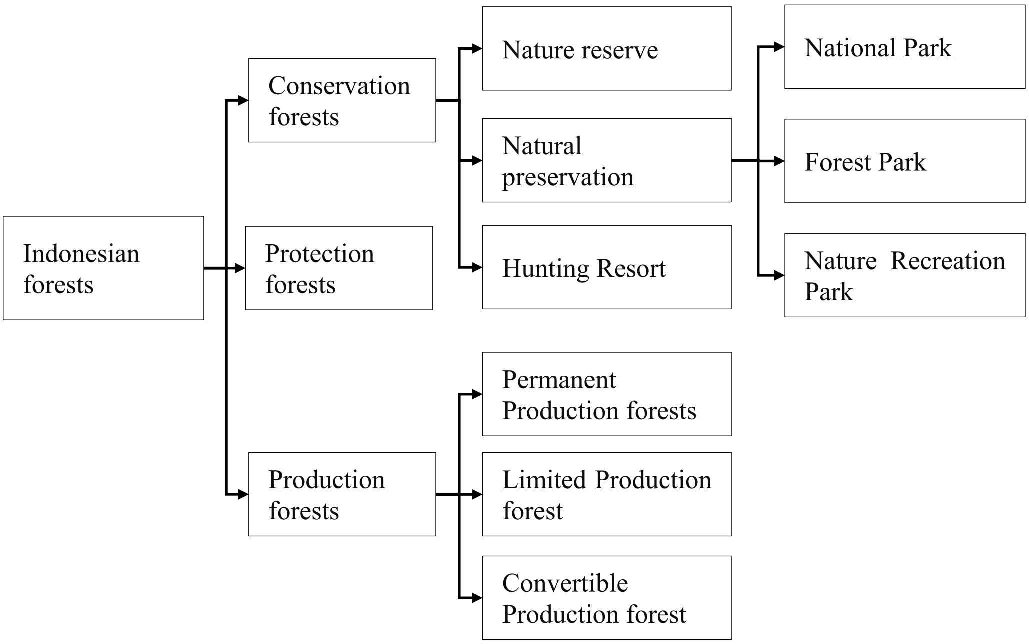


Figure 2-1: Indonesian forest function (adapted from Indonesian Ministry of Forestry 2012)

The development and application of the conservation prioritization in the Indonesian FMU, with the study site of SAFP, rise the opportunity and challenge. The fact that SAFP is one of the successfully assigned FMU; it is a good role model for other FMU development. The successful development and application of the conservation prioritization in SAFP in order to support the conservation planning can be the key to the similar application in other FMUs.

2.2.5.1. Opportunity for the priority application

The two main groups of the conservation tasks, namely preservation and rehabilitation, are generic terms that can be further adjusted and detailed in the development and application. Two considerations in defining the appropriate task are the purpose of the FMU assignment and C&I for SFM. SAFP has been managed by a site-level management body since 2010 (Government of the South Kalimantan Province, 2010). The FMU assignment in SAFP gave opportunity the application of the forest landscape prioritization.

According to Government of the Republic of Indonesia (1989) the purpose of the SAFP establishment were for (1) genetic resource preservation, (2) research (3) education, training and extension, (4) nature recreation / tourism, (5) natural scenery and micro-climate, and (6) hydrological safety measure. In addition, the prioritization task can be also based on the C&I for SFM. ITTO (2005) proposed seven criteria for SFM of tropical forests. Another C&I was also proposed in the Montreal Process (The Montreal Process Working Group, 2009) and Helsinki Process (Ministerial Conference on the Protection of Forests in Europe, 2001). Considering those, we proposed *biodiversity preservation* and *forest & land rehabilitation* as the main tasks for forest conservation prioritization in the park. Those proposed tasks are in accordance with the purposes of the SAFP establishment and also the C&I for SFM.

SAFP has a promising opportunity for developing a procedure for forest landscape prioritization. Its vast resources in terms of its size, ecosystem types, role and the FMU development phase have the potential to be the role model for tropical FMU to achieve better conservation planning. In turns, the SFM within the FMU framework could be expected.

2.2.5.2. Challenge in the priority application

Zonation is a major conservation strategy for the park management as the result of the prioritization process. In 1989, four zones were established to accommodate the origin of each forest function, namely (1) intensive use, (2) limited use, (3) protection, and (4) flora and fauna preservation zones. The zonation apparently did not comply with the scientific sound prioritization, however. A new delineation of those zones was proposed in the long-term planning in 2011 (Forestry Service of South Kalimantan Province, 2011). Unfortunately, the procedure about the zonation was not well explained. Since the requirements of the conservation prioritization procedure are repeatable (Trombulak et al., 2010) and objective (Liu et al., 2006), the current zonation still needs to be improved. In addition, the zonation also relatively static spatially and temporally. The application of the conservation prioritization in SAFP has the challenge to complement the current zonation system.

Even the proposed framework has a potential applicability in SAFP. The proposed procedure in SAFP still needs further studies. *First*, it needs to design the appropriate prioritization framework for conservation that accommodate appropriate concept, criteria, and approach for supporting forest conservation planning. *Second*, the application of the prioritization framework needs to be assessed in FMU application. Spatial and temporal dimensions that characterize the forest landscape should be acknowledged in the application. The optimum priority proportion also needs to be determined by forest manager. Some studies used arbitrary proportions of 5% (Woodhouse et al., 2000) 10% (Geneletti, 2004), or 30% (Zhang et al., 2014) as the priority proportion. *Third*, the proposed prioritization procedure only based on the conservation perspective. Thus, the technical aspects to address the resultant priority area still need to be considered such as resource availability, cost, and technical difficulties.

2.2.6. Summary of the literature review

Developing the conservation prioritization framework for forest planning in FMU requires a sequencing procedure. The procedure for the prioritization development is site-specific. Therefore, each site will have a different result depends on its landscape characteristics. The following is the underlined procedure on the development of the prioritization framework in SAFP.

1. Identification of tasks on both preservation and rehabilitation. The task is the goal in the prioritization.
2. Identification of components in each task which represent value/importance and threat/urgency

3. Identification of sub-components within each component
4. Assessment of biophysical parameters within each sub-component
5. Weighting of each criterion

In each step of the prioritization procedure listed above, some externalities must be considered. The purpose of the forest assignment and C&I of SFM are two externalities for the task identification. In the subsequent levels, value/importance or threat/urgency, forest landscape characteristics, and scale, spatial and temporal aspects are among externalities that must be considered in the prioritization process as shown in Figure 2-2.

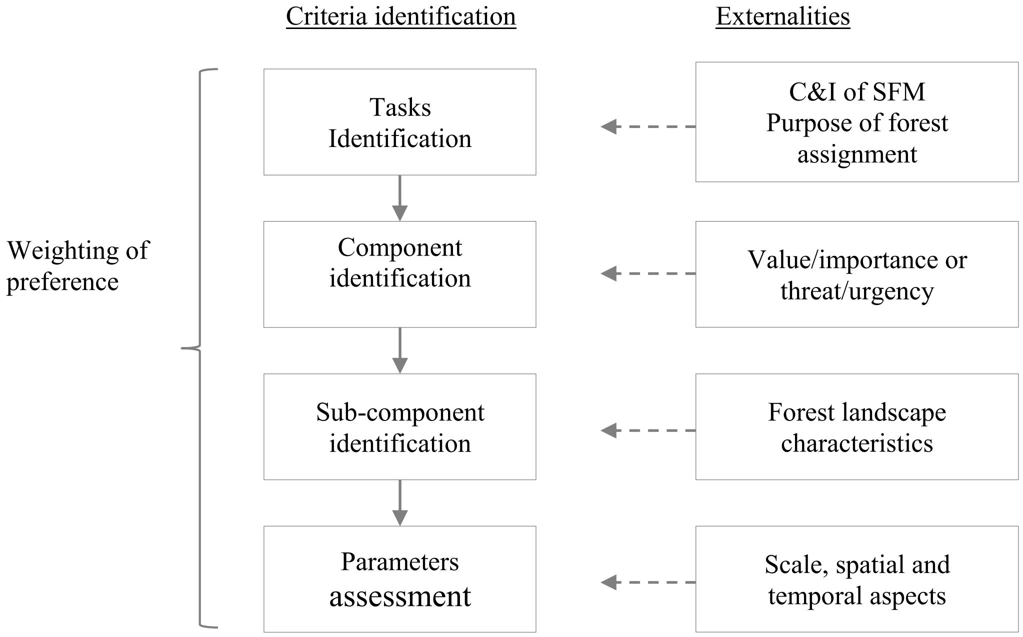


Figure 2-2: Prioritization procedure for conservation prioritization in SAFP

2.3. A GIS-based Multi-criteria Analysis

2.3.1. Conservation tasks definition

Task in conservation planning adopts the contemporary conservation concept that was proposed by Vinas (2004) which stated that conservation consists of two main tasks, namely (1) preservation and (2) restoration. Further, this study adjusted restoration into rehabilitation consider that the latest term is more appropriate (Roni et al., 2005). Rehabilitation is termed as the improvement of the forestland to the optimal condition until its functional state for the environment service.

Defining either preservation or rehabilitation tasks should consider the purpose of the forest management. SAFP is one of the forest parks that is part of the natural preservation area, within the Conservation Forest category. Since the conservation forest is forest are with typical characteristics with the aim function to conserve biodiversity and ecosystem thereof (Government of the Republic of Indonesia, 1999), therefore the management task in the SAFP must in accordance with the conserving the biodiversity and ecosystem.

Furthermore, in a broader and generic perspective, the established criteria and indicator: C&I for SFM was also reviewed. ITTO (1998), for example, listed seven C&I for SFM that was specifically targeted for tropical forests which have been revised in ITTO (2005) as follow.

Criterion 1: Enabling conditions for sustainable forest management

Criterion 2: Extent and condition of forests

Criterion 3: Forest ecosystem health

Criterion 4: Forest production

Criterion 5: Biological diversity

Criterion 6: Soil and water protection

Criterion 7: Economic, social and cultural aspects

Accordingly, other C&I for SFM have been also developed for other forest types such as in Montréal Process, that consists of seven criteria (The Montreal Process Working Group, 2009). European countries have also developed similar criteria and indicator for Pan-European region (Ministerial Conference on the Protection of Forests in Europe, 2001) which was known as Helsinki process. However, the Montreal and Helsinki processes were not developed specifically for tropical forest. The C&I from ITTO (2005), is considerably more appropriate for Indonesian forest landscape. Those available C&Is are presented in the following table.

Table 2-1: Criteria and indicators for SFM

Tasks	Related to			
	SAFP purpose	ITTO	Helsinki process	Montreal process
Biodiversity preservation	Purpose 1, 2, 3, 5	Criterion 5	Criterion 4	Criterion 1
Land rehabilitation	Purpose 6	Criterion 6	Criterion 5	Criterion 4

Preservation refers to keeping the entity as it is. This is certainly needed to be further specified in the application in the forest. What entity retained must be carefully defined? It is certain that preservation task must be addressed on the forest entity that has a good value for conservation such as preservation of old-growth forest, preservation of big mammal, etc. Since biodiversity is a generic terminology to encompass all good value entities in the forest landscape, therefore, this study considers using biodiversity preservation as the preservation task. Meanwhile, **rehabilitation** refers to improving the forest entity into the functional state. It needs to define what the entity to be rehabilitated. This study considers forest rehabilitation as the rehabilitation task. It encompassed not only vegetation, but also related to improving carrying capacity of the land to support its function. Conservation tasks and their description are shown in the Table 2-2.

Table 2-2: Conservation tasks for Sultan Adam Forest

No	Task	Description
1.	Preservation	Preservation of biodiversity encompasses all activities to preserve the biodiversity of species and forest ecosystems.
2.	Rehabilitation	Rehabilitation of biodiversity encompasses all activities to improve forest and land resource functions, carrying capacities and productivities.

2.3.2. Conservation component identification

Subsequent level of criteria called components, need to be identified under each of the conservation task: preservation and rehabilitation. The components were categorized into value/importance and threat/urgency in each conservation task. Therefore, under the preservation task, it needs to identify the value and threat components while, under the rehabilitation task, the importance and urgency components need to be identified.

In the preservation prioritization, biodiversity was the appropriate for the value component. Biodiversity value has been widely applied as the main consideration in recent studies on the conservation prioritization such as in Balaguru et al. (2006), Soosairaj et al. (2007), and Pouzols and Moilanen (2014). Meanwhile, deforestation and forest degradation was proposed to represent the threat component for preservation task. Deforestation and forest degradation can cause ecological and socioeconomic effects (Alig et al., 2010b). In addition, it is also relevant to the context that Indonesian forest suffer from deforestation which counts the second highest rate of deforestation among the tropical countries (Margono et al., 2010).

In the rehabilitation prioritization, soil and water conservation was selected as the importance component. The use of component has been widely studied in the study on the soil and water conservation such as in Indonesian Ministry of Forestry (2013) and Phua and

Minowa (2005). The aim of the forest rehabilitation to achieve the forestland in the functional state is relevant to the soil and water conservation component. Recover ability is introduced as an urgency component for the rehabilitation task. The need for rehabilitation across the forest landscape should consider the urgency since each forestland's tract has different recovery ability. It is assumed that the forestland that has good recovery ability has less urgency to be rehabilitated.

2.3.3. Sub-component identification and ranks

Sub-component identification must consider the forest landscape characteristic (Figure 2-2). Therefore, the listed sub-components in a particular site are different compared to others. On the application of conservation prioritization in SAFP, the listed criteria in the sub-components level were done by the following.

1. Possible criteria were identified by literature review;
2. All criteria were listed under the corresponding component;
3. Number of optimum criteria was consulted with the stakeholders;
4. Each criterion was assigned its rank by the stakeholder in SAFP;
5. The rank of the criteria among stakeholder were averaged by a simple arithmetic mean;
6. Three criteria at the sub-component level (under each of the component) were selected.

The resultant of the procedure above is definitely different if the same procedure was applied to other sites. It depends on the forest landscape characteristics, which are justified by the perception of the stakeholders or decision makers. However, since the most important aspect in prioritization is the clarity of its procedure and application, the procedure above was appropriately applied in SAFP.

2.3.4. Decision-making preference by weighting techniques

Weights were applied to the relative preference among the criteria. Some weighting methods have been widely used in the MCA. The most common method is equal weight (Phua and Minowa, 2005) which consider all criteria in the same level are evenly weighted. Another method is Analytic Hierarchy Process (AHP) that tries to use a descriptive approach in decision-making (Saaty, 2005) among intangible criteria. It is a semi-qualitative method in decision-making (Intarawichian and Dasananda, 2010).

2.3.4.1. Equal and proportionally-equal weight

Equal weight (evenly weight) is probably the most commonly used weighting method since it is simple and easy to use. Without well understanding the relative importance among criteria, the equal weight is the most reasonable weighting method. Equal weight has been used in many decision-making applications. In each criterion (component, sub-component, or parameter), the weight is assign evenly among branches. Proportionally equal weight is similar to equal weight. The difference is that it has proportional adjustment in each branch. For the case of forest rehabilitation prioritization,

2.3.4.2. Rule of weight

Key person may have a preference on the relative importance among criteria. Phua and Minowa (2005) gave an example how the key person (analyst) select one of the most significant criteria and assigned 1/2 weight to it. The other criteria take the rest of ½ weight equally. This weighting method gives benefit in some circumstances, for example, where the key person has previous knowledge about the area under study and objective sight on the assessing the relative importance among criteria.

2.3.4.3. Analytic Hierarchy Process (AHP)

Introduction to AHP

It is a semi-qualitative method in decision-making (Intarawichian and Dasananda, 2010). It is a descriptive approach to decision-making among intangible criteria (Saaty, 2005). Weight for each criterion was estimated by a pairwise comparison. In each comparison, it must be decided the degree of importance among criteria based on the preference as shown in the following table.

Table 2-3: Scale preference between two criteria in AHP

Scale	Degree of preference	Explanation
1	Equally	Two activities contribute equally to the objective
3	Moderately	Experience and judgment slightly to moderately favor one activity over another
5	Strongly	Experience and judgment strongly or essentially favor one activity over another
7	Very strongly	An activity is strongly favored over another and its dominance is showed in practice
9	Extremely	The evidence of favoring one activity over another is of the highest degree possible of an affirmation
2, 4, 6, 8	Intermediate values	Used to represent compromises between the preferences in weights 1, 3, 5, 7 and 9
Reciprocals	Opposites	Used for the inverse comparison

Adapted from Intarawichian and Dasananda (2010)

Participants

AHP was performed to assess the management preference on the intangible criteria in conservation prioritization. Since the object of the study is SAFP, therefore, the targeted participants in AHP are the decision makers and stakeholders who are involved in the SAFP management. The pairwise comparison calculation was performed by an excel worksheet with the geometric method to calculate the weight. Number of 20 participants were questioned to make a comparison as shown in Table 2-4.

Table 2-4: Participants of AHP in SAFP

Group	Number of participants
Experts	2
Decision makers	5
Technical staffs	5
Stakeholder / community	8
Total	20

Summary of AHP

The AHP was calculated in the **Appendix A** in page 237. The main goal of the calculation is in each of preservation and rehabilitation task. Therefore, the total of all weight in the criteria for preservation or rehabilitation tasks is one. The summary of the AHP is shown in Table 2-5.

Table 2-5: Summary of pairwise comparison for SAFP prioritization

No	Task / Component	Component	Category	Weight
1.	Preservation	value	Vegetation	.209
			Forest fragmentation	.133
			Species status	.158
		Threat	Forest fire	.205
			Settlement	.152
			Accessibility	.143
2.	Forest rehabilitation	Importance and Urgency	Vegetation	.525
			Erosion	.205
			Topography	.191
			Land management	.079

2.3.5. Hierarchy of decision

The proposed hierarchy of decision in conservation prioritization in SAFP is shown in Figure 2-3.

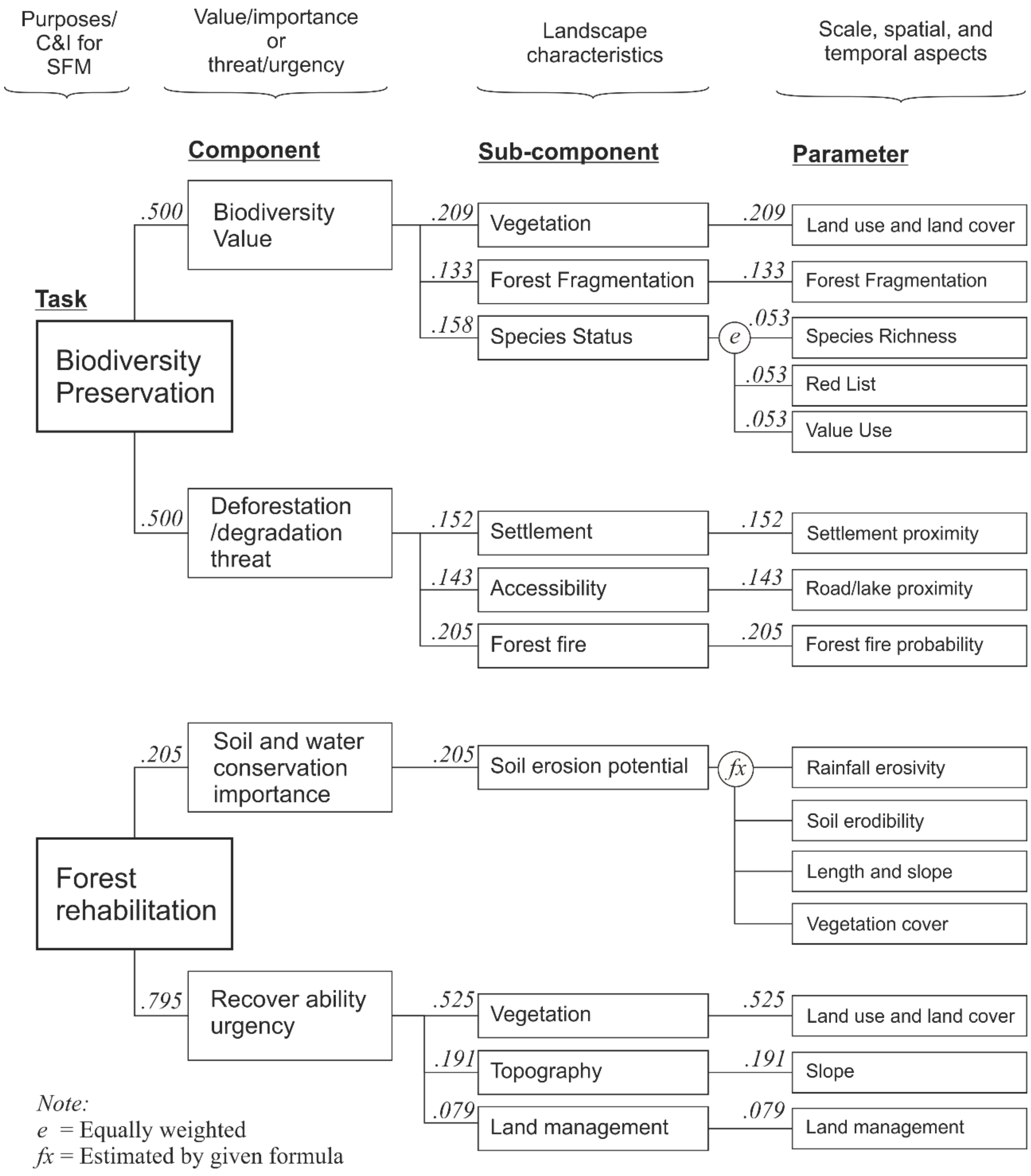


Figure 2-3: The framework of conservation prioritization of SAFP

Conservation prioritization framework, as shown in Figure 2-3, was the result of the literature review on references and combined within a GIS-based hierarchical framework. The criteria candidates were evaluated by the decision makers and stakeholders (Table 2-4) to select the appropriate criteria. The references used in the identification of the criteria for the levels of task, component, sub-component are listed in Table 2-6.

Table 2-6: References on the criteria identification

No	Criteria	Level of Criteria	References
1	Preservation	Task	Viñas (2005), Roni et al. (2005), Nislow et al. (2010)
2	Biodiversity value	Component	Sunderlin and Resosudarmo (1996), Balaguru et al. (2006), Alig et al. (2010b) Soosairaj et al. (2007), and Pouzols and Moilanen (2014).
3	Vegetation	Sub-component	Valente and Vettorazzi (2008), Phua and Minowa (2005), Soosairaj et al. (2007), Nislow et al. (2010)
4	Forest fragmentation	Sub-component	Aksenov et al. (2006)
5	Species status	Sub-component	Balaguru et al. (2006), Soosairaj et al. (2007)
6	Deforestation/degradation threat	Component	Balaguru et al. (2006), Soosairaj et al. (2007)
7	Settlement proximity	Sub-component	Balaguru et al. (2006), Soosairaj et al. (2007), Phua and Minowa (2005)
8	Accessibility proximity	Sub-component	Balaguru et al. (2006), Phua and Minowa (2005)
9	Forest fire	Sub-component	Tomich et al. (1998), Langner (2009)
10	Rehabilitation	Task	Viñas (2005), Roni et al. (2005), Indonesian Ministry of Forestry (2013)
11	Soil and water	Component	Indonesian Ministry of Forestry (2013)
12	Soil erosion potential	Sub-component	Dissmeyer et al. (1980), Indonesian Ministry of Forestry (2013), KKES (2002)
13	Hazard prevention	Sub-component	Phua and Minowa (2005)
14	Recoverability urgency	Component	Indonesian Ministry of Forestry (2013)
15	Vegetation	Sub-component	Indonesian Ministry of Forestry (2013)
16	Topography	Sub-component	Indonesian Ministry of Forestry (2013)
17	Land management	Sub-component	Indonesian Ministry of Forestry (2013)

2.4. GIS-based prioritization

2.4.1. What is priority area

The core of the conservation planning is conservation prioritization. Further, Carwardine et al. (2008) mentioned that the essence of the conservation planning is prioritization, which is identifying the smallest possible are to be managed. In practice, a GIS-based prioritization is widely accepted in forest application (Geneletti, 2004; Moilanen et al., 2011; Phua and Minowa, 2000).

The area that has the highest index on the GIS-based prioritization is the priority area. Resultant priority area depends on the proportion used to determine the priority. The proportion of 25% was used arbitrarily as the priority proportion in this study.

2.4.2. GIS-based Prioritization procedure

Geographic Information System (GIS) approach was used for conservation prioritization. This study adapted Phua and Minowa (2005) to perform a GIS-based multi-criteria decision-making. All pixels in criteria (component, sub-component or parameter) can be represented as

$$X = \left\{ x^1, x^2, \ldots, x^K \right\} \qquad \text{Eq. 2-2}$$

Each pixel has a multi-criteria *i*-attributes. One x_i^k represents the score of the attribute i by pixel k as below.

$$x^k = \left(x_1^k, x_2^k, \ldots, x_I^k \right) \qquad \text{Eq. 2-3}$$

where $k = 1, 2, \ldots, K$; $i = 1, 2, \ldots, I$

The evaluation of the forest preservation prioritization can be obtained by using the equation below.

$$C^k = \sum_{i=1}^{I} w_i x_i^k \qquad \text{Eq. 2-4}$$

where C^k is the designated forest preservation priority by *k*-th alternative. x^k is the *k*-th alternative which represents one pixel contains *i* indicators with standardized score as a GIS layer. The w_i in Equation 2-4 was determined by the weighting method, whether equal, proportionally equal, rule-of-weight or AHP.

2.4.3. Standardization of value (index)

Standardization is needed due to non-commensurate of the criteria (Phua and Minowa, 2005). This study adopts the minimum and maximum scores as the scaling points. The values of every criterion were calculated as indices, which means that all values were normalized into 0 – 1 range. For the criteria where a higher score indicates higher importance, it was standardized using Equation 2-5. Otherwise, Equation 2-6 was used.

$$x_i^k = \frac{s_i^k - s_i^{\min}}{s_i^{\max} - s_i^{\min}} \qquad \text{Eq. 2-5}$$

$$x_i^k = \frac{s_i^{\max} - s_i^k}{s_i^{\max} - s_i^{\min}} \qquad \text{Eq. 2-6}$$

where $s^{\min}$ is the minimum score and $s^{\max}$ is the maximum score for each criterion. The normalization was also applied in the regression analysis for the species status index.

2.5. Change analysis

Kappa analysis is widely used to analyse the accuracy of the classification map from remotely sensed imagery (Jensen, 2005; Lillesand and Kiefer, 1994). The similar concept was also used to detect the change of the Land Use and Land Cover (LULC) from different year (Jensen, 2004; Torahi and Rai, 2011). Kappa analysis uses a Kappa statistics of $\widehat{K}$ (K hat) which is an estimation of the Kappa that can be calculated as in the following formula

$$\widehat{K} = \frac{N\sum_{i=1}^{k} x_{ii} - \sum_{i=1}^{k} x_{i+} \times x_{+i}}{N^2 - \sum_{i=1}^{k} x_{i+} \times x_{+i}} \qquad \text{Eq. 2-7}$$

where k is number of rows (in this case was land cover classes) in the matrix, x_{ii} is number of observations in row i and column i, and x_{i+} and x_{+1} are the marginal totals for row i, respectively and N is the observation total number.

Kappa statistic ($\widehat{K}$) can be categorized into several categories following Landis and Koch (1977). In addition, in remote sensing application, Jensen (2004) simplified the category of the Kappa statistic into three classes as shown in Table 2-7. The kappa statistics lower than 0.4 is considered as change, between 0.4 and 0.8 is moderately change, and above 0.8 is no change.

Table 2-7: Kappa statistic category

Kappa statistic $\widehat{K}$	Category	Change category	Agreement category
< 0.00	Poor	Change	Poor agreement
00 – 0.20	Slight	Change	Poor agreement
0.21 – 0.40	Fair	Change	Poor agreement
0.41 – 0.60	Moderate	Moderate change	Moderate agreement
0.61 – 0.80	Substantial	Moderate change	Moderate agreement
0.81 – 1.00	Almost perfect	No change	Good agreement

Adapted from Landis and Koch (1977) and Jensen (2004)

Change analysis is interchangeably used with accuracy assessment. Accuracy assessment is used to assess the resultant LULC classes derived from the remotely sensed imagery. While the agreement between the resultant prioritizations were also performed to assess the difference in methodology used. The term of the agreement was used instead of change in that analysis.

2.6. Proposed framework in the recent forest prioritization

This study developed and applied prioritization for conservation planning. Prioritization has been widely used for identifying nature preserve area (Carwardine et al., 2008) or zoning within designed nature preserve area (Mulyana et al., 2010; Soosairaj et al., 2007). However, the application of the prioritization for conservation planning has not studied yet. Thus, this study explored the prioritization development and its application to support the forest planning in FMU level management. Some advances in this study compare with the recent forest prioritization studies are in concept, criteria, approach and possible application as shown in Table 2-8.

Table 2-8: The differences or improvements in the study compare with recent practices

Aspects	Current / Existing practices	The study's approach
Concept	Conservation planning is the preservation	Conservation planning is the combination of preservation and rehabilitation
Criteria	Identified and evaluated	Components are divided into value/importance and threat/urgency; then all criteria were identified and evaluated for each component
Approach	Species approach • Specific purpose • Costly • Long period of analysis	Landscape approach • Comprehensive purpose • Economical • Short period of analysis • Ignores details
Application	• Relatively static (Spatial and temporally) • For legal guidance	• Spatial and temporally dynamic • For planning purpose

2.6.1. Conservation concept

The proposed framework for conservation planning in forest landscape was in debt to the recent concept of conservation that has been discussed in Viñas (2005) that mentioned that there are four alternatives dealing with an object. It can be *kept*, *changed*, *destroyed* or *returned to the previous condition*. Among those actions, conservation deals with the two alternatives: keep it or returning it to the previous condition. Thus, it was summarized that forest conservation consists of two main tasks of **preservation** and **rehabilitation**.

Most recent studies on the conservation prioritization do not consider both preservation and rehabilitation. Studies by Geneletti (2004), Nislow et al. (2010), Balaguru et al. (2006), Soosairaj et al. (2007) considered conservation as merely preservation. Geneletti (2004), for example, started the conservation priorities identification by defining criteria for preservation and followed by evaluation on the criteria. Neglecting rehabilitation as part of the conservation leads to costly consequence. This confirmed that the typical focus on the conservation planning is designing the biological reserve (Carwardine et al., 2008). In fact, forest management deals with many actions need to be considered to achieve the conservation goals, including rehabilitation. Therefore, this study considered that conservation consists of two tasks of preservation and rehabilitation.

2.6.2. Criteria identification

Further, in order broke down both preservation and rehabilitation into components, the similar approaches by Nislow et al. (2010) was adopted. Two components of preservation task were defined, namely *value* and *threat*. Under the rehabilitation task, the *importance* and *urgency* components were identified. Then, all relevant criteria were identified and evaluated under each of the components.

In the next step of prioritization framework development, all identified criteria were listed under four component of *value*, *threat*, *importance*, and *urgency*. The criteria identification were adopted from many references by considering the specific condition of the study site. Since Nislow et al. (2010) underlined that proper methods for making prioritization procedure must use explicit criteria for allowing tracking the prioritization, therefore, this study refers to some references.

Even a study used different approach when designing the component, commonly used criteria were considered in this study. For example, a study in India by Balaguru et al. (2006) used vegetation type, species' richness, endemic species, and red-listed species for identifying conservation priority. Those criteria were considered to be adopted in the preservation task even the main concept was different. The soil and water conservation in Phua and Minowa (2005) was also accommodated as one of the criteria. However, it was modified as one of the criteria for the rehabilitation task. In short, even this study started with a different approach in designing the framework; this study adopted many listed criteria commonly used in the references.

2.6.3. Landscape approach

As it has been discussed that there is a recent shift from single species to the landscape approach in conservation analysis (Trombulak and Baldwin, 2010). This study used the landscape approach since it offers some advantages for the conservation planning. It considers the whole forest as an ecosystem rather than focusing on single species. As the consequence, the approach omits many details that make the analysis simpler than species' approach. This advantage of the landscape approach is relevant to forest planning that requires simpler and faster analysis.

However, this study does not compare the landscape approach with species' approach. Since the prioritization application is aimed as the complementary on the zonation and special zone assignment, therefore, the species based is still considered as a valuable approach for forest planning, especially for zonation or special zone assignment.

2.6.4. Application

Zonation is a critical tool for forest landscape management. SAFP has been divided into four zones of preservation zone, protection zone, limited-use zone and intensive use zone (Forestry Service of South Kalimantan Province, 2011; Government of the Republic of Indonesia, 1989). In addition, the FMU management may establish a special zone to accommodate local communities, public facilities and infrastructure (Mulyana et al., 2010). The zonation system and special zone assignment are beneficial to FMU management. In the advance development of FMU in Indonesia, however, the conservation planning need spatial and temporally dynamic tool. Therefore, this study considered conservation prioritization can be developed to support the conservation planning in FMU. The prioritization application, which has been widely used for the nature reserve, was extended to support the forest planning within FMU.

2.7. Lessons learned

On the literature review of the conservation prioritization concept and application and the progress of the methodological approach to perform the conservation prioritization, it can be summarized into the following points.

1. Conservation is often regarded as preservation activities. Since the contemporary conservation concept included rehabilitation as an integral part of conservation, the application of the concept of forest landscape management needs to be studied.

2. Conservation prioritization procedure consists of determining criteria and assessing weights. Criteria, which is preferably developed based on MCA, consists of tasks, component, sub-components, and parameters. Meanwhile, weight that represents the decision-making preference is defined by AHP or other weighting methods.
3. Conservation task, which can be in either preservation or rehabilitation, must recognize the purposes of the forest establishment and or C&I of SFM. The task is the main goal in the top hierarchy of MCA. In conservation prioritization, therefore there are two main goal of MCA, namely preservation and rehabilitation.
4. Identification of the component under each conservation task should consider *value/importance* and *threat/urgency*. The acknowledgment on the threat/urgency component is often neglected. However, the significance of the threat/urgency still need to be studied.
5. Parameters for each sub-component are identified by acknowledge scale, spatial and temporal aspects of the forest landscape. All parameters for forest conservation prioritization should have spatial and temporal dimensions as the consequence of the landscapes approach.
6. Among available weighting methods, AHP is the most favored method since it has combined the analytic process into decision-making. However, other available methods show their applicability in some studies.
7. The framework for conservation prioritization has appropriately developed by considering the landscape characteristics of SAFP and some improvements from current or existing practices. However, the application of the framework still need to be studied in terms of how the conservation concept, criteria identification, and landscape approaches contribute to better prioritization in forest conservation planning.

Chapter 3: Forest Landscape Biophysical Assessment for Tropical Forest Landscape Prioritization

3.1. Introduction

Forest landscape biophysical assessment is indispensable in conservation prioritization. Conservation prioritization framework, as shown in Figure 2-3, was developed by a GIS-based multi-criteria analysis. It has several levels of hierarchy of criteria (task, component, sub-component, and parameter). Parameter was assessed from the forest landscape biophysical conditions. Therefore, forest landscape biophysical assessment is essential for conservation prioritization.

Applying landscape perspective in preservation prioritization acknowledge the fundamental concept of landscape, namely scale (King, 2005), spatial and temporal (Turner et al., 2001). Scale was adopted in data selection for the analysis referring to Woolmer (2010) that the scale of 1:25,000 – 100,000 for feature and the resolution of 25 – 100 meters are appropriate for landscape analysis. Spatial and temporal were assessed in the patterns of the biophysical conditions in 1993, 2003 and 2013 as part of the purpose of this chapter.

This chapter is aimed to prepare the biophysical conditions data and assess their spatial and temporal changes. Since biophysical conditions were assessed for the parameter of conservation prioritization, therefore, the spatial and temporal patterns of the biophysical conditions affect the prioritization. The biophysical conditions can be categorized in the sub-component categories as land use and land cover (LULC), forest fragmentation, species status, settlement, accessibility, forest fire, soil erosion potential, hazard prevention, topography, and land management.

3.2. Land use and land cover (LULC)

3.2.1. LULC Method

3.2.1.1. LULC Data

The study on LULC used two types of data, namely remotely sensed data and ground check data (Table 3-1). Landsat 5, Landsat 7 and Landsat imageries were the sources of the LULC classification for 1993, 2003, and 2013, respectively. In order to assess the accuracy of the LULC classification in 2013, ground check data was used for the accuracy assessment.

Table 3-1: Data for LULC analysis

No	Data	Type	Scale, resolution, number	Year	Coverage, extent	Source
1.	Landsat 5 imagery	Raster	30 m multi 15 m pan	1993	117-62 117-63	USGS
2.	Landsat 7 imagery	Raster	30 m multi 15 m pan	2003	117-62 117-63	USGS
3.	Landsat 8 imagery	Raster	30 m multi 15 m pan	2013	117-62 117-63	USGS
4.	Ground check	Vector Point	96 points	2012	SAFP	Field work

Remotely sensed data

Remotely sensed data for LULC was derived from multi-sensors Landsat imagery. Landsat 5 TM was used to derive the LULC data in 1993, Landsat 7 ETM+ was used for LULC data in 2003, and Landsat 8 was used for LULC data in 2013. All Landsat images were obtained from the United State Geological Survey (USGS) in the L1GT product processing level. The study site of SAFP is located at the edge between two scenes of the World Reference System 2 (WRS-2), which was used by Landsat 5, 7 and 8. Thus, in one-year observation, path/row 117/62 and 117/63 were obtained. The position of SAFP within the WRS-2 is shown in Figure 3-1.

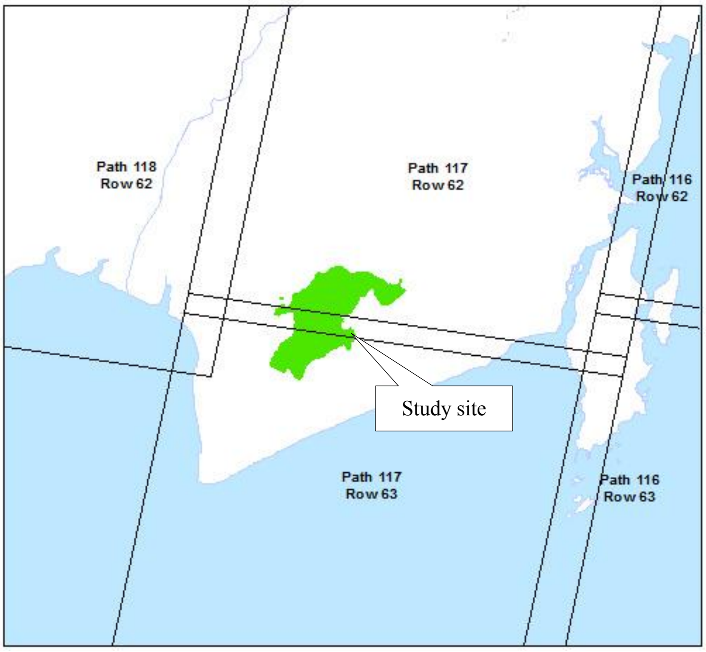


Figure 3-1: Position of SAFP in the World Reference System-2

Landsat 5, 7 and 8 have different specifications that are related to wavelength and band composition. Acknowledgment on the specification of the sensor being used in each Landsat satellite will benefit to the proper image analysis. The specification of the Landsat 5, 7 and 8 and their sensors are presented in the following table.

Table 3-2: Specification of the Landsat 5, 7 and 8

Sensor	Bands / Name	Wavelength µm	Resolution
Landsat 5 TM	B1 – visible	0.45 – 0.52	30 m
	B2 – visible	0.52 – 0.60	30 m
	B3 – visible	.0.63 – 0.69	30 m
	B4 – Near-infrared	0.76 – 0.90	30 m
	B5 – Near-infrared	1.55 – 1.75	30 m
	B6 – Thermal	10.40 – 12.50	120 m
	B7 – Mid-Infrared	2.08 – 2.35	30 m
Landsat 7 ETM+	B1 – visible	0.450 – 0.515	30 m
	B2 – visible	0.525 – 0.605	30 m
	B3 – visible	0.630 – 0.690	30 m
	B4 – Near-infrared	0.750 – 0.900	30 m
	B5 – Near-infrared	1.550 – 1.75	30 m
	B6 – Thermal	10.40 – 12.5	60 m
	B7 – Mid-Infrared	2.090 – 2.35	30 m
	B8 – Panchromatic	0.520 – 0.900	15 m
Landsat 8 OLI/TIRS	B1 – Coastal aerosol	0.43 – 0.45	30 m
	B2 – Blue	0.45 – 0.51	30 m
	B3 – Green	0.53 – 0.59	30 m
	B4 – Red	0.64 – 0.67	30 m
	B5 – Near Infrared	0.85 – 0.88	30 m
	B6 – SWIR 1	1.57 – 1.65	30 m
	B7 – SWIR 2	2.11 – 2.29	30 m
	B8 – Panchromatic	0.50 – 0.68	15 m
	B9 – Cirrus	1.36 – 1.38	30 m
	B10 – Thermal Infrared 1	10.60 – 11.19	100 m
	B11 – Thermal Infrared 2	11.50 – 12.51	100 m

Source: USGS (2012)

Ground check data

Ground check data was obtained in 2012. The observed ground checkpoints were used to check the accuracy of the LULC classification in 2013. The 1-year difference between ground check data and satellite image were considerably insignificant. The observation points were purposively distributed across the study site consider the representativeness among zonation and LULC classes. The summary of the ground checkpoint is shown in the following table.

Table 3-3: Distribution of the ground checkpoint among LULC

Zone	Number of points
Preservation	21
Protection	28
Limited Use	2
Intensive Use	45
Total	96

The locations of the ground checkpoints were established in SAFP purposively with the location shown in Figure 3-2. The result of the fieldwork on the ground check data was presented in the **Appendix B** in Page 240.

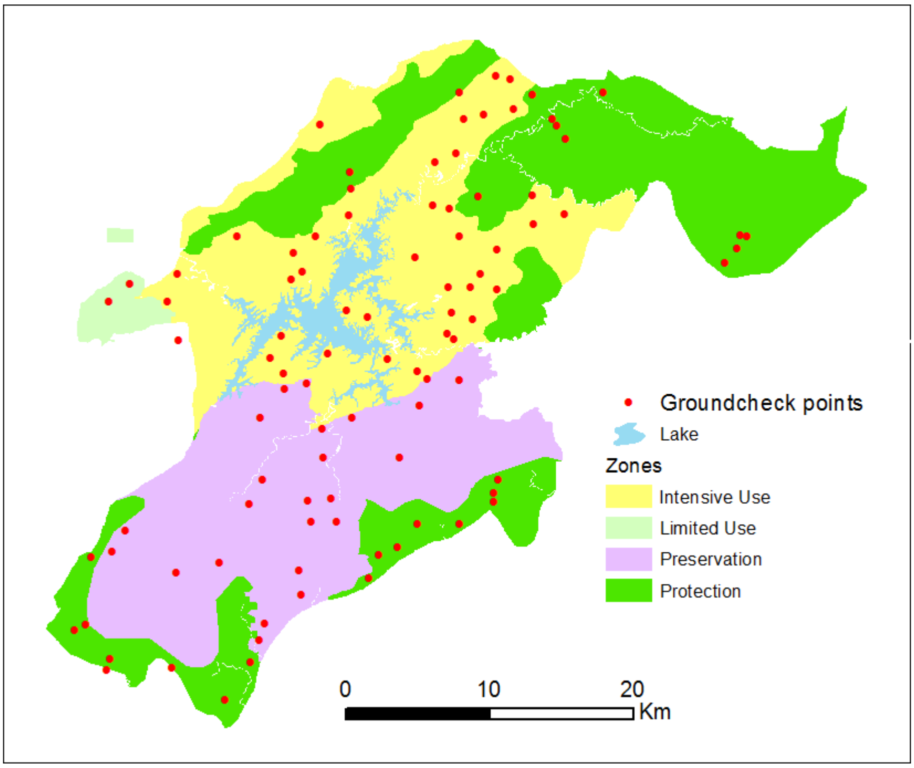


Figure 3-2: Spatial distribution of ground checkpoints

3.2.1.2. LULC Analysis

Image preprocessing

Image preprocessing consisted of some steps of image arrangements before being processed in the image analysis. The following were processing steps for the Landsat images in this study.

- Projection: The Universal Transverse Mercator (UTM) Zone 50 South is used in this study. All images were projected into UTM 50 S.
- Geometric transformation: Since this study used a temporal analysis on the Landsat images in 1993, 2003 and 2013. Thus, a relative accurate position among those images is required. One of the Landsat 8 image scenes was set as the 'master' for geometric transformation. Other Landsat 8, Landsat 7 and Landsat 5 images were geometrically registered to that 'master' image.
- Composite and pan-sharpened: Composite and pan-sharpened image were generated for visual assessment in plotting the training area and for visual inspection in post-classification.

Top of atmospheric reflectance

To reduce the effect of the atmosphere on the Landsat images, this study used a top atmospheric (TOA) reflectance with the dark object subtraction (DOS) method as suggested by Song et al. (2001). The DOS method assumes that there is a high probability that there are at least few pixels within an image which should be black or zero reflectance (Chavez, 1988). The best method to perform DOS was provided by DOS3. However, due to its complex correction method, Congedo and Munafò (2012) suggested DOS1 as it provided very similar result compare to DOS3.

As the study use L1GT product in 16-bit integer format, it can be easily converted to TOA radiance or reflectance using the scaling factor in the metadata (USGS, 2012). Conversion from digital number (DN) to satellite radiance unit (L) was calculated by the following equation.

$$L_\lambda = \left(\frac{LMAX_\lambda - LMIN_\lambda}{Q_{calmax} - Q_{calmin}}\right)(Q_{cal} - Q_{calmin}) + LMIN_\lambda \qquad \text{Eq. 3-1}$$

Then the satellite radiance was then converted into top atmospheric (TOA) reflectance by the following equation.

$$\rho = \frac{\pi L d^2}{\mathrm{ESun}_\lambda \cos\theta} \qquad \text{Eq. 3-2}$$

The TOA reflectance for all bands of Landsat 8 was calculated by *i.toar* function in GRASS GIS software (GRASS Development Team, 2012).

Topographic normalization

Topographic normalization is important for image classification (Füreder, 2010), especially in a rough terrain site (Wei et al., 2008). In order to avoid the influence of the topographic illumination, topographic correction was performed by using a c-factor method. Various methods have been proposed for topographic normalization such as Minnaert correction, C-correction and statistic-empirical correction for topographic normalization (Füreder, 2010). However, Hantson and Chuvieco (2011) and Riaño et al. (2003) disclosed that the c-correction and the empiric-statistic correction were the best results for topographic correction on Landsat TM ETM+.

The topographic correction must preserve the original means and decrease the standard deviation (Law and Nichol, 2004). As can be shown in the Figure 3-3 that topographic normalization produce a relatively similar tone on the east and west sides of the hill in one part of the study site (SAFP). It was expected that the topographic normalization improved the image classification result.

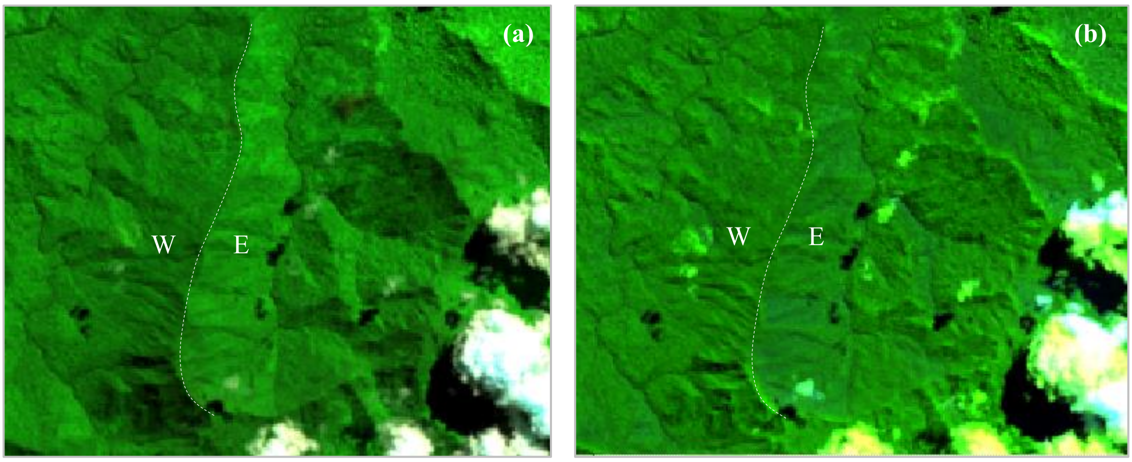


Figure 3-3: Composite of Band 7-5-3 of Landsat 8 images in (a) before topographic normalization and (b) after topographic normalization at Landsat taken at 19 June 2013

Multi-temporal Relative Radiometric Normalization (RRN)

This study uses three different image acquisition years (1993, 2003 and 2013) and also different sensors (TM, ETM+ and OLI/TIRS). Atmospheric correction was performed to remove the atmospheric effect on the images. Therefore, the images taken in different years might have the same characteristic. However, different sensors produced different spectral ranges of each targeted bands. Normalization was required therefore RRN was performed.

Set of bands of Landsat 8 image was selected as the 'master' to normalize the corresponding band in Landsat 5 and Landsat 7. RRN was performed in each band by using a Pseudo Invariant Features (PIFs) (Huete, 1998). The PIFs for the lower DN and upper DN are determined by the following formula (Yang and Lo, 2000).

$$PIFs = \left\{ \left(\frac{B4}{B2} \right) \leq t_1 \text{ and } \left(B4 \geq t_2 \right) \right\}$$

Eq. 3-3

Where t_1 and t_2 were defined as the thresholds for lower and upper DN respectively. The thresholds were defined by slicing the DN visually and compared with the composite image one each acquisition date. Since the RRN was performed in each band, therefore number of PIFs plot that regressed each band in Landsat 5 and Landsat 7 with the corresponding band in Landsat 8 as the 'master'. The example of the PIFs plot is shown in Figure 3-4.

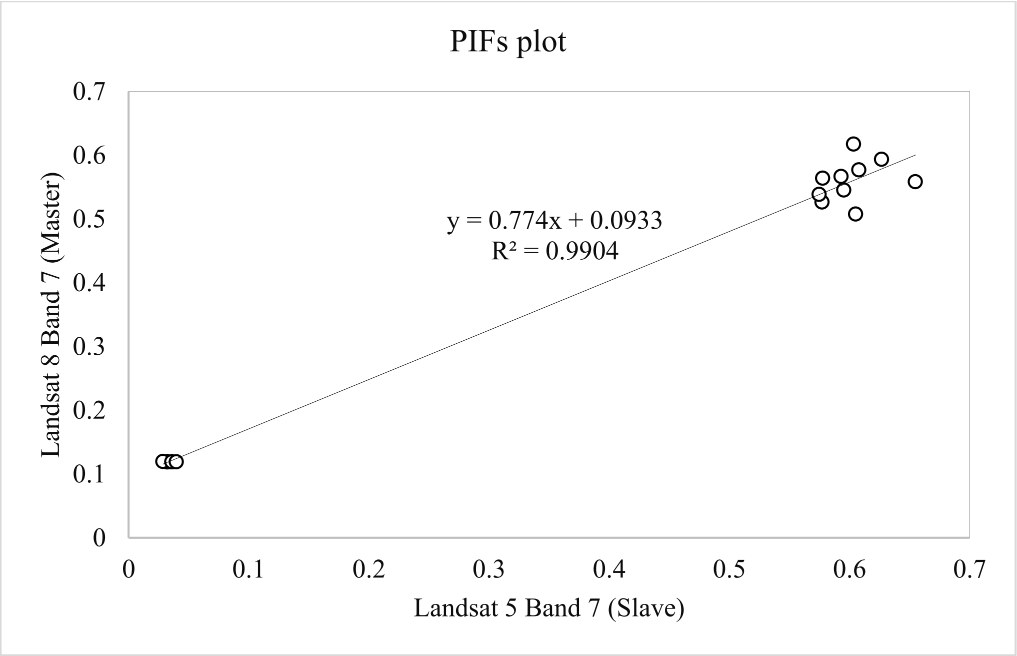


Figure 3-4: An example of PIFs plot in Band 7 (Landsat 5, slave) and Band 7 (Landsat 8, master)

Based on the equation in Figure 3-4. A new Band 7 (Landsat 5) was therefore generated from the old one by the formula of $y = 0.774x + 0.0933$.

Image mosaicking

Image mosaicking was implemented to stitch two different scenes of the Landsat images into one image. Image mosaicking was the consequence of the two path/row in the study site as shown in Figure 3-1. Mosaicking was performed on the image that has been pre-processed (atmospheric correction, topographic normalization and RRN). The simple mosaicking rule was applied. The image in the path/row 117/63 was used as the 'master'. In which SAFP was not covered by the 'master' image, the image in the path/row 117/62 was used.

Cloud and cloud shadow removal

Cloud on each image was removed by different methods. Landsat 8 used Quality Assessment (QA) band to remove the cloud while Landsat 5 and 7 used Automatic Cloud Cover Assessment (ACCA).

Table 3-4: Cloud removal method for Landsat imageries

Satellite	Acquisition year	Cloud removal method
Landsat 8	2013	QA band
Landsat 7	2003	ACCA
Landsat 5	1993	ACCA

In Landsat 8, cloud was removed by investigating the QA band as described by USGS (2013). As the value of the QA band was stored in 16 bit, the conversion of the value to a binary was carried out. If the value of the bit 14 and bit 15 are 'cloud' or 'maybe cloud', thus the pixel was categorized as cloud (Table 3-5). In Landsat 7 and 5, cloud was removed by the ACCA method using GRASS GIS software (GRASS Development Team, 2012). One pixel buffer was added as cloud to incorporate the border of the cloud that could not be detected by the QA band.

Table 3-5: Bit and explanation in Quality Assessment (QA) band

Bit	Description	Note
15 14	Cloud confidence	Double bit explanation 00= Not determined 01= No 10= Maybe 11= Yes Single bit explanation 0 = No 1 = Yes
13 12	Cirrus confidence	
11 10	Snow/ice confidence	
9 8	Vegetation confidence	
7 6	Reserved for cloud shadow	
5 4	Water confidence	
3	Reserved	
2	Terrain occlusion	
1	Dropped frame	
0	Designated fill	

Adapted from USGS (2013)

As the automated cloud cover assessment algorithm and QA band don't include the cloud shadow detection (Irish et al., 2006), the brightness value of NIR band (**band 5** in Landsat 8) was used to detect the shadow as explained by Martinuzzi et al. (2007). A simple density slicing of band 5 combined with visual inspection of the ground-truth image is used to detect the cloud shadow.

Water body identification

Water body was identified from the imagery by a simple slicing method as discussed by Frazier and Page (2000) on the band 5 (of Landsat 5 and Landsat 7). In Landsat 8, the similar wavelength of band 6 was used instead. The band 5 (or band 6) were used to detect the water body by density slicing method combined with visual verification on the pan-sharpened image.

Classification

LULC classes have been guided in the Indonesian National Standard (NSI) No. 7645:2010 by the National Standard Agency of Indonesia. Since the LULC topology must follow the corresponding scale, it requires selecting the appropriate scale for the analysis. This study adopted the standard LULC classes on the scale of 1:250,000 as follow.

Table 3-6: Land use and land cover classification classes

LULC	Description
(Dryland) Forest	Dry land forest that includes a lowland forest, hill, and mountainous forest, or highland
Mixed plantation	Agricultural land, covered by various vegetation.
Shrub/bush	Dry land that has been covered with various vegetation, which is dominated by natural short woody vegetation. Indonesian shrub/bush is usually ex-logged forest, which does not show the logging patterns.
Grassland	Cleared land dominated by various grasses. This includes the *Imperata cylindrica* and savanna.
Bare land	Land without natural, semi-natural or artificial cover
Water body	Lake or river

Adapted from NSI No. 7645:2010

Landsat image classification used a band combination proposed by Chang and Yoon (2003) who proposed Band 2, Band 7 and PC2 of Landsat 7 imagery. For Landsat 8 and Landsat 5 imagery, the corresponding bands (similar wavelength) were used, for example, Band 2 in Landsat 7 (0.525 – 0.605 μm) is corresponding to Band 3 in Landsat 8 (0.53 – 0.59 μm). Therefore, Band 3, Band 7 and PC2 were used for Landsat 8. The bands used in the classification are presented in the following table.

Table 3-7: Bands used in classification

Sensors	Bands fo Classification	Bands for PC2
Landsat 5	Band 2, Band 7 and PC2	1, 2, 3, 4, 5, 7
Landsat 7	Band 2, Band 7 and PC2	1, 2, 3, 4, 5, 7
Landsat 8	Band 3, Band 7 and PC2	2, 3, 4, 5, 6, 7

The classification of Landsat images was performed by using a supervised classification method. For that purpose, Training Areas (TAs) were made by using ground check data (Table 3-3 and Figure 3-2). Since the ground check is set of point data, therefore, training area were delineated by using the ground check location and visual appearance on composite 742, 543, PC2 and Normalized Difference Vegetation Index (NDVI) imagery of the image. TA delineation and the ground checkpoint on the Landsat 8 imagery (2013) was shown in Figure 3-5.

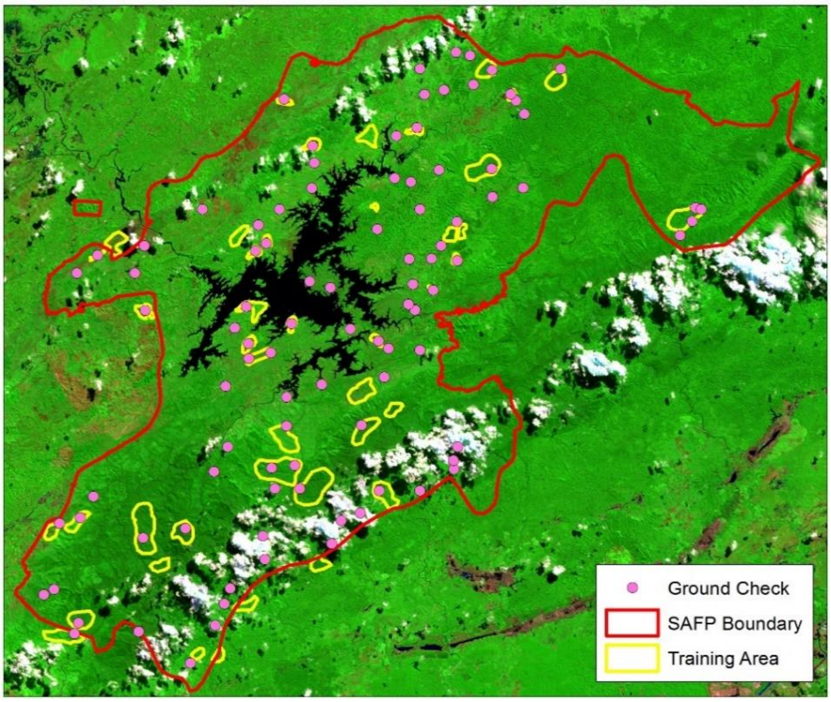


Figure 3-5: The distribution of the training area and ground check

The composite of bands 742 in Landsat 7 (or bands 753 in Landsat 8) and PC2 showed the great enhancement on the training area delineation. The composite image provides a true color composition that provide nearly similar appearance compare to direct visual observation. In addition, the composite image was also pan-sharpened with the 15 m panchromatic band that gave more enhancement on the image texture. Principal Component (PC) images as the resultant of the Principal Component Analysis (PCA) also provided a rich visualization especially to differentiate the almost similar appearances on the true color composite images. An example of the true color composite and PC2 in TA delineation is showed in Figure 3-6.

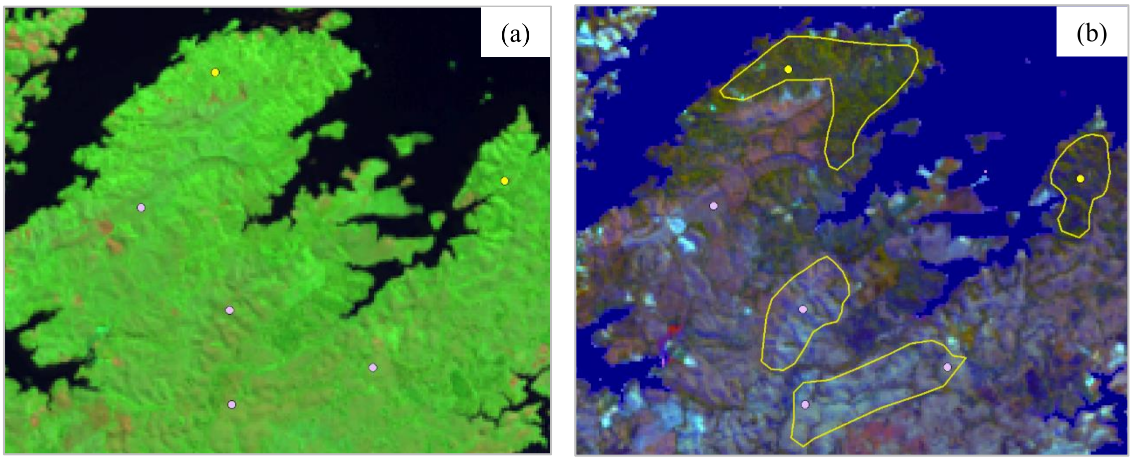


Figure 3-6: TA delineation on (a) composite of band 753 and (b) PC2 of Band 2 – 7 of Landsat 8 imagery

Number of 43 training areas that were delineated purposively by considering the proportion of the LULC and the spatial distribution of the training area as shown in Figure 3-5. TA was only made to the Landsat 8 image (2013).

A supervised classification with a maximum likelihood method was performed by using GRASS GIS Software (GRASS Development Team, 2012). Since the training area was taken from the Landsat 8 images (2013), the signature of the training area from Landsat 2013 was used to classify LULC classes from Landsat 5 (1993) and Landsat 7 (2003). With the use of TOA reflectance and RRN on Landsat 5 and Landsat 7 to the 'master' image of Landsat 8, therefore it is expected that the signature of the TA in 2013 can be used for image classification on Landsat 5 and Landsat 7. The procedure that is termed as *signature extension* or *signature generalization* is widely used for different location, time, or sensor (Laborte et al., 2010) including the application for forest change analysis using Landsat imagery (2001).

Post-classification enhancement

Post-classification enhancement was performed to improve the quality of the resultant classes and classify the unclassified pixels. Noise was spotted on the image that in some degree can be neglected. A majority filter technique was used to remove noise pixels by a 9 x 9 window. In addition, some unclassified pixels were generated during LULC classification. Thus, a visual inspection of the true composite image and pan-sharpened and corresponding available land use and land cover maps were performed to assign the unclassified pixels.

Accuracy assessment

Obtaining LULC classes from remotely sensed imagery needs criteria to assess whether the resultant LULC class is acceptable for further analysis. An accuracy assessment needs a ground check data that directly observe the LULC in the field. Since this study use three years observation (1993, 2003 and 203). Accuracy assessment was only performed on the LULC in year 2013. Accuracy assessments were not performed on Landsat 5 and 7 images due to unavailability of the ground check data in 1993 and 2003.

Assessments were performed either visually or statistically on the Landsat 8 image (2013). First accuracy assessment was a visual inspection. Comparing visual appearance is the most common assessment for comparing image analysis (Janzen et al., 2006). The resultant LULC classes were compared with pan-sharpened, NDVI, and PC2 images for the visual inspection. The second assessment was a statistical analysis comparing the resultant LULC class with the ground check data. The assessment was known as a precision measure since it is considered as a measure of agreement in the absence of chance (Lillesand and Kiefer, 1994). The purpose of this accuracy assessment is to assess the quality of the classification process by comparing the spatial distribution of the classes with the ground check data or with the field knowledge of the analyst. The kappa statistic was calculated from the accuracy assessment. The statistical accuracy assessment was analysed similar to the change analysis as it has been discussed on page 44.

Normalized Difference Vegetation Index (NDVI)

NDVI image was used for visual assessment and TA delineation. NDVI images were also needed for species' indices estimation. The species' data was obtained from fieldworks on the sampling plots. Thus, NDVI images were used to estimate the continuous (grid) data of the species' status from point data (plots). NDVI is formulated as follow (Chen et al., 1999).

$$NDVI = \frac{NIR - RED}{NIR + RED} \qquad \text{Eq. 3-4}$$

Where:

$NDVI$: Normalized difference vegetation index

NIR : Near-infrared spectral reflectance

RED : Red spectral reflectance

Since the values of NDVI are different from Landsat sensors (TM, ETM+, and OLI), a cross-comparative analysis was required (Li et al., 2014). The NDVI image of Landsat 5 (1993) and Landsat 7 (2003) were normalized by the NDVI image of Landsat 8 (2013) using pseudo invariant features (Wei et al., 2008). Number of 30 points on the coincident highest and lowest NDVI pixels between two compared NDVI images were identified and regressed. The following are the developed formula to normalize the NDVI of Landsat 5 and Landsat 7 into the NDVI of Landsat 8.

$$NDVI_{\mathrm{L5\,(normalized)}} = 1.4152 \cdot NDVI_{\mathrm{L8}} - 0.2336 \quad \text{with } R^2 = 0.9969 \qquad \text{Eq. 3-5}$$

$$NDVI_{\mathrm{L7\,(normalized)}} = 1.3616 \cdot NDVI_{\mathrm{L8}} - 0.2143 \quad \text{with } R^2 = 0.9979 \qquad \text{Eq. 3-6}$$

Direct causes of the deforestation

Deforestation in SAFP was correlated with possible direct causes, namely forest fire, settlement, and accessibility. Change analysis was performed to estimate the deforestation in each forest fire class, settlement class or accessibility class. The deforestation in each class of the direct causes was analysed to find their correlation. Other possible direct causes of deforestation such as logging, cattle raising, and urbanization were neglected because insignificance of those factors in the study site.

Simple regression analysis were performed to find the correlation between deforestation and forest fire class, settlement distance class, and accessibility class as shown in the following regression models.

$$Y_i = b_0 + b_1 X_i + e_i \qquad \text{Eq. 3-7}$$

where Y_i is decadal deforestation as the dependent variable, b_0 and b_1 are regression model coefficients that are determined in the analysis, X_i is dependent variable (either forest fire class, settlement distance class or accessibility class), and e_i is the residual error. The expected outputs were the determination coefficient (R^2) and the significance of the regression model (*Fsig*).

3.2.2. LULC Result

3.2.2.1. Resultant LULC classes

LULC classification was performed on the multi-sensors Landsat imagery with a supervised classification into six LULC classes of forest, mixed-plantation, shrub/bush, grassland, bare land, and water body. The resultant LULC classes in 1993, 2003 and 2013 is shown in the following figure.

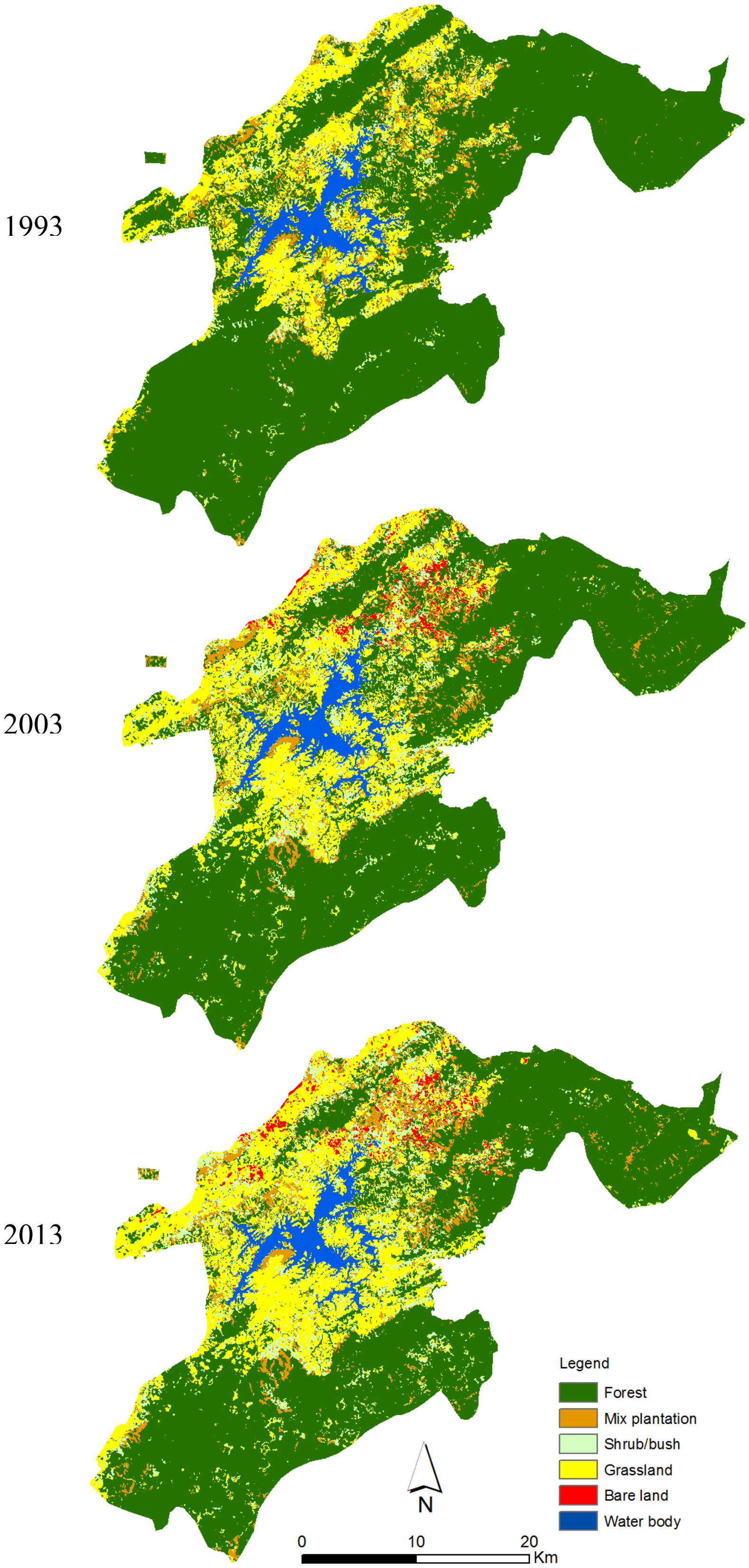


Figure 3-7: LULC classes of SAFP in 1993, 2003 and 2013

3.2.2.2. *Accuracy assessment*

The resultant LULC classes were evaluated by the Kappa accuracy assessment using ground check data. Only the resultant LULC classes in 2013 were evaluated due to unavailability of the ground truth data in 1993 and 2003 images. Water body was removed from the analysis since it is not considered as the forestland. The resultant Kappa value of 0.64 (Table 3-8) was considered as moderate based on the criteria in Jensen (2004).

Table 3-8: Accuracy assessment on the LULC classes in SAFP

Ground Check	LULC Class						Producer Accuracy
	F	MP	SB	GL	BL	Total	
F	46	1	1	2	0	51	92.2
MP	4	4	1	2	1	11	36.4
SB	2	2	4	4	1	13	30.8
GL	0	0	1	17	0	18	94.4
BL	0	0	0	1	2	3	66.7
Total	52	7	7	26	4	96	
User Accuracy	90.4	57.1	57.1	65.4	50.0		Overall 77.1% Kappa 0.64

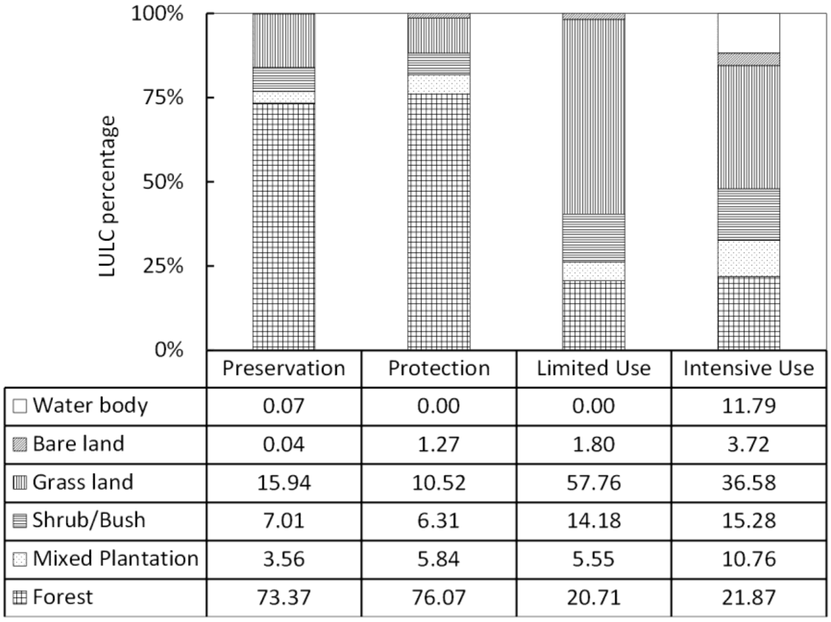
F = forest, MP = mixed plantation, SB = shrub/bush, GL = grassland, BL = bare land.

3.2.2.3. *Spatial pattern of LULC*

The spatial pattern of the LULC classes was analysed in terms of its distribution among the management zones, namely the preservation, protection, limited use and intensive use zones. As can be seen in Table 3-9 and Figure 3-8 that the most dominant LULC classes in preservation and protection zones are forest with the area of 24,803 ha (73.37%) and 31.217 (76.07%), respectively. On the other hand, the most dominant LULC class in both limited use and intensive use zones is grassland with the area of 1,239 ha (57.76%) and 14.170 ha (36.58%).

Table 3-9: The size of LULC classes in each zone in 2013

Zones	Forest	Mix Plantation	Shrub/Bush	Grassland	Bare land	Total
Preservation	26,053	1,252	2,253	4,479	5	34,042
Protection	33,483	1,836	1,824	3,420	496	41,058
Limited Use	647	102	238	1,152	2	2,141
Intensive Use	11,689	3,740	5,517	11,739	1,209	33,894
Total	71,872 (64.7%)	6,930 (6.2%)	9,832 (8.8%)	20,790 (18.7%)	1,712 (1.5%)	111,135 (100%)



	Preservation	Protection	Limited Use	Intensive Use
□ Water body	0.07	0.00	0.00	11.79
▨ Bare land	0.04	1.27	1.80	3.72
▥ Grass land	15.94	10.52	57.76	36.58
▤ Shrub/Bush	7.01	6.31	14.18	15.28
⊡ Mixed Plantation	3.56	5.84	5.55	10.76
⊞ Forest	73.37	76.07	20.71	21.87

Figure 3-8: The percentage of LULC classes in each zone in 2013

There was a significant LULC change in the study site. In 1993-2003 period, forest decreased with the rate of 1.4% yr^{-1}. Other LULC classes increased with the rate of 0.67% yr^{-1} (mixed plantation), 5.99% yr^{-1} (shrub/bush), 2.53% yr^{-1} (grassland) in Table 3-10 . In the 2003-2013 period, forest also decreased with the rate of 0.99% yr^{-1}. Other LULC classes increased with the percentage of 1.25% yr^{-1} (mixed plantation), 1.3% yr^{-1} (shrub/bush), 1.84% yr^{-1} (grassland), and 1.74% yr^{-1} (bare land).

Table 3-10: Change of LULC of SAFP in 1993, 2003, and 2013

LULC Classes	1993		2003		2003		Annual change rate (%)	
	ha	%	ha	%	ha	%	1993 – 2003	1993 – 2003
Forest	82,811	72	71,714	62	64,935	56	-1.43	-0.99
Mixed Plantation	6,513	6	6,961	6	7,885	7	0.67	1.25
Shrub/Bush	5,494	5	9,831	8	11,181	10	5.99	1.30
Grassland	16,304	14	20,931	18	25,116	22	2.53	1.84
Bare land	10	0	1,697	1	2,016	2	66.37	1.74
Water body	4,591	4	4,591	4	4,591	4	0.00	0.00
Total	115,724	100	115,724	100	115,724	100		

To draw the changes among the LULC classes, a change diagram, as shown in Figure 3-9, was constructed. Each change was compared with the size of the origin LULC to define which change is significant. As can be seen, that in the 1993-2003 period the change from mixed-plantation to grassland was the most significant (>20%). The forest class changed mostly into grassland, and a little portion changed to mixed-plantation and shrub/bush. There was also a small portion of the change from shrub/bush into grassland. In 2003-2013 period, the most significant LULC change was from shrub/bush to grassland (>20%). The change from mixed plantation and bare land into grassland were also identified. The LULC changes in SAFP mostly ends with grassland because there was no significant change from the grassland into another LULC classes.

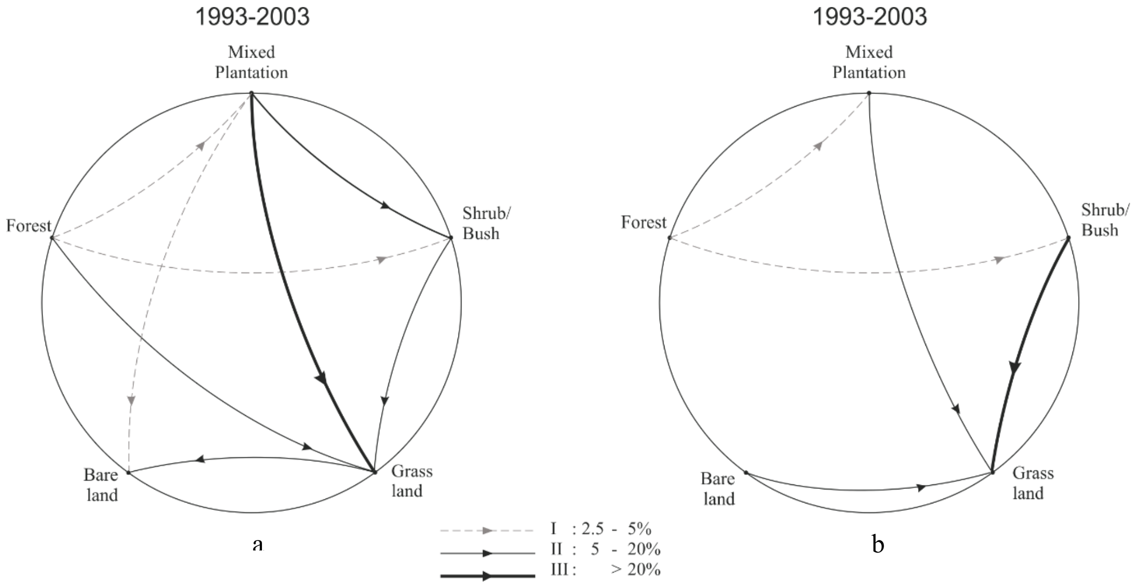


Figure 3-9: LULC changes in (a) 1993-2003 and (b) 2003-2013 periods in SAFP

Forest, suffered from deforestation. As Figure 3-9 shows that in 1993-2003 period, forest changed into grassland, mixed-plantation, and shrub/bush. In 2003-2013 period, forest also changed into mixed-plantation and shrub/bush. The size of the forest LULC in each zone and its trend can be seen in Figure 3-10.

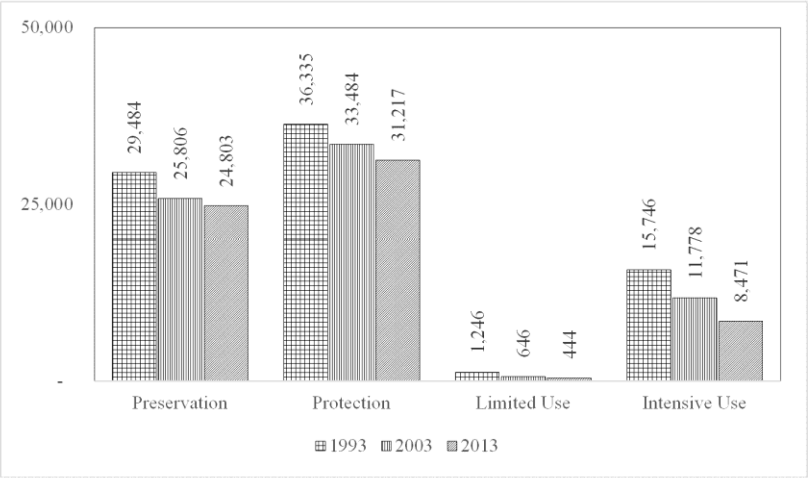


Figure 3-10: Forest area in zones of SAFP in 1993, 2003 and 2013

In the period of 1993-2003, deforestation in SAFP occurs with the annual rate of 1.43%. That deforestation rate was much higher in limited use (6.36%) and intensive use zones

(2.89%) compare to those in the preservation (1.32%) and protection zones (0.81%). The deforestation slightly decreased in the 2003-2013 period with the rate of 0.99% yr^{-1} for SAFP, 3.67% yr^{-1} for limited use, 3.24% yr^{-1} for intensive use, 0.4% yr^{-1} for preservation and 0.7% yr^{-1} for protection zones (Figure 3-11).

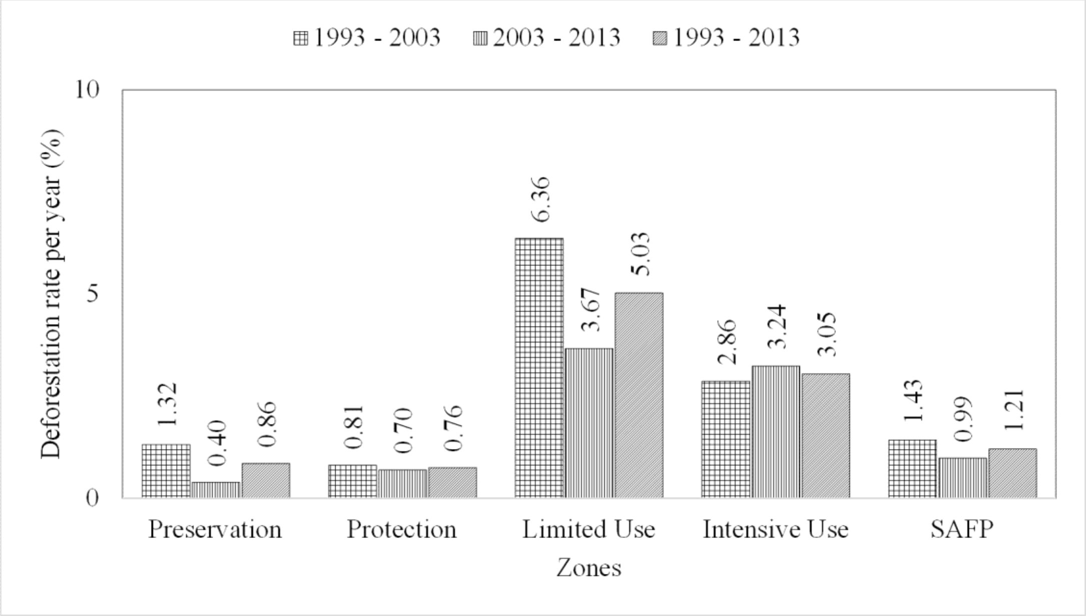


Figure 3-11: Annual deforestation rate in SAFP in 1993-2003 and 2003-2013

The change of the LULC was also studied in terms of its distribution among zone in 1993, 2003 and 2013. In 1993, forest dominated the LULC in all zones. Preservation and protection zones took significant proportion of forest while limited use and intensive use zones had about half of the area were covered with forest. However, the forest dominance decreased significantly in 2003 and 2013, especially in limited use and intensive use zones. Preservation and protection zones were still dominated by forest in 2013 while limited use and intensive use zones were dominated by grassland Figure 3-12.

	Prs	Prt	Lu	Iu
🟥 BL	0	4	0	6
🟨 GL	2400	2438	678	10806
🟨 SB	1090	991	93	3301
🟩 MP	793	1257	117	4313
🟩 F	29515	36259	1241	15832

	Prs	Prt	Lu	Iu
🟥 BL	2	494	2	1227
🟨 GL	4440	3402	1149	11949
🟨 SB	2198	1801	238	5520
🟩 MP	1266	1815	106	3789
🟩 F	25890	33438	633	11773

	Prs	Prt	Lu	Iu
🟥 BL	16	522	39	1473
🟨 GL	5354	4285	1232	14177
🟨 SB	2355	2601	312	5942
🟩 MP	1201	2397	115	4210
🟩 F	24871	31145	430	8457

Note:
Prs = Preservation zone
Prt = Protection zone
Lu = Limited use zone
Iu = Intensive use zone
BL = Bare land
GL = Grass land
SB = Shrub/bush
MP = Mixed plantation
F = Forest

Figure 3-12: Proportion of LULC class among zones in 1993, 2003 and 2013

3.2.2.4. Temporal pattern of LULC

The temporal change of the LULC was assessed by a confusion matrix in order to estimate the agreement among the observation years. From 1993 to 2003, the resultant Kappa statistics was 0.696 that mean the LULC classes in 2003 had a moderate agreement compare to that in 1993. Meanwhile, from 2003 to 2013, the resultant Kappa statistics was 0.808 that mean the LULC classes in 2013 had a good agreement compare to those in 2003. The confusion matrices of LULC change were shown in Table 3-11 and Table 3-12. The temporal pattern of LULC was analysed using change analysis as it has been discussed on page 44.

Table 3-11: Change of LULC class area (ha) of SAFP from 1993 to 2003

1993	2003				
	F	MP	SB	GL	BL
F	71,620	3,252	3,397	4,367	211
MP	59	3,655	1,270	1,326	170
SB	15	23	4,803	518	116
GL	41	47	287	14,731	1,217
BL					11

Kappa statistic 0.696; F = forest, MP = mixed plantation, SB = shrub/bush, GL = grassland, BL = bare land

Table 3-12: Change of LULC class area (ha) of SAFP from 2003 to 2013

1993	2003				
	F	MP	SB	GL	BL
F	64,707	2,722	2,768	1,444	94
MP	84	5,117	1,200	550	27
SB	66	67	7,106	2,406	112
GL	45	11	118	20,544	223
BL	2	6	19	104	1,594

Kappa statistic 0.808; F = forest, MP = mixed plantation, SB = shrub/bush, GL = grassland, BL = bare land

3.2.2.5. Direct causes of deforestation

Since the forest is the most important LULC in SAFP, therefore it is important to find the cause of the deforestation in SAFP. The deforestation rate in 1993-2003 period was 1.43%, and it decreased to 0.99% in 2003 – 2013 period (Table 3-10). However, the direct cause of the deforestation was not shown in the figures, and it needs further analysis to correlate the deforestation with the possible direct causes namely forest fire, settlement, and accessibility).

The regression analysis result in Figure 3-13 show that there was a high correlation between deforestation and forest fire probability and accessibility while between deforestation and settlement distance has no significant correlation. The deforestation increased when the forest fire probability increased (Figure 3-13a) and similarly, the deforestation increased when the accessibility increase (Figure 3-13e). The results show that deforestation has positive correlations with both forest fire probability and accessibility. However, there was no visually observed trend in the correlation between deforestation and settlement (Figure 3-13c). It was supported by the determination coefficients between deforestation and forest fire class (Figure 3-13b) and between deforestation and accessibility class (Figure 3-13f) were R^2 of 0.7424 and 0.8569, respectively. Meanwhile, the determination coefficient between deforestation and settlement distance class was very low ($R^2 = 0.0008$).

On the regression model significances, correlation between deforestation and forest fire (Figure 3-13b) has the FSig 0.006, correlation between deforestation and settlement (Figure 3-13d) has an *FSig* 0.947 and correlation between deforestation and accessibility (Figure 3-13f) has a FSig 0.001. Those figures show that the regression between deforestation and either forest fire and accessibility existed, while between deforestation and settlement did not exist.

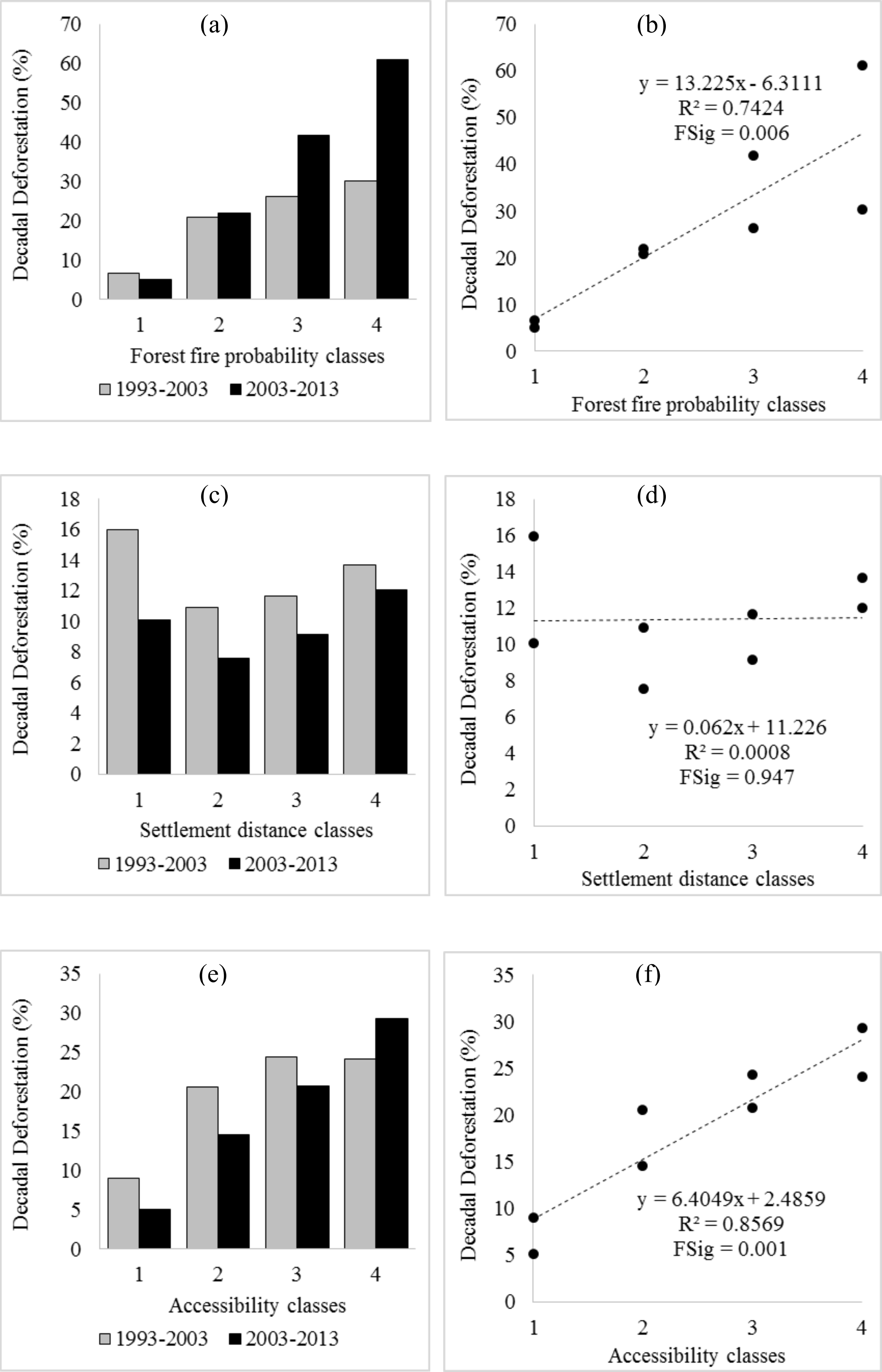


Figure 3-13: Regression analysis of deforestation and its direct causes (either forest fire, settlement or accessibility)

3.2.3. LULC discussion

The results show that there is a significant spatial distribution of the LULC classes among the management zones. In 2013, forest dominated both preservation and protection zones while grassland dominates limited use and intensive use zones. Since the preservation zone has a function for genetic reserve of the locally endemic flora and fauna (Government of the South Kalimantan Province, 2010), the forest LULC dominance was essential to support the function of the forest as the habitat (Tabarelli et al., 1999). In protection zone, a high portion of forest LULC was also required to maintain the function of zone to protect and regulated the hydro-orological function of SAFP (Government of the South Kalimantan Province, 2010).

Meanwhile, the dominance of grassland LULC in limited use and intensive use zones shows that the two zones had deforested. The grassland did not naturally exist in SAFP; rather it was the resultant process of LULC change (Forestry Service of South Kalimantan Province, 2011). In 1993-2003 period, some portions of mixed-plantation, forest, and shrub/bush changed into grassland. Meanwhile in 2003-2013 period, only the conversion from mixed-plantation, shrub/bush, and bare land into grassland were significant. The dominant species in the grassland LULC in SAFP is *alang-alang* grass (*Imperata cylindrica*). This also confirms that the deforestation in tropic is often ended with *alang-alang* grass (Yonekura et al., 2010).

Deforestation in SAFP changed during study period. In 1993-2003 period, deforestation was estimated at 1.43% yr^{-1}. This rate decreased in 2003-2013 period into 0.99% yr^{-1}. Comparing the figures with the national deforestation rate of 610,000 $ha.yr^{-1}$ (or 0.46% yr^{-1}) (Indonesian Ministry of Forestry, 2012), the deforestation rate in SAFP is higher than that at the national level.

Knowing the direct causes of deforestation in SAFP is urgently required to reduce the deforestation. The result showed that forest fire and accessibility (distance from road/lake) have positive correlations with deforestation. Deforestation is significantly higher in the area which forest fire probability is high. This study is coherent with Langner (2009) that forest fire is considered as one of the important factor accelerating deforestation in the tropic. Since there is no logging activity in SAFP, therefore, road/lake presence is likely related to shifting cultivation and forest fire. Higher accessibility contributes to the higher forest fire probability (Murdiyarso et al., 2002) which in turn cause the deforestation. Forest fire is also the main tool for land clearing in Indonesia including for shifting cultivation (Tomich et al., 1998) which is likely the main threat on the deforestation in SAFP. Forest fire and accessibility therefore significantly caused deforestation in SAFP.

However, distance from the settlement has no significant correlation with the deforestation. The road/lake features more represent the accessibility effect on the deforestation compare to the settlement. The effect of the settlement could be already represented in the accessibility since all road/lake as the accessibility features in SAFP also pass the settlement features.

3.3. Forest fragmentation

3.3.1. Forest fragmentation method

3.3.1.1. Forest fragmentation Data

Forest fragmentation analysis used the resultant LULC data as the result of the LULC classification (Figure 3-7). The LULC classes were classified into two dichotomous categories of forest and non-forest. The two classes were the input for the forest fragmentation using morphological analysis.

3.3.1.2. Forest fragmentation Analysis

This study used the morphological approaches on the forest fragmentation based on the study by Vogt et al. (2007) which divided forest into four main categories, i.e., core forest, perforated forest, edge forest and patch forest. The analysis is performed by the Landscape Fragmentation Tool version 2.0 (Parent and Hurd, 2007) within the ArcGIS 10 software. The tool analysed and classed the forest into four categories as shown in the following table.

Table 3-13: Categories of the forest based on morphological approach

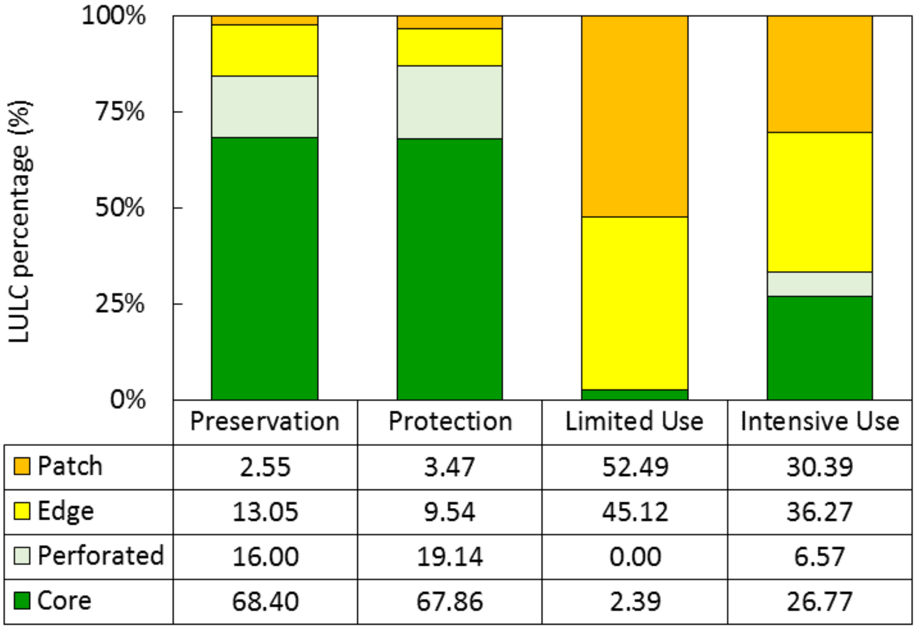
Forests	Description
Core forest	Forest pixel that are not degraded by 'edge effect'
Perforated forest	Forest pixel along the edge of an interior gap in a forest that are degraded by 'edge effect'
Edge forest	forest pixels along the exterior perimeter of a forest that are degraded by the 'edge effect'
Patch forest	small isolated fragments of forest that are completely degraded by 'edge effect'

Adapted from (Parent and Hurd, 2007)

3.3.2. Forest fragmentation Result

3.3.2.1. Spatial pattern of forest fragmentation

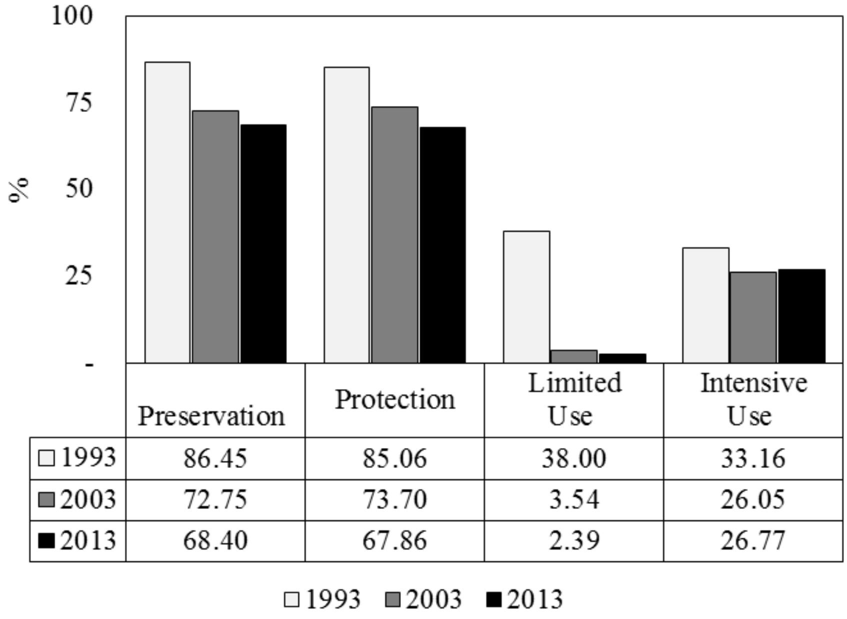
Forest fragmentation in 2013 was spatially distributed across the zones as shown in Figure 3-14. Core forest dominated the preservation (68.40%) and protection zones (67.86%). Interestingly, patch forest dominated the limited use zone (52.49%) and edge forest dominated the intensive use zone (36.27%). It is noted that the proportion of the core forest in the limited use zones is only at 2.39%.



	Preservation	Protection	Limited Use	Intensive Use
🟧 Patch	2.55	3.47	52.49	30.39
🟨 Edge	13.05	9.54	45.12	36.27
☐ Perforated	16.00	19.14	0.00	6.57
🟩 Core	68.40	67.86	2.39	26.77

Figure 3-14: The proportion of forest fragmentation in each zone of SAFP in 2013

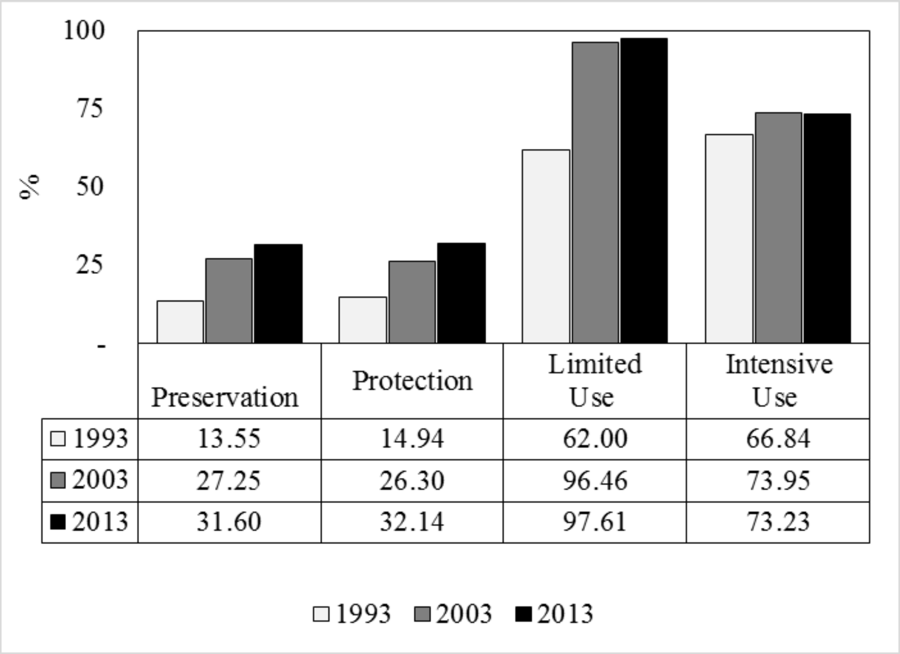
Along the increased of deforestation in SAFP, the forest fragmentation also increased. The fragmentation was represented by the decrease in the core forest and the increase of the non-core (perforated, edge and patch) forests. As can be shown in Figure 3-15 that the proportion of core forest has a decreased trend in all zones.



	Preservation	Protection	Limited Use	Intensive Use
☐ 1993	86.45	85.06	38.00	33.16
▨ 2003	72.75	73.70	3.54	26.05
■ 2013	68.40	67.86	2.39	26.77

Figure 3-15: Proportion of core forest of SAFP in 1993, 2003, and 2013

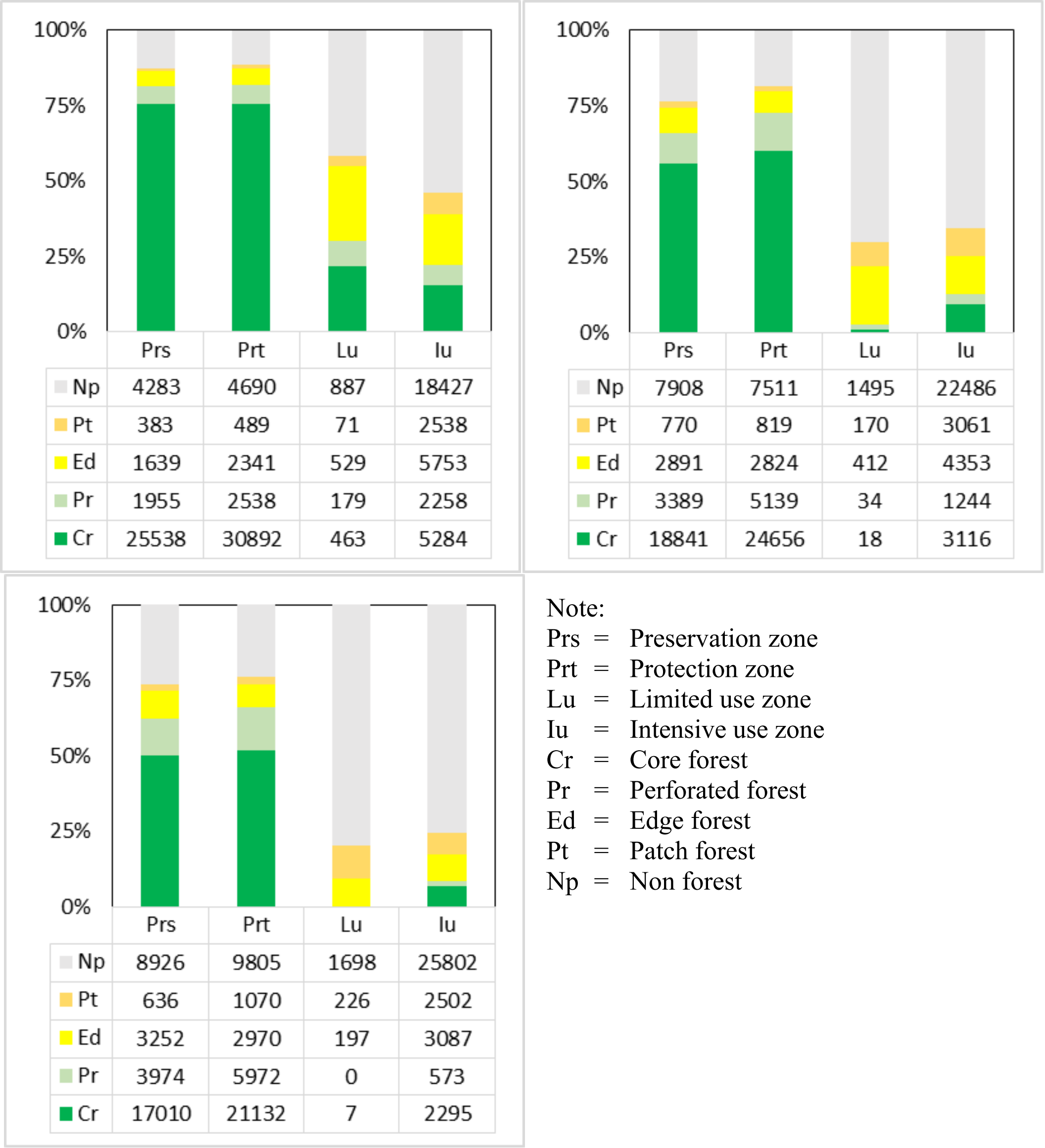
Meanwhile, the proportion of the non-core forests (perforated, patch, edge, and patch) had increasing trends (Figure 3-16) among zones.



	Preservation	Protection	Limited Use	Intensive Use
□ 1993	13.55	14.94	62.00	66.84
▨ 2003	27.25	26.30	96.46	73.95
■ 2013	31.60	32.14	97.61	73.23

Figure 3-16: Proportion of non-core forest of SAFP in 1993, 2003, and 2013

The spatial changes of the forest fragmentation were analysed by looked back the forest fragmentation proportion in 1993, 2003 and finally 2013. Core forest dominated SAFP in 1993, 2003 and 2013 in both preservation and protection zones. However, its percentage is decreasing. Non-core forest (perforated, edge, patch, and non-forest) significantly increased within the study period in all zones (Figure 3-17).



	Prs	Prt	Lu	Iu
Np	4283	4690	887	18427
Pt	383	489	71	2538
Ed	1639	2341	529	5753
Pr	1955	2538	179	2258
Cr	25538	30892	463	5284

	Prs	Prt	Lu	Iu
Np	7908	7511	1495	22486
Pt	770	819	170	3061
Ed	2891	2824	412	4353
Pr	3389	5139	34	1244
Cr	18841	24656	18	3116

	Prs	Prt	Lu	Iu
Np	8926	9805	1698	25802
Pt	636	1070	226	2502
Ed	3252	2970	197	3087
Pr	3974	5972	0	573
Cr	17010	21132	7	2295

Note:
Prs = Preservation zone
Prt = Protection zone
Lu = Limited use zone
Iu = Intensive use zone
Cr = Core forest
Pr = Perforated forest
Ed = Edge forest
Pt = Patch forest
Np = Non forest

Figure 3-17: Proportion and area (ha) of forest fragmentation among zones in 1993, 2003 and 2013

3.3.2.2. Correlation between forest fragmentation and deforestation

The correlation between forest fragmentation and deforestation was examined by analysed their correlation in a simple regression as shown in Table 3-18. The proportion of the core forest increased if the forest area increased with the coefficient determination of 0.9663. On the other hand, the proportion of the non-core forests (perforated, edge and patch forests) decreased if the forest area increased. Thus, core forest has a positive correlation with forest area, and non-core forests have negative correlations with forest area.

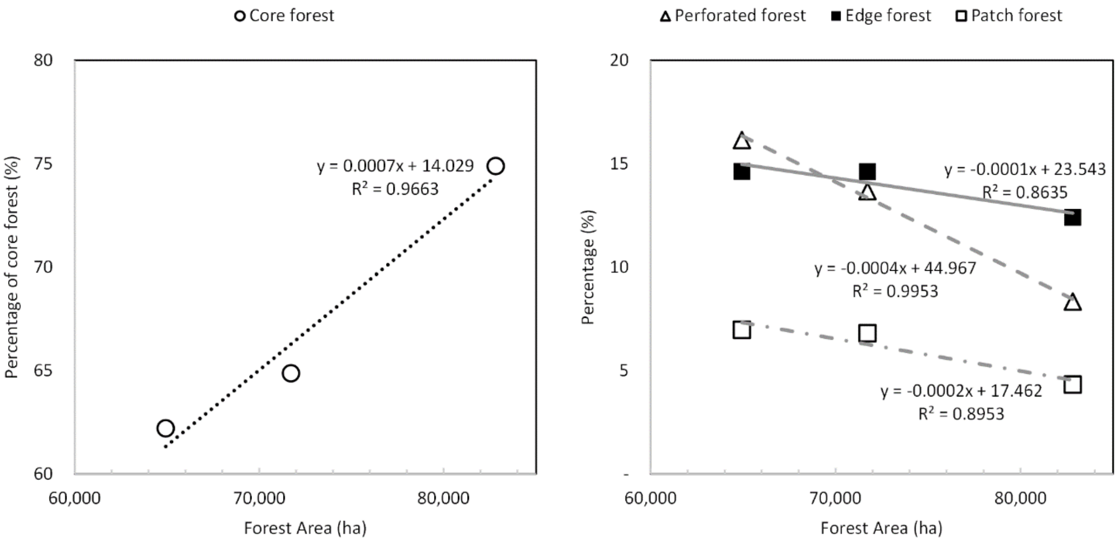


Figure 3-18: The correlation between (a) Forest Area (ha) and (b) proportion of core and non-core forests

3.3.2.3. *Temporal pattern of forest fragmentation*

The temporal change of the forest fragmentation was assessed by a confusion matrix in order to estimate the changes of the forest fragmentation in the study periods. In 1993 – 2003, the Kappa statistics was 0.644 that mean the forest fragmentation classes in 2003 has a moderate agreement compare to those in 1993. Meanwhile, in 2003 – 2013, the Kappa statistics was 0.781 that mean the forest fragmentation classes in 2013 also has a moderate agreement compare to those in 2003. The confusion matrices of forest fragmentation classes' change were shown in Table 3-14 and Table 3-15. Temporal pattern of forest fragmentation was analysed using change analysis as it has been discussed on page 44.

Table 3-14: Change of the forest fragmentation class area (ha) of SAFP from 1993 to 2003

1993	Forests (2003)				
	Core (Cr)	Perforated (Pr)	Edge (Ed)	Patch (Pt)	Non-forest (Np)
Cr	46,628	6,483	4,059	545	4,462
Pr	2	3,266	1,665	205	1,792
Ed	-	53	4,738	1,732	3,739
Pt	-	-	-	2,245	1,236
Np	-	5	17	93	28,172

Kappa statistics = **0.644**

Table 3-15: Change of the forest fragmentation class area (ha) of SAFP from 2003 to 2013

2003	Forests (2013)				
	Core (Cr)	Perforated (Pr)	Edge (Ed)	Patch (Pt)	Non-forest (Np)
Cr	39,545	4,077	1,406	128	1,473
Pr	825	6,331	1,395	138	1,117
Ed	60	13	6,601	1,264	2,542
Pt	1	7	50	2,866	1,896
Np	14	91	55	37	39,203

Kappa statistic **0.781**

3.3.3. Fragmentation discussion

The fragmentation was moderately changes in both periods with the Kappa statistics of 0.644 and 0.781 for 1993 – 2003 and 2003 – 2013, respectively. The kappa statistic in the second period was relatively higher than that in the first period, in which means that forest fragmentation was relatively changed more in the first period. This condition is similar to the changes in the LULC class as shown in Table 3-11 and Table 3-12.

The core forest in both 1993 – 2003 and 2003 – 2013 periods had decreased trends. Meanwhile, non-core forests (perforated, edge and patch forests) had increased trends. The increase of core forest and the decrease of the non-core forests have a strong correlation with deforestation (Figure 3-18). This supports the idea that deforestation leads to forest fragmentation (Alig et al., 2010b; Broadbent et al., 2008), therefore, reducing deforestation will also reduce forest fragmentation.

On the spatial and temporal changes of the forest fragmentation as shown in Table 3-14 and Table 3-15, it can be seen that in the period of 1993 – 2003 and 2003 – 2013, forest fragmentations changed moderately. The Kappa statists on both periods were in between 0.4 and 0.8 which according to Jensen (2004) the range was categorized as the moderate agreement.

3.4. Species status

3.4.1. Species status method

3.4.1.1. Species status data

Species' status consists of three major parameters, namely species richness (*SR*), red list status (*RL*) and value use (*VU*). Those parameters were measured the forest inventory with 44 plots within 11 clusters that were systematically distributed in SAFP. Further, in order to estimate *SR*, *RL* and *VU* parameters for the whole study site, regression analyses were performed between those parameters with possible influencing factors (NDVI, elevation and fragmentation) as the dependent variables. Data used in the species status analysis is presented in Table 3-16.

Table 3-16: Data for species status estimation

No	Data	Type	Scale, resolution, number	Year	Coverage, extent	Source
1.	Sample Plot	Point, Attribute	11 clusters 44 plots	2010 2011 2012	SAFP	SAFP Office Field work Field work
2.	NDVI Images	Raster	30 m	1993 2003 1993	117-62 117-63	USGS
4.	SRTM DEM	Raster	90 m	2000	SAFP	USGS
5.	Fragmentation	Raster	30 m	2013	SAFP	Fragmentation analysis

Sample plots data were taken from the provincial forest inventory that were designed by Forestry Service of South Kalimantan Province. The cluster sampling was originally applied for National Forest Inventory (NFI) in Indonesia (FAO, 2007) which was undertaken from 1989 to 1996. The cluster inventory system was applied systematically by a grid of 20 km x 20 km. In each cluster, number of nine plots with the size of 100 m x 100 m were made and measured. Since the ground survey for NFI was finished in 1996 (FAO, 2010), therefore, Forestry Service of South Kalimantan Province adopted the system from 2010.

A modification in the grid and number of plots in each cluster were introduced. Grid was changed into 10 km x 10 km and number of plots in each grid were four with the size of 50 m x 50 m. The size of 50 m x 50 m is used to measure the tree level vegetation. Within each plot, there are smaller plot of 20 m x 20 m, 10 m x 10 m and 5 m x 5 m for pole, sapling and seedling levels of vegetation. Since the biodiversity index was highly influenced by the size of the plot (Soosairaj et al., 2007), and the landscape perspective prioritization does not need detail data (Trombulak and Baldwin, 2010), this study use only tree level vegetation within 50 m x 50 m plot. Spatial configuration of the cluster plots is shown in Figure 3-19 and Figure 3-20.

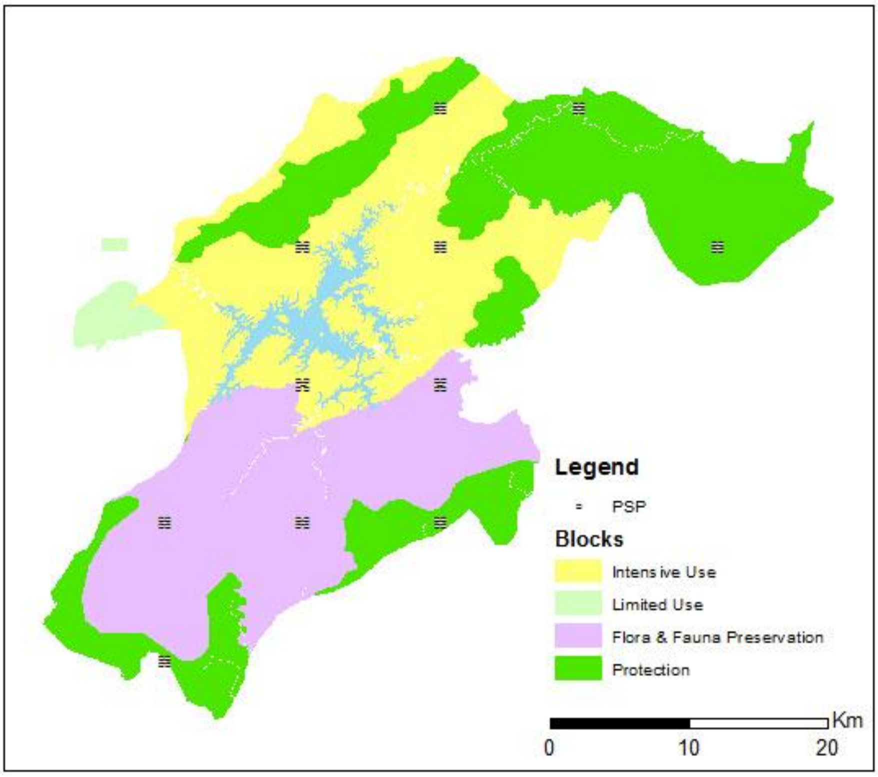


Figure 3-19: Permanent Sample Plots within the SAFP

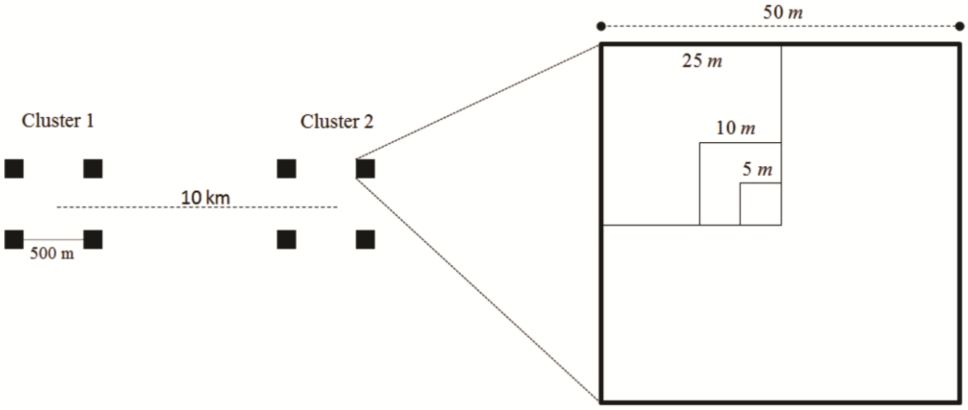


Figure 3-20: Configuration and size of the plots

The resultant SR, RL and VU from the cluster plots were tallied in Appendix D (page 243) that was then summarized in **Appendix E** (page 243). The corresponding value of possible influencing factors (elevation, NDVI, and fragmentation classes) that coincidence with the position of the plot were extracted for the further regression analysis.

3.4.1.2. Species status analysis

Cluster inventory

Cluster sampling is common in forestry with various size and geometric type of sample plot (Köhl et al., 2006). Further, for the cluster sampling with an equal number and size of the sample plot, Köhl et al. (2006) showed the formula to estimate the population mean as the mean of the cluster means as follow

$$\hat{\bar{y}}_{clust} = \frac{1}{n}\sum_{i=1}^{n}\hat{\bar{y}}_i \qquad \text{Eq. 3-8}$$

Where n is number of clusters and $\hat{\bar{y}}_i$ is the mean in cluster i. Since this study use the equal size and number of plots that, therefore, the mean of the cluster means as the population mean was unbiased (Kangas, 2006). While, the estimator for the mean-variance was estimated by the following equation

$$\widehat{\text{var}}\left(\hat{\bar{y}}_{clust}\right) = \frac{1}{n-1}\sum_{i=1}^{n}\left(\hat{\bar{y}}_i - \hat{\bar{y}}_{clust}\right)^2 \qquad \text{Eq. 3-9}$$

Species' status consists of three parameters of *SR*, *RL,* and *VU*. The three parameters belongs to each tree species recorded in each sampling plots. The sum of all three parameters represents the species' index of the corresponding sampling plot.

Species' richness estimation

SR was estimated by Margalef's richness index (Soosairaj et al., 2007) with the formula of

$$D_{mg} = \left((S-1)/\ln N\right) \qquad \text{Eq. 3-10}$$

where D_{mg} is the Margalef's index, S is the number of species recorded, and N is the total number of individuals in the sampling plot. The margalef's index in each plot represents the *SR* of the corresponding plot.

Red list status estimation

Red list status of each plot was estimated by determining the score of each tallied tree in each plot. The red list score of each tree was checked and then summed to represent the RL status of the plot. The score RL category follows the red list status in the IUCN's red list status (shown in **Appendix C** on page 242). It was scored with the Table 3-17. The sum of the score of each species' status in one plot represents the species' status of the plot.

Table 3-17: IUCN's red list status and its score

Red list category	score
Not Evaluated	0
Data Deficient	0
Least Concern	1
Near Threatened	2
Vulnerable	3
Endangered	4
Critically Endangered	5
Extinct in the Wild	6
Extinct	7

Value use estimation

VU represents the potential direct benefit that local people can take from each tree species, either consumption (food, fodder, fuel, and timber) and medicinal/culture (Table 3-18). The category was adopted from Soosairaj et al. (2007) with regrouping based on the consultation with the SAFP stakeholders.

Table 3-18: Value use category and its score

Value use category	Score
Food, fodder, fuel, timber	1
Culture, medicinal	2

Species' status index

Species' status in one plot was the sum of its SR, RL, and VU. Those three parameters were equally weighted as shown in the following equation.

$$Species\ Status = SR + RL + VU \qquad \text{Eq. 3-11}$$

Species' status was presented in the index between zero and one. The resultant species status, as shown in Equation 3-11, were then normalized into the index. The resultant species status across the study site was classified into four classes by a natural break classification as very high, high, low and very low classes as shown in Table 3-9.

Table 3-19: The classification of species' status

Classes	Description
1	Very high
2	High
3	Low
4	Very Low

Regression of SR, RL, and VU with influencing factors

Species' data collected from sampling plots represented the plot, and therefore it was considered as point data. *SR*, *RL,* and *VU* need to be converted into continuous (grid) data. Various techniques and models have been used to correlate biodiversity and influencing factors such as NDVI (Gillespie, 2005; Gould, 2000; Martinuzzi et al., 2008), elevation (McCain and Grytnes, 2010; Stiegel et al., 2011), and forest fragmentation (Fahrig, 2003).

Multiple linear regressions were applied to regress *SR*, *RL*, and *VU* with influencing factors (elevation, NDVI, and fragmentation) as shown in the following models.

$$SR = b_0 + b_1\left(elv\right) + b_2\left(NDVI\right) + b_3\left(frag\right) + e_i \qquad \text{Eq. 3-12}$$

$$RL = b_0 + b_1\left(elv\right) + b_2\left(NDVI\right) + b_3\left(frag\right) + e_i \qquad \text{Eq. 3-13}$$

$$VU = b_0 + b_1\left(elv\right) + b_2\left(NDVI\right) + b_3\left(frag\right) + e_i \qquad \text{Eq. 3-14}$$

where *elv* is elevation (m), *NDVI* is Normalize Difference Vegetation Index, and *frag* is the fragmentation class, b_1, b_2 and b_3 are regression model coefficients that were determined in the analysis. Since all the dependent and independent values have significant values' range, therefore, all variables were normalized into the scale of 0 -1 with the normalization method as shown on page 43.

3.4.2. Species status result

3.4.2.1. Forest inventory result

Forest inventory is crucial to describe the potential of the SAFP. The resultant forest inventory was calculated to describe the SAFP potential in SR, RL, and VU. As can be shown in **Appendix F** (page 291), the descriptive statistics on the species' status can be summarized as follow.

Table 3-20: Descriptive statistics on the species' status in SAFP

No	Parameters	Mean	Mean's variance	Standard Deviation	Confidence Interval (95% 2-tailed)
1	Species richness	2.54	1.55	0.38	2.32 – 2.76
2	Red list status	32.50	731.18	8.15	27.68 – 37.32
3	Value use	38.89	1,018.84	9.62	33.20 – 44.58

Source: Data analysis in **Appendix F** (page 291)

The plot of the cluster inventory was systematically placed in the study site. Thus, there were various LULC corresponding to each plot. Forest or non-forest LULC presumably have significantly different SR, RL, and VU. In order to assess the differences, ANOVA analysis was performed. It shows that the value of SR, RL and VU between LULC (forest, mixed-plantation, shrub/bush, grassland and bare land) are significantly different with the *FSig* lower than 0.001 as shown in **Appendix F** (page 291). Further, in the post hoc analysis, only forest that has significantly difference in SR, RL and VU from other LULC while mixed-plantation, shrub/bush, grassland and bare land have no significantly difference compare to each other.

3.4.2.2. SR, RL and VU estimation

Species' status of the forest landscape was estimated by SR, RL, and VU. All variables values were normalized into 0 – 1 scale due to significant range difference and also the presence of the categorical data in the independent variable. A multiple regression analyses was performed to estimate the species' status of study site. The summarized data plot (**Appendix E** on page 290) were analysed in the multiple linear regression analysis (**Appendix G** in page 298). The resultant regression models in estimating SR, RL and VU are as follow.

Table 3-21: Regression models to estimate species' status

Species parameter	Linear Models	R^2	*Fsig*
SR	$SR = -0.103 - 0.003elv + 0.356NDVI + 0.665frag$	0.711	< 0.01
RL	$RL = 0.047 - 2.32elv + 0.0306NDVI + 0.729frag$	0.891	< 0.01
VU	$VU = 0.031 + 0.051elv + 0.01NDVI + 0.624frag$	0.897	< 0.01

The models in Table 3-21 were used to estimate the continuous (grid) data for 1993, 2003 and 2013.

3.4.2.3. Spatial pattern of species' status

Change of species' status was studied in terms of its distribution among zone in 1993, 2003 and 2013. As can be seen in Figure 3-21 that there were trends that the very high species index was counted in preservation and protection zones, while very low species index was observed in limited use and intensive use zones.

	Prs	Prt	Lu	Iu
🟩 Very high	26019	32741	636	7480
🟩 High	3048	2955	534	5815
🟨 Low	442	562	71	2538
🟧 Very low	4288	4692	887	18427

	Prs	Prt	Lu	Iu
🟩 Very high	19405	28392	49	4359
🟩 High	5422	4117	415	4353
🟨 Low	1060	927	170	3061
🟧 Very low	7911	7513	1495	22486

	Prs	Prt	Lu	Iu
🟩 Very high	18057	25754	7	2868
🟩 High	5901	4188	197	3087
🟨 Low	912	1202	226	2502
🟧 Very low	8927	9806	1698	25802

Note:
Prs = Preservation zone
Prt = Protection zone
Lu = Limited use zone
Iu = Intensive use zone

Figure 3-21: Proportion and area (ha) of species' status among zones in 1993, 2003 and 2013

3.4.2.4. Temporal pattern of species' status

The temporal change of the species' status was also assessed by a confusion matrix in order to estimate the agreement among the observation years. From 1993 to 2003, the resultant Kappa statistics of 0.670 was calculated which mean that the species' index in 2003 has a moderate agreement compare to those in 1993. Meanwhile, from 2003 to 2013, the resultant Kappa statistics of 0.807 was calculated which mean that the forest fragmentation classes in 2013 also has a good agreement compare to those in 2003. The confusion matrices of forest fragmentation classes' change were shown in Table 3-22 and Table 3-23. Temporal pattern of forest fragmentation was analysed using change analysis it has been discussed on page 44.

Table 3-22: Change of species' index class area (ha) of SAFP from 1993 to 2003

1993	2003			
	Very low	Low	High	Very high
Very low	28,178	94	18	4
Low	1,251	2,354	7	-
High	4,125	1,928	6,140	159
Very high	5,851	842	8,141	52,042

Kappa statistic **0.670**

Table 3-23: Change of species' index class area (ha) of SAFP from 2003 to 2013

2003	2013			
	Very low	Low	High	Very high
Very low	39,204	45	90	67
Low	1,938	3,161	117	2
High	2,845	1,367	9,276	818
Very high	2,246	270	3,890	45,799

Kappa statistic **0.807**

3.4.3. Species status discussion

Landscape approach forest prioritization concerned the forest as the landscape and ignored the detail on the species' biodiversity (Trombulak and Baldwin, 2010; Valente and Vettorazzi, 2008). Selecting only three species for the species' indicator neglected other species such as non-tree vegetation and fauna. However, the purpose of the forest landscape prioritization is to support conservation planning with general data and fast analysis. Taking into account per species' biodiversity also costly and is not really needed in the landscape analysis. However, if the species based data is already available, it is recommended that the data be acknowledged in the prioritization. Therefore, taking into account only tree level vegetation is considered appropriate for preservation prioritization in forest landscape in SAFP.

The resultant SR, RL and VU among plots significantly different among LULC. Forest has the highest index in SR, RL, and VU while bare land has the lowest among all. It underline the importance of the forest as the main LULC in SAFP that has the vital function to support the biodiversity of the site.

This study confirms that biodiversity has correlation with influencing factor, namely elevation, NDVI and forest fragmentation. This finding is similar to some previous studies. McCain and Grytnes (2010) and Stiegel et al. (2011) revealed that there was a negative correlation between biodiversity and elevation. It means that higher elevation has lower biodiversity. That is similar to the resultant model in Table 3-21 that SR has a negative coefficient on the elevation in SR and RL models. However, VU has a positive correlation with elevation. Since VU is not considered as the biodiversity condition, and it rather represent the human use of the biodiversity, therefore, this research still confirms the previous studies. The positive correlation between biodiversity and NDVI (Gillespie, 2005; Gould, 2000; Martinuzzi et al., 2008) was also confirmed. In all models (Table 3-21), NDVI has a positive coefficient in SR, RL, and VU. On the correlation between species' status with fragmentation, this study found that SR, RL, and VU has a positive correlation with forest fragmentation that similar to the finding by Fahrig (2003).

3.5. Settlement and accessibility

Settlement and accessibility cause of deforestation (Barber et al., 2014). The influences of the settlement and accessibility factors on the study site were assessed by the presence of the major disturbance in the SAFP. Shifting cultivation was considered as the main threat on the deforestation and forest degradation in SAFP. Since SAFP is a conservation forest without logging is permitted. Therefore deforestation and forest degradation in SAFP is from shifting cultivation. Assessing the presence of the shifting cultivation in the forest is hardly assessed, especially for landscape prioritization. Another approach was used by analyzing the presence of the forest fire as the representative of the shifting cultivation activities in SAFP. This approach was supported by the fact that the majority of the forest fire in Indonesia is anthropogenic (Adinugroho et al., 2005) as the tool for land clearing including in shifting cultivation (Tomich et al., 1998). Therefore, the settlement and accessibility impact on the forest was measured by the distribution of the forest fire from either settlement or road/lake.

3.5.1. Settlement and accessibility method

3.5.1.1. Settlement and accessibility data

Data used for the settlement and accessibility analysis are MODIS firespot, settlement, road, and lake. MODIS firespot is used to estimate the presence of the shifting cultivation in SAFP via monitoring the forest fire. A period of 2001 – 2013 was used to monitor the presence of the forest fire in SAFP. Settlement, road and lake vector data were derived from the Indonesian basemap. In order to estimate the trend of the settlement and accessibility influence on the forest, number of FMU was increased to cover all of the 11 FMUs in South Kalimantan Province were used. All data used is shown in the following table.

Table 3-24: Data for settlement and accessibility analysis

No	Data	Type	Scale, resolution	Year	Coverage, extent	Source
1.	MODIS Firespot	Vector point	1 km 1-2 day	2001 – 2013	South Kalimantan Province	USGS
2.	Settlement	Vector point	1:50,000	1991 1999 2007	South Kalimantan Province	Bakosurtanal /BIG
3.	Road	Vector point	1:50,000	1991 1999 2007	South Kalimantan Province	Bakosurtanal /BIG
4.	Lake	Vector point	1:50,000	1991 1999 2007	South Kalimantan Province	Bakosurtanal /BIG

The selection of the MODIS firespot data as a proxy of forest fire location has some limitations. The firespot points are not truly the locations of fires. The 1 kilometer spatial resolution of the MODIS images (Giglio, 2010) can be considered as a low spatial resolution image. In addition, the real forest fire in the field never exists in point, but rather in the area. However, sensing the forest fire by the satellite images has enormous advantages from early fire detection capability (Nakau et al., 2006), very high temporal resolution and near real-time data availability. In addition, this study tried to assess the spatial forest fire distribution in a quite large study area. It is, therefore, considerably appropriate to use MODIS firespot to represent forest fire location in this study.

3.5.1.2. *Settlement and accessibility analysis*

This study used a stochastic approach to estimating the degree of threats to the forest from settlement and accessibility. Two parameter estimations were performed in firespot spatial distribution from settlement and firespot spatial distribution from road/lake. Euclidean distances from the closest settlement and closest road/lake were calculated for each firespot. The Empirical Distribution Function (EDF) was estimated on ascending sorted distance data using a median formula (Murthy et al., 2004) of $\hat{F}(x_i) = (i - 0.3)/(n + 0.4)$ where $\hat{F}(x_i)$ is the cumulative empirical probability, i is the rank of the i-th sorted firespot distance and n is the total number of firespot. The resultant EDF has possible value within 0 – 1 range.

The 2-parameters Weibull distribution model was selected because its elasticity which can mimic many distributions such as Normal, Lognormal, Exponential and Rayleigh distributions (Murthy et al., 2004). The distribution also has ability to fit data from various field such as life, weather, economics, administration, hydrology, biology or engineering science (Rinne, 2009). The Weibull Probability Density Function (PDF) is the distribution for continuous variables. Bedient and Huber (1992) suggested using Cumulative Distribution Function (CDF) that is the integral form of the PDF. The PDF of 2-parameters Weibull Distribution can be written as

$$f(x) = (\beta/\alpha)(x/\alpha)^{\beta-1} \exp\left(-(x/\alpha)^{\beta}\right) \qquad \text{Eq. 3-15}$$

with its corresponding CDF of

$$F(x) = 1 - \exp\left(-(x/\alpha)^{\beta}\right) \qquad \text{Eq. 3-16}$$

where x is the distance from either settlement or lake/road ($x \geq 0$) (km), α is scale parameter ($\alpha \geq 0$) and β is shape parameter ($\beta \geq 0$)

To estimates the distribution parameters from sample data, some parameter estimation methods have been developed. This study uses Maximum Likelihood Estimator (MLE) to estimate α- and β-parameters because it is a robust and converge estimation for the Weibull distribution (Gove, 2003). Moreover, the software to perform the MLE is available in the open source R Statistical Software (R Development Core Team, 2011) with additional *fitdistrplus*, *survival*, *splines* and *reshape2* packages.

The likelihood function assumes that there is an unknown parameter (θ) in the PDF (Equation 3-17) which is then written as $f(x, \theta)$. Thus, the likelihood function of the random sample is the joint density of $x_1, x_2, \ldots, x_n$ and the unknown parameter (θ) (Bhattacharya, 2010) as follow.

$$L = \prod_{i=1}^{n} f_{x_i}(x, \theta) \qquad \text{Eq. 3-17}$$

Using the Eq. 3-10 and Eq. 3-11, the likelihood function is then written as

$$L(x_1, \ldots, x_n, \alpha, \beta) = \prod_{i=1}^{n} (\beta/\alpha)(x/\alpha)^{\beta-1} \exp\left(-(x/\alpha)^{\beta}\right) \qquad \text{Eq. 3-18}$$

The MLE of θ is the value of θ that maximize the value of the likelihood function (L). By taking logarithm of Equation 3-18 and then differentiated it respect to β and α and equating to zero, the Equation 3-19 and Equation 3-20 were generated.

$$\frac{\partial \ln L}{\partial \beta} = \frac{n}{\beta} + \sum_{i=1}^{n} \ln x_i - \frac{1}{\alpha} \sum_{i=1}^{n} x_i^{\beta} \ln x_i = 0 \qquad \text{Eq. 3-19}$$

$$\frac{\partial \ln L}{\partial \alpha} = \frac{-n}{\alpha} + \frac{1}{\alpha^2} \sum_{i=1}^{n} x_i^{\alpha} = 0 \qquad \text{Eq. 3-20}$$

By eliminating α in the Equation 3-19 and Equation 3-20, the Equation 3-21 was used to estimate β.

$$\left(\sum_{i=1}^{n} x_i^{\beta} \ln x_i \Big/ \sum_{i=1}^{n} x_i^{\beta} \right) - \frac{1}{\beta} - \frac{1}{n} \sum_{i=1}^{n} \ln x_i = 0 \qquad \text{Eq. 3-21}$$

The iterative calculation was applied to solve the Equation 3-21. If β-parameter has been estimated at the iteration, the α-parameter can be solved by the Equation 3-22.

$$\alpha = \sum_{i=1}^{n} x_i^{\beta} \Big/ n \qquad \text{Eq. 3-22}$$

3.5.1.3. *Goodness-of-fit test*

This study used Kolmogorov-Smirnov Test (K-S test) to measure the discrepancy between the resultant distribution (Weibull CDF) and the firespot data distribution (EDF). A significance level of $\rho = 0.01$ was used in the test. If the resultant probability of K-S test (K-S ρ) was bigger than 0.01, then the resultant distribution fit the data. K-S test calculated the maximum value of the difference (D) of EDF and CDF (Rinne, 2009) which can be shown in the following formula.

$$D = \sup\left(\left|EDF - CDF\right|\right) \qquad \text{Eq. 3-23}$$

Where D is the maximum different between CDF and EDF, *EDF* is the empirical Distribution Function, and *CDF* is the Cumulative Distribution Function.

3.5.1.4. *Probability classification*

Probability classification of forest fire spatial distribution was performed. The numbers of four classes (Class I – IV) were derived from the CDF of firespot in all fit distributions by using equal proportions method. Thus, the fire probability was divided by 3 quartiles, i.e. Q_1 ($F(x) = 0.25$), Q_2 ($F(x) = 0.5$) and Q_3 ($F(x) = 0.75$) as shown in Figure 3-22. The resultant four classes were compared with a number of firespot falls in each class, to validate the result. The Sultan Adam Forest Park (FMU XI) was selected for validation.

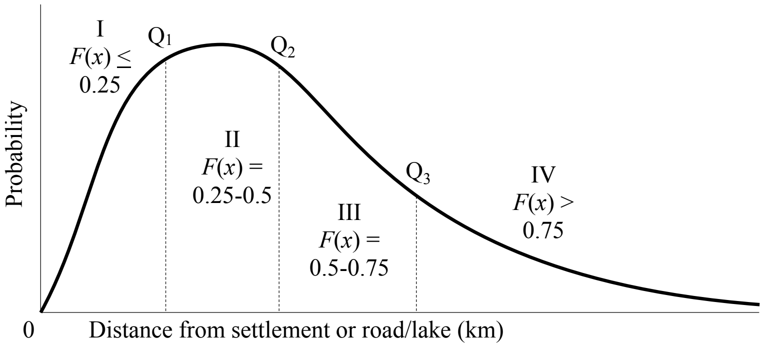


Figure 3-22: Forest fire spatial probability classes

3.5.1.5. Multiple linear regression

In order to find a correlation between resultant firespot spatial distributions and accessibility conditions in Table 3-25, multiple regression analysis were performed using backward elimination method by the following model.

$$\alpha_s ; \beta_s ; \alpha_{rl} ; \beta_{rl} = f\left(A, NS, PS, RI\right) \qquad \text{Eq. 3-24}$$

Where α_s is the scale parameter (from settlement), β_s is the shape parameter (from settlement), α_{rl} is the scale parameter (from road/lake), β_{rl} is the shape parameter (from road/lake), *A* is the size of the forest (ha), *NS* is the number of settlement (km^{-2}), *PS* is the proportion of settlement size (ha.km^{-2}), and *RI* is the road intensity (m.ha^{-1}).

Table 3-25: Potential explanatory variables of forest accessibility conditions for α- and β-parameters

FMU	A (ha)	NS (ha^{-1})	PS ($ha.km^{-1}$)	RI (m/ha)
I	144,448	0.0284	0.190	3.028
II	208,555	0.0110	0.162	5.040
III	108,849	0.0129	0.188	9.411
IV	145,116	0.0069	0.040	3.677
V	116,784	0.0103	0.306	3.731
VI	275,920	0.0022	0.011	7.085
VII	92,968	0.0151	0.153	10.432
VIII	91,709	0.0185	0.136	1.308
IX	99,042	0.0505	0.199	3.365
X	118,508	0.0017	0.007	3.721
XI	115,624	0.0242	0.191	1.579

A = size of the forest; NS = number of settlement; PS = proportion of settlement size; RI = road intensity

3.5.2. Settlement and accessibility result

Distribution fitting was successfully performed in both firespot spatial distribution from the settlement and road/lake. Sets of α- and β-parameters for all eleven FMUs and each FMU were successfully estimated. The plots of histograms and estimated firespot spatial distributions from the settlement are shown in Figure 3-23 while those from road/lake are shown in Figure 3-24.

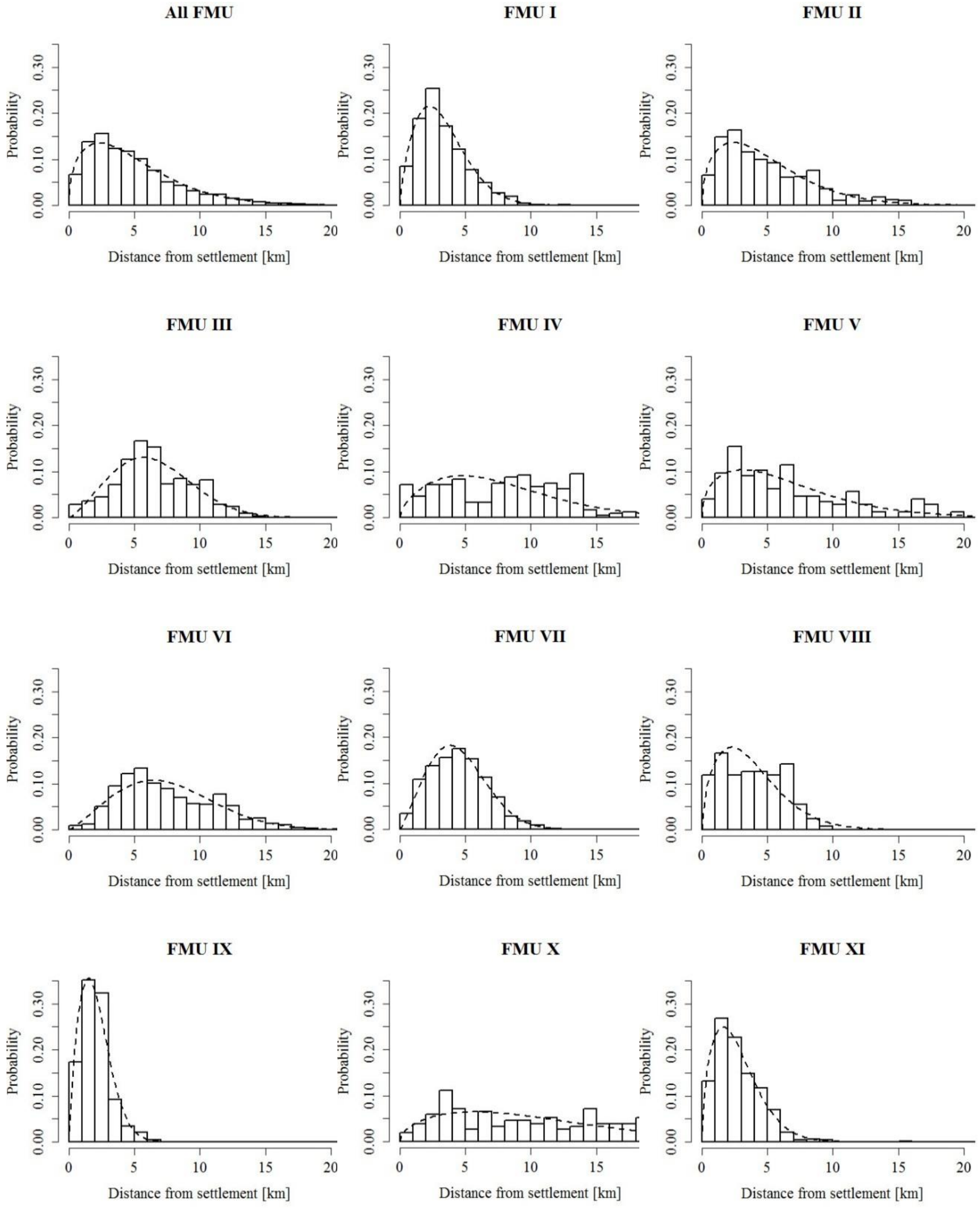


Figure 3-23: Histograms and estimated firespot spatial distribution from the settlement in 11 FMUs

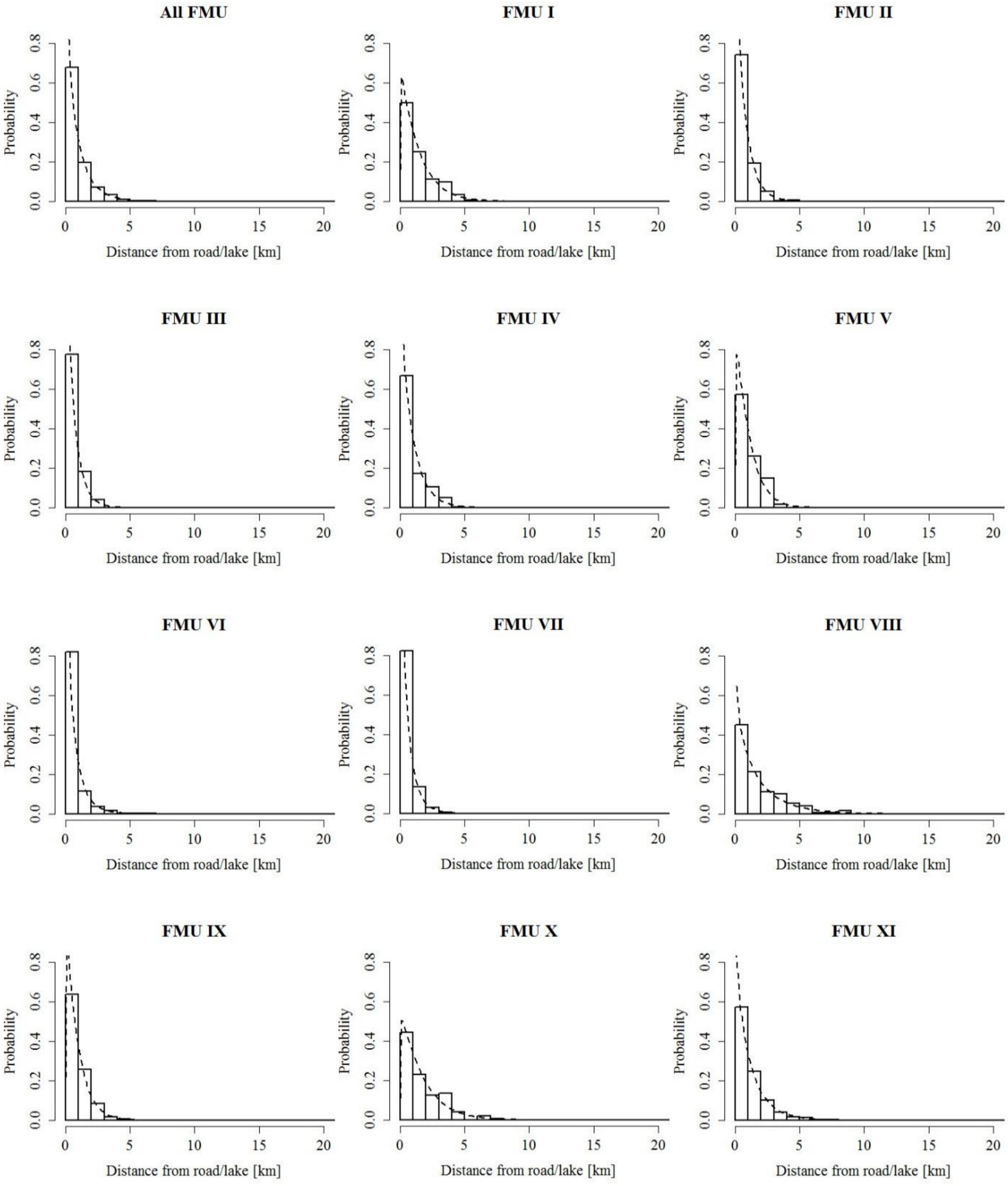


Figure 3-24: Histograms and estimated firespot spatial distribution from road/lake in 11 FMUs

The estimated parameters of firespot spatial distribution from the settlement in all 11 FMUs were $\alpha_s = 5.45$ and $\beta_s = 1.42$. However, parameters vary in each FMU within the range of $\alpha_s = 2.29 – 5.6$ and $\beta_s = 1.23 – 2.22$. While the estimated parameters from road/lake in all

11 FMUs were $\alpha_{rl} = 0.87$ and $\beta_{rl} = 0.86$ within the range of $\alpha_{rl} = 0.5 – 1.87$ and $\beta_{rl} = 0.81 – 1.03$. The list of estimated distribution parameters is presented in Table 3-26.

Table 3-26: Estimated distribution parameters and K-S test Results

FMU	From settlement			From road/lake		
	α_s	β_s	K-S ρ	α_{rl}	β_{rl}	K-S ρ
I	3.64	1.76	0.425	1.43	1.03	0.212
II	4.41	1.55	0.037	0.72	0.95	0.916
III	5.60	1.89	0.000*	0.57	0.91	0.036
IV	4.12	1.23	0.000*	0.93	0.99	0.136
V	4.20	1.55	0.111	0.93	0.99	0.136
VI	5.09	1.72	0.000*	0.57	0.81	0.587
VII	4.93	2.22	0.264	0.50	0.83	0.044
VIII	4.24	1.58	0.243	1.79	0.89	0.677
IX	2.29	1.83	0.156	0.94	1.03	0.957
X	3.71	1.42	0.007*	1.87	1.02	0.659
XI	3.02	1.62	0.643	1.23	0.93	0.887
All FMU	5.45	1.42	0.016	0.87	0.86	0.215

*Significant at 0.01

The discrepancies between estimated distribution and the firespot data distribution were tested by KS-test. It is observed that, from the settlement, there are four distributions of FMU III, FMU IV, FMU VI and FMU X that did not pass the K-S test. On the other hand, all firespot distributions from road/lake fit the firespot data in All FMUs (Table 3-26).

Since the firespot spatial distributions were estimated in probabilistic models, quartiles and mode of those distributions were easily derived from the model as shown in Table 3-27. For all FMUs, the first quartile (Q_{s1}) of 2.26 km, the second quartile (Q_{s2}) of 4.21 km and the third quartile (Q_{s3}) of 6.85 km were derived from firespot distribution from the settlement. Meanwhile, the first quartile (Q_{rl1}) of 0.2 km, the second quartile / median (Q_{rl2}) of 0.57 km and the third quartile (Q_{rl3}) of 1.27 km were derived from firespot distribution from road/lake. The modes Mo that represent the highest probability of firespot were derived at $Mo_s = 2.31$ km from the settlement (ranges 1.04 – 3.77 km). Meanwhile, for the firespot distribution from road/lake, modes can be derived only in FMU I, FMU IX and FMU X with the range of 0.04 – 0.05 km.

Table 3-27: Quartiles and modes of estimated firespot spatial distribution

FMU	From settlement				From road/lake			
	Q_{s1} (km)	Q_{s2} (km)	Q_{s3} (km)	Mo_s (km)	Q_{rl1} (km)	Q_{rl2} (km)	Q_{rl3} (km)	Mo_s (km)
I	1.80	2.96	4.39	2.26	0.43	1.00	1.96	0.05
II	1.98	3.48	5.44	2.27	0.19	0.49	1.01	-
III	2.89	4.61	6.65	3.76	0.15	0.38	0.81	-
IV	1.49	3.05	5.38	1.04	0.26	0.64	1.30	-
V	1.88	3.32	5.18	2.16	0.26	0.64	1.30	-
VI	2.47	4.11	6.15	3.07	0.12	0.36	0.85	-
VII	2.81	4.18	5.71	3.77	0.11	0.32	0.73	-
VIII	1.93	3.36	5.21	2.25	0.44	1.19	2.59	-
IX	1.16	1.87	2.74	1.49	0.28	0.66	1.28	0.04
X	1.54	2.86	4.67	1.56	0.55	1.31	2.58	0.04
XI	1.41	2.41	3.70	1.68	0.32	0.83	1.75	-
All FMU	2.26	4.21	6.85	2.31	0.20	0.57	1.27	-

Q_1 = first quartile; Q_2 = second quartile (median); Q_3 = third quartile; and *Mo* = modes (peak)

Four classes were generated in FMU XI (Figure 3-25). From the settlement, number of firespots are 181 (23%) in class I, 200 (26%) in class II, 189 (24%) in class III and 214 (27%) in class IV. On the other hand, from road/lake classes, number of firespots are 189 (24%) in class I, 203 (26%) in class II, 191 (24%) in class III and 201 (26%) in class IV. The validation shows that the probabilities within the classes closely match with the expected proportion of 25% in each class.

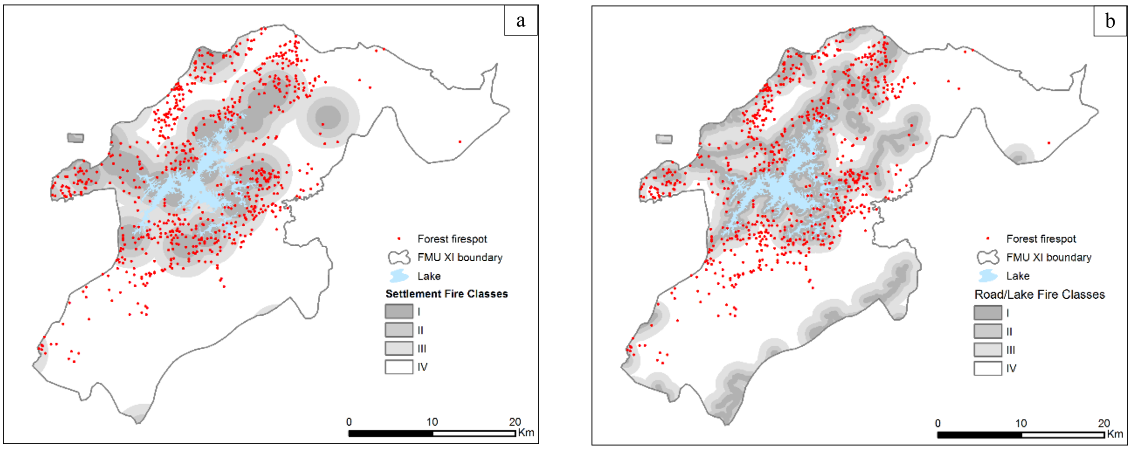


Figure 3-25: Map of firespot distribution in SAFP overlaid with firespot spatial probability classes (a) from settlement and (b) from road/lake

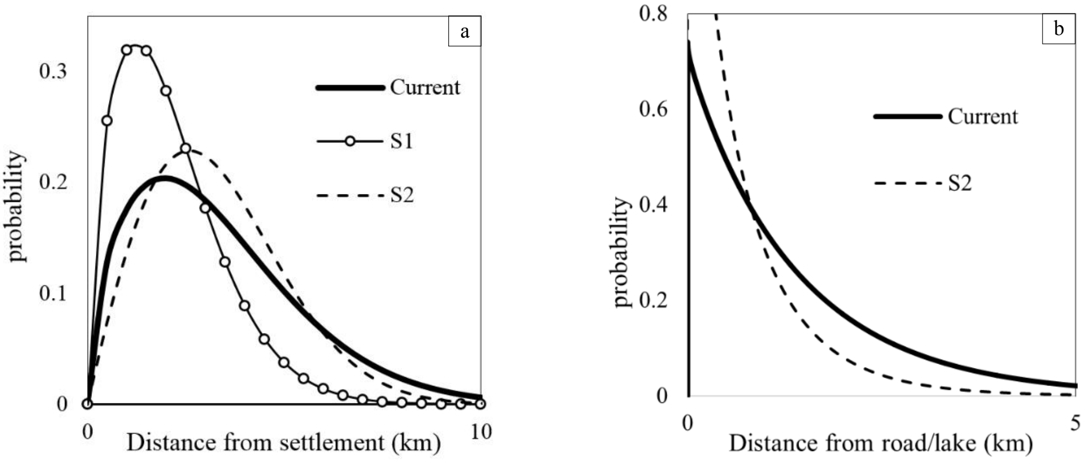
Multiple linear regression analysis regressed firespot spatial distribution (distribution parameters) and forest accessibility conditions. The selected linear models are $\alpha_s = 5.103 - 57.248 \cdot NS$ (with $R^2 = 0.77$; Fsig = 0.01) and $\beta_s = 1.476 + 0.063 \cdot RI$ (with $R^2 = 0.65$; Fsig = 0.03) for the firespot distribution from settlement. While, $\alpha_{rl} = 1.617 - 0.12 \cdot RI$ (with $R^2 = 0.57$; Fsig = 0.01) and $\beta_{rl} = 1.015 - 0.015 \cdot RI$ (with $R^2 = 0.33$; Fsig = 0.07) were selected for the firespot distribution from road/lake (Table 3-28).

Table 3-28: The multiple regression analysis results between α- and β-parameters and forest accessibility conditions

Distribution parameters	Explanatory Variables	R^2	Fsig	Models
α_s	*NS*	0.77	0.01	$\alpha_s = 5.103 - 57.248 \cdot NS$
β_s	*RI*	0.65	0.03	$\beta_s = 1.476 + 0.063 \cdot RI$
α_{rl}	*RI*	0.57	0.01	$\alpha_{rl} = 1.617 - 0.12 \cdot RI$
β_{rl}	*RI*	0.33	0.07	$\beta_{rl} = 1.015 - 0.015 \cdot RI$

Note: α_s = scale parameter for settlement; β_s = shape parameter for settlement; α_{rl} = scale parameter for road/lake; β_{rl} = shape parameter for road/lake; *NS* = number of settlement (sett.km^{-2}); *RI* = road density (m.ha^{-1})

The resultant regression models show that the firespot distribution depends on *NS* and or *RI*. The increase in both *NS* and *RI* from the currently estimated condition in FMU XI was simulated. The first simulation (S1) shows that the increase in NS by 100% shifts the firespot distribution closer to settlement. While, the increase of RI by 400% shifts the firespot distribution away from the settlement and closer to road/lake (Figure 3-26).



S1: *NS* increase by 100%; S2: *RI* increase by 400%

Figure 3-26 Simulations on the increase of *NS* and *RI* (in FMU XI) on firespot distribution (a) from settlement and (b) from road/lake

3.5.3. Settlement change

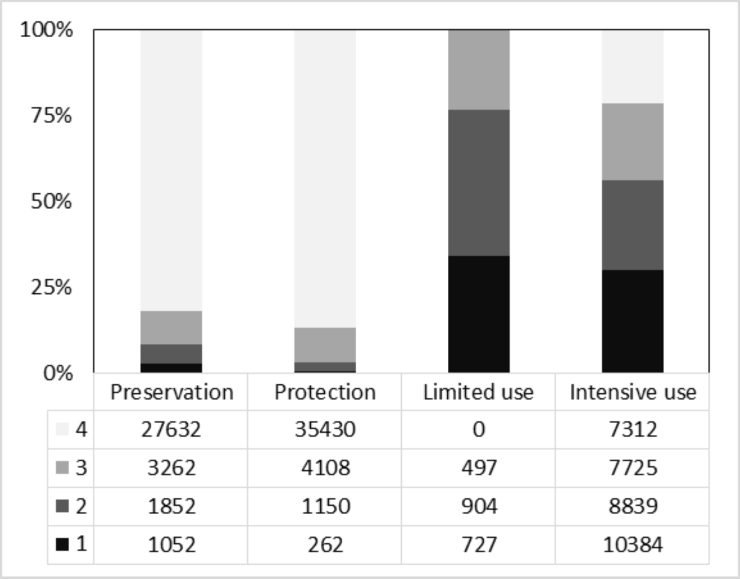
Proximity to settlement is generated by using a Euclidean Distance method. It estimates the straight-line distance from any location to the closest settlement. The distance from the settlement needs to be classed in term of the degree of the possible impact of the settlement to the forest. Various approaches have been developed to quantify the effect of the settlement (human) to the forest. This study used a proximity to the settlement for forest fire activity by using the following classes.

Table 3-29: The classification for proximity to the settlement

Class	Distance (meter)	Description
1	0 – 1,410	Very close
2	1,410 – 2,410	Close
3	2,410 – 3,700	Far
4	> 3,700	Very far

The settlement distribution in the study site was assumed unchanged during the study periods. Since the establishment of the Riam Kanan Lake for DAM and electricity power generation, most of the settlements were translocated to another area. Moreover, in accordance with the establishment of the SAFP in 1989, it is prohibited to build, or extend the settlement. Therefore, the proximity to the settlement in SAFP was estimated the same for the period of the analysis.

As can be shown in Figure 3-27 that preservation and protection zones were dominated by proximity to settlement class 4 (very far). The proportion of the class 1 (very close) and class 2 (close) dominated the limited use and intensive use zone.



	Preservation	Protection	Limited use	Intensive use
4	27632	35430	0	7312
3	3262	4108	497	7725
2	1852	1150	904	8839
1	1052	262	727	10384

Note: Class 1= very close, class 2 = close, class 3 = far, class 4 = very far

Figure 3-27: Proportion of settlement proximity in SAFP

3.5.4. Accessibility change

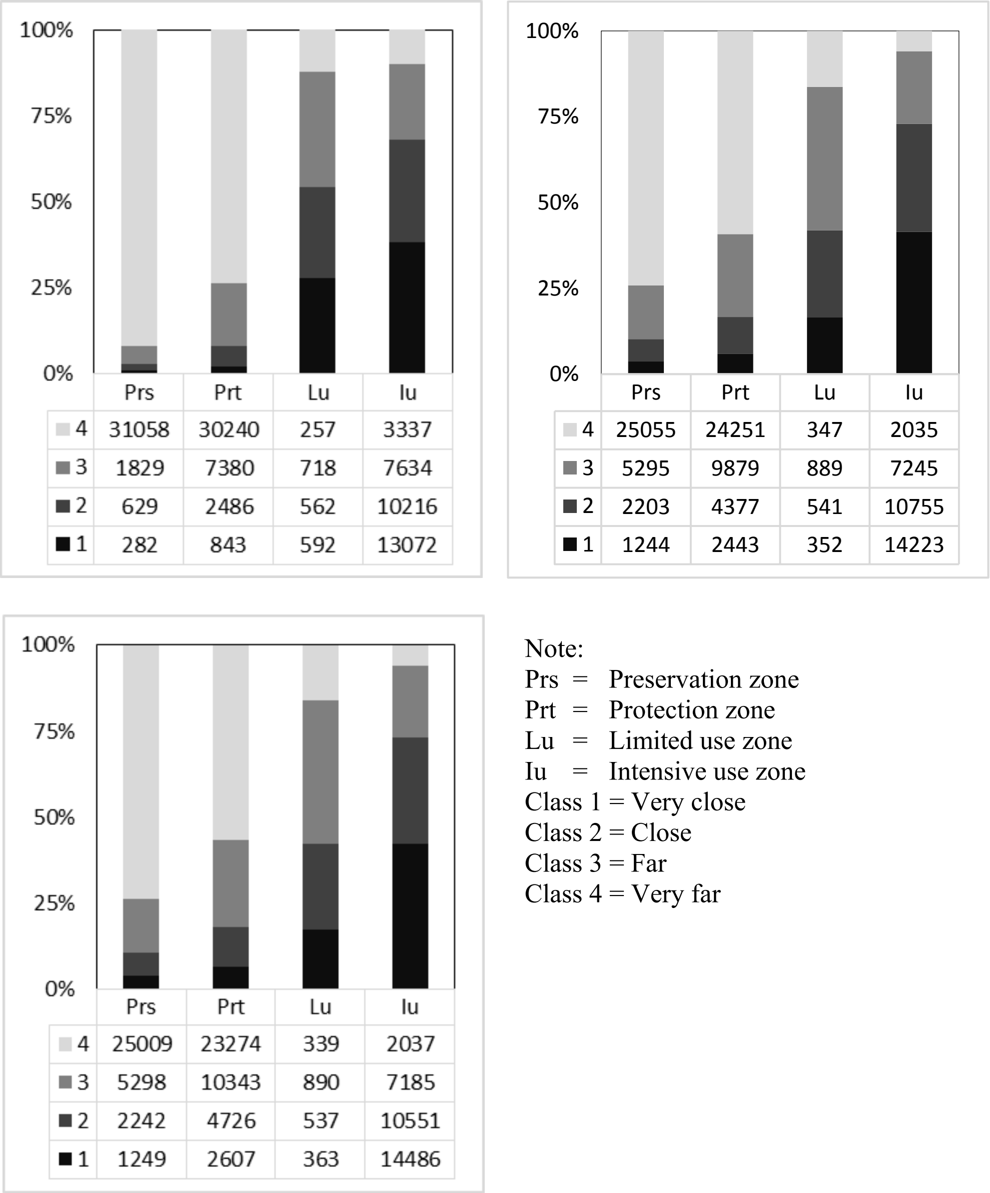
Two accessibility features were used to assess the accessibility of the forest, namely road and lake. Road feature was extracted from 1991, 1999 and 2007 Indonesian basemap with the scale of 1: 50,000. However due to the updating inaccuracy, additional accessibility features extraction from a satellite image was used. The extraction was performed on the pan-sharpened image by visual delineation method.

Road and lake are the two transportation features in SAFP. To estimate the accessibility condition, therefore, both road and lake were included in the analysis. A Euclidean Method was also used to estimate the straight distance from any location in the SAFP to either the closest road or lake/river. Further, a classification system to quantify the accessibility characteristic was used.

Table 3-30: The classification for proximity to road, lake and river

Class	Distance (meter)	Description
4	0 – 320	Very close
3	320 – 830	Close
2	830 – 1,750	Far
1	> 1,750	Very far

The change in the accessibility was studied in terms of its distribution among zones in 1993, 2003 and 2013 (Figure 3-28). Generally, it can be observed that within the period of analysis, class 1 (very close) and class 2 (close) dominated the limited use and intensive use zones. Meanwhile, the class 3 (far) and class 4 (very far) dominated the preservation and protection zone. There were increasing trends of class 1 (very close) and class 2 (close), while decreasing trends were observed in class 3 (far) and class 4 (very far).



Note:
Prs = Preservation zone
Prt = Protection zone
Lu = Limited use zone
Iu = Intensive use zone
Class 1 = Very close
Class 2 = Close
Class 3 = Far
Class 4 = Very far

Figure 3-28: Proportion and area (ha) of accessibility class among zones in 1993, 2003 and 2013

The temporal change of the accessibility classes was assessed by a confusion matrix in order to estimate the agreement among the observation years. From 1993 to 2003, the resultant Kappa statistics of 0.708 was calculated which mean that the accessibility classes in 2003 has a moderate agreement compare to those in 1993. Meanwhile, from 2003 to 2013, the resultant Kappa statistics of 0.958 was calculated which mean that the accessibility classes in 2013 has good agreement compare to those in 2003. The confusion matrices of LULC change were shown in Table 3-31 and Table 3-32. Temporal pattern of forest fragmentation was analysed using change analysis as it has been discussed on page 44.

Table 3-31: Change of accessibility class area (ha) of SAFP from 1993 to 2003

1993	2003			
	Very close	Close	Far	Very far
Very close	14,229	457	103	-
Close	939	12,618	327	8
Far	697	1,138	15,527	198
Very far	2,396	3,663	7,351	51,483

Kappa statistic **0.708**

Table 3-32: Change of accessibility class area (ha) of SAFP from 2003 to 2013

2003	2013			
	Very close	Close	Far	Very far
Very close	17,943	316	3	
Close	600	17,004	272	
Far	71	503	22,515	218
Very far	90	233	925	50,440

Kappa statistic **0.958**

3.5.5. Settlement and accessibility discussion

The study on the settlement and accessibility impacts on the forest through the presence of the forest fire is relevant due to the main deforestation and degradation threat in SAFP is from shifting cultivation. In addition, the forest fire in Indonesia is 99% anthropogenic (Adinugroho et al., 2005) and the main tool for land clearing in shifting cultivation is fire (Tomich et al., 1998). Therefore, the forest fire presence in SAFP is presumably related to the presence of the shifting cultivation. Even the spatial forest fire spatial distribution has been modelled in many studies; it still faces a backward due to the adoption of an arbitrary method in the classification of forest fire risk from accessibility features, i.e. settlement, road, and lake. This study explores a stochastic approach using 2-parameters Weibull distribution.

It was seen that in 4 FMUs (FMU III, FMU IV, FMU VI and FMU X) the estimated spatial distributions of firespot from settlement did not fit the data (Table 3-26) because the

K-S ρ values were lower than the defined 0.01 threshold. As can be seen in Figure 3-23, the estimated distributions in those FMUs have wide discrepancies from the histograms. It is visually observed the presence of multimodality of firespot distribution on those four FMUs can be the reason for unfit Weibull distribution.

The highest firespot probability (mode) from settlement for all FMUs is at 2.31 km (Table 3-27). The mode is considerably far from the settlement even the settlement is considered as a source of forest fire hazard. However, since the settlement is both the hazard and the mitigation sources, it is still meaningful to classify the forest fire probability start from the settlement even the area closer to settlement was not the highest probability of forest fire. On the other hand, in forest fire spatial distribution from road/lake, the mode is right on the road or edge of the lake. Hence, the classification of forest fire probability can be started on the road or the lake.

The α-parameter determines the span of the Weibull distribution. It also shows the characteristic of life in which about 63.21% (Rinne, 2009) of the forest fire occurs before $x = \alpha$. The α-parameter provides quick figure about the resultant distributions. In firespot distribution from the settlement, the characteristic of life for all FMUs is 5.45 km (ranges 2.29 – 5.45 km) from settlement. While, in firespot distribution from road/lake, the characteristic of life for all FMUs is 0.87 km (ranges 0.5 – 1.87 km). Hence, forest fire distribution is more concentrated around road/lake instead of around settlement.

The β-parameters determine the shape of the distribution and, therefore, determine the flexibility of the distribution. If $\beta = 1$ the distribution is identical to the exponential distribution, If $\beta = 2$ the distribution is identical to the Rayleigh distribution, and if β is between 3 and 4 the distribution is close to normal distribution (Rinne, 2009). In firespot distribution from the settlement, the β-parameters is 1.42 (ranges 1.23 – 2.22) while from road/lake the β-parameters is 0.86 (ranges 0.81 – 1.03). Forest fire spatial distribution from road/lake has mode around the road or edge of the lake because β is close to 1. Meanwhile, the forest fire spatial distributions from the settlement show the unimodal shape with mode noticeably far (ranges 1.04 – 3.77 km) from settlement.

Further, as an additional analysis to correlate the behavior of the distribution (parameters) with explanatory variables, the regression analysis were used. The regression models in Table 3-28 is beneficial to predict the effect of the change in *NS* and *RI* on the forest fire spatial distribution from accessibility. As shown in Figure 3-26, the increase in *NS* shifts the firespot distribution closer to settlement. Higher *NS* within forest may reduce the range of human activities within the forest. While, the increase of *RI* shifts firespot distribution farther from settlement and closer to road/lake. The *RI* affects not only the firespot spatial distribution from road/lake, but also from settlement. The road/lake extends the forest fire spatial distribution farther from settlement.

This study provides evidence that forest fire is more anthropogenic rather than naturally occurs. First, the forest fire probability is relatively low in the area closer to settlement and increase until it reaches the maximum probability. Human prefers to minimize the forest fire in the area closer to settlement. Second, the probability of forest fire decreases after it reaches the maximum probability. The distance barriers the forest fire to ignite deeper into the forest due to human limitation to travel from settlement to deeper forest. Third, the highest fire probability is right on the road or edge of the lake. Traveling farther from road/lake increase the cost and certainly not preferred.

The stochastic approach provides a quantitative method compare to arbitrary approach for assessing the effect of the accessibility on the forest fire spatial distribution and therefore also on the shifting cultivation in SAFP. This approach also has an advantage due to the nature of the forest fires are stochastic (Gilless and Fried, 1998). The approach also gives practical benefit for forest fire management due to its flexible application for probability classification.

Settlement was assumed unchanged in the period of analysis. The assumption is related to the fact that the settlement has been enclaved from the forest and, therefore, there is no further allowance to expand deeper into the forest. Legally, there is no further permission that community can expand the settlement or build another settlement in SAFP. The settlement is mainly located in the use zones (limited use and intensive use). The proportion of the class of 'very close' is very high in the zones. Contrary, the preservation and protection zones were dominated by 'very far' class.

Similarly, the class of 'very close' to road/lake dominated the limited use and intensive use zones while 'far' and 'very far' classes dominated the preservation and protection zones. Even the accessibility assumed changed, however, the change in 1993 – 2003 period was moderate while in the 2003 – 2013 period the accessibility considerably unchanged. The Kappa statistics for 1993 – 2003 and 2003 – 2013 were 0.708 and 0.985, respectively.

3.6. Forest fire

3.6.1. Forest fire method

3.6.1.1. Forest fire data

Forest fire data were derived from NOAA/AVHRR forest fire satellite monitoring program from Indonesian Ministry of Forestry (1994 – 1999) and MODIS Fire Information for Resource Management System (FIRMS) (2000 – 2013). MODIS firespot data was downloaded from https://earthdata.nasa.gov/data/near-real-time-data/firms with the specification shown in Table 3-29.

Table 3-33: MODIS firespot specification

Attribute	Short Description	Long Description
Latitude	Latitude	Center of 1km fire pixel but not necessarily the actual location of the fire as one or more fires can be detected within the 1km pixel.
Longitude	Longitude	Center of 1km fire pixel but not necessarily the actual location of the fire as one or more fires can be detected within the 1km pixel.
Brightness	Brightness temperature 21 (Kelvin)	Channel 21/22 brightness temperature of the fire pixel measured in Kelvin.
Scan	Along Scan pixel size	The algorithm produces 1km fire pixels but MODIS pixels get bigger toward the edge of scan. Scan and track reflect actual pixel size.
Track	Along Track pixel size	The algorithm produces 1km fire pixels but MODIS pixels get bigger toward the edge of scan. Scan and track reflect actual pixel size.
Acq_Date	Acquisition Date	Data of MODIS acquisition.
Acq_Time	Acquisition Time	Time of acquisition/overpass of the satellite (in UTC).
Satellite	Satellite	A = Aqua and T = Terra.
Confidence	Confidence (0-100%)	This value is based on a collection of the intermediate algorithm quantities used in the detection process. It is intended to help users gauge the quality of individual hotspot/fire pixels. Confidence estimates range between 0 and 100% and are assigned one of the three fire classes (low-confidence fire, nominal-confidence fire, or high-confidence fire).
Version	Version (Collection and source)	The number before the decimal refers to the collection (e.g. MODIS Collection 5). The number after the decimal indicates the source of Level 1B data; 0 indicates data processed in near-real time by NASA-LANCE, .1 indicates data sourced from MODAPS (with a 2 month lag) and processed by FIRMS. For example, data with the version listed, as “5.0” is collection 5 are processed by NASA-LANCE; “5.1” is Collection 5 data processed by MODAPS. Information on collections and on the differences between Rapid Response and MODAPS.
Bright_T31	Brightness temperature 31 (Kelvin)	Channel 31 brightness temperature of the fire pixel measured in Kelvin.
FRP	Fire Radiative Power (MW – megawatts)	Depicts the pixel-integrated fire radiative power in MW (megawatts).

Source: NASA (2013)

The obtained data of NOAA and MODIS firespots were in TXT format that consists of the coordinate list with auxiliary information. The TXT data was plotted into a geographic data as shown in Figure 3-29.

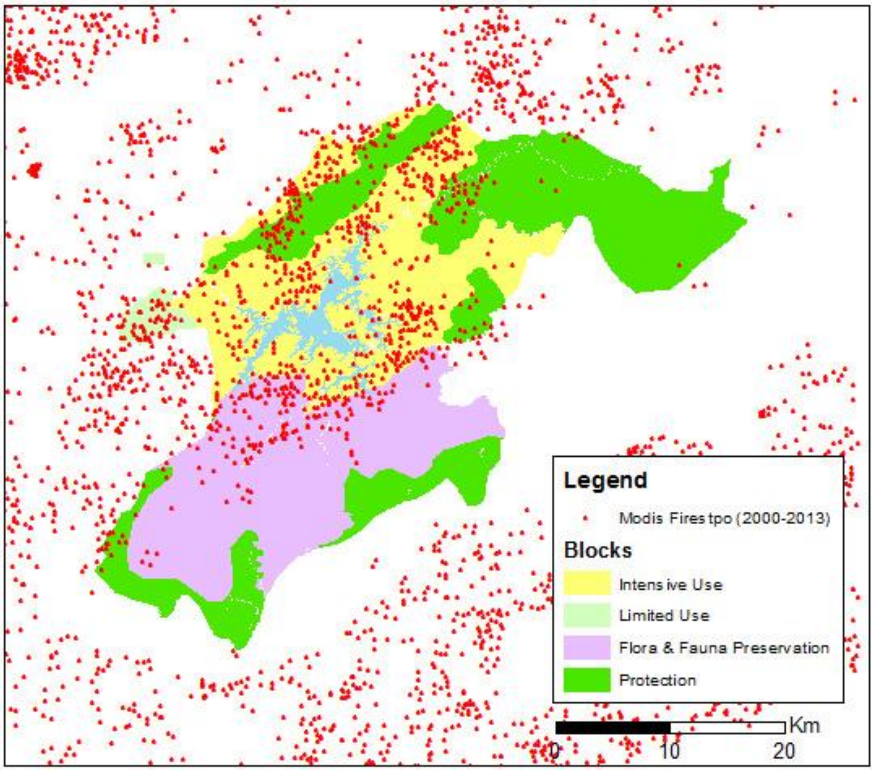


Figure 3-29: Firespot distribution in SAFP (2001 – 2013)

In order to estimate the historical forest fire on study period (2013, 2003 and 1993), historical forest fire data from MODIS firespot in the corresponding year (+/- 2 years) were analysed. The unavailability of the firespot data either before 1994 limited the analysis. The data used to estimate the severity of the forest fire is shown in Table 3-34.

Table 3-34: Firespot data used for historical forest fire severity

No	Data	Scale, resolution	Year	Coverage	Source
1.	MODIS Firespot	1 km; 1-2 days	2011-2013	SAFP	USGS
2.	MODIS Firespot	1 km; 1-2 days	2001-2005	SAFP	USGS
3.	NOAA AVHR Firespot	1 km; 1-2 days	1994-1995	SAFP	MoF

3.6.1.2. Forest fire analysis

NOAA/AVHR and MODIS firespot were obtained in a TXT point format. In order to estimate the forest fire probability, fire spots data were converted into continuous grid data with Kernel Density Estimation (KDE) method. Its searching radius (bandwidth) was estimated by double *Rdmean* formula of $RDMean = \frac{1}{2}\sqrt{A/N}$, where *A* is the size of the study site and *N* is number of firespot within the study site during period of analysis (Kuter et al., 2011).

$$\text{searchin gradius} = 2\left(RDMean\right) = 2\left(\frac{1}{2}\sqrt{\frac{A}{N}}\right) = \sqrt{\frac{A}{N}} \qquad \text{Eq. 3-25}$$

Considering that the size of the SAFP without the lake is 111,135 hectares (1.2 x 10^9 m^2) and number of firespot for the period of 2009-2013 is 189. Therefore the double *RDMean* is 2,434 m. The resultant forest fire index from the KDE was classified into four classes by a natural break classification as very high, high, low and very low classes as shown in Table 3-35. The class limit was determined by analysis.

Table 3-35: The classification of forest fire density

Class	Description
1	Very high
2	High
3	Low
4	Very low

3.6.2. Forest fire result

3.6.2.1. Forest fire density

Forest fire probability were assessed in 1993, 2003 and 2013. The resultant forest fire indices that were estimated by the KDE are shown in Figure 3-30, Figure 3-31 and Figure 3-32.

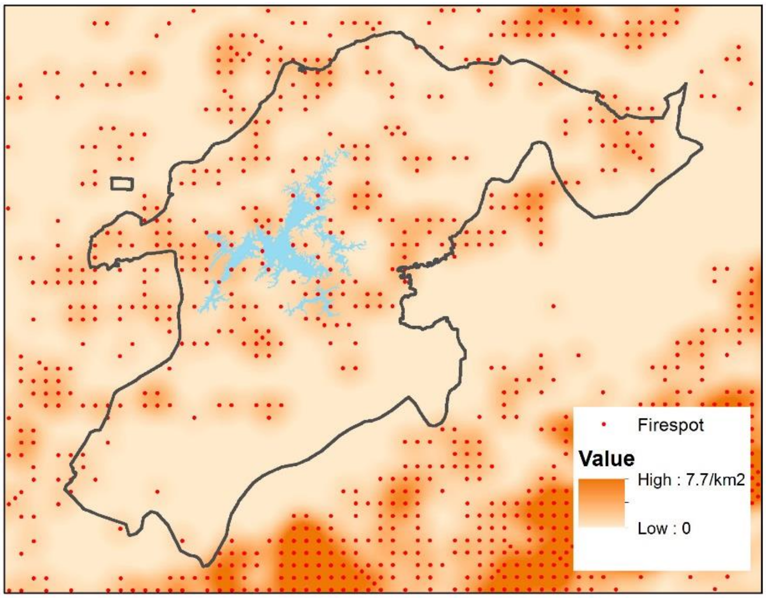


Figure 3-30: Forest fire map with kernel density estimation for 1993

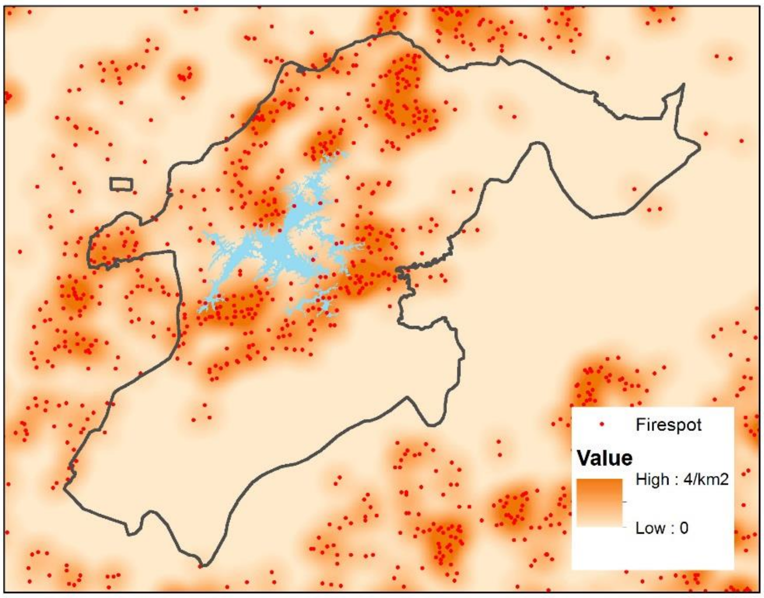


Figure 3-31: Forest fire map with kernel density estimation for 2003

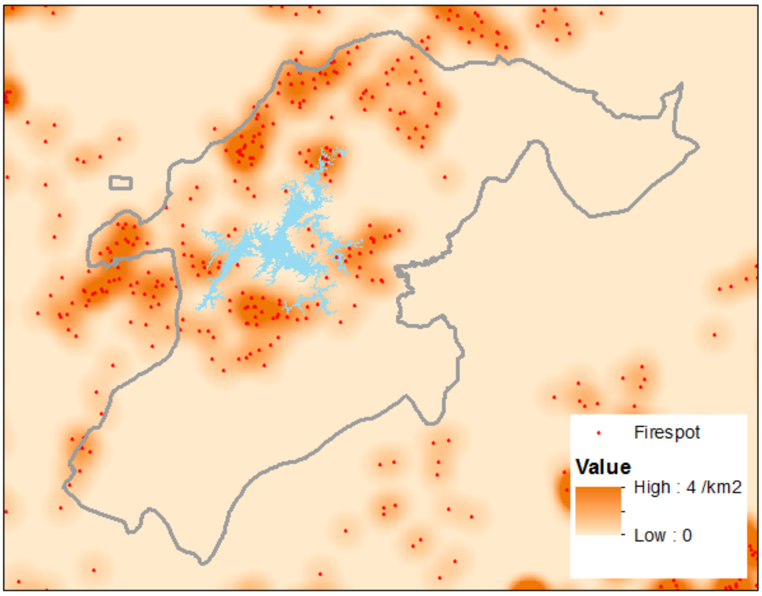
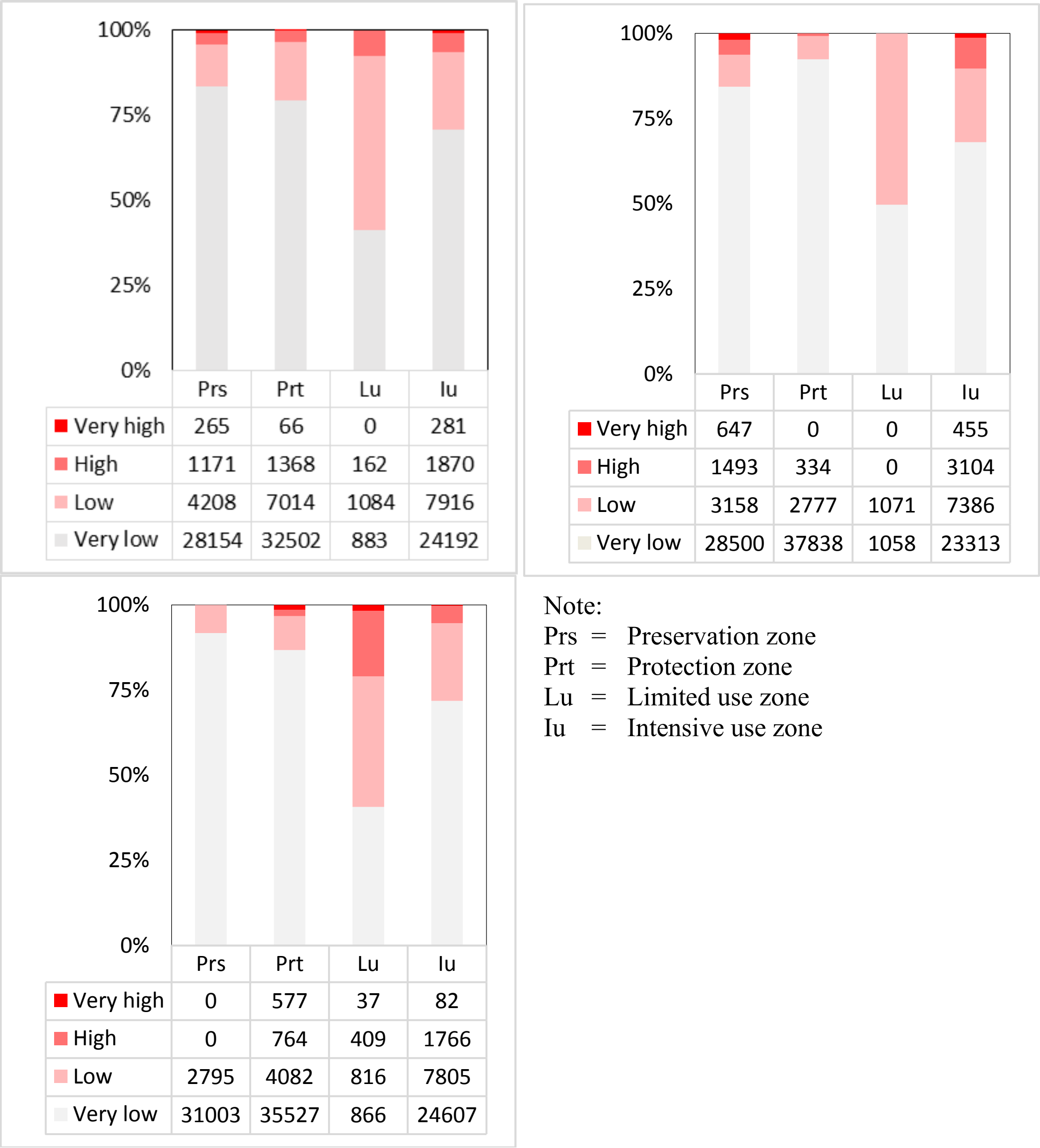


Figure 3-32: Forest fire map with kernel density estimation for 2013

3.6.2.2. Spatial pattern of forest fire

The change of the forest fire classes was studied in terms of its distribution among zone in 1993, 2003 and 2013 (Figure 3-33). Forest fire classes' distribution among zones has significant spatial change. Very high forest fire probability class mostly distributed in intensive use and preservation zone in 1993 and 2003. However, in 2013 the class mostly occurred in the protection and limited use zones. Overall, only limited use has less than 50% area of very low forest fire probability.



	Prs	Prt	Lu	Iu
Very high	265	66	0	281
High	1171	1368	162	1870
Low	4208	7014	1084	7916
Very low	28154	32502	883	24192

	Prs	Prt	Lu	Iu
Very high	647	0	0	455
High	1493	334	0	3104
Low	3158	2777	1071	7386
Very low	28500	37838	1058	23313

	Prs	Prt	Lu	Iu
Very high	0	577	37	82
High	0	764	409	1766
Low	2795	4082	816	7805
Very low	31003	35527	866	24607

Note:
Prs = Preservation zone
Prt = Protection zone
Lu = Limited use zone
Iu = Intensive use zone

Figure 3-33: Proportion and area (ha) of forest fire class among zones in 1993, 2003 and 2013

3.6.2.3. Temporal pattern

The temporal change of the forest fire class was assessed by a confusion matrix in order to estimate the agreement among the observation years. From 1993 to 2003, the resultant Kappa statistics was 0.113 that mean that the forest fire class in 2003 has a poor agreement compare to those in 1993. Meanwhile, from 2003 to 2013, the resultant Kappa statistics of 0.261 was calculated that also mean the forest fire class in 2013 has a poor agreement compare to those in 2003. The confusion matrices of forest fire change were shown in Table 3-36 and Table 3-37. The temporal pattern of forest fire was analysed using change analysis as it has been discussed on page 44.

Table 3-36: Change of forest fire class (ha) of SAFP from 1993 to 2003

1993	2003			
	Very low	Low	High	Very high
Very low	75,568	8,831	3,694	639
Low	14,205	4,452	1,101	464
High	3,580	865	126	-
Very high	356	244	11	-

Kappa statistic **0.113**

Table 3-37: Change of forest fire class (ha) of SAFP from 2003 to 2013

2003	2013			
	Very low	Low	High	Very high
Very low	81,191	8,151	1,328	38
Low	7,402	4,867	1,482	642
High	2,851	1,935	129	16
Very high	559	544	-	-

Kappa statistic **0.261**

3.6.3. Forest fire discussion

Forest fire is mostly distributed in the use zones (limited-use and intensive use zones). Since the two zones are located surrounding the lake and relatively closer to settlement and high accessibility, this condition is similar to Murdiyarso et al. (2002) who stated that higher access and closer to human means higher fire threat on the forest. However, SAFP management still should aware that there are some proportions of very high and high forest fire probabilities also identified in preservation and protection zones.

Forest fire temporally changed significantly in SAFP. Its resultant change indicators were significantly lower than 0.4 in both periods (1993 – 2003 and 2003 – 2013). The significant change of forest fire support the idea that the main threat in SAFP is shifting cultivation that occupy and abandon the land regularly. Hariyadi and Ticktin (2012) revealed that shifting cultivation in Indonesia has a highly temporal change due to the land occupation rotation within forest. Since forest fire is the main tool for land clearing including for shifting cultivation (Tomich et al., 1998) therefore the main cause of the high spatial and temporal change of forest fire is the use of fire for land clearing for shifting cultivation.

3.7. Soil erosion potential

3.7.1. Soil erosion potential method

3.7.1.1. Soil erosion potential data

Soil erosion potential was assessed by using rainfall, soil type, lithology, topography, land use land cover (LULC), and land management data. Rainfall data were obtained from Banjarmasin (Syamsudin Noor) and Kotabaru (Stagen) Weather Stations that are located ca. 35 km and 130 km from the study site, respectively. An average of ten years of rainfall data was derived from 1992 to 2013 for each station. Then, the point-based gauged average rainfall data were converted into a continuous rainfall data for the whole study site by a Kriging method followed Mair and Fares (2011). Soil data were derived from the soil type map (1:250,000 scale) from Indonesian Center for Agricultural Land Resources Research and Development issued in 2011. The lithological information was extracted from the Geological map of Banjarmasin (1:250,000 scale) issued by the Indonesian Geological Development and Research Center in 1994. Topographical data (slope, divergence, and convergence) were derived from the Shuttle Radar Topographic Mission (SRTM) DEM that has 90 meters resolution. LULC data was obtained from Landsat imagery.

Table 3-38: Data for soil erosion potential assessment

No	Data	Type	Scale, resolution	Year	Coverage, extent	Source
1.	Rainfall Gauge	Attribute	Monthly	1992 – 2013	SAFP	BMKG
2.	Soil type	Vector	1 : 250,000	2011	Banjarmasin	ICALRD
3.	SRTM	Raster	90 m	2000	South Kalimantan Province	NASA
4.	LULC	Raster	30 m	1993 2003 2013	SAFP	LULC analysis

Rainfall Data

Rainfall erosivity was estimated by using monthly rainfall (Lenvain 1989 in Asdak 1995) by using monthly rainfall intensity (P) with the formula of $R = 2.21P^{1.36}$ where R is erosivity of the rainfall and P is monthly rainfall (mm). For yearly rainfall data, the estimation of the rainfall erosivity used the formula of $R = (0.41H)^{1.09}$ where R is the rainfall erosivity and H is yearly rainfall intensity ($mm.yr^{-1}$). As this study assess three observed years (1993, 2003 and 2013), therefore the yearly rainfall intensity in the corresponding year was used; rainfall data of 1992 – 1994 for 1993, rainfall data of 2002 – 2004 for 2003 and rainfall data of 2011 – 2013 for 2013.

Soil Erodibility

Soil erodibility was estimated by soil types. For the application in forestry, KKES (2002) and Kartasapoetra (1991) proposed estimating the soil erodibility by the Table 3-39. Its spatial distribution across SAFP is presented in Figure 3-34.

Table 3-39: Soil erodibility of soil types

No	Soil types	K
1	Alluvial, planosol, hidromorf kelabu, laterik	0.20
2	Latosol	0.23
3	Mediteranian	0.24
4	Andosol, grumosol, podsol, podsolik	0.26
5	Regosol, litosol, organosol, renzina	0.31

Adapted from KKES (2002) and Kartasapoetra (1991)

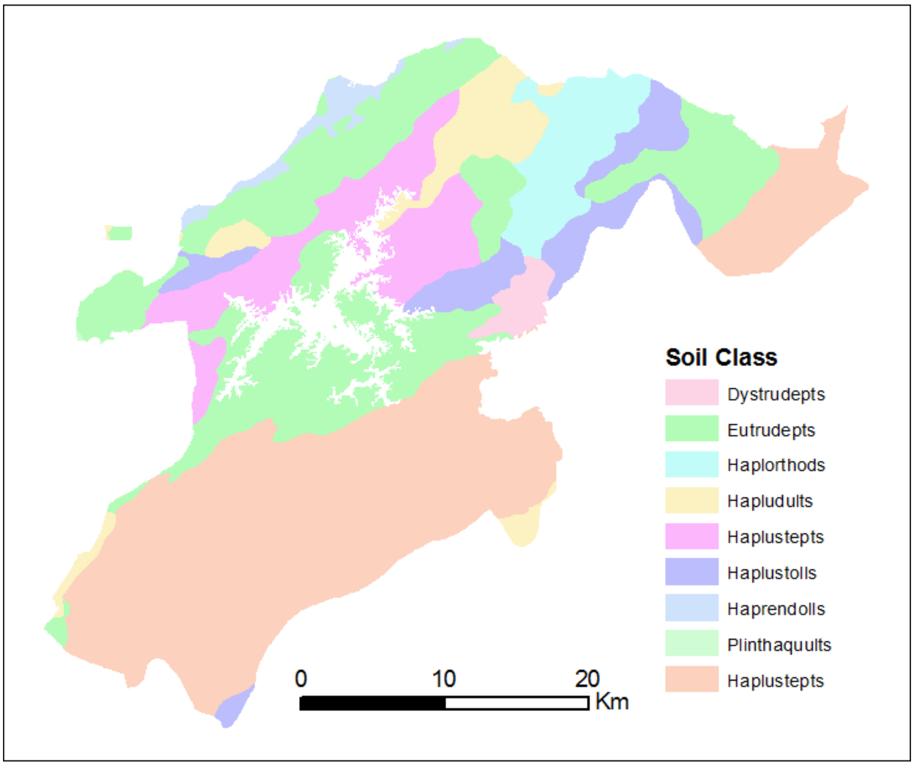


Figure 3-34: Soil type map in SAFP

Topography (LS)

Topographic factor in USLE consists of the length of slope (L) and slope (S). However, some studies have been carried out to provide a simple estimation of both L and S. For the degraded land application in Indonesia, Ministry of Forestry (1986) provided a simple estimation to estimate the topographic factors as shown in Table 3-40.

Table 3-40: LS values for various slope

Slope class	Slope Range (%)	LS
1	0 – 5	0.25
2	5 – 15	1.20
3	15 – 35	4.25
4	35 – 50	9.50
5	> 50	12.00

Adapted from Indonesian Ministry of Agriculture (1980)

Vegetation management (CP)

Vegetation management consists of *C* and *P* factors. Some efforts have been conducted to estimate CP value for various land use and land cover types. This study used CP value adapted from Hammer (1981) as can be seen in Table 3-41.

Table 3-41: *CP* factors in SAFP

Class	LULC	CP
1	Forest	0.01
2	Mixed plantation	0.07
3	Shrub/bush	0.10
4	Grassland	0.02
5	Bare land	0.85

Adapted from Hammer (1981)

3.7.1.2. Soil erosion potential analysis

Estimation of the soil erosion potential was performed by the Universal Soil Loss Equation (USLE) (Dissmeyer et al., 1980; Kinnell and Risse, 1998). The USLE has components of rainfall intensity THE, soil erodibility (K), topographic condition (LS), and vegetation management (CP). It is used to predict the long-term average annual soil loss (A) by using six components includes rainfall erosivity THE, soil erodibility (K), topographic factor (LS), and cropping management factor (CP) in the equation below.

$$A = RKLSCP \qquad \text{Eq. 3-26}$$

Where *A* is soil erosion potential (ton ha-1 yr-1), *R* is rainfall erosivity, *K* is soil erodibility, *LS* is length and slope of the land, and *CP* is vegetation management. The resultant soil erosion potential that was calculated by the equation above was classified into five classes as shown in the following table.

Table 3-42: Soil erosion potential classes

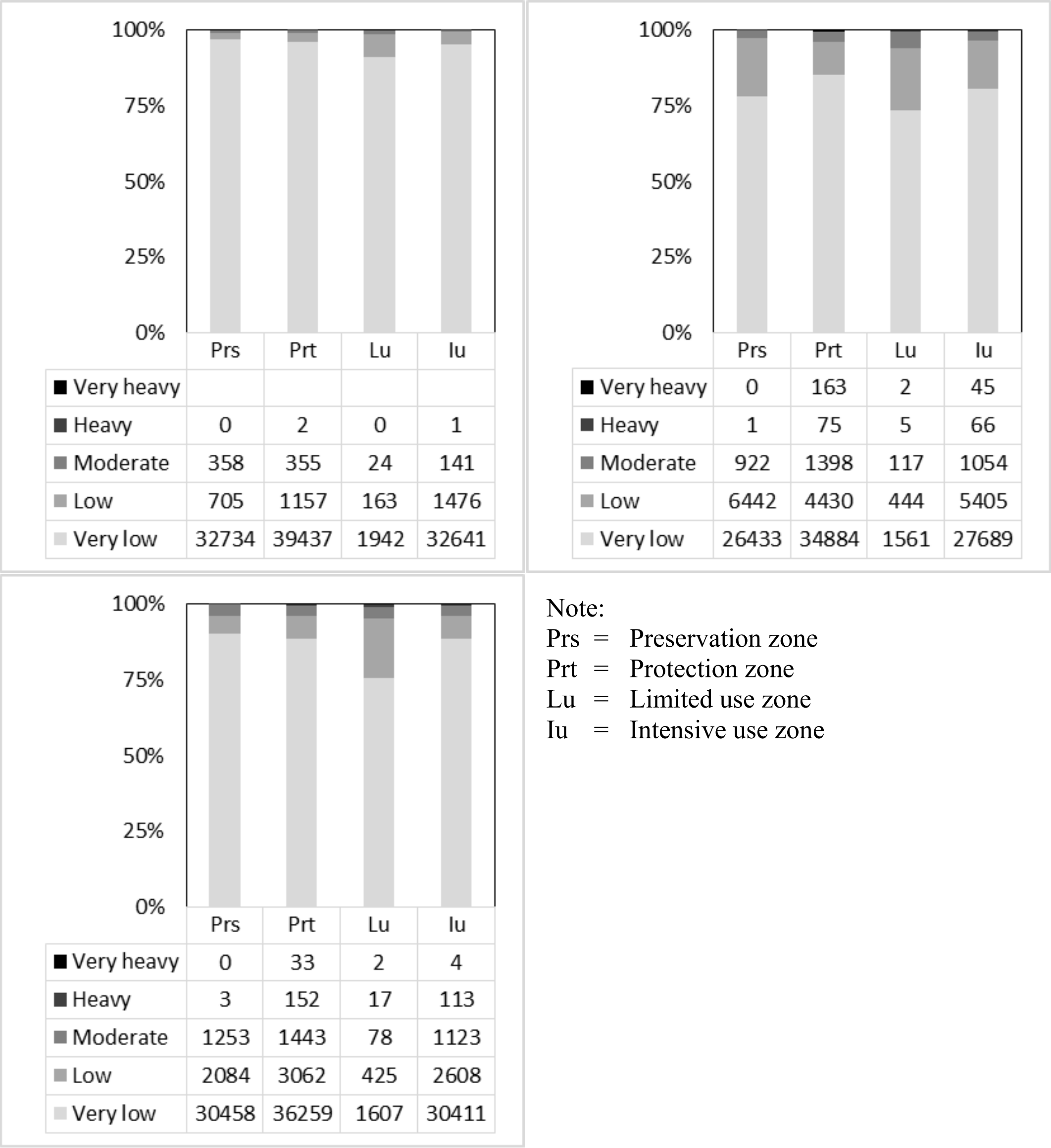
Class	Soil erosion potential ($ton.ha^{-1}.yr^{-1}$)
I (very low)	0 – 15
II (low)	15 – 60
III (moderate)	60 – 180
IV (heavy)	180 – 480
V (very heavy)	> 480

Source: Kinnell and Risse (1998)

3.7.2. Soil erosion potential result

3.7.2.1. Spatial pattern

The change of the soil erosion potential was studied in terms of its distribution among zone in 1993, 2003 and 2013. Throughout the study period, the proportions of ‘very heavy’ and ‘heavy’ classes were considerably insignificant. The most dominant was very low class that has more than 75% proportion.



	Prs	Prt	Lu	Iu
■ Very heavy				
■ Heavy	0	2	0	1
■ Moderate	358	355	24	141
■ Low	705	1157	163	1476
■ Very low	32734	39437	1942	32641

	Prs	Prt	Lu	Iu
■ Very heavy	0	163	2	45
■ Heavy	1	75	5	66
■ Moderate	922	1398	117	1054
■ Low	6442	4430	444	5405
■ Very low	26433	34884	1561	27689

	Prs	Prt	Lu	Iu
■ Very heavy	0	33	2	4
■ Heavy	3	152	17	113
■ Moderate	1253	1443	78	1123
■ Low	2084	3062	425	2608
■ Very low	30458	36259	1607	30411

Note:
Prs = Preservation zone
Prt = Protection zone
Lu = Limited use zone
Iu = Intensive use zone

Figure 3-35: Proportion and area (ha) of soil erosion potential class among zones in 1993, 2003 and 2013

3.7.2.2. Temporal pattern

The temporal change of the soil erosion potential class was assessed by a confusion matrix in order to estimate the agreement among the observation years. From 1993 to 2003, the resultant Kappa statistics of 0.245 was calculated which mean that the soil erosion potential class in 2003 has a poor agreement compare to those in 1993. Meanwhile, from 2003 to 2013, the resultant Kappa statistics of 0.486 was calculated which mean that the forest fire class in 2013 has a moderate agreement compare to those in 2003. The confusion matrices of the class of the soil erosion potential were shown in Table 3-43 and Table 3-44. Temporal pattern of soil erosion potential was analysed using change analysis it has been discussed on page 44.

Table 3-43: Change of soil erosion potential class (ha) of SAFP from 1993 to 2003

1993	2003				
	Very low	Low	Moderate	Heavy	Very heavy
Very low	90,055	13,963	2,471	126	140
Low	510	2,587	339	9	57
Moderate	2	171	681	11	12
Heavy	-	-	-	1	2
Very heavy					

Kappa statistic = 0.245

Table 3-44: Change of soil erosion potential class (ha) of SAFP from 2003 to 2013

2003	2013				
	Very low	Low	Moderate	Heavy	Very heavy
Very low	87,714	1,932	885	35	1
Low	10,698	5,630	386	6	2
Moderate	300	600	2,586	5	1
Heavy	2	6	40	99	-
Very heavy	22	11	1	140	36

Kappa statistic = 0.486

3.7.3. Soil erosion potential discussion

Soil erosion potential mostly distributed in the use zones (limited-use and intensive use zones). The proportion of the very heavy and heavy classes of soil erosion potential increased in those zones. Lack of the forest cover in the zones (Figure 3-12 on page 74) is the possible reason since vegetation is one of the important soil erosion components. Other factors such as rainfall and rainfall erodibility are relatively similar through the study site, then vegetation management plays a crucial role in assessing the soil erosion potential.

Soil erosion potential changes differently across time. In the period of 1993 – 2003, soil erosion potential significantly change with the change indicator (Kappa statistics) less than 0.4. However, in the second period (2003 – 2013), the soil erosion potential had moderately changed with the Kappa statistic in 0.4 – 0.8 interval. The changes are related to the change in the LULC temporal classes which also had higher Kappa statistics in the second period compare to that in the first period.

3.8. Hazard prevention

3.8.1. Hazard prevention method

3.8.1.1. Hazard prevention data

Hazard prevention used topographic, rainfall, soil and geological data as shown in Table 3-45. Scale and resolution of the data have been selected appropriately for the forest landscape analysis as Woolmer (2010) proposed 1:25,000 – 100,000 for feature and 25 – 100 meters for cell size as the appropriate scale and resolution

Table 3-45: Data type, resolution, acquisition, coverage and source

No	Data	Scale, resolution	Year	Coverage, extent	Source
1.	SRTM	90 m	2000	South Kalimantan Province	NASA
2.	Rainfall Gauge	Monthly	1954 – 2013	SAFP	BMKG
3.	Soil type	1 : 250,000	2011	Banjarmasin	ICALRD
4.	Geological map	1 : 250,000	1989	Banjarmasin	ICALRD

3.8.1.2. Hazard prevention analysis

Three natural hazards related to soil and water conservation were examined. Phua and Minowa (2005) proposed landslide, flood and drought prevention as criteria that were examined using the formulas in Table 3-46 and the scores in Table 3-47. The total hazard prevention score is then estimated by the following equation.

$$hazard = 0.69(landslide) + 0.11(flood) + 0.2(drought) \quad \text{Eq. 3-27}$$

Table 3-46: Hazard prevention index

Hazard prevention (and weight)		Formula
Landslide	(0.69)	0.3 slope + 0.2 annual rainfall + 0.2 soil depth + 0.15 geology + 0.15 topography
Flood	(0.11)	0.2 slope + 0.2 annual rainfall + 0.25 soil depth + 0.15 geology + 0.2 topography
Drought	(0.20)	0.1 slope + 0.25 annual rainfall + 0.3 soil depth + 0.15 geology + 0.15 topography

Adapted from Phua and Minowa (2000)

Table 3-47: Scores for landslide, flood and drought prevention

Prevention	Classes	Slope	Annual rainfall	Soil depth	Geology	Topography
Landslide	High (3)	> 25%	> 4,000	Thin	Igneous (Granite)	Convergence
	Medium (2)	15 – 25%	3,000 – 4,000	Medium	Igneous (Ultrabasic)	Planar
	Low (1)	0 – 15%	≤ 3,000	Thick	Sedimentary	Divergence
Flood	High (3)	0 – 15%	> 4,000	Thick	Igneous (Granite)	Convergence
	Medium (2)	15 – 25%	3,000 – 4,000	Medium	Igneous (Ultrabasic)	Planar
	Low (1)	> 25%	≤ 3,000	Thin	Sedimentary	Divergence
Drought	High (3)	> 25%	≤ 3,000	Thick	Igneous (Granite)	Convergence
	Medium (2)	15 – 25%	3,000 – 4,000	Medium	Igneous (Ultrabasic)	Planar
	Low (1)	0 – 15%	> 4,000	Thin	Sedimentary	Divergence

Adapted from Phua and Minowa (2000)

The resultant hazard prevention index was classified into four classes by a natural break classification as shown in Table 3-42. The class limit of the class depend on the resultant hazard prevention index, and it was determined during analysis.

Table 3-48: Soil erosion potential classes

Class	Description
1	Very low
2	Low
3	Medium
4	Very high

3.8.2. Hazard prevention result

Hazard prevention is another sub-component of value/importance for the rehabilitation prioritization. This component was not accommodated in the common practice in Indonesia but was considered in Borneo Island by Phua and Minowa (2005) which consists of drought, flood and landslide prevention. Hazard prevention score was distributed unevenly in the SAFP. The high score is mostly located in the south and east part of the park. On the other hand, the low scores of hazard prevention were located in the north part as shown in Figure 3-36.

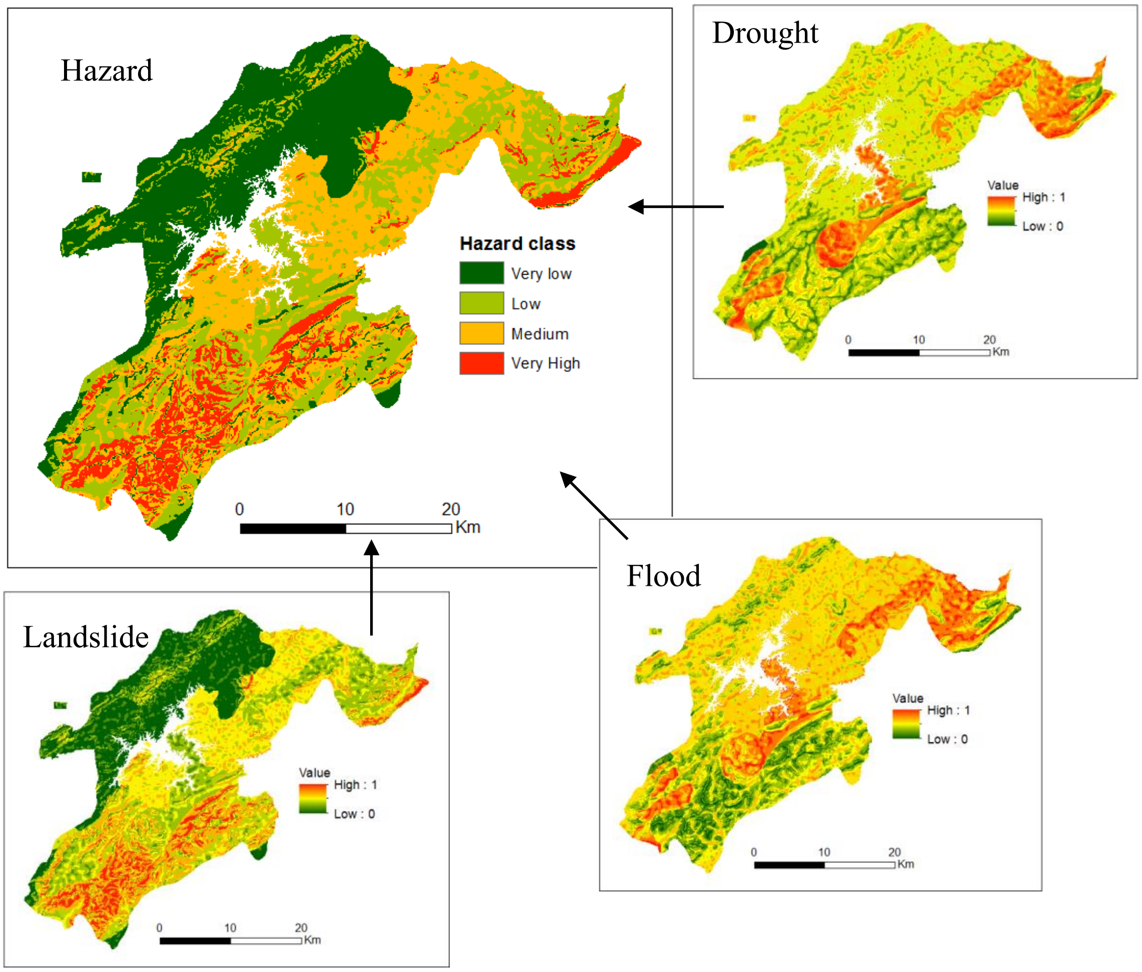
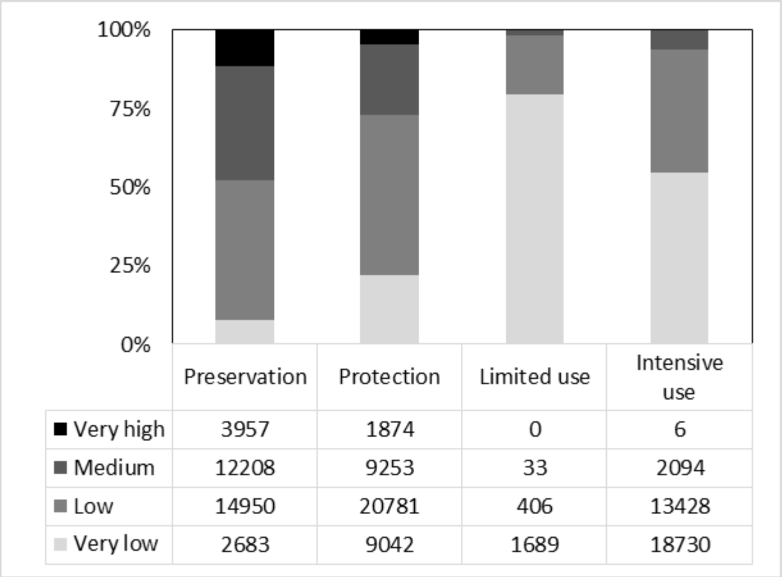


Figure 3-36: Landslide, flood, and drought hazard prevention

Parameters for hazard prevention estimation considers slope, annual rainfall, soil depth, geology, and topographical convergence. Considering those parameters can be assumed unchanged during the study period, therefore the hazard prevention was considered steady during the study period as shown in Figure 3-37. Very low hazard prevention class dominated limited use and intensive zones with the proportion more than 50% of the zone.

Very high hazard prevention class occurred mostly in preservation and protection zones with 3,957 ha and 1,874 ha respectively.



	Preservation	Protection	Limited use	Intensive use
■ Very high	3957	1874	0	6
■ Medium	12208	9253	33	2094
■ Low	14950	20781	406	13428
■ Very low	2683	9042	1689	18730

Figure 3-37: Proportion and area (ha) of hazard prevention classes for 1993 – 2013

3.8.3. Hazard prevention discussion

Hazard prevention was assumed temporally consistent which, therefore, its temporal change was neglected. The assumption is highly relevant to the data used for the analysis of topography, rainfall, soil type, and geological data. Those data are considerably consistent in the period of analysis of 1993 – 2003 and 2003 – 2013. If the study has longer analysis periods, for example in centennial interval, the temporal change of the hazard prevention can be more significant.

Preservation and protection zones have important roles in hazard prevention. As can be seen in Figure 3-37 that the spatial distribution of the very high and medium classes for hazard prevention are mostly located in the preservation and protection zones. This condition is related to the topographic condition in SAFP. Hilly and mountainous topography is located in the south part of the site, which is located in both preservation and protection zone (Figure

3-38). Therefore, it is obvious that the two zones have high priority for the hazard prevention in SAFP.

3.9. Topography

3.9.1. Topography method

3.9.1.1. Topography data

Analysis on the topographic in SAFP used a Digital Elevation Model (DEM) from the Shuttle Radar Topographic Mission (SRTM). The use of SRTM DEM has been widely adopted in many studies in Indonesia such as in Suwandana et al. (2012). The topographic condition of SAFP is presented in Figure 3-38.

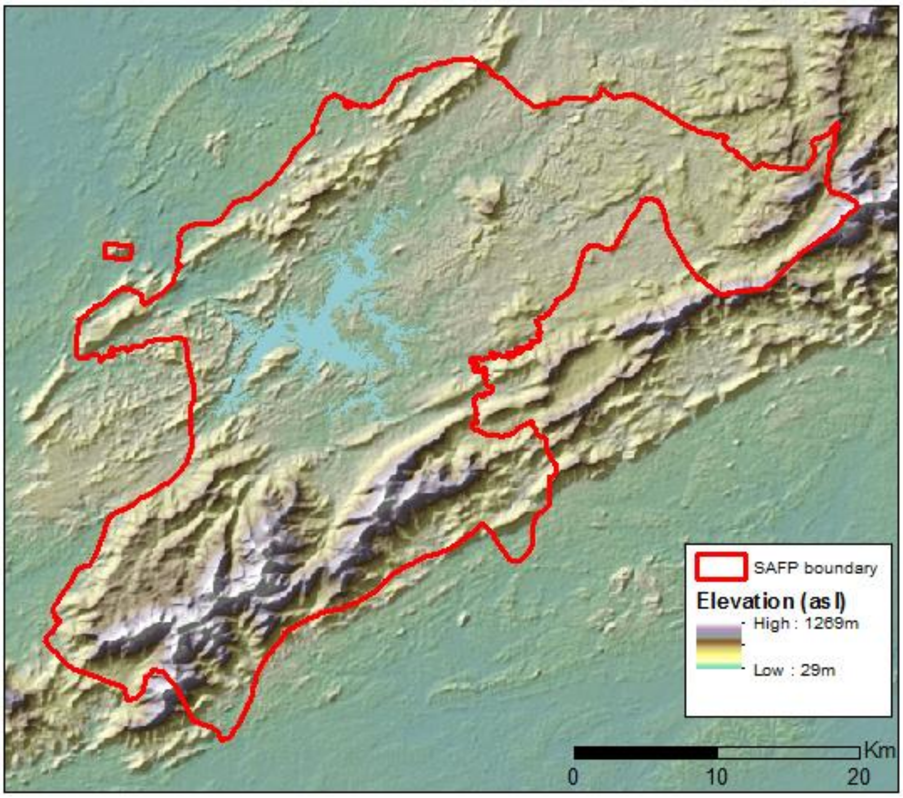


Figure 3-38: Topographic map of SAFP

3.9.1.2. Topography analysis

Resampling

Topographic data was obtained from Shuttle Radar Topographic Mission (SRTM) version 4.1 from The CGIAR Consortium for Spatial Information (CGIAR-CSI). Since the resolution of the SRTM DEM is 90 m, and this data is used to normalize the Landsat imagery for LULC classification, therefore, a resampling technique was used. The SRTM data was resampled from 90 m into 30 m with cubic interpolation technique.

All analysis was performed in UTM Zone 50 South projection and WGS 1984 datum in raster (grid) format with 30 m x 30 m pixel size. Multispectral bands of the Landsat images were originally obtained at 30 m resolution. Forest fragmentation and NDVI data that derived from Landsat images also had that resolution. Elevation data from SRTM DEM, however, was obtained in 90 m. Thus, a bicubic interpolation (Keeratikasikorn and Trisirisatayawong, 2008) resampling method was applied to obtain 30 m resolution of elevation and slope data. Moreover, interpolation from vector data (sampling plot, road, lake, and settlement) also performed directly into 30 m as the targeted resolution.

Slope

Slope data was used for assessing the erosion rate potential and recovery ability of the forest and land. Slope was also used for the soil erosion potential estimation (Table 3-40). The classification of the slope for soil erosion potential and for recoverability component are similar as shown in the following table.

Table 3-49: Classification of slope

Class	Slope (%)
1	0 – 8
2	8 – 15
3	15 – 25
4	25 – 40
5	> 40%

Indonesian Ministry of Agriculture (1980)

3.9.2. Topography result

The topographical condition in SAFP varies from flat land in the middle of the park surrounding the Riam Kanan Lake to the mountainous land in the south part (Figure 3-39).The most dominant slope class was level (32.2%), followed by gentle (19.7%), then moderate (17.1%), steep (18.6%), and very steep (12.3%) as can be seen in Table 3-9.

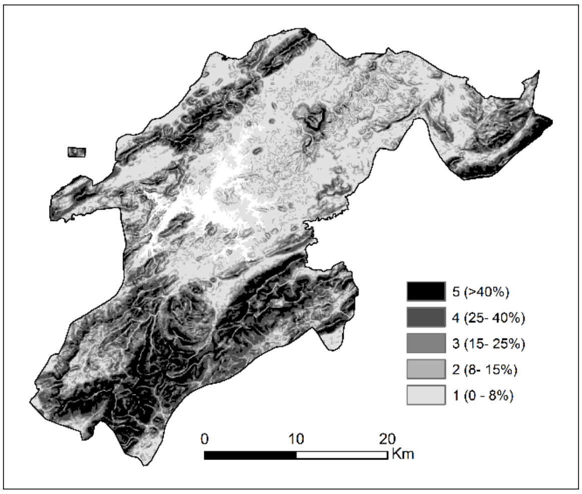


Figure 3-39: Slope class map in SAFP

Table 3-50: Slope classes in SAFP

SAFP Zones	Slope class				
	1 (level) 0-8%	0 (gentle) 8-15%	0 (moderate) 15-25%	4 (steep) 25-40%	5 (very steep) > 40%
Preservation	4,283	4,649	6,759	10,070	8,281
Protection	10,125	8,707	8,485	8,698	5,043
Limited Use	497	444	437	554	209
Intensive Use	20,902	8,091	3,351	1,401	149
Total	35,807 (32.2%)	21,891 (19.7%)	19,032 (17.1%)	20,723 (18.6%)	13,682 (12.3%)

The most dominant slope class in preservation zone was very steep (slope >40%) and steep (slope 25-40%), while the most dominant slope class in intensive use zone was level (slope 0-8%) as can be seen in Figure 3-40. Topographic parameter was assumed unchanged in the period of analysis. Therefore, slope that was chosen as the biophysical condition represents the topography was also considered steady. Preservation zone was dominated by very high slope class, followed by medium and low slope class. While, intensive use zone was dominated by very low slope class followed by low slope class).

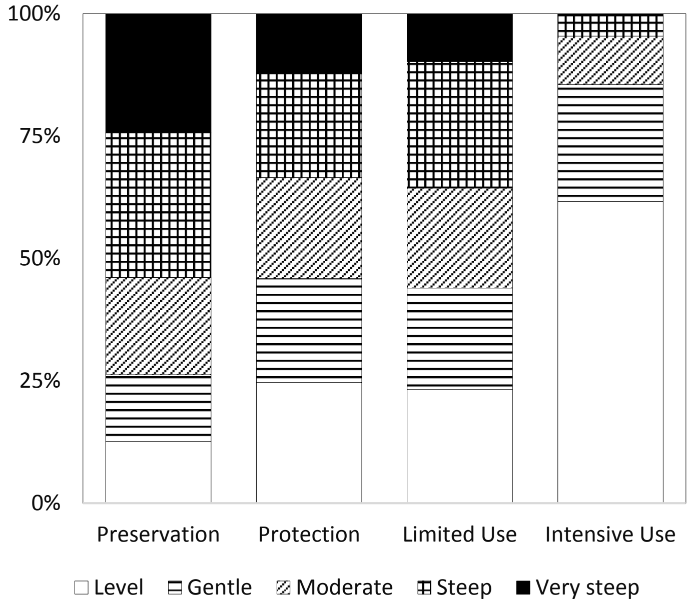


Figure 3-40: Slope proportion in each zone in SAFP

3.10. Land management

The availability of definite forest boundary, forest patrol and extension is among the considered management components for the rehabilitation prioritization (Indonesian Ministry of Forestry, 2013). Considering the study site is a forest management unit that has the same management condition, a uniform management score of 0.5 (medium) was used across the study site. The land management index was the same throughout the study period from 1993 to 2013.

3.11. Summary of biophysical spatial and temporal changes

Biophysical condition in SAFP has spatial and temporal changes. The changes in spatial and temporal dimensions were quantified using a Kappa statistical analysis that have been discussed on page 44. The change of the biophysical condition may be considered as a change (Kappa statistics < 0.4), moderate change (Kappa statistics is between 0.4 and 0.8), and no-change (Kappa statistics > 0.8). The summary of all biophysical condition change in SAFP is presented in Table 3-51. Some biophysical conditions were assumed unchanged due to the nature of the data. Settlement, hazard prevention, topography and land management are four factors that were considered unchanged.

Table 3-51: Summary of change analysis on biophysical parameters

Parameter	Kappa statistic ($\hat{K}$)		Change category	
	1993-2003	2003-2013	1993-2003	2003-2013
LULC / Vegetation	0.696	0.808	Moderate	No change
Forest fragmentation	0.644	0.781	Moderate	Moderate
Species status	0.670	0.807	Moderate	No Change
Accessibility	0.708	0.958	Moderate	No change
Forest fire	0.113	0.261	Change	Change
Soil erosion potential	0.245	0.486	Change	Moderate

Forest fire is the most change biophysical in SAFP. In both periods of 1993 – 2003 and 2003 – 2013, forest fire were categorized as changes since both Kappa statistics in the two periods were lower than 0.4. Interestingly, there is no biophysical condition that no-change in both periods of study. All biophysical condition in Table 3-51 has at least a moderate change in one period of analysis.

3.12. Conclusion

1. The two-decadal deforestation rate at SAFP was 1.43%, which is much higher than the national level deforestation rate in the state forest land of 0.46%. Deforestation has a strong correlation with forest fire probability and accessibility.
2. Forest fragmentation has a significant correlation with deforestation. It is confirmed that deforestation causes forest fragmentation. Core forest has a positive correlation with total forest area while fragmented forest (perforated, edge and patch forests) have negative correlations with the total forest area.
3. Species' status index has a god correlation with elevation, NDVI, and forest fragmentation. It confirmed that the widely used linear model successfully regressed biodiversity with its influencing factors. However, the developed models were site-specific and applied only in SAFP.
4. Quantifying the influence of the settlement and accessibility using a stochastic analysis on the forest fire distribution showed its great applicability. It was successfully modeled the distribution of the forest fire, which was therefore shifting cultivation, from the settlement and accessibility in SAFP. The resultant models to predict the distribution were generated and applied significantly on the 11 FMUs in South Kalimantan Province.
5. Forest fire has significantly changed spatially and temporally in both periods of study (1993 – 2003 and 2003 – 2013). It is the most changes biophysical condition in SAFP. This support the idea that forest fire is the tool for shifting cultivation.
6. High soil erosion potential index is dominantly located in the limited use and intensive use zone. However, it changed in 1993 – 2003 period and moderately changed in 2003 – 2013 period. The changes on the soil erosion potential were dominantly caused by the change in LULC.

7. Hazard prevention is assumed to be constant over the study periods since its parameters were mainly constant. Its spatial patterns showed that high hazard prevention index was mostly located in the preservation and protection zones which were dominated by the mountainous topography.
8. Topographic condition is also assumed to be constant over the study periods. High slope index is dominantly located in the preservation and protection zones which are located in the south and east parts of SAFP. The topographical condition is similar to the hazard prevention since the model to estimate the hazard prevention use topographical data.
9. Biophysical condition and, therefore, the parameter of conservation prioritization have spatial and temporal patterns. LULC, forest fragmentation, species' status, accessibility, forest fire, and soil erosion potential spatially and temporally changed. Among all factors, forest fire is the most change biophysical condition in SAFP in both period of analysis (1993 – 2003 and 2003 – 2013).

Chapter 4: Preservation Prioritization of Tropical Forest Landscape

4.1. Introduction

Indonesian tropical forests suffer from deforestation and forest degradation. Hence, Sustainable Forest Management (SFM) as the central concept of the sustainability of the forest management in Indonesia is essential. In order to achieve the SFM, Indonesian government has a concern to develop Forest Management Unit (FMU) to achieve the SFM in the forest landscape level. FMUs can be defined as the smallest management unit accordingly with its forest function for efficient and sustainable forest management (Indonesian Ministry of Forestry, 2011). There are three main forest function in Indonesia, namely, (1) conservation, (2) protection, and (3) production (Indonesian Ministry of Forestry, 2012). Accordingly, either conservation FMU, protection FMU or production FMU must be assigned to the forests. Indonesian government issued the legal basis for the FMU in Law No 41/1999 which stipulated that FMU must be assigned to all Indonesian forests (Government of the Republic of Indonesia, 1999). However, Kartodihardjo et al. (2011) stated that the mandate was neglected in practice. Legislation, mobilization of resources, and FMU organization are still under development. FMUs as the site-level forest management are expected to achieve SFM effectively.

One of the urgent need for managing FMU is conservation prioritization. Conservation value does not only belong to conservation forest, but also in production forest (The Consortium for Revision of the HCV Toolkit Indonesia, 2009), which, therefore, the conservation issues applied on all FMUs. Since identifying the smallest possible area is the main task of the forest planning (Carwardine et al., 2008), prioritization has been the main concern for conservation. Prioritization is also required because conserving natural resources is expensive (The World Bank, 2005) while resource is also limited (Viñas, 2005) due to competition with other needs such as education, infrastructure, and health (Sierra et al., 2002).

One of the main conservation tasks is preservation (Viñas, 2005) as the result of the alarming rate of deforestation and forest degradation. The preservation prioritization is also relevant to the biological diversity criterion in Criteria and Indicator (C&I) for SFM (ITTO, 2005). Then, biodiversity preservation prioritization is required in all FMUs.

However, most the prioritization (or even conservation) studies relies on the biodiversity value such as in Balaguru et al. (2006), Eeley et al. (2001), Sulistioadi (2004), and Klimek et al. (2014). In determining particular area for designing a biological reserve, the practice may be appropriate. Nevertheless, for the application of the prioritization in supporting the planning within the area (FMU) needs to consider the threat component (Carwardine et al., 2008). Some studies have concerned the threat component in prioritization, such as in Soosairaj et al. (2007), Phua and Minowa (2005). The spatial and temporal difference of the threat component addition was not explored, however.

The developed framework for conservation prioritization has introduced both components of value and threat (Figure 2-3). This chapter was aimed to assess the significance of the threat component addition into the preservation prioritization and the spatial and temporal patterns of the preservation prioritization in the forest landscape. This chapter is expected to contribute to the application of the appropriate prioritization preservation framework to achieve the SFM in the forest landscape. In the broader sense, the achievement of the SFM in all Indonesian tropical forest can be reasonably expected. This chapter assesses the application of the developed prioritization framework (Figure 2-3) on its preservation task.

4.2. Methodology

4.2.1. Preservation prioritization framework

A GIS-based structured hierarchy prioritization framework was developed (Figure 2-3). The main goal of preservation was set as the top level of the hierarchy. It was determined based on the purpose of the forest establishment and the Criteria and Indicators (C&I) for SFM in tropical forest (ITTO, 2005). Components were identified at the subsequent level either value or threat. The abundance of the biodiversity resources was considered as value/importance component while deforestation/degradation were considered as threat/urgency component. Therefore, preservation priority is a combination of biodiversity value and deforestation/degradation threat (Figure 4-1).

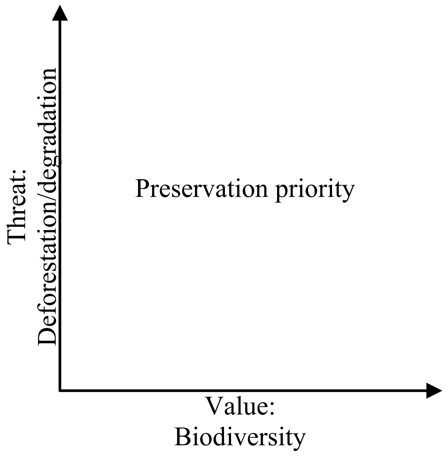


Figure 4-1: Preservation priority as the combination of value and threat components

As the subsequent of the biodiversity value component, three sub-components were identified, namely vegetation, forest fragmentation, and species' status. Under the deforestation/degradation threat, three sub-components of settlement, accessibility, and forest fire sub-components were selected. Finally, parameters from biophysical conditions were derived in each corresponding sub-components.

The preferences of the decision maker were accommodated as the weight in each component, sub-component and parameter that were assessed by AHP. The resultant of AHP analysis on the weight of the criteria was presented in the **Appendix A** on page 237 with the summary as follow.

Table 4-1: Summary of pairwise comparison for preservation in SAFP

Components	Sub-component	Weight*
value	Vegetation	.209
	Forest fragmentation	.133
	Species status	.158
Threat	Forest fire	.205
	Settlement	.152
	Accessibility	.143

Note: Weights have been normalized with ½ for value and threat
Source: Data analysis in **Appendix A** (page 237)

4.2.2. Data

This study used remotely sensed images, base map, and field survey. Landsat imagery were acquired for Land Use and Land Cover (LULC) parameter. NOAA-AVHRR and MODIS firespot data were obtained for forest firespot distribution. Another additional raster data of SRTM data was used to derive elevation, and then slope parameter. Settlement, road, lake and settlement features were extracted from Indonesian base map scale 1:50,000 that was issued by Indonesian Geospatial Information Agency (BIG). Field survey data were also obtained for ground truth of LULC classes and providing species' data. Three decadal acquisitions were taken in 1993, 2003, and 2013. The analysis of the biophysical condition in Chapter 3 was used as the input for the analysis in this chapter.

4.2.3. Analysis

4.2.3.1. Vegetation

Land use and land cover in 1993, 2003, and 2013 were selected to represent vegetation sub-component. LULC classes were derived from multi-year set of Landsat imageries. Five Landsat 5 TM images (1993), six Landsat 7 ETM+ images (2003) and six Landsat 8 OLI/TIRS (2013) were analysed. For the accuracy assessment of the 2013 LULC, set of 96 points ground truth were used. Image analysis techniques on geometric correction, top-of-atmospheric correction, topographic normalization, multi-temporal radiometric normalization, cloud and cloud shadow removal were performed. LULC classes were derived by a supervised classification using Band 7, Band 2 and PC2 for Landsat 5 and Landsat 7 imageries. While for Landsat 8, Band 7, Band 3 and PC2 were used. Post classification enhancement was performed on unclassified pixels by noise removal and visual inspection of the corresponding existing LULC maps. Five LULC classes were derived as shown in Table 4-2. The scores were generated based on the LULC class importance for biodiversity as the result of the AHP analysis.

Table 4-2: Score of LULC classes from classification of Landsat images

LULC Class	AHP weight
Forest	0.510
Mixed-plantation	0.231
Shrub/bush	0.131
Grassland	0.084
Bare land	0.044

Source: Data analysis in **Appendix A** (page 237)

4.2.3.2. Forest fragmentation

The morphological approach was used in the forest fragmentation following Vogt et al. (2007). The analysis is performed by the Landscape Fragmentation Tool version 2.0 (Parent and Hurd, 2007) within the ArcGIS 10 software. The tool analysed and classed the forest class into four categories as shown in the following table. The weights were generated from the fragment importance based on the AHP analysis.

Table 4-3: Categories of the forest based on morphological approach

Forests	Description	AHP weight
Core forest	Forest pixel that are not degraded by 'edge effect'	0.484
Perforated forest	Forest pixel along the edge of an interior gap in a forest that are degraded by 'edge effect'	0.253
Edge forest	forest pixels along the exterior perimeter of a forest that are degraded by the 'edge effect'	0.144
Patch forest	small isolated fragments of forest that are completely degraded by 'edge effect'	0.081
Non-forest	Pixel that are not covered with forest	0.039

Adapted from Parent and Hurd (2007); AHP weight from **Appendix A** (page 237)

4.2.3.3. Settlement and accessibility

Settlement and accessibility were two threats to the forest with the basic assumption that higher access and closer to human means higher threat on the forest (Murdiyarso et al., 2002). Settlement and accessibility were analysed using the major deforestation and the forest degradation threat in the study site, namely shifting cultivation. A quantitative method to assess the settlement and accessibility influence as the threats on forest has been discussed in Chapter 3 (page 97). The weighting methods was used to estimate the weight of the settlement proximity and accessibility as shown in Table 4-4 and Table 4-2.

Table 4-4: Score of the classification for proximity to the settlement by AHP

Class	Distance (meter)	AHP Score
1	0 – 1,410	0.427
2	1,410 – 2,410	0.314
3	2,410 – 3,700	0.188
4	> 3,700	0.071

Source: Data analysis in **Appendix A** (page 237)

Table 4-5: Score of the classification for proximity to the road, lake, and river by AHP

Class	Distance (meter)	AHP Score
1	0 – 320	0.475
2	320 – 830	0.293
3	830 – 1,750	0.151
4	> 1,750	0.081

Source: Data analysis in **Appendix A** (page 237)

4.2.3.4. Forest fire

Forest fire threat to deforestation and forest degradation was estimated by historical forest fire data that was derived from NOAA-AVHRR and MODIS firespots. Three years firespot data closest to the designated years (1993, 2003 and 2013) were analysed. Due to unavailability of forest fire data in 1993, therefore, the closest available data of 1997-1999 was used. A kernel density estimation (KDE) method was used to convert the point data of forest fire into continuous (grid) data. Double of *Rdmean* method (Kuter et al., 2011) used to estimate searching radius (bandwidth) with $RDmean = \frac{1}{2}\sqrt{A/N}$ where A is the size of the polygon of the study site and *N* is the number of firespots. Forest fire classes were derived from the following table.

Class	Classes	AHP Score
1	Very high	0.531
2	High	0.275
3	Low	0.131
4	Very low	0.064

Source: Data analysis in **Appendix A** (page 237)

4.2.3.5. Preservation priority change

The analysis of the preservation change was performed to evaluate (1) the significance of the addition of the threat component into the framework of preservation prioritization, and (2) the spatial and temporal change of the resultant priority area in 1993-2003 and 2003-2013. The priority area was set arbitrary at 0.25; therefore, 25% area that has the highest biodiversity index was selected as the priority area for preservation without threat component. As much as 25% area that has highest preservation index (considers biodiversity and threat components) was selected as the priority area for preservation with threat component.

Change analysis of the preservation prioritization was assessed by a confusion matrix with the Kappa statistics as it has been discussed on page 44. The resultant Kappa statistics was categorized into three categories. If it is less than 0.4 is considered as change (poor agreement), between 0.4 and 0.8 is moderately change (moderate agreement), and more or equal to 0.8 is considered as no change (good agreement).

4.3. Result

4.3.1. Significance of threat component on the preservation prioritization

The introduction of the threat component on the preservation prioritization was assessed by performing two prioritizations. First prioritization considered only biodiversity value as the only component while the second prioritization considered biodiversity value and deforestation/degradation threat as the two components. The difference between the two prioritizations was assessed by the confusion matrix as shown in the following tables.

Table 4-6: Preservation priority area (ha) with the addition of threat component in 1993

Value component only	Value and threat components		Total
	Non-priority	Priority	
Non-priority	64,958	13,067	78,026
Priority	18,478	14,632	33,109
Total	83,436	27,699	111,135

Kappa statistic **0.288**

Table 4-7: Preservation priority area (ha) with the addition of threat component in 2003

Value component only	Value and threat components		Total
	Non-priority	Priority	
Non-priority	67,037	13,312	80,350
Priority	16,562	14,223	30,785
Total	83,599	27,536	111,135

Kappa statistic **0.306**

Table 4-8: Preservation priority area (ha) with the addition of threat component in 2013

Value component only	Value and threat components		Total
	Non-priority	Priority	
Non-priority	68,766	13,237	82,003
Priority	14,172	14,960	29,132
Total	82,938	28,197	111,135

Kappa statistic **0.356**

The addition of the threat component into preservation framework significantly changed the preservation priority area in 1993, 2003 and 2013. The Kappa statistic for the difference between with and without the threat component were 0.288, 0.306, and 0.356 for 1993, 2003, and 2013, respectively (Table 4-6, Table 4-7 and Table 4-8). All of those values are less than 0.4 that means categorized as changes. The comparison map between preservation with and without threat component is shown in Figure 4-2.

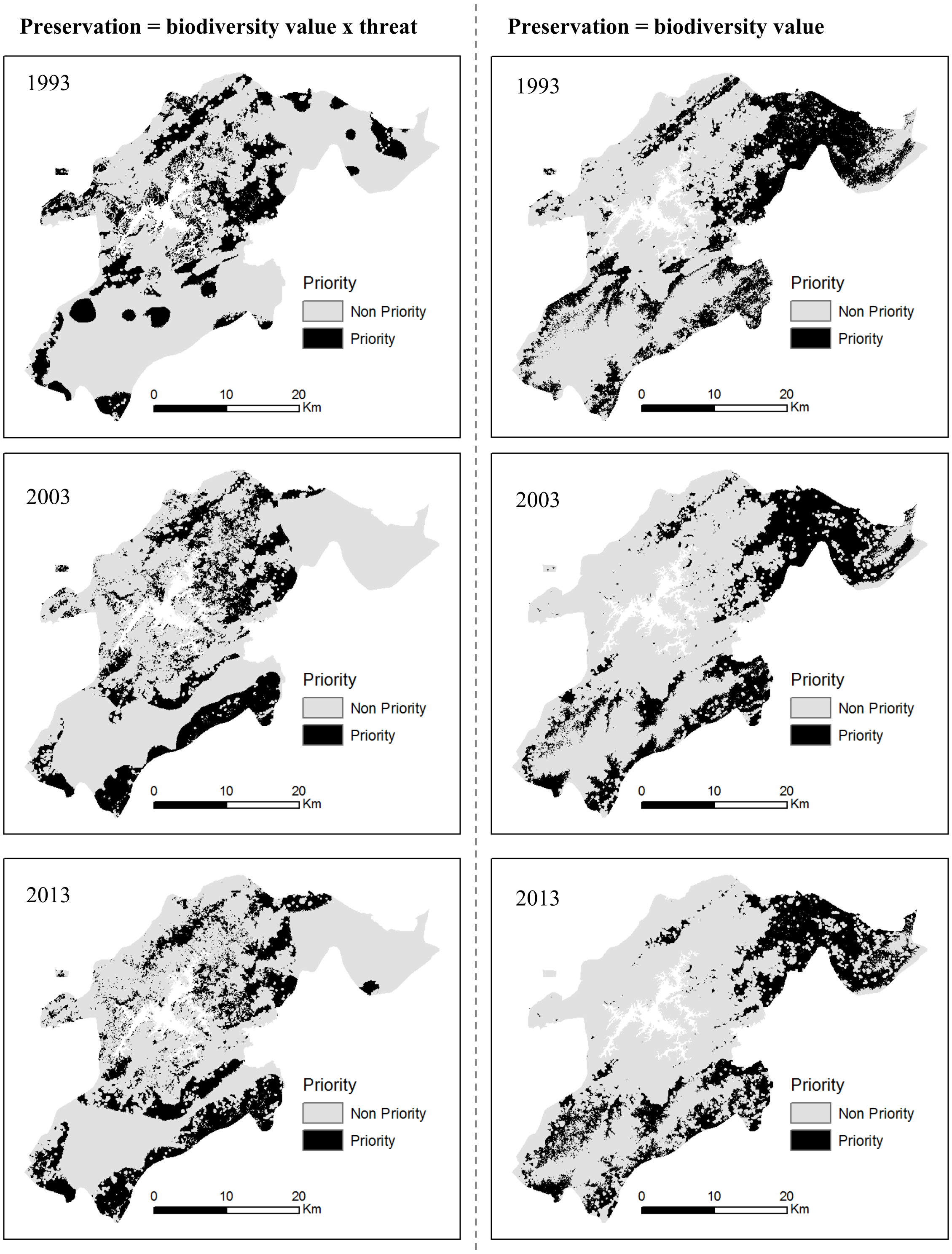


Figure 4-2: Comparison maps between preservation with and without threat component

4.3.2. Change of the preservation priority in 1993 – 2003 and 2003 – 2013

4.3.2.1. Spatial change

Preservation priority was spatially distributed in SAFP. Low preservation index is mostly located in the middle of the park or surrounding the Riam Kanan Lake. While, high preservation index dominated the south and east parts of the park. Interestingly, there were increased and decreased of preservation indices in as shown in Figure 4-3. Box 1 shows the decrease of the preservation index in the limited use zone in 2003. In the south part of the park (Box 2), there was an increase of the priority are in 2003. In 2013, the recognizable priority increase was located in the east part of the park (Box 3).

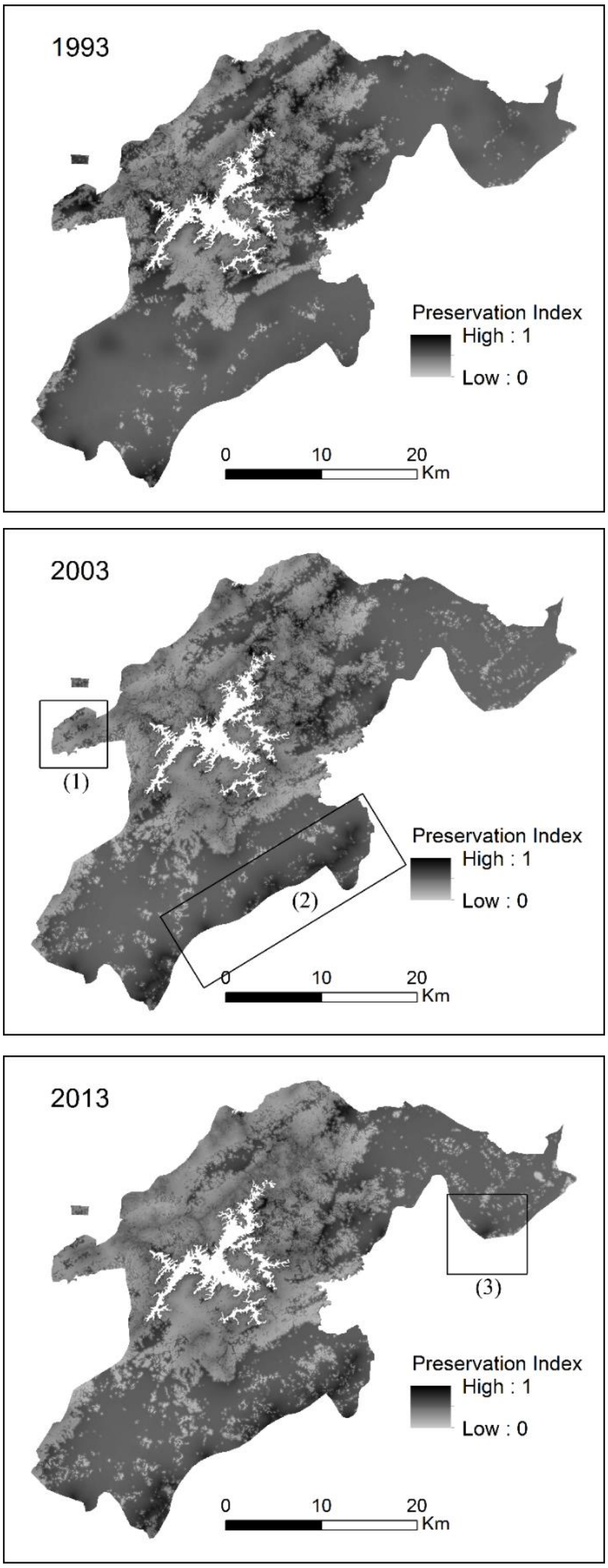
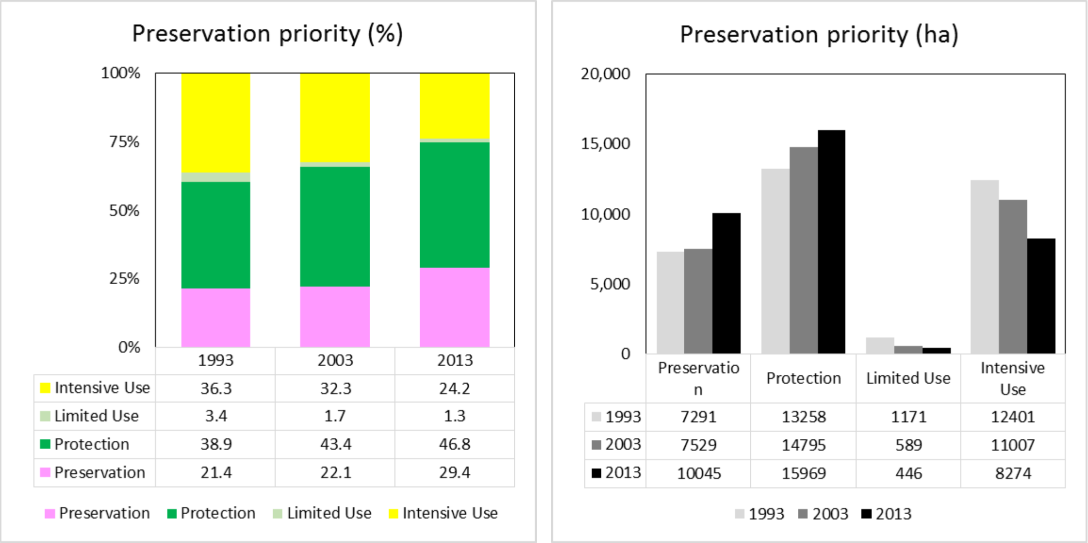


Figure 4-3: Preservation index in 1993, 2003 and 2013

Preservation priority increased in both preservation and protection zones and decreased in both limited use and intensive use zones. As can be shown in Figure 4-4 that from the estimated priority area in 1993, as much as 21.4% was in preservation zone that then increased in 2003 to 22.1% and finally to 29.4% in 2013. The increase was also identified in protection zones that had 38.9% in 1993 then increased to 43.4% in 2003 and finally at 46.8% in 2013. Contrary, there were decreases of preservation priority in both limited use and intensive use zones. From the estimated priority area, limited use zone had 3.4% in 1993, 1.7% in 2003 and 1.7% in 2013. Intensive use zone also had decreased trend that counted for 36.3% in 1993, 32.3% in 2003 and 24.2% in 2013.



	1993	2003	2013
Intensive Use	36.3	32.3	24.2
Limited Use	3.4	1.7	1.3
Protection	38.9	43.4	46.8
Preservation	21.4	22.1	29.4

	Preservation	Protection	Limited Use	Intensive Use
1993	7291	13258	1171	12401
2003	7529	14795	589	11007
2013	10045	15969	446	8274

Figure 4-4: Distribution of the preservation priority area among zones in 1993, 2003 and 2013

4.3.2.2. Temporal change

Preservation priority in 2003 had a poor agreement with that in 1993 while preservation priority in 2013 had a moderate agreement with that in 2003. The temporal change of the preservation priority area was assessed by a confusion matrix in order to estimate the agreement among the observation years. From 1993 to 2003, the resultant Kappa statistics was 0.231 that mean preservation priority in 2003 has a poor agreement compare to that in 1993. Meanwhile, from 2003 to 2013, the resultant Kappa statistics was 0.667 that mean preservation priority in 2013 has a moderate agreement compare to those in 2003. Both in 1993 – 2003 and 2003 – 2013 periods, the preservation priority area changed with different Kappa statistic. The confusion matrices of preservation priority area were shown in Table 4-9 and Table 4-10.

Table 4-9: Change of preservation priority area (ha) from 1993 to 2003

1993	2003		
	Non-priority	Priority	Total
Non-priority	67,559	15,877	83,436
Priority	16,040	11,659	27,699
Total	83,599	27,536	111,135

Kappa statistic 0.231

Table 4-10: Change of preservation priority area (ha) from 2003 to 2013

2003	2013		
	Non-priority	Priority	Total
Non-priority	76,308	7,291	83,599
Priority	6,631	20,905	27,536
Total	82,938	28,197	111,135

Kappa statistic 0.667

4.4. Discussion

Conservation can be divided into two main tasks, namely preservation and restoration (Viñas, 2005). The most relevant preservation task in forest landscape is to maintain biological diversity which is explicitly listed as one of SFM’s criterion for tropical forest (ITTO, 2005) and also for non-tropical forests (Ministerial Conference on the Protection of Forests in Europe, 2001; The Montreal Process Working Group, 2009). Identifying areas that have high biodiversity value has been discussed in many studies (Sulistioadi et al., 2004; The Consortium for Revision of the HCV Toolkit Indonesia, 2009). However, those studies considered biodiversity value as the only component in the preservation. In fact, threat also should be included in the conservation prioritization (Nislow et al., 2010). Therefore, preservation was considered as the combination of biodiversity value and its threat. This study assessed the significance of the threat component in preservation prioritization.

Identified threat components in Indonesian forests are deforestation and forest degradation as it has been discussed on page 25. The introduction of the threat component into preservation prioritization has been accommodated in some studies such as in Soosairaj et al. (2007) and Phua and Minowa (2005). However, the significance of the addition was not studied yet. Since spatial is one of the fundamental aspects of the landscape, therefore assessing the spatial significance of the threat component on the preservation prioritization was urgently required.

The result shows that that the addition of the threat component into preservation prioritization spatially changed the resultant priority area. In 1993, 2003 and 2013, the resultant priority areas had poor agreement between ‘with’ and ‘without’ the threat component. The incorporation of the threat into preservation priority is, therefore, a significant concept on the preservation prioritization.

Preservation priority in both preservation and protected zones increased while those in limited and intensive use zone decreased. As can be seen in Figure 4-4 that priority area was dominantly located in either preservation zone or protection zone with the increasing trends in 1993 – 2003 and 2003 – 201. Thus, it could be expected that it will still increase in the future. The preservation activities such as area protection and patrol are, therefore, should be more focused on the preservation and protection zones. Forest manager should aware those spatial and temporal patterns and take necessary management measures on the changes.

Preservation priority area changed significantly in 1993 – 2003 and moderate changed in 2003 – 2013. The changes are contributed from either/both biodiversity value or/and deforestation/degradation threat. Different changes in the priority area underline the spatial and temporal patterns of the preservation in SAFP. Characteristics of the forest landscape on the spatial and temporal changes of the biophysical condition is the main possible cause of the changes.

Comparing the changes in the preservation priority with the change of the biophysical condition (Table 3-51), it can be seen that the change in preservation priority related to the change of its sub-components. LULC, forest fragmentation, species status accessibility and forest fire are among the changed biophysical conditions in 1993 – 2003. As the result, the preservation priority in 1993 – 2003 also changed. In the period of 2003 – 2013, some biophysical conditions did not change, i.e. LULC, species' status, and accessibility. Preservation priority change from ‘change’ in 1993 – 2003 into ‘moderate change’ in 2003 - 2013.

The acknowledgment on the spatial and temporal patterns of the preservation prioritization is required in managing SAFP. There is no single pattern (‘change’ or ‘moderate change’) reflected the preservation prioritization condition in SAFP. It depends on the spatial and temporal patterns of its criteria in the prioritization framework. Exploring the spatial and temporal patterns of the biophysical condition is needed for acknowledging the spatial and temporal patterns of the preservation prioritization.

4.5. Conclusion

1. The inclusion of the threat component into preservation prioritization significantly changed the resultant priority area. In all observation years of 1993, 2003 and 2013, the resultant preservation priority areas between ‘with’ and without the threat component had poor agreements. Therefore, the addition of the threat component into the preservation prioritization framework is spatially significant.

2. Preservation priority area changed spatially and temporally. There were increasing trends of the priority area in preservation and protection zones. Meanwhile, the decreasing trends were observed in limited use and intensive use zones. The acknowledgment on the spatial and temporal patterns of the preservation is, therefore, crucial in its prioritization. The SAFP forest managers should aware that preservation priority spatial and temporal patterns.
3. Preservation priority changed in 1993 – 2003 period and moderately changed in 2003 – 2013 period. The spatial and temporal changes of the preservation prioritization were affected by the changes in biophysical conditions.

Chapter 5: Rehabilitation Prioritization of Tropical Forest Landscape

5.1. Introduction

The need for Sustainable Forest Management (SFM) increase to combat deforestation and forest degradation in Indonesian tropical forests. One of the main strategies to achieve the SFM is managing all Indonesian forests under the Forest Management Unit (FMU). Since the role of the FMU is crucial in the Indonesian forest management, it is expected that the sustainability in FMU will contribute to the SFM to all Indonesian forests. In Indonesian Ministry of Forestry (2011) it has been stated that FMU can be defined as the smallest management unit accordingly with its forest function for efficient and sustainability.

Conservation is often considered as merely preservation and neglecting rehabilitation as an integral part of the conservation. Carwardine et al. (2008) mentioned that conservation mostly deals with designing biological reserve. This study adopted the contemporary concept of conservation in Viñas (2005) that the conservation has two main tasks of preservation and restoration. The new concept considers that rehabilitation is an integral part of the conservation. In Indonesia, the rehabilitation task has been adopted as forest and land rehabilitation which has been implemented since 1950s (Center for International Forestry Research, 2007). However, rehabilitation still considered as the separated activity from the conservation.

Since the identification of the smallest possible priority area is the main purpose of forest planning (Carwardine et al., 2008) to achieve a sustainable forest management (Tambe et al., 2011), prioritization became a core concern for the rehabilitation. Forest rehabilitation is expensive because of improper valuation of the natural ecosystem (The World Bank, 2005) and limited resources (Viñas, 2005) brought about by competition with other needs such as education, infrastructure and health (Sierra et al., 2002). Failure to prioritize the appropriate area for forest rehabilitation leads to costly consequences. Therefore, the priority area for forest rehabilitation needs to be identified in forest planning.

The developed framework for conservation prioritization in SAFP has acknowledged rehabilitation as one of main part of conservation as it is shown in Figure 2-3. Similar to the preservation prioritization that has been discussed in Chapter 4, the two components of importance and urgency were used. Some practices focused on the soil and water conservation as the only component for the rehabilitation prioritization. That practice neglected the recoverability of the forest as the urgency component. Indonesian Ministry of Forestry (2013) started to acknowledge the importance of the urgency component in the rehabilitation in the new forest rehabilitation guidelines.

This chapter was aimed to assess the significance of the addition of the recoverability urgency into the rehabilitation prioritization framework and the spatial and temporal patterns of the rehabilitation prioritization in the forest landscape. This chapter is expected to contribute to the application of the appropriate prioritization rehabilitation framework to achieve the SFM in the forest landscape. In the broader sense, the achievement of the SFM in all Indonesian tropical forest can be reasonably expected. This chapter assessed the application of the developed prioritization framework (Figure 2-3) on its rehabilitation task.

5.2. Methodology

5.2.1. Rehabilitation prioritization framework

A GIS-based structured hierarchy prioritization framework was developed (Figure 2-3). The main goal of rehabilitation was set as the top level of the hierarchy. It was determined based on the purpose of the forest establishment and the Criteria and Indicators (C&I) for SFM in tropical forest (ITTO, 2005). Components were identified at the subsequent level either importance or urgency. Soil and water conservation was considered as importance component while recoverability was considered as the urgency component. Therefore, rehabilitation priority is a combination of soil and water conservation importance and recoverability urgency (Figure 5-1).

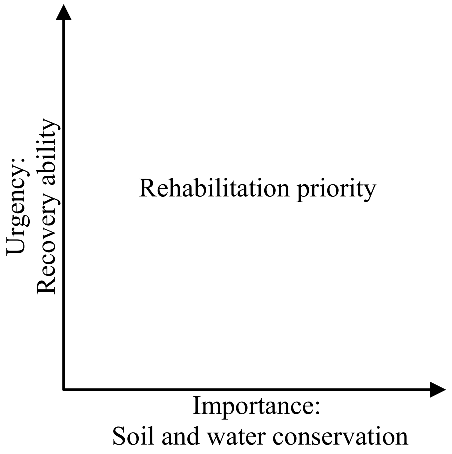


Figure 5-1: Rehabilitation priority as the combination of importance and urgency components

As the subsequent of the soil and water conservation component, only one sub-components was identified, namely soil erosion potential. The higher rate of the soil erosion potential the higher its importance. Under the recoverability component, three sub-components of vegetation, topography, and land management were identified. Finally, parameters from biophysical conditions were derived in each of those sub-components.

The preferences of the decision maker were accommodated as the weight in each component, sub-component and parameter that were assessed by AHP. The resultant AHP analysis on the weight of the criteria was presented in the **Appendix A** on page 237 with the summary as follow.

Table 5-1: Summary of pairwise comparison for rehabilitation in SAFP

Components	Sub-component	Weight
Importance: Soil and water conservation	Soil erosion potential	.205
Urgency	Vegetation	.525
	Topography	.191
	Land management	.079

Source: Data analysis in **Appendix A** (page 237)

5.2.2. Data

This study used rainfall, soil type, lithology, topography, land use land cover (LULC), and land management data. Rainfall data was obtained from the Banjarmasin (Syamsudin Noor) and Kotabaru (Stagen) Weather Stations, which are located ca. 35 km and 130 km from the study site, respectively. Rainfall data from 1992 to 2013 was derived for each station. Then, the point-based gauged average rainfall data were converted into a continuous rainfall data for the whole study site by a Kriging method following Mair and Fares (2011). Soil data were derived from the soil type map (1:250,000 scale) from Indonesian Center for Agricultural Land Resources Research and Development issued in 2011. The lithological information was extracted from the Geological map of Banjarmasin (1:250,000 scale) issued by the Indonesian Geological Development and Research Center in 1994. Topographical data (slope, divergence, and convergence) were derived from the Shuttle Radar Topographic Mission (SRTM) DEM that has 90 meters resolution. LULC data was obtained from remotely sensed imagery of Landsat 8 acquired in 2013. The output of the forest landscape biophysical assessment in Chapter 3 (page 50) was used as the input in this chapter.

5.2.3. Analysis

5.2.3.1. *Soil erosion potential*

The soil erosion potential was estimated by the Universal Soil Loss Equation (USLE) following the standard procedure in “A Guide for Predicting Sheet and Rill Erosion on Forest Land” by (Dissmeyer et al., 1980). The USLE equation is $A = R \cdot K \cdot L \cdot S \cdot C \cdot P$ where A is the computed soil loss per unit area, R is the rainfall and runoff factor, K is the soil erodibility factor, L is the slope length factor, S is the slope steepness factor, C is the cover and management factor, and P is the support practice factor. The USLE method is widely used in the soil erosion potential estimation in some studies in Indonesia.

Rainfall data from 1993 to 2013 were converted into rainfall and runoff factor by using the formula proposed by Bols (1978): $R = 2.5P^2/100(0.073P + 0.73)$ where P is annual rainfall intensity. The formula which was originally developed for Java and Madura Islands was also adopted in Malaysia by Teh (2011) due to its simplicity and similarity of the climatic conditions. Since soil erodibility factor (K) depends on the soil physical and chemical properties (Ministry of Public Work, 2012), the K values in the study site are $K=0.24$ and $K=0.23$ for Mediterranean and Latosol soil types respectively (Kartasapoetra, 1991; KKES, 2002). The slope length and slope steepness factor (LS) were estimated using the formula proposed by McCool et al. (1997): $L = (\lambda/22.13)^m$ where L is the slope length factor, λ is the field slope length (in meter), and m is a dimensionless exponent that depends on slope steepness (which are m=0.5 for slopes > 5%, m=0.4 for 4% and m=0.3 for <3%). The C and P factors were estimated together as CP factor following Hammer (1981) such as forest (CP=0.01), mixed plantation (CP=0.07), shrub/bush (CP=0.1), grassland (CP=0.02) and bare land (CP=0.85). The resultant soil erosion potential was scaled from 0 to 1 scale.

The relative weight of soil erosion potential classes were analysed using AHP as shown in the following Table 5-2. The AHP was conducted to estimate the consensus among the decision makers and stakeholders in putting relative importance among criteria. The AHP procedure and participants are shown on page 38.

Table 5-2: Weight of soil erosion potential classes

Soil Erosion Classes (ton/ha/yr)	AHP weight
> 480	0.473
180 – 480	0.265
60 – 180	0.144
5 – 60	0.067
< 5	0.042

Source: Pair-wise comparison matrix in **Appendix A** (page 237)

5.2.3.2. Land use and land cover change

LULC data were derived from Landsat 8 imagery of path/row 117/62 and 117/63 in 2013 downloaded from USGS (http://earthexplorer.usgs.gov/). A standard technique of image processing (geometric correction, atmospheric correction, topographic normalization, and cloud or cloud shadow masking) was performed. In order to get a cloudless LULC, a number of three acquisition dates in each path/row of the Landsat images was used. One image was set as the master while others were used to fill the cloud or cloud shadow on that master image. The combination of Band 7, Band 3 and PC2 (of Band 2, 3, 4, 5, 6, and 7) were used following Chang and Yoon (2003). Six LULC classes were derived and scored, namely forest (1), mixed plantation (2), shrub/bush (3), grassland (4), bare land (5), and water body (6). The water body classes were then excluded from the analysis. The relative weight of LULC classes was analysed using AHP as shown in the following table.

Table 5-3: Weight of LULC classes for rehabilitation

LULC Class	AHP weight
Bare land	0.437
Grassland	0.284
Shrub/bush	0.166
Mixed plantation	0.069
Forest	0.046

Source: Pair-wise comparison matrix in **Appendix A** (page 237)

5.2.3.3. Topography

The topographical condition was represented by slope that was derived from SRTM DEM. There were five slope classes used, namely class 1 (< 8%), class 2 (8 – 15%), class 3 (15 – 25%), class 4 (25 – 40%) and class 5 (>40%) (Indonesian Ministry of Forestry, 2013). The relative weight of topography classes was analysed using AHP as shown in the following table.

Table 5-4: Weight of slope classes for the rehabilitation prioritization

Soil Erosion Classes (ton/ha/yr)	AHP weight
> 40	0.468
25 – 40	0.259
15 – 25	0.146
8 – 15	0.079
0 – 8	0.049

Source: Pair-wise comparison matrix in **Appendix A** (page 237)

5.2.3.4. Rehabilitation priority change

Change analysis on rehabilitation priority change was performed to assess (1) the significance of the addition of the recoverability urgency into the rehabilitation prioritization framework, and (2) to assess the spatial and temporal change of the resultant priority area in 1993-2003 and 2003-2013. The proportion of the priority area was arbitrary set at 0.25, therefore, 25% of the area, that has highest soil and water conservation index was selected as the priority area for rehabilitation without the urgency component. As much as 25% of the area that has highest rehabilitation index was selected as the priority area for rehabilitation with the urgency component.

Change analysis of the rehabilitation prioritization was assessed by a confusion matrix with the Kappa statistics as it has been discussed on page 44. The resultant Kappa statistics was categorized into three categories. If it is less than 0.4 is considered as change (poor agreement), between 0.4 and 0.8 is moderately change (moderate agreement), and more or equal to 0.8 is considered as no change (good agreement).

5.3. Results

5.3.1. Significance of the recoverability component on the rehabilitation prioritization

The introduction of the recoverability component on the rehabilitation prioritization was assessed by performing two prioritizations. First prioritization consider only soil and water conservation importance as the only component while the second prioritization consider recoverability urgency as the additional component. The difference between the two prioritizations was assessed by the confusion matrix with Kappa statics as shown in the following tables.

Table 5-5: Rehabilitation priority area (ha) with and without recoverability urgency in 1993

Importance component only	Importance and urgency components		Total
	Non-priority	Priority	
Non-priority	82,552	27,703	110,255
Priority	-	880	880
Total	82,552	28,583	111,135

Kappa statistic **0.045**

Table 5-6: Rehabilitation priority area (ha) with and without recoverability urgency in 2003

Importance component only	Importance and urgency components		Total
	Non-priority	Priority	
Non-priority	82,071	25,216	107,288
Priority	869	2,978	3,847
Total	82,940	28,195	111,135

Kappa statistic **0.133**

Table 5-7: Rehabilitation priority area with and without recoverability urgency in 2013

Importance component only	Importance and urgency components		Total
	Non-priority	Priority	
Non-priority	81,326	25,587	106,914
Priority	1,149	3,073	4,221
Total	82,475	28,660	111,135

Kappa statistic **0.129**

The addition of the recoverability component into rehabilitation framework significantly change the rehabilitation priority in 1993, 2003 and 2013. As can be seen in Table 5-5, Table 5-6 and Table 5-7 that recoverability urgency component change significantly the resultant priority area with all Kappa statistics are lower than 0.4. The comparison map between the rehabilitation prioritization with and without the urgency component is shown in Figure 5-2.

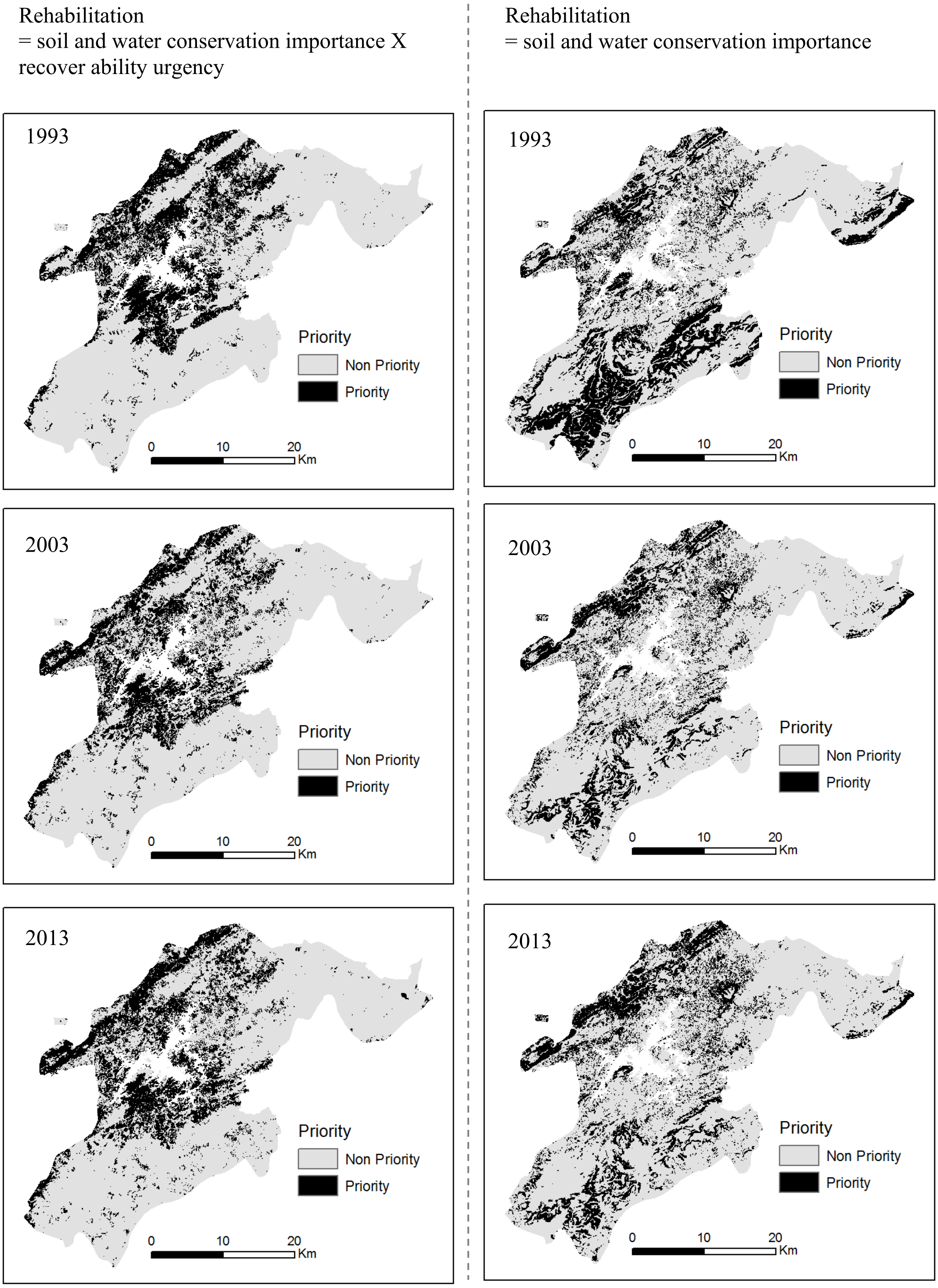


Figure 5-2: Comparison maps between rehabilitation with and without recoverability component

5.3.2. Change of the rehabilitation priority in 1993 – 2003 and 2003 – 2013

5.3.2.1. Spatial change

Rehabilitation priority area was dominantly located in the intensive use zone with the proportion than 50% throughout of the study period (Figure 5-3). The proportion of the rehabilitation priority area in the intensive use zone was 64.5% in 1993, 53.8% in 2003 and 55% in 2013. Rehabilitation priority were also found in preservation and protection zones with similar percentages, namely 15.7% for preservation zone and 16.8% for protection zone in 1993, 21.3% for preservation and 18.9% for protection zone in 2003, and 21.2% for preservation and 19.4% for protection zone in 2013. Insignificant rehabilitation priority was found in limited use zone with 3.1%, 4.7% and 4.6% for 1993, 2003 and 2013, respectively.

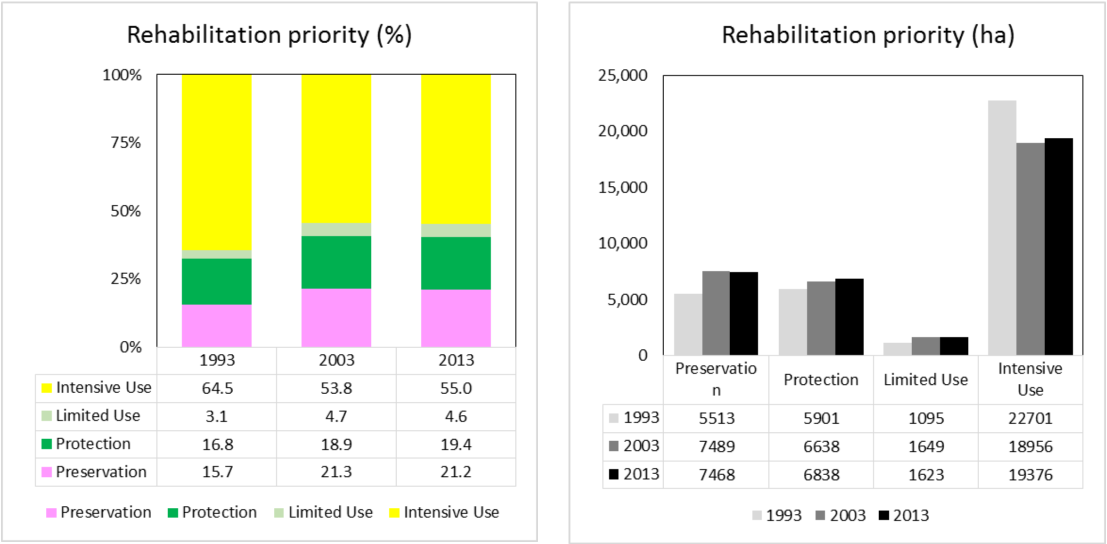


Figure 5-3: Distribution of the rehabilitation priority area among zones in 1993, 2003 and 2013

In the first period (1993 – 2003), the change of the spatial distribution of the priority area among zones were significant while, in the second period (2003 – 2013) the change of the priority area among zones were not significant. In intensive use zone, for example, the rehabilitation priority area decrease significantly from 64.5% into 53.8% in 1993 – 2003, while it slightly increase from 53.8% to 55% in 2003 – 2013 period. Similar change was also observed in preservation, protection, and limited use zones. In those zones, the rehabilitation priority area increased in 1993 – 2003 and relatively stable in 2003 – 2013 period.

5.3.2.2. Temporal change

The temporal change of the rehabilitation priority area was assessed by a confusion matrix in order to estimate the agreement among the observation years. From 1993 to 2003, the resultant Kappa statistics was 0.264 that mean the rehabilitation priority area in 2003 has a poor agreement compare to those in 1993. Meanwhile, from 2003 to 2013, the resultant Kappa statistics of 0.816 was calculated that mean the rehabilitation priority area in 2013 has a good agreement compare to those in 2003. Rehabilitation priority area changed in 1993 – 2003 and unchanged in 2003 – 2013. The confusion matrices of rehabilitation priority area were shown in the following tables.

Table 5-8: Change of rehabilitation priority area (ha) from 1993 to 2003

1993	2003		
	Non-priority	Priority	Total
Non-priority	75,619	6,933	82,552
Priority	7,321	21,261	28,583
Total	82,940	28,195	111,135

Kappa statistic 0.264

Table 5-9: Change of rehabilitation priority area (ha) from 2003 to 2013

2003	2013		
	Non-priority	Priority	Total
Non-priority	78,823	4,117	82,940
Priority	3,652	24,543	28,195
Total	82,475	28,660	111,135

Kappa statistic 0.816

5.4. Discussion

Rehabilitation as the integral part of the conservation has started to be acknowledged. Viñas (2005) considered rehabilitation as one task of conservation together with the preservation. The rehabilitation prioritization have been studied in many studies. However, its spatial and temporal patterns in the forest landscape have not been explored. Since the spatial and temporal aspects of the forest landscape are essential, therefore, this study assess the spatial and temporal patterns of the rehabilitation prioritization in SAFP.

The addition of the recoverability component into the rehabilitation prioritization spatially changed the resultant priority area. In 1993, 2003 and 2013, the resultant priority areas had poor agreement between ‘with’ and ‘without’ the recoverability component. The incorporation of the recoverability component into rehabilitation priority (Center for International Forestry Research, 2007) is, therefore, a significant concept on the rehabilitation prioritization. The guideline on the spatial data arrangement for degraded land (Indonesian Ministry of Forestry, 2013) which included the recovery ability component is considerably appropriate. As the consequence, its application is spatially significant.

Rehabilitation priority area in SAFP was mainly located in the intensive use zone. Its presence in preservation, protection, and limited use zones, were not dominant throughout of the study periods. In 1993 – 2003 period, the rehabilitation priority in intensive use zone decreased while in preservation, protection and intensive use zones increased. On the other hand, in 2003 – 2013 period, rehabilitation priority area in all zones had insignificant changes.

Rehabilitation priority area changed in 1993 – 2003 and no changed in 2003 – 2013. The confusion matrices and their Kappa statistic show that there was a difference in the spatial and temporal changes of the rehabilitation priority between two periods. As can be seen in the framework (Figure 2-3) of the conservation prioritization that there are four sub-components of the rehabilitation prioritization, namely soil erosion potential, vegetation, topography and land management. The topography and land management sub-components were assumed static in the period of analysis. Therefore, rehabilitation priority depended on the spatial and temporal changes of the soil erosion potential and vegetation. As can be shown in Table 5-10 that rehabilitation priority changed in 1993 – 2003 period that correspondent to the change in soil erosion potential and moderate change in vegetation. This condition was different compared to 2003 – 2013 period that the rehabilitation priority unchanged, it correspondent to the moderate changed in soil erosion potential, and no changed in vegetation. Since vegetation accounted for a significant weight in the prioritization framework (0.525 out of 1) as can be seen in Table 2-3, therefore, the no change condition in the vegetation was responsible for the no-change condition in rehabilitation priority in 2003 – 2013.

Table 5-10: Change of the sub-components and rehabilitation changes

Rehabilitation priority / biophysical condition	Kappa statistic ($\widehat{K}$)		Change category	
	1993-2003	2003-2013	1993-2003	2003-2013
Soil erosion potential	0.245	0.486	Change	Moderate change
Vegetation	0.696	0.808	Moderate change	No change
Topography	-	-	-	-
Land management	-	-	-	-
Rehabilitation priority	0.264	0.816	Change	No change

The acknowledgment of the spatial and temporal changes of the rehabilitation prioritization is required in SAFP. There is no single pattern (change or no change) reflects the rehabilitation priority in SAFP. Exploring the spatial and temporal patterns of the biophysical conditions is needed to acknowledge the spatial and temporal patterns of the rehabilitation priority.

5.5. Conclusion

1. The incorporation of the recoverability as the urgency component into the rehabilitation prioritization significantly change the spatial priority area. In all observation years (1993, 2003 and 2013), rehabilitation priority areas changed significantly between 'with' and 'without' the recoverability component. Therefore, the inclusion of the recoverability component into the prioritization framework is essential.
2. Rehabilitation priority was spatially and temporally changed. There were increasing trends of the rehabilitation priority in preservation, protection, and limited use zones. Meanwhile, a decreasing trend was observed in intensive use zones. However, the most dominant priority area was located in the intensive use zone throughout the study periods.
3. In 1993 – 2003 period, rehabilitation priority area changed significantly while in 2003 – 2013 period it did not change. The vegetation sub-component significantly contributed to the 'no changed' condition of the rehabilitation priority in 2003 – 2013. The acknowledgment on the spatial and temporal patterns of the biophysical conditions is, therefore, crucial for the rehabilitation prioritization.

Chapter 6: Tropical Forest Zonation Based on Landscape Prioritization Regimes

6.1. Introduction

Zonation and special zone assignment are indispensable instruments for forest planning. Four zones of preservation, protection, limited use, and intensive use zones had been assigned to SAFP (Government of the Republic of Indonesia, 1989). Each zone has specific allowable and recommended management activities as listed in Table 1-1. Further, to accommodate the local community need, SAFP management has established the special zone for settlement within SAFP.

Unfortunately, as it has been shown in Figure 1-1 (page 9), zonation or special zone assignment are spatially and temporally static. The zonation in SAFP, which was assigned in the long-term forest plan in 2011, will apply until 20 years. In fact, SAFP manager needs a more dynamic guideline in shorter period of forest plans, such as 5-years or 1-year forest plan. The landscape conservation prioritization using the landscape approach is expected to meet that need.

This study has developed the conservation prioritization framework as can be seen in Figure 2-3. The applications of the framework in preservation (Chapter 4) and rehabilitation (Chapter 5) were also studied, especially in terms of spatial and temporal patterns. However, the applications of prioritization were assessed preservation and rehabilitation separately. The acknowledgment of the rehabilitation as the integral part of the preservation (Viñas, 2005) has not been evaluated. The concept was considerably new since most of the study on conservation only consider preservation such as in Geneletti (2004), Nislow et al. (2010), Balaguru et al. (2006), Soosairaj et al. (2007). Even rehabilitation has been considered as one of the conservation tasks. However, the integration of preservation and rehabilitation has not been explored.

This chapter was aimed to formulate the proposed contribution of the forest landscape prioritization for forest landscape zonation within FMU. The integration of the preservation and rehabilitation was emphasized. Since their application have been studied separately in Chapter 4 and Chapter 5, therefore, combining the two was proposed to contribute to the forest SAFP management, as the complement to the zonation or special zone assignment in FMU. A new concept of the prioritization regime was introduced. Its spatial and temporal patterns were analysed, and the comparison with the SAFP zone was reviewed.

6.2. Methodology

Conservation consists of two main tasks, namely **preservation** and **rehabilitation**. Each of the task has different activities in practices. Preservation is focused on how to protect valuable biodiversity assets while rehabilitation is focused on how to improve the condition of the forest ecosystem into its functional state. Those two tasks were separately practiced. Thus, the combination of the two tasks may introduce a useful concept for forest landscape management, called the prioritization regime, as can be seen in Figure 6-1.

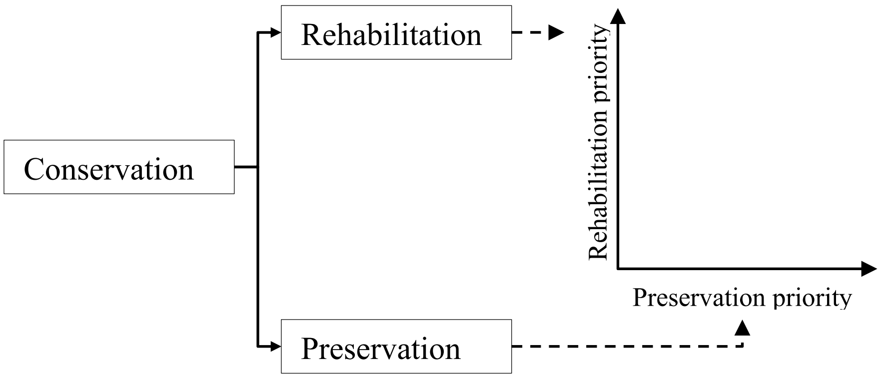


Figure 6-1 Preservation and rehabilitation tasks as the base for prioritization matrix

Both preservation and rehabilitation priorities were categorized into two classes. The equal class limit was used which therefore 0.5 was selected as the class limit. Thus, four regions in the prioritization regimes were proposed as shown in Figure 6-2, namely conservation, preservation, rehabilitation, and enhancement prioritization regimes.

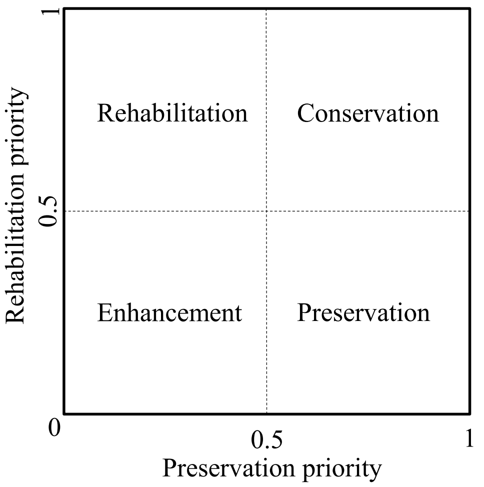


Figure 6-2: Prioritization regimes

Conservation regime was assigned to the areas that have high preservation and high rehabilitation priorities. Both preservation and rehabilitation tasks were prioritized in the regime. The area may have high conservation value and deforestation threats and at the same time it also needs to be rehabilitated to increase its capacity to regulate the soil and water conservation. *Preservation regime* was assigned to the areas that have high preservation and low rehabilitation priorities. Only preservation is prioritized in the regime without necessary for rehabilitation. The area may have high conservation value and deforestation threats, but its capacity to regulate the soil and water conservation is relatively adequate. *Rehabilitation regime* was assigned to the area that has low preservation priority but high rehabilitation priorities. Only rehabilitation task is suggested in the regime without necessary for the preservation. The area may have low conservation value and low deforestation threat, but its capacity to regulate the soil and water conservation needs to be improved. *Enhancement regime* was assigned to the area that has low preservation and low rehabilitation priorities. Neither conservation nor rehabilitation tasks is prioritized in the regimes. The area may have high conservation value, but low threat, therefore, its preservation priority is low. The area may also has low conservation value and low threat however it no need to be rehabilitated due to its capacity to regulate the soil and water conservation is sufficient. The criteria used for proposed preservation regimes in the forest landscape was showed in Table 6-1.

Table 6-1 Proposed prioritization regimes as the basis for the forest landscape zonation

No	Prioritization regimes	Priority criteria
1	Conservation regimes	High preservation (> 0.5) High rehabilitation (> 0.5)
2	Preservation regimes	High preservation (> 0.5) Low rehabilitation (< 0.5)
3	Rehabilitation regimes	Low preservation (< 0.5) High rehabilitation (> 0.5)
4	Enhancement regimes	Low preservation (< 0.5) Low rehabilitation (< 0.5)

Prioritization regimes were analysed in term of its spatial and temporal patterns. The change analysis of the prioritization regime was assessed by a confusion matrix with the Kappa statistics as it has been discussed on page 44. The resultant Kappa statistics was categorized into three categories. If it is less than 0.4 is considered as change (poor agreement), between 0.4 and 0.8 is moderately change (moderate agreement), and more or equal to 0.8 is considered as no change (good agreement). The spatial and temporal analysis were carried out in 1993, 2003 and 2013 conditions.

Further, current zonation in SAFP and proposed prioritization regimes were compared and spatially analysed. The function of many-to-many relationship was mapped based on the judgment which zones were appropriate for each prioritization regime. One regime may considerably appropriate for more than one zones. Conservation and preservation regimes were appropriate for either preservation or protection zones. Rehabilitation regime was appropriate for either limited use or intensive use zones. Enhancement regime was appropriate for any zones. Those relations are shown in the following Figure.

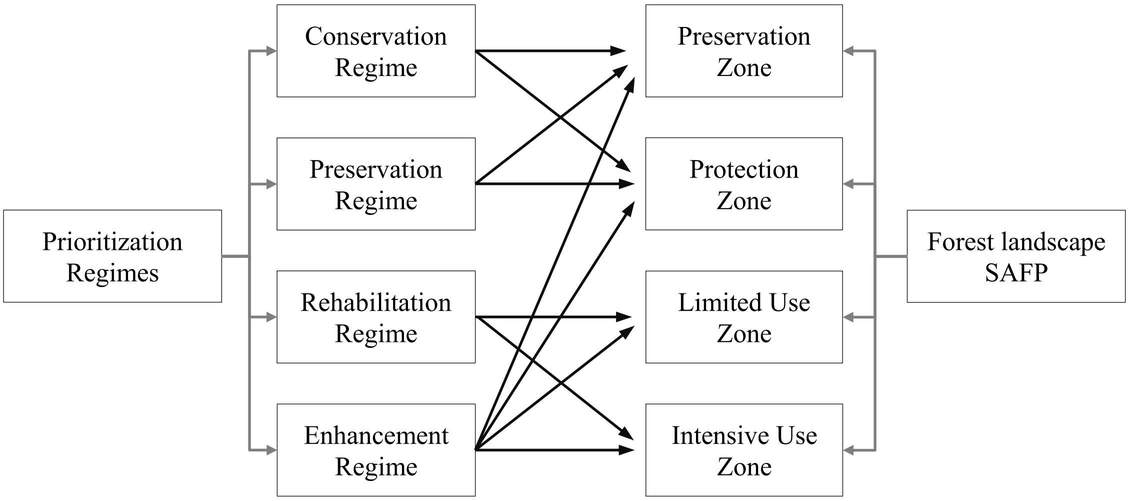


Figure 6-3 many-to-many correlation between prioritization regimes and zonation

6.3. Results

6.3.1. Spatial and temporal patterns of prioritization regimes

The most dominant prioritization regime in 2013 is Preservation Regime that counts for 58,573 ha (52.7%) followed by Enhancement Regime at 41,966 ha (37.76%). The rehabilitation regime takes the area of 10,553 ha (9.5%) while the conservation regime insignificantly counts for only 43 ha (0.04%) of the SAFP's forest landscape. The proposed prioritization regimes spatial pattern in 2013 differs compare to the condition in 2003 and 1993. The temporal change of the prioritization regime in 1993, 2003 and 2013 can be seen in Table 6-2 and Figure 6-4.

Table 6-2 Prioritization regimes in 1993, 2003 and 2013

Regimes	1993		2003		2013	
	ha	%	ha	%	ha	%
Conservation	10,530	9.48	42	0.04	43	0.04
Preservation	66,156	59.53	60,743	54.66	58,573	52.70
Rehabilitation	5,096	4.59	8,490	7.64	10,553	9.50
Enhancement	29,353	26.41	41,861	37.67	41,966	37.76
Total	111,135		111,135		111,135	

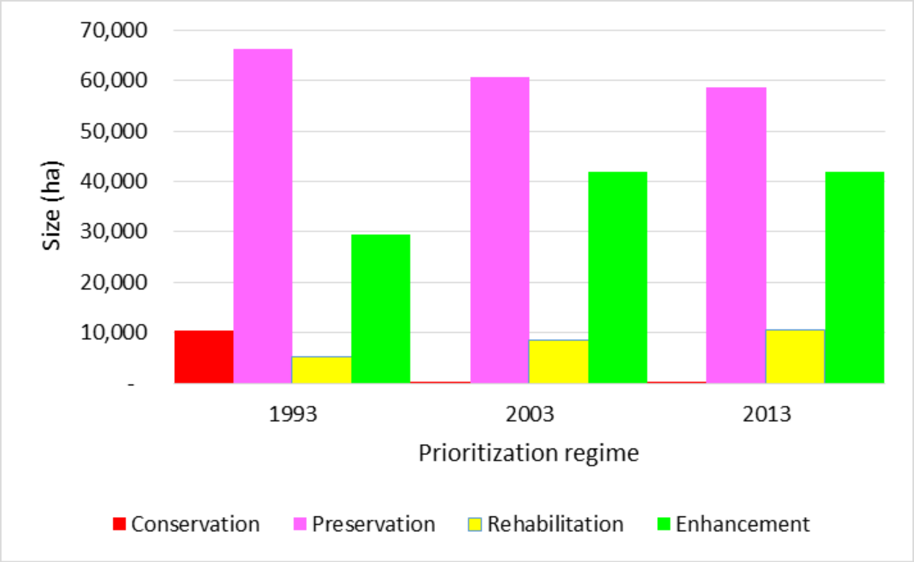


Figure 6-4 Prioritization regimes in 1993, 2003 and 2013

From the table and figure above, it can be seen that conservation regime has a decreasing pattern. It started from 9.48% in 1993, then it fallen to 0.04% in both 2003 and 2013. The Preservation regime also has a similar trend that started at 59.53% in 1993, and then decreased significantly to 54.66% in 2003. Finally, it stood at 52.7% in 2013. Contrary, both rehabilitation and enhancement regimes have increasing trends. In 1993, the Rehabilitation regime was at 4.59%. It increased to 7.64% in 2003 and increased again to 9.5% in 2013. Similarly, enhancement regime started at 26.41% in 1993. It increased rapidly to 37.67% in 2003, and then slightly increase to 37.76% in 2013. The trends show that both conservation and preservation regimes have decreasing trends while both rehabilitation and enhancement regimes have increasing trends.

The temporal change of the prioritization regime was also assessed by a confusion matrix in order to estimate the agreement among the observation years. From 1993 to 2003, the resultant Kappa statistics was 0.371 that means the prioritization regime in 2003 had a poor agreement compare to those in 1993. Meanwhile, from 2003 to 2013, the resultant Kappa statistics was 0.727 that mean the prioritization regime in 2013 had a good agreement compare to those in 2003. The confusion matrices of the prioritization regime were shown in Table 6-3, and Table 6-4. Temporal pattern of forest fragmentation was analysed using change analysis it has been discussed on page 44.

Table 6-3: Change of prioritization regimes (ha) from 1993 to 2003

Regimes (1993)	Regimes (2003)			
	Conservation	Preservation	Rehabilitation	Enhancement
Conservation	15	183	2,629	7,704
Preservation	20	51,039	2,059	13,038
Rehabilitation	-	5	2,059	3,032
Enhancement	7	9,517	1,742	18,087

Kappa statistic **0.371**

Table 6-4: Change of prioritization regimes (ha) from 2003 to 2013

Regimes (2003)	Regimes (2013)			
	Conservation	Preservation	Rehabilitation	Enhancement
Conservation	1	40	-	42
Preservation	51,906	935	7,886	60,743
Rehabilitation	23	8,268	176	8,490
Enhancement	6,644	1,310	33,903	41,861

Kappa statistic **0.727**

6.3.2. Forest landscape zonation based on prioritization regimes

SAFP has four zones, i.e. preservation, protection, limited use and intensive use zones. The zones were spatially distributed as can be shown in Figure 6-5a. As the comparison, the proposed prioritization regimes were shown in Figure 6-5b. The proposed prioritization regimes have visually agreement with the SAFP zonation. Conservation and preservation regimes were distributed in the south and east parts of SAFP. This condition is relevant to the corresponding zones (preservation and protection) that had similar spatial distribution. In the middle of the park, which was dominated by intensive use zone also has the appropriate proposed rehabilitation and enhancement regimes.

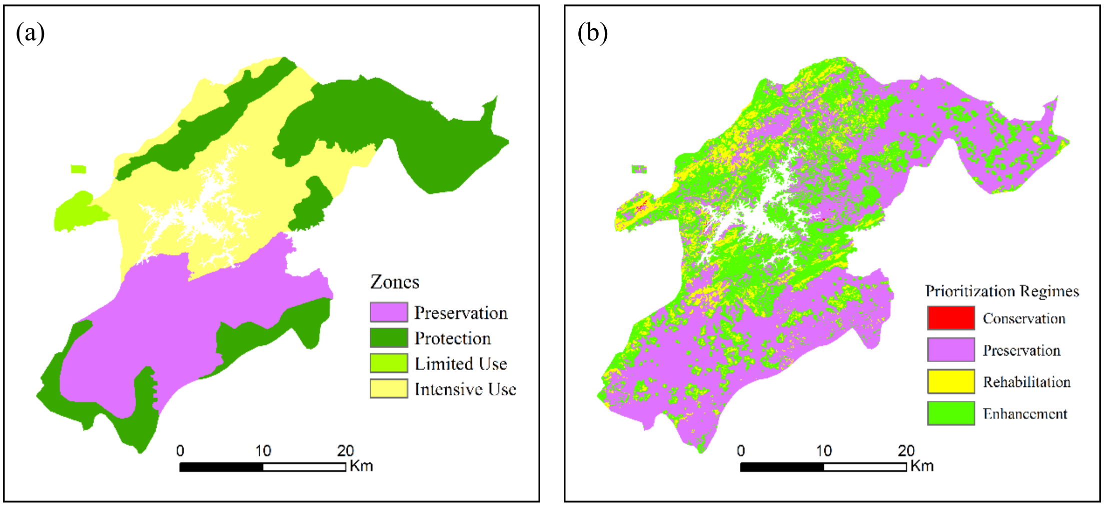


Figure 6-5 Map of (a) current SAFP zones and (b) proposed prioritization regimes

The result of the spatial analysis of comparing the zonation and prioritization regimes is presented in the confusion matrix in Table 6-5.

Table 6-5 Management zones and proposed prioritization regimes in SAFP

Size (ha)		Regimes			
		Conservation	Preservation	Rehabilitation	Enhancement
Zones	Preservation	2	20,452	4,131	9,213
	Protection	1	27,096	4,605	9,248
	Limited Use	23	430	1,076	600
	Intensive use	93	10,496	7,555	16,115

Based on the appropriateness function between prioritization regimes and zonation as shown in Figure 6-3, therefore the appropriateness of the current zonation was compared with the prioritization regimes with the matrix in Table 6-6. Preservation and protection zones were 66,011 ha (59%) appropriate and 8,736 ha (8%) not appropriate. On the other hand, the limited and intensive use zones have 25,346 ha (23%) appropriate while 11,042 ha (10%) is not appropriate.

Table 6-6 Review on the SAFP's zonation based on the prioritization regime (ha)

Zones	Prioritization regime	
	Appropriate for reservation and protection zones	Appropriate for limited/intensive uses zones
Preservation and protection	66,011	8,736
Limited and intensive uses	11,042	25,346

Kappa statistic = 0.59

The agreement between current zonation and prioritization regimes were assessed by Kappa statistical analysis as it has been discussed on page 44. The resultant Kappa statistics of 0.59 was considered as a moderate agreement.

6.4. Discussion

This chapter formulated the integration of preservation and the rehabilitation for forest landscape prioritization. As the result, the prioritization regimes was proposed that consists of four regimes based on the prioritization matrix as shown in Figure 6-2, namely (1) conservation regime, (2) preservation regime, (3) rehabilitation regime and (4) enhancement regime. Further, the spatial and temporal patterns of the prioritization regimes were assessed. In addition, the prioritization regime was used to review the current zonation in SAFP.

Prioritization regimes have particularly related activities. Based on the listed management activities for SAFP in Table 1-1. The appropriateness of the activities within the proposed prioritization regimes was evaluated by literature study. The activities in SAFP can be summarized and grouped into the following categories.

1. Area protection and patrol
2. Land rehabilitation

3. Flora and fauna enhancement
4. Nature service and non-timber extractions
5. Research
6. Ecotourism

Area protection and patrol are appropriate for high preservation priority area. It does not consider rehabilitation priority. Area protection and patrol activities therefore only consider the high preservation priority as the target. According to Figure 6-2, therefore, the area protection and patrol activities are suggested in the conservation and preservation regimes.

Land rehabilitation is appropriate for high rehabilitation priority area. It does not consider the preservation priority. According to Figure 6-2, therefore, the land rehabilitation is suggested in both conservation and rehabilitation regimes. However, since the condition of rehabilitation regime and conservation regimes are different, it needs to differentiate the methodology for the land rehabilitation in the two regimes. The common land rehabilitation activity (Indonesian Ministry of Forestry, 2013) uses intensive land preparation that is appropriate to take place on the rehabilitation regime. More caution methods must be applied to land rehabilitation activity in conservation regime. Even conservation regime needs land rehabilitation to increase its capacity for soil and water conservation, however, due to its high preservation priority, the intensive land rehabilitation does not suite for the conservation regime. Thus, more intensive land preparation may be applied in rehabilitation regime while more conservative land preparation must be applied in conservation regime.

Flora and fauna enhancement are appropriate for the area that has low priorities in both preservation and rehabilitation. Therefore, the flora and fauna enhancement is suggested in the enhancement regime. The regime has low preservation priority that means the biodiversity and or deforestation/degradation are low. The enhancement of flora and fauna in the area can be expected to increase the biodiversity. Moreover, the enhancement regime also has low rehabilitation priority. The activity can be focused on how to increase the biodiversity rather than to protect the soil and water. The selection of the right species of both flora and fauna and habitat enhancement can be maximized in enhancement regime.

Nature service and non-timber extractions are activities to extract the benefit of nature service the forest landscape without disturbing the forest as an ecosystem. Nature service extraction has been carried out by the construction of the dam within the park that supports electric power, irrigation, and fishery. Since there is no site specific for nature service extraction, the whole SAFP is considered as the appropriate area for providing the nature service.

Non-timber extraction is appropriate for high preservation priority as the social counter on the high deforestation and degradation threats. Therefore, non-timber extraction is appropriate for either conservation or preservation regimes. As can be seen from the framework in Figure 2-3 that deforestation/degradation threats consist of human-related criteria, namely the settlement, accessibility and forest fire. Non-timber extraction is expected to increase the social awareness of the importance of the forest landscape in supporting human’s needs. Non-timber timber use has been allowed in the SAFP such as for medicine plants, honeybee, mushroom and orchid (Government of the South Kalimantan Province, 2010). The appropriate scheme for the non-timber extraction must be carefully defined. Agroforestry is the possible candidate for the non-timber extraction in SAFP.

Since agroforestry has been promoted in tropics as a natural resources management strategy (Schroth et al., 2004), agroforestry offers promising benefit for SAFP. There are many successful examples how agroforestry was applied in Indonesian state forestlands (Hariyadi and Ticktin, 2012; Kusters et al., 2007; Kusters et al., 2008; Sunderlin et al., 2001). Since the community takes benefit from the agroforestry, threat to the forest can be decreased.

Government and local community need to negotiate (Suyanto et al., 2005) for managing conservation or preservation regimes. The purpose of the preserving the biodiversity value must be compromised with the social requirement to accommodate the community needs especially in species' composition. Even some agroforestry have been reportedly successful with particular species such as rubber, coffee and cocoa (Sunderlin et al., 2001), cinnamon (Hariyadi and Ticktin, 2012) or dipterocarp resin (Kusters et al., 2007), detail concept of agroforestry needs further analysis.

Research activity in SAFP should be focused on the biodiversity because the area is part of the Indonesian's nature preservation areas. The activity is appropriate for high biodiversity area. Preservation and enhancement regimes are considerably appropriate for the research activity. Research activity is proposed since it is one of the Indonesian biodiversity strategies (Indonesian Ministry of Environment, 2009).

Ecotourism activity is appropriate for areas that have high preservation priorities. Therefore, ecotourism is suggested in conservation and preservation regimes. It is expected that the ecotourism activity will increase the awareness of the importance of the forest landscape. In addition, high preservation priority is expected to close to human-related activities because it considers settlement, accessibility and forest fire. Thus, the feasibility of the ecotourism can be expected. Another significant consideration for ecotourism in SAFP is the presence of Riam Kanan Lake that is located in the center of the SAFP. Even though the lake was excluded from the analysis due to its status as a non-forest landscape, however, the presence of the lake must be considered as the potential ecotourism asset.

Further, ecotourism may be expected to support conservation activities. Though, ecotourism can be effective to support conservation only under certain circumstances (Krüger, 2005). Negative effects of the ecotourism need to be avoided such as the increase of the accessibility of the forest. Further study on the ecotourism feasibility and profitability is required, however.

This study proposed the prioritization regimes as the combination between preservation and rehabilitation. Each of regime has appropriate activities as it has been discussed in previous paragraphs. The summary of the appropriate activities in each conservation regimes is presented in the following table.

Table 6-7 Proposed prioritization regimes as the basis for the forest landscape zonation

No	Regimes	Priority criteria	Corresponding zones	Recommended activities
1	Conservation	High preservation High rehabilitation	Preservation / protection	• Area protection & patrol • Land rehabilitation • Non-timber uses / agroforestry • Nature service extraction • Ecotourism
2	Preservation	High preservation Low rehabilitation	Preservation / protection	• Area protection & patrol • Non-timber uses / agroforestry • Research • Ecotourism • Nature service extraction
3	Rehabilitation	Low preservation High rehabilitation	Limited/intensive use	• Land rehabilitation • Nature service extraction
4	Enhancement	Low preservation Low rehabilitation	All zones	• Flora & fauna enhancement • Research • Nature service extraction

Prioritization regime has spatial and temporal patterns. Preservation regime was the most dominant regime in SAFP throughout of the study period, followed by enhancement regime and rehabilitation regime. Conservation regime was significant in 1993, but it plummeted almost to zero in the following decades. Preservation and conservation regimes had decreasing trends while enhancement and rehabilitation regimes had decreasing trend. The spatial and temporal changes of the prioritization regime was contributed by the changes in preservation and rehabilitation priorities. In turn, it also depends on the biophysical conditions that found as parameters in the prioritization framework.

Based on the confusion matrix and Kappa statistical analysis, the prioritization regime in 1993 – 2003 period changed. The changed was related to the change in both preservation and rehabilitation priority. In 1993 – 2003, both preservation priority (Table 4-9) and rehabilitation priority (Table 5-8) changed that correspond with the change of the prioritization regime (Table 6-3). In 2003 - 2013, preservation priority (Table 4-10) moderately changed, and rehabilitation priority (Table 5-9) no changed that correspond with the moderate changed of the prioritization regime (Table 6-4).

Current zonation had a moderate agreement with the proposed prioritization regime. Forest zonation in SAFP was assigned in the long-term (20-year) forest plan. Further landscape management is detailed in mid-term (5-years) and short-term (1-year) plan. Even the zonation was and indispensable tool for forest planning, however, it is spatially and temporally static. This study therefore proposed the prioritization regime as the combination between preservation and rehabilitation. However, the proposed prioritization regime also showed its functionality in supporting the zonation itself including reviewing the current zonation.

The prioritization regime is suggested as one of the bases for forest zonation. However, since the approach in conservation prioritization was landscape approach, which ignore the detail in analysis, therefore the detail concept of forest zonation still need to consider other factors such as the presence of special ecosystems that are omitted in the prioritization analysis. Riparian vegetation is one of significant ecosystem that likely omitted from the analysis due to its higher spatial resolution compare to the prioritization. The importance of the corridor for improving habitat is also not accommodated in the prioritization. Lastly, Riam Kanan Lake ecosystem that is strongly correlated with the forest landscape was also omitted from the prioritization analysis.

6.5. Conclusion

1. Since forest zonation and special zone assignment were considerably static, therefore, the forest manager need a complementary tool that acknowledge the spatial and temporal patterns of the forest landscape. Thus, the prioritization regime was introduced as the combination between preservation and rehabilitation.
2. The introduction of the prioritization regime, the combination of preservation and rehabilitation, showed its functionality in supporting forest planning. The corresponding activities within each regime provide great guidance for the forest manager.
3. Prioritization regimes have spatial and temporal patterns in SAFP. In 1993 – 2003, prioritization regime changed, while in 2003 – 2013 prioritization regime moderately changed. The spatial and temporal patterns of both preservation and rehabilitation were responsible for the patterns of the prioritization regime. Since the decadal analysis showed the spatial and temporal changes of the prioritization regime, therefore, it is recommended that its application should be less than every 10 years.
4. Prioritization regimes also showed its possible application in evaluating the current zonation. Zonation in SAFP has a moderate agreement with the proposed conservation prioritization regimes (in 2013 condition). Since the prioritization regime was the resultant of the landscape approach, therefore, it can be expected that the prioritization regime can frequently be analysed.
5. Prioritization regime, is proposed as one tool in FMU zonation. Since zonation need to be assigned in the long-term forest plan (20 years), therefore, prioritization regime is suggested in the shorter terms forest plan (5-years or 1-year forest plan).

Chapter 7: Optimization and Sensitivity in Tropical Forest Landscape Prioritization for Conservation Planning

7.1. Introduction

Prioritization of the forest landscape is a dynamic process. There are many options influence the resultant priority area. Different identification and selection of the options leads to different prioritization results. In addition, prioritization also has spatial and temporal patterns. Prioritization has spatially distributed which, therefore, it has a specific spatial distribution across forest landscape. It also changes temporally.

Priority area is a portion of the highest priority index, which is assigned as the priority, while the rest is classed as non-priority. Defining priority area is, therefore, equal to categorizing the priority index into two classes, namely priority and non-priority. It is critical to determine the threshold between priority and non-priority. The most common practice for defining priority is by arbitrarily set the proportion which considerably reasonable such as 5% (Woodhouse et al., 2000) 10% (Geneletti, 2004), or 30% (Zhang et al., 2014). The arbitrarily set is acceptable if there is no such quantitative assessment of the optimum proportion for priority. Therefore, finding the optimum priority proportion is needed.

The resultant priority area depends on the prioritization method. However, there are many applications use different criteria or weight in prioritization. For example, the most common criteria for the forest rehabilitation priority in Indonesia are erosion rate, land cover, slope and land management (Indonesian Ministry of Forestry, 2013). Meanwhile, on Borneo island, Phua and Minowa (2005) used natural hazard prevention which covers landslide, drought, and flood prevention as criteria for prioritization of soil and water conservation. Liu et al. (2003) used vegetation cover, drifting sand coverage, annual desertification and population pressure for land rehabilitation in China. Thus, criteria for conservation prioritization vary among applications. In addition, prioritization also depends on the weights of each component; whether they are equally weighted (Jiménez-Alfaro et al., 2010; Marshall and Homans, 2006; Phua and Minowa, 2005), weighted by key figures (Phua and Minowa, 2005), or analysed through Analytic Hierarchy Process (AHP) (Intarawichian and Dasananda, 2010; Jaiswal et al., 2014; Saaty, 2005).

This study was aimed to assess the optimum proportion for conservation priority and to assess the sensitivity of the conservation prioritization framework in forest landscape. The optimum proportion was needed as the guidance of the prioritization in FMU. While, the sensitivity analysis contribute to better understanding of the effect of the criteria and weight on the prioritization framework.

7.2. Methodology

7.2.1. Optimization on the priority proportion

Optimum proportion is determined by considering two main aspects as follow.

1. Temporal consistency; Temporal consistency is related to the consistency of the resultant priority area across time. It is expected that the priority area does not change significantly over time.
2. “As small as possible” principle. The principle in conservation prioritization is finding as small as possible area (Carwardine et al., 2008). Forest managers could not distribute all resource to all forest landscapes. Instead, they need only a small portion, which has relatively higher priority compare others.

The two aspects above were balanced in finding the optimum proportion. If the proportion is too small, for example, close to zero proportion, the change over time must be enormous. The priority area in a particular year can completely change in the next year. Contrary, if the proportion is too big, for example, close to 100%, it can be expected that the change in the priority area is insignificant. Balancing between temporal consistency and "as small as possible" principles is required.

This study used the preservation and rehabilitation prioritization in 1993 – 2003 and 2003 – 2013 to assess the optimum priority proportion. An Analytic Hierarchy Process (AHP) weighting method was used. Simulations were performed by changing priority proportions into 2.5%, 5%, 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, and 90%. Each proportion was used to produce its corresponding priority area. The temporal changes of the resultant priority areas in each proportion were analysed. The focus of this study is only on the priority area only. Therefore, the average agreement/accuracy (of producer and user accuracies) instead of Kappa statistic was used to assess the priority changes. Plots of average agreement were analysed by regression analysis. The minimum average agreement of 80% was selected as the minimum requirement. The framework of the optimum proportion for forest landscape prioritization was shown in Figure 7-1.

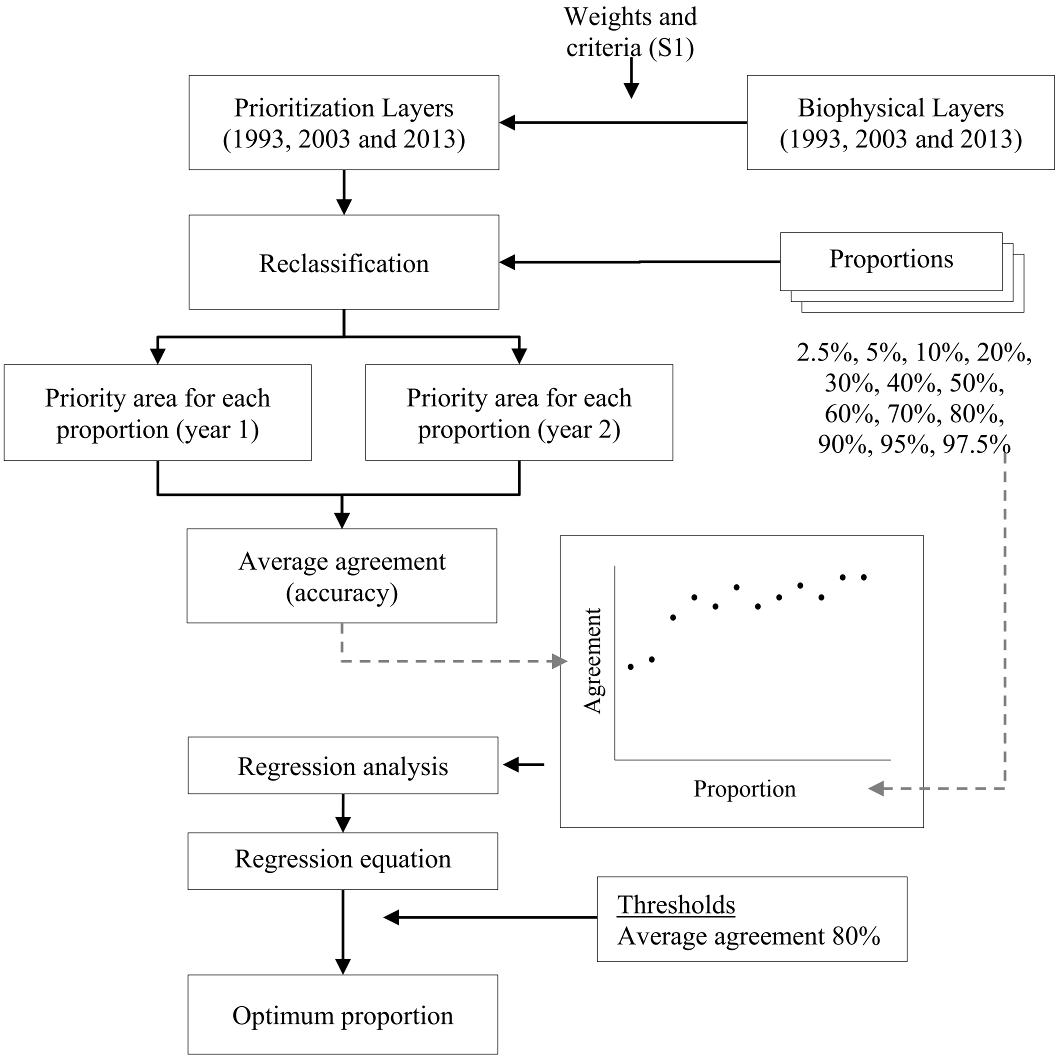


Figure 7-1: Framework for optimization of priority proportion

Regression analysis was selected to relate the selected proportion and its average agreement in simulations. The model selection for regression analysis depends on the following assumptions.

1. Low proportion will result in high temporal change of the priority area and therefore very low average agreement. At the minimum limit, if the proportion is zero, then the average agreement is presumably also zero.

2. High proportion will result in low temporal change of the priority area and therefore very high average agreement. At the maximum limit, if the proportion is 100%, then the average accuracy is also 100%.

Based on the assumptions above, linear regression, and logarithmic models were used with the following regression models.

Linear regression model $Y_i = b_0 + b_1 X_i + e_i$ Eq. 7-1

Logarithmic regression model $Y_i = b_0 + b_1 \left(\ln X_i \right) + \varepsilon_i$ Eq. 7-2

Where Y_i is the average accuracy as the dependent variable, b_0 and b_1 are regression model coefficients that are determined in the analysis, X_i is the proportion as the independent variable, and e_i is the residual error.

7.2.2. Sensitivity analysis on change of the weights and criteria

Sensitivity analysis was performed to assess the effect of the methods (criteria and weight) on the resultant priority area. The prioritization framework in Figure 7-2 show how the prioritization framework was changed by removal and addition of particular criteria and weight. The changes in the criteria and weight were performed in the sensitivity analysis.

The resultant priority area depends on the prioritization framework. This chapter used a GIS-based hierarchical decision-making framework as can be shown in Figure 2-3. Thus, the framework was modified in several simulations as can be seen in Figure 7-2. Scenarios were developed to assess the effect of the criteria and weight.

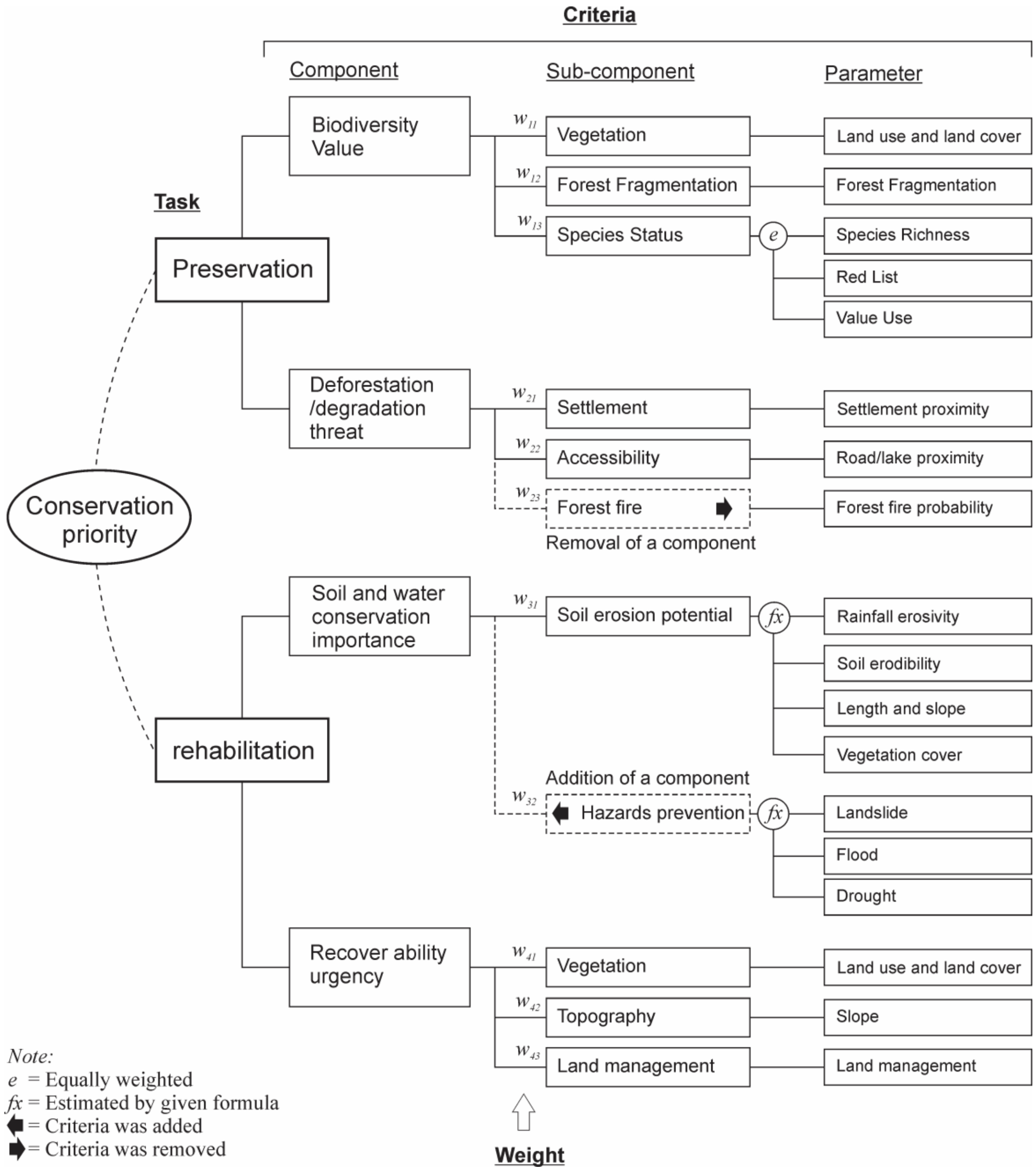


Figure 7-2: The removal and addition of criteria into the prioritization framework

Number of four scenario (S1 – S4) was developed in the sensitivity analysis. The standard weighting scenario in this study was AHP (S1). The weightings then changed into equal weights (S2) that equally weighted all sub-component. The third weighting method is proportionally equal (S3) that each criterion has equal weight in each branch. Finally, rule of weight (S4) was introduced which give one of the criteria more weight compare to other in each branch. The detail on the weightings used is presented in part 2.3.4 of page 37.

In addition, to assess the sensitivity of the resultant priority due to the change of the criteria, Scenario 5 (S5) was developed. One criterion (in sub-component level) was excluded/included in both preservation and rehabilitation prioritization. Forest fire sub-component was removed from preservation prioritization while hazards prevention sub-component was introduced in the rehabilitation prioritization as can be seen in Figure 7-2.

Scenarios for assessing sensitivity analysis was shown in the following table.

Table 7-1 Scenarios used in the analysis

Criteria Task/ Sub-component	AHP (S1)	Equal (S2)	Proportionally equal (S3)	Rule of weight (S4)	AHP with criteria removal (S5)
Preservation					
1. Vegetation	.209	1/6	1/6	¼	.263
2. Forest fragmentation	.133	1/6	1/6	1/8	.167
3. Species status	.158	1/6	1/6	1/8	.199
4. Settlement	.152	1/6	1/6	¼	.191
5. Accessibility	.143	1/6	1/6	1/8	.180
6. Forest fire	.205	1/6	1/6	1/6	N/A
Rehabilitation					
1. Soil erosion potential	.205	¼	½	½	.184
2. Hazard prevention	-	-	-	-	.115
3. Vegetation	.525	¼	1/6	¼	.431
4. Topography	.191	¼	1/6	1/8	.184
5. Land management	.079	¼	1/6	1/8	.086

Note: Forest fire criteria was excluded in S5 while hazard component was introduced

Each prioritization scenario (S1 – S5) was performed in 1993, 2003, and 2013. Three scenarios (S2 – S4) were compared to the control scenario (S1) to find the effect of the weighting method. Meanwhile, S5 was compared to the S1 for finding the effect of the criteria addition/removal. Change analysis were performed to assess the agreement between compared scenarios. The framework of the sensitivity analysis was shown in Figure 7-3. The priority areas in all scenarios were estimated in 25% proportion.

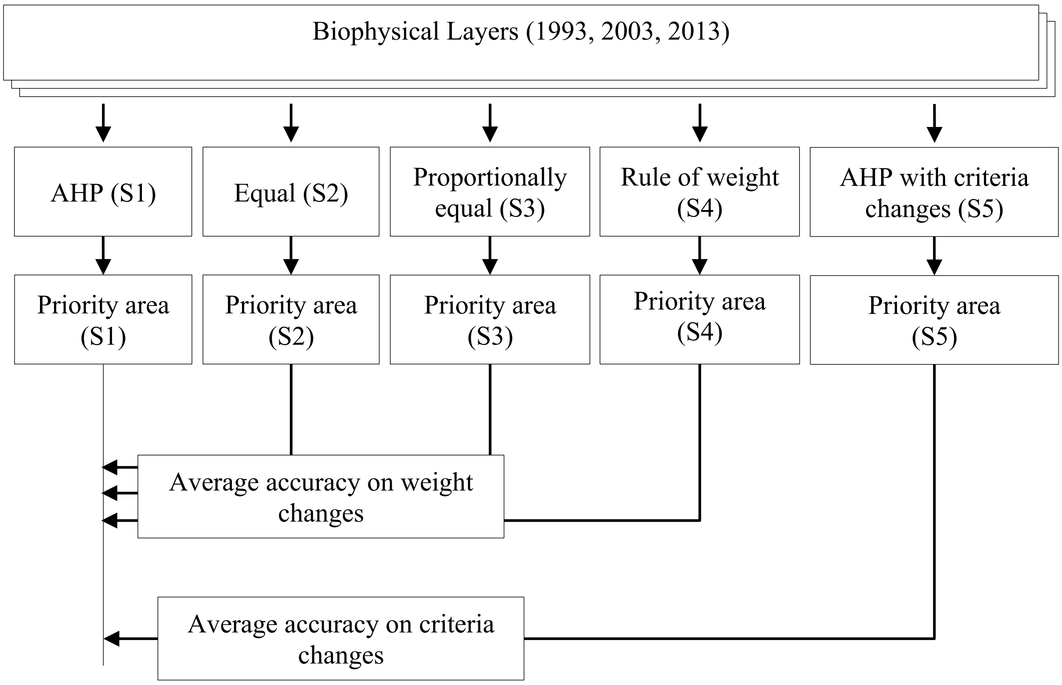


Figure 7-3: Sensitivity analysis on the change in the weights and criteria for preservation and rehabilitation prioritization

7.3. Results

7.3.1. Optimum priority proportion

7.3.1.1. Optimum preservation priority proportion

The average agreements between producer and user accuracies were calculated for different proportions of preservation priority (Table 7-2). The regression analysis were performed to correlate the proportion and the average agreement.

Table 7-2: Agreements for the **preservation** priority proportions in 1993-2003 and 2003-2013

Proportion	1993-2003			2003-2013		
	Producer	User	Average	Producer	User	Average
2.5	24.8	25.0	24.9	29.4	25.7	27.6
5	35.0	34.5	34.7	43.8	46.5	45.2
10	40.7	37.7	39.2	62.1	64.1	63.1
20	41.5	39.6	40.6	72.9	73.5	73.2
30	45.0	42.5	43.8	76.6	79.2	77.9
40	53.1	50.6	51.9	80.6	82.8	81.7
50	61.5	59.7	60.6	72.7	94.3	83.5
60	70.1	70.9	70.5	89.8	88.8	89.3
70	78.7	78.8	78.7	91.7	91.5	91.6
80	84.5	84.2	84.4	93.5	93.2	93.4
90	91.8	91.7	91.7	96.2	96.3	96.3

The regression analysis shows that both linear and logarithmic models fit with the data (Table 7-3). The regression analysis between proportions and the resultant average agreements was performed with the result is shown in **Appendix H** on page 302 and 305. The selected linear and logarithmic models shows their usability by showing the significant value of ANOVA (*Fsig* <0.01), therefore the two models can be used to describe the relation between preservation proportion and the average agreement.

Table 7-3: Summary of the regression analysis between **preservation** priority proportions and the average agreements in 1993 – 2003 and 2003 – 2013

Model	Period	Models	R^2	Fsig
Linear	1993 – 2003	$y = 26.801 + 0.713x$	0.980	<0.01
	2003 – 2013	$y = 49.163 + 0.616x$	0.772	<0.01
Logarithmic	1993 – 2003	$y = 1.836 + 16.665\ln(x)$	0.805	<0.01
	2003 – 2013	$y = 16.031 + 17.932\ln(x)$	0.983	<0.01

Source: Data analysis in **Appendix H** on page 302 and 305

However, a visual inspection of the regression plot (Figure 7-4 and Figure 7-5) and the comparative value of R^2, linear model explained better than logarithmic model in 1993 – 2003 period, while logarithmic model explained better than linear model in 2003 – 2013 period. Therefore, this study selects the linear model to regress the preservation priority proportion with the average agreement in 1993 – 2003 period while for 2003 – 2013 period, the logarithmic model was used.

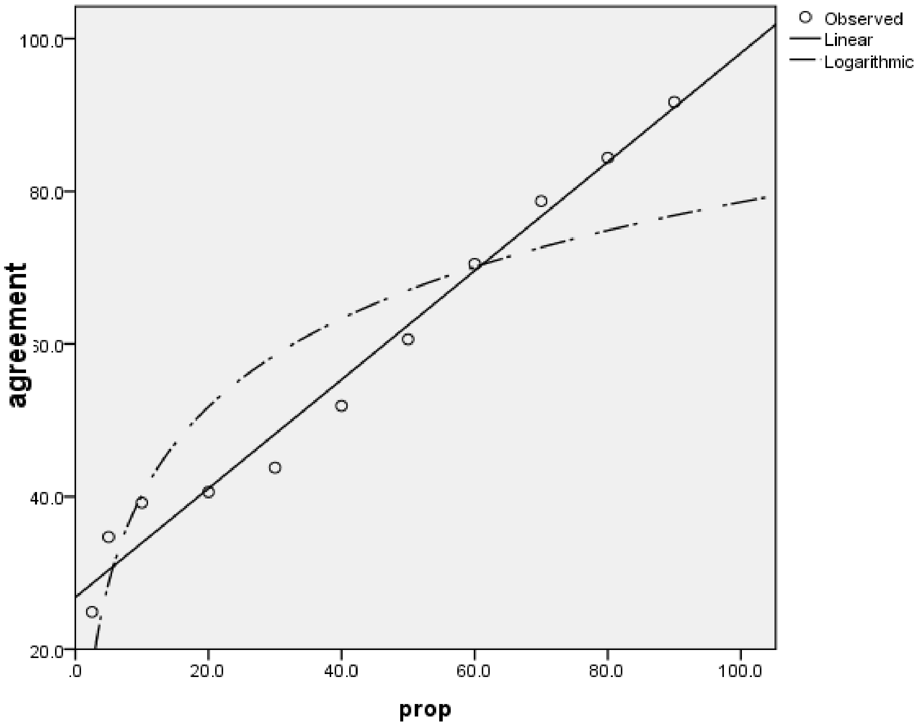


Figure 7-4: Average agreement in several preservation priority proportion (1993 – 2003)

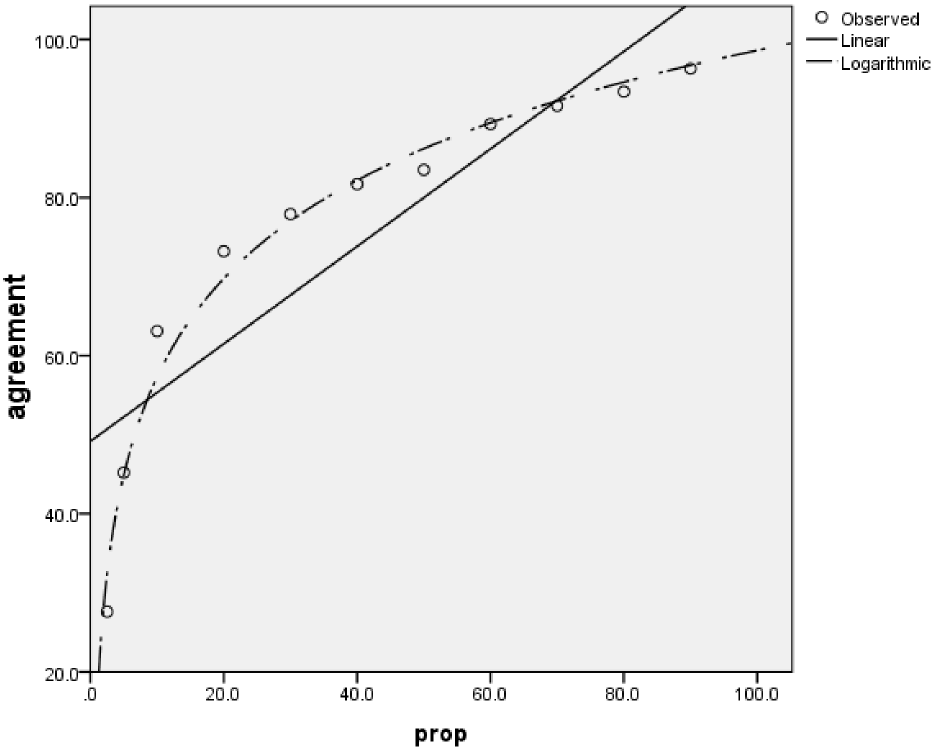


Figure 7-5: Average agreement in several preservation priority proportion (2003 – 2013)

Optimum proportions were determined by the linear model in 1993 – 2003 and logarithmic model in 2003 – 2013. The optimum proportions that met the minimum average agreement of 80% were calculated by the equations of $y = 26.801 + 0.713x$ for 1993 – 2003 period and the equation of $y = 16.031 + 17.932 \times \ln(x)$ for 2003 – 2013 period. The optimum rehabilitation proportion for 1993 – 2003 was **75%**. While the optimum rehabilitation proportion for 2003 – 2013 was **35%**.

7.3.1.2. Optimum rehabilitation priority proportion

The average agreements between producer and user accuracies were calculated for different proportions of rehabilitation priority (Table 7-4). The regression analysis were performed to correlate the proportion and the average agreement.

Table 7-4: Agreements for the **rehabilitation** priority proportions in 1993-2003 and 2003-2013

Proportion	1993-2003			2003-2013		
	Producer	User	Average	Producer	User	Average
2.5	24.8	25.0	24.9	29.4	25.7	27.6
5	35.0	34.5	34.7	43.8	46.5	45.2
10	40.7	37.7	39.2	62.1	64.1	63.1
20	41.5	39.6	40.6	72.9	73.5	73.2
30	45.0	42.5	43.8	76.6	79.2	77.9
40	53.1	50.6	51.9	80.6	82.8	81.7
50	61.5	59.7	60.6	72.7	94.3	83.5
60	70.1	70.9	70.5	89.8	88.8	89.3
70	78.7	78.8	78.7	91.7	91.5	91.6
80	84.5	84.2	84.4	93.5	93.2	93.4
90	91.8	91.7	91.7	96.2	96.3	96.3

The regression analysis shows that both linear and logarithmic models fit the data. The regression analysis between simulated proportions and the resultant average agreements was performed with the resultant analysis is shown in **Appendix H** on page 308 and 311. The selected linear and logarithmic models shows their usability by showing the significant value of ANOVA (Fsig <0.01), therefore the two models can be used to describe the relation between the rehabilitation proportion and the average agreement.

Table 7-5: Summary of the regression analysis between **rehabilitation** priority proportions and the average agreements in 1993 – 2003 and 2003 – 2013

Model	Period	Models	R^2	Fsig
Linear	1993 – 2003	$y = 35.243 + 0.861x$	0.755	<0.01
	2003 – 2013	$y = 80.4 + 0.171x$	0.865	<0.01
Logarithmic	1993 – 2003	$y = -11.863 + 25.3\ln(x)$	0.981	<0.01
	2003 – 2013	$y = 75.952 + 3.532\ln(x)$	0.553	<0.01

Source: Data analysis in **Appendix H** on page 308 and 311

However, a visual inspection of the regression plot (Figure 7-6 and Figure 7-7) and the comparative value of R^2, logarithmic model explained better than linear model in 1993 – 2003 period, while linear model explained better than logarithmic model in 2003 – 2013 period.

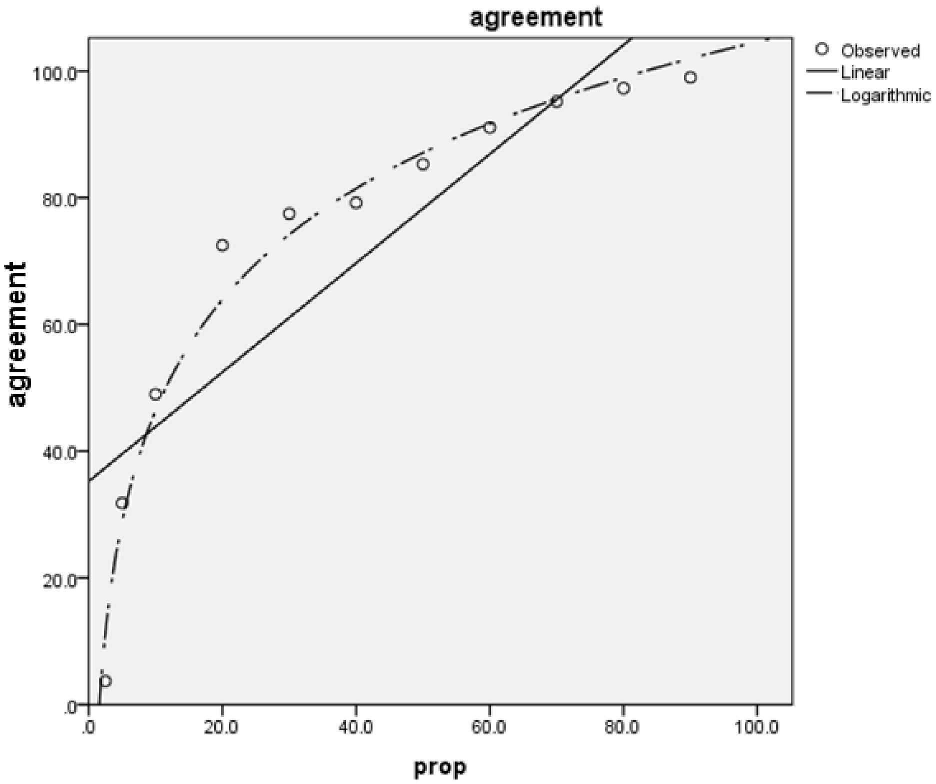


Figure 7-6: Average agreement in several rehabilitation priority proportion (1993 – 2003)

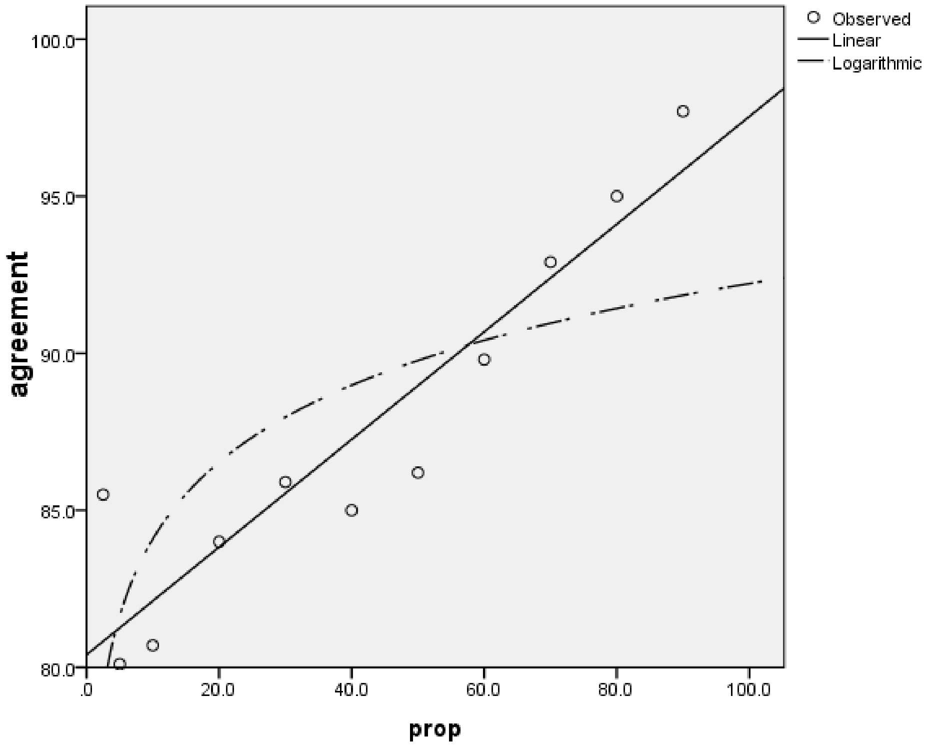


Figure 7-7: Average agreement in several rehabilitation priority proportion (2003 – 2013)

Determining the optimum proportions were determined by the logarithmic model in 1993 – 2003 and linear model in 2003 – 2013. The optimum proportions that met the minimum average agreement of 80% were calculated by the equations of $y = -11.863 + 25.3\ln(x)$ for 1993 – 2003 period and the equation of $y = 80.4 + 0.171x$ for 2003 – 2013 period. The optimum rehabilitation proportion for 1993 – 2003 was **38%**. While the optimum rehabilitation proportion for 2003-2013 was not able to be determined.

7.3.2. Sensitivity to the change of weights

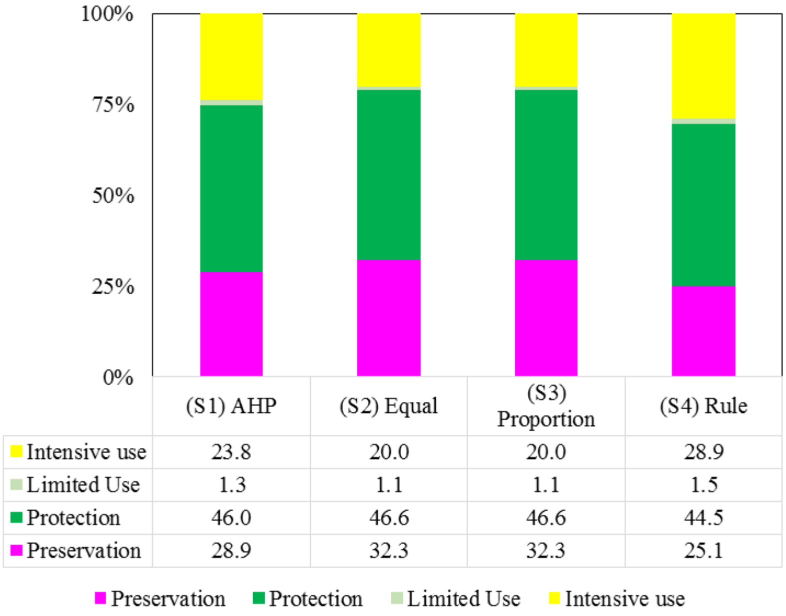
7.3.2.1. Change of weight effects on preservation

Sensitivity analysis on the change of weights was performed by comparing S1 with S2, S3 and S4 consecutively. The agreement in the comparison was assessed by the confusion matrix with Kappa statistics. S2 and S3 have equal Kappa values (Table 7-6). Both have Kappa statistics of 0.9. Meanwhile, S4 has lowest Kappa statistics. However, all of the compared scenarios (S2 – S4) have high agreement with S1.

Table 7-6 Kappa Statistics for compared preservation scenarios

Scenarios	Kappa statistic compare to S1
Equal (S2)	0.90
Proportional (S3)	0.90
Rule of Weight (S4)	0.87

In order to assess the spatial distribution of the preservation priority area among scenarios, spatial analysis were performed to calculate the priority area in each zone. Using S2, preservation priority area is mostly located in protection zone (46%), followed by preservation zone (28.9%), intensive use zone (23.8%) and insignificantly in limited use zone (1.3%). S2 and S3 put more priority areas for both preservation and protection zones but less priority area in limited use and intensive use zones. Meanwhile, S4 put lower priority areas for both preservation and protection zones but more priority area in limited and intensive use zones. The spatial distribution of the preservation priority area is presented in Figure 7-8.



	(S1) AHP	(S2) Equal	(S3) Proportion	(S4) Rule
🟨 Intensive use	23.8	20.0	20.0	28.9
🟩 Limited Use	1.3	1.1	1.1	1.5
🟩 Protection	46.0	46.6	46.6	44.5
🟪 Preservation	28.9	32.3	32.3	25.1

Figure 7-8 Distribution of the preservation priority (%) among scenarios and zones

7.3.2.2. Change of weight effects on rehabilitation

On the rehabilitation prioritization, S2 and S3 had equal Kappa statistic of 0.79 while S3 had the lowest agreement with Kappa statistics of 0.68as can be shown in Table 7-7

Table 7-7 Kappa Statistics for compared rehabilitation scenarios

Scenarios	Kappa statistic (compare to S1)
Equal (S2)	0.79
Proportional (S3)	0.68
Rule of Weight (S4)	0.79

In assessing the spatial distribution of the rehabilitation priority area among scenarios, spatial analysis were performed. Using S1, rehabilitation priority area is dominantly located in intensive use zone (53.9%), followed by preservation zone (21.5%), protection zone (19.9%) and limited use zone (4.7%). All alternatives scenarios (S2 – S4) produced less rehabilitation priority area in intensive use zone and higher priority area in limited preservation, protection, and limited use zones. The spatial distribution of the rehabilitation priority area among zones is presented in the following figure.

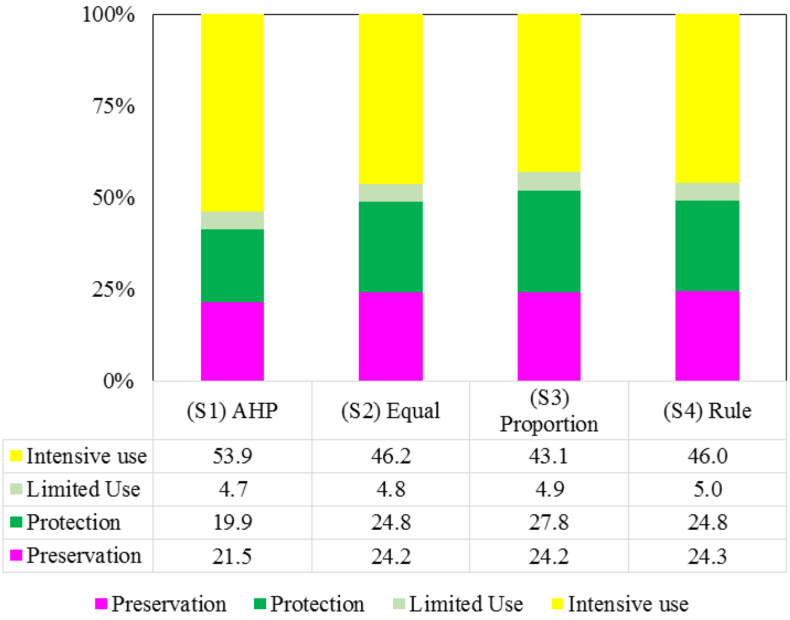


Figure 7-9 Distribution of the rehabilitation priority (%) among scenarios and zones

7.3.3. Sensitivity to the change of the criteria

7.3.3.1. Change of criteria effects on preservation

The sensitivity analysis on the change in criteria in preservation prioritization was performed by excluded the forest fire sub-component. The forest fire criterion was excluded from the preservation prioritization using AHP weighting methods in S5. The resultant preservation priority area was compared with the S1 with the confusion matrix in the following table.

Table 7-8 The priority comparison between AHP (S1) and without forest fire (S5) for preservation (ha)

AHP	AHP with forest fire removed	
	Non-priority	Priority
Non-priority	79,195	3,746
Priority	4,142	24,052

Kappa statistics = **0.813**

Based on the confusion matrix in Table 7-8 above, it can be calculated the Kappa statistics of 0.813. Since the Kappa statistic above 0.8 was considered as 'no change', therefore, the exclusion of the forest fire criteria from the preservation prioritization framework does not change the resultant priority area.

7.3.3.2. Change of criteria effects on rehabilitation

The sensitivity analysis on the change in criteria in the rehabilitation prioritization was performed by including the hazard prevention sub-component. The hazard prevention criterion was included from the rehabilitation prioritization S5. The resultant rehabilitation priority area was compared with the S1.

Table 7-9 The priority comparison between AHP (S1) and without forest fire (S5) for rehabilitation (ha)

AHP	AHP with hazard prevention added	
	Non-priority	Priority
Non-priority	78,804	4,729
Priority	5,816	21,786

Kappa statistics = **0.769**

Based on the confusion matrix in Table 7-9, it was calculated that the Kappa statistics was 0.769. Since the Kappa statistic above 0.8 was considered as 'moderate change', therefore, the addition of the hazard prevention criteria into the rehabilitation prioritization framework moderately change the resultant priority area.

7.4. Discussion

7.4.1. Optimum priority proportion

The study on the optimum proportion for conservation prioritization is important because the current studies on prioritization use arbitrary set of proportions (Geneletti, 2004; Woodhouse et al., 2000; Zhang et al., 2014). Since arbitrary proportion is not favorable, it needs to confirm whether a quantitative method is applicable to seek the appropriate proportion in prioritizing forest landscape.

Linear and logarithmic models were successfully regressed the priority proportion and the average agreement in both preservation and rehabilitation prioritizations. The resultant ANOVA significances (*Fsig*) for both models were significant (*Fsig* <0.01). Selecting which model is more favorable over another is difficult since based on the coefficient of determination (R^2) and visual observation, both of linear and logarithmic model interchangeably more favorable over another. The two models showed their usability to meet the requirement of the optimum priority proportion, namely temporal consistency and 'as small as possible' principles.

There was no single optimum proportion calculated for both preservation and rehabilitation in 1993 – 2003 and 2003 – 2013. For preservation prioritization, it was calculated that the optimum proportion for preservation was 75% in 1993 – 2003 and 35% in 2003 – 2013. Higher temporal change then higher priority proportion is needed. Higher optimum proportion in 1993 – 2003 is related to higher temporal change of the preservation priority with Kappa statistics of 0.2321 (Table 4-9 page 155). Much lower optimum proportion was found in 2003 – 2013 period that related to lower temporal change of the preservation priority with the Kappa statistics of 0.667 (Table 4-10 page 155).

The optimum proportion for rehabilitation in 2003 – 2013 was not able to be determined. As can be shown in Figure 7-7 that as small as 0% proportion on the linear regression model has more than 80% average agreement. The possible cause of this condition is the insignificance on the temporal rehabilitation change. This condition is relevant with Table 5-8 (page 170) and Table 5-9 (page 170) that the temporal change of the rehabilitation priority area in 2003 – 2013 was categorized as no change. Therefore, it also confirms that the higher temporal change then higher priority proportion is needed.

This study shows that the regression analysis cannot select the appropriate model and value for the optimum priority proportion in either preservation or rehabilitation. Even the linear and logarithmic models show their good performances, however, neither one of them is consistently favorable over another. The optimum proportion is also hard to be consistently defined since it depends on the spatial and temporal change of the preservation and rehabilitation prioritizations. Thus, arbitrary proportion for determining priority area in forest landscape still the appropriate option.

In management practice, the priority proportion merely depend on the available management resources. Finding as small as possible area for prioritization (Carwardine et al., 2008) needs to be adjusted to the budget and human resources ability. The condition of Indonesian conservation that often understaffed and under budgeted (Meijaard, 2014) appropriately becomes the consideration for the priority proportion. FMU manager may determine the area to be prioritized under certain budget and or staff as the constraints, and then the priority area is spatially determined by the GIS-based prioritization framework.

7.4.2. Sensitivity due to change of weight

Sensitivity analysis of weights did not try to find the best method but, instead, try to find the agreement of the simple methods with AHP. AHP is considered as the most preferred method. However, AHP needs prior study on the management preference. Simpler weighting methods are available such as equal weight, proportionally equal, and rule-based. Those methods need no prior study or information on decision-making preferences. Thus, comparing the resultant priority area by AHP and other methods may be considered for selecting the weighting method.

Equal, proportionally equal and rule of weight can be good alternatives for weighting method in conservation prioritization. The result shows that those methods have good agreements with AHP with all Kappa statistics more than 0.8 (Table 7-6 and Table 7-7). The AHP is certainly still the best choice for the weighting in preservation and rehabilitation prioritizations. However, the AHP method needs a prior study to quantify the management preference. If the forest manager has sufficient resource, the AHP is the favorable method. Meanwhile, for no prior study and information on decision-making preference, any of equal, proportionally equal and rule-of-weight methods can be used.

7.4.3. Sensitivity due to change of criteria

Sensitivity analysis due to change in criteria is aimed to assess the effect of the criteria changes. It simulated the removal of forest fire from the criteria for preservation prioritization and the addition of the hazard prevention from the rehabilitation prioritization. Forest fire was removed in the simulation since it has a significant change in both 1993 – 2003 and 2003 – 2013 (Table 3-51 in page 139). Meanwhile, hazard prevention was included in the simulation since it has been introduced as one of the criteria for prioritization in Borneo Island (Phua and Minowa, 2005) that shares the same island with SAFP.

The removal of the forest fire criteria from the preservation framework does not change the resultant priority area. The resultant confusion matrix with the Kappa statistics of 0.813 show that there is no difference in the resultant preservation priority area between 'with' and ‘without’ forest fire criteria (Kappa statistics > 0.8). From the overall weight of 1.0 for the preservation prioritization, forest fire takes 0.205 weight (Figure 2-3) which is the highest among deforestation/degradation components. However, the significant weight does not guarantee that the omission of the forest fire contributes to the significant change of the resultant priority area.

The addition of the hazard prevention criteria into the rehabilitation prioritization framework produced a medium agreement. The resultant confusion matrix shows the Kappa statistic of 0.769. Based on the Kappa statistics categories in Jensen (2004) as it is shown in Table 2-7, the addition of the hazard prevention moderately change the resultant rehabilitation priority area. However, the resultant agreement is still far from changing the prioritization result since the resultant Kappa statistics is much higher than the change category of 0.4.

The result shows that the removal and addition of the selected criteria do not significantly change the resultant priority area. It confirmed that criteria selection has a wide spectrum of choices without significant difference in result. Since the prioritization or framework could not be evaluated in terms of right or wrong, therefore, developing the acceptable (Balaguru et al., 2006), repeatable and objective (Liu et al., 2006) framework is important in conservation prioritization.

7.5. Conclusion

1. The regression model successfully applied to find the optimum proportion for both preservation and rehabilitation prioritizations. However, identifying the most favorable model between linear and logarithmic models is difficult since the two models are interchangeably favorable over another between different study periods and different prioritizations.

2. The single optimum proportion cannot be determined by the regression models. The optimum proportion is certainly influenced by the spatial and temporal patterns of the resultant prioritization. The higher spatial and temporal changes the higher proportion is needed. The arbitrary set of priority proportion (Geneletti, 2004; Woodhouse et al., 2000; Zhang et al., 2014) or balancing with the availability of staff and budget are considerably appropriate in determining the priority proportions.
3. AHP is the preferred method for determining the weight in each criterion. However, since the AHP needs a prior study on the management preferences, therefore, equal, proportionally equal or rule of weight methods can be alternatives for prioritization analysis. Those weighting methods have high agreement compare to AHP.
4. The removal of forest fire criteria from preservation prioritization and the addition of the hazard prevention criteria from the rehabilitation prioritization did not change the resultant priority area significantly. Criteria selection has a wide choice without significance difference. The acceptable, repeatable and objective criteria selection is considerably appropriate for the conservation prioritization.

Chapter 8: General Conclusion and Recommendation

8.1. General Conclusion

8.1.1. Summary of findings

This study has found several findings in the conservation prioritization in SAFP. Each of finding was listed in the conclusion part of each chapter. However, all of those conclusions can be summarized into the following points.

1. This study has successfully developed and applied the conservation prioritization in the forest landscape with the introduction of new conservation concept, redefined criteria/component identification, and landscape approach.
2. The resultant framework for prioritization was developed specifically for SAFP. Thus, the framework is site-specific, and it cannot be automatically adopted in other sites. The procedure, how to develop the prioritization framework as discussed in Chapter 2, is a valuable guideline for the adoption.
3. Spatial and temporal patterns of the biophysical conditions affect the spatial and temporal patterns of both preservation and rehabilitation.
4. The incorporation of the threat component into preservation prioritization significantly change the resultant priority area. In addition, the incorporation of the recoverability component into the rehabilitation prioritization also significantly change the resultant rehabilitation priority area. Therefore, redefined criteria identification into value/importance and threat/urgency as proposed by Nislow et al. (2010) is crucial in conservation prioritization.
5. Priority area changed spatially in temporally. Preservation priority area changed in 1993 – 2013 period and moderately changed in 2003 – 2013 period. While, the rehabilitation

priority area changed in 1993 – 2003 but no changed in 2003 – 2013. The acknowledgment on their patterns is indispensable for forestry planning.

6. The conservation concept that consider preservation and rehabilitation as the two main conservation tasks shows its usable application for forest planning. Prioritization regime as the combination of preservation and rehabilitation showed its applicability in supporting forest planning and evaluating the current zonation. Therefore, it was proposed as the complementary tool in FMU forest planning.
7. The developed prioritization framework has low sensitivity for the change of the weight and criteria. Different weighting methods and different criteria did not significantly change the resultant priority area. Criteria selection has a wide range of choices without significance difference. The acceptable, repeatable and objective criteria selection is considerably appropriate for developing framework of conservation prioritization.
8. The linear and logarithmic models showed their significance in regressing the priority proportion and the average accuracy. However, the single optimum proportions for prioritization in preservation or rehabilitation were hardly estimated due to its spatial and temporal change. Thus, the recent practice of arbitrary set proportion or adjusting the availability of the management resources are considerably still appropriate in determining priority proportion.

8.1.2. Scientific contribution

This study has contributed to scientific knowledge in two main phases. *First*, it successfully developed the conservation prioritization framework and its developing procedure for forest landscape prioritization by introducing more appropriate conservation concept, redefined criteria identification, and landscape approach. Even the resultant framework has a site-specific application in SAFP. However, it shows great possibility for the adoption in other FMU. *Second*, it successfully showed the application of the framework and its spatial and temporal patterns in an FMU level analysis. Since the biophysical conditions have spatial and temporal patterns, therefore, the resultant conservation prioritizations were influenced by those patterns. It also highlighted the significance of the redefined criteria into value/importance and threat/urgency. Further, the application of the conservation prioritization shows its possible contribution to the forest planning by providing alternatives to management activities and evaluation on the forest zonation. Finally, it emphasized the non-sensitivity of the developed framework, in terms of weighting and criteria selection, and underlined the importance of developing the acceptable, repeatable and objective prioritization framework.

8.1.3. Limitation

This study has some limitations that mostly rely on the fact that the study site of SAFP is only one of the example of FMU in Indonesia. Therefore, the implementation of the results of this research on the conservation prioritization in FMU needs to consider the following considerations.

- *First*, the proposed conservation framework was developed specifically for SAFP. The resultant criteria and weights, as shown in Figure 2-3, can be applied only in SAFP. Its application in other sites needs to be reviewed and adjusted.
- *Second*, procedure in the prioritization framework development is a generic that may be applied to other sites with caution. The difference on the site characteristics between SAFP and the site should be considered.
- *Third,* this study uses landscape approach for conservation prioritization that ignore some details on the species' basis. The availability of the valuable data in the forest landscape may be considered in the analysis.

8.2. Recommendation

8.2.1. Basic ideas for implementation

Conservation prioritization has a great application in managing forest landscape within FMU. Two scenarios of the implementation of conservation prioritization were advised. *First*, in the conservation FMU, conservation prioritization support the conservation planning as the main planning in the conservational FMU such as in forest parks, national parks, nature reserves, nature recreation parks, and hunting resorts. *Second*, the application of the conservation prioritization in production and protection forests. It is certain that conservation aspect still exists in those non-conservational forests (Kartodihardjo et al., 2011). However, since conservation is not the main function of the two forest types, the application of the conservation prioritization is as an additional planning.

Prioritization is the core of the conservation planning (Carwardine et al., 2008). The application of the conservation prioritization certainly contributes to FMU management by providing decision tool to acknowledge spatial and temporal patterns of the forest. Zonation and special zone assignment are among available decision tools in FMU. The two have considerably static spatially and temporally. On the other hand, conservation prioritization more acknowledges spatial and temporal patterns. Complementing conservation prioritization with zonation and special zone assignment will improve decision-making in FMU. In turn, the site level SFM is reasonable expected. It cannot be concluded that the implementation of conservation prioritization will result in the SFM in the forest landscape. Nevertheless, the contribution of the conservation prioritization to achieve the SFM is significant. In the end, the SFM in Indonesian forests is expected. The implementation of the conservation prioritization in FMUs and its contribution to the SFM in Indonesian forests is shown in Figure 8-1.

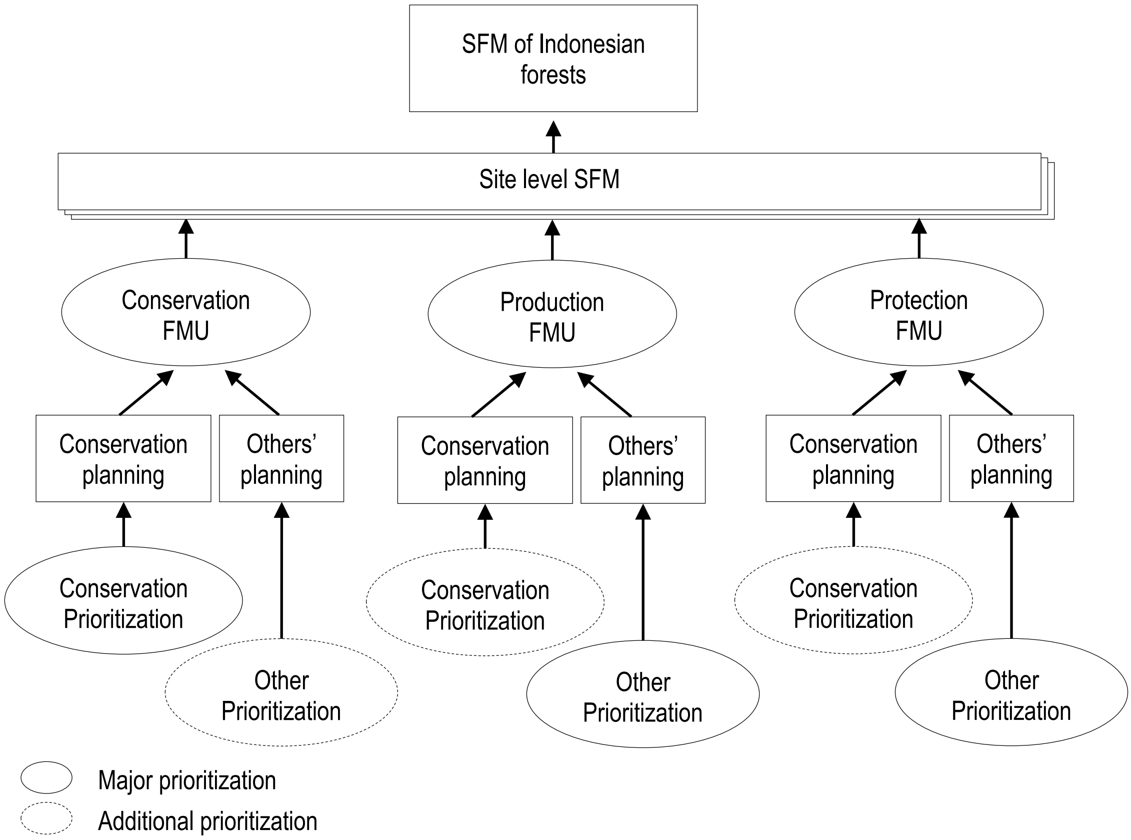


Figure 8-1 Conservation prioritization implementation in Indonesian forests

8.2.2. Future perspective

The implementation of prioritization in forest landscape management of FMU has a promising implementation in supporting forest planning. However, the conservation priority, which was presented in this study, is only one aspect in achieving SFM. In accordance with C&I of SFM for tropical forest (ITTO, 2005), there are seven C&I for SFM as follow.

Criterion 1 : Enabling conditions for sustainable forest management

Criterion 2 : Extent and condition of forests

Criterion 3 : Forest ecosystem health

Criterion 4 : Forest production

Criterion 5 : Biological diversity

Criterion 6 : Soil and water protection

Criterion 7 : Economic, social and cultural aspects

Conservation prioritization that encompass preservation and rehabilitation prioritizations in this study is related to Criterion 5 and Criterion 6. In the case of the conservation forest, including SAFP, the two criterion covers main forest management activities. However, other five criteria still needed to be studied on the types of FMU (conservation, production, and protection) and site characteristics.

The prioritization framework development in this study can be used as the reference for prioritization of other SFM criterion. However, caution is highly required. The main conservation concepts that consider two SFM criteria (preservation and rehabilitation) may not apply to another prioritization. The study on the other prioritization may consider only one criterion or even only cover part of the issue within a particular criterion.

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Appendix A: The pair-wise comparison matrix

Criteria	1	2	3	4	5	6	Rating
1. Vegetation (biodiversity)							
(1) Forest	1						0.510
(2) Mixed plantation	0.330	1					0.231
(3) Shrub/bush	0.226	0.463	1				0.131
(4) Grassland	0.173	0.305	0.523	1			0.084
(5) Bare land	0.132	0.194	0.277	0.368	1		0.044
Consistence ratio: 0.025							
Consensus: 94.9%							
2. Forest fragmentation							
(1) Core forest	1						0.484
(2) Perforated forest	0.379	1					0.253
(3) Edge forest	0.245	0.392	1				0.144
(4) Patch forest	0.200	0.289	0.417	1			0.081
(5) Non-forest	0.114	0.182	0.215	0.377	1		0.039
Consistence ratio: 0.030							
Consensus: 97.9%							
3. Species status							
(1) Very high	1						0.517
(2) High	0.402	1					0.280
(3) Low	0.256	0.373	1				0.130
(4) Very low	0.191	0.240	0.452	1			0.073
Consistence ratio: 0.026							
Consensus: 98.9%							
4. Settlement proximity (km)							
(4) 0 – 1.41	1						0.427
(3) 1.41 – 2.41	0.665	1					0.314
(2) 2.41 – 3.70	0.464	0.527	1				0.188
(1) > 3.70	0.174	0.235	0.353	1			0.071
Consistence ratio: 0.003							
Consensus: 96.6%							
5. Accessibility (km)							
(1) 0 – 0.32	1						0.475
(2) 0.32 – 0.83	0.588	1					0.293
(3) 0.83– 1.75	0.316	0.452	1				0.151
(4) > 1.75	0.178	0.298	0.470	1			0.081
Consistence ratio: 0.004							
Consensus: 98.4%							
6. Forest fire							
(4) Very high	1						0.531
(3) High	0.398	1					0.275
(2) Low	0.236	0.376	1				0.131
(1) Very low	0.164	0.223	0.364	1			0.064
Consistence ratio: 0.029							
Consensus: 99.1%							

Criteria	1	2	3	4	5	6	Rating
7. Soil erosion potential							
(ton.ha^{-1}.yr^{-1})							
(1) > 480	1						0.473
(2) 180 – 480	0.397	1					0.265
(3) 60 – 180	0.253	0.408	1				0.144
(4) 5 – 60	0.182	0.243	0.386	1			0.076
(5) < 5	0.136	0.172	0.238	0.377	1		0.042
Consistence ratio: 0.034							
Consensus: 99.0%							
8. Hazard prevention							
(1) Very high	1						0.523
(2) High	0.419	1					0.269
(3) Medium	0.258	0.439	1				0.135
(4) Low	0.167	0.254	0.468	1			0.072
Consistence ratio: 0.011							
Consensus: 99.1%							
9. Vegetation (rehabilitation)							
(1) Bare land	1						0.437
(2) Grassland	0.501	1					0.284
(3) Shrub/bush	0.333	0.440	1				0.166
(4) Mixed plantation	0.176	0.238	0.334	1			0.069
(5) Forest	0.141	0.168	0.229	0.573	1		0.046
Consistence ratio: 0.017							
Consensus: 98.2%							
10. Topography (%)							
(1) Very steep (> 40	1						0.468
(2) Steep (25 – 40)	0.417	1					0.259
(3) Moderate (15 – 25)	0.260	0.449	1				0.146
(4) Gentle (8 – 15)	0.189	0.271	0.425	1			0.079
(5) Level (0 – 8)	0.152	0.192	0.280	0.470	1		0.049
Consistence ratio: 0.022							
Consensus: 98.7%							
11. Land **management**							
(1) Good	1						0.598
(2) Medium	0.408	1					0.283
(3) Poor	0.231	0.364	1				0.119
Consistence ratio: 0.023							
Consensus: 98.5%							
12. **Preservation value**							
(1) Vegetation	1						0.418
(2) Forest fragmentation	0.732	1					0.266
(3) Species status	0.660	1.366	1				0.316
Consistence ratio: 0.020							
Consensus: 97.3%							
13. **Deforestation threat**							
(1) Forest fire	1						0.411
(2) Settlement	0.758	1					0.303
(3) Accessibility	0.679	0.966	1				0.286
Consistence ratio: 0.001							
Consensus: 97.2%							

Criteria	1	2	3	4	5	6	Rating
***14.* Forest rehabilitation**							
(1) Vegetation	1						0.525
(2) Erosion	0.335	1					0.205
(3) Slope	0.329	0.896	1				0.191
(4) Land management	0.197	0.337	0.356	1			0.079
Consistence ratio: 0.014							
Consensus: 99.7%							

Appendix B: Ground checkpoints

No	*X*	*Y*	*Year*	*Zone*	*Field LULC*	*LULC Class*
1	298,785	9,623,876	2011	Intensive Use	Grassland	Grassland
2	302,415	9,621,766	2011	Protection	Forest	Forest
3	296,337	9,617,798	2012	Intensive Use	Mix Plantation	Bare land
4	302,331	9,616,532	2012	Intensive Use	Mix Plantation	Mix Plantation
5	291,948	9,613,578	2012	Intensive Use	Forest	Forest
6	294,227	9,611,467	2012	Intensive Use	Forest	Forest
7	295,155	9,609,526	2012	Intensive Use	Mix Plantation	Mix Plantation
8	292,454	9,604,883	2011	Intensive Use	Forest	Grassland
9	286,883	9,605,305	2012	Intensive Use	Mix Plantation	Grassland
10	288,487	9,602,688	2010	Preservation	Grassland	Grassland
11	290,850	9,599,649	2010	Preservation	Forest	Forest
12	292,117	9,595,007	2010	Protection	Forest	Forest
13	297,688	9,598,130	2010	Protection	Forest	Forest
14	284,435	9,596,611	2010	Preservation	Forest	Forest
15	283,844	9,591,799	2010	Preservation	Forest	Forest
16	277,851	9,588,845	2012	Preservation	Forest	Forest
17	277,851	9,595,176	2010	Preservation	Forest	Forest
18	271,773	9,594,585	2012	Preservation	Mix Plantation	Forest
19	268,143	9,587,747	2010	Protection	Shrub/Bush	Forest
20	281,480	9,602,097	2012	Preservation	Grassland	Grassland
21	274,727	9,610,454	2010	Intensive Use	Shrub/Bush	Shrub/Bush
22	279,539	9,615,013	2012	Intensive Use	Grassland	Grassland
23	287,474	9,618,305	2012	Protection	Forest	Forest
24	281,318	9,598,127	2010	Preservation	Forest	Forest
25	286,085	9,596,802	2010	Preservation	Forest	Forest
26	285,515	9,599,602	2010	Preservation	Shrub/Bush	Shrub/Bush
27	285,499	9,601,647	2010	Preservation	Grassland	Grassland
28	280,369	9,596,367	2010	Preservation	Forest	Mix Plantation
29	275,407	9,612,410	2012	Intensive Use	Bare land	Grassland
30	270,729	9,610,247	2012	Limited Use	Grassland	Grassland
31	270,344	9,610,767	2010	Limited Use	Bare land	Bare land
32	284,174	9,605,654	2012	Intensive Use	Grassland	Grassland
33	294,383	9,607,883	2012	Intensive Use	Forest	Forest
34	297,636	9,611,354	2012	Intensive Use	Forest	Forest
35	287,376	9,619,518	2012	Protection	Forest	Forest
36	287,309	9,616,517	2012	Intensive Use	Mix Plantation	Grassland
37	298,558	9,625,922	2011	Intensive Use	Forest	Forest
38	297,569	9,626,173	2011	Intensive Use	Shrub/Bush	Mix Plantation
39	285,331	9,622,837	2012	Intensive Use	Grassland	Grassland
40	284,286	9,612,120	2012	Intensive Use	Forest	Forest
41	284,060	9,612,585	2012	Intensive Use	Forest	Forest
42	283,496	9,613,897	2012	Intensive Use	Grassland	Grassland
43	295,815	9,611,494	2012	Intensive Use	Forest	Forest
44	296,486	9,612,400	2012	Intensive Use	Forest	Forest
45	297,606	9,614,130	2012	Intensive Use	Grassland	Grassland
46	313,490	9,613,150	2011	Protection	Forest	Forest
47	314,353	9,614,150	2011	Protection	Forest	Forest

No	***X***	***Y***	***Year***	***Zone***	***Field LULC***	***LULC Class***
48	278,653	9,609,628	2012	Intensive Use	Shrub/Bush	Mix Plantation
49	282,657	9,608,089	2012	Intensive Use	Mix Plantation	Mix Plantation
50	282,306	9,607,192	2012	Intensive Use	Grassland	Grassland
51	282,110	9,605,439	2012	Intensive Use	Grassland	Grassland
52	269,379	9,592,677	2012	Protection	Grassland	Grassland
53	271,116	9,593,800	2012	Preservation	Shrub/Bush	Shrub/Bush
54	268,880	9,588,153	2010	Protection	Forest	Forest
55	270,211	9,586,344	2010	Protection	Forest	Forest
56	271,199	9,585,158	2010	Protection	Forest	Forest
57	278,687	9,582,746	2012	Protection	Forest	Forest
58	280,434	9,585,418	2012	Protection	Forest	Forest
59	281,505	9,588,060	2012	Preservation	Forest	Forest
60	281,089	9,586,968	2012	Preservation	Forest	Forest
61	283,990	9,590,108	2010	Preservation	Forest	Forest
62	288,722	9,591,242	2012	Protection	Forest	Forest
63	289,408	9,592,895	2012	Protection	Forest	Forest
64	290,739	9,593,415	2010	Protection	Forest	Forest
65	297,419	9,596,548	2010	Protection	Forest	Forest
66	297,393	9,597,155	2010	Protection	Forest	Forest
67	300,106	9,624,906	2011	Protection	Forest	Forest
68	296,695	9,623,500	2011	Intensive Use	Bare land	Bare land
69	293,320	9,620,205	2011	Intensive Use	Mix Plantation	Shrub/Bush
70	294,791	9,620,817	2011	Intensive Use	Mix Plantation	Forest
71	295,312	9,623,161	2011	Intensive Use	Shrub/Bush	Bare land
72	301,822	9,622,718	2011	Protection	Forest	Forest
73	301,445	9,623,200	2011	Protection	Shrub/Bush	Grassland
74	314,580	9,615,125	2011	Protection	Forest	Forest
75	287,169	9,609,879	2012	Intensive Use	Grassland	Grassland
76	288,623	9,609,432	2012	Intensive Use	Grassland	Grassland
77	290,035	9,606,482	2012	Intensive Use	Shrub/Bush	Grassland
78	292,062	9,605,643	2012	Intensive Use	Forest	Grassland
79	292,943	9,603,755	2012	Preservation	Shrub/Bush	Grassland
80	293,517	9,607,390	2012	Intensive Use	Shrub/Bush	Grassland
81	295,404	9,608,313	2012	Intensive Use	Forest	Forest
82	293,209	9,617,220	2012	Intensive Use	Mix Plantation	Mix Plantation
83	294,355	9,616,940	2012	Intensive Use	Mix Plantation	Forest
84	300,144	9,615,892	2012	Intensive Use	Forest	Shrub/Bush
85	300,102	9,617,877	2012	Intensive Use	Mix Plantation	Forest
86	275,000	9,585,000	2010	Protection	Forest	Forest
87	275,000	9,595,000	2010	Preservation	Forest	Forest
88	285,000	9,595,000	2010	Preservation	Forest	Forest
89	295,000	9,595,000	2010	Protection	Forest	Forest
90	285,000	9,605,000	2012	Intensive Use	Grassland	Grassland
91	295,000	9,605,000	2012	Preservation	Shrub/Bush	Forest
92	285,000	9,615,000	2012	Intensive Use	Shrub/Bush	Shrub/Bush
93	295,000	9,615,000	2012	Intensive Use	Grassland	Shrub/Bush
94	315,000	9,615,000	2011	Protection	Forest	Forest
95	295,000	9,625,000	2011	Protection	Grassland	Grassland
96	305,000	9,625,000	2011	Protection	Forest	Forest

Appendix C: Trees species and their status in sampling plots

Species Name	Red listed categories	Value Use
Artocarpus odoratissimus	Not Evaluated	Food
Bouea macrophylla	Not Evaluated	Food
Caethocarpus grandiflorus	Not Evaluated	Timber
Calophyllum inophyllum	Least Concern	Timber
Canarium ovatum	Vulnerable	Food
Cotylelobium lanceolatum	Vulnerable	Timber
Diospyros macrophylla	Not Evaluated	Timber
Dipterocarpus borneensis	Not Evaluated	Timber
Dipterocarpus caudiferus	Not Evaluated	Timber
Dipterocarpus rigidus	Critically Endangered	Timber
Dryobalanops beccarii	Endangered	Timber
Durio kutejensis	Vulnerable	Food
Dysoxylum pachyrhache	Not Evaluated	Timber
Eurycoma longifolia	Not Evaluated	Medicinal
Eusideroxylon zwageri	Vulnerable	Food
Ficus indicata	Not Evaluated	Culture
Guioa diplopetala	Not Evaluated	Timber
Intsia bijuga	Vulnerable	Medicinal
Melaleuca cajuputi	Not Evaluated	Medicinal
Octomeles sumatrana	Least Concern	Timber
Podium javanicum	Not Evaluated	Timber
Saraca declinata	Not Evaluated	Fuel
Schima wallichii	Not Evaluated	Timber
Shorea bracteolata	Endangered	Timber
Shorea leprosula	Endangered	Timber
Shorea ovalis	Endangered	Timber
Shorea scollaris	Not Evaluated	Timber
Syzygium pycnanthum	Not Evaluated	Food
Toona sureni	Not Evaluated	Timber
Vitex Pubescen	Not Evaluated	Timber

Appendix D

Cluster ID	2759595		X	275000
Plot ID	1		Y	9595000

No	Latin Name	Genus	Red List	Value Use
1	*Artocarpus odoratissimus*	Artocarpus	0	1
2	*Artocarpus odoratissimus*	Artocarpus	0	1
3	*Artocarpus odoratissimus*	Artocarpus	0	1
4	*Artocarpus odoratissimus*	Artocarpus	0	1
5	*Calophyllum inophyllum*	Calophyllum	1	2
6	*Calophyllum inophyllum*	Calophyllum	1	2
7	*Diospyros macrophylla*	Diospyros	0	2
8	*Diospyros macrophylla*	Diospyros	0	2
9	*Dipterocarpus borneensis*	Dipterocarpus	0	2
10	*Dipterocarpus borneensis*	Dipterocarpus	0	2
11	*Dipterocarpus borneensis*	Dipterocarpus	0	2
12	*Dipterocarpus borneensis*	Dipterocarpus	0	2
13	*Dipterocarpus borneensis*	Dipterocarpus	0	2
14	*Dipterocarpus borneensis*	Dipterocarpus	0	2
15	*Dipterocarpus borneensis*	Dipterocarpus	0	2
16	*Dipterocarpus caudiferus*	Dipterocarpus	0	2
17	*Dipterocarpus rigidus*	Dipterocarpus	5	2
18	*Dryobalanops beccarii*	Dryobalanops	4	2
19	*Dryobalanops beccarii*	Dryobalanops	4	2
20	*Dryobalanops beccarii*	Dryobalanops	4	2
21	*Dryobalanops beccarii*	Dryobalanops	4	2
22	*Dysoxylum pachyrhache*	Dysoxylum	0	2
23	*Dysoxylum pachyrhache*	Dysoxylum	0	2
24	*Melaleuca cajuputi*	Melaleuca	0	2
25	*Podium javanicum*	Podium	0	2
26	*Podium javanicum*	Podium	0	2
27	*Podium javanicum*	Podium	0	2
28	*Saraca declinata*	Saraca	0	1
29	*Shorea bracteolata*	Shorea	4	2
30	*Shorea leprosula*	Shorea	4	2
31	*Shorea leprosula*	Shorea	4	2
32	*Shorea leprosula*	Shorea	4	2
33	*Shorea leprosula*	Shorea	4	2
34	*Shorea ovalis*	Shorea	4	2
35	*Shorea ovalis*	Shorea	4	2
36	*Shorea ovalis*	Shorea	4	2
37	*Shorea ovalis*	Shorea	4	2
38	*Shorea ovalis*	Shorea	4	2
39	*Shorea ovalis*	Shorea	4	2
40	*Shorea ovalis*	Shorea	4	2
41	*Shorea ovalis*	Shorea	4	2
42	*Shorea scollaris*	Shorea	0	2
43	*Shorea scollaris*	Shorea	0	2
44	*Shorea scollaris*	Shorea	0	2

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45	*Shorea scollaris*	Shorea	0	2
46	*Shorea scollaris*	Shorea	0	2
47	*Syzygium pycnanthum*	Syzygium	0	1
48	*Toona sureni*	Toona	0	2
49	*Toona sureni*	Toona	0	2
50	*Vitex Pubescen*	Vitex	0	2
51	*Vitex Pubescen*	Vitex	0	2
52	*Vitex Pubescen*	Vitex	0	2
53	*Vitex Pubescen*	Vitex	0	2
54	*Vitex Pubescen*	Vitex	0	2
55	*Vitex Pubescen*	Vitex	0	2
Total			75	104

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Cluster ID	2759595		X	275000
Plot ID	2		Y	9595000

No	Latin Name	Genus	Red List	Value Use
1	*Artocarpus odoratissimus*	Artocarpus	0	1
2	*Artocarpus odoratissimus*	Artocarpus	0	1
3	*Artocarpus odoratissimus*	Artocarpus	0	1
4	*Calophyllum inophyllum*	Calophyllum	1	2
5	*Diospyros macrophylla*	Diospyros	0	2
6	*Diospyros macrophylla*	Diospyros	0	2
7	*Dipterocarpus borneensis*	Dipterocarpus	0	2
8	*Dipterocarpus borneensis*	Dipterocarpus	0	2
9	*Dipterocarpus borneensis*	Dipterocarpus	0	2
10	*Dipterocarpus borneensis*	Dipterocarpus	0	2
11	*Dipterocarpus borneensis*	Dipterocarpus	0	2
12	*Dipterocarpus borneensis*	Dipterocarpus	0	2
13	*Dipterocarpus borneensis*	Dipterocarpus	0	2
14	*Dryobalanops becarii*	Dipterocarpus	5	2
15	*Dryobalanops becarii*	Dipterocarpus	5	2
16	*Dryobalanops becarii*	Dipterocarpus	5	2
17	*Dryobalanops becarii*	Dipterocarpus	5	2
18	*Dryobalanops becarii*	Dipterocarpus	5	2
19	*Dryobalanops becarii*	Dipterocarpus	5	2
20	*Dryobalanops becarii*	Dipterocarpus	5	2
21	*Dysoxylum pachyrhache*	Dysoxylum	0	2
22	*Podium javanicum*	Podium	0	2
23	*Podium javanicum*	Podium	0	2
24	*Podium javanicum*	Podium	0	2
25	*Podium javanicum*	Podium	0	2
26	*Shorea ovalis*	Shorea	4	2
27	*Shorea ovalis*	Shorea	4	2
28	*Shorea leprosula*	Shorea	4	2
29	*Shorea leprosula*	Shorea	4	2
30	*Shorea leprosula*	Shorea	4	2
31	*Shorea leprosula*	Shorea	4	2
32	*Shorea ovalis*	Shorea	4	2
33	*Shorea ovalis*	Shorea	4	2
34	*Shorea leprosula*	Shorea	4	2
35	*Shorea leprosula*	Shorea	4	2
36	*Shorea leprosula*	Shorea	4	2
37	*Shorea bracteolata*	Shorea	4	2
38	*Shorea scollaris*	Shorea	0	2
39	*Shorea scollaris*	Shorea	0	2
40	*Toona sureni*	Toona	0	2

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41	*Toona sureni*	Toona	0	2
42	*Toona sureni*	Toona	0	2
43	*Toona sureni*	Toona	0	2
44	*Vitex Pubescen*	Vitex	0	2
45	*Vitex Pubescen*	Vitex	0	2
Total			84	87

Appendix D

Cluster ID	2759595		X	275000
Plot ID	3		Y	9595000

No	Latin Name	Genus	Red List	Value Use
1	*Vitex Pubescen*	Vitex	0	2
2	*Vitex Pubescen*	Vitex	0	2
3	*Calophyllum inophyllum*	Calophyllum	1	2
4	*Podium javanicum*	Podium	0	2
5	*Podium javanicum*	Podium	0	2
6	*Podium javanicum*	Podium	0	2
7	*Podium javanicum*	Podium	0	2
8	*Toona sureni*	Toona	0	2
9	*Dipterocarpus borneensis*	Dipterocarpus	0	2
10	*Dipterocarpus borneensis*	Dipterocarpus	0	2
11	*Dipterocarpus borneensis*	Dipterocarpus	0	2
12	*Dysoxylum pachyrhache*	Dysoxylum	0	2
13	*Dysoxylum pachyrhache*	Dysoxylum	0	2
14	*Dysoxylum pachyrhache*	Dysoxylum	0	2
15	*Dysoxylum pachyrhache*	Dysoxylum	0	2
16	*Diospyros macrophylla*	Diospyros	0	2
17	*Diospyros macrophylla*	Diospyros	0	2
18	*Shorea ovalis*	Shorea	4	2
19	*Shorea ovalis*	Shorea	4	2
20	*Shorea leprosula*	Shorea	4	2
21	*Shorea leprosula*	Shorea	4	2
22	*Shorea ovalis*	Shorea	4	2
23	*Shorea ovalis*	Shorea	4	2
24	*Shorea leprosula*	Shorea	4	2
25	*Shorea leprosula*	Shorea	4	2
26	*Shorea ovalis*	Shorea	4	2
27	*Shorea ovalis*	Shorea	4	2
28	*Shorea ovalis*	Shorea	4	2
29	*Shorea leprosula*	Shorea	4	2
30	*Shorea ovalis*	Shorea	4	2
31	*Shorea leprosula*	Shorea	4	2
32	*Artocarpus odoratissimus*	Artocarpus	0	1
33	*Artocarpus odoratissimus*	Artocarpus	0	1
34	*Artocarpus odoratissimus*	Artocarpus	0	1
35				
36				
37				
38				
39				
40				
Total			57	65

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Cluster ID	2759595	X	275000
Plot ID	4	Y	9595000

No	Latin Name	Genus	Red List	Value Use
1	*Artocarpus odoratissimus*	Artocarpus	0	1
2	*Artocarpus odoratissimus*	Artocarpus	0	1
3	*Calophyllum inophyllum*	Calophyllum	1	2
4	*Calophyllum inophyllum*	Calophyllum	1	2
5	*Syzygium pycnanthum*	Syzygium	0	1
6	*Syzygium pycnanthum*	Syzygium	0	1
7	*Diospyros macrophylla*	Diospyros	0	2
8	*Diospyros macrophylla*	Diospyros	0	2
9	*Dipterocarpus rigidus*	Dipterocarpus	5	2
10	*Dipterocarpus borneensis*	Dipterocarpus	0	2
11	*Dipterocarpus borneensis*	Dipterocarpus	0	2
12	*Dipterocarpus borneensis*	Dipterocarpus	0	2
13	*Dipterocarpus borneensis*	Dipterocarpus	0	2
14	*Dipterocarpus borneensis*	Dipterocarpus	0	2
15	*Dipterocarpus rigidus*	Dipterocarpus	5	2
16	*Dryobalanops becarii*	Dipterocarpus	5	2
17	*Dryobalanops becarii*	Dipterocarpus	5	2
18	*Dryobalanops becarii*	Dipterocarpus	5	2
19	*Dryobalanops becarii*	Dipterocarpus	5	2
20	*Dysoxylum pachyrhache*	Dysoxylum	0	2
21	*Melaleuca cajuputi*	Melaleuca	0	2
22	*Melaleuca cajuputi*	Melaleuca	0	2
23	*Podium javanicum*	Podium	0	2
24	*Podium javanicum*	Podium	0	2
25	*Saraca declinata*	Saraca	0	1
26	*Shorea ovalis*	Shorea	4	2
27	*Shorea leprosula*	Shorea	4	2
28	*Shorea leprosula*	Shorea	4	2
29	*Shorea ovalis*	Shorea	4	2
30	*Shorea ovalis*	Shorea	4	2
31	*Shorea leprosula*	Shorea	4	2
32	*Shorea ovalis*	Shorea	4	2
33	*Shorea leprosula*	Shorea	4	2
34	*Shorea bracteolata*	Shorea	4	2
35	*Shorea scollaris*	Shorea	0	2
36	*Shorea scollaris*	Shorea	0	2
37	*Shorea scollaris*	Shorea	0	2
38	*Toona sureni*	Toona	0	2
39	*Toona sureni*	Toona	0	2
40	*Toona sureni*	Toona	0	2

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41	*Vitex Pubescen*	Vitex	0	2
42	*Vitex Pubescen*	Vitex	0	2
43	*Vitex Pubescen*	Vitex	0	2
44	*Vitex Pubescen*	Vitex	0	2
45	*Vitex Pubescen*	Vitex	0	2
Total			68	85

Appendix D

Cluster ID	2759585		X	275000
Plot ID	5		Y	9585000

No	Latin Name	Genus	Red List	Value Use
1	*Vitex Pubescen*	Vitex	0	2
2	*Shorea ovalis*	Shorea	4	2
3	*Eurycoma longifolia*	Eurycoma	0	2
4	*Schima wallichii*	Schima	0	2
5	*Intsia bijuga*	Intsia	3	2
6	*Shorea ovalis*	Shorea	4	2
7	*Eurycoma longifolia*	Eurycoma	0	2
8	*Saraca declinata*	Saraca	0	1
9	*Syzygium pycnanthum*	Syzygium	0	1
10	*Shorea ovalis*	Shorea	4	2
11	*Eurycoma longifolia*	Eurycoma	0	2
12	*Eurycoma longifolia*	Eurycoma	0	2
13	*Dipterocarpus borneensis*	Dipterocarpus	0	2
14	*Shorea ovalis*	Shorea	4	2
15	*Shorea leprosula*	Shorea	4	2
16	*Bouea macrophylla*	Bouea	0	1
17	*Calophyllum inophyllum*	Calophyllum	1	2
18	*Dipterocarpus borneensis*	Dipterocarpus	0	2
19	*Dipterocarpus borneensis*	Dipterocarpus	0	2
20	*Shorea scollaris*	Shorea	0	2
21	*Shorea leprosula*	Shorea	4	2
22	*Dipterocarpus borneensis*	Dipterocarpus	0	2
23	*Octomeles sumatrana*	Octomeles	1	2
24	*Dipterocarpus borneensis*	Dipterocarpus	0	2
25	*Shorea leprosula*	Shorea	4	2
26	*Intsia bijuga*	Intsia	3	2
27	*Calophyllum inophyllum*	Calophyllum	1	2
28	*Caethocarpus grandiflorus*	Caethocarpus	0	2
29	*Dipterocarpus borneensis*	Dipterocarpus	0	2
30	*Schima wallichii*	Schima	0	2
31	*Calophyllum inophyllum*	Calophyllum	1	2
32	*Eurycoma longifolia*	Eurycoma	0	2
33	*Eurycoma longifolia*	Eurycoma	0	2
34	*Artocarpus odoratissimus*	Artocarpus	0	1
35	*Dipterocarpus borneensis*	Dipterocarpus	0	2
36	*Schima wallichii*	Schima	0	2
37				
38				
39				
40				
Total			38	68

Appendix D

Cluster ID	2759585		X	275000
Plot ID	6		Y	9585000

No	Latin Name	Genus	Red List	Value Use
1	*Shorea leprosula*	Shorea	4	2
2	*Shorea leprosula*	Shorea	4	2
3	*Dipterocarpus borneensis*	Dipterocarpus	0	2
4	*Dipterocarpus borneensis*	Dipterocarpus	0	2
5	*Dipterocarpus borneensis*	Dipterocarpus	0	2
6	*Eurycoma longifolia*	Eurycoma	0	2
7	*Caethocarpus grandiflorus*	Caethocarpus	0	2
8	*Shorea ovalis*	Shorea	4	2
9	*Eurycoma longifolia*	Eurycoma	0	2
10	*Saraca declinata*	Saraca	0	1
11	*Shorea leprosula*	Shorea	4	2
12	*Dipterocarpus borneensis*	Dipterocarpus	0	2
13	*Eurycoma longifolia*	Eurycoma	0	2
14	*Intsia bijuga*	Intsia	3	2
15	*Artocarpus odoratissimus*	Artocarpus	0	1
16	*Shorea scollaris*	Shorea	0	2
17	*Shorea scollaris*	Shorea	0	2
18	*Melaleuca cajuputi*	Melaleuca	0	2
19	*Shorea leprosula*	Shorea	4	2
20	*Artocarpus odoratissimus*	Artocarpus	0	1
21	*Shorea leprosula*	Shorea	4	2
22	*Eurycoma longifolia*	Eurycoma	0	2
23	*Dipterocarpus borneensis*	Dipterocarpus	0	2
24	*Dipterocarpus borneensis*	Dipterocarpus	0	2
25	*Dipterocarpus borneensis*	Dipterocarpus	0	2
26	*Shorea scollaris*	Shorea	0	2
27	*Intsia bijuga*	Intsia	3	2
28	*Dipterocarpus borneensis*	Dipterocarpus	0	2
29	*Dipterocarpus caudiferus*	Dipterocarpus	0	2
30	*Schima wallichii*	Schima	0	2
31	*Dipterocarpus borneensis*	Dipterocarpus	0	2
32	*Dipterocarpus borneensis*	Dipterocarpus	0	2
33	*Eurycoma longifolia*	Eurycoma	0	2
34	*Dysoxylum pachyrhache*	Dysoxylum	0	2
35	*Dipterocarpus borneensis*	Dipterocarpus	0	2
36	*Dipterocarpus borneensis*	Dipterocarpus	0	2
37	*Calophyllum inophyllum*	Calophyllum	1	2
38	*Dipterocarpus borneensis*	Dipterocarpus	0	2
39	*Shorea bracteolata*	Shorea	4	2
40				
Total			35	75

Appendix D

Cluster ID	2759585	X	275000
Plot ID	7	Y	9585000

No	Latin Name	Genus	Red List	Value Use
1	*Dysoxylum pachyrhache*	Dysoxylum	0	2
2	*Shorea leprosula*	Shorea	4	2
3	*Eurycoma longifolia*	Eurycoma	0	2
4	*Dipterocarpus borneensis*	Dipterocarpus	0	2
5	*Bouea macrophylla*	Bouea	0	1
6	*Shorea leprosula*	Shorea	4	2
7	*Dipterocarpus borneensis*	Dipterocarpus	0	2
8	*Octomeles sumatrana*	Octomeles	1	2
9	*Shorea leprosula*	Shorea	4	2
10	*Eurycoma longifolia*	Eurycoma	0	2
11	*Shorea ovalis*	Shorea	4	2
12	*Calophyllum inophyllum*	Calophyllum	1	2
13	*Dipterocarpus borneensis*	Dipterocarpus	0	2
14	*Dipterocarpus borneensis*	Dipterocarpus	0	2
15	*Shorea leprosula*	Shorea	4	2
16	*Caethocarpus grandiflorus*	Caethocarpus	0	2
17	*Bouea macrophylla*	Bouea	0	1
18	*Guioa diplopetala*	Guioa	0	2
19	*Eurycoma longifolia*	Eurycoma	0	2
20	*Shorea ovalis*	Shorea	4	2
21	*Eurycoma longifolia*	Eurycoma	0	2
22	*Shorea leprosula*	Shorea	4	2
23	*Dipterocarpus caudiferus*	Dipterocarpus	0	2
24	*Dipterocarpus rigidus*	Dipterocarpus	5	2
25	*Dipterocarpus borneensis*	Dipterocarpus	0	2
26	*Eurycoma longifolia*	Eurycoma	0	2
27	*Shorea leprosula*	Shorea	4	2
28	*Dipterocarpus borneensis*	Dipterocarpus	0	2
29	*Shorea ovalis*	Shorea	4	2
30	*Dipterocarpus borneensis*	Dipterocarpus	0	2
31	*Caethocarpus grandiflorus*	Caethocarpus	0	2
32	*Eurycoma longifolia*	Eurycoma	0	2
33	*Shorea ovalis*	Shorea	4	2
34	*Dipterocarpus borneensis*	Dipterocarpus	0	2
35	*Shorea ovalis*	Shorea	4	2
36				
37				
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39				
40				
Total			51	68

Appendix D

Cluster ID	2759585		X	275000
Plot ID	8		Y	9585000

No	Latin Name	Genus	Red List	Value Use
1	*Eurycoma longifolia*	Eurycoma	0	2
2	*Melaleuca cajuputi*	Melaleuca	0	2
3	*Shorea ovalis*	Shorea	4	2
4	*Artocarpus odoratissimus*	Artocarpus	0	1
5	*Dipterocarpus borneensis*	Dipterocarpus	0	2
6	*Dipterocarpus borneensis*	Dipterocarpus	0	2
7	*Dipterocarpus borneensis*	Dipterocarpus	0	2
8	*Intsia bijuga*	Intsia	3	2
9	*Dipterocarpus borneensis*	Dipterocarpus	0	2
10	*Calophyllum inophyllum*	Calophyllum	1	2
11	*Shorea ovalis*	Shorea	4	2
12	*Dipterocarpus borneensis*	Dipterocarpus	0	2
13	*Caethocarpus grandiflorus*	Caethocarpus	0	2
14	*Intsia bijuga*	Intsia	3	2
15	*Cotylelobium lanceolatum*	Cotylelobium	3	2
16	*Diospyros macrophylla*	Diospyros	0	2
17	*Artocarpus odoratissimus*	Artocarpus	0	1
18	*Dipterocarpus borneensis*	Dipterocarpus	0	2
19	*Eurycoma longifolia*	Eurycoma	0	2
20	*Dipterocarpus borneensis*	Dipterocarpus	0	2
21	*Dipterocarpus borneensis*	Dipterocarpus	0	2
22	*Caethocarpus grandiflorus*	Caethocarpus	0	2
23	*Dipterocarpus borneensis*	Dipterocarpus	0	2
24	*Shorea leprosula*	Shorea	4	2
25	*Shorea leprosula*	Shorea	4	2
26	*Eurycoma longifolia*	Eurycoma	0	2
27	*Shorea leprosula*	Shorea	4	2
28	*Shorea leprosula*	Shorea	4	2
29	*Dipterocarpus borneensis*	Dipterocarpus	0	2
30	*Shorea leprosula*	Shorea	4	2
31	*Dipterocarpus borneensis*	Dipterocarpus	0	2
32	*Shorea ovalis*	Shorea	4	2
33	*Eurycoma longifolia*	Eurycoma	0	2
34	*Shorea ovalis*	Shorea	4	2
35	*Dipterocarpus borneensis*	Dipterocarpus	0	2
36	*Dipterocarpus borneensis*	Dipterocarpus	0	2
37	*Dipterocarpus borneensis*	Dipterocarpus	0	2
38	*Shorea ovalis*	Shorea	4	2
39	*Shorea leprosula*	Shorea	4	2
40				
Total			54	76

Appendix D

Cluster ID	2859595		X	285000
Plot ID	9		Y	9595000

No	Latin Name	Genus	Red List	Value Use
1	*Bouea macrophylla*	Bouea	0	1
2	*Caethocarpus grandiflorus*	Caethocarpus	0	2
3	*Caethocarpus grandiflorus*	Caethocarpus	0	2
4	*Caethocarpus grandiflorus*	Caethocarpus	0	2
5	*Caethocarpus grandiflorus*	Caethocarpus	0	2
6	*Calophyllum inophyllum*	Calophyllum	1	2
7	*Calophyllum inophyllum*	Calophyllum	1	2
8	*Calophyllum inophyllum*	Calophyllum	1	2
9	*Cotylelobium lanceolatum*	Cotylelobium	3	2
10	*Cotylelobium lanceolatum*	Cotylelobium	3	2
11	*Dipterocarpus borneensis*	Dipterocarpus	0	2
12	*Dipterocarpus borneensis*	Dipterocarpus	0	2
13	*Dipterocarpus borneensis*	Dipterocarpus	0	2
14	*Dipterocarpus borneensis*	Dipterocarpus	0	2
15	*Dipterocarpus borneensis*	Dipterocarpus	0	2
16	*Durio kutejensis*	Durio	3	1
17	*Eusideroxylon zwageri*	Eusideroxylon	3	1
18	*Eusideroxylon zwageri*	Eusideroxylon	3	1
19	*Eusideroxylon zwageri*	Eusideroxylon	3	1
20	*Ficus indicata*	Ficus	0	2
21	*Guioa diplopetala*	Guioa	0	2
22	*Intsia bijuga*	Intsia	3	2
23	*Intsia bijuga*	Intsia	3	2
24	*Octomeles sumatrana*	Octomeles	1	2
25	*Schima wallichii*	Schima	0	2
26	*Schima wallichii*	Schima	0	2
27	*Schima wallichii*	Schima	0	2
28	*Shorea bracteolata*	Shorea	4	2
29	*Shorea bracteolata*	Shorea	4	2
30	*Shorea leprosula*	Shorea	4	2
31	*Shorea leprosula*	Shorea	4	2
32	*Shorea leprosula*	Shorea	4	2
33	*Shorea leprosula*	Shorea	4	2
34	*Shorea ovalis*	Shorea	4	2
35	*Shorea ovalis*	Shorea	4	2
36	*Shorea ovalis*	Shorea	4	2
37	*Shorea ovalis*	Shorea	4	2
38	*Shorea ovalis*	Shorea	4	2
39				
40				
Total			72	71

Appendix D

Cluster ID	2859595		X	285000
Plot ID	10		Y	9595000

No	Latin Name	Genus	Red List	Value Use
1	*Bouea macrophylla*	Bouea	0	1
2	*Caethocarpus grandiflorus*	Caethocarpus	0	2
3	*Caethocarpus grandiflorus*	Caethocarpus	0	2
4	*Caethocarpus grandiflorus*	Caethocarpus	0	2
5	*Calophyllum inophyllum*	Calophyllum	1	2
6	*Calophyllum inophyllum*	Calophyllum	1	2
7	*Calophyllum inophyllum*	Calophyllum	1	2
8	*Calophyllum inophyllum*	Calophyllum	1	2
9	*Cotylelobium lanceolatum*	Cotylelobium	3	2
10	*Cotylelobium lanceolatum*	Cotylelobium	3	2
11	*Dipterocarpus borneensis*	Dipterocarpus	0	2
12	*Dipterocarpus borneensis*	Dipterocarpus	0	2
13	*Dipterocarpus borneensis*	Dipterocarpus	0	2
14	*Durio kutejensis*	Durio	3	1
15	*Eusideroxylon zwageri*	Eusideroxylon	3	1
16	*Eusideroxylon zwageri*	Eusideroxylon	3	1
17	*Eusideroxylon zwageri*	Eusideroxylon	3	1
18	*Eusideroxylon zwageri*	Eusideroxylon	3	1
19	*Guioa diplopetala*	Guioa	0	2
20	*Schima wallichii*	Schima	0	2
21	*Intsia bijuga*	Intsia	3	2
22	*Intsia bijuga*	Intsia	3	2
23	*Intsia bijuga*	Intsia	3	2
24	*Intsia bijuga*	Intsia	3	2
25	*Shorea ovalis*	Shorea	4	2
26	*Shorea leprosula*	Shorea	4	2
27	*Shorea leprosula*	Shorea	4	2
28	*Shorea leprosula*	Shorea	4	2
29	*Shorea ovalis*	Shorea	4	2
30	*Shorea ovalis*	Shorea	4	2
31				
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39				
40				
Total			61	54

Appendix D

Cluster ID	2859595		X	285000
Plot ID	11		Y	9595000

No	Latin Name	Genus	Red List	Value Use
1	*Bouea macrophylla*	Bouea	0	1
2	*Caethocarpus grandiflorus*	Caethocarpus	0	2
3	*Caethocarpus grandiflorus*	Caethocarpus	0	2
4	*Caethocarpus grandiflorus*	Caethocarpus	0	2
5	*Caethocarpus grandiflorus*	Caethocarpus	0	2
6	*Calophyllum inophyllum*	Calophyllum	1	2
7	*Calophyllum inophyllum*	Calophyllum	1	2
8	*Calophyllum inophyllum*	Calophyllum	1	2
9	*Calophyllum inophyllum*	Calophyllum	1	2
10	*Calophyllum inophyllum*	Calophyllum	1	2
11	*Calophyllum inophyllum*	Calophyllum	1	2
12	*Calophyllum inophyllum*	Calophyllum	1	2
13	*Dipterocarpus borneensis*	Dipterocarpus	0	2
14	*Dipterocarpus borneensis*	Dipterocarpus	0	2
15	*Dipterocarpus borneensis*	Dipterocarpus	0	2
16	*Eusideroxylon zwageri*	Eusideroxylon	3	1
17	*Eusideroxylon zwageri*	Eusideroxylon	3	1
18	*Eusideroxylon zwageri*	Eusideroxylon	3	1
19	*Eusideroxylon zwageri*	Eusideroxylon	3	1
20	*Eusideroxylon zwageri*	Eusideroxylon	3	1
21	*Octomeles sumatrana*	Octomeles	1	2
22	*Schima wallichii*	Schima	0	2
23	*Schima wallichii*	Schima	0	2
24	*Shorea bracteolata*	Shorea	4	2
25	*Shorea ovalis*	Shorea	4	2
26	*Shorea ovalis*	Shorea	4	2
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40				
Total			35	46

Appendix D

Cluster ID	2859595	X	285000
Plot ID	12	Y	9595000

No	Latin Name	Genus	Red List	Value Use
1	*Bouea macrophylla*	Bouea	0	1
2	*Bouea macrophylla*	Bouea	0	1
3	*Bouea macrophylla*	Bouea	0	1
4	*Caethocarpus grandiflorus*	Caethocarpus	0	2
5	*Caethocarpus grandiflorus*	Caethocarpus	0	2
6	*Calophyllum inophyllum*	Calophyllum	1	2
7	*Calophyllum inophyllum*	Calophyllum	1	2
8	*Calophyllum inophyllum*	Calophyllum	1	2
9	*Cotylelobium lanceolatum*	Cotylelobium	3	2
10	*Dipterocarpus borneensis*	Dipterocarpus	0	2
11	*Dipterocarpus borneensis*	Dipterocarpus	0	2
12	*Dipterocarpus borneensis*	Dipterocarpus	0	2
13	*Dipterocarpus borneensis*	Dipterocarpus	0	2
14	*Durio kutejensis*	Durio	3	1
15	*Eusideroxylon zwageri*	Eusideroxylon	3	1
16	*Schima wallichii*	Schima	0	2
17	*Schima wallichii*	Schima	0	2
18	*Schima wallichii*	Schima	0	2
19	*Schima wallichii*	Schima	0	2
20	*Shorea bracteolata*	Shorea	4	2
21	*Shorea bracteolata*	Shorea	4	2
22	*Shorea leprosula*	Shorea	4	2
23	*Shorea leprosula*	Shorea	4	2
24	*Shorea leprosula*	Shorea	4	2
25	*Shorea ovalis*	Shorea	4	2
26	*Shorea ovalis*	Shorea	4	2
27	*Shorea ovalis*	Shorea	4	2
28	*Shorea ovalis*	Shorea	4	2
29	*Shorea ovalis*	Shorea	4	2
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40				
Total			52	53

Appendix D

Cluster ID	2859605		X	285000
Plot ID	13		Y	9605000

No	Latin Name	Genus	Red List	Value Use
1	*Bouea macrophylla*	Bouea	0	1
2	*Bouea macrophylla*	Bouea	0	1
3	*Bouea macrophylla*	Bouea	0	1
4	*Caethocarpus grandiflorus*	Caethocarpus	0	2
5	*Caethocarpus grandiflorus*	Caethocarpus	0	2
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Total			0	7

Appendix D

Cluster ID	2859605		X	285000
Plot ID	14		Y	9605000
No	Latin Name	Genus	Red List	Value Use
1	*Bouea macrophylla*	Bouea	0	1
2	*Bouea macrophylla*	Bouea	0	1
3	*Bouea macrophylla*	Bouea	0	1
4	*Caethocarpus grandiflorus*	Caethocarpus	0	2
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10				
11				
12				
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Total			0	5

Appendix D

Cluster ID	2859605	X	285000
Plot ID	15	Y	9605000

No	Latin Name	Genus	Red List	Value Use
1				
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4	No Data			
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39				
40				
Total			0	0

Appendix D

Cluster ID	2859605	X	285000
Plot ID	16	Y	9605000

No	Latin Name	Genus	Red List	Value Use
1	*Dipterocarpus borneensis*	Dipterocarpus	0	2
2	*Shorea ovalis*	Shorea	4	2
3	*Shorea ovalis*	Shorea	4	2
4	*Shorea ovalis*	Shorea	4	2
5	*Artocarpus odoratissimus*	Artocarpus	0	1
6	*Dysoxylum pachyrhache*	Dysoxylum	0	2
7	*Octomeles sumatrana*	Octomeles	1	2
8	*Caethocarpus grandiflorus*	Caethocarpus	0	2
9	*Dipterocarpus borneensis*	Dipterocarpus	0	2
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Total			13	17

Appendix D

Cluster ID	2959595		X	295000
Plot ID	17		Y	9595000

No	Latin Name	Genus	Red List	Value Use
1	*Caethocarpus grandiflorus*	Caethocarpus	0	2
2	*Intsia bijuga*	Intsia	3	2
3	*Shorea bracteolata*	Shorea	4	2
4	*Shorea bracteolata*	Shorea	4	2
5	*Caethocarpus grandiflorus*	Caethocarpus	0	2
6	*Shorea leprosula*	Shorea	4	2
7	*Guioa diplopetala*	Guioa	0	2
8	*Podium javanicum*	Podium	0	2
9	*Shorea bracteolata*	Shorea	4	2
10	*Dipterocarpus caudiferus*	Dipterocarpus	0	2
11	*Caethocarpus grandiflorus*	Caethocarpus	0	2
12	*Schima wallichii*	Schima	0	2
13	*Dipterocarpus borneensis*	Dipterocarpus	0	2
14	*Shorea ovalis*	Shorea	4	2
15	*Shorea leprosula*	Shorea	4	2
16	*Saraca declinata*	Saraca	0	1
17	*Octomeles sumatrana*	Octomeles	1	2
18	*Octomeles sumatrana*	Octomeles	1	2
19	*Dipterocarpus borneensis*	Dipterocarpus	0	2
20	*Dipterocarpus borneensis*	Dipterocarpus	0	2
21	*Calophyllum inophyllum*	Calophyllum	1	2
22	*Shorea ovalis*	Shorea	4	2
23	*Shorea ovalis*	Shorea	4	2
24	*Calophyllum inophyllum*	Calophyllum	1	2
25	*Cotylelobium lanceolatum*	Cotylelobium	3	2
26	*Shorea leprosula*	Shorea	4	2
27	*Shorea leprosula*	Shorea	4	2
28	*Eurycoma longifolia*	Eurycoma	0	2
29	*Schima wallichii*	Schima	0	2
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Total			50	57

Appendix D

Cluster ID	2959595		X	295000
Plot ID	18		Y	9595000

No	Latin Name	Genus	Red List	Value Use
1	*Caethocarpus grandiflorus*	Caethocarpus	0	2
2	*Melaleuca cajuputi*	Melaleuca	0	2
3	*Shorea leprosula*	Shorea	4	2
4	*Shorea scollaris*	Shorea	0	2
5	*Dipterocarpus borneensis*	Dipterocarpus	0	2
6	*Intsia bijuga*	Intsia	3	2
7	*Shorea ovalis*	Shorea	4	2
8	*Shorea scollaris*	Shorea	0	2
9	*Shorea ovalis*	Shorea	4	2
10	*Shorea ovalis*	Shorea	4	2
11	*Dipterocarpus borneensis*	Dipterocarpus	0	2
12	*Shorea bracteolata*	Shorea	4	2
13	*Saraca declinata*	Saraca	0	1
14	*Calophyllum inophyllum*	Calophyllum	1	2
15	*Dipterocarpus borneensis*	Dipterocarpus	0	2
16	*Shorea bracteolata*	Shorea	4	2
17	*Saraca declinata*	Saraca	0	1
18	*Dipterocarpus rigidus*	Dipterocarpus	5	2
19	*Caethocarpus grandiflorus*	Caethocarpus	0	2
20	*Shorea ovalis*	Shorea	4	2
21	*Durio kutejensis*	Durio	3	1
22	*Shorea ovalis*	Shorea	4	2
23	*Shorea leprosula*	Shorea	4	2
24	*Bouea macrophylla*	Bouea	0	1
25	*Dipterocarpus borneensis*	Dipterocarpus	0	2
26	*Shorea ovalis*	Shorea	4	2
27	*Eurycoma longifolia*	Eurycoma	0	2
28	*Eurycoma longifolia*	Eurycoma	0	2
29	*Shorea ovalis*	Shorea	4	2
30	*Dipterocarpus borneensis*	Dipterocarpus	0	2
31	*Shorea ovalis*	Shorea	4	2
32	*Shorea scollaris*	Shorea	0	2
33	*Dipterocarpus borneensis*	Dipterocarpus	0	2
34	*Shorea ovalis*	Shorea	4	2
35	*Diospyros macrophylla*	Diospyros	0	2
36	*Dipterocarpus borneensis*	Dipterocarpus	0	2
37	*Shorea ovalis*	Shorea	4	2
38				
39				
40				
Total			68	70

Appendix D

Cluster ID	2959595		X	295000
Plot ID	19		Y	9595000
No	Latin Name	Genus	Red List	Value Use
1	*Shorea leprosula*	Shorea	4	2
2	*Eurycoma longifolia*	Eurycoma	0	2
3	*Dipterocarpus borneensis*	Dipterocarpus	0	2
4	*Bouea macrophylla*	Bouea	0	1
5	*Shorea leprosula*	Shorea	4	2
6	*Shorea leprosula*	Shorea	4	2
7	*Dipterocarpus borneensis*	Dipterocarpus	0	2
8	*Dipterocarpus borneensis*	Dipterocarpus	0	2
9	*Shorea leprosula*	Shorea	4	2
10	*Shorea ovalis*	Shorea	4	2
11	*Syzygium pycnanthum*	Syzygium	0	1
12	*Podium javanicum*	Podium	0	2
13	*Shorea ovalis*	Shorea	4	2
14	*Calophyllum inophyllum*	Calophyllum	1	2
15	*Bouea macrophylla*	Bouea	0	1
16	*Dipterocarpus borneensis*	Dipterocarpus	0	2
17	*Shorea leprosula*	Shorea	4	2
18	*Intsia bijuga*	Intsia	3	2
19	*Shorea leprosula*	Shorea	4	2
20	*Eurycoma longifolia*	Eurycoma	0	2
21	*Shorea ovalis*	Shorea	4	2
22	*Calophyllum inophyllum*	Calophyllum	1	2
23	*Shorea ovalis*	Shorea	4	2
24	*Dipterocarpus borneensis*	Dipterocarpus	0	2
25	*Dipterocarpus borneensis*	Dipterocarpus	0	2
26	*Artocarpus odoratissimus*	Artocarpus	0	1
27	*Shorea leprosula*	Shorea	4	2
28	*Shorea ovalis*	Shorea	4	2
29	*Schima wallichii*	Schima	0	2
30	*Shorea ovalis*	Shorea	4	2
31	*Ficus indicata*	Ficus	0	2
32	*Melaleuca cajuputi*	Melaleuca	0	2
33	*Shorea leprosula*	Shorea	4	2
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40				
Total			61	62

Appendix D

Cluster ID	2959595		X	295000
Plot ID	20		Y	9595000

No	Latin Name	Genus	Red List	Value Use
1	*Calophyllum inophyllum*	Calophyllum	1	2
2	*Eurycoma longifolia*	Eurycoma	0	2
3	*Shorea ovalis*	Shorea	4	2
4	*Shorea leprosula*	Shorea	4	2
5	*Shorea leprosula*	Shorea	4	2
6	*Shorea leprosula*	Shorea	4	2
7	*Eurycoma longifolia*	Eurycoma	0	2
8	*Octomeles sumatrana*	Octomeles	1	2
9	*Dipterocarpus borneensis*	Dipterocarpus	0	2
10	*Shorea bracteolata*	Shorea	4	2
11	*Eusideroxylon zwageri*	Eusideroxylon	3	1
12	*Eusideroxylon zwageri*	Eusideroxylon	3	1
13	*Dipterocarpus borneensis*	Dipterocarpus	0	2
14	*Dipterocarpus borneensis*	Dipterocarpus	0	2
15	*Dipterocarpus borneensis*	Dipterocarpus	0	2
16	*Dipterocarpus borneensis*	Dipterocarpus	0	2
17	*Shorea ovalis*	Shorea	4	2
18	*Shorea leprosula*	Shorea	4	2
19	*Bouea macrophylla*	Bouea	0	1
20	*Dipterocarpus borneensis*	Dipterocarpus	0	2
21	*Shorea ovalis*	Shorea	4	2
22	*Octomeles sumatrana*	Octomeles	1	2
23	*Shorea ovalis*	Shorea	4	2
24	*Shorea ovalis*	Shorea	4	2
25	*Calophyllum inophyllum*	Calophyllum	1	2
26	*Dipterocarpus borneensis*	Dipterocarpus	0	2
27	*Shorea leprosula*	Shorea	4	2
28	*Ficus indicata*	Ficus	0	2
29	*Calophyllum inophyllum*	Calophyllum	1	2
30	*Dipterocarpus borneensis*	Dipterocarpus	0	2
31	*Schima wallichii*	Schima	0	2
32	*Shorea ovalis*	Shorea	4	2
33	*Eusideroxylon zwageri*	Eusideroxylon	3	1
34	*Dipterocarpus borneensis*	Dipterocarpus	0	2
35	*Octomeles sumatrana*	Octomeles	1	2
36	*Shorea ovalis*	Shorea	4	2
37	*Shorea leprosula*	Shorea	4	2
38	*Dipterocarpus borneensis*	Dipterocarpus	0	2
39	*Dipterocarpus borneensis*	Dipterocarpus	0	2
40	*Eurycoma longifolia*	Eurycoma	0	2
41	*Octomeles sumatrana*	Octomeles	1	2
42	*Eurycoma longifolia*	Eurycoma	0	2
43	*Dipterocarpus borneensis*	Dipterocarpus	0	2
Total			72	82

Appendix D

Cluster ID	2959605		X	295000
Plot ID	21		Y	9605000

No	Latin Name	Genus	Red List	Value Use
1	*Bouea macrophylla*	Bouea	0	1
2	*Bouea macrophylla*	Bouea	0	1
3	*Bouea macrophylla*	Bouea	0	1
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Total			0	3

Appendix D

Cluster ID	2959605	X	295000
Plot ID	22	Y	9605000

No	Latin Name	Genus	Red List	Value Use
1	*Dipterocarpus borneensis*	Dipterocarpus	0	2
2	*Dipterocarpus borneensis*	Dipterocarpus	0	2
3	*Podium javanicum*	Podium	0	2
4	*Dipterocarpus borneensis*	Dipterocarpus	0	2
5	*Ficus indicata*	Ficus	0	2
6	*Caethocarpus grandiflorus*	Caethocarpus	0	2
7	*Calophyllum inophyllum*	Calophyllum	1	2
8	*Durio kutejensis*	Durio	3	1
9	*Shorea ovalis*	Shorea	4	2
10	*Eurycoma longifolia*	Eurycoma	0	2
11	*Shorea ovalis*	Shorea	4	2
12	*Shorea bracteolata*	Shorea	4	2
13	*Shorea ovalis*	Shorea	4	2
14	*Dipterocarpus borneensis*	Dipterocarpus	0	2
15	*Eusideroxylon zwageri*	Eusideroxylon	3	1
16	*Dipterocarpus caudiferus*	Dipterocarpus	0	2
17	*Shorea ovalis*	Shorea	4	2
18	*Shorea leprosula*	Shorea	4	2
19	*Shorea scollaris*	Shorea	0	2
20	*Shorea ovalis*	Shorea	4	2
21				
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Total			35	38

Appendix D

Cluster ID	2959605		X	295000
Plot ID	23		Y	9605000

No	Latin Name	Genus	Red List	Value Use
1	*Melaleuca cajuputi*	Melaleuca	0	2
2	*Shorea leprosula*	Shorea	4	2
3	*Shorea leprosula*	Shorea	4	2
4	*Eurycoma longifolia*	Eurycoma	0	2
5				
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Total			8	8

Appendix D

Cluster ID	2959605		X	295000
Plot ID	24		Y	9605000

No	Latin Name	Genus	Red List	Value Use
1				
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3				
4		No Data		
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Total			0	0

Appendix D

Cluster ID	2859615	X	285000
Plot ID	25	Y	9615000

No	Latin Name	Genus	Red List	Value Use
1				
2				
3				
4		No Data		
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Total			0	0

Appendix D

Cluster ID	2859615		X	285000
Plot ID	26		Y	9615000

No	Latin Name	Genus	Red List	Value Use
1	*Intsia bijuga*	Intsia	3	2
2	*Shorea leprosula*	Shorea	4	2
3	*Dipterocarpus borneensis*	Dipterocarpus	0	2
4	*Dipterocarpus borneensis*	Dipterocarpus	0	2
5	*Shorea leprosula*	Shorea	4	2
6	*Intsia bijuga*	Intsia	3	2
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Total			14	12

Appendix D

Cluster ID	2859615	X	285000
Plot ID	27	Y	9615000

No	Latin Name	Genus	Red List	Value Use
1				
2				
3				
4		No Data		
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Total			0	0

Appendix D

Cluster ID	2859615		X	285000
Plot ID	28		Y	9615000

No	Latin Name	Genus	Red List	Value Use
1	*Shorea scollaris*	Shorea	0	2
2	*Toona sureni*	Toona	0	2
3	*Shorea leprosula*	Shorea	4	2
4	*Melaleuca cajuputi*	Melaleuca	0	2
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Total			4	8

Appendix D

Cluster ID	2959615		X	295000
Plot ID	29		Y	9615000

No	Latin Name	Genus	Red List	Value Use
1				
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4	No Data			
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40				
Total			0	0

Appendix D

Cluster ID	2959615		X	295000
Plot ID	30		Y	9615000

No	Latin Name	Genus	Red List	Value Use
1				
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3				
4		No Data		
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40				
Total			0	0

Appendix D

Cluster ID	2959615		X	295000
Plot ID	31		Y	9615000

No	Latin Name	Genus	Red List	Value Use
1				
2				
3				
4		No Data		
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Total			0	0

Appendix D

Cluster ID	2959615	X	295000
Plot ID	32	Y	9615000

No	Latin Name	Genus	Red List	Value Use
1	*Calophyllum inophyllum*	Calophyllum	1	2
2	*Shorea leprosula*	Shorea	4	2
3	*Dipterocarpus borneensis*	Dipterocarpus	0	2
4	*Dysoxylum pachyrhache*	Dysoxylum	0	2
5	*Dipterocarpus borneensis*	Dipterocarpus	0	2
6	*Saraca declinata*	Saraca	0	1
7	*Shorea ovalis*	Shorea	4	2
8	*Dysoxylum pachyrhache*	Dysoxylum	0	2
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Total			9	15

Appendix D

Cluster ID	2959625		X	295000
Plot ID	33		Y	9625000
No	Latin Name	Genus	Red List	Value Use
1	*Shorea leprosula*	Shorea	4	2
2	*Guioa diplopetala*	Guioa	0	2
3	*Shorea leprosula*	Shorea	4	2
4	*Dipterocarpus borneensis*	Dipterocarpus	0	2
5	*Shorea ovalis*	Shorea	4	2
6	*Diospyros macrophylla*	Diospyros	0	2
7	*Artocarpus odoratissimus*	Artocarpus	0	1
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Total			12	13

Appendix D

Cluster ID	2959625		X	295000
Plot ID	34		Y	9625000

No	Latin Name	Genus	Red List	Value Use
1	*Shorea leprosula*	Shorea	4	2
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Total			4	2

Appendix D

Cluster ID	2959625	X	295000
Plot ID	35	Y	9625000

No	Latin Name	Genus	Red List	Value Use
1	*Shorea ovalis*	Shorea	4	2
2	*Dipterocarpus borneensis*	Dipterocarpus	0	2
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Total			4	4

Appendix D

Cluster ID	2959625		X	295000
Plot ID	36		Y	9625000
No	Latin Name	Genus	Red List	Value Use
1	*Ficus indicata*	Ficus	0	2
2	*Shorea ovalis*	Shorea	4	2
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Total			4	4

Appendix D

Cluster ID	3059625		X	305000
Plot ID	37		Y	9625000

No	Latin Name	Genus	Red List	Value Use
1				
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4		No Data		
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Total			0	0

Appendix D

Cluster ID	3059625		X	305000
Plot ID	38		Y	9625000

No	Latin Name	Genus	Red List	Value Use
1	*Melaleuca cajuputi*	Melaleuca	0	2
2	*Shorea leprosula*	Shorea	4	2
3	*Dipterocarpus borneensis*	Dipterocarpus	0	2
4	*Eurycoma longifolia*	Eurycoma	0	2
5	*Shorea leprosula*	Shorea	4	2
6	*Dipterocarpus borneensis*	Dipterocarpus	0	2
7	*Shorea ovalis*	Shorea	4	2
8	*Calophyllum inophyllum*	Calophyllum	1	2
9	*Shorea ovalis*	Shorea	4	2
10	*Eurycoma longifolia*	Eurycoma	0	2
11	*Dipterocarpus borneensis*	Dipterocarpus	0	2
12	*Shorea ovalis*	Shorea	4	2
13	*Dipterocarpus borneensis*	Dipterocarpus	0	2
14	*Eurycoma longifolia*	Eurycoma	0	2
15	*Intsia bijuga*	Intsia	3	2
16	*Dipterocarpus borneensis*	Dipterocarpus	0	2
17	*Shorea ovalis*	Shorea	4	2
18	*Caethocarpus grandiflorus*	Caethocarpus	0	2
19	*Eurycoma longifolia*	Eurycoma	0	2
20	*Shorea leprosula*	Shorea	4	2
21	*Shorea ovalis*	Shorea	4	2
22	*Shorea leprosula*	Shorea	4	2
23	*Cotylelobium lanceolatum*	Cotylelobium	3	2
24	*Shorea ovalis*	Shorea	4	2
25	*Shorea ovalis*	Shorea	4	2
26	*Dipterocarpus borneensis*	Dipterocarpus	0	2
27	*Artocarpus odoratissimus*	Artocarpus	0	1
28	*Dipterocarpus borneensis*	Dipterocarpus	0	2
29	*Caethocarpus grandiflorus*	Caethocarpus	0	2
30	*Shorea leprosula*	Shorea	4	2
31	*Dipterocarpus borneensis*	Dipterocarpus	0	2
32	*Eurycoma longifolia*	Eurycoma	0	2
33	*Shorea leprosula*	Shorea	4	2
34	*Podium javanicum*	Podium	0	2
35	*Shorea ovalis*	Shorea	4	2
36	*Durio kutejensis*	Durio	3	1
37	*Shorea scollaris*	Shorea	0	2
38	*Toona sureni*	Toona	0	2
39	*Dipterocarpus borneensis*	Dipterocarpus	0	2
40				
Total			66	76

Appendix D

Cluster ID	3059625		X	305000
Plot ID	39		Y	9625000

No	Latin Name	Genus	Red List	Value Use
1	*Calophyllum inophyllum*	Calophyllum	1	2
2	*Shorea ovalis*	Shorea	4	2
3	*Schima wallichii*	Schima	0	2
4	*Dipterocarpus borneensis*	Dipterocarpus	0	2
5	*Shorea leprosula*	Shorea	4	2
6	*Canarium ovatum*	Canarium	3	1
7	*Dipterocarpus borneensis*	Dipterocarpus	0	2
8	*Eurycoma longifolia*	Eurycoma	0	2
9	*Dipterocarpus borneensis*	Dipterocarpus	0	2
10	*Eurycoma longifolia*	Eurycoma	0	2
11	*Dipterocarpus borneensis*	Dipterocarpus	0	2
12	*Shorea leprosula*	Shorea	4	2
13	*Shorea ovalis*	Shorea	4	2
14	*Calophyllum inophyllum*	Calophyllum	1	2
15	*Shorea ovalis*	Shorea	4	2
16	*Shorea leprosula*	Shorea	4	2
17	*Shorea ovalis*	Shorea	4	2
18	*Shorea scollaris*	Shorea	0	2
19	*Shorea ovalis*	Shorea	4	2
20	*Shorea leprosula*	Shorea	4	2
21	*Eurycoma longifolia*	Eurycoma	0	2
22	*Shorea ovalis*	Shorea	4	2
23	*Shorea bracteolata*	Shorea	4	2
24	*Shorea ovalis*	Shorea	4	2
25	*Dipterocarpus borneensis*	Dipterocarpus	0	2
26	*Eurycoma longifolia*	Eurycoma	0	2
27	*Shorea ovalis*	Shorea	4	2
28	*Calophyllum inophyllum*	Calophyllum	1	2
29	*Dipterocarpus borneensis*	Dipterocarpus	0	2
30	*Dipterocarpus borneensis*	Dipterocarpus	0	2
31	*Shorea ovalis*	Shorea	4	2
32	*Shorea ovalis*	Shorea	4	2
33	*Caethocarpus grandiflorus*	Caethocarpus	0	2
34	*Diospyros macrophylla*	Diospyros	0	2
35	*Eurycoma longifolia*	Eurycoma	0	2
36	*Shorea leprosula*	Shorea	4	2
37	*Intsia bijuga*	Intsia	3	2
38	*Eurycoma longifolia*	Eurycoma	0	2
39	*Eusideroxylon zwageri*	Eusideroxylon	3	1
40				
Total			76	76

Appendix D

Cluster ID	3059625	X	305000
Plot ID	40	Y	9625000

No	Latin Name	Genus	Red List	Value Use
1	*Shorea ovalis*	Shorea	4	2
2	*Shorea leprosula*	Shorea	4	2
3	*Dipterocarpus borneensis*	Dipterocarpus	0	2
4	*Syzygium pycnanthum*	Syzygium	0	1
5	*Dipterocarpus borneensis*	Dipterocarpus	0	2
6	*Caethocarpus grandiflorus*	Caethocarpus	0	2
7	*Eurycoma longifolia*	Eurycoma	0	2
8	*Schima wallichii*	Schima	0	2
9	*Shorea ovalis*	Shorea	4	2
10	*Eurycoma longifolia*	Eurycoma	0	2
11	*Dipterocarpus borneensis*	Dipterocarpus	0	2
12	*Dipterocarpus borneensis*	Dipterocarpus	0	2
13	*Shorea leprosula*	Shorea	4	2
14	*Shorea leprosula*	Shorea	4	2
15	*Intsia bijuga*	Intsia	3	2
16	*Intsia bijuga*	Intsia	3	2
17	*Eurycoma longifolia*	Eurycoma	0	2
18	*Shorea leprosula*	Shorea	4	2
19	*Dipterocarpus borneensis*	Dipterocarpus	0	2
20	*Dipterocarpus borneensis*	Dipterocarpus	0	2
21	*Dipterocarpus borneensis*	Dipterocarpus	0	2
22	*Schima wallichii*	Schima	0	2
23	*Intsia bijuga*	Intsia	3	2
24	*Shorea leprosula*	Shorea	4	2
25	*Dipterocarpus borneensis*	Dipterocarpus	0	2
26	*Toona sureni*	Toona	0	2
27	*Eurycoma longifolia*	Eurycoma	0	2
28	*Diospyros macrophylla*	Diospyros	0	2
29	*Shorea ovalis*	Shorea	4	2
30	*Calophyllum inophyllum*	Calophyllum	1	2
31	*Shorea leprosula*	Shorea	4	2
32				
33				
34				
35				
36				
37				
38				
39				
40				
Total			46	61

Appendix D

Cluster ID	3159615	X	315000
Plot ID	41	Y	9615000

No	Latin Name	Genus	Red List	Value Use
1	*Intsia bijuga*	Intsia	3	2
2	*Artocarpus odoratissimus*	Artocarpus	0	1
3	*Saraca declinata*	Saraca	0	1
4	*Vitex Pubescen*	Vitex	0	2
5	*Dipterocarpus borneensis*	Dipterocarpus	0	2
6	*Dipterocarpus borneensis*	Dipterocarpus	0	2
7	*Shorea ovalis*	Shorea	4	2
8	*Intsia bijuga*	Intsia	3	2
9	*Dipterocarpus borneensis*	Dipterocarpus	0	2
10	*Melaleuca cajuputi*	Melaleuca	0	2
11	*Dipterocarpus borneensis*	Dipterocarpus	0	2
12	*Calophyllum inophyllum*	Calophyllum	1	2
13	*Dipterocarpus borneensis*	Dipterocarpus	0	2
14	*Shorea ovalis*	Shorea	4	2
15	*Calophyllum inophyllum*	Calophyllum	1	2
16	*Dysoxylum pachyrhache*	Dysoxylum	0	2
17	*Shorea ovalis*	Shorea	4	2
18	*Dipterocarpus borneensis*	Dipterocarpus	0	2
19	*Shorea leprosula*	Shorea	4	2
20	*Shorea ovalis*	Shorea	4	2
21	*Eurycoma longifolia*	Eurycoma	0	2
22	*Intsia bijuga*	Intsia	3	2
23	*Shorea ovalis*	Shorea	4	2
24	*Shorea leprosula*	Shorea	4	2
25	*Shorea leprosula*	Shorea	4	2
26	*Caethocarpus grandiflorus*	Caethocarpus	0	2
27	*Shorea leprosula*	Shorea	4	2
28	*Podium javanicum*	Podium	0	2
29	*Eurycoma longifolia*	Eurycoma	0	2
30	*Guioa diplopetala*	Guioa	0	2
31	*Dipterocarpus rigidus*	Dipterocarpus	5	2
32	*Shorea leprosula*	Shorea	4	2
33	*Cotylelobium lanceolatum*	Cotylelobium	3	2
34				
35				
36				
37				
38				
39				
40				
Total			59	64

Appendix D

Cluster ID	3159615		X	315000
Plot ID	42		Y	9615000

No	Latin Name	Genus	Red List	Value Use
1	*Shorea leprosula*	Shorea	4	2
2	*Dipterocarpus borneensis*	Dipterocarpus	0	2
3	*Artocarpus odoratissimus*	Artocarpus	0	1
4	*Intsia bijuga*	Intsia	3	2
5	*Vitex Pubescen*	Vitex	0	2
6	*Artocarpus odoratissimus*	Artocarpus	0	1
7	*Shorea leprosula*	Shorea	4	2
8	*Cotylelobium lanceolatum*	Cotylelobium	3	2
9	*Eurycoma longifolia*	Eurycoma	0	2
10	*Shorea ovalis*	Shorea	4	2
11	*Calophyllum inophyllum*	Calophyllum	1	2
12	*Ficus indicata*	Ficus	0	2
13	*Shorea scollaris*	Shorea	0	2
14	*Dipterocarpus borneensis*	Dipterocarpus	0	2
15	*Shorea ovalis*	Shorea	4	2
16	*Dipterocarpus borneensis*	Dipterocarpus	0	2
17	*Eurycoma longifolia*	Eurycoma	0	2
18	*Dipterocarpus rigidus*	Dipterocarpus	5	2
19	*Cotylelobium lanceolatum*	Cotylelobium	3	2
20	*Shorea bracteolata*	Shorea	4	2
21	*Shorea ovalis*	Shorea	4	2
22	*Toona sureni*	Toona	0	2
23	*Cotylelobium lanceolatum*	Cotylelobium	3	2
24	*Eurycoma longifolia*	Eurycoma	0	2
25	*Guioa diplopetala*	Guioa	0	2
26	*Dipterocarpus borneensis*	Dipterocarpus	0	2
27	*Dipterocarpus borneensis*	Dipterocarpus	0	2
28	*Shorea leprosula*	Shorea	4	2
29	*Dipterocarpus borneensis*	Dipterocarpus	0	2
30	*Dipterocarpus borneensis*	Dipterocarpus	0	2
31				
32				
33				
34				
35				
36				
37				
38				
39				
40				
Total			46	58

Appendix D

Cluster ID	3159615		X	315000
Plot ID	43		Y	9615000

No	Latin Name	Genus	Red List	Value Use
1	*Caethocarpus grandiflorus*	Caethocarpus	0	2
2	*Dipterocarpus borneensis*	Dipterocarpus	0	2
3	*Eurycoma longifolia*	Eurycoma	0	2
4	*Shorea ovalis*	Shorea	4	2
5	*Dipterocarpus borneensis*	Dipterocarpus	0	2
6	*Bouea macrophylla*	Bouea	0	1
7	*Caethocarpus grandiflorus*	Caethocarpus	0	2
8	*Shorea leprosula*	Shorea	4	2
9	*Shorea ovalis*	Shorea	4	2
10	*Shorea ovalis*	Shorea	4	2
11	*Shorea ovalis*	Shorea	4	2
12	*Cotylelobium lanceolatum*	Cotylelobium	3	2
13	*Podium javanicum*	Podium	0	2
14	*Shorea leprosula*	Shorea	4	2
15	*Eurycoma longifolia*	Eurycoma	0	2
16	*Eurycoma longifolia*	Eurycoma	0	2
17	*Shorea ovalis*	Shorea	4	2
18	*Caethocarpus grandiflorus*	Caethocarpus	0	2
19	*Dipterocarpus borneensis*	Dipterocarpus	0	2
20	*Melaleuca cajuputi*	Melaleuca	0	2
21	*Shorea ovalis*	Shorea	4	2
22	*Dipterocarpus borneensis*	Dipterocarpus	0	2
23	*Intsia bijuga*	Intsia	3	2
24	*Shorea leprosula*	Shorea	4	2
25	*Calophyllum inophyllum*	Calophyllum	1	2
26	*Shorea leprosula*	Shorea	4	2
27	*Caethocarpus grandiflorus*	Caethocarpus	0	2
28	*Caethocarpus grandiflorus*	Caethocarpus	0	2
29	*Bouea macrophylla*	Bouea	0	1
30	*Shorea leprosula*	Shorea	4	2
31	*Caethocarpus grandiflorus*	Caethocarpus	0	2
32				
33				
34				
35				
36				
37				
38				
39				
40				
Total			51	60

Appendix D

Cluster ID	3159615	X	315000
Plot ID	44	Y	9615000

No	Latin Name	Genus	Red List	Value Use
1	*Schima wallichii*	Schima	0	2
2	*Shorea ovalis*	Shorea	4	2
3	*Shorea ovalis*	Shorea	4	2
4	*Shorea leprosula*	Shorea	4	2
5	*Calophyllum inophyllum*	Calophyllum	1	2
6	*Schima wallichii*	Schima	0	2
7	*Shorea scollaris*	Shorea	0	2
8	*Bouea macrophylla*	Bouea	0	1
9	*Dipterocarpus borneensis*	Dipterocarpus	0	2
10	*Caethocarpus grandiflorus*	Caethocarpus	0	2
11	*Caethocarpus grandiflorus*	Caethocarpus	0	2
12	*Dipterocarpus borneensis*	Dipterocarpus	0	2
13	*Dipterocarpus borneensis*	Dipterocarpus	0	2
14	*Artocarpus odoratissimus*	Artocarpus	0	1
15	*Shorea ovalis*	Shorea	4	2
16	*Shorea bracteolata*	Shorea	4	2
17	*Shorea scollaris*	Shorea	0	2
18	*Octomeles sumatrana*	Octomeles	1	2
19	*Shorea leprosula*	Shorea	4	2
20	*Eurycoma longifolia*	Eurycoma	0	2
21	*Bouea macrophylla*	Bouea	0	1
22	*Shorea bracteolata*	Shorea	4	2
23	*Dipterocarpus borneensis*	Dipterocarpus	0	2
24	*Shorea ovalis*	Shorea	4	2
25	*Eurycoma longifolia*	Eurycoma	0	2
26	*Shorea leprosula*	Shorea	4	2
27	*Dipterocarpus borneensis*	Dipterocarpus	0	2
28	*Shorea ovalis*	Shorea	4	2
29	*Eurycoma longifolia*	Eurycoma	0	2
30	*Shorea ovalis*	Shorea	4	2
31				
32				
33				
34				
35				
36				
37				
38				
39				
40				
Total			46	57

Appendix E: Summary of the Plot Data

Plot	Cluster	Year	LULC	N	S	Dependent values			Independent values		
						SR	*RL*	*VU*	*elv*	*ndvi*	*frag*
1	2759595	2010	F	55	18	4.24	75	104	337	0.56	4
2	2759595	2010	F	45	13	3.15	84	87	320	0.48	4
3	2759595	2010	F	34	10	2.55	57	65	439	0.49	4
4	2759595	2010	F	45	17	4.20	68	85	354	0.45	4
5	2759585	2010	F	36	15	3.91	38	68	877	0.62	4
6	2759585	2010	F	39	15	3.82	35	75	930	0.45	3
7	2759585	2010	GL	35	12	3.09	51	68	1076	0.49	4
8	2759585	2010	F	39	11	2.73	54	76	803	0.37	4
9	2859595	2011	F	38	15	3.85	72	71	438	0.63	4
10	2859595	2011	F	30	12	3.23	61	54	338	0.54	4
11	2859595	2011	F	26	9	2.46	35	46	363	0.57	4
12	2859595	2011	F	29	11	2.97	52	53	407	0.59	4
13	2859605	2011	GL	5	2	0.62	0	7	102	0.63	0
14	2859605	2011	GL	4	2	0.72	0	5	97	0.60	0
15	2859605	2011	GL	0	0	0.00	0	0	99	0.58	0
16	2859605	2011	F	9	6	2.28	13	17	92	0.51	1
17	2959595	2012	F	29	15	4.16	50	57	150	0.55	3
18	2959595	2012	F	37	15	3.88	68	70	241	0.16	4
19	2959595	2012	F	33	13	3.43	61	62	329	0.61	4
20	2959595	2012	F	43	11	2.66	72	82	158	0.56	4
21	2959605	2012	GL	3	1	0.00	0	3	283	0.60	0
22	2959605	2012	F	20	13	4.01	35	38	281	0.61	2
23	2959605	2012	GL	4	3	1.44	8	8	268	0.69	0
24	2959605	2012	GL	0	0	0.00	0	0	334	0.59	0
25	2859615	2012	GL	0	0	0.00	0	0	147	0.59	0
26	2859615	2012	MP	6	3	1.12	14	12	85	0.65	0
27	2859615	2012	GL	0	0	0.00	0	0	74	0.51	0
28	2859615	2012	SB	4	4	2.16	4	8	84	0.62	0
29	2959615	2012	SB	0	0	0.00	0	0	145	0.48	0
30	2959615	2012	GL	0	0	0.00	0	0	138	0.51	0
31	2959615	2012	SB	0	0	0.00	0	0	170	0.58	0
32	2959615	2012	MP	8	6	2.40	9	15	151	0.69	0
33	2959625	2012	F	7	6	2.57	12	13	176	0.67	0
34	2959625	2012	MP	1	1	0.00	4	2	127	0.60	0
35	2959625	2012	GL	2	2	1.44	4	4	113	0.60	0
36	2959625	2012	GL	2	2	1.44	4	4	125	0.62	0
37	3059625	2012	BL	0	0	0.00	0	0	129	0.43	0
38	3059625	2012	F	39	14	3.55	66	76	163	0.53	4
39	3059625	2012	F	39	13	3.28	76	76	150	0.58	3
40	3059625	2012	F	31	11	2.91	46	61	156	0.57	4
41	3159615	2012	F	33	16	4.29	59	64	246	0.48	4
42	3159615	2012	F	30	15	4.12	46	58	310	0.52	3
43	3159615	2012	F	31	11	2.91	51	60	196	0.49	4
44	3159615	2012	F	30	12	3.23	46	57	189	0.51	4

Note :
F = Forest
MP = Mixed plantation
SB = Shrub/bush
Gl = Grass land
BL = Bare land
N = Total tree species in the plot

S = Number of tree species in the plot
SR = Species Richness / Margalef Index
RL = Sum of Red List Index
VU = Sum of Value Use
elv = Elevation (m)
ndvi = Normalized Difference Vegetation Index
frag = Fragmentation class

Appendix F: Descriptive statistics of species status

Table G-1 Mean of SR, RL and RL in each cluster

No	Cluster	Number of plot	Species Richness	Red List Status	Value Use
1	2759585	4	3.39	44.50	71.75
2	2759595	4	3.54	71.00	85.25
3	2859595	4	3.13	55.00	56.00
4	2859605	4	0.90	3.25	7.25
5	2859615	4	0.82	4.50	5.00
6	2959595	4	3.53	62.75	67.75
7	2959605	4	1.36	10.75	12.25
8	2959615	4	0.60	2.25	3.75
9	2959625	4	1.36	6.00	5.75
10	3059625	4	2.43	47.00	53.25
11	3159615	4	3.64	50.50	59.75

F.1. Mean of SR, RL and VU

$$\text{Mean formula for cluster } \hat{\bar{y}}_{clust} = \frac{1}{n}\sum_{i=1}^{n}\hat{\bar{y}}_i$$

- Mean of SR

$$\begin{aligned}\hat{\bar{y}}_{clust(SR)} &= \frac{1}{11}\left(3.39+3.54+\cdots+3.64\right)\\ &= 2.54\end{aligned}$$

- Mean of RL

$$\begin{aligned}\hat{\bar{y}}_{clust(RL)} &= \left(44.5+71+\cdots+50.5\right)\\ &= 32.5\end{aligned}$$

- Mean of VU

$$\begin{aligned}\hat{\bar{y}}_{clust(VU)} &= \frac{1}{11}\left(71.75+85.25+\cdots+59.75\right)\\ &= 38.89\end{aligned}$$

F.2. Mean variance of SR, RL and VU

Formula for variance of cluster mean $\widehat{\mathrm{var}}\left(\hat{\bar{y}}_{clust}\right)=\frac{1}{n-1}\sum_{i=1}^{n}\left(\hat{\bar{y}}_{i}-\hat{\bar{y}}_{clust}\right)^{2}$

- Mean variance of SR

$$\begin{aligned}\widehat{\mathrm{var}}\left(\hat{\bar{y}}_{clust(SR)}\right)&=\frac{1}{n-1}(3.39-2.25)^2+(3.54-2.25)^2+\cdots+(3.64-2.25)^2\\&=1.55\end{aligned}$$

- Mean variance of RL

$$\begin{aligned}\widehat{\mathrm{var}}\left(\hat{\bar{y}}_{clust(RL)}\right)&=\frac{1}{n-1}(44.5-32.5)^2+(71-32.5)^2+\cdots+(50.5-32.5)^2\\&=731.18\end{aligned}$$

- Mean variance of VU

$$\begin{aligned}\widehat{\mathrm{var}}\left(\hat{\bar{y}}_{clust(VU)}\right)&=\frac{1}{n-1}(71.75-38.89)^2+(85.25-38.89)^2+\cdots+(59.75-38.89)^2\\&=1{,}018.84\end{aligned}$$

F.3. Variance analysis between LULC

To compare the resultant of SR, RL and VU among plots, a variance analysis was performed to determine whether the resultant data in those species parameters. ANOVA analysis was performed by SPSS software with the output below.

Descriptive statistics

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
SR	Forest	25	3.37520	.639939	.127988	3.11105	3.63935	2.276	4.290
	Mixed-Plantation	3	1.17333	1.203025	.694567	-1.81515	4.16181	.000	2.404
	Shrub/bush	2	1.08200	1.530179	1.082000	-12.66611	14.83011	.000	2.164
	Grassland	12	.73042	.968737	.279650	.11491	1.34592	.000	3.094
	Bareland	2	.00000	.000000	.000000	.00000	.00000	.000	.000
	Total	44	2.24611	1.533194	.231138	1.77998	2.71225	.000	4.290
RL	Forest	25	53.28	18.409	3.682	45.68	60.88	12	84
	Mixed-Plantation	3	9.00	5.000	2.887	-3.42	21.42	4	14
	Shrub/bush	2	2.00	2.828	2.000	-23.41	27.41	0	4
	Grassland	12	5.58	14.532	4.195	-3.65	14.82	0	51
	Bareland	2	.00	.000	.000	.00	.00	0	0
	Total	44	32.50	28.787	4.340	23.75	41.25	0	84
VU	Forest	25	63.00	20.123	4.025	54.69	71.31	13	104
	Mixed-Plantation	3	9.67	6.807	3.930	-7.24	26.58	2	15
	Shrub/bush	2	4.00	5.657	4.000	-46.82	54.82	0	8
	Grassland	12	8.25	19.036	5.495	-3.85	20.35	0	68
	Bareland	2	.00	.000	.000	.00	.00	0	0
	Total	44	38.89	33.288	5.018	28.77	49.01	0	104

Note:
N = number of individual
SR = Species Richness
RL = Red List
VU = Value Use

ANOVA table

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
SR	Between Groups	75.692	4	18.923	29.069	.000
	Within Groups	25.387	39	.651		
	Total	101.079	43			
RL	Between Groups	25119.043	4	6279.761	23.294	.000
	Within Groups	10513.957	39	269.589		
	Total	35633.000	43			
VU	Between Groups	33819.515	4	8454.879	23.844	.000
	Within Groups	13828.917	39	354.588		
	Total	47648.432	43			

Post Hoc Tests

Multiple Comparisons

LSD

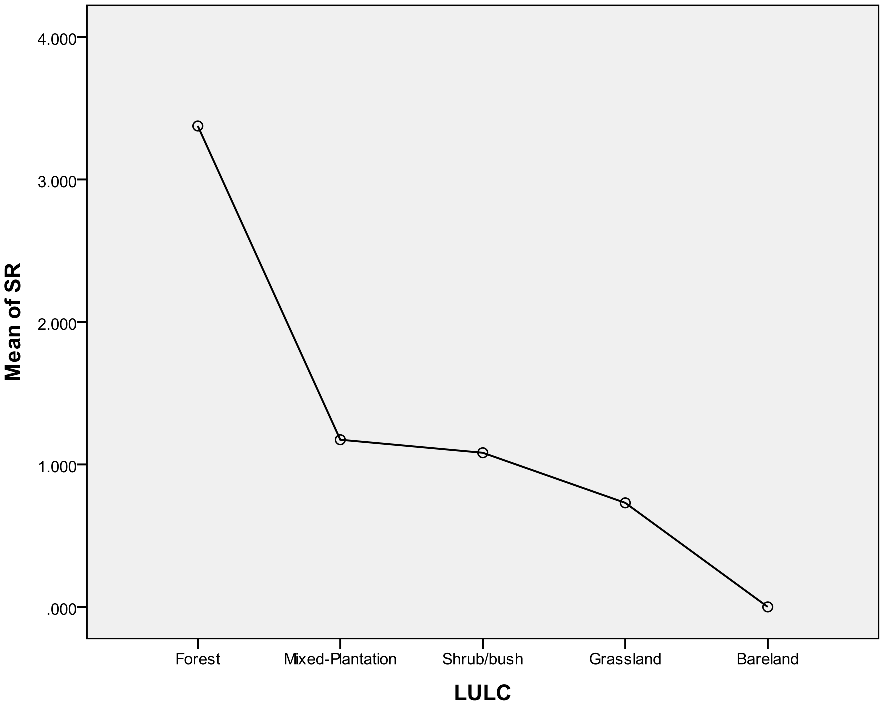
Dependent Variable	(I) LULC	(J) LULC	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
SR	Forest	Mixed-Plantation	2.201867*	.492976	.000	1.20473	3.19900
		Shrub/bush	2.293200*	.592890	.000	1.09397	3.49243
		Grassland	2.644783*	.283346	.000	2.07166	3.21791
		Bareland	3.375200*	.592890	.000	2.17597	4.57443
	Mixed-Plantation	Forest	-2.201867*	.492976	.000	-3.19900	-1.20473
		Shrub/bush	.091333	.736524	.902	-1.39843	1.58109
		Grassland	.442917	.520801	.400	-.61050	1.49634
		Bareland	1.173333	.736524	.119	-.31643	2.66309
	Shrub/bush	Forest	-2.293200*	.592890	.000	-3.49243	-1.09397
		Mixed-Plantation	-.091333	.736524	.902	-1.58109	1.39843
		Grassland	.351583	.616220	.572	-.89484	1.59801
		Bareland	1.082000	.806822	.188	-.54995	2.71395
	Grassland	Forest	-2.644783*	.283346	.000	-3.21791	-2.07166
		Mixed-Plantation	-.442917	.520801	.400	-1.49634	.61050
		Shrub/bush	-.351583	.616220	.572	-1.59801	.89484
		Bareland	.730417	.616220	.243	-.51601	1.97684
	Bareland	Forest	-3.375200*	.592890	.000	-4.57443	-2.17597
		Mixed-Plantation	-1.173333	.736524	.119	-2.66309	.31643
		Shrub/bush	-1.082000	.806822	.188	-2.71395	.54995
		Grassland	-.730417	.616220	.243	-1.97684	.51601

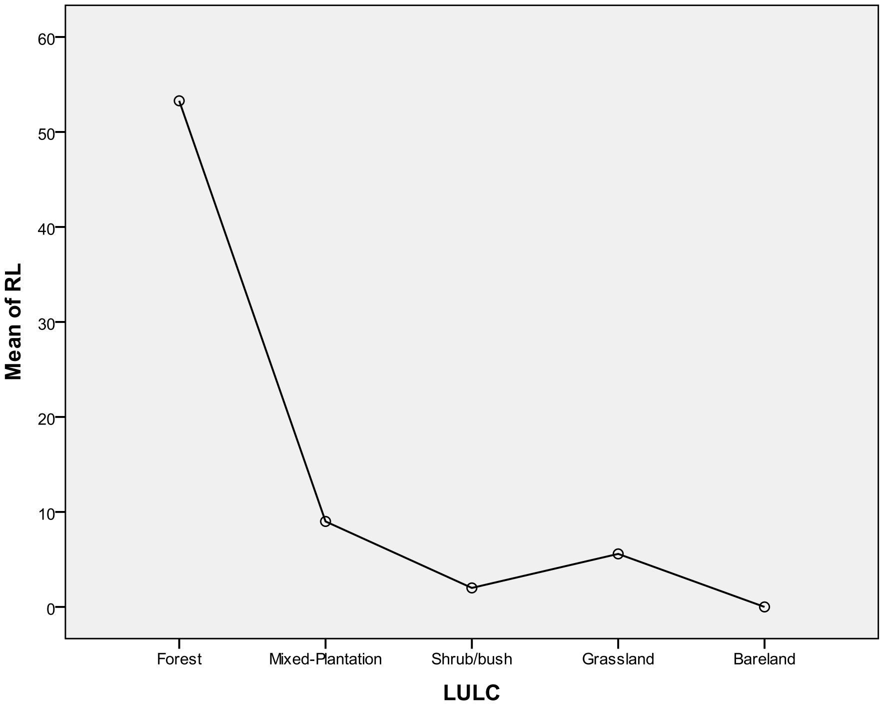
RL	Forest	Mixed-Plantation	44.280*	10.032	.000	23.99	64.57
		Shrub/bush	51.280*	12.066	.000	26.88	75.68
		Grassland	47.697*	5.766	.000	36.03	59.36
		Bareland	53.280*	12.066	.000	28.88	77.68
	Mixed-Plantation	Forest	-44.280*	10.032	.000	-64.57	-23.99
		Shrub/bush	7.000	14.989	.643	-23.32	37.32
		Grassland	3.417	10.599	.749	-18.02	24.85
		Bareland	9.000	14.989	.552	-21.32	39.32
	Shrub/bush	Forest	-51.280*	12.066	.000	-75.68	-26.88
		Mixed-Plantation	-7.000	14.989	.643	-37.32	23.32
		Grassland	-3.583	12.540	.777	-28.95	21.78
		Bareland	2.000	16.419	.904	-31.21	35.21
	Grassland	Forest	-47.697*	5.766	.000	-59.36	-36.03
		Mixed-Plantation	-3.417	10.599	.749	-24.85	18.02
		Shrub/bush	3.583	12.540	.777	-21.78	28.95
		Bareland	5.583	12.540	.659	-19.78	30.95
	Bareland	Forest	-53.280*	12.066	.000	-77.68	-28.88
		Mixed-Plantation	-9.000	14.989	.552	-39.32	21.32
		Shrub/bush	-2.000	16.419	.904	-35.21	31.21
		Grassland	-5.583	12.540	.659	-30.95	19.78
VU	Forest	Mixed-Plantation	53.333*	11.506	.000	30.06	76.61
		Shrub/bush	59.000*	13.838	.000	31.01	86.99
		Grassland	54.750*	6.613	.000	41.37	68.13
		Bareland	63.000*	13.838	.000	35.01	90.99
	Mixed-Plantation	Forest	-53.333*	11.506	.000	-76.61	-30.06
		Shrub/bush	5.667	17.190	.743	-29.10	40.44
		Grassland	1.417	12.155	.908	-23.17	26.00
		Bareland	9.667	17.190	.577	-25.10	44.44
	Shrub/bush	Forest	-59.000*	13.838	.000	-86.99	-31.01
		Mixed-Plantation	-5.667	17.190	.743	-40.44	29.10
		Grassland	-4.250	14.382	.769	-33.34	24.84
		Bareland	4.000	18.830	.833	-34.09	42.09
	Grassland	Forest	-54.750*	6.613	.000	-68.13	-41.37
		Mixed-Plantation	-1.417	12.155	.908	-26.00	23.17
		Shrub/bush	4.250	14.382	.769	-24.84	33.34
		Bareland	8.250	14.382	.570	-20.84	37.34
	Bareland	Forest	-63.000*	13.838	.000	-90.99	-35.01
		Mixed-Plantation	-9.667	17.190	.577	-44.44	25.10
		Shrub/bush	-4.000	18.830	.833	-42.09	34.09
		Grassland	-8.250	14.382	.570	-37.34	20.84

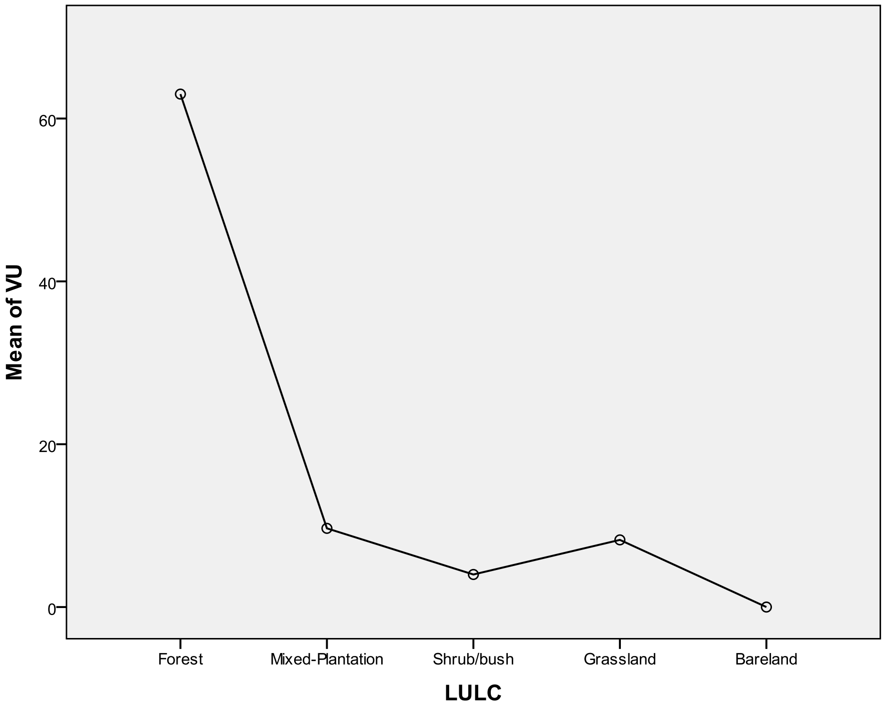
*. The mean difference is significant at the 0.05 level.

Note: From the post hoc test, using Least Significant Difference (LSD) method above it can be seen that forest has significantly different compare to other LULCs in *SR*, *LR*, or *VU* while other LULCs (mixed-plantation, shrub/bush, grassland and bare land) have insignificant difference compare to each other.

Means plots


4.000
3.000
2.000
1.000
.000
Mean of SR
Forest
Mixed-Plantation
Shrub/bush
Grassland
Bareland
LULC


60
50
40
30
20
10
0
Mean of RL
Forest
Mixed-Plantation
Shrub/bush
Grassland
Bareland
LULC


Mean of VU
60
40
20
0
Forest
Mixed-Plantation
Shrub/bush
Grassland
Bareland
LULC

Appendix G: Linear Regression for Species Status Index

G.1. Dependent and independent variables

Plot	Normalized dependent values			Normalized independent values		
	SR	*RL*	*VU*	*elv*	*ndvi*	*frag*
1	0.99	0.89	1.00	0.31	0.81	1.00
2	0.73	1.00	0.84	0.30	0.70	1.00
3	0.59	0.68	0.63	0.41	0.71	1.00
4	0.98	0.81	0.82	0.33	0.65	1.00
5	0.91	0.45	0.65	0.82	0.90	1.00
6	0.89	0.42	0.72	0.86	0.65	0.75
7	0.72	0.61	0.65	1.00	0.71	1.00
8	0.64	0.64	0.73	0.75	0.54	1.00
9	0.90	0.86	0.68	0.41	0.91	1.00
10	0.75	0.73	0.52	0.31	0.78	1.00
11	0.57	0.42	0.44	0.34	0.83	1.00
12	0.69	0.62	0.51	0.38	0.86	1.00
13	0.14	0.00	0.07	0.09	0.91	0.00
14	0.17	0.00	0.05	0.09	0.87	0.00
15	0.00	0.00	0.00	0.09	0.84	0.00
16	0.53	0.15	0.16	0.09	0.74	0.25
17	0.97	0.60	0.55	0.14	0.80	0.75
18	0.90	0.81	0.67	0.22	0.23	1.00
19	0.80	0.73	0.60	0.31	0.88	1.00
20	0.62	0.86	0.79	0.15	0.81	1.00
21	0.00	0.00	0.03	0.26	0.87	0.00
22	0.93	0.42	0.37	0.26	0.88	0.50
23	0.34	0.10	0.08	0.25	1.00	0.00
24	0.00	0.00	0.00	0.31	0.86	0.00
25	0.00	0.00	0.00	0.14	0.86	0.00
26	0.26	0.17	0.12	0.08	0.94	0.00
27	0.00	0.00	0.00	0.07	0.74	0.00
28	0.50	0.05	0.08	0.08	0.90	0.00
29	0.00	0.00	0.00	0.13	0.70	0.00
30	0.00	0.00	0.00	0.13	0.74	0.00
31	0.00	0.00	0.00	0.16	0.84	0.00
32	0.56	0.11	0.14	0.14	1.00	0.00
33	0.60	0.14	0.13	0.16	0.97	0.00
34	0.00	0.05	0.02	0.12	0.87	0.00
35	0.34	0.05	0.04	0.11	0.87	0.00
36	0.34	0.05	0.04	0.12	0.90	0.00
37	0.00	0.00	0.00	0.12	0.62	0.00
38	0.83	0.79	0.73	0.15	0.77	1.00
39	0.76	0.90	0.73	0.14	0.84	0.75
40	0.68	0.55	0.59	0.14	0.83	1.00
41	1.00	0.70	0.62	0.23	0.70	1.00
42	0.96	0.55	0.56	0.29	0.75	0.75
43	0.68	0.61	0.58	0.18	0.71	1.00
44	0.75	0.55	0.55	0.18	0.74	1.00

Note: Dependent and independent variables for the regression analysis were the normalized values of SR, RL, VU as the dependent variables and the normalized values of *elv*, NDVI, and *frag* as the independent variables. The source of the real value is shown in Appendix E (page 290) while the normalization method is shown on page 43.

G.2. Regression between Species Richness and influencing factors

Dependent Variable : Species Richness (SR)
Independent Variable : Elevation (elv), Normalized Difference Vegetation Index (ndvi), and Fragmentation class (frag)

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	frag, ndvi, elv[b]	.	Enter

a. Dependent Variable: sr
b. All requested variables entered.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.842[a]	.710	.688	.19948

a. Predictors: (Constant), frag, ndvi, elv

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.842[a]	.710	.688	.19948

a. Predictors: (Constant), frag, ndvi, elv

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	3.891	3	1.297	32.595	.000[b]
	Residual	1.592	40	.040		
	Total	5.483	43			

a. Dependent Variable: sr
b. Predictors: (Constant), frag, ndvi, elv

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-.103	.220		-.470	.641
	elv	-.003	.164	-.002	-.015	.988
	ndvi	.356	.249	.134	1.428	.161
	frag	.665	.079	.890	8.397	.000

a. Dependent Variable: sr

Selected model: $SR = -0.103 - 0.003elv + 0.356ndvi + 0.665frag$

G.3. Regression between Red List and influencing factors

Dependent Variable : Red List status (RL)
Independent Variable : Elevation (elv), Normalized Difference Vegetation Index (ndvi), and Fragmentation class (frag)

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	frag, ndvi, elv[b]	.	Enter

a. Dependent Variable: rl
b. All requested variables entered.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.944[a]	.891	.883	.11722

a. Predictors: (Constant), frag, ndvi, elv

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	4.504	3	1.501	109.281	.000[b]
	Residual	.550	40	.014		
	Total	5.054	43			

a. Dependent Variable: rl
b. Predictors: (Constant), frag, ndvi, elv

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.047	.129		.363	.719
	elv	-.232	.096	-.146	-2.408	.021
	ndvi	.030	.146	.012	.206	.838
	frag	.729	.047	1.016	15.663	.000

a. Dependent Variable: rl

Selected model: $RL = 0.047 - 2.32elv + 0.0306ndvi + 0.729frag$

G.3. Regression between Value Use and influencing factors

Dependent Variable : Value use status (*vu*)

Independent Variable : Elevation (*elv*), Normalized Difference Vegetation Index (*ndvi*), and Fragmentation class (*frag*)

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	frag, ndvi, elv[b]	.	Enter

a. Dependent Variable: vu

b. All requested variables entered.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.947[a]	.897	.890	.10627

a. Predictors: (Constant), frag, ndvi, elv

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	3.950	3	1.317	116.594	.000[b]
	Residual	.452	40	.011		
	Total	4.402	43			

a. Dependent Variable: vu

b. Predictors: (Constant), frag, ndvi, elv

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.031	.117		.268	.790
	elv	.051	.087	.034	.578	.566
	ndvi	.010	.133	.004	.074	.942
	frag	.624	.042	.931	14.781	.000

a. Dependent Variable: vu

Selected model: $VU = 0.031 + 0.051 elv + 0.01 ndvi + 0.624 frag$

Appendix H: Regression for Proportion Optimization

H.1. Regression estimation for preservation optimization (1993 – 2003)

Dependent Variable : Average agreement

Independent Variable : Preservation proportion (prop) in percentage

Case Processing Summary

	N
Total Cases	11
Excluded Cases[a]	0
Forecasted Cases	0
Newly Created Cases	0

a. Cases with a missing value in any variable are excluded from the analysis.

Linear Estimation (preservation 1993 – 2003)

Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
.990	.980	.977	3.340

The independent variable is prop.

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	4831.046	1	4831.046	433.142	.000
Residual	100.382	9	11.154		
Total	4931.427	10			

The independent variable is prop.

Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
prop	.713	.034	.990	20.812	.000
(Constant)	26.801	1.745		15.361	.000

Logarithmic (preservation 1993 – 2003)

Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
.897	.805	.784	10.329

The independent variable is prop.

ANOVA

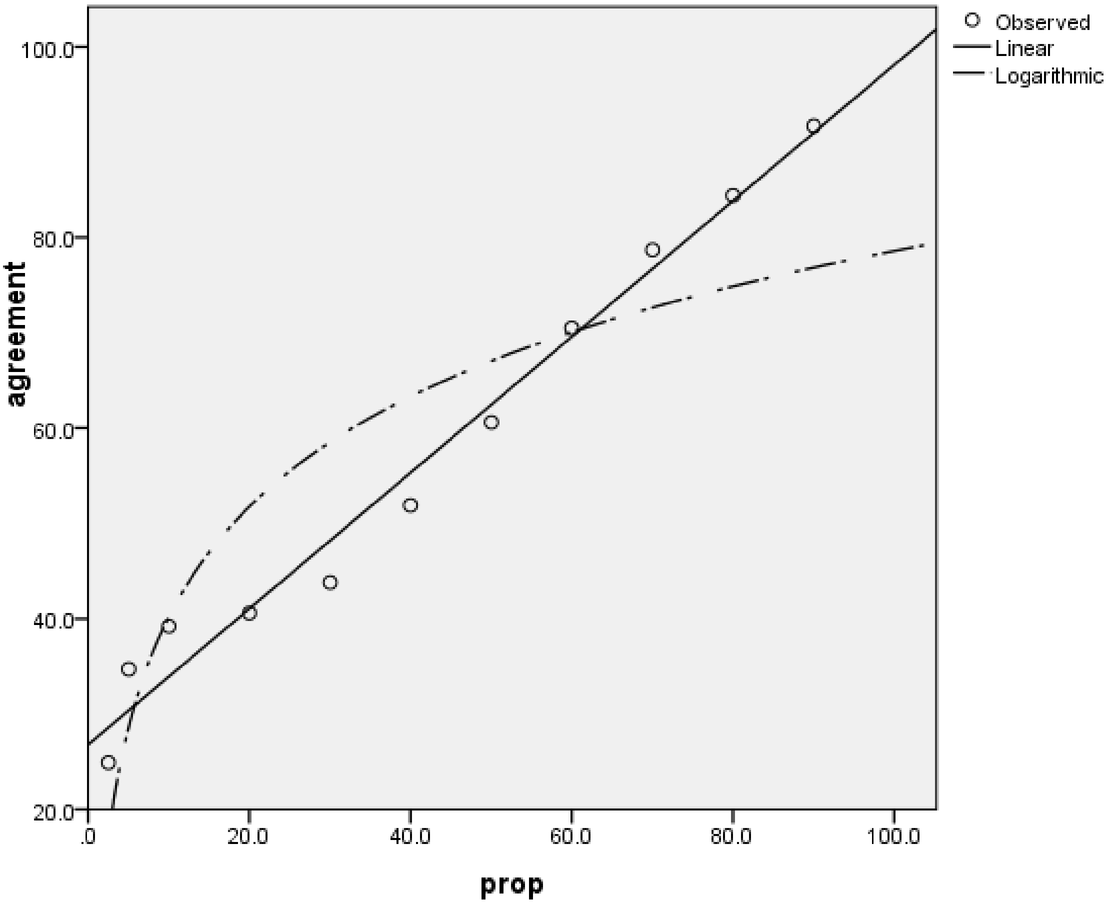
	Sum of Squares	df	Mean Square	F	Sig.
Regression	3971.295	1	3971.295	37.226	.000
Residual	960.133	9	106.681		
Total	4931.427	10			

The independent variable is prop.

Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
ln(prop)	16.665	2.731	.897	6.101	.000
(Constant)	1.836	9.478		.194	.851

Linear and Logarithmic Plots (preservation 1993 - 2003)



H.2. Regression for preservation optimization (2003 – 2013)

Dependent Variable : Average agreement

Independent Variable : Preservation proportion (prop) in percentage

Case Processing Summary

	N
Total Cases	11
Excluded Cases[a]	0
Forecasted Cases	0
Newly Created Cases	0

a. Cases with a missing value in any variable are excluded from the analysis.

Linear Estimation (preservation 2003 - 2013)

Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
.879	.772	.747	10.884

The independent variable is prop.

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	3610.932	1	3610.932	30.483	.000
Residual	1066.128	9	118.459		
Total	4677.060	10			

The independent variable is prop.

Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
prop	.616	.112	.879	5.521	.000
(Constant)	49.163	5.686		8.646	.000

Logarithmic Estimation (preservation 2003 - 2013)

Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
.991	.983	.981	2.968

The independent variable is prop.

ANOVA

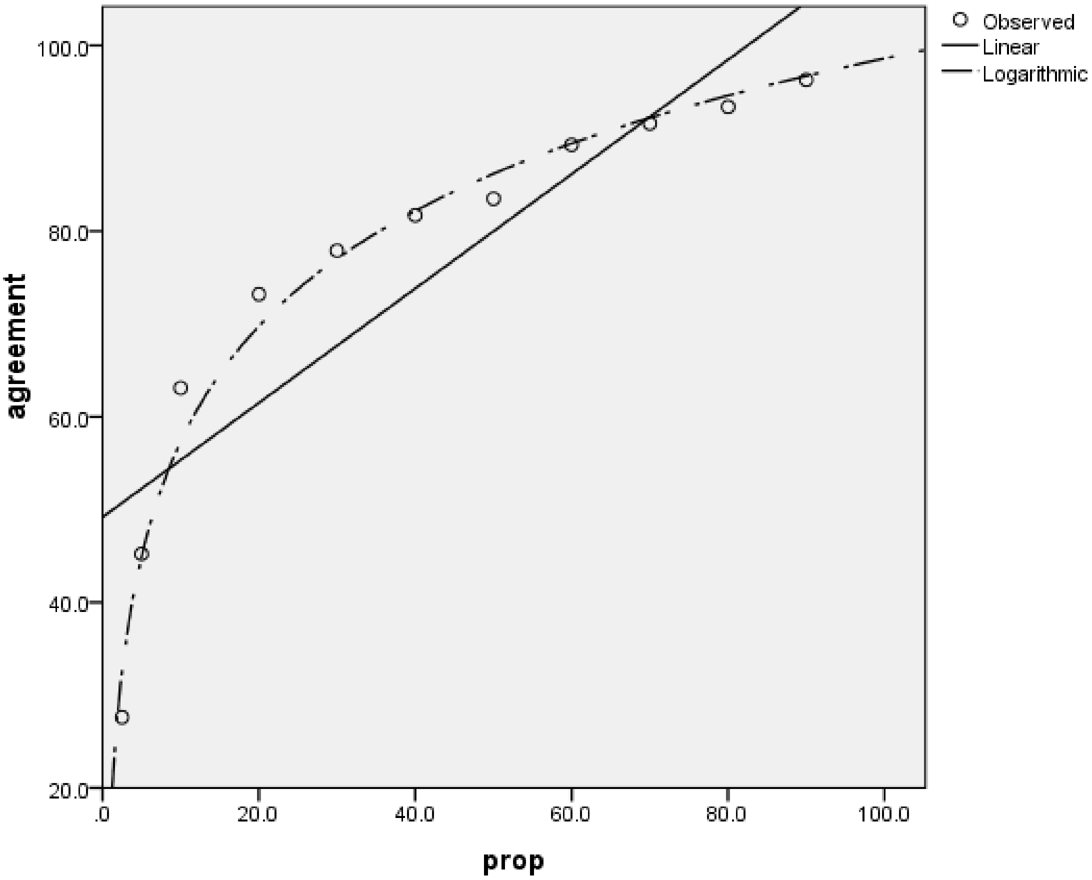
	Sum of Squares	df	Mean Square	F	Sig.
Regression	4597.796	1	4597.796	522.054	.000
Residual	79.264	9	8.807		
Total	4677.060	10			

The independent variable is prop.

Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
ln(prop)	17.932	.785	.991	22.848	.000
(Constant)	16.031	2.723		5.887	.000

Linear and Logarithmic Plots (preservation 2003 - 2013)



H.3. Regression for rehabilitation optimization (1993 – 2003)

Dependent Variable : Average agreement

Independent Variable : Rehabilitation proportion (prop) in percentage

Case Processing Summary

	N
Total Cases	11
Excluded Cases[a]	0
Forecasted Cases	0
Newly Created Cases	0

a. Cases with a missing value in any variable are excluded from the analysis.

Linear Estimation (rehabilitation 1993 – 2003)

Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
.869	.755	.728	15.937

The independent variable is prop.

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	7045.697	1	7045.697	27.742	.001
Residual	2285.770	9	253.974		
Total	9331.467	10			

The independent variable is prop.

Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
prop	.861	.163	.869	5.267	.001
(Constant)	35.243	8.326		4.233	.002

Logarithmic Estimation (rehabilitation 1993 – 2003)

Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
.990	.981	.979	4.456

The independent variable is prop.

ANOVA

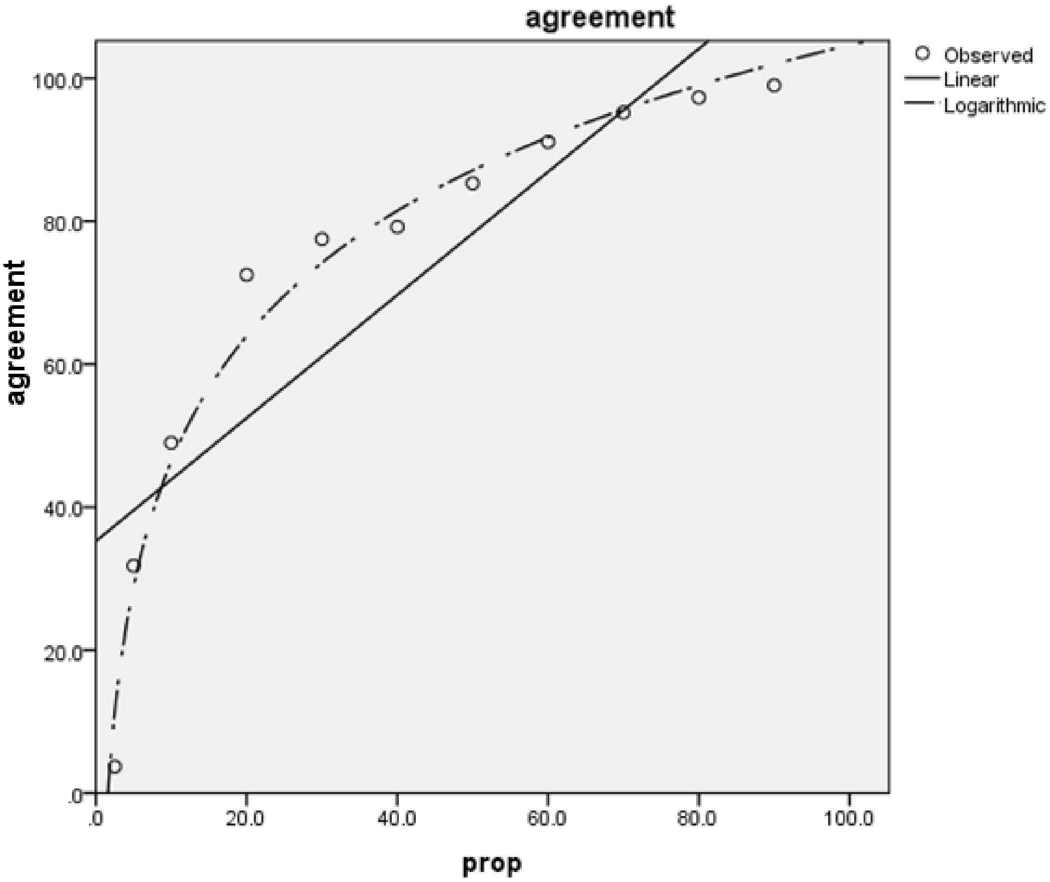
	Sum of Squares	df	Mean Square	F	Sig.
Regression	9152.738	1	9152.738	460.892	.000
Residual	178.729	9	19.859		
Total	9331.467	10			

The independent variable is prop.

Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
ln(prop)	25.300	1.178	.990	21.468	.000
(Constant)	-11.863	4.089		-2.901	.018

Linear and Logarithmic Plots (rehabilitation 1993 – 2003)



H.4. Regression for rehabilitation optimization (2003 – 2013)

Dependent Variable : Average agreement

Independent Variable : Rehabilitation proportion (prop) in percentage

Case Processing Summary

	N
Total Cases	11
Excluded Cases[a]	0
Forecasted Cases	0
Newly Created Cases	0

a. Cases with a missing value in any variable are excluded from the analysis.

Linear Estimation (rehabilitation 2003 – 2013)

Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
.930	.865	.850	2.196

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	279.067	1	279.067	57.851	.000
Residual	43.415	9	4.824		
Total	322.482	10			

The independent variable is prop.

Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
prop	.171	.023	.930	7.606	.000
(Constant)	80.400	1.147		70.070	.000

Logarithmic Estimation (rehabilitation 2003 – 2013)

Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
.744	.553	.504	4.001

The independent variable is prop.

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	178.383	1	178.383	11.141	.009
Residual	144.099	9	16.011		
Total	322.482	10			

The independent variable is prop.

Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
ln(prop)	3.532	1.058	.744	3.338	.009
(Constant)	75.952	3.672		20.685	.000

Linear and Logarithmic Plots (rehabilitation 2003 – 2013)