ANALYSIS OF THE FOREST COVER CHANGE PROCESS, USING REMOTE SENSING AND GIS,

A *Case Study in Sultan Syarif Hasyim Grand Forest Park, Riau Province, Indonesia*

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Analysis of The Forest Cover Change Process, Using Remote Sensing and GIS, A Case Study in Sultan Syarif Hasyim Grand Forest Park, Riau Province, Indonesia

By

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Disclaimer

This document describes work undertaken as part of a programme of study at the Faculty of Geo-information Science and Earth Observation (ITC) University of Twente, Enschede, The Netherlands and School of Architecture, Planning and Policy Development, Institut Teknologi Bandung, Indonesia. All views and opinions expressed therein remain the sole responsibility of the author, and do not necessarily represent those of two institutions.

Abstract

Forest cover change resulting in deforestation is one of the major problems in Indonesia. Land cover change, especially due to the conversion of forested areas into other uses, has been identified as a contributing factor to climate change. Riau has been experiencing a high deforestation rate in recent years. Land use and land cover change occur because of the rapid regional and urban development. By law, the regional development in Riau should be implemented based on the Riau's Regional Spatial Land Use Plan (RTRW). The development of Riau Province, on the one side, needs land availability. Meanwhile the land availability is relatively limited. This situation causes many conflicts of interest among land users which finally create inconsistency between the existing land use and the spatial land use plan (RTRW). This research was aimed at assessing the forest cover change process in SSH GHP and its role in resulting in deforestation. Besides, this study tries to find out the rate, locations and the main drivers of the deforestation as well as the inconsistency between the existing land use and the spatial land use plan as a result of the forest land use change process in SSH GFP. This research has effectively used remote sensing data to investigate changes in the forest cover of SSH GFP between 1989 and 2009. Land cover types of SSH GFP were classified using supervised classification and the temporal change was evaluated. Maximum likelihood classification showed an overall accuracy 79,21 % and Kappa statistic 0,7299 for image 2009. Forest was the most dominant land cover type in 1989 with total area of 5,504 Ha (93 %). But since 1989 forested area in the grand forest park has clearly been decreasing, while oil palm plantation has significantly been increasing. During 1989-2009, the forest cover decreased and it changed into shrubs, open areas (bare land), crop and oil palm plantation. The remaining forest cover in 2000, 2005 and 2009 was around 3033 Ha (51 %), 2661 ha (45 %) and 1725 Ha (29 %) respectively. The rate and area of deforestation in the period 1989-2000, 2000-2005, and 2005-2009 were 5.42 % (237 ha/year), 2.6 % (139 ha/year) and 10.84 % (287 ha/year) respectively. The average rate for the entire period was 5.8 % with total area of 3779 ha (189 ha/year). The proximate causes/direct drivers of deforestation in SSH GFP are illegal logging, land clearing for oil palm plantation development and roads development. The indirect/underlying drivers are population increase, demand of palm oil production, and weak law enforcement and political situation. There are two main other land uses existing in the study area that are not consistent with the spatial land use planning of Riau Province. Those are for oil palm plantation (1,571 ha) and crop (244 ha). The digression of the existing land use from the spatial land use plan is 30 % (1,815 ha). The highest digression exists in Kampar Regency (50 % or around 1,495 ha). The second one occurs in Pekanbaru City (15 % or about 98 ha). The third one is in Siak Regency (10 % or 221 ha).

Keywords: Forest cover change, deforestation, drivers, regional development, land use planning, Riau, Indonesia

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I. INTRODUCTION

1.1. Background

Development often creates some impacts on the environment components. Development and greater economic activities mostly lead to environment degradation and possible economic and ecological collapse if development does not consider carrying capacity. Environmental problems usually occur as a consequence of the economic growth. Therefore, development must consider economic, social and environmental aspects (Soemarwoto, 1994).

Some developing countries have better economic growth indicated by improvement of export and income, good health and better education. On the other hand, the economic growth itself in some cases brings about environmental problems for forest resource such as deforestation, degradation and so on.

Forest resource in many developing countries plays important roles in the national economic development both as a source of countries' national income and as a source of livelihood for local people. Moreover, forest is very important for global environment.

Forest trees play an important role in regulating our climate because during photosynthesis, trees remove carbon dioxide (CO_2) from the atmosphere as they grow and store it as carbon in carbohydrates, lignin and cellulose (Rollinson, 2007). From this view, forest trees keep CO_2 concentration in the atmosphere low. If CO_2 concentration in the atmosphere increases, it will contribute to global warming, causing severe weather events, damaging the economy, causing pollution, flooding, damaging infrastructure, disasters, etc. In other words, rising CO_2 have an adverse effect on human welfare (Barker, 2005).

Forests cover approximately 30% of the Earth's land surface and provide critical ecosystem goods and services, including food, fodder, water, shelter, nutrient cycling, and cultural and recreational value. Forests also provide habitat for a wide range of species and help alleviate land degradation and desertification (UNFCCC, 2007).

1.1.1. Land cover change and global Deforestation

Land-cover change, especially the conversion of forest areas into other uses, has been identified as a contributing factor to climate change, accounting for 33 percent of the increase in atmospheric CO_2 (de Sherbinin, 2002). In 1990s, 0.38 percent of forests were converted into other land uses every year (i.e. deforested) (FAO, 2001).

Nowadays, many forest areas change to non forest, global deforestation is one of the core problems of global environmental change(Cassel-Gintz and Petschel-Held, 2000). Government of Indonesia-FAO stated that tropical deforestation estimated for 1990–1995 was 116,756 km^2 per year globally (GoI-FAO, 1996). In the period of 2000-2005, net global forest loss was estimated to be about 7.3 million hectares per year (FAO, 2009).

After Brazil, Indonesia is the second largest annual net loss in forest area from 2000 to 2005 (FAO, 2006). Ten countries with the largest annual net negative change rate and the largest net loss in forest area from 2000 to 2005 are given in Appendix 27.

In the context of global climate change, deforestation contributes significantly to global CO_2 emission which is considered the second largest source of anthropogenic greenhouse gas emissions (IPCC, 2007). Tropical forest may be decisive in global efforts to stabilize greenhouse gas (GHG) concentrations at levels that avoid dangerous interference in the climate system (Santilli, 2005). On a global scale, land use, land use change, and forestry (LULUCF) activities are currently net sources of carbon dioxide to the atmosphere, mainly as a result of deforestation and forest degradation (Harris *et al.*, 2008). Tropical deforestation is expected to remain a major emission source for the foreseeable future (Kindermann *et al.*, 2007).

Deforestation is most prominent in tropical regions such as Africa, Latin America and parts of Asia. FAO (2009) stated that the Asia and the Pacific region contains 18.6% of the world's forest area located in a wide range of ecosystems, including tropical and temperate forests, mangroves, mountains and deserts. Rapid socio-economic development in this region is having significant impacts on all sectors, including forestry; demand for wood products is increasing simultaneously (FAO, 2009).

Two dominant development paths are rapid economic growth through industrialization of some countries and agriculture as main source of livelihoods for other countries, both paths lead to forest loss (FAO, 2009).

1.1.2. Deforestation in Indonesia

Indonesia is situated on the equator and has a vast and dense tropical forest. Hence, Indonesia has numerous natural resources with valuable biodiversity, not only for Indonesia, but also for international society. After Brazil and Zaire, Indonesia ranks third in its endowment in tropical rain forest (Sunderlin *et al.*, 2005). So Indonesia plays an important role in contributing to carbon sequestration from the forest area. But Indonesia is also the world's largest emitter of CO_2 due to deforestation and forest land use change.

Indonesia is also facing the deforestation problem (World_Bank, 1994). According to FAO (1990), the forest cover in Indonesia reduced from 74 % to 54 % in the period of 30-40 years. In 1996 total cover in Indonesia is 120.6 million ha or 69% of total territory (GoI-FAO, 1996). While in 2003, it decreased to more than 90 million ha, equivalent to 46 percent of total land area. FAO (2009) stated that during 2000-2005, annual change of forest cover in Indonesia was 1.87 million ha (2.0%). Ministry of Forestry also described that the deforestation rate in Indonesia during 1985-1997 was around 1.6 million ha per year, while during 1997-2000 it was 2.8 million per ha and deforestation rate in 2000-2005 was 1.08 million ha per year (MoF, 2008).

Deforestation also occurred in some regions in Indonesia. Especially in Riau Province, deforestation occurred rapidly and it is a serious environment issue in local, national or global scale. Many conservation forests in Riau Province such as Grand Forest Park or National Park face deforestation problems.

1.1.3. Drivers of deforestation

The drivers of deforestation vary from a region to another region (Badiozamani, 2007); (Lambin and Geist, 2003); (Rademakers *et al.*, 2010) and they stated that tropical forests disappeared as a result of many pressures, acting in various combination. They also stated that deforestation is caused by multiple drivers, including conversion for agricultural uses, infrastructure development and wood extraction. These three drivers are mentioned in 96%, 72%, and 67 % of the studies investigating causes of deforestation in a meta-analysis of (Geist and Lambin, 2002).

In addition, economic factors such as agricultural product prices etc play an important role in driving deforestation (UNFCCC, 2006). The Ministry of Forestry stated that Indonesian forests have been disturbed from social economic activities related to regional development and unsustainable practices by many sectors and actors (MoF, 2003). So, there is rarely a single direct or indirect driver responsible for deforestation; most often, multiple processes work simultaneously or successively causing deforestation (Rademakers *et al.*, 2010).

According to (Rademakers *et al.*, 2010) there are two kinds of drivers ; direct and indirect drivers, also called proximate causes and underlying drivers (Lambin and Geist, 2003). Direct drivers/proximate causes of deforestation are those causes directly leading to forest decline. So, there are human activities or direct actions at the local level, such as agricultural expansion, that originate from intended land use and directly impact forest cover.

Next to the direct drivers of deforestation, one can also observe more indirectly related global drivers affecting the pressure levels on the direct drivers. The indirect drivers of deforestation are a complex interplay of many economic, institutional/governance policies including land tenure systems, and technological and demographic/socio-cultural factors (Rademakers *et al.*, 2010); (de Sherbinin, 2002).

The world population are projected to increase from 6.4 billion in 2005 to 7.5 billion in 2020 to 8.2 billion in 2030. As a consequence, food demand will increase significantly, as will the pressures on land to accommodate the housing, transportation and other needs of this growing population (Rademakers *et al.*, 2010).

The local governance and institutions play roles in setting the policies and legislation to protect and/or sustainably manage forests. In certain cases they can be considered a potential indirect driver of deforestation. If a country is facing a low capacity for good governance and the enforcement of policies and laws, it may be more prone to deforestation activities, such as illegal logging, unsustainable forest management, etc. (Rademakers *et al.*, 2010).

Lambin and Geist (2003) said that governance drivers of deforestation in South East Asia are policies facilitating colonization and state plantations, large transmigration projects, weak enforcement of forestry law, and insecure land ownership.

Regional development, not only gives positive impacts for human welfare, but also generates negative impacts on the forest indirectly. Riau province is one of province that has achieved good results as seen from the level of economic growth and rapid regional development (BPS, 2009), but environment problem such as deforestation also found in this region.

There are many factors in Indonesia that directly cause deforestation. The direct cause can be either legal (transmigration, logging concession, timber plantation, oil palm plantation, road and infrastructure construction), or illegal (illegal logging, agriculture activities, encroachment) (MoF, 2003); (Sunderlin and Resosudarmo, 2004). Indirect drivers such as demand for agriculture products and timber, additional pressure from population growth, global policy incentives such as bio-fuels targets contribute to forest clearance.

Reformation era, decentralization or regional autonomy applied in Indonesia is based on law 22 of 1999. Indirectly, the reformation and autonomy era sometimes create the negative impacts for environment and natural resources such as forest. Many cities/regencies allow companies to open the forest area in order to improve the economic development and generate revenue. So, reformation is one of the indirect drivers, causing farmers to clear forest.

Other drivers playing an important contribution to deforestation are policy incentives. They can be either direct, such as subsidies, or indirect, such as for building roads or encouraging migration to them, land tenure systems, and other governance related incentives. They act globally, regionally and locally (Eliasch, 2008).

World Bank (1994) stated that programs conducted by government such as transmigration, plantation and logging caused 67 % of all deforestation. The development and growth of plantation can threaten the forest cover. The main factor contributing to forest clearance in Indonesia in the last decennia is agriculture expansion (Miyamoto, 2005). Main agriculture expansion especially in Riau Province is oil palm plantation development. Development of new plantations has resulted in greater conversion of forest areas with high conservation value and has been threatening the rich biodiversity in the ecosystem (RSPO, 2007). Rapid increasing demand has made oil palm a booming business with related consequences for natural forests.

1.1.4. Oil Palm Plantation Development

Palm oil is an important and versatile raw material for both food and non-food industries, which contributes to the economic development of the producing countries and to the diets of millions of people around the world (RSPO, 2007) The increasing demand for biofuel to replace fossil fuels leads to a higher demand for palm oil. As consequences, oil plantation has grown rapidly in order to supply the demand of palm oil, but on the other hand, oil palm plantation is the threat to biodiversity in Southeast Asia (Wilcove and Koh, 2010). Oil palm continues to expand across the tropical forest. He also said that those concerned about the impacts of oil palm on biodiversity must face some harsh social, economic, and ecological realities.

Oil palm cultivated area in the world is increasing rapidly. We can see the increasing as shown in the figure 1.

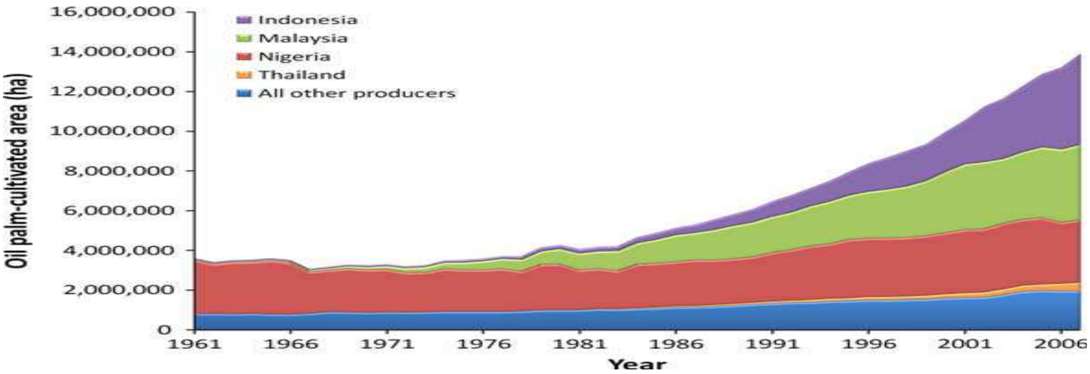


Figure 1 The increase in oil-palm cultivated area from 1961 to 2007 in the world's four largest producers of oil palm *(source : (Wilcove and Koh, 2010).*

From 1990 to date, the area under oil palm cultivation has increased by approximately 43%, which are mostly located in Malaysia and Indonesia - the world's largest producer of palm oil (Wilcove and Koh, 2010). While well-managed oil palm plantations into sustainable agriculture model, in terms of economic performance and social and environmental responsibility, there are serious concerns that not all palm oil produced in a sustainable manner today.

Indonesia is recorded as a country that has an area of more than 1 million ha for oil palm cultivation in 2006. In figure 2 showed the extent of oil palm cultivation in 2006.

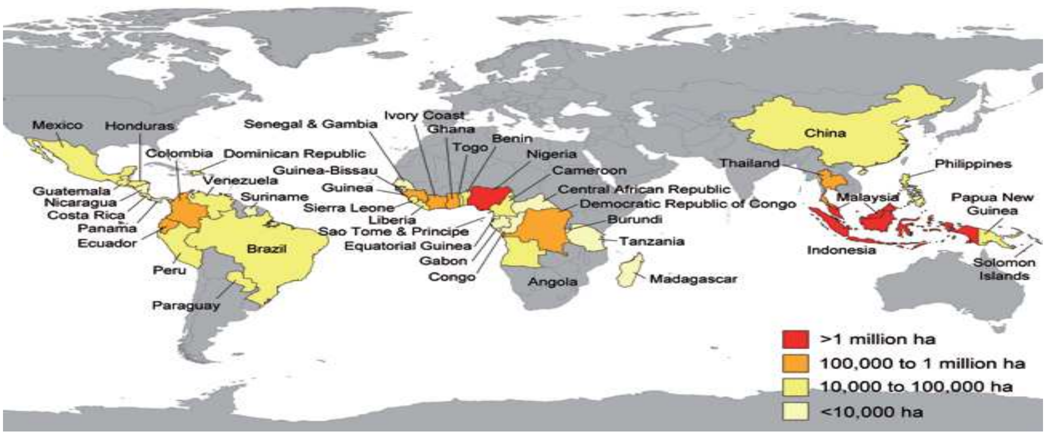


Figure 2 The extent of oil palm cultivation in 43 oil palm-producing countries in 2006.
(Source : Koh and Wilcove (2008).

Indonesia is experiencing the biggest rate of increase in term of forests converted into oil palm plantation. In 30 year period (1967-1997) oil palm plantations have increased 20 times

(Casson, 1999). Sumatera has the majority of existing oil palm plantations of Indonesia, mainly located in 4 provinces namely North Sumatera, Riau, Jambi and South Sumatera (Sharma, 2009). Oil palm plantation development in Riau is growing rapidly as the impacts of regional development with related consequences to forest resources loss in Riau province.

1.1.5. Forest and Regional Development in Riau

Riau Province located in Sumatera Island ranks first in the distribution of forest cover in Sumatera. Forest in Riau (with a total area of about 4,320,792 hectares), on the basis of the Forest Land Use Plan of Riau (TGHK), are divided, according to forest functions, into four types namely; conservation forest, protection forest, permanent production forest and limited production forest.

However, currently the natural forest resource in Riau is in a serious condition since it tends to decrease annually. This is because many oil palm plantations and forest plantation industries have been built in Riau. WWF in 2008 stated that forest in Riau declined by 65 % over the past 25 years and deforestation has been driven by oil palm plantations, pulp and paper industries, infrastructures, and other plantations.

Riau has the largest oil palm plantation area in Indonesia. The development of oil palm plantation in Riau tends to increase rapidly. The total area of oil palm plantations increase significantly from 2,078 hectares in 1980 to 1,679,845 hectares in 2008 (BPS, 2009). The development of plantation indirectly accelerates road construction for improving the accessibility. In 1998, the length of road in Riau was 13,338 km and in 2008 increased to 22,130,59 km (BPS, 2009).

Population in Riau increased from 3,279,000 inhabitants in 1990 to 5,189,154 inhabitants in 2008 (BPS, 2009). Conversion of forest land creates benefits by allowing expansion of agricultural and sustenance for a rapid growing population. Data on population shows a strong inverse relationship to forest cover (Sunderlin and Resosudarmo, 2004). The forest declined in Riau not only occurs in production forest but also in conservation forest such as Grand Forest Park.

1.1.6. Grand Forest Park

One of the functions of the forest is a conservation function. Riau Province has several conservation forests. One of which is ***Sultan Syarif Hasyim Grand Forest Park (SSH GFP).*** It is the only one Grand Forest Park in Riau Province. GFP is a nature conservation area which functions not only for biodiversity conservation, but also for research, education, ecotourism, recreation and for the habitat of various flora and fauna. Moreover, the park functions as a city forest and a green open space.

SSH GFP is situated in two regencies and one city namely Kampar Regency, Siak Regency and Pekanbaru City. Unfortunately, the condition of the SSH GFP has been in a serious problem. Based on the decree of the Minister of Forestry of the Republic of Indonesia Number 348 dated

26th May 1999, the area of SSH GFP was 6172 Ha. But now, the existing forested area decreases gradually. To manage the grand forest park, the Management Unit of SSH GFP has been established in 2009 based on the Governor of Riau Decree Number 61 dated 20th February 2009.

1.2. Research Problem

Land cover change, especially the conversion of forested areas into other uses, has been identified as a contributing factor to climate change, accounting for 33 percent of the increase in atmospheric CO_2 (de Sherbinin, 2002). The most significant historical change in land cover has been the expansion of agricultural land at the expense of forest land. Other, poor agricultural practices in developing countries are mainly causes of land degradation

In a local scope, a land cover change problem can be seen in Riau Province. On the one hand, Riau Province's tropical forest is a very potential carbon store. But on the other hand, Riau Province has been experiencing a high deforestation rate in recent years. Riau thus contributes significantly to Indonesia's GHG emissions through land use/land use change and forestry.

The rapid oil palm development in Riau Province has created negative impacts on environment. The oil palm development in this province, on the one side, needs land availability. Meanwhile the land availability is relatively limited. This situation causes many conflicts of interest among land users which finally create inconsistency between the existing land use and the spatial land use plan (RTWP).

By law, all development activities in Riau including oil palm development should be implemented based on the Riau's Regional Spatial Use Plan (RTRW), a spatial planning which describes the structure and pattern of the future spatial use plan of the region. The spatial use on the basis of the Riau's Regional Spatial Use Plan is divided into two main kinds namely the spatial uses for cultivation purposes (agriculture, plantation, settlement etc) and for protection purposes (conservation forest, protection forest etc).

As a conservation forest, the Grand Forest Park of Sultan Syarif Hasim, based on the Riau's Regional Spatial Use Plan (RTRW), belongs to the spatial use for protection purposes such as for biodiversity conservation, research, education, ecotourism, recreation area and a wildlife habitat. It also maintains the micro-climate and protects the biodiversity. In conclusion, the development for cultivation purposes such as oil palm plantation etc in the grand forest park is not allowed at all. Unfortunately, the grand forest park has encountered a very serious problem and tends to decrease gradually because of human activities. This condition can lead to degradation and deforestation. This is due to the emergence of many plantations surrounding and inside the grand forest park.

One of the main causes of the above conditions is due to the lack of integrated and detailed spatial information that can support policy making in the rescue of the GFP. Important information about the forest cover change spots that lead into deforestation takes place most, the extent, and how the process evolves over time, including the drivers, and if there is a direct relation with the oil palm demand are not available yet so that such poor information creates difficulties for the grand forest park management and protection.

From this point of view, forest cover change process, how it leads into deforestation, the rate and locations of deforestation need to be assessed including an analysis of the main drivers and the inconsistency between the existing land use and land use plan in SSH GFP from the Regional Spatial Use Plan of Riau Province (RTRW).

Therefore, this research analyzed the process of forest cover change in the GFP, where the deforestation areas are, rate and including analysis of the main drivers of deforestation and the comparison of the existing land use compared to the land use plan of the GFP according to the Riau's Regional Spatial Use Plan (RTRW). It is hoped that this research will assist the government of Riau Province and the management unit of SSH GFP to develop appropriate planning and strategies and define priorities and actions for conserving forests currently under deforestation in order to avoid and reduce further deforestation.

Finally, by understanding the existing land-use and land-cover change process, we can better understand the process of land cover change and finally contribute to the good management and protection of the grand forest park.

1.3. Research Objectives

The General Objective is to assess forest cover change in SSH GHP, its role in resulting in deforestation. Besides, this study tries to find out the locations, rate, and main drivers of deforestation as well as the inconsistency between the existing land use and the land use plan of the SSH GFP due to the forest land use change process in SSH GFP.

The Specific objectives :

1. To assess the forest cover change process resulting in deforestation in SSH GFP.
2. To identify the locations and rate of deforestation of SSH GFP.
3. To analyze the main drivers of deforestation in SSH GFP.
4. To analyze the inconsistency between the existing land use and the land use plan of the GFP according to the Regional Spatial Use Plan of Riau Province (RTRW).

1.4. Research Questions

1. How does the forest cover change process occur in SSH GFP?
2. Where are the locations and what are the rates of deforestation in SSH GFP?
3. What are the main drivers of deforestation in SSH GFP?
4. How is the inconsistency between the existing land use and the land use plan of the GFP according to the Riau's Regional Spatial Use Plan (RTRW)?

1.5. Conceptual Framework

The conceptual framework of this research incorporates forest cover changes process resulting in deforestation and the regional development in Riau Province. Regional Development in Riau based on Regional Spatial Land Use Plan (RTRW) of Riau Province. RTRW of Riau province regulates regional spatial planning into two major guidelines which are protected area and cultivation area. Cultivation area includes plantation, industry, infrastructure, agriculture, settlement, etc should be implemented in non forest area. However, many cultivation areas were implemented in forested area. Land use and land cover change occurred in recent years because of the rapid regional and urban development. Riau province has been experiencing a high deforestation rate. This situation also occurs in conservation forest such as Grand Forest Park. Understanding of forest cover change process and current forest condition and the drivers of deforestation is important for proper planning in the future. The flowchart in figure 3 shows the conceptual framework of this research.

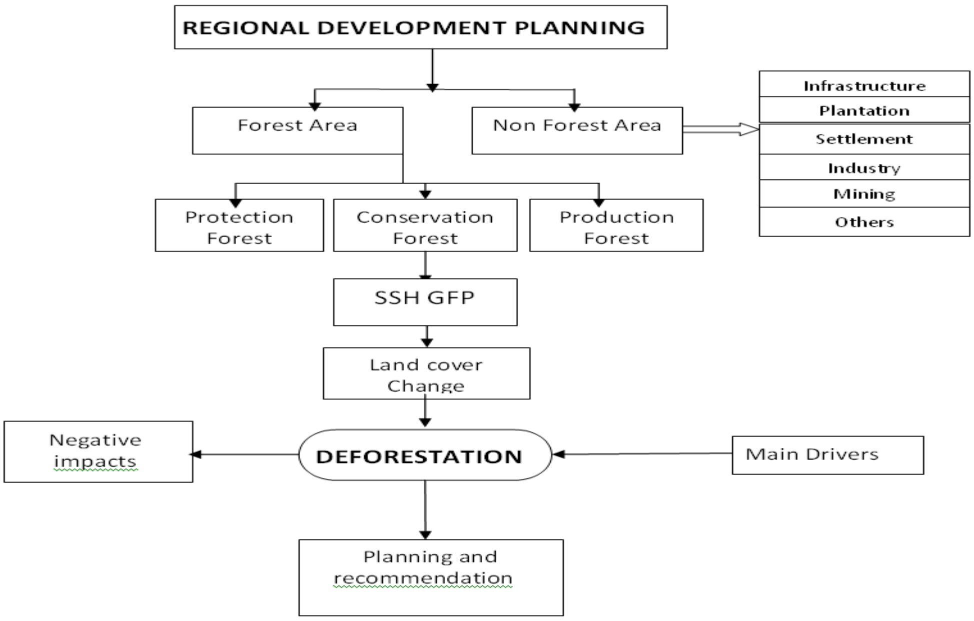


Figure 3 Conceptual framework

1.6. Thesis Structure

This report consist of 5 chapters, these are:

Chapter 1, Explains thesis background and problem. Objective and research question were determined to limit and focus methodology and analysis.

Chapter 2, Reviews literature related to and support this study from various aspects.

Chapter 3, Gives overview to the reader about condition of the study area and details the materials and methods that used to answer the research questions in this study.

Chapter 4, Results, presents the main results obtained by the research.

Chapter 5, Discussions, discussed the main finding of this study, analyzing the result.

Chapter 6, Concludes the research and overviews the scope for further research.

II. CONCEPTS AND DEFINITIONS

2.1. Land cover and land use

Land cover is defined as the observed physical cover including the vegetation (natural or planted) and human constructions that cover the earth's surface. Land cover includes water, ice, bare rock, and sand surfaces (Herold, 2009). Di Gregio (2005) stated that land cover is the observed biophysical cover on the earth's surface confined to the description of vegetation and man-made features. The primary units for characterizing land cover are categories such as forest or open water or continuous variables classifiers (e.g. fraction of tree canopy cover) (Herold, 2009).

Gomarasca (2009) defined land cover as physical surface of the earth which has combinations in various feature of natural and cultivated vegetation and man-made infrastructures, while water, glaciers, rocks and bare soil and surface without vegetation though being part of terrestrial surface, and not of land cover, but often considered land cover for practical reasons.

Land use is characterized by the arrangements, activities and inputs people undertake in a certain land cover type to produce, change or maintain it. Definition of land use in this way establishes a direct link between land cover and the actions of people in their environment (Di Gregorio, 2005). Land use, which concerns the purpose or function for which the land is being used, should be considered separately from land cover type. Land use is described as human activities on land while land cover refers to the vegetation and artificial construction covering the land surface (Anderson *et al*, 1976).

Human being is the agent of the land use, and the land use's dynamics are indicator of the land use changes and the purpose for which lands are being used commonly have associated types of cover whether they be forest, agricultural, residential, or industrial (Anderson *et al.*, 2001).

2.2. Land cover and land use Change

Land-use and land-cover change (LULCC) also known as land change is a general term for the human modification of Earth's terrestrial surface (Pontius, 2007). The change is in the physical surface of the Earth (vegetation, water, urban centres, etc.). Land cover change as a quantitative change in the area of a given type of land cover (Lampyet *et al.*, 2005). Meyer and Turner (1994) defined land use change as the alteration on the way humans use land.

Land use change as affected by human institutions, population size, economic development, technology and other factors. While land use change is often a drivers of environment and climate change (CCSP, 2006). Land use change is often associated with a change in land cover. Humans have been using and modifying land to obtain food and other resources for thousands of years. Monitoring and mediating the negative consequences of LULCC while sustaining the production of essential resources has therefore become a major priority of researchers and policymakers around the world (IPCC, 2000).

2.3. Forest/ Forest Cover

Forests are usually composed of many individual stands in different stages of development and with different characteristics. Thus, a forest can include a range of different forested ecosystems composed of different species and different ages and having different carbon stock densities (t C ha^{-1}) (IPCC, 2006).

Forest/forest cover is land on which trees form the dominant vegetation type. The FAO defines forest as land with tree crown cover of more than 10 percent of the ground and land area of more than 0.5 ha. In addition, the trees should characteristically reach a minimum height of 5 m at maturity. It should be noted that a canopy cover threshold of 10 percent represents quite sparse tree cover; most natural forest in Indonesia is closed canopy forest. In this research, the term forest refers to the whole forest (as a landscape), including its forest stands (its component units).

2.4. Deforestation

In the context of Kyoto Protocol deforestation is defined as a direct human induced conversion of forested land to non-forested land. FAO in IPCC (2000) stated that deforestation refers to change of land cover with depletion of tree crown cover to less than 10%. Changes within the forest class (e.g., from closed to open forest) that negatively affect the stand or site and, in particular, lower the production capacity are termed forest degradation.

IPCC (2000) defined deforestation as conversion of forest to non-forest. So conversion of forests to pasture, cropland, or other managed uses is referred to as “deforestation”. Ministry of Forestry Republic Indonesia defines deforestation as “conversion of forest land into non-forestland” such as agriculture lands, estate crops, settlement, or industrial area, etc (MoF, 2006). So the definition of deforestation in this research is the changing of forest to other land cover. In many developing countries most of forests have been exposed to intensive logging and repeated fires, these forests may change into grassland or critical lands.

2.5. Oil Palm

The strong demand for food especially fats and oil has encouraged and influenced expansion of oil palm cultivation in Indonesia. Started from Sumatera Island, it spread out to other island such as Kalimantan, Sulawesi and Papua. Oil palm production contributes to the development of rural area in improvement of standard of living of rural population. Nowadays the main demand for palm oil comes from the biofuel industry. Palm oil is now starting to be used and ingredients in bio-diesel and as a fuel to be burn in power stations to produce electricity. Friend of Earth stated that the global demand for this commodity increases due to the new market for palm oil (FoE, 2006).

Palm tree (*Elaeis guineensis*) is the tropical forest palm native to West and Central Africa. It was first brought to Indonesia as an ornamental plant in 1948. In 1969, Indonesia produces palm oil and palm kernel, but used for the domestic market and partly was exported. Until the early 1970s palm oil cultivation was done by big plantation companies. Small private companies and farmers come into this business in 1975 (Bangun, 2006);(Sheil *et al.*, 2009)).

Soil and climate in many places in Indonesia are suitable for oil palm growth. But the soil and climatic conditions are also suitable for other crops such as palm trees, rubber, cocoa and spices. In the year 1974 palm oil prices in international markets were very high, efforts were made to increase production. The government established a program called Nucleus Estate Scheme (NES), in which state owned plantation company helps farmers to grow oil palm. Plantation companies provide seeds, technical assistance and financing to small businesses. Their products were purchased by the company factory. Grown in plantations it produces 3-8 times more oil from a given area than any other tropical or temperate oil crop (Bangun, 2006); (Sheil *et al.*, 2009).

As a result, this policy makes impact for more and more farmers and small companies are interested to plant oil palm. As a result of growth of oil palm area after the year 1975, oil palm plantation area has been increased. Major components of oil palm plantation area are large companies (both foreign and domestic), state enterprise, private owned and small businesses. Currently about 32% of the total planted area owned by small holders, about 50% to large companies and about 18% to state-owned companies (Bangun, 2006).

2.6. Grand Forest Park

Taman Hutan Raya (Grand Forest Park), based on Law of Republic Indonesia Number 5 year 1990 is one of conservation forest that is having particular characteristics to protect life support systems, biodiversity of flora and fauna, utilization of natural resources and its ecosystem.

GFP is a nature conservation are that primarily used for the purpose of collection of flora and fauna, either natural or artificial for the purposes of science, education and training, culture, tourism, and recreation.

2.7. Image classification

Image classification is the process of assigning pixels to classes (Jensen, 1996). Kerle *et al*., (2004) defined image classification as the selection and preparation of the image data, definition of clusters in the feature space, selection of classification algorithm and validation of the result. There are two classification categories exist which are supervised classification in which the operator controls the entire procedure and unsupervised classification, where by most of the process is automated.

Supervised classification

Supervised classification involves applying a training process closely controlled by the analyst who must have good experience in the field (area of interest), because in this method the operator defines the spectral characteristics of the classes by identifying sample areas (training areas). The training samples (pixel representing known locations of the area being classified) are then used to classify the remainder of the images (Hussin, 2003); Landstrom (2003) in Gondwe (2005).

Unsupervised classification

In unsupervised classification a statistical clustering technique is employed to combine pixels of similar feature into groups (classes). Kerle *et al*. (2004) stated that the main purposed of unsupervised classification is to produce spectral groupings based on certain spectral similarities.

Brandts *et al.*(2009) stated that the supervised approach is preferred by most researchers because it generally gives more accurate class definitions and the higher accuracy than the unsupervised classification. Both the supervised and unsupervised classifications use the services of a classifier algorithm of which the maximum likelihood is the most popular. Maximum likelihood is actually the probability that a pixel belonging to specific classes. It is a statistical decision rule that examines the probability function of a pixel for each of the classes, and assigns the pixel to the class with the highest probability and is perhaps the most widely used classification method. It is one of the most popular methods of classification in remote sensing and usually provides the highest classification accuracies (Hubert-Moy *et al.*, 2001).

2.8. Change Detection

Change detection is the process of identifying differences in the state of object or phenomenon by comparing observations made on them at different times (Landstrom, 2003 cited in Gondwe (2005). Essentially, it involves the ability to quantify temporal effects using multi temporal data sets (Singh, 1989). Satellite imagery has been well utilized in the natural science communities for measuring qualitative and quantitative terrestrial land cover changes (Collins and Woodcock, 1996).

Many change detection methods have been developed and used for various applications. They can be broadly divided into: post-classification and spectral change detection approaches (Singh, 1989). Spectral change detection techniques rely on the principle that land cover changes result in persistent changes in spectral signature of the affected land surface (Chen, 2000), while post classification is among the most widely applied techniques for change detection purposes. Numerous studies have been carried out using post classification approach. In post classification change detection approach two images from different dates are classified and labelled (Chen, 2000). The area of change is then extracted through the direct comparison of the classification results (ITC, 2003). For the old images, it was classified through selection of training area for classification by using land cover map in the corresponding year and picking training sample from unchanged area and also by verifying with people (local knowledge). Main advantage of post classification include detailed information of the original land cover that change into certain land covers.

2.9. Drivers of deforestation

The Millennium Ecosystem Assessment (MEA) defined a driver is any natural or human-induced factor that directly or indirectly causes a change in an ecosystem (Carpenter *et al.*, 2006). According to Rademakers *et al*. (2010), there are two kind of drivers, direct and indirect drivers of deforestation, also called proximate causes and underlying drivers (Geist and Lambin, 2002). Direct drivers/proximate cause of deforestation are those that directly lead to forest decline. For example, 'excessive logging' or 'forest conversion into agricultural land' directly implies a reduction of forests. So, there are human activities or immediate actions at the local level, such as agricultural expansion, that originate from intended land use and directly impact forest cover.

An indirect driver operates more diffusely by altering one or more direct drivers, so it can also observe more indirectly related global drivers affecting the pressure levels on the direct drivers. The indirect drivers of deforestation are a complex interplay of many economic, institutional/governance, technological and demographic/cultural factors (Rademakers *et al.*, 2010).

Deforestation is caused by multiple drivers and pressures, including conversion for agricultural uses, infrastructure development, wood extraction, agricultural product prices, and a complex set of additional institutional and location-specific factors (Rademakers *et al.*, 2010) which can be extremely important in certain localities. There is rarely a single direct or indirect driver responsible for deforestation; most often, multiple processes work simultaneously or sequentially causing deforestation (Rademakers *et al.*, 2010). Tropical deforestation is best explained by multiple factors rather than single variables (Nelson *et al.*, 2006).

According to Rademakers *et al*., (2010) the main broad categories of global indirect deforestation drivers are economic growth and associated pressures on natural resources, the influence of worldwide policy-making/governance and technological innovation, demographic changes and associated pressures on natural resources. Furthermore, additional pressure from population growth, global policy incentives could also create pressure for forest clearance. The policy, lack of clear and secure land tenure can be a major factor driving deforestation in many nations (Eliasch, 2008).

III. MATERIAL AND METHODS

3.1. Study Area

3.1.1. Location

Sultan Syarif Hasyim Grand Forest Park is located in Riau Province, Sumatera Island, Indonesia. *Taman Hutan Raya/Tahura* (Grand Forest Park) is a natural conservation area designed to provide a habitat of indigenous and/or introduced plants and animals for research, science, education, culture, recreation and tourism purposes. SSH GFP is situated in two regencies and one city namely Kampar Regency, Siak Regency and Pekanbaru City with a total area of 6,172 ha. it can be reached from Pekanbaru City Center within 20 minutes. The position of the Grand Forest Par is geographically between the coordinates $0^0 37'$ N - $0^0 44'$ N and $101^0 20'$E-$101^0 28'$E.

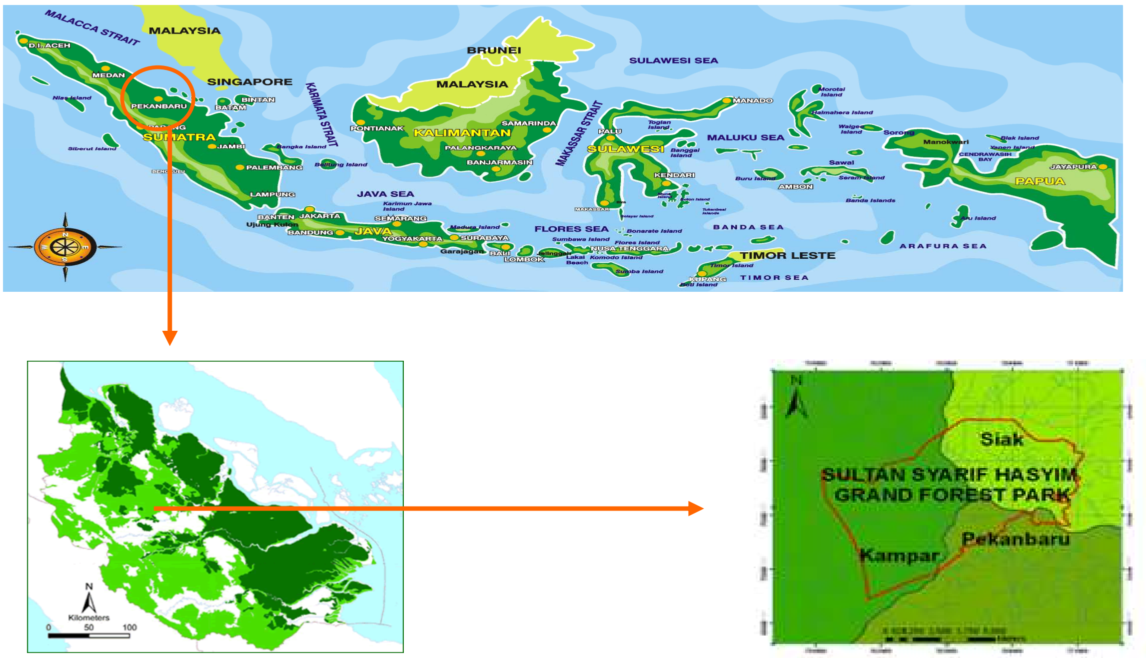


Figure 4 Map of Study Area

3.1.2. Climate

The study area has a wet tropical climate with average rainfall ranging from 2000-3000 mm per year with approximately 207 days of rain per year (BPS, 2009) and is affected by the dry and rainy seasons. Furthermore, according to records of Meteorological Station Simpang Tiga, Pekanbaru, the average air temperature in 2008 showed a maximum temperature of 34.6 Celsius with minimum temperature of 22.0 Celsius and average humidity of 80 %.

3.1.3. Topography

This area includes the Takuana forest cluster with topography flat to undulating. The average elevation is 21 m above sea level and there are river flowing through the study area. SSH GFP area is the catchment area of Siak watershed. The biggest river is Takuana river.

3.1.4. Social economic situation

Based on the data 2009, the total population of these three regencies/city is 1,804,414 people and the highest population increase is in the period 1980-1990 which is 6.63 % . This high population growth rate is because of migration to this region. The total population in Kampar Regency, Siak Regency and Pekanbaru City is shown in the following table.

Table 1 Population in Kampar Regency, Siak Regency and Pekanbaru City

Regencies/City	Population			
	1980	1990	2000	2009
1. Siak	53,270	131,579	238,468	329,807
2. Kampar	174,842	288,382	445,106	640,230
3. Pekanbaru	237,762	398,694	582,240	834,378
Total	465,874	818,655	1,265,314	1,804,414

Source : (BPS, 2009)

The local people living surrounding the grand forest park earn their living through agriculture and plantations, loggers, trading, cattle raising and fishery. The average income per capita is 1,075,300 rupiah (100 USD) per month.

3.1.5. Forest Resources

The SSH GFP is rich with flora and fauna. The dominant species of flora are the family of *Diepterocarpaceae,Lauraceae, Euphorbiaceae, Anacardiaceae, Guttiferae, Sapetaceae*. Fauna species are high variety, at least 42 types of bird, 4 reptile types. Among 42 bird types, there is one species of bird that is the only one in Sumatera namely Srigunting Sumatera (*Sumatranus dicrurus*), besides other birds like hawk (*Haliaetus, sp*), Hornbill (*Buceros rhinoceros*), etc. While mammal species mostly are protected species, such as sumatera elephant, sumatran tiger, forest pig, etc (FSoRP, 2005).

3.1.6. The Process of the Establishment

According to Regional Land Use Plan of Riau Province (RTRW) Number 10 in the year 1994, the area of SSH GFP was stated and categorized as Protected Area. In 1994, Governor of Riau Province proposed and recommended the area to the Ministry of Forestry as a Grand Forest Park. Finally, the Minister of Forestry and Plantation established the area as Grand Forest Park in 1999 according to the Minister of Forestry and Plantation Republic Indonesia Decree Number 348/Kpts-II/1999, 26 May 1999. The grand forest park is further named *Taman Hutan Raya Sultan Syarif Hayim* (Sultan Syarif Hasyim Grand Forest Park) covering 6,172 ha.

The process of the establishment took a long time (5 years). This situation influenced the quality of vegetation in the park. During the long process of the establishment (from 1994-1999), deforestation took place and followed by oil palm plantation settled in the park.

3.1.7. Management and Organization

The management has also been changed since the decentralization era implemented in Indonesia. Before 2000, the management of the area was under the responsibility of the Central Government of Indonesia (Ministry of Forestry) and since 2001 the management has been handled by the provincial government of Riau Province. In this period, a master plan of SSH GFP was completed in 2004, but this plan could not be implemented because there was no a special management unit that responsible for managing the SSH GFP. Finally, in 2009, based on Governor of Riau Decree Number : 61 date 20 February 2009 about the establisment of SSH GFP Office, the SSH GFP management unit was established under the Forestry Services of Riau Province.

3.2. Materials

3.2.1. Imageries and maps

The imageries and maps that were used in this study as shown in the table 2 and 3 :

Table 2 List of imageries used in the research

No	Images	Resolution	Date of Acquisition	Source
a.	Landsat 1989	30 meter	07 September 1989	WWF
b.	Quick look spot 1 , 1997	-	01 March 1997	http://www.crisp.nus.edu.sg/
c.	Landsat 2000	30 meter	26 April 2000	Ministry of Forestry
d.	Landsat 2005	30 meter	24 Mei 2005	Ministry of Forestry
e.	Landsat 2009	30 meter	18 March 2009	http://glovis.usgs.gov
f.	Landsat 2009	30 meter	15 December 2009	http://glovis.usgs.gov

Table 3 List of maps used in the research

No.	Maps	Year	Source
a.	Road Map of Riau	1990- 2000, 2007	http://www.sumatranforest.org Ministry of Forestry
b.	River Map of Riau	2007	Ministry of Forestry
c.	Study area (SSH GFP)	1999	Forestry Services of Riau Province
d.	Administrative Map	2007	Regional Planning and Development Agency of Riau (Bappeda)
e.	Settlement Map of Riau	2007	Regional Planning and Development Agency of Riau (Bappeda)
f.	RTRWP (Regional Spatial Plan) Riau	1994	Regional Planning and Development Agency of Riau (Bappeda)
g.	Deforestation map of Sumatera	1990, 2000,	Ministry of Forestry-Wildlife Conservation Society-Indonesia Program (WCS-IP)

3.2.2. Other Data

a. Population of Kampar Regency (source: the Central Bureau of Statistics of Kampar Regency)

b. Population of Pekanbaru City (source: the Central Bureau of Statistics of Pekanbaru City)

c. Population of Siak Regency (source: Central Bureau of Statistics of Siak Regency)

3.2.3. Software

Software used for this study was ERDAS Imagine 9.3 to process remotely sensed data especially to classify land cover change. ArcGIS 9.3 used to process data in GIS operation especially for overlay and spatial analysis. SPPS was used for statistical analysis, MS Word, Microsoft Visio 2003 and MS Excel were used for the thesis writing and calculation.

3.3. Methods

Library studies and literature review were done by exploring relevant papers for this research topic from many sources such as a book, journal, internet and other publications from local and international publications.

3.3.1. Collecting Data

Data collected consisted of primary and secondary data. Primary data were taken from observations in the field and interviews. The secondary data were imageries, maps, reports, land cover and other documents from institutions.

3.3.2. Field Work

a. Land Cover

The purpose of this field work was to observe the study area and collect the ground truth data for land cover classification. Field work was carried out in July and August 2009 by using maps, GPS, digital camera and stationary were provided. The area was observed and coordinate points and the land cover of the area were recorded. To take coordinate points in the area, the researcher stratified it first in to stratum based on homogenous of shape, pattern, color, etc. For each stratum in the field, the researcher selected and recorded random coordinate points in several places, representative for the strata. 149 sample points were selected for the whole stratum. It was classified into 6 classes of land cover types which are: forest, (oil palm) plantation, shrub, crop, water, and open area (bare land). The coordinate points are given in Appendix 1.

b. Interview

The purpose of the interviews was to explore about the issues related deforestation in Sultan Syarif Hasyim Grand Forest Park. The interviews were carried out on July and August 2009 with a purposive sampling. In this interview process, four key persons were selected to be interviewed. They were from Sultan Syarif Hasyim Grand Forest Park (SSH GFP) Office, Forestry Services of Pekanbaru City, Forestry Services of Siak Regency, Forestry Services of Kampar Regency. The types of question and summary of the answers are presented in Appendix 2.

3.3.3. Land cover change analysis

A time-series analysis was conducted to determine deforestation rate using four different images from 1989, 2000, 2005, and 2009. This analysis was done using ERDAS Imagine 9.3. and ArcGIS software. Quick look SPOT 1 1997 also was used to confirm the trend and how the change between this period. It was not used for actual classification.

The selection of these periods was based on management changes and political situation. The reasons of selection of periods are described as follows:

Table 4 Selection of period

Period	Information	Image
1989-1997	The time before reformation era in Indonesia and the management of land responsible by central government.	07 September 1989, 01 March 1997
1997-2000	Reformation era started. Weak law enforcement in this period.	01 March 1997, 26 April 2000
2000-2005	After reformation era and autonomy era (decentralization) was implemented in Indonesia and management of SSH GFP handled by local government.	26 April 2000, 24 Mei 2005
2005-2009	Process of establishment of management of SSH GFP and recent condition of study area.	24 Mei 2005, 18 March 2009, 15 December 2009

In this study, satellite imageries and spatial analysis were used. As a consequence of using these analyses, there were 4 main steps which were image processing, image classification, accuracy assessment and change detection.

a. Image processing

Land cover change analysis was done through processing four different satellite imageries (Landsat 1989, Landsat 2000, Landsat 2005, and Landsat 2009). Image preparation (geo coding and geo referencing) were done using topographic map.

b. Image classification

Digital image classification for image 2009 was done using supervised classification in six land cover classes using software ERDAS Imagine 9.3. Supervised classification means that the operator will determine the samples (training area) based on the spectral characteristic of the classes. Supervised classification was used because it generally gives more accurate class definitions and higher accuracy than the unsupervised approach (Tso and Mather, 2009). Supervised classification was carried out using ERDAS 9.3 with Maximum Likelihood Algorithm. Selection of training areas was based on the ground truth points obtained from the field.

For image 1989, 2000 and 2005, selection of training area for classification was done by picking training sample from unchanged area and by verifying with people (local knowledge) of the study area and Google Earth also was used carefully to verify the land cover types. The workflow of image classification can be seen in the figure 5.

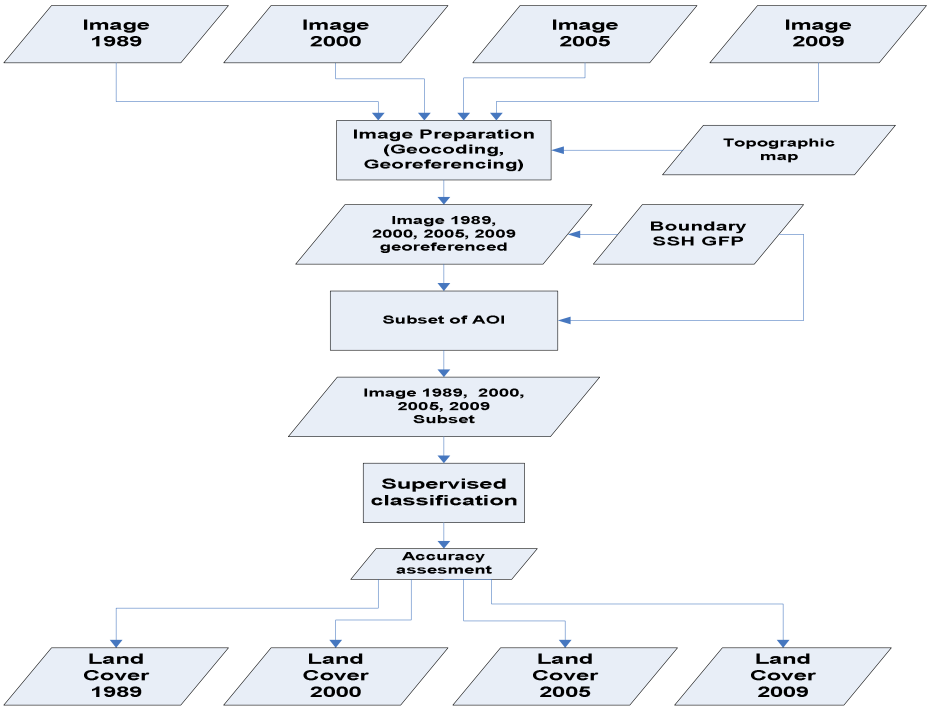


Figure 5 Flow chart of land cover classification.

For land cover 1997, classification could not be done through supervised classification since imagery for 1997 (spot 1) only quick look from SCRISP Singapore. This image is sufficient since no available image during 11 year (between 1989 and 2000), but general trend of the change need to be known. So this image used only for knowing the general trend of forest cover change through manual and visual interpretation in order to know the trend of land cover change in 1997.

For land cover classification, there are six land cover classes which are forest, (oil palm) plantation, shrub, crop, water /lake, and open area (cleared). This classes use in order to identify forest cover change process in the study area. The description of land cover classes are :

Table 5 Description of Land Covers Classes

Land cover	Description
Forest	Areas that are predominantly covered by trees with close canopy cover. Forest cover dominated by trees such as *Acacia mangium*.
Shrub	Areas that are dominated by shrubs such as pandan (*Pandanus sp*), alang-alang (*Imperata cylindrica*), pakis (*Dpalazium escelentum*),
Crop	Areas dominated by horticultural farm such as maize, fruit etc.
Oil palm plantation	Areas that are covered by oil palm (*Elaeis guineensis*)
Bare land (cleared land)	Area that are dominated by bare land and cleared land.
Water	Water
Cloud	Area in the images that covered by clouds and theirs shadows.

c. Accuracy Assessment

Accuracy assessment is an important feature of land-cover mapping, not only as a guide to map quality and reliability, but also in understanding thematic uncertainty and its likely implications for the end user (Bektas and Goksel, 2003). In this study, accuracy of the classification was calculated through kappa statistic and error matrix. An error matrix shows the number of correctly classified image sampling units in the diagonal. The kappa statistic is a measure of agreement of the image data and the reference data (Jensen, 1986). 101 references point from field data were used to assess the accuracy of Landsat image 2009.

Because of ground truth data was not available for year 2005, the accuracy for the image 2005 was assessed using land cover map made by Forestry Services of Riau Province. The map was made by through ground check and survey to the field and published by this institution.

For land cover 2000 and 1989, because ground data from past year were not available for this year, the accuracy for the image 2000 only was verified using deforestation map in Sumatera 1990-2000 published by Ministry of Forestry and Wildlife Conservation Society-Indonesia Program (WCS-IP). The accuracy assessment could be done only for land cover type forest and non forest since the land cover map used for references only has two classification types which are forest and non forest.

d. Change detection

Spatial analysis was done in ARCGIS 9.3 to analyze change detection in order to find change area from different land covers produced. First the land cover map from four different years 1989, 2000, 2005, and 2009 were exported from raster to vector using ARCGIS and then, GIS overlay in ArcMap was done for 3 sequences land cover changes for the period 1989 to 2000, 2000 to 2005 and 2005 to 2009. The output table from overlay of the maps of the different year was used to qualify and quantify the land cover change. The attribute table of the changed map was exported to MS Excel for generation of the change matrix to understand land cover change process.

Workflow of land cover change analysis can be seen in the figure 6.

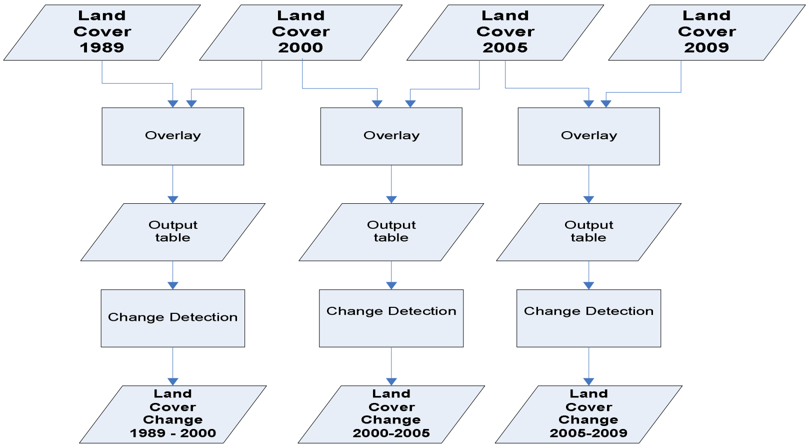


Figure 6 Flow chart of land cover change analysis.

3.3.4. Forest cover change, deforestation and deforestation rate

The primary interest in this change detection study was to identify forest cover that had been changed to non forest in order to know the forest cover change process resulting deforestation. Deforestation for each year were calculated and then used for calculating deforestation rate.

a. Deforestation

Firstly, the classified land cover maps were reclassified into two categories which are forest and non forest. Forest was reclassified as "forest". Shrub, oil palm plantation, crop, bare land and water were reclassified as "non forest".

Forest areas and non forest for each year (1989, 2000, 2005 and 2009) were measured using ArcGIS. The change from forest to non forest was classified as deforestation. In order to identify deforestation area for 3 sequential periods, deforestation was quantified for period 1989-2000, 2000-2005, and 2005-2009. Workflow of forest cover change analysis resulting deforestation can be seen in the Figure 7.

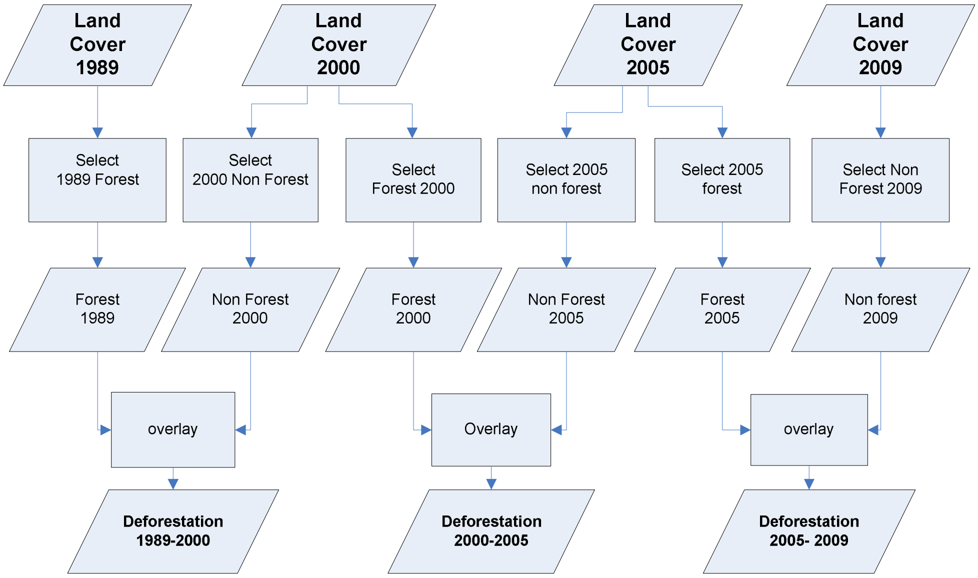


Figure 7 Deforestation analysis

b. Deforestation rate

Deforestation rate varies for each period, so it needs to be calculated for each year. Deforestation rate is important to know which period has rapid deforestation. The deforestation rate is calculated using the formula suggested by Puyravaud, 2003. This formula is selected because this formula was derived from compound interest law and more intuitive than the formula used by FAO because it is derived from the mean annual rate of change. (Puyravaud, 2003).

The formula is :

$$r = (1/(t2-t1)) x\ 1n\ (A2/A1)) \qquad (1)$$

where :

r = rate of deforestation

t2 and t1 = time

A2 and A1 = forest cover at time t2 and t1

Note : In this research, the rate is presented in percentage (r x 100).

3.3.5. Analyzing the drivers

From the previous study, there are many drivers mentioned. There is rarely a single driver responsible for deforestation; most often, multiple processes work simultaneously causing deforestation (Rademakers *et al.*, 2010) .

a. Direct Drivers/Proximate cause

Direct drivers of deforestation are those causes directly leading to forest decline (Rademakers *et al.*, 2010). To analyze these direct drivers, firstly, the possible drivers of deforestation especially in the regional development activities were analyzed. In this step, the map of regional development activities was collected. The maps are transmigration map, logging concession map, plantation map, forest plantation map, road map, mining map. The maps were overlaid with the map of study area. The contribution of each factor to deforestation was analyzed.

Base on overlaid maps of regional development in the study area, there are no transmigration, logging concession, forest plantation, and mining in the area. But from land cover change detection and data collection, there are oil palm plantation and road construction inside the area. So this research focuses on oil palm plantation expansion, road development and socio economic to analyze the drivers of deforestation in study area.

1). Oil palm plantation expansion.

From land cover classification, the activities that directly convert the forest area to non forest area were identified. It showed that there is one activity that mainly occurs on the study area which is oil palm plantation expansion. The oil palm plantation expansion and contribution of oil palm plantation to forest loss has been analyzed through spatial analysis in order to know the land cover/land use that mainly occurs in that area resulting deforestation. The spatial analysis is described in the figure 8.

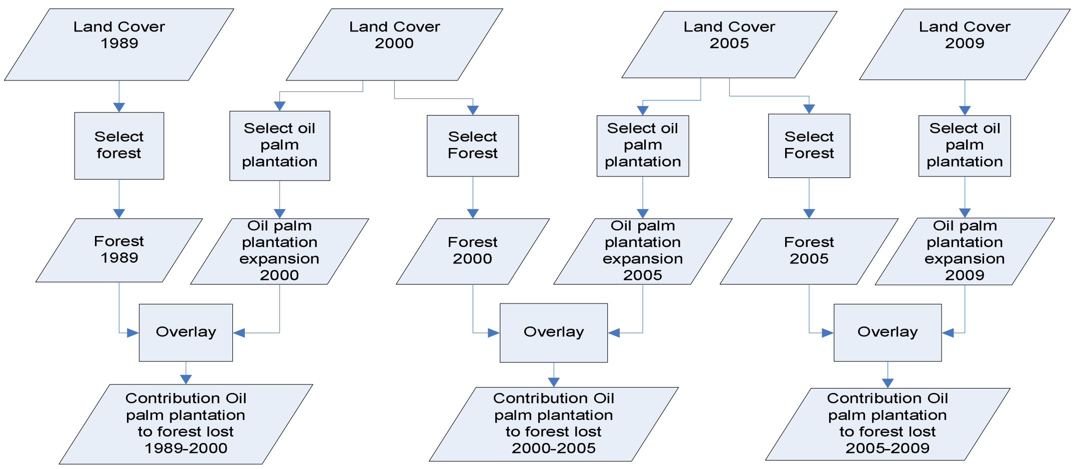


Figure 8 Flow chart for oil palm plantation expansion and its contribution to forest lost.

2.) Road development

From the data analyzed, there are road infrastructures in the study area. The development of road effect the forest lost. To analyze the forest lost due to road development has been analyzed as describe in the figure 9.

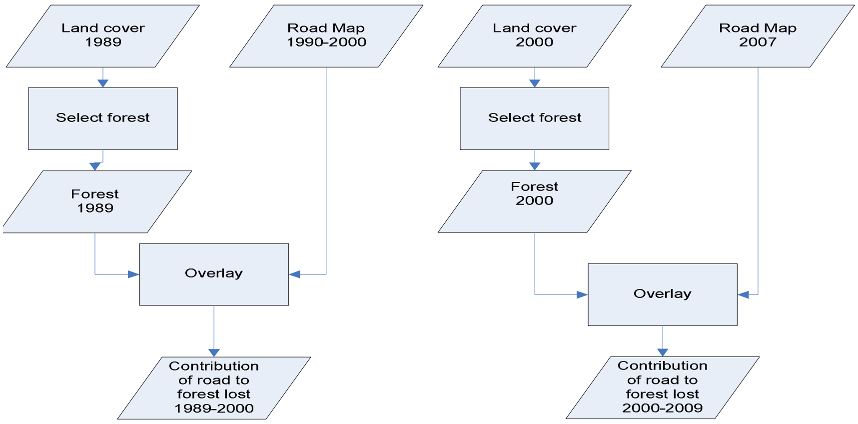


Figure 9 Flow chart development of road effect the forest loss

Proximity analysis

Deforestation is highly related to proximity to road and urban areas as well (Greenberg *et al.*, 2005). The existence of road in the study area creates accessibility to the forest and pressure to forest also increase. The deforestation occurrence related to distance from road and settlement was done through spatial analysis in ArcGIS. The distance classes to road was classified into 7 classes: (1) 0-250 m; (2) 250-500 m; (3) 500-750 m; (4) 750-1000 m; (5) 1000-1250 m; (6) 1250-1500 m; (7)> 1500 m. The distance classes to settlement was classified into 7 classes : (1) 0-1 km; (2) 1-2 km; (3)2-3 km; (4) 3-4 km; (5)4-5 km;(6) 5-6 km; (7) > 6 km. Forest loss used as parameter in calculating distance classes was forest loss from 1989-2009. The flow cart of deforestation occurrence related to distance from road and settlement was given in Appendix 3.

Statistical analysis

The deforestation occurrence related to distance from road and settlement was analyzed through linear regression to know the relationship between deforestation occurrence and distance to road. The relationship between deforestation occurrence and distance from road and settlement were tested by correlation coefficient and regression line. Scatter plot shows the relationship of distance to road and settlement (X axis) and deforestation (Y axis). Linear regression also used to characterize relationship between variables (Dendukuri and Caroline, 2004). Marshal (1987) stated that a regression line can be determined to show the relationship between two variables according to a statistical model.

3). Illegal logging activities

Most of forests in Indonesia are threatened by deforestation from logging activities. Logging activities were analyzed through the Logging Concession Map in the region. There are no logging concessions in the study area. However, illegal logging activities were explored through data collection of illegal logging cases and the interview result from forestry services of Riau Province, Pekanbaru, Siak and Kampar regency.

b. Indirect drivers/Underlying causes

The indirect drivers of deforestation are a complex interplay of many economic, institutional/governance policies, and demographic/socio-cultural factors (Rademakers *et al.*, 2010). From the interviews and analyzed data, it was obtained which economic, institutional/government policies and demographic / socio cultural factors could affect deforestation in the study area.

1). Economic aspect

For the economic aspect, statistical analysis was done to know the relation between deforestation and oil palm plantation expansion, and also relation between deforestation and palm oil production in Riau Province. These relations were examines by comparing 9 year empirical data on deforestation, oil palm plantation and palm oil production.

Demand for agricultural product is continued to rise. The increasing demand can be pressure on forest land. How the increasing of demand of oil palm affect the forest also was analyzed through the analyzing of statistic oil palm data. The correlation between palm oil production and volume export of CPO Indonesia and correlation between volume export of CPO Indonesia and the global demand of palm oil were tested statistically as well.

Statistical analysis

Linear regression was used to know the relationship between deforestation and oil palm plantation expansion, deforestation and palm oil production in Riau Province, palm oil production of Riau province and volume export of CPO Indonesia and correlation between volume export of CPO Indonesia and the global demand of palm oil. The relationships were tested by correlation coefficient and regression line. A regression line can be determine to show relationship between 2 variable according to statistical model (Till, 1974; Marshal, 1987).

The parameter of deforestation is forest cover loss for each year from 1989 to 2009 and oil palm plantation expansion from 2000 to 2009 in the study area. Then, the years were selected that represented both variable (deforestation and oil palm plantation expansion).The selected years are from 2000 to 2009 (9 years). Time series statistics on annual palm oil production in Riau province were assembled from Statistics Bureau of Riau for each year from 2000 to 2008. Volume export of CPO Indonesia is the statistic data of volume export of CPO Indonesia from 2000 to 2007 and the global demand of palm oil is from year 2000 to 2007.

2). Demographic factor

For demographic factors, the relation between population increase and forest cover change was analyzed statistically. Generally, more population lead for more demand for food and land, which in turn results into more land clearing for agricultural expansion that leads to more forest land being converted. The population data was obtained from statistic data from Statistic Board of Kampar Regency, Pekanbaru City, Siak Regency and Riau Province.

Statistical analysis

First of all, forest cover for each year from 1989 to 2009 was obtained from the spatial analysis result. The common years for both variable (deforestation and population) are from 1989 to 2009 (20 year). The relationship between population increase and forest cover was tested by correlation coefficient and regression line. Linear regression is used to characterize linear relationship between variable that it involves only two variables the outcome or dependent variable and the predictor or independent variable (Dendukuri and Caroline, 2004). The dependent variable is forest cover (y axis) and independent variable is population (x axis). Two-dimensional scatter plot are done to visualize a relation (correlation) between two variable between x and y (population and forest cover).

3.3.6. Consistency analysis between existing land use and regional spatial land use plan

By law, the regional development in Riau should be implemented based on the Riau's Regional Spatial Land Use Plan (RTRW). The development of Riau Province needs land availability. Meanwhile the land availability is relatively limited. The need of land accelerates some activities such as illegal logging and plantation development. The establishment of plantation and logging activities in study area proves that all those activities were illegal. This situation finally create inconsistency between the existing land use and the spatial land use plan (RTWP).

Forest land allocated in RTRW was converted into other land uses. Comparison of existing land use and Regional Spatial Use Plan (RTRW) in protected area was evaluated through spatial analysis. Spatial analysis was done to identify the consistency existing land use and Regional Spatial Use Plan in the study area. According to RTRW of Riau Province, the study area was categorized as protected area. However, there other land uses exist in study area that are not according to spatial land use plan of Riau Province and spatial land use plan of each region which are Pekanbaru, Kampar and Siak Regency. The land use that is supposed to be protected area, in reality is used for cultivation purposes. Land cover/land use map in the study area was overlaid to RTRWP of Riau Province. The land uses that not accordance with spatial land use plan was considered as inconsistence to spatial land use plan. On the other hand, the land uses that accordance with spatial land use plan was considered as consistence to spatial land use plan. The consistence was measured for each region which are Riau, Kampar, Siak and Pekanbaru in order to understand how consistency/inconsistency of existing land use and regional spatial land use plan (RTRW) for each region.

IV. RESULTS

4.1. Land cover classification

Land cover of SSH GFP is classified in order to identify the change of land cover/land use in the study area. From this land cover, the change in the study area can be observed. Land cover classification in the year 2009, 2005, 2000, 1989 is depicted in figures 10, 11, 12, and 13 respectively.

4.1.2. Land cover classification for 2009

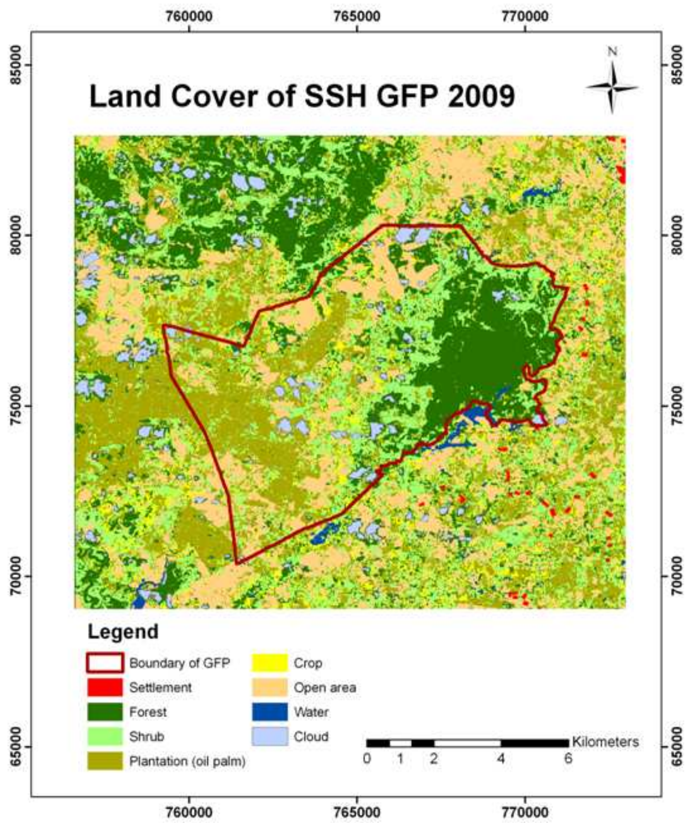


Figure 10 Land cover map 2009

Land cover in 2009 was dominated by forest, shrub oil palm plantation and open area (bare land). The total area for each classes more less equal.

Accuracy Assessment

The accuracy assessment of the classification is based on the error confusion matrix. The classified image 2009 has overall accuracy **79.21 %** and Kappa statistic **0.7299**. Error matrix and the total accuracy report for classified image 2009 can be seen in the table 6 and 7. Detail Kappa statistic is given in Appendix 5.

Table 6 Error matrix of land cover 2009 classification

Classified Data	Unclassified	forest	shrub	plantation (oil palm)	crop	bare land	water	Row Total
Unclassified	0	0	0	0	0	0	0	0
Forest	0	**18**	2	0	0	1	0	21
Shrub	0	0	**12**	2	0	2	0	16
Plantation	0	3	1	**30**	2	3	0	39
Crop	0	0	0	0	**3**	0	0	3
open area	0	0	1	2	0	**11**	0	14
Water	0	0	0	0	0	0	**6**	6
Column Total	**0**	**22**	**17**	**34**	**5**	**17**	**6**	**101**

Table 7 Accuracy Assessment for Land Cover 2009

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy
Unclassified	0	0	0	---	---
Forest	22	21	18	81.82%	85.71%
Shrub	17	16	12	70.59%	75.00%
Plantation	34	39	30	88.24%	76.92%
Crop	5	3	3	60.00%	100.00%
open area	17	14	11	64.71%	78.57%
Water	6	6	6	100.00%	100.00%
cloud shadow	0	2	0	---	---
Cloud	0	0	0	---	---
Totals	**101**	**101**	**80**		
Overall Accuracy	**79.21%**				

Producer accuracy is calculated by dividing the total number of correctly classified pixels for a class by the total number of reference sites for that class. The user accuracy is calculated by dividing the number of correct accuracy sites for a category by the total number of accuracy assessment sites that were classified in that category.

The class “water” has the highest producer accuracy which is 100 %, followed by forest, plantation and shrub while the class open area and crop has the least. It implies that water has the highest probability of a references site being correctly classified. However, in the user accuracy, class “crop” and “”water” has the highest which is 100 % and it followed by forest. In this case, the class shrub grass has the least accuracy. It implies that crop has the highest probability that a pixel on the map actually represents that category on the ground.

4.1.3. Land cover classification for 2005

Land cover classification of SSH GFP in 2005 is depicted in this figure 11.

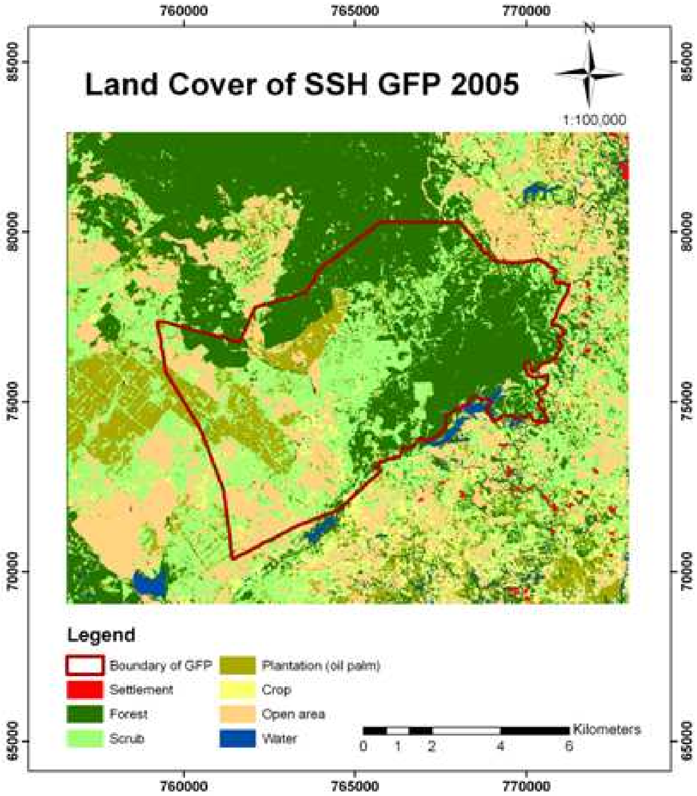


Figure 11 Land cover map 2005

Total forest cover was 45 % of the total area. The remaining land cover was shrub, open area (bare land), crop and water. The oil palm plantation occurred in north part and western part of the study area. The establishment of oil palm plantation also occurred outside (western part) the area of SSH GFP.

Accuracy assessment

The classified image 2005 has overall accuracy **80,00 %** and Kappa statistic **0.7219.** The detail of accuracy assessment for classified image 2005 is given in Appendix 6, 7 and 8. For this classified image 2005, because ground truth data were not available for this year, the accuracy for the image 2005 only was assessed using land cover map made by Forestry Services of Riau Province scale 1: 50,000. This land cover map was made through an interpretation of a landsat image in March 2004. No information of the percentage of accuracy of this map, but this map was made through a ground check and survey in the field by staffs of Forestry Services of Riau Province. The test sample for reference data was derived randomly from this land cover map and also was verified with Google earth map of 2007.

4.1.4. Land cover classification for 2000

Land cover classification of SSH GFP in 2000 is depicted in this figure 12.

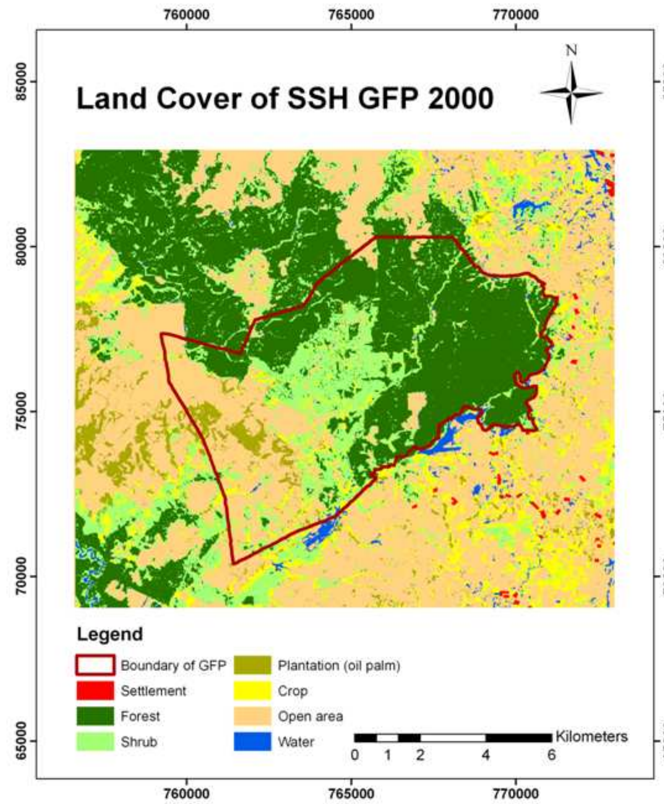


Figure 12 Land cover map 2000

The forest cover was only half of total area (51 %) in 2000. In the western part, there were more open areas (20 %) and oil palm plantation occurred in this part as well (3 %). The establishment of oil palm plantation also occurred outside the area of SSH GFP especially in the western part of GFP.

Accuracy Assessment

For the classified image 2000, because ground data from past year were not available for this year, the accuracy for the image 2000 only was verified using the deforestation map in Sumatera 1990-2000 published by the Ministry of Forestry scale 1:150.000. The test sample for reference data was derived randomly from this map. An accuracy assessment for classified image 2000 could only be done for land cover class forest and non forest since the deforestation map for references only has two classes which are forest and non forest. For this reason, it is not enough to do an accuracy assessment for the whole land cover classes. Accuracy only can be used for forest and non forest. The overall accuracy is **82 %** with Kappa **0.6206**. Detail error matrix, accuracy report and kappa statistic for land cover classification 2000 is given in Appendix 9, 10 and 11.

4.1.4. Land cover classification for 1989

Land cover classification of SSH GFP in the year 1989 is depicted in this figure 13.

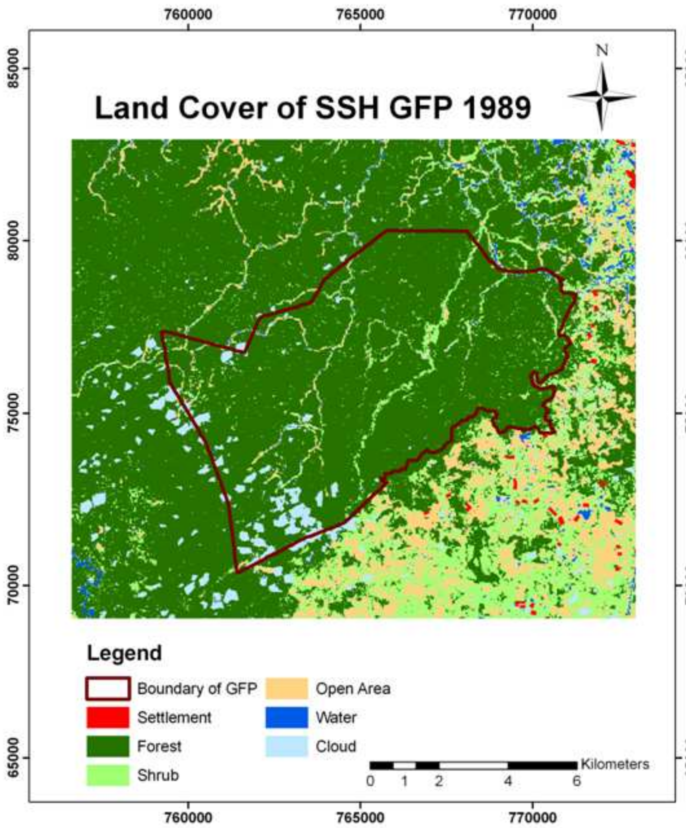


Figure 13 Land cover map 1989

In 1989, most of SSH GFP area was covered by forest (93 %). Only small area in the middle part of SSH GFP was dominated by shrub, and in the south-eastern part outside of SSH GFP, the land was covered by shrub and open area (bare land).

Accuracy Assessment

For the classified image 1989, because ground data were not available for this year, the accuracy for the image 1989 was verified using the deforestation map in Sumatera 1990-2000 published by the Ministry of Forestry scale 1:150.000 as applied for the accuracy assessment for classification of image 2000. The accuracy for the classified image 1989 only could be done for land cover class forest and non forest since the deforestation map for references only has two classes which are forest and non forest. The overall accuracy for image classification 1989 is **86 %** with Kappa **0.7154**. Detail error matrix, accuracy report and kappa statistic for land cover classification 1989 is given in Appendix 12, 13, and 14.

Quicklook from SPOT 1 1997 also used in order to identify ongoing trend of land cover and land cover change in the study area. The map of quicklook is given in Appendix 4.

4.1.5. Land Cover Area.

The image acquired in 1989 has cloud cover of 414 ha (6.4 % Ha), while the image acquired in 2000, and 2005 is cloud free. Meanwhile, the image acquired in 2009 has cloud cover 240 ha (3.7 %). So the cloud is omitted and it is not taken into account for change detection analysis. After subtraction of cloud of image in year 1989 and 2009, the total area becomes 5,907 ha out of 6,172 ha for all these images. The total area for each land cover type in SSH GFP is presented in table 7.

Table 8 Land Cover Area

Land Cover	1989 (ha)	%	2000 (ha)	%	2005 (ha)	%	2009 (ha)	%
Forest	5504	93	3033	51	2661	45	1725	29
Shrub	256	4	1241	21	1768	30	1396	24
Oil palm plantation	0	0	192	3	627	11	1570	26
Crop	0	0	222	4	154	2	244	4
Open Area	118	2	1190	20	677	11	944	16
Water	29	1	29	1	20	1	28	1
Total	**5907**	**100**	**5907**	**100**	**5907**	**100**	**5907**	**100**

4.2. Land cover change analysis

The change detection from 1989 to 2009 shows the decreasing of forest cover over time and on the other hand the increasing of oil palm plantation, while shrub and crop remain more or less constant since 2000 until 2009. Open area increased significantly from 1989 to 2000, and from 2000 to 2005 it decreased because of conversion to oil palm plantation, and from 2005 to 2009 it increased again. The change maps for each period are depicted in figure 14,15 and 16 respectively.

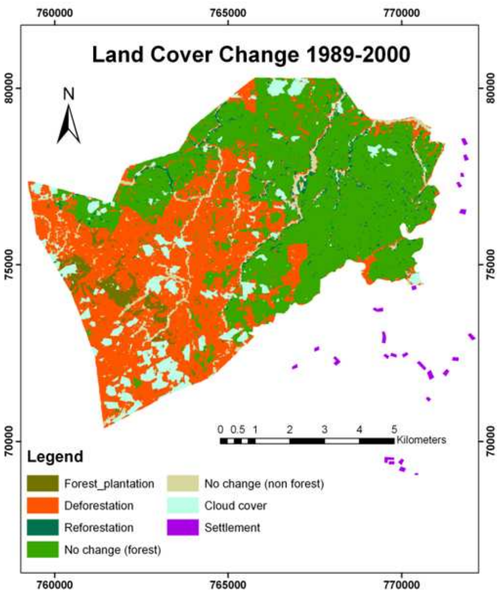


Figure 14 Land Cover Change map 1989-2000

In land cover change 1989-2000, the forest cover decreased and it was converted into shrub, plantation, and crop. Forest cover change occurred in the middle and south-western part of SSH GFP. The forest area was converted into shrub, and then in the western part, there are more open area (cleared land) and oil palm plantation occurred. Change matrix can be seen in Appendix 15.

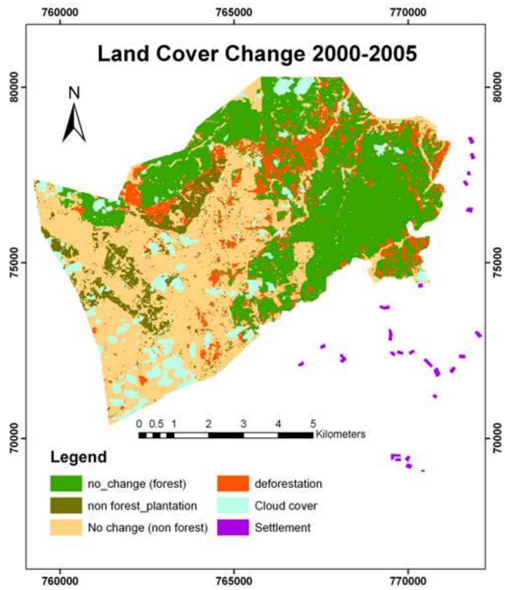


Figure 15 Land Cover Change map 2000-2005

In land cover change 2000-2005, forest cover decreased from 3,033 (51 %) ha in the year 2000 to 2,661 (45 %) in year 2005. The forest was converted into shrub, oil palm and open area. On the other hand, the oil palm plantation increased. The total oil palm plantation increased from (192 (3 %) in 2000 to 627 Ha (10 %) in 2005. Change matrix can be seen in Appendix 16.

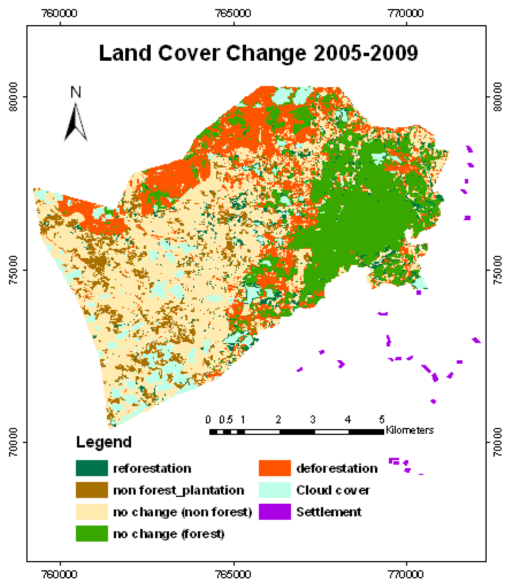


Figure 16 Land Cover Change map 2005-2009

In land cover change 2005-2009, forest cover in northern part and north-western part of GFP decreased and was converted into bare land (cleared land). So deforestation occurred in this part. The remaining forest in 2009 was 1,725 Ha (29 %) from 2,661 Ha (45 %) in 2005. The open area (bare land) increased in this period. The oil palm plantation increased in the western part and in the northwest part as well. Open area (bare land) in this part was converted into oil palm plantation. So the total oil palm plantation increased from 627 Ha (11 %) in 2005 to 1,570 Ha (26 %) in 2009. Change matrix can be found in

Appendix 17.

In figure 17 is shown the overall land cover temporal dynamics of all classes and the change of the area of each class at different time can be seen in the table 9.

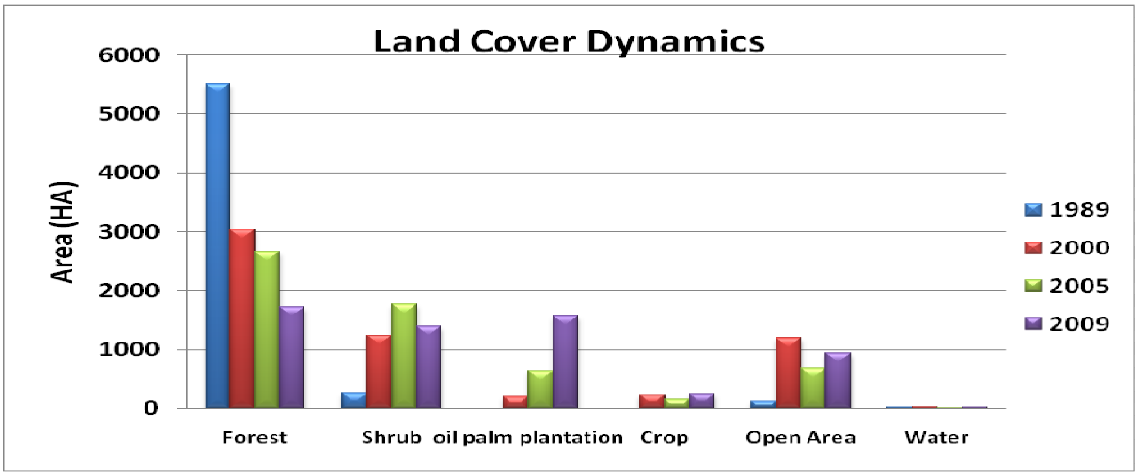


Figure 17 Land Cover dynamics from 1989-2009

Table 9 The change in land cover

Land Cover	Area (Ha)					Change (ha)			
	1989	2000	2005	2009		1989-2000	2000-2005	2005-2009	1989-2009
Forest	5504	3033	2661	1725		-2471	-372	-936	-3779
Shrub	256	1241	1768	1396		985	527	-372	1140
Plantation (oil palm)	0	192	627	1570		192	435	943	1570
Crop	0	222	154	244		222	-68	90	244
Open Area	118	1190	677	944		1072	-513	267	826
Water	29	29	20	28		0	-9	8	-1

From the table above, it can be seen the continuous decrease of forest cover in the study area from 1989 until 2009. In the year 1989, about 5,504 ha (93 %) of SSH GFP was covered by forest, but it has decreased to 3,033 ha in the year 2000 and continue to decline in the year 2005 into 2,661 ha and in 2009 the remaining forest cover only 1,725 Ha (29 % of SSH GFP). The highest forest loss is in the period 1989-2000 (2,471 ha) whereas, on the contrary, plantation (oil palm) increased significantly. In 2000 it covered about 192 Ha, but it has increased to 627 ha in the year 2005 and in year 2009 it continued to grow up in to 1,570 ha. The change in land cover 1989-2000, 2000-2005, 2005-2009 especially for the change of forest into other land covers and conversion land cover into oil palm plantation are presented in the figure 18, 19, 20, 21, 22 and 23 respectively and the detail change matrix are presented in Appendix 15, 16 and 17.

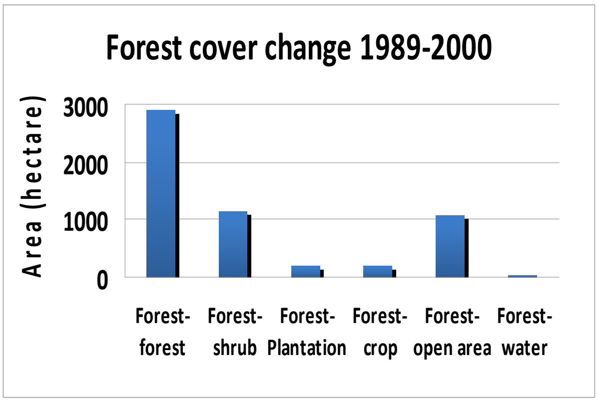


Figure 18 Forest conversion 1989-2000

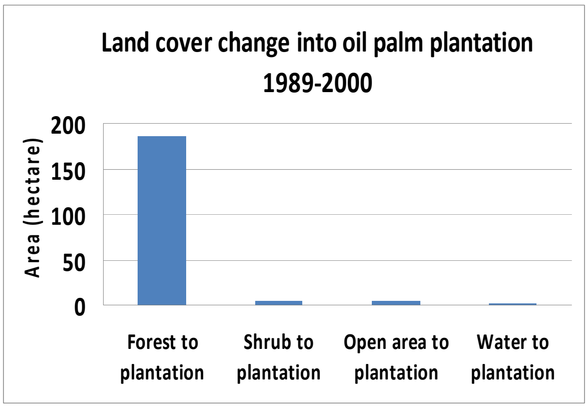


Figure 19 The origin of oil palm plantation 1989-2000

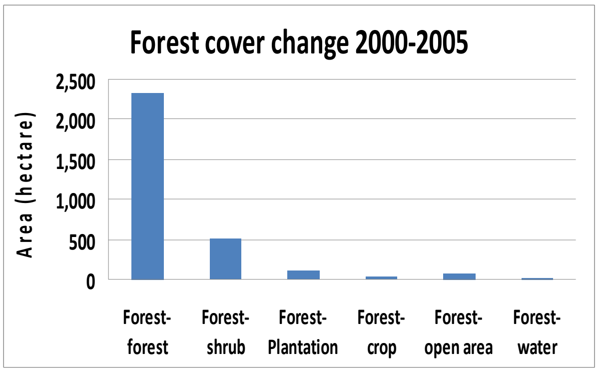


Figure 20 Forest conversion 2000-2005

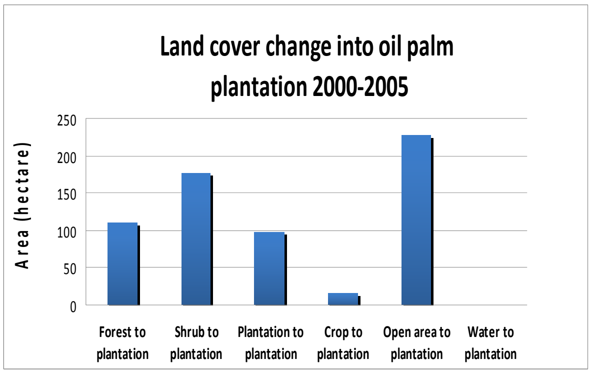


Figure 21 The origin of oil palm plantation 2000-2005

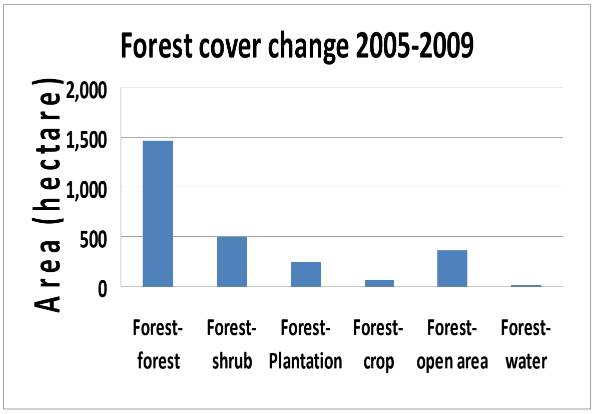


Figure 22 Forest conversion 2005-2009

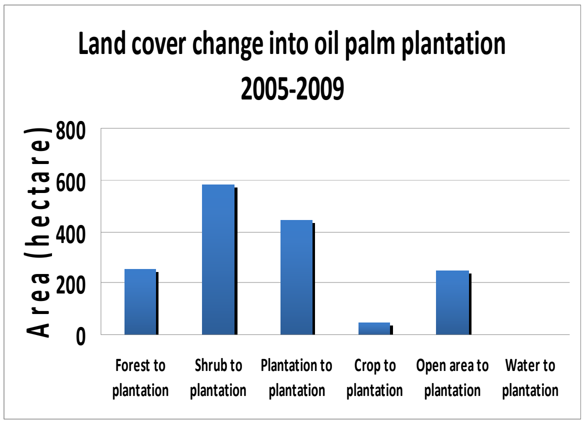


Figure 23 The origin of oil palm plantation 2005-2009

4.3. Deforestation

Forest cover change occurred resulting in deforestation in the study area. The deforestation area from the year 1989 to the year 2000 is presented in table 9.

Table 10 Deforestation area during 1989-2009

1989-2000	percentage	2000-2005	percentage	2005-2009	percentage
237 ha/year	22 %	139 ha/year	11 %	287 ha/year	19 %

Deforestation area for each period can be seen in this figure 24.

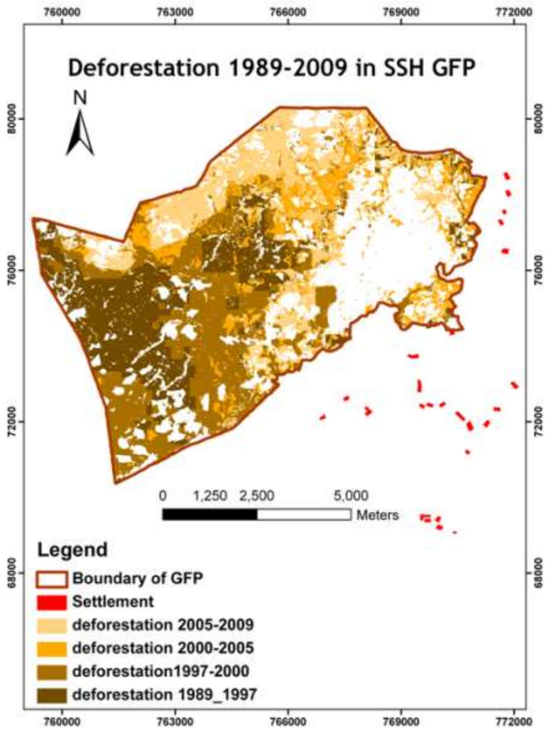


Figure 24 Deforestation area in SSH GFP 1989-2009.

Deforestation 1989-1997 is estimated based on quick look data and used for demonstration of the trend only.

The highest deforestation area occurs during period 1989-2000 which is about 2,613 ha (22 %). Compared to national deforestation in table 10, Forestry Department of Republic Indonesia said that the highest deforestation occurred in period 1997-2000 (MoF, 2008). In this period reformation era happened in Indonesia in year 1998. National deforestation is presented in table 11.

Table 11 National Deforestation

Period	Deforestation area (Ha)
1985-1997	1,8 million ha/year
1997-2000	2.84 million ha/year
2000-2005	1.08 million ha/year

Source: Ministry of Forestry of Republic Indonesia (MoF, 2008).

The high deforestation in the period of 1997-2000 is probably because during reformation era and transition era a change took place from central into decentralized government policy, leading to uncertainty about responsibilities for forest protection (Nawir *et al.*, 2008).

Deforestation rate

From deforestation that occurred during the 1989-2009, we can see the rate of deforestation for each period in the table 11.

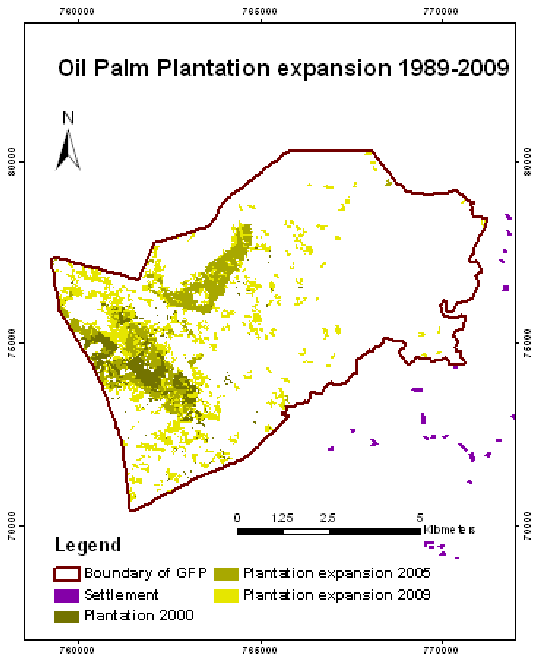
Table 12 Deforestation rate during 1989-2009

Period	Total area GFP	Deforestation area (Ha)	Deforestation area (Ha)/year	Rate per year
1989-2000	5907	2613	237	5.42 %
2000-2005	5907	694	139	2.60 %
2005-2009	5907	1150	287	10.84 %

The average rate for the entire period (1989-2009) is 5.8 % with total are 3,779 ha (189 ha/year).

4.4. Oil palm plantation expansion

Oil palm expansion in SSH GFP was shown in the year 2000. In 1997, some of forest area in the year 1989 changed into open area (bare/cleared land), and in 2000, some of open area in 1997 changed into become oil palm plantation. From the image and land cover 2000 can be seen that oil palm plantation was built in the western part of SSH GFP. The total area of oil palm plantation was 192 ha in 2000, in 2005 oil palm plantation increased by 627 ha. In 2009 oil palm plantation remained increasing by 1571 ha. The increase of oil palm plantation during 2000-2009 in SSH is depicted in figure 25. The total area and percentage of oil palm plantation in SSH GFP during 1989 – 2009 is the depicted in this figure 26.



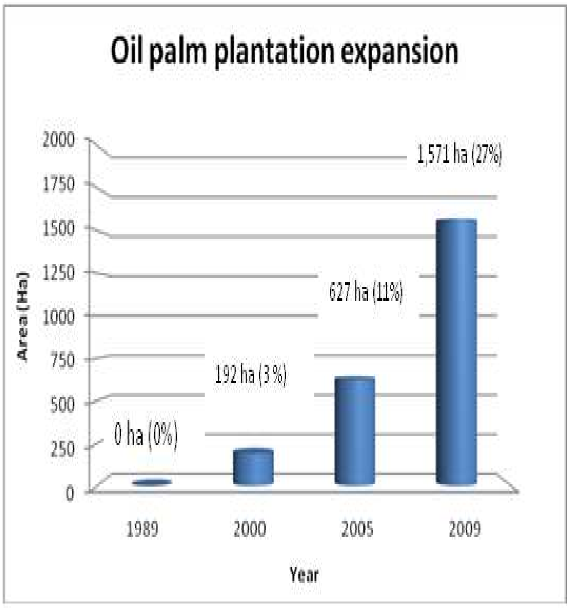


Figure 25 **Map of oil palm plantation expansion**

Figure 26 **Oil palm plantation area in 1989-2009**

From the figure above we can see that the process of establishment of oil palm plantation happened before 2000. An in 2000 about 192 Ha (3 %) of area SSH GFP was oil palm plantation and it increased significantly until 2009.

4.4.1 Land cover conversion for oil palm plantation

During year 1989-2000, the oil palm plantation established inside SSH GFP replaces the forest area. Some of the oil palm plantation in 2000 convert forest area in 1989 and some convert non forest area in 1989. The total area of Oil palm plantation in 2000 was 192 Ha, consisted of plantation convert forest 1989 was 185 Ha, and plantation convert non forest 1989 is 7 Ha.

During year 2000-2009, the oil palm plantation established in SSH GFP convert the non forest area. Some of the oil palm plantation in 2009 convert forest area in 2000 and some convert non forest area in 2000. The total area of oil palm plantation in 2009 is 1,571 Ha, consist of plantation replaced forest 2000 was 369 Ha, and plantation convert non forest 2000 was 1053 Ha and plantation that has already established in 2000 was 149 Ha. In this figure 27 and 28, shows the map of land cover conversion into oil palm plantation 1989-2000 and 2000-2009.

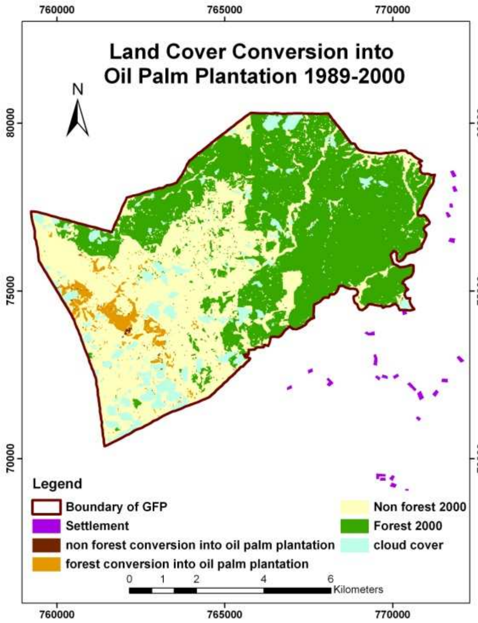


Figure 27 Land cover conversion into oil palm plantation 1989-2000

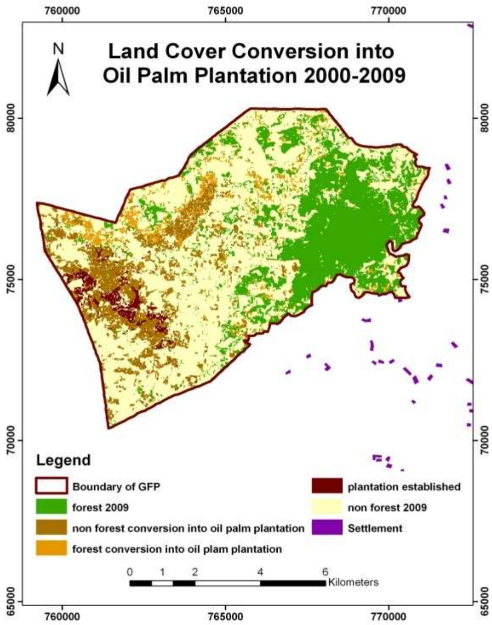


Figure 28 Land cover conversion into oil palm plantation 2000-2009

4.5. Infrastructure development

Roads can facilitate deforestation due to increased accessibility to forest area. The roads are easy route for activities causing deforestation. The existing of road can encourage people to establish oil palm plantation. Road provide access to loggers, and also to cultivators. Oil palm plantations are increasing rapidly in the study area, and it also leading to construction of more roads for transportation. The construction of roads can be a threat of the forest. Based on analysis of the road data, there were road developments inside the area. The road development in SSH GFP 1990 to 2000 is shown in the figure 29.

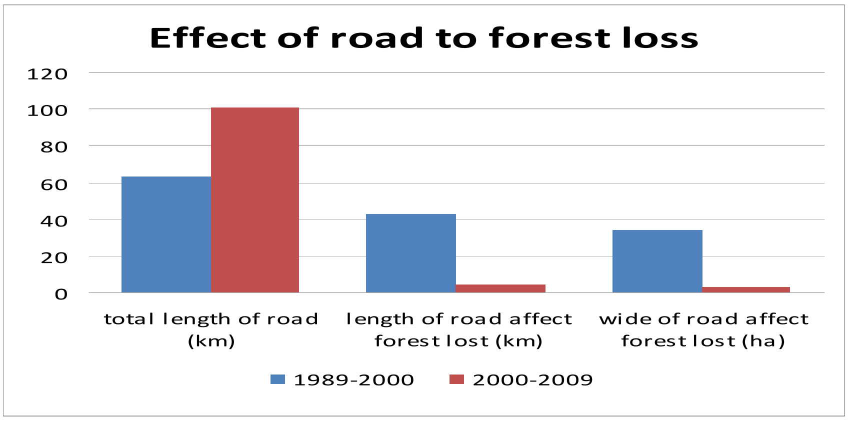


Figure 29 Road development in SSH GFP

The development of road affected the forest lost. The total length of road inside the SSH GFP is 63.52 Km. From the total length of the road, the area that has converted forest to non forest is 42.82 km (approximately 34 Ha) in year 1989-2000, and in year 2000-2009 is 3.99 km (approximately 3 Ha).

4.6. Proximity analysis

Deforested area from distance to roads and settlements

Deforested areas that were present in five distance ranges from the nearest road during in the year 1989-2009 are depicted in figure 30. The major deforested areas occurred between 0-250 meters from the nearest road which is 2,251 ha.

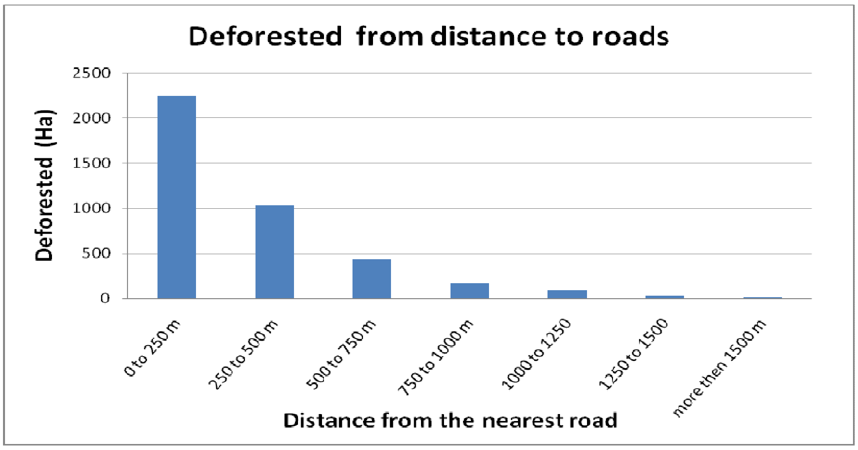
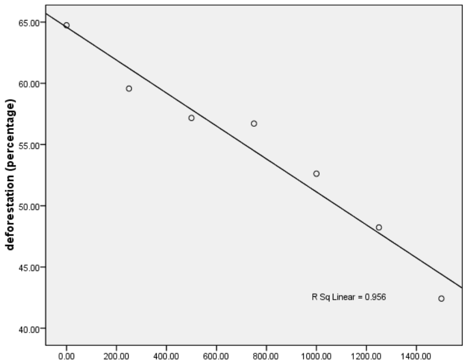


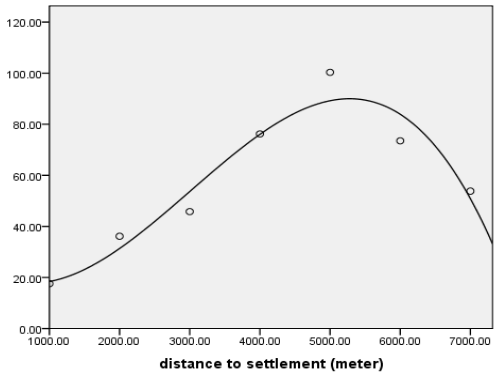
Figure 30 Deforested area from distance to roads.

Statistical analysis was done to understand the relationships between distance from road and deforested area and distance from settlement and deforested area. Linear regression was done to illustrate the relationship. The parameter of deforestation used is the percentage of deforestation area per each class. The relationship between distance from road and deforested area is shown in figure 31. The plots show relationship with R^2 = 0.947. This plot revealed an apparent relationship between distance from road and deforested area. The relationship between distance from settlement and deforested area is shown in figure 30. The plot shows the polynomial relationships with R^2 = 0.860. Detailed statistical analysis results and table are presented in Appendix 18 and 19.



y=-0.013x+64.586

Figure 31 Scatter plot of distance from road vs deforested area



y = -1.547E-9x3 + 1.396E-5x2 – 0.018 +24.113,

Figure 32 Scatter plot of distance from settlement vs deforested area

4.7. Analysis of socio economic factors

4.7.1. Economic aspect

Demand of Oil Palm

Riau is one of the provinces in Indonesia that has the largest area for oil palm plantation. From the data of the Statistical Bureau of Riau in 2009, Riau Province has 1.6 million hectares of oil palm plantation area in 2008. Indonesia is an exporter of oil palm. The global demand of palm oil also increases annually and it generates increasing development of oil palm plantations in order to produce the more palm oil. In this figure 33 are shown the growth of the area and production of oil palm plantation in last 20 year.

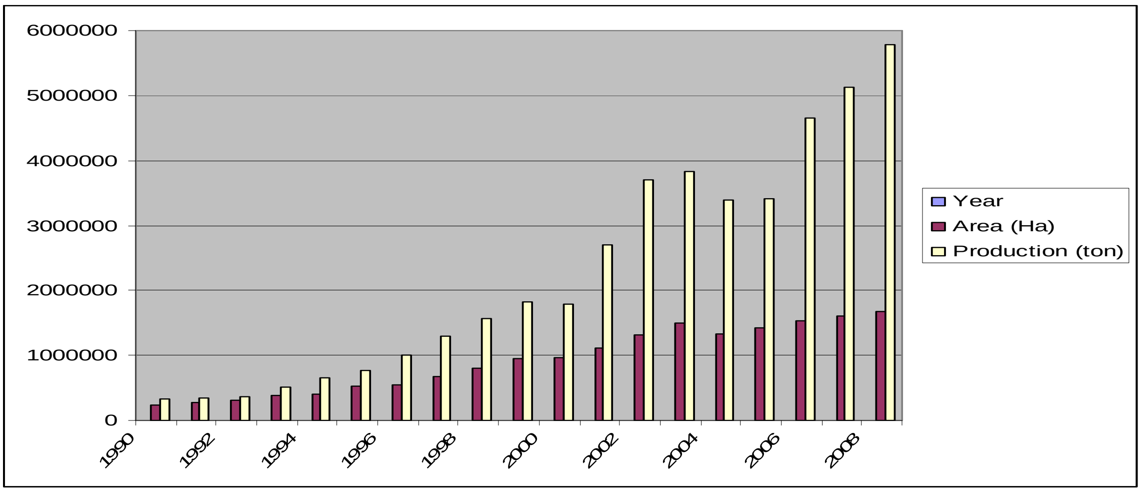


Figure 33 The growth oil palm plantation in Riau Province

(Source : BPS, 2009 and data analysis)

Deforestation and Oil palm plantation

Some of oil palm plantation expansion converts the forest and there are oil plantations without license from the government. The relationship between oil palm plantation expansion and deforestation was analyzed statistically. In these graphs show the forest cover decrease, deforestation and the oil palm plantation increase in the study area.

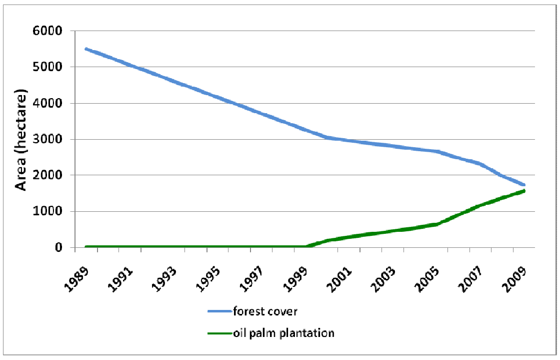


Figure 34 Forest cover and the oil palm plantation increase 1989-2009

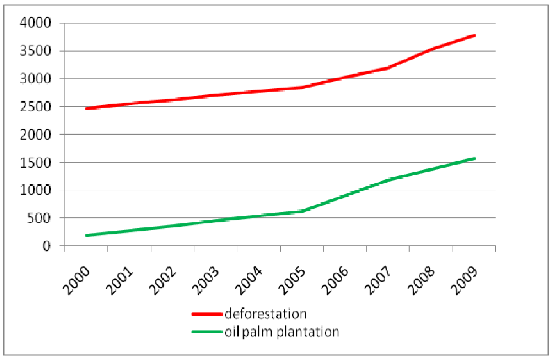
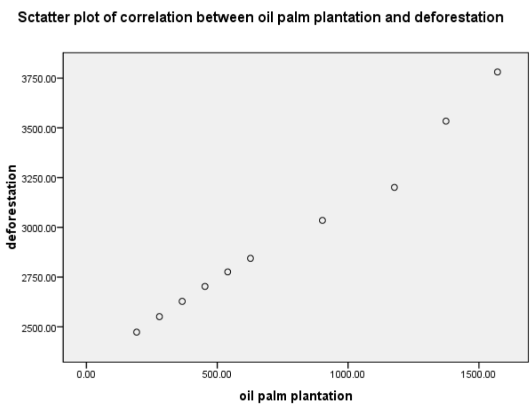


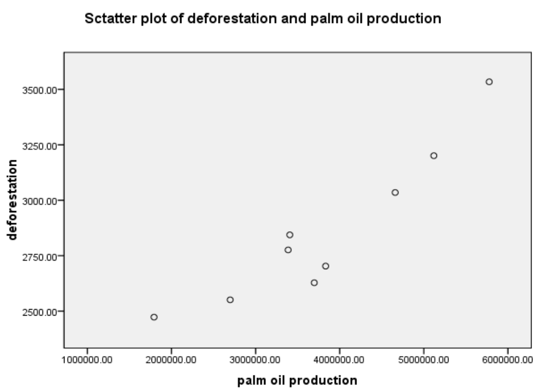
Figure 35 Deforestation and oil palm plantation increase 2000-2009

The correlation between oil palm plantation and deforestation was tested through linear regression. The result show that there are relation between deforestation and oil palm plantation expansion is SSH GFP. From the calculation, It was found that the relationship between deforestation and oil palm plantation has strong relationship with positive correlation and r^2 = 0.981. High r value indicates high/strong correlation between 2 variables. So there is a strong and positive relationship between deforestation and oil palm plantation expansion. In this figure 36 shows scatter plot between deforestation and oil palm plantation expansion. Statistical results can be seen in Appendix 20. In addition, statistical analysis was done to understand the relationship between deforested and oil palm production as shown in figure 36. The plots show relationship with R^2 = 0.867. Detail statistical results can be seen in Appendix 21.



$y = 1.102x-2506, R^2 = 0.981$

Figure 36 Scatter plot between deforestation and oil palm plantation expansion



$y = 3337.x - 6E+06$ $R^2 = 0.867$

Figure 37 Scatter plot of deforestation and palm oil production of Riau

4.7.2. Demographic factor

Forest cover change and population analysis

SSH GFP is located in 3 regencies, which area Kampar, Siak and Pekanbaru. Based on the Statistic Bureau of Kampar Regency, Statistic Bureau of Siak Regency, and Statistic Bureau of Pekanbaru City, the population surrounding the area of SSH GFP increase annually. The figure increasing of population and the decreasing of forest cover are given in figure 38 and 39.

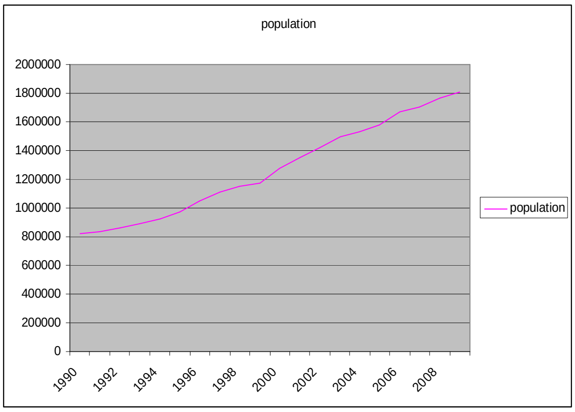


Figure 39 Graph of existing population number

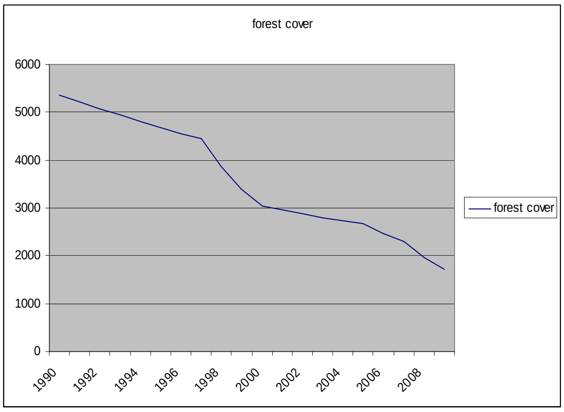


Figure 38 Graph of existing forest cover

Correlation coefficient and regression analysis

The correlation between population increase and deforestation (forest lost) is tested with the correlation coefficient and regression line. Scatter plot shows the relationship between increase (X axis) and deforestation (Y axis). The coefficient of correlation can show the (positive or negative correlation) (Marshal, 1987). Both variables (population and forest cover) for 20 years (1990-2009). Data population is given in

Appendix 26. (source : BPS, 2009).

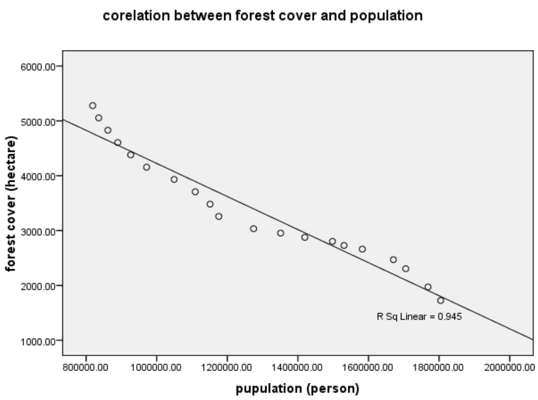


Figure 40 Correlation between population and forest cover

A Scatter plot was made for those years with both variables and it can be seen from the scatter plot that the relationship has relatively straight-line pattern, so that simple linear regression can be appropriately used in order to show the relationship between those variable (population increase and forest cover). From the calculation, It was found that the relationship between population and forest cover has strong relationship with negative correlation and r^2 = 0.945 (r = 0.972).

High r value indicates high/strong correlation between 2 variables. So there is a strong and negative relationship between population increase and forest cover. The calculation result can be seen in this table 13 and detail result is presented in Appendix 24.

Table 13 Statistic analysis result of correlation between population and forest cover.

Dependent Variable	R	R Square	Adjusted R Square	Coefficients (Constant)	Coefficients population	F	t	Sig.
Deforestation	.972[a]	.945	.942	7239.443	-.003	310.778	-17.629	.000[a]

Regression analysis generates the following regression equation: Y = - 0.003x + 7239.443 and Tcal > Ttable = 17.629 > 10.983. It means that confidence interval 95 %, Tcal > Ttable, it indicated the high significance of the equation. Because of Tcal is negative (-17.629), it mean population has negative correlation with forest cover. The more the population increase, the more the forest cover reduces.

So from the result we can conclude that the increase of population has correlation with the increasing of deforestation area. The increasing of population is followed by the decreasing of forest area in SSH GFP. In Indonesia, as well as in developing countries, deforestation is difficult to avoid. This is mainly due to the increasing population, thus increasing demand for agricultural land, settlements and others (Pratiwi, 1998).

4.8. The consistency analysis between existing land use and the spatial land use plan

According to the regional spatial use plan of Riau Province (RTRW), the study area was categorized as protected area (6,172 Ha). However, the area of existing land use and land use planning in study area is significantly different. From the spatial analysis result, there are two main other land uses existing in the study area that not according to spatial land use planning of Riau Province which are oil palm plantation (1,571 ha) and crop (244 ha). The inconsistency between the existing land use and land use plan is 30 % (1,815 ha). The differences between existing land use and land use planning for each region is illustrated in table 14.

Table 14 The inconsistency between existing land use and spatial land use plan

REGION	Spatial land use planning for protected area (ha)	Existing land use		Existing land use not according to spatial planning (ha)	Inconsistency (%)
		Plantation (ha)	Crop (ha)		
Kampar Regency	2991	1310	185	1495	50
Pekanbaru City	662	85	13	98	15
Siak Regency	2254	177	45	221	10
RIAU	5907	1571	244	1815	30

V. DISCUSSION

5.1 Land cover mapping

5.1.1. Land cover classification

Land cover types were classified from Landsat Images into six classes namely forest, shrub, oil palm plantation, open area (bare land), crop and water for determining land cover/use situation in SSH GFP. The classified images of 1989, 2000, 2005 and 2009 are the important aspects in understanding of forest cover change in SSH GFP.

One of the major problems using Landsat data in tropical countries is finding cloud cover free data. The image obtained from landsat in this particular area misses a part of data as result of this situation. The image acquired in 1989 has a cloud cover of 414 ha (6.4 % Ha), while the image acquired in 2000, and 2005 is free from cloud. Meanwhile, the image acquired in 2009 has a cloud cover 239 ha (3.7 %). Nonetheless, this image still can be used since the cloud cover is only in the small area. So the cloud is omitted and it is not taken into account for change detection analysis.

5.1.2. Accuracy Assessment

Accuracy assessment is important to assess the quality of classification by comparing the classification result with the reference data or ground truth. The overall accuracy for the classification of the landsat image 2009 is 79.21 %. It means that about 20 % of the classification does not match with the reference data. Kappa statistic (0.7299) revealed that 72,99 % of the whole classification is in agreement with the reference data used for the assessment. Interpretation of Kappa statistic 0.6-0.8 is good agreement, so the interpretation of Kappa statistic at this level is consider good agreement (Cohen, 1960).

One of the challenges for this study is the ”ground truthing” data for the classification of the images of 1989, 2000 and 2005. The only source of data available is the land cover maps of the corresponding year. The land cover map 2005 made by Forestry Services of Riau Province was used to assess the accuracy of the land cover classification. This map was made based on field surveys by Forestry Services of Riau Province and it was published in the Master Plant document of SSH GFP. The test sample for reference data was derived randomly from this map and also was verified carefully with the 2007 Google Earth. In such cases, secondary reference data e.g. land cover map 2005 allows the detection of the type of the land cover change in terms of land cover classes. To assist either classification or verification, using the Google Earth might also be useful (Midora, 2009).

The land cover map 1989 and 2000 could not be assessed for the all classes, because lack of land covers maps in those years as reference data. Nevertheless, the accuracy for land cover map 1989 and 2000 still can be verified with using the deforestation map in Sumatera 1990-2000 published by Ministry of Forestry. This maps was made by Ministry of Forestry in corporation with

Forestry-Wildlife Conservation Society-Indonesia Program (WCS-IP) based on field surveys and ground checking in the field. The accuracy for the classification of the classified image 1989 and 2000 are 86 % and 82 %, respectively. This value only refers to class forest and non forest. The accuracy for land cover 1989 and 2000 is higher than the others because the classes for reference only have 2 classes which are forest and no forest. Hence we cannot asses the accuracy for the whole classes, but the figures give an indication of the quality of the classifications for our specific purposes: forest cover change detection.

5.2. Land cover change

The post classification comparison change detection approach was applied in comparing two independently produced classified land cover maps from images of two different dates. However, the number of change areas cannot be trusted 100 % correct, since the accuracy of classification images is not 100 %.

The change detection from 1989 to 2009 shows the decreasing of forest cover over time and on the other hand the increasing of oil palm plantation, while shrub and crop remain more or less constant since 2000 until 2009. This indicates that there is a trend of forest cover change process in the study area. Most forest cover change occurred in the middle and south-western part of SSH GFP.

The change detection showed that the increase in oil palm plantation mainly came from forest, shrub and open area (bare land). Looking at the series of images it shows that forest is first converted into bare and shrub land, and only later into oil palm. This confirms the statement on illegal logging: after forest is cleared by illegal logging, oil palm producers benefit from the open space and start planting oil palm. Initially this is not seen on the image because the oil palm trees are still small and partly covered in shrubs. On later images this oil palm is recognizable. This is confirmed by (Fombad, 2009). His research suggested that most forest resources were converted first to bare land and then the bare land was converted to agriculture expansion. But another research showed that research, most forest cover was converted directly to become smallholder oil palm plantation (Epole Njuma, 2009). The reason for this condition, there was a Tree Crop Initiative Programme in that area where free supply of oil palm seedlings and fertilizers financed by World Bank, so forest directly converted into smallholder oil palm plantation.

In the period 2000-2005, the original land cover conversion into oil palm plantation are open area (227 ha or 36 %), shrub (176 ha or 28%) and forest (111 ha or 18 %). Meanwhile, the other classes, which are crop and water are not significant. Only 2 % of crop was converted into oil palm plantation in this period. This indicates that farmers do not convert or sell their fields for oil palm production. They rather use open space for that. However, the period 1989-2000 there are 111 ha (18 %) of forest area directly converted into oil palm plantation in this period.

In land cover change 2005-2009 shown that forest cover in northern and north-western part of GFP decreased and was converted into bare land (cleared land). So deforestation occurred in this part. The open area (bare land) was increasing in this period. The oil palm plantation increased in the western part and in the northwest part as well. In year 2005-2009, 36 % of oil palm plantation came from shrub, and 16 % from forest and 16 % from open area. This again confirms that forest land was first converted into bare land shrub, probably through illegal logging, and then into oil palm. Only 3 % of crop converted into oil palm plantation. So, in this period, most of the oil palm plantation was established in the area of shrub, forest and open area. The total oil palm plantation increased from 627 Ha (11 %) in 2005 to 1,570 Ha (26 %) in 2009.

Using the land cover classification results, the annual deforestation rate in SSH GFP for the period 1989-2009 could be calculated. This calculation supported the fulfilment of the second objective of this research which is to identify the locations and rate of deforestation in SSH GFP. The highest forest loss is in the period of 1989-2000. During 1989-2000, 45 % of the total area was experiencing forest loss. The oil palm plantations were contributing up to 185 Ha conversion from forest or 7,08 % of the total forest lost during this period. The loss of forest during this period is probably occurred mainly because of reformation era in the period 1997-2000, when law enforcement was weak and few control mechanisms in place. Ministry of Forestry said that the highest deforestation occurred in period 1997-2000 because in this period reformation era happened in Indonesia in year 1998 (MoF, 2008). From the interview result, rampant illegal logging occurred since reformation era which started in 1998 and it could not be controlled well because of uncertain political situation in this time. Interview result is given in Appendix 2.

Most of the forest loss during this period was related to illegal logging activities that occurred especially in the reformation era. Unfortunately, the detailed forest lost in this period cannot be assessed because lack of data available in this time but from quick look SPOT 1 1997 image (see Appendix 4), the trend can be seen that forest loss was continued significantly in this period.

The annual deforestation rate in 2000-2005 was decreased compared to the period of 1989-2000, with annual rate of 2,6 % per year, a total 694 ha forest was converted to non forest. In this period the political situation was more or less stable and autonomy era has been implemented in Indonesia. Compared to national deforestation, deforestation in this period also decreased from 2,84 million ha/year in period 1997-2000, to 1,08 million ha/year in period 2000-2005 (MoF, 2008).

The annual deforestation rate observed for the period of 2005-2009 is 10,84 % with total deforestation 1,145 Ha that approximately 287 Ha per year were cleared in SSH GFP. This rate indicates a continuous process of deforestation in the study area. The high deforestation in this period occurred because of illegal logging activities especially in the north part of study area and also the increasing of oil palm plantation. Data of illegal logging cases occurred in this period can be seen in Appendix 25. Compared to national deforestation rate in the whole period in SSH GFP is high. If the rate of deforestation continues without strong attention and protection from all stakeholders, it can be predicted that the remaining forest area in SSH GFP will be lost in to the next certain years.

5.3. Analysis of drivers

Geist and Lambin (2002) divided drivers deforestation into two categories which are proximate cause and underlying drivers. Rademakers *et al.,* (2010) stated that proximate causes can also be called direct driver and underlying drivers as indirect drivers.

From the result it shows that proximate cause/direct drivers that mainly occur in SSH GFP are illegal logging, land clearing for oil palm plantation, and road development. The indirect/underlying drivers of deforestation in SSH GFP are population growth, demand of palm oil production, weak law enforcement and political situation that contribute to forest decline.

These factors are considered as drivers of deforestation in SSH GFP. The population growth, demand of palm oil production, weak law enforcement and political situation are indirectly effecting the pressure level on the illegal logging action, and also lead land clearing activities for oil palm plantation and these actions are easier because of the road development in the study area can increase the accessibility. This result supported by some literature such as Rademakers *et al.,* (2010) stated that the is rarely a single direct or indirect driver responsible for deforestation; most often, multiple processes work simultaneously or successively causing deforestation. De Sherbinin (2002) also stated that the indirect drivers of deforestation are a complex interplay of many economic, institutional/governance policies including land tenure systems, and technological and demographic/socio-cultural factors.

The drivers (direct drivers/proximate cause and indirect drivers/underlying drivers) of deforestation in SSH GFP are discussed as follows:

5.3.1 Direct Drivers

a. Oil palm plantation expansion

Regional development in Riau province has achieved good results as seen from the level of economic growth. According to BPS 2009, Riau Province has economic growth and the highest gross regional domestic revenue (PDRB) in Indonesia, with the average growth is 23 percent. In the period 2000-2007, the economic growth in Riau Province is 8.40 %. The high economic growth is caused by agriculture sector especially subsector plantation.

In 1996, the agricultural sector as the economic backbone of the rural people of Riau, only has growth of 2 percent while the industrial sector amounted to 14 percent. But in 2002 the agriculture sector has started improving with the growth rate was 6.06 percent, while the industrial sector, 12.47 percent. During the period 2002-2007 the growth in the agricultural sector is good which is equal to 6.79 %. The high growth in the agricultural sector because it is supported by export-oriented plantation crops like rubber, coconut and palm oil that growing rapidly. (BPS, 2009) .

Riau is one of provinces in Indonesia that has the largest area for oil palm plantation. From the data of Statistical Bureau of Riau, 2009, Riau province has 1.6 million hectare of oil palm plantation area in 2008. In figure 34 chapter 4 is shown the growth of the area and production of oil palm plantation in last 20 years. Therefore, Riau province is the second largest in its contribution of palm oil production compare to other province.

From graph in figure 35 it is shown that, although the shape of the two lines is the same, indicating a strong similarity in the trend, there is a gap between deforestation and oil palm plantation where total area of oil palm plantation is not equal to deforested area. Generally, total deforested area is more than total oil palm plantation in the same year. This condition occurred because deforested areas exist because forest is not directly converted into oil palm plantation, but it converted first to open area (bare land) or shrub. Besides that, it also because in land cover classification, it is difficult to identify the tiny oil palm plantation that still growing, so the classification might be mix between open area (bare land) and tiny oil palm plantation. The relation between deforestation and oil palm production also has relationship with $R^2 = 0.981$. These results also supported by literature that stated that there is a direct relationship between the growth of oil palm estates and deforestation in Malaysia and Indonesia (Clay, 2004). The reason behind the observed trend can be population growth and demand of palm oil production. The population is growing while the land is limited. Increasing price of palm oil product leads people to expand more land for developing oil palm plantation. Demand and land pressures resulting from population pressure may drive for higher agricultural production. Besides population pressure infrastructure development also puts pressure on the land.

Globally, the most prominent drivers is agricultural expansion coupled with wood extraction and infrastructure expansion. These three factors combined are present in the global cases. The expansion of agriculture land and pastures is present, generally in combination with other causes (Nelson *et al.*, 2006). Barbier and Burgess (2001) showed in their study that agricultural expansion is the main factor determining forest resources loss in most areas of the tropical world. (Hartemink *et al.*, 2008) stated that forest are cleared for the expansion of cropland, wood extraction, or infrastructure expansion.

According to the United Nations Framework Convention on Climate Change (UNFCCC, 2007), the overwhelming direct cause of deforestation is agriculture. Subsistence farming is responsible for 48% of deforestation; commercial agriculture is responsible for 32% of deforestation; logging is responsible for 14% of deforestation and fuel wood removals make up 5% of deforestation.

Scientists today agree that agricultural expansion is the most important direct driver of land use change globally, followed by infrastructure development and wood extraction (Rademaeker, *et all*, 2010).

b. Infrastructure development and proximity analysis

There were road developments inside the area of SSH GFP during period 1990-2000. The development of road can facilitate deforestation due to increased accessibility to forest area. Oil palm plantations are leading to construction of more roads for transportation and accessibility. The construction of roads can be a threat of the forest.

In this study, the impact of roads on deforestation is clear as shown in figure 30 chapter 4. The major deforested areas occur from the nearest road. It was shown from the result that road has influenced deforestation, shown by the closer distance to the road, the larger area of deforestation. There are several reasons; the main reason is with easy access lead the increasing deforestation near to the road. Roads can facilitate deforestation due to increased accessibility to forest area. The existing of road can stimulate people to establish oil palm plantation. Road and land use play an important coupled role in forest dynamics (Frietas *et al.*, 2010). Road provide access to loggers, cultivators and encroachers who can cause deforestation (Grainger, 1993 cited in (1998).

Yuwono *et al*., (2007) stated that infrastructure development such as road construction contributes to further fragmentation of conservation area. SHH GFP is categorized as a conservation forest that suppose to be protected because of its function, but unfortunately the lost of forest resources occurred continuously. However, many factors work together in the deforestation process and Road only one of the key factors through improving access to remote and inaccessible areas. Several study such as Mena, et al (2006) also stated that roads are direct and underlying drivers of deforestation across spatial scale. Grainger (1993) after (Apan and Peterson, 1998)identified proximity of roads as one of underlying cause of deforestation.

Regression analysis shows that there are correlation between deforestation and distance to settlement with $R^2 = 0.860$. Scatter plot in figure 37 shows the relationship. The plot shows that when 1 km distance from the settlement is reached, the graph increases toward a peak until 5 km and then begins to slope again. This condition because there is an open area between settlement and boundary of SSH GFP, so the major deforestation does not occur in the close distance to the settlement. And then there are offices of SSH GFP at the boundary of SSH GFP near to the settlement, so people are searching the areas far away from this office that are accessible because of roads. The major deforested area occurred in the distance of 4-5 km from the settlement since the control of management is weak and people are more convenient to do their activities there More than 6 km, the deforestation was reduced because the longer distance at which the resources are located, the smaller the chance that people will go there. In this situation distance begins to be a limiting factor. Gondwe (2005) in his research also found that deforestation tend to increase in the farther to settlement and it tend to decrease after certain distance from the settlement.

Infrastructure developments such as road are considered drivers of deforestation, accelerating forest fragmentation. The development of road is sometimes threatening forest area, because people can reach the forest area easily (Young, 1994). Roads and land use play an important role in forest dynamics. Road construction and improvement increase accessibility of remote areas, allowing logging, hunting and deforestation for new agricultural (Nagendra et al., 2003; (Fearnside, 2007).

c. Illegal logging

Most of forests in Indonesia are threatened by deforestation from logging activities. Through overlaying logging concession map in the region, it can be seen that there is no logging concession inside the study area. So there are no legal logging activities inside the study area, but illegal logging activities could have happened in this area. However, contribution of illegal logging activities is difficult to determine, but from the forest cover change process, it can be seen that in 1997 and 2000, the forest area was first converted to open area in large scale. This conversion (from forest to open area (cleared land) could be due to illegal logging activities and followed by land clearing for oil palm plantation. Moreover, the interview results from stakeholders generally states that there are rampant illegal logging activities in the study area during this period without decisive action from the government, especially during this period (1997-2000).

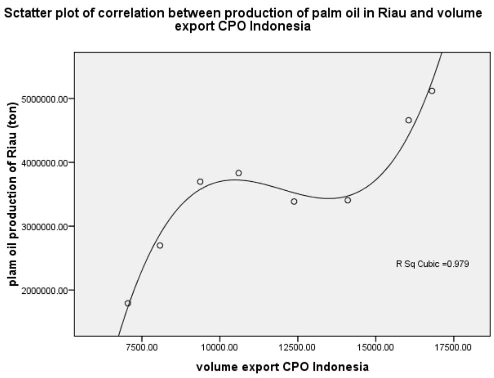
Total area deforested due to illegal logging activities is difficult to calculate, because of lack of data and the activities happened in the past time and no enough data available to depict the detail contribution of logging activities in the area. However, according to the data got from Forestry services in Riau Province, there are several cases of illegal logging activities in year 2002, 2004 2006 and 2008 that has been handled to court. The illegal logging cases are given in Appendix 25.

5.3.2 Indirect driver/underlying drivers

The demand of palm oil production

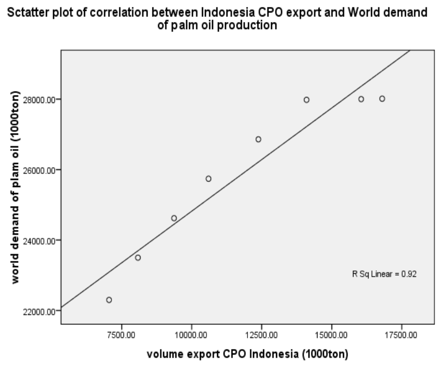
The global demand of oil palm plantation also increases annually and it generates the increasing of the development of oil palm plantation in order to produce the more oil palm production. In 2005, Indonesia states its intention to develop biodiesel and bioethanol industries to meet 2 percent of the country's fuel need by 2010 (Wakker, 2006). In early 2006, the government revealed a plan to establish 3 million hectares of new oil palm plantation to achieve these targets. Subsequently, government, private sector and smallholders develop oil palm plantations. However much of the development of oil palm plantations, either in large scale or small scale, converted the forest. Indonesia is experiencing the biggest rate of increase in term of forest converted into oil palm plantation. In period of 30 year, oil palm plantations have increased 20 times with 12 percent average annual increases in crude palm oil production (Casson, 1999).

Palm oil production also has relationship with volume export of CPO Indonesia. Statistical analysis results illustrate the relationship between palm oil production and volume export of Crude Palm Oil (CPO) Indonesia. It is shown in figure 2. The plots show relationship with R^2 = 0.748. This indicates a relation between palm oil production and volume export of CPO Indonesia. In addition**,** statistical analysis also was done to illustrate the relationship between Indonesian CPO export and world demand. It is shown in figure 3. The plots show relationship with R^2 = 0.926. Detail statistic results are presented in Appendix 22 and 23.



Y = -0.006x2+386.375x-119861.552

Figure 41 Correlation between production of oil palm in Riau province and volume export Indonesia



y = 0.586x + 18960.749

Figure 42 Correlation between Indonesian CPO export and word demand of oil palm production

The increasing demand oil palm production generates the development of oil palm plantation in order to fulfil the demand of palm oil production. On the other hand, land for agriculture is limited and people prefer to expand oil palm plantation into the protected areas, as was demonstrated in this study.

Weak law enforcement and poor protection aggravates this situation. The political situation and lack of management for this GFP also generates this situation since the management of SSH GFP has been established in year 2009, whereas the establishment the area to Grand Forest Park was in 1999. The long time transition between the establishment of Grand forest park and the establishment of the management accelerates impact on the GFP condition.

Economic factors are present in many cases and clearly dominate the underlying causes. Commercialization and the growth of mainly timber markets as well as market failures are frequently reported to drive deforestation and thus, constitute a strong underlying driving force of deforestation.

Furthermore, demand for agriculture products and timber, additional pressure from population growth, global policy incentives such as biofuels targets could also create pressure for forest clearance. The policy, lack of clear and secure land tenure can be a major factor driving deforestation in many nations (Eliasch, 2008). Global and national demand for agricultural products also creates new land demands and influence rates of deforestation (Fearnside, 2008).

b. Population increase

The result revealed that that the relationship between population and forest cover has strong relationship with negative correlation and $r^2 = 0.945$ ($r = 0.972$). High r value indicates high/strong correlation between two variables. The increasing of population generates other human activities that can impact to the environment such as encroachment, agriculture expansion, introduction of network road, illegal logging, etc and finally it has impact of the increasing of deforestation area. It shows that the increasing of population followed by the decreasing of forest area in SSH GFP.

This is supported by some literature showing the relationship of population and forest cover. Brown and Pearce (1993) described that in most cases; population increase is accompanied by deforestation and generally indicates a positive correlation between population growth and deforestation. FAO (1990) ; Barbier *et al*., (1993) cited in Sunderlin and Resosudarmo (2004) stated that there is a negative correlation between forest cover and population numbers. Moreover, rapid human population growth leading to pressure on land resources has been notes to have negative contribution by most literature on land use/cover change (Verburg *et al.*, 2006); (Wright, 2005).

5.4. The inconsistency between existing land use and spatial land use plan

The Regional Spatial Land Use Plan (RTRW) of Riau Province as stated in Provincial Government Degree No. 10 of 1994 is a product of a spatial planning which describes the structure and pattern of the future spatial use plan of the region. It describes the strategy and vision of national development policy into regional spatial plan. RTRW of Riau province regulates regional spatial planning into 2 major guidelines of regional development which are protected area and cultivation area. Cultivation area includes plantation, industry, tourism, agriculture, settlement, and priority area. The regional development in Riau should be implemented based on the Riau's Regional Spatial Land Use Plan (RTRW). The development of Riau Province, on the one side, needs land availability. Meanwhile the land availability is relatively limited. This situation causes land use many conflicts which finally create inconsistency between the existing land use and the spatial land use plan (RTWP). This can be seen from forest land allocated in RTRW converted into other land uses. According to RTRW of Riau Province, the study area was categorized as protected area (6,172 Ha). However, the area of existing land use and land use planning in study area is significantly different.

The two main other land uses existing in the study area that are not inconsistent with the spatial land use planning of Riau Province are the oil palm plantation and crop. The digression of the existing land use from the spatial land use plan is 30 % (1,815 ha). The highest digression exists in Kampar Regency (50 % or around 1,495 ha). The second one occurs in Pekanbaru City (15 % or about 98 ha). The third one is in Siak Regency (10 % or 221 ha).

From the interview result, during 1994-2000, local government in Kampar regency in sub district level gave some SKT (Land letter) for agriculture area to the local people, but the area overlapped with SSH GFP. So the location was inside SSH GFP. This policy might be one of the factors the change of land use in the study area.

The influence of worldwide policy-making/governance such as reformation era and regional development in Indonesia and technological innovation can influence deforestation in both positive and negative ways such as for alternative energy policies: the use of biomass and biofuels is increasingly encouraged by many governments around the world and needs to be assessed as a driver of deforestation. Similarly, land use policies and planning can act as indirect drivers of deforestation if environmental concerns are not accounted for it.

5.5. Limitation of this research

1. The lack of the exactly right date/period of imagery data for the study area especially for year between 1989 and 2000. So only quick look spot 1 for year 1997 was available for understanding the ongoing trend of forest cover change, especially for period of reformation era.
2. Lack of ground truth data as references for land cover maps 1989, 2000 and 2005, so the accuracy only can be done using land cover map in the corresponding year and data from google earth were used for reference 2005. Especially for 1989 and 2000 accuracy only can be use for class forest and non forest, so the accuracy for oil palm plantation in this year could not be assessed especially for year 2000, because oil palm plantation shown in this year, but for 1989 was no oil palm plantation and most land cover in this year was forest.

VI. CONCLUSION AND RECOMMENDATION

6.1. Conclusions

This research has effectively used remote sensing data to investigate changes in the forest cover of SSH GFP between 1989 and 2009. Information about the forest cover change over time and the analyses of the factor causing/driving this change is important for management and planning of the remaining natural resources in the study area. Based on the observation during fieldwork and data analysis, the research is able to provide answers and conclusion to the following research questions:

1. How does the forest cover change process occur in SSH GFP ?

Forest is the most dominant land cover type in 1989 which is 5504 Ha (93 %), but forest cover change has been occurring in SSH GFP since 1989 – 2009. Forested area in SSH GFP clearly decreases, while oil palm plantation significantly increases.

- During 1989-2000, the forest cover decreased and it was converted to shrub (1,135 ha or 21 %), open area (1,080 ha or 20%), crop (193 ha or 4%) and oil palm plantation (185 ha or 3%). The remaining forest cover in 2000 is 3,033 Ha (51 %).
- In the period 2000-2005, forest changed into shrub (504 ha or 17 %), oil palm plantation (111 ha or 4 %), open area (68 Ha or 2 %) and crop 10 ha (0.01 %). The remaining forest cover in 2005 is 2661 ha (51 %).
- From 2005 to 2009, forest cover also reduced to become 1,725 Ha (29 %). Forest cover changed into shrub 498 ha (19 %), open area (359 ha or 13 %) and oil palm plantation (254 ha or 10 %) and crop (74 ha or 0.03 %).

So, the change detection from 1989 to 2009 shows there is a decrease of forest cover over time and an increase of oil palm plantation. Meanwhile, shrub and crop remain more or less constant from 2000 until 2009.

2. What are the rates and where are the deforested areas in SSH GFP?

The rate of deforestation in SSH GFP in period 1989-2000 is 5.42 %. Deforestation area is 2,612 Ha (237 ha/year). In the period 2000-2005 is 2.6 %. Deforestation area is 694 Ha (139 ha/year). During 2005-2009, deforestation rate is 10.84 % with total area 1,150 Ha (287 ha/year). The average rate for the entire period is 5.8 % with total are 3779 ha (189 ha/year). In land cover change 1989-2000, most deforestation occurred in the middle and south-western part of SSH GFP. In the period 2000-2005, most deforestation occurred in the middle and north-eastern part of SSH GFP. In 2005-2009, deforestation mainly occurred in the northern and north-western part of GFP.

3. What are the main drivers of deforestation in SSH GFP?

The main drivers of deforestation in SSH GFP are divided into two categories which are proximate causes/direct drivers and underlying causes/indirect drivers. The main drivers for proximate causes/direct drivers are illegal logging, land clearing for oil palm plantation development and roads development. The underlying/indirect drivers are increase in population, demand of palm oil production, and weak law enforcement and political situation.

4. How inconsistent is between the existing land use and The Regional Spatial Use Plan of Riau Province?

There are two existing land uses in the study area that are inconsistent with The Regional Spatial Use Plan of Riau Province meaning that the land is used in an inappropriate way or against the law. Those are oil palm plantation (1571 ha) and crop (244 ha). The uses of land for oil palm plantation and crop in the SSH GFP are prohibited because the study area is a protected area according to The Regional Spatial Use Plan of Riau Province. The digression of the existing land use from The Regional Spatial Use Plan of Riau Province is 30 % (1,815 ha). This figure implies that about 30% of the study area has been misused. For each region, the existing land use in Kampar Regency is most inconsistent with a percentage of 50 % (1495 ha) whereas the second one is Pekanbaru city with an inconsistency percentage of 15 % (98 ha). The third one is Siak Regency which has an inconsistency percentage of 10 % (221 ha).

6.2. Recommendations

1. It is necessary to disseminate forest information and implement reforestation programs and REDD (Reducing Emission from Deforestation and Degradation) programs in SSH GFP and involve the local community in the management and planning of SSH GFP.
2. Patrol activities along the boundary of SSH GFP need to be conducted intensively in order to improve the quality and awareness of the local community attitudes toward the SSH GFP.
3. Government should consider the deforestation in SSH GFP through action plans which involve Kampar Regency Government because the deforestation and oil palm plantation mostly occurred in this regency.
4. Law enforcement must be taken toward illegal activities in SSH GFP. For the oil palm plantation expansion inside the SHH GFP, It is important to propose win-win solution or land compensation among stakeholder involved.
5. Criteria of RSPO should be implemented in Riau Province in order to avoid further deforestation in forest area especially in SSH GFP.
6. Regional development should not only consider the economic benefit but also environment impacts and conservation aspects.

Further research

Further research that is important to be done is to identify the priority area for reforestation, and vulnerability assessment of the SSH GFP to deforestation is also important to continue this study.

REFERENCES

Anderson, J.R., E., E., Hardy, T., J., Roach, Richard E. Witmer, 2001. A Land Use And Land Cover Classification System For Use With Remote Sensor Data, . Geological Survey Professional Paper 964

Apan, A.A., Peterson, J.A., 1998. Probing tropical deforestation - The use of GIS and statistical analysis of georeferenced data. Applied Geography 18, 137-152.

Badiozamani, G., 2007. Addressing Deforestation and Forest Degradation Through International Policy.

Bangun, D., 2006. Indonesia Palm Oil Industry. Presented at the National Institute of Oilseed Products Annual Convention, Phoenix, Arizona, U.S.A.

Barbier, E.B., Burgess, J.C., 2001. The Economics of Tropical Deforestation. Journal of Economic Surveys (15 (3), 413-433.

Barker, J.F., 2005. Is Economic Growth good for the Environment? An approach to this question using the Environmental Kuznets Curve Hypothesis. http://www.population- growth-migration.info/ essays /economyk.html.

Bektas, F., Goksel, C., 2003. Remote Sensing And GIS Integration For Land Cover Analysis, A Case Study: Gokceada Island.

BPS, 2009. Riau in Figure 2009. Badan Pusat Statistik Provinsi Riau, Pekanbaru.

Brandts, T., M, P., Mather, 2009. Classification Methods For Remotely Sensed Data. Tailor and Francis Group. LLC.

Brown, K., Pearce, D.W., 1993. Causes of Tropical Deforestation: the Economic and Statistical Analysis of Factors giving rise to the Loss of.

Tropical Forests. UCL Press, London. , pp. 217-225.

Carpenter, S.R., E. M. Bennett, Peterson., G.D., 2006. in press: Editorial: Special Feature on Scenarios for Ecosystem Services. Ecology and Society.

Cassel-Gintz, M., Petschel-Held, G., 2000. GIS-based assessment of the threat to world forests by patterns of non-sustainable civilisation nature interaction. Journal of Environmental Management 59, 279-298.

Casson, A., 1999. The Hesitant Boom: Indonesia’s Oil Palm Sub-Sector in an Era of Economic Crisis and Political Change Program on the Underlying Causes of Deforestation, Bogor Indonesia. Centre for International Forestry Research.

CCSP, 2006. The U.S. Climate Change Science Program (CCSP) Climate Change Science Program, and The Subcommittee Global Change Research. "Our Changing Planet: The U.S. Climate Change Science Program for Fiscal Year 2006. Washington: Climate Change Science Program Office.

Chen, X., 2000. Using Remote Sensing and GIS to analyze Land Cover Change and its impacts on the regional sustainable development. International Journal of Remote Sensing 23(1).

Clay, J., 2004. Palm oil. In: World agriculture and the environment: a commodity-bycommodity guide to impacts and practices. Island Press, Washington, DC., 2-3-235.

Cohen, J., 1960. A Coefficient of Agreement for Nominal Scale. Educat Psychol Measre 20, 37-46.

Collins, J.B., Woodcock, C.E., 1996. As assessment of several linear change detection techniques for mapping forest mortality usingmultitemporal LandsatTM data. Remote Sensing of Environment, 56, 66-77.

de Sherbinin, A., 2002. A CIESIN Thematic Guide to Land-Use and Land-Cover Change (LUCC). Center for International Earth Science Information Network (CIESIN) Columbia University Palisades, NY, USA.

Dendukuri, N., Caroline, R., 2004. Correlation and Regression. The Canadian Association of Radiologists, and the American Journal of Roentgenology, McGill University, Canada.

Di Gregorio, A., 2005. UN Land Cover Classification System (LCCS) - classification concepts and user manual for Software version 2, Available at: www.glcn-lccs.org.

Eliasch, 2008. Climate Change: Financing Global Forests: "The Eliasch Review"

Epole Njuma, M., 2009. Land cover change analysis of smallholder oil palm growers in relation to government policy in the moist tropical forest of Southern Cameroon. ITC, Enschede, p. 70 p.

FAO, 1990. Situation and Outlook of the Forestry Sector in Indonesia. Volume 1.

FAO, 2001. Global Forest Resources Assessment 2000, main report. Food and Agriculture Organization of the United Nations.

FAO, 2006. Global Forest Resources Assessment 2005. Main report, Food and Agriculture Organization of the United Nations.

FAO, 2009. State of the World's Forest. Food and Agriculture Organization of the United Nations.

Fearnside, 2007. Brazil's Cuiabá-Santarém (BR-163) highway: the environmental cost of paving a soybean corridor through the Amazon. Environmental Management 39(2007), pp. 601-614. .

Fearnside, 2008. The roles and movements of actors in the deforestation of Brazilian Amazonia. Ecology and Society 13 (2008), p. 23.

FoE, 2006. The use of palm oil for biofuel and as biomass for energy. Friends of the Earth Netherlands and the Swedish Society for Nature Conservation (SSNC), Amsterdam.

Fombad, E.E., 2009. The loss of forest resources and societal adaptive strategies in the Southern part of Ashanti Mampong district, Ghana. ITC, Enschede, p. 54 p.

Frietas, S.R., Hawbaker, T.J., Metzger, J.P., 2010. Effects of roads, topography, and land use on forest cover dynamics in the Brazilian Atlantic Forest. Forest Ecology and Management vol. 259, pp. 410-417

FSoRP, 2005. Sultan Syarif Hasyim Grand Forest Park (in Indonesian). Forestry Services of Riau Province, Pekanbaru.

Geist, H.J., Lambin, E.F., 2002. Proximate causes and underlying driving force of tropical deforestation. Bioscience 52, 143-150.

GoI-FAO, 1996. National Forest Inventory of Indonesia: Final Forest Resources Statistics Report. . Directorate General of Forest Inventory and Land Use Planning, Ministry of Forestry, Government of Indonesia and Food and Agriculture Organization of the United Nation, Jakarta.

Gomarasca, 2009. Land Use/Land Cover Classification Systems. Springer.

Gondwe, G.F., 2005. Assessing deforestation : proximate causes and their contribution to tree cover change in off - reserve areas of Goaso, Ghana. ITC, Enschede, p. 62 p.

Greenberg, J.A., Kefauver, S.C., Stimson, H.C., Yeaton, C.J., Ustin, S.L., 2005. Survival analysis of a neotropical rainforest using multitemporal satellite imagery. Remote Sensing of Environment 96, 202-211.

Harris, N.L., Petrova, S., Stolle, F., Brown, S., 2008. Identifying optimal areas for REDD intervention: East Kalimantan, Indonesia as a case study. Environ. Res. Lett. 3.

Hartemink, A.E., Veldkamp, T., Bai, Z.G., 2008. Land cover change and soil fertility decline in tropical regions. Turk. J. Agric. For. 32, 195-213.

Herold, M., 2009. Assessment of the status of the development of the standards for the Terrestrial Essential Climate Variables.

Hubert-Moy, L., A, C., L, L.D., A, C., P, P., 2001. A Comparison of Parametric Classification Procedures of Remotely Sensed Data Applied on Different Landscape Units. . Remote Sensing of Environment 75, 174-187.
Hussin, Y.A., 2003. In Geoinformatics for tropical ecosystems (Ed, Roy.,P.S.). Bishen Singh Mahendra Pal Singh, Dehra, Dun, India.
IPCC, 2000. IPCC Special Report on Land Use, Land-Use Change And Forestry. The Hague.
IPCC, 2006. Guidelines for National Greenhouse Gas Inventories. The National Greenhouse Gas Inventories Programme Institute for Global Environmental Strategies, Japan.
IPCC, 2007. Climate Change 2007 : Synthesis Report. Intergovernmental Panel on Climate Change (IPCC).
ITC, 2003. Manual on construction of landuse change maps. ITC, Enschede.
Jensen, J.R., 1986. Introductory digital immage processing : a remote sensing perspective. Prentice-Hall, Engelwood Cliffs.
Jensen, J.R., 1996. Introductory Digital Processing, A Remote Sensing Perspective.
Kerle, N., L.L.FJanssen, Huurneman, G.C., 2004. Principles of remote sensing : an introductory textbook. ITC, Enschede, The Netherlands.
Kindermann, G., Obersteiner, M., Sohngen, B., Sathaye, J., Andrasko, K., Rametsteiner, E., Schlamadinger, B., Wunder, S., Beach, R., 2007. Global cost estimates of reducing carbon emissions through avoided deforestation. Environmental Science 105, 10302–10307.
Koh, L.P., Wilcove, D.S., 2008. Is oil palm agriculture really destroying tropical biodiversity? . Conservation Letters 1, 60-64.
Lambin, Geist, 2003. Dynamics of land-use and land-cover change in tropical regions Annual Review Of Environment And Resources Volume: 28 Pages: 205-241 , 2003
Lampyet, B.L., Barron.E.J., Pollard, D., 2005. Impacts of agriculture and urbanization on the climate of the Northeastern United States. . Global and Planetary Change 49, 203-221.
Marshal, D., 1987. Statistic for Geoscientists. Pergamon Press, England.
Meyer, W.B., Turner, B.L., 1994. Global Land-Use and Land Cover Change: An Overview IN II, B.L.T. & Meyer, W.B. (Eds) Change in Land Use and Land Cover. University Press, Cambridge.
Midora, L., 2009. The use of MODIS NDVI data for land cover change detection in HCVF, High Conservation Value Forest, to support certification of sustainable oil palm production. ITC, Enschede, p. 67p.
Miyamoto, 2005. Forest conversion to rubber around Sumatran villages in Indonesia : Comparing the impacts of road construction, transmigration projects and population. Forestry and Forest Products Research Institute,.
MoF, 2003. Five Policies Priority in Forestry (in Indonesia). Ministry of Forestry of Republic of Indonesia, Jakarta.
MoF, 2006. Statistic of Forestry (in Indonesia). Ministry of Forestry of Republic Indonesia.
MoF, 2008. Deforestation Rate in Indonesia 2008 Ministry of Forestry of Republic Indonesia.
Nawir, A.A., Murniati, Rumboko, L., 2008. Forest rehabilitation in Indonesia: where to after three decades? Center for InternationalForestry Research (CIFOR), 2008., Bogor, Indonesia: .
Nelson, G.C., Elena Bennett , Asmeret A. Berhe , Kenneth Cassman, Ruth DeFries, T., homas Dietz, Achim Dobermann, Andrew Dobson, Anthony Janetos, Marc Levy, Diana Marco, Nebojsa Nakicenovic, Brian O'Neill, Richard Norgaard, Gerhard Petschel-Held, Dennis Ojima, Prabhu Pingali, and, R.W., Monika Zurek, 2006. Anthropogenic Drivers of Ecosystem Change: an Overview, ecologyandsociety.
Pontius, R., 2007. Land-use_and_land-cover_change and climate change.
Pratiwi, 1998. Body Forestry Research and Development. . Forest Research Bulletin. .

Puyravaud, J.-P., 2003. Standardizing the calculation of the annual rate of deforestation. Forest Ecology and Management 177, 593-596.

Rademakers, K., Eichler, L., Berg, J., Obersteiner, M., Havlik, P., 2010. Study on the evolution of some deforestation drivers and their potential impacts on the costs of an avoiding deforestation scheme. Directorate-General for Environment, European Commission, Rotterdam.

Rollinson, T.J.D., 2007. Forest and Climate Change : Conclusions and Way Forward. Edinburgh.

RSPO, 2007. RSPO Principles and Criteria for Sustainable Palm Oil Production. Including Indicator and Guidance.

Santilli, M., 2005. Tropical deforestation and the Kyoto Protocol

Climate Change Volume: 71 Pages: 267-276

Sharma, B., 2009. Modelling carbon stock in oil palm using system's approach. Enschede, ITC, p. 66p.

Sheil, D., Casson, A., Meijaard, E., van Noordwjik, M., Gaskell, J., Sunderland-Groves, J., Wertz, K., Kanninen, M., 2009. The impacts and opportunities of oil palm in Southeast Asia: What do we know and what do we need to know? Center for International Forestry Research (CIFOR), Bogor, Indonesia, p. 67p.

Singh, A., 1989. Digital change detection techniques using remotely sensed data. International Journal of Remote Sensing, , 989-1003.

Soemarwoto, O., 1994. Ecology, Environment and Development (In indonesia) Djambatan, Jakarta.

Sunderlin, W.D., Angelson, A., Belcher, B., Burgers, P., Nasi, R., Santoso, L., Wunder, S., 2005. Livelihoods, Forests, and Conservation in Developing Countries : An Overview. World Development 33 (9), 1383-1402.

Sunderlin, W.D., Resosudarmo, I.A.P., 2004. Rates and Causes of Deforestation in Indonesia: Towards a Resolution of the Ambiguities Ocassional Paper No 9 (I).

Till, R., 1974. Statistical Method for Earth Scientist. MaacMillan Press, London.

Tso, B., Mather, P.M., 2009. Classification Methods for Remotely Sensed Data CR Press, Florida.

UNFCCC, 2006. Highlights from GHG emissions data for 1990 to 2004 for Annex I Parties.

UNFCCC, 2007. Investment and financial flows to address climate change. unfccc.int. UNFCCC. pp.

Verburg, P.H., K. P. Overmars, M. G. A. Huigen, Groot, W.T.D., Veldkamp, T.A., 2006. Analysis of the effect of land use change on propected area in Philipines. Applied Geography 26, 153-173.

Wakker, E., 2006. The Kalimantan Border Oil Palm Mega-project. Friends of the Earth Netherlands and the Swedish Society for Nature Conservation (SSNC), Amsterdam.

Wilcove, D., Koh, L., 2010. Addressing the threats to biodiversity from oil-palm agriculture. Biodiversity and Conservation 19, 999-1007.

World_Bank, 1994. Indonesia : Environment and Development. Washington DC. .

Wright, S.J., 2005. Tropical forests in a changing environment. Trends in Ecology & Evolution 20, 553-560.

Yuwono, E.H., Susanto, P., Saleh, C., Andayani, N., Prasetyo, D., Atmoko, S.S.U., 2007. Guidelines for Better Management Practices on Avoidance, Mitigation and Management of Orang Utans conflict in and around Oil Palm Plantations WWF, Indonesia, 56p.

APPENDICES

Appendix 1 Field work coordinate points

No	POINT_X	POINT_Y	Land Cover
1	764738.435597	72183.186392	crop
2	764627.855880	72485.819310	crop
3	764426.820267	73054.218225	crop
4	764509.254764	72742.353831	crop
5	764216.383048	73228.045937	crop
6	764076.935176	73089.697075	crop
7	764590.533730	72907.409732	crop
8	764955.788886	72429.432784	crop
9	770481.236449	74696.934391	forest
10	770186.715868	74725.059323	forest
11	769963.590286	74886.283254	forest
12	769885.536879	75078.002742	forest
13	769684.393162	75204.511530	forest
14	770167.242613	75309.545483	forest
15	769886.148104	75707.057128	forest
16	769767.685912	75666.740255	forest
17	769687.282810	75609.540912	forest
18	769718.071611	75899.345091	forest
19	769674.378738	76045.292797	forest
20	769824.644868	76202.094774	forest
21	770042.707836	76263.974251	forest
22	768726.428649	79222.632923	forest
23	768695.477503	79253.346910	forest
24	768562.314737	79523.395810	forest
25	763181.062226	76921.198052	forest
26	763839.495792	77834.188975	forest
27	764432.877169	78913.094018	forest
28	770018.760947	74675.191899	forest
29	769749.616774	74686.427917	forest
30	769658.061251	74659.646741	forest
31	769719.248991	74788.745343	forest
32	769672.144223	74954.666480	forest
33	769940.697707	76113.342569	forest
34	760908.090167	76216.376104	forest
35	760991.139177	76545.214526	forest
36	760737.405294	76704.878301	forest
37	762242.567039	76843.906102	forest
38	770819.611486	78431.502019	forest
39	770846.032779	78191.201544	forest
40	766934.714421	74287.693418	forest
41	766507.874527	74163.335487	forest

42	770042.454607	75543.649581	open_area
43	769934.485917	75551.585013	open_area
44	769970.971404	75587.865487	open_area
45	770074.648312	76112.796100	open_area
46	762060.206791	71386.967990	open_area
47	761800.810342	71751.907215	open_area
48	761862.850803	71380.116270	open_area
49	760301.671164	75835.043244	open_area
50	759819.108625	75837.880506	open_area
51	761569.568586	76603.885726	open_area
52	761551.143795	76330.389797	open_area
53	761706.080217	75786.565159	open_area
54	762398.591278	76607.370487	open_area
55	762820.049938	75071.125119	open_area
56	763310.794947	77299.232303	open_area
57	763582.732547	77855.568995	open_area
58	764797.820378	79066.930192	open_area
59	764901.800447	78387.861552	open_area
60	763899.114395	76156.398260	open_area
61	763701.292975	75839.788278	open_area
62	767692.709815	80159.357060	open_area
63	764490.579334	74899.858757	open_area
64	763965.165590	73934.700306	open_area
65	763915.293232	74712.128078	open_area
66	760779.200374	73441.511296	open_area
67	770148.869553	80298.955383	plantation
68	769560.705282	81036.171332	plantation
69	766688.267074	72153.689564	plantation
70	766038.508808	72417.656278	plantation
71	766082.166943	71681.392129	plantation
72	765760.544997	71468.590909	plantation
73	765630.473762	71776.748307	plantation
74	765717.175999	71596.713295	plantation
75	766317.802715	70549.417474	plantation
76	766255.944241	70524.804876	plantation
77	763379.204579	70123.995202	plantation
78	761429.971968	70952.785512	plantation
79	762295.380502	72551.091300	plantation
80	761893.411588	72182.155098	plantation
81	762345.551509	72428.198912	plantation
82	762079.058683	72090.055146	plantation
83	762518.008499	72757.080792	plantation
84	762666.400385	72950.744119	plantation
85	762480.636852	73285.602506	plantation
86	762437.245726	73460.737292	plantation
87	761892.743638	73595.684941	plantation
88	761088.156192	74240.605555	plantation

89	760685.885914	74516.970789	plantation
90	761088.200398	74148.419302	plantation
91	760401.193578	74731.934318	plantation
92	760500.534564	73994.494785	plantation
93	760927.034828	74793.645343	plantation
94	760443.584532	75346.527364	plantation
95	760122.435402	75469.285726	plantation
96	759707.169762	75756.088143	plantation
97	761898.099759	75316.506983	plantation
98	762479.611103	75408.978354	plantation
99	762934.019101	76060.658703	plantation
100	762695.700498	76317.435889	plantation
101	763403.810023	76875.215891	plantation
102	764238.690663	77548.608714	plantation
103	764436.425175	78028.088189	plantation
104	764597.168182	78252.188113	plantation
105	764612.866141	77800.472985	plantation
106	764347.177893	77118.451970	plantation
107	764029.033915	76783.341615	plantation
108	763633.033550	76251.526683	plantation
109	763500.196933	75888.855546	plantation
110	763562.369690	75271.228332	plantation
111	761923.607082	73743.198500	plantation
112	763779.899525	73227.837058	plantation
113	763872.834475	72951.317689	plantation
114	761986.083824	72458.758882	plantation
115	763440.089086	72244.339467	plantation
116	763622.797622	71827.122208	plantation
117	763625.902866	71801.925669	plantation
118	768224.309532	79894.438067	shrub
119	768122.873854	79836.918830	shrub
120	768042.605565	79530.189259	shrub
121	768149.939279	79549.298625	shrub
122	768509.780442	79419.192459	shrub
123	768400.302555	79359.210717	shrub
124	768253.180183	79116.671833	shrub
125	768491.147261	79555.932262	shrub
126	768378.839052	79583.530102	shrub
127	764860.211032	78052.888432	shrub
128	764260.720000	76804.968514	shrub
129	765819.442709	77530.975124	shrub
130	766376.232575	77592.719122	shrub
131	765250.468115	77100.470831	shrub
132	765244.570599	76526.746337	shrub
133	765120.254208	75828.200818	shrub
134	764861.646755	75195.044186	shrub
135	767891.114518	79360.479004	shrub

136	767795.346206	79113.973101	shrub
137	767693.419885	78811.228244	shrub
138	767528.954499	78604.943686	shrub
139	767226.264080	78295.642439	shrub
140	770644.686154	78697.845214	shrub
141	770434.087369	78562.826655	shrub
142	769310.072811	75209.547907	water_body
143	768790.581276	74766.771213	water_body
144	768101.174334	73859.888688	water_body
145	767862.987492	73832.114878	water_body
146	767689.759345	73815.128554	water_body
147	767488.708481	73760.023473	water_body
148	769674.935178	75556.985537	water_body
149	768604.947093	74812.774307	water_body

Appendix 2 List of Questions and Interview Results

LIST OF QUESTION AND ANSWER OF THE INTERVIEW

1. General

a. When was SSH GFP established, and who is responsible for SSHGFP management?

SSH GFP Office	• SSHGFP establish in 1999 base on Minsitry of Forestry decree Number 348/Kpts-II/1999 issued on 26 Mei 1999. • Responsibility of management is before 2001 is Central Government, after 2001 is Riau Province (Forestry Services of Riau Province), Since 2009, SSH GFP was managed by SSH GFP Office
Forestry Services of Pekanbaru	• SSHGFP establish in 1999 • Forestry services of Riau province
Forestry Services of Siak	• SSHGFP establish in 1999, but the process of establishment from round 1994. • Forestry services of Riau province
Forestry Services of Kampar	• In 1999 • Responsibility : Forestry Services of Riau

b. Is there a special division from your office that responsible for SSHGFP Management?

SSH GFP Office	No special institution. Only Forestry Services, but since 2009 it has establish the institution which is SSHGFP Office for managing SSH GFP.
Forestry Services of Pekanbaru	It is no special division.
Forestry Services of Siak	It is no special division in Forestry services of Siak Region.
Forestry Services of Kampar	It is no special division.

2. Problem

a. What is the main problem of SSHGFP ?

SSH GFP Office	a. Encroachment /Occupation b. Illegal logging c. Oil palm plantation expansion d. Inadequate Infrastructure and facilities of SSH GFP office e. Less of support of all stakeholders in SSHGFP management.

Forestry Services of Pekanbaru	Encroachment and land tenure
Forestry Services of Siak	Land tenure and illegal logging
Forestry Services of Kampar	Encroachment Land Conversion for plantation (oil palm) Boundary is not clear yet
b. What are the factors that can SSHGFP has threatened in its sustainability	
SSH GFP Office	Near from Pekanbaru city (accessibility), Easy to reach No protection and Low enforcement Security personnel is not patrol No controlling because the institution of SSHGFP newly formed.
Forestry Services of Pekanbaru	Near from road, so easy to reach Less information / illumination The boundary is not clear yet Less / weak management and law enforcement
Forestry Services of Siak	Accessibility, such as near from road and easy to reach.
Forestry Services of Kampar	Near from existing agriculture
c. What are the main cause and drivers of deforestation in SSH GFP ?	
SSH GFP Office	▪ First motivation is for illegal logging activities, and followed by land clearing for agriculture, plantation with the motivation is economic factor. ▪ Land tenure in SSH GFP because of : Giving SKT (land letter) by "oknum" (unscrupulous members) of Head of Sub District. • Encroachment, occupy by people that • opened the new land for agriculture and • plantation • Weak protection and low enforcement,
Forestry Services of Pekanbaru	Encroachment and occupation for plantation No controlling, less protection and no management Population and migration to the surrounding area and people need the land for livelihood.
Forestry Services of Siak	Firstly illegal logging for chip wood Then, followed by occupation from forest to agriculture and oil palm plantation.
Forestry Services of Kampar	Because of minimum land for plantation belong to community and then it effect encroachment to SSHGFP because easy acces to the area.

d. Some of the area was damaged and deforestaed and there is area occupied by the community and planted oil palm, Why is it happend ?	
SSH GFP Office	• Less security in the past. • Politic change because of reformation • No institution that control the area • There is low law enforcement
Forestry Services of Pekanbaru	• Because of the need of agriculture land • No monitoring and less protection
Forestry Services of Siak	Occupation from existing oil palm plantation that occupy from Kota Garo, Kampar Regency, in the boundary of Siak Regency and Kampar Regency. The occupation is not from people in Minas District, Siak Regency.
Forestry Services of Kampar	• Plantation and agricultural land need • Boundary of SSHGFP is not clear in the field • Less controlling • Less of socialization and illumination either for people/community or government officer in district level.

e. Who own the land ? and do they have permit/license from government ?	
SSH GFP Office	• Community, individually, businessman. • In Kampar Regency, some of them have SKT (land Latter)
Forestry Services of Pekanbaru	• Community and businessman • In Pekanbaru They don’t have permit.
Forestry Services of Siak	• First indication, the land belong to Farmer Group from Kampar Regency but recently it suspected change and belong to the businessman from Pekanbaru • In Siak Regency, they don’t have permit.
Forestry Services of Kampar	• Farmer Group and Community • There are not Licenses from forestry, but there are land latter (SKT) from district/sub district.

f. When illegal looging in SSH GFP happen and Who is involved?	
SSH GFP Office	Since 1996 it has happened, but the illegal logging occurred in large scale during reformation era when law was not implemented well. Community, businessman involved.
Forestry Services of Pekanbaru	From the past, but more in reformation era
Forestry Services of Siak	Before 1999

	And 2008 and 2009 in Siak Regency there was illegal logging. Community near the SSHGFP
Forestry Services of Kampar	From 1995's Community and businessman.

3. Community involved

a. Is the community involved in encroachment on SSHGFP?

SH GFP Office	Yes, and in some case, after they cleared the land, the local community sold the land to the people outside.
Forestry Services of Pekanbaru	Yes
Forestry Services of Siak	Yes, and some of them have been funished.
Forestry Services of Kampar	Yes, but there are also newcomers.and some of them have been processed in the court

b. **How the role of the community for forest sustainability? Are they participate in ?**

SSH GFP Office	Some Less participates especially in Kampar Regency, but some also want to not disturb SSH GFP.
Forestry Services of Pekanbaru	In Pekanbaru, they will participate, if we invited or performed illumination
Forestry Services of Siak	Nowdays, Community in Minas district that directly bordering SSH GFP have awareness about existence of SSH GFP, they did not dare to occupy SSH GFP because there had been people of Minas arrested for taking wood.
Forestry Services of Kampar	The problem was too complex. Actually they less participate. They use the existing land for their plantation.

c. Is the community involved in planning and program of SSH GFP ?

SSH GFP Office	No so to be involved in.
Forestry Services of Pekanbaru	Community to be involved in if there are a activities, but for the planning itself never.
Forestry Services of Siak	No involved in real
Forestry Services of Kampar	Never to be involved in

4. Planning and solution

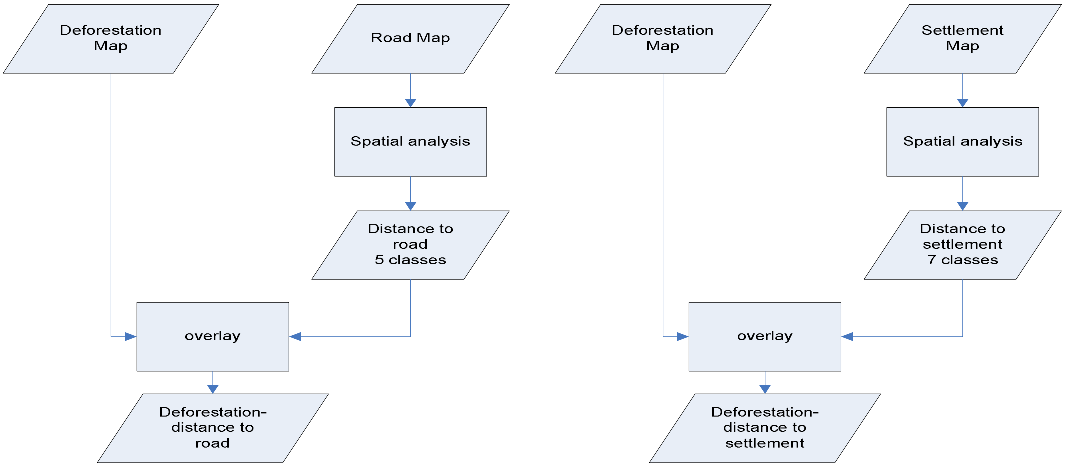
a. How strategies for overcoming deforestation in SSH GFP?

SSH GFP Office	a. For area that still forest, it need to improve the security in that area. b. Guidance through the dissemination of brochure and making billboards. c. Routine patrols done intensively. d. Law enforcement
Forestry Services of Pekanbaru	Improve Security. Make the boundaries clear. Agreement with the local community. Involving communities to develop SSH GFP
Forestry Services of Siak	Maintaining the integrity of the area SSH GFP area free of claims, empower the community to be involved in maintaining the forest sustainability and then started began reforestation activities.
Forestry Services of Kampar	a. Inventory the forest (SSH GFP) b. Re-measurements of SSH GFP area and know the width of the SSH GFP clearly and definitely. c. Approach (community leaders) in this activity, d. Do activities that impact for community welfare. e. For the open area that opened by community, communities are asked to be returned to government with the compensation.

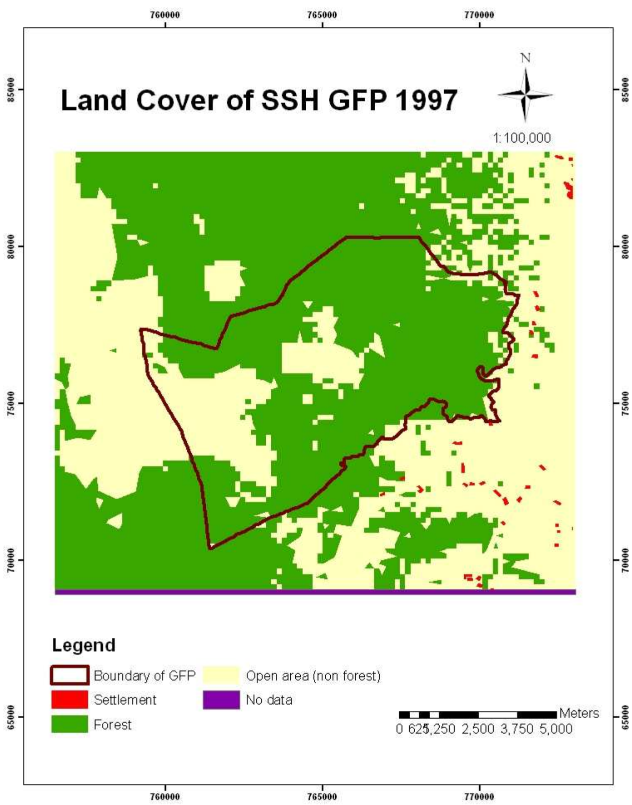
b. How does the solution to overcome the problems in the area that has become GFP oil palm plantation ?

SSH GFP Office	There are 3 solutions: a. Secured, drop oil palm and punish the suspect. b. Allowed the plant grows until 1 cycle. After that, the plant revoked/culled. c. 3. Agro forestry Program
Forestry Services of Pekanbaru	Land compensation
Forestry Services of Siak	Should look for win-win solution where oil palm plantations that already exist was left until a certain time (limited) but the requirement is : those who have oil palm, given the obligation to keep SSH GFP, given the obligation to do the planting of forest trees with a given time they will leave SSH GFP and has fulfilled the required obligations.
Forestry Services of Kampar	a. Requested to be returned to the State with the compensation. b. Requested to be returned to the State without any compensation but given the opportunity to manage for 1 (one) cycle with the consequence they will replace it with the plant and by their own cost.

Appendix 3 The flow cart of deforestation occurrence related to distance from road and settlement.



Appendix 4 Quick look from SPOT image 1997



Appendix 5 Total kappa statistic for land cover 2009 classification

Overall Kappa Statistics = 0.7299

Conditional Kappa for each Category

Class Name	Kappa
Unclassified	0
Forest	0.8174
Shrub	0.6994
Plantation	0.6521
Crop	1
open area	0.7423
Water	1

Appendix 6 Error matrix of land cover 2005 classification

Classified Data	Unclassified	forest	shrub	plantation (oil palm)	crop	open area	water	Row Total
Unclassified	0	0	0	0	0	0	0	0
Forest	0	39	2	0	0	0	0	41
Shrub	0	3	14	9	0	0	0	26
Plantation	0	0	0	18	0	0	0	18
Crop	0	0	0	0	0	1	0	1
open area	0	0	1	4	0	6	0	11
Water	0	0	0	0	0	0	3	3
Colum total	0	42	17	31	0	7	3	100

Appendix 7 Accuracy Assessment for Land Cover 2005

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy
Unclassified	0	0	0	---	---
Forest	42	41	39	92.86%	95.12%
Shrub	17	26	14	82.35%	53.85%
Plantation	31	18	18	58.06%	100.00%
Crop	0	1	0	---	---
open area	7	11	6	85.71%	54.55%
Water	3	3	3	100.00%	100.00%
open area	0	0	0	---	---
Totals	100	100	8075		
Overall Classification Accuracy = 80.00%					

Appendix 8 Total kappa statistic for land cover 2005.

Overall Kappa Statistics = 0.7219	
Conditional Kappa for each Category	
Class Name	**Kappa**
Unclassified	0
Forest	0.9159
Shrub	0.4439
Plantation	1
Crop	0
open area	0.5112
Water	1

Appendix 9 Error matrix of land cover 2000 classification

	Reference Data			
Classified Data	**Unclassified**	**forest**	**non forest**	**Row Total**
Unclassified	0	0	0	0
forest	0	29	13	42
non forest	0	5	53	58
Column Total	0	34	66	100

Appendix 10 Accuracy Assessment for Land Cover 2000

Class Name	**Reference Totals**	**Classified Totals**	**Number Correct**	**Producers Accuracy**	**Users Accuracy**
Unclassified	0	0	0	---	---
forest	34	42	29	85.29%	69.05%
non forest	66	58	53	80.30%	91.38%
Totals	100	100	82		
Overall Classification Accuracy = 82.00%					

Appendix 11 Total kappa statistic for land cover 2000

Overall Kappa Statistics = 0.6206	
Conditional Kappa for each Category.	
Class Name	**Kappa**
Unclassified	0
forest	0.531
Non forest	0.7465

Appendix 12 Error matrix of land cover 1989 classification

Classified Data	Reference Data				
	Unclassified	forest	non forest	cloud	Row Total
Unclassified	0	0	0	0	0
forest	0	58	8	0	66
non forest	0	0	28	0	28
Cloud	0	2	4	0	6
Column Total	0	34	66	66	100

Appendix 13 Accuracy Assessment for Land Cover 1989

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy
Unclassified	0	0	0	---	---
forest	60	66	58	96.67%	87.88%
nonforest	40	28	28	70.00%	100.00%
Cloud	0	6	0	-	-
Totals	100	100	86		
Overall Classification Accuracy = 86.00%					

Appendix 14 Total kappa statistic of land cover 1989

Overall Kappa Statistics = 0.7154

Conditional Kappa for each Category.

Class Name	Kappa
Unclassified	0
forest	0.697
Non forest	1
Cloud	0

Appendix 15 Change Matrix Land Cover 1989-2000

1989	2000						
	Forest	Shrub	Plantation (oil palm)	Crop	Open area	Water	Grand Total
Forest	**2,892**	1,135	185	194	1,080	18	5,504
Shrub	107	**73**	3	19	46	8	256
Open area	29	26	3	7	**51**	2	118
Water	5	7	1	2	13	**1**	29
Grand Total	**3,033**	**1,241**	**192**	**222**	**1,190**	**29**	**5,907**

Appendix 16 Change Matrix Land Cover 2000-2005

	2005						
2000	**Forest**	**Shrub**	**Plantation (oil palm)**	**Crop**	**Open area**	**Water**	**Grand Total**
Forest	**2,338**	504	111	10	68	2	**3,033**
Shrub	205	**650**	176	40	165	5	**1,241**
Plantation (oil palm)	5	74	**98**	6	9	0	**192**
Crop	23	120	15	**25**	39	0	**222**
Open area	76	415	227	72	**393**	7	**1,190**
Water	14	5	0	1	3	**6**	**29**
Grand Total	**2,661**	**1,768**	**627**	**154**	**677**	**20**	**5,907**

Appendix 17 Change Matrix Land Cover 2005-2009

	2009						
2005	**Forest**	**Shrub**	**Plantation (oil palm)**	**Crop**	**Open area**	**Water**	**Grand Total**
Forest	**1,465**	498	254	74	359	11	2,661
Shrub	197	**606**	580	107	275	3	1,768
Plantation (oil palm)	25	123	**442**	12	25	0	627
Crop	7	36	46	**18**	47	0	154
Open area	25	132	247	32	**236**	5	677
Water	6	1	1	1	2	**9**	20
Grand Total	**1,725**	**1,396**	**1,570**	**244**	**944**	**28**	**5,907**

Appendix 18 Statistic result for correlation between deforestation and distance to road

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.978[a]	.956	.947	1.70297

a. Predictors: (Constant), distance to road

b. Dependent Variable: deforestation

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	316.848	1	316.848	109.254	.000[a]
	Residual	14.501	5	2.900		
	Total	331.349	6			

a. Predictors: (Constant), distance to road b. Dependent Variable: deforestation

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	64.586	1.160		55.659	.000
	distance to road	-.013	.001	-.978	-10.452	.000

a. Dependent Variable: deforestation

Appendix 19 Statistic result for correlation between deforestation and distance to settlement

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.736[a]	.542	.450	281.99124

a. Predictors: (Constant), distance to settlement

b. Dependent Variable: deforestation

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	470603.571	1	470603.571	5.918	.059[a]
	Residual	397595.286	5	79519.057		
	Total	868198.857	6			

a. Predictors: (Constant), distance to settlement

b. Dependent Variable: deforestation

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	69.571	238.326		.292	.782
	distance to settlement	.130	.053	.736	2.433	.059

a. Dependent Variable: deforestation

Appendix 20 Statistical result for correlation between deforestation and oil palm plantation expansion

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.991[a]	.981	.979	62.83769

a. Predictors: (Constant), oil palm plantation expansion

b. Dependent Variable: deforestation

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1662326.246	1	1662326.246	420.994	.000[a]
	Residual	31588.604	8	3948.576		
	Total	1693914.850	9			

a. Predictors: (Constant), oil palm plantation expansion

b. Dependent Variable: deforestation

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	2285.975	38.080		60.031	.000
	oil palm plantation expansion	.890	.043	.991	20.518	.000

a. Dependent Variable: deforestation

Appendix 21 Statistical result for correlation between deforestation and palm oil production

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.931[a]	.867	.848	133.07996

a. Predictors: (Constant), palm oil production

b. Dependent Variable: deforestation

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	808242.301	1	808242.301	45.637	.000[a]
	Residual	123971.921	7	17710.274		
	Total	932214.222	8			

a. Predictors: (Constant), palm oil production

b. Dependent Variable: deforestation

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1868.188	153.449		12.175	.000
	palm oil production	.000	.000	.931	6.756	.000

a. Dependent Variable: deforestation

Appendix 22 Statistic result for correlation between Riau palm oil production and Indonesia CPO export

Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
.865	.748	.647	621309.210

The independent variable is volume export CPO Indonesia (1000ton).

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	5.722E12	2	2.861E12	7.412	.032
Residual	1.930E12	5	3.860E11		
Total	7.652E12	7			

The independent variable is volume export CPO Indonesia (1000ton).

Coefficients

	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
volume export CPO Indonesia (1000ton)	386.375	597.049	1.343	.647	.546
volume export CPO Indonesia (1000ton) ** 2	-.006	.025	-.483	-.233	.825
(Constant)	-119861.552	3372785.351		-.036	.973

Excluded Terms

	Beta In	t	Sig.	Partial Correlation	Minimum Tolerance
volume export CPO Indonesia (1000ton) ** 3[a]	34.180	6.620	.003	.957	.000

a. The tolerance limit for entering variables is reached.

Appendix 23 Statistic result for correlation between Indonesia CPO export and word demand of palm oil production

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.959[a]	.920	.906	679.20295

a. Predictors: (Constant), volume export CPO Indonesia (1000ton)

b. Dependent Variable: world demand of plam oil (1000ton)

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	3.173E7	1	3.173E7	68.782	.000[a]
	Residual	2767899.918	6	461316.653		
	Total	3.450E7	7			

a. Predictors: (Constant), volume export CPO Indonesia (1000ton)

b. Dependent Variable: world demand of plam oil (1000ton)

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	18960.749	867.765		21.850	.000
	volume export CPO Indonesia (1000ton)	.586	.071	.959	8.293	.000

a. Dependent Variable: world demand of plam oil (1000ton)

Appendix 24 Statistical result for correlation between forest cover and population

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.972[a]	.945	.942	250.21823

a. Predictors: (Constant), pupulation (person)

b. Dependent Variable: forest cover (hectare)

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1.946E7	1	1.946E7	310.778	.000[a]
	Residual	1126964.926	18	62609.163		
	Total	2.058E7	19			

a. Predictors: (Constant), pupulation (person)

b. Dependent Variable: forest cover (hectare)

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	7239.443	224.296		32.276	.000
	pupulation (person)	-.003	.000	-.972	-17.629	.000

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	7239.443	224.296		32.276	.000
	pupulation (person)	-.003	.000	-.972	-17.629	.000

a. Dependent Variable: forest cover (hectare)

Appendix 25 Illegal logging cases in SSH GFP

No.	Year	Suspected name	Confiscated goods	Court	Crime
1.	2002	1. Harahap 2. Ujang	Truck 2 unit	Punished	Illegal logging activities
2.	2004	1. Firman 2. Bujang	Chain saw	Punished	Illegal logging activities
3.	2006	1. Marudut Sidabutar 2. Tuna Manalu	SKT (lisence of land)	Process	Illegal land clearing activities
4.	2009	In prosses	In proccess	Process	Illegal logging and illegal land clearing activities

Source: Interview result and data collection

Appendix 26 Data of population

YEAR	KAMPAR	SIAK	PEKANBARU	TOTAL
1990	288382	131579	398694	818655
1991	301619	139921	394133	835673
1992	315463	148792	397330	861585
1993	329943	158226	401477	889645
1994	345087	168257	412918	926262
1995	360927	178925	431464	971315
1996	377493	190268	481681	1049443
1997	394820	202331	512123	1109274
1998	412942	215159	523076	1151178
1999	415344	228800	531635	1175779
2000	449506	238786	586223	1274515
2001	496910	256097	597971	1350978
2002	524296	270075	625313	1419684
2003	556575	287922	653435	1497932
2004	544542	296252	689834	1530628
2005	559586	302691	720197	1582474
2006	603473	312536	754467	1670476
2007	615517	318585	771429	1705531
2008	637758	328560	802287	1768605
2009	640230	329807	834378	1804414

Appendix 27 Highest deforestation rate and net annual area change per country globally

Country	Annual change rate (in %)	Country	Annual change in 1000Ha/year
Comoros	-7.4%	Brazil	-3,103 (*-0.6%)*
Burundi	-5.2%	Indonesia	-1,871 *(-2.0%)*
Togo	-4.5%	Sudan	-589 *(-0.8%)*
Mauritania	-3.4%	Myanmar	-466 *(-1.4%)*
Nigeria	-3.3%	Zambia	-445 *(-1.0%)*
Afghanistan	-3.1%	Tanzania	-412 *(-1.1%)*
Honduras	-3.1%	Nigeria	-410 *(-3.3%)*
Benin	-2.5%	DR Congo	-319 *(-0.2%)*
Uganda	-2.2%	Zimbabwe	-313 *(-1.7%)*
Philippines	-2.1%	Venezuela	-288 *(-0.6%)*
World	-0.18%	World	-7,317 *(-0.18%)*

Source: *Global Forest Resources Assessment* 2005 (FAO, 2006).