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# LAND USE AND LAND COVER CHANGE INSIDE PRODUCTION FOREST IN SOUTH KALIMANTAN PROVINCE, INDONESIA, AS ANALYZED USING LANDSAT IMAGERY AND DYNAMIC SYSTEM MODEL

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**KEY WORDS:** Dynamic system model, forest area, forestry land use planning, interpretative structural model

**ABSTRACT:** The pressure on forests in Indonesia increases as population growth continues, together with the rise of higher demand for land for development purposes. This study was conducted in South Kalimantan Province, Indonesia. The objectives of the study are: (i) to analyze changes in land use and land cover in forest areas, (ii) to model changes in land use and land cover, focusing on production forests, the area of forest where land cover should be maintained, and (iii) to formulate policy recommendations based on the two previous objectives. Changes in land use and land cover were analyzed using a series of Landsat imageries from 2000, 2003, 2006, 2009, 2011 and 2014. The supervised classification imagery analysis was performed using image interpretation software. The results of the image analysis were then overlaid with the Forest Area Status map, which outlined a delineation of production forest in the forest area. The results of the quantitative data were used as inputs for dynamic system modeling, which was performed using Powersim Constructor 8.1. Descriptive policy recommendations were compiled based on interviews with experts which then analyzed using interpretative structural modeling. The result showed an increasing shift trend inside production forest, from forest land cover towards non-forest land use and land cover. An analysis using dynamic system models can predict a decrease in forest cover if land use policies in forest area are functioning under the assumption of business-as-usual. The main factors causing pressure on production forest areas are minimal law enforcement, high intensity of illegal loggings and the high number of development permits given to mining and plantation sectors. Several recommendations can be made according to the study results.

## 1. INTRODUCTION

The pressure on forests in Indonesia is rising as the number of people increase. Such a growth of population brought along a diversity of economic activities and an ever more high demand for land for development. This pressure has caused a quite extensive deforestation. Data indicates that the loss caused by deforestation was estimated at 1.8 million hectares each year (Khan, 2010; Elias, 2013). Such destruction has caused the emergence of critical land, both in protected forests and conservation areas affecting an extent of 8.1 million hectares, as well as 27.7 million hectares in production forest. Until 2004, an estimated 30.19 million hectares of land were considered as critical land in Indonesia, in which about 6.89 million hectares were categorized as highly critical land (Kusmana, 2011). The latest data from the Ministry of Forestry (2013) showed that the extent of deforestation during the period of 2011-2012 is 613,480 ha.year$^{-1}$ (Kusmana, 2011; Widiatmaka *et al*., 2015). Various attempts have been made to minimize the damage. Efforts undertaken by the Ministry of Forestry has so far reduced the speed of the destruction (Kusmana, 2011), but still, the deforestation rates remain high to this day.

One of an early indication of forest damage is the change in land use and land cover from forest cover to non-forest cover. There are many factors that cause such changes. One of the causes is the change from forest cover into cultivation land, which is as a matter of fact legal for development needs. Such requirement can be the need of land for a variety of other non-forest uses as well as the needs of forest product such as timber. There are also changes in land cover which are prohibited, such as illegal logging and the use of forest land for cultivation such as settlements and plantations. The latter were carried out unlawfully and violates certain regulations.

The government of Indonesia has set the law regarding the allocation of forest land utilization through legislations directed by the Ministry of Forestry (2012). Underneath the regulations, there are designated areas for cultivation and non-forestry activities, while other places may be kept as a forest. Moreover, there are different levels of preservation within the forest areas; for example, one place should remain as a protected forest while others are maintained as production forest. Although regulations were already set in addressing this issue, unfortunately in reality there are still a number of land utilizations in the forests which are not in accordance with their initial designations. This is certainly not good, because it would trigger a reduction of the hydro-orology function of the forest.

Kalimantan is one of the major islands in Indonesia which is naturally rich in forest resources. Together with the tropical rainforest in the Amazon, tropical rainforests in Kalimantan are centers that maintain the sustainability of the planet through their various ecological functions. In addition, these Indonesian forests are generally rich in biodiversity; each has its own ecosystem functions. As an illustration on the richness of forest biodiversity in Indonesia: there are 515 species of mammals (12% of the world's mammals, first ranked in the world), 1,531 species of birds (17% of the world's birds, fourth ranked), 511 species of reptiles (7.3% of the world's reptiles, third ranked), 270 species of amphibians (fifth ranked), 2,837 species of invertebrates, 121 species of butterflies (first ranked), and 3,800 species of plants (Nandika, 2005; Kusmana, 2011). Although the land area of Indonesia makes up only 1.3% of the earth's surface (Kusmana, 2011), its biodiversity however constitutes an important part of the world's biodiversity. As such, the impact of forest loss in Kalimantan would not only be felt on the island of Borneo or just in Indonesia, but also by the entire planet. Therefore, an evaluation of such a condition becomes very important; to what extent has the changes from forest land cover to non-forest land use occurred within a certain time?

Geographic Information System and remote sensing are very useful in monitoring natural resources. Through its ability to conduct a wide scale and multi-temporal monitoring function, it is possible to manage natural resource more efficiently. Various studies have been conducted to monitor the forest area using GIS and remote sensing (Aronoff, 2005; Ambarwulan, 2010). The dynamic system model, initially introduced by Forester (1961), is able to model and predict future trends based on empirical data. Various studies and programs have used this method: including ranching and husbandry (Turner *et al*., 2013), ecological restoration (Crookes *et al*., 2013); urban system (Zarghami & Akbariyeh, 2012), mining resources (Elshkaki, 2013), wetland utilization (Ma *et al*, 2012;), agricultural sustainability (Saysel *et al*., 2002; Widiatmaka *et al*., 2014), land use, regional planning and management (Shen *et al*., 2009; Luo *et al*., 2010), and biological processes (Zhu, 2012). In terms of land use and land cover, if we know what has happened earlier based on the remote sensing data, this can be used to predict future tendencies by using dynamic system modelling.

The objectives of this study were to: (i) analyze changes in land cover and land use in production forests in South Kalimantan province, (ii) build the model changes land use in the production forest area-based dynamic system, (iii) develop policy recommendations and strategies to reduce the pressures deriving from changes in land use in the production forest area.

## 2. METHODS

### 2.1 Research Area

The research was conducted in the forest area of the province of South Kalimantan (**Figure 1**). The province has an area of 37,530.52 km$^2$, which amounts to 6.98 percent of the island of Kalimantan and 1.96 percent of the total area of Indonesia. This province lies at 114º19'13" - 116º33'28" E and 1º21'49" - 4º10'14" S. A big percentage (22.76 percent) of soil at South Kalimantan is alluvial hydromorphic soil. Non-hydromorphic soils were limited and dispersed in undulating areas. On lower watershed areas, the soil is dominated by alluvial soil and peat land; the latter with a fairly high acidity level. A total of 74.81 percent of the territory of South Kalimantan province lies on a slope that is below 15 percent while 31.09 percent of it is located at an altitude of 25-100 meters above sea level. The average temperature at the research area in 2010 ranged from 22.0ºC to 33.7ºC. The average humidity was between 73% until 96% each month. Rainfall records in 2010 showed that the highest rainfall in this area occurred in June, which was 365.7 mm while the lowest rainfall (171.00 mm) was in May (Statistics of South Kalimantan, 2011).

### 2.2 Analysis

The research was conducted in several steps: (i) delineation of forest area status according to the regulations in force, (ii) interpretation of land use and land cover using Landsat imagery; this was done for the whole province, however this article emphasizes on production- and limited production forests, (iii) modeling the change of land use and land cover of production forest area, using the dynamic system models including its validation, and (iv) defining recommended actions to maintain forest cover based on interpretative structural model.

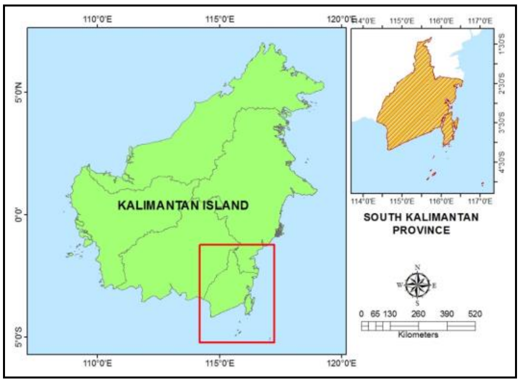



**Figure 1**. Research area of South Kalimantan Province

a. **Delineation of forest areas status**. The status of forest area was delineated by the map of Forest Area Status of the Planology Agency, Ministry of Forestry (2009). Under the regulation, the forest area consists of protected forest, production forest (both limited production forest and production forest), convertible production forest, and certain designated area for other utilization. Protected forest is an area that needs to be preserved, this includes conservation forests, nature reserves, wildlife sanctuaries and national parks. Limited Production Forest is a forest that is maintained as forest area and serves to produce timber, however it can only be exploited on a limited basis through selective logging. Forest products that can be exploited can be both wood and non-wood forest products. Permanent forest production and convertible forest production are also types of forest included. Cultivation activities in the forest are permitted within the 'area for other utilization'. In accordance with the regulations, initially the forest areas were officially regulated by the State. Designated forest areas in the province of South Kalimantan have gone through several changes within the years of 1984, 1991, 1999, and 2009. For this study, we used a map of Forest Area Status of 2009. During this study, the map will only be used to delineate areas that will be examined to see the changes in land use and land cover.

b. **The imagery interpretation for land use and land cover change**. As a starting point in this study, land use and land cover were delineated using OLI TIRS Landsat imagery of 2014. Supervised imagery interpretation was performed using image interpretation software. Field checking was done to see land use and land cover in the field and by matching them with the obtained image on the software. During this fieldwork, interviews were conducted with the people living around the forest. The results of the field checking were then used to re-interpret the images and obtain the final land use and land cover. The interpretation with Landsat imagery produced 19 kinds of land use and land cover based on the national standards of imagery interpretation (SNI, 2010). Land use and land cover from preceding years were interpreted using the image archive, by referring to the most recent imagery. This paper presents only the results of land cover and land use analyzed in areas designated as production forest.

c. **Modeling changes in land use and land cover inside production forest using dynamic system model and its validation.** In this study, dynamic system modeling is used to simulate changes in land use and land cover. System dynamics model is designed to analyze complex physical-socio-economic systems (Shen *et al*., 2009; Widiatmaka *et al*., 2014). The methodology was presented in detail by Forrester (1968). All system dynamic models are made out of three kinds of variables: stock, rate, and auxiliary, and two kinds of flows: physical/material and information (Widiatmaka *et al*., 2014). In system dynamics, simulation is governed entirely by the passage of time and is referred to as " time-step " simulation (Shen *et al*., 2009; Widiatmaka *et al*., 2014). The purpose of a dynamic system study is to understand how and why the dynamic systems are generated and to search for managerial policies to improve the situation. Changes in land cover and land use could be viewed as a system that can be made as a model. The models built are described through causal loops (**Figure 2**). Dynamic system modeling was performed using quantitative data on forest cover area change using Powersim Constructor 8.1.

d. **Defining recommended action for maintaining forest cover based on interpretative structural model (ISM).** The method of ISM is considered effective to resolve, manage and establish a structure on complex issues (Eriatno, 2003). The basic principle of this methodology is identification of the system structure that provides the capability to formulate effective systems for better decision making. The result of this modeling is to have a structure of the problem and its solution by going through interviews with stakeholders. In this study, 5 experts' respondents were involved in the interviews.

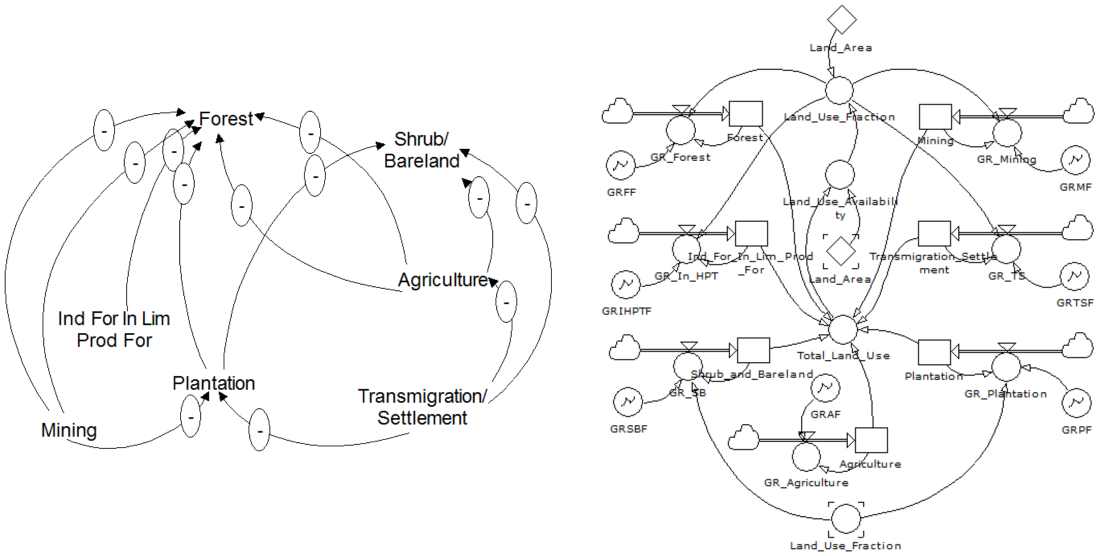



**Figure 2**. Causal loop of dynamic system model for land use and lan cover inside production forest

## 3. RESULT AND DISCUSSION

**Forest Areas Statuses of South Kalimantan Province.** Based on the forest area status map, the forests in South Kalimantan Province is divided into several status. They consist of Protected Forest with an area of 483,388.7 ha (13%), Forest of Nature Reserve and Tourism covers an area of 130,323.4 ha (3.5%), Permanent Production Forest has an area of 836,770.3 ha (22.5%), Limited Production Forest includes an area of 132,559.4 ha (3.6%), Convertible Production Forest, contains an area of 199,135.9 ha (5.4%), the area for other land utilization encompasses 1,924,539.3 ha (51.8%), and finally the water body is made up of an area of 10,018.5 ha (0.3%).

**Land use and land cover inside the production forest.** The results of the analysis of imagery interpretation of land cover and land use in the production forest are presented in **Table 1 and Figure 3**. In Table 1 the results for forest industrial plants are immediately given distinctions based on the locations; those which are located in a permanent production forest and in a limited production forest. In accordance with the regulations, cultivation of industrial plants may be conducted in a permanent production forest, whereas in limited production forest this activity is not allowed. The analysis showed that some forest covers have decreased and some others have increased. Land cover and land use which have decreased among other secondary forest, secondary mangrove forest, and mixed dry land agriculture. Meanwhile, areas that have an increase of land cover and land use in the period 2000 - 2014 are forest of industrial plant, shrub, dry land agriculture, plantation and mining areas.

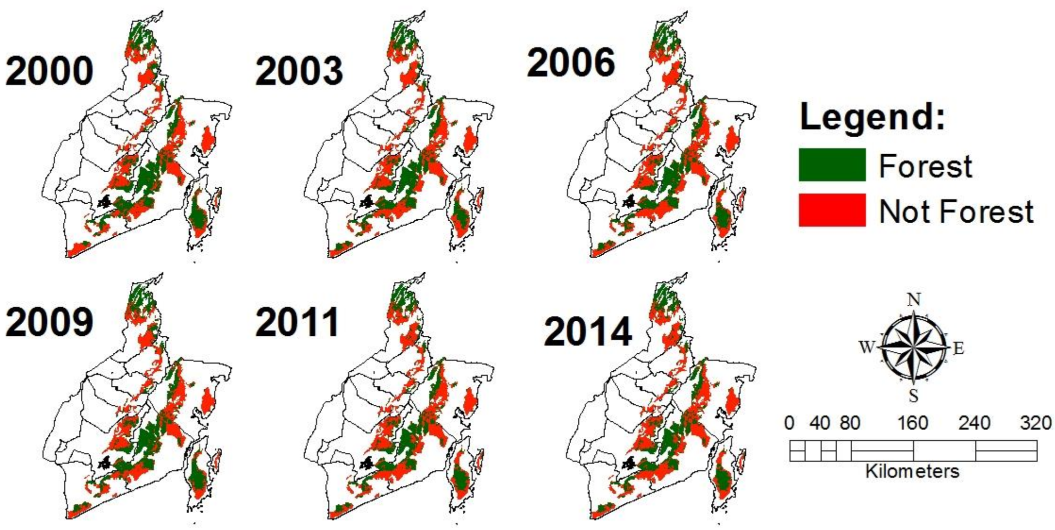



**Figure 3**. Land use and land cover change in Production Forest of South Kalimantan Province

**Table 1**. Changes in land cover and land use in the province of South Kalimantan (ha)

| Land Use/Land Cover | Year | | | | | |
|---|---|---|---|---|---|---|
| | **2000** | **2003** | **2006** | **2009** | **2011** | **2014** |
| Primary Dry Land Forest | 5,459 | 5,454 | 5,452 | 5,450 | 5,448 | 5,430 |
| Secondary Dry Land Forest | 390,830 | 377,481 | 341,103 | 327,978 | 323,833 | 324,610 |
| Pimary Mangrove Forest | 122 | 119 | 124 | 127 | 125 | 120 |
| Secondary Mangrove Forest | 1,209 | 1,427 | 884 | 879 | 933 | 938 |
| Secondary Swamp Forest | 2,164 | 2,162 | 2,161 | 2,165 | 2,168 | 2,158 |
| Industrial Forest | 43,585 | 58,479 | 56,709 | 67,131 | 66,396 | 64,549 |
| - In Production Forest | 42,846 | 57,937 | 56,166 | 66,588 | 65,854 | 64,006 |
| - In Limited Production Forest | 739 | 542 | 540 | 535 | 549 | 541 |
| Shrub | 216,855 | 209,907 | 220,411 | 221,851 | 225,360 | 221,764 |
| Swamp Shrub | 10,652 | 10,339 | 7,303 | 7,287 | 7,234 | 7,228 |
| Dry Land Agriculture | 70,303 | 74,022 | 74,595 | 77,402 | 77,232 | 76,162 |
| Mixed Dry Land Agriculture | 179,030 | 179,909 | 181,013 | 180,559 | 179,558 | 177,611 |
| Paddy Field | 309 | 382 | 293 | 375 | 365 | 360 |
| Pond | 82 | 204 | 201 | 195 | 196 | 203 |
| Plantation | 23,067 | 30,401 | 34,654 | 38,208 | 38,208 | 37,204 |
| Settlement | 1,421 | 1,421 | 1,421 | 1,421 | 1,421 | 1,421 |
| Transmigration Area | 668 | 665 | 667 | 653 | 658 | 664 |
| Bare Land | 15,712 | 6,546 | 25,030 | 13,802 | 15,888 | 12,565 |
| Mining | 7,381 | 9,918 | 16,814 | 23,345 | 23,810 | 35,830 |
| Water Body | 225 | 219 | 221 | 217 | 227 | 218 |
| Swamp | 29 | 27 | 23 | 25 | 27 | 20 |
| **Total** | **1,012,688** | **1,027,561** | **1,025,785** | **1,036,193** | **1,035,490** | **1,033,602** |

Such land use and land cover in production forest can then be grouped into 3 (three) groups, namely land use and land cover: (i) which are in accordance with the designation of production forests; these include primary dry land forest, secondary dry land forest, primary mangrove forest, secondary mangrove forest, primary swamp forest, secondary swamp forest, shrub, swamp shrub, bare land. These can be labeled as “forest land cover”; (ii) that does not comply with the designation of production forests; which include dry land agriculture, mixed dry land agriculture, paddy fields, pond, plantation, settlement, transmigration area and mining area. These are regarded as “non-forest land cover”; and (iii) which is not assesed; these includes clouds, water bodies and swamps. An industrial plantation forest is considered as production forest if it is located in a permanent production forest. However, if it is located in a limited production forest, it should be classified as not in accordance with the designation of a production forest. The total area of the three groups of land use and land cover in production forest is presented in **Table 2**.

**Table 2**. Change of forest and non-forest cover in production forest area of South Kalimantan Province

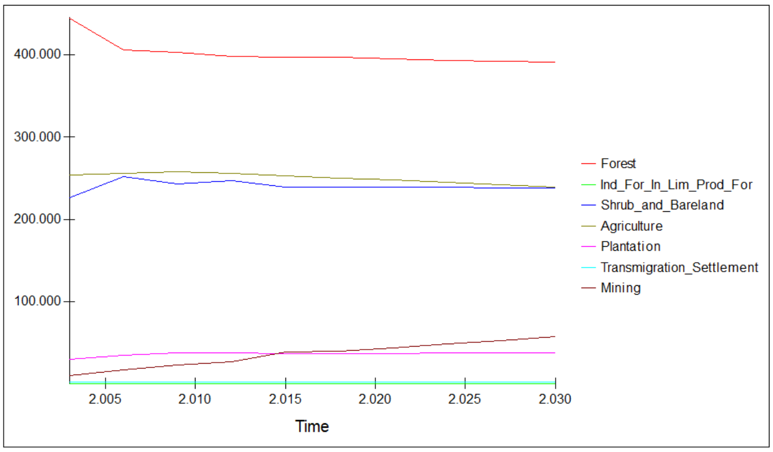
| Landuse | Year | | | | | |
|---|---|---|---|---|---|---|
| | **2000** | **2003** | **2006** | **2009** | **2011** | **2014** |
| Forest Land Cover (Ha) | 442,629 | 444,589 | 405,898 | 403,183 | 398,357 | 397,287 |
| Non-Forest Land Cover (Ha) | 526,216 | 524,256 | 562,945 | 565,661 | 532,317 | 534,395 |
| Not assessed | 242 | 242 | 242 | 242 | 242 | 237 |
| **Total** | **969,087** | **969,087** | **969,087** | **969,087** | **969,087** | **969,087** |

From the table, it appears that in 2000, the non-forest land cover is bigger than the forest land cover. In percentage, the non-forest land cover reaches 54.3% of the total forest cover in production forest. This fact is alarming, since forest land cover should have been more dominant. It can also be seen that there is a tendency of a decrease of forest land cover and an increase of non-forest land cover within the period of 2000 to 2014. In 2000, the non-forest land cover was 526 216 ha, or 54.3% of the area of production forest. In 2014, the non-forest land cover increased to 534,395 ha, or 55.1% of the area of production forest.

**System Dynamic Model of Land Use and Land Cover Change.** The changes of land use and land cover based on the data from of the period of 2000 to 2014 became then the input for dynamic system modelling. After the simulation is done, the first step to look at is the validity of the resulted model. Several parameters were used for validation, i.e. the Absolute Mean Error (AME) and the Absolute Variation Error (AVE). AME is the difference between the average values of the results of simulation with the actual value, while the AVE is the deviation of variation (variance) of simulation value with actual variation. The limits of acceptable deviations were between 1-10% (Hartrisari, 2007). The result of model validation for several parameters are presented in **Table 3**. The validation results show that the model is valid to make the estimation because AME and AVE values are below the threshold permitted. The result of the model is presented in **Figure 4**.

**Table 3**. Validation of dynamic system model for change of land use and land cover inside production forest of South Kalimantan (area in hectares)

| Year | Forest Land Cover | | Agriculture | | Plantation | | Mining | |
|---|---|---|---|---|---|---|---|---|
| | Actual | Simulated | Actual | Simulated | Actual | Simulated | Actual | Simulated |
| 2003 | 444,590 | 444,590 | 254,313 | 254,313 | 30,401 | 30,401 | 9,918 | 9,918 |
| 2006 | 405,898 | 405,393 | 255,901 | 255,915 | 34,654 | 34,656 | 16,814 | 16,818 |
| 2014 | 403,183 | 403,167 | 258,336 | 258,372 | 38,208 | 38,189 | 23,345 | 23,280 |
| Mean | 417,890 | 417,717 | 256,183 | 256,200 | 34,421 | 34,415 | 16,692 | 16,672 |
| AME | 0.04159 | | 0.00652 | | 0.01622 | | 0.12133 | |
| Variance | 357,664,638 | | 2,786,436 | 2,786,436 | 10,185,353 | 10,138,390 | 30,054,790 | 29,7699,23 |
| AVE | 1.1890701 | | 1.795880 | | 0.461084 | | 0.947823 | |




Legend: 1: Forest; 2: plantation of industrial forest in limited production forest; 3: shrub and bare land; 4: dry land agriculture; 5: plantation; 6: transmigration settlement; 7: mining

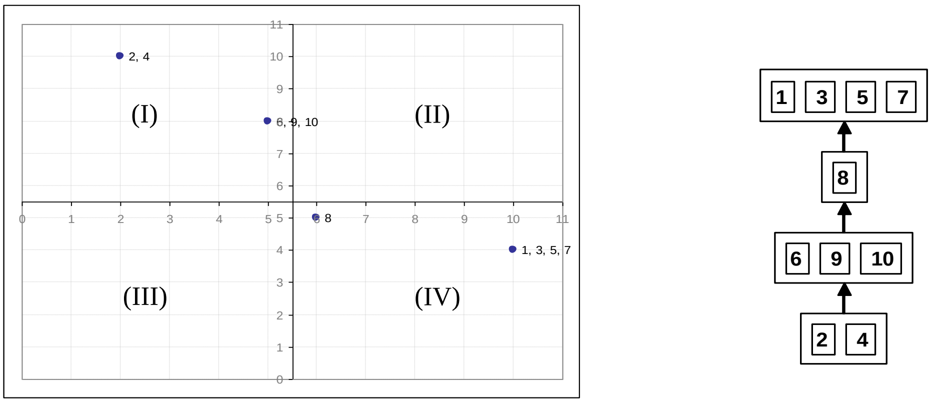
**Figure 4.** Predicted land use and land cover area of production forest in South Kalimantan Province according to dynamic system model of forest land use and land cover change

**Table 4**. Predicted land use and land cover according to dynamic system model (in hectares)

| Year | Forest Land Cover | Non Forest Land Cover | | | |
|---|---|---|---|---|---|
| | | Shrub and bare land | Agriculture | Plantation | Mining |
| 2003 | 444,590 | 226,792 | 254,313 | 30,401 | 9,918 |
| 2006 | 405,392 | 252,410 | 255,915 | 34,656 | 16.817 |
| 2009 | 403,167 | 242,909 | 258,371 | 38,189 | 23,280 |
| 2012 | 398,102 | 246,571 | 256,046 | 37,741 | 27,375 |
| 2015 | 396,951 | 239,442 | 253,204 | 36,868 | 38,982 |
| 2018 | 396,454 | 239,367 | 250,393 | 36,983 | 40,201 |
| 2021 | 394,953 | 239,141 | 247,614 | 37,333 | 44,006 |
| 2024 | 393,286 | 238,888 | 244,866 | 37,727 | 48,650 |
| 2027 | 391,806 | 238,663 | 242,148 | 38,082 | 53,227 |
| 2030 | 390,579 | 238,477 | 239,460 | 38,381 | 57,396 |

The results of the analysis using dynamic system model show that the non-forest area in production forests will increase in the coming years. The forest cover, which in 2003 amounted to 444,590 ha, is estimated to decrease to 390,579 ha in 2030. This decrease will be partly fueled by the increasing trend of plantation and mining area. Plantation will increase, from 30,401 ha in 2003 to 38,381 ha in 2030. Mining area will expand from 9,918 ha in 2003, to 57,396 ha in 2030. This upsurge of plantation and mining areas will be the most important increase in the next years.

**Result of Interpretative Structural Model.** The results using interpretative structural modeling analysis are presented in **Figure 5**. The structure of policies were composed according to the different quadrants. Quadrant (1) contains the driving variable, which has a strong influence but is less dependent. Therefore, it can be categorized as a strong and powerful variable in the system. In quadrant (2), there is a leverage variable which has a strong influence with substantial dependence. This variable is still considered as powerful. The variables in quadrant (3) have a marginal influence and small dependency. Consequently it is free in the system. Output variables in quadrant (4) have little influence on the system but are of high dependence. There are 10 fundamental problems resulting from the experts' discussion on the cause of high pressure on production forests. Factors of main concern in quadrant 1 are encroachment, illegal logging, and weakness of law enforcement. The next factors that need consideration are the operations control post-plantation, licenses of plantation and mining, and the implementation of the spatial plan. The active movements of the communities around the forest, despite its low effect still require attention. The last factor is associated with population growth, this includes the high dependency of communities around the forest, shifting pattern during cultivation, people with capitals encouraging farmers to go into forests, and population growth.




Factor's code: (1) high dependence of communities to the forest (2) forest encroachment and illegal logging, (3) shifting cultivation, (4) lack of law enforcement, (5) people with capitals encouraging farmers to explore the forest, (6) control of post plantations operations; (7) population growth; (8) high activity of forest communities; (9) implementation of official spatial land use plans; (10) tightening the license of plantation and mining

**Figure 5**. The result of interpretative structural modeling

From the results of this study, several main and fundamental recommendations can be given: (i) the tightening of license for new plantations and coal mining, (ii) law enforcement to minimize illegal logging activities, (iii) community forest development should focus on bare land and shrub.

## 4. CONCLUSION

This research has been conducted in production forests in the province of South Kalimantan, on an island that is considered as one of the centers of the world green. Land use and land cover analysis have been combined with forest areas delineation. This then shows that even on a land cover map of 2000, the non-forest cover was relatively higher than forest land cover in the production forest areas. The trend of changes in forest cover to non-forest cover has increased, as discovered by image analysis up to 2014. If the policy of the forest utilization continues in a business-as-usual manner, such trend will continue until 2030, as established by the result of dynamic system model. Based on the interpretative structural modeling analysis, there are 10 factors that put on pressures on forest areas. To overcome them, several main policy changes are suggested, which are: tightening the creation of licenses for new plantations and coal mining, tightening law enforcement to minimize illegal logging activities, and a stronger focus on community forest development.

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