BIOTROPIA Vol. 25 No. 2, 2018: 103 - 111 DOI: 10.11598/btb.2018.25.2.792

SYSTEM DYNAMICS MODELING OF LAND USE CHANGE IN WEST KALIMANTAN, INDONESIA

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Received 23 December 2016 / Accepted 02 January 2018

ABSTRACT

The main effects of human activities on the environment result in land use and land cover changes. Land over exploitation and development activities in West Kalimantan of Indonesia necessitated the focus of this research which aims to analyzing and predicting land use changes in West Kalimantan. The results of such a study assist researchers, planners and policy makers to formulate suitable land use policies in the future in order to balance economic development and natural resource conservation. Moreover, it makes Indonesia shift from middle incomes to become a developed country in 2030. Methodology employs field observation, key informant interviews, focus group discussions and system dynamics modeling. The field observation covered communities in several locations in the study site to identify pattern of land use. The system dynamics was applied to analyze the land use change system and estimate the extents of land cover change in the future. The study showed several outcomes: (i) The main leverage factors in the land use change system in West Kalimantan were the desire to reach the expected economic growth and the increased per capita consumption of edible oil globally; (ii) In the business as usual modeling, the increasing global demand for edible oil will lead to significant increment of oil palm plantation area, even the total area of plantation could be wider compare to that of the remaining forest area by 2030; (iii) Key interventions that need to be considered in the future is to conduct reforestation (with reforestation rate of at least 0.5% per year) and limited oil palm plantation development to maximum of 50% of developed area.

Keywords: agroforestry, land use, oil palm development, system dynamics, West Kalimantan

INTRODUCTION

This paper is about the insufficiency of land use policy in Indonesia, particularly in West Kalimantan province. The current policy has accelerated deforestation in the Province with average forest conversion rate of 2.9%/year during the period of 1989 to 2008 (Carlson *et al.* 2012). Deforestation is one of the key human transformations globally (Williams 2000) and land use/cover change in tropical regions is widely accepted as an important component of global change (Houghton 2005; Laurance 1999). Land use change has considerable impacts on worldwide biodiversity, global and local climate, biogeochemical cycles, soil degradation, hydrology, food security, soil quality and human well-being (Foody 2002; IPCC 2007, 2014; Lambin *et al.* 2003; Manandhar *et al.* 2009; Sala *et al.* 2000; Trimble & Crosson 2000). Nonetheless, land cover/land use changes do not only have negative effects, as some changes are related to positive increase of food and fiber yields for peoples' health and wealth (Lambin & Geist 2006) particularly in developing countries Deforestation also contributes to job creations

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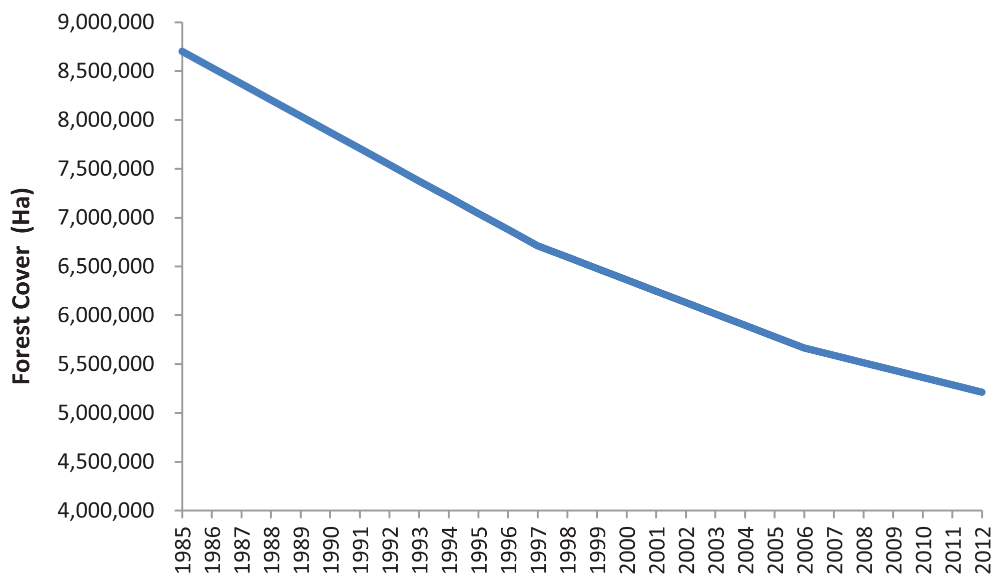
(Rist *et al.* 2010) and economic growth (Naidoo 2004).

Indonesia includes West Kalimantan Province, which needs to maintain economic growth to shift from middle income to becoming a developed country by 2030. Meanwhile, it also needs to maintain and conserve the remaining forests and biodiversity. Indonesia relies on forest resources for its economic development for more than four decades. The forestry sector became the second highest contributor of foreign exchange to Indonesian economy after oil and gas sector in the 1980s. The estimated forest cover of 170 million hectares around 1900 decreased to less than 100 million hectares by the end of the 20th century due to over-exploitation in the sector. Along with forests loss, Indonesia also lost its biodiversity, wood supply, income, and various ecosystem services (Barber *et al.* 2002). Underlying causes of deforestation in Indonesia are complex, and cover various aspects of market failure, inappropriate policy implementation in relation to forest management, lack of governance capacity at central and district levels, and other, broader socioeconomic and political issues (Resosudarmo *et al.* 2012).

Forest cover decline continues in West Kalimantan, as shown in Fig. 1. Like other parts of Kalimantan, large-scale deforestation and degradation in West Kalimantan was initially caused by the extraction of the commercially important *Dipterocarp* tree species for durable hardwood, but in recent years the conversion of degraded forest to monoculture plantations, such as: oil palm plantation, fiber plantation (pulp and paper) and rubber plantation, has played a greater role (Gaveau *et al.* 2014; Abood *et al.* 2015). In West Kalimantan, oil palm plantation began in 1980s and reached 1,060,251 hectares in 2012. The Government of West Kalimantan released the target for oil palm plantation in this region of 1.5 million hectares in 2025 (Dinas Perkebunan Kalimantan Barat 2014). Global demand of palm oil predicted will be increased in future to meet growing global vegetable oil demand, both for food and for biodiesel (McCarthy & Lei 2010; Miettinen *et al.* 2012). This situation will lead to more deforestation in West Kalimantan, because oil palm plantation development has traditionally increased by the conversion of primary or secondary forest (Sheil *et al.* 2009).

Recent literature largely discussed the drivers or impact of deforestation, but there is a minimum attention on how much forest land needs to be reserved for sustainable growth and what maximum area of oil palm plantation could be allowed to develop within the landscape.This research tried to address these issues and therefore aimed to (1) identify the leverage factors of land use systems, (2) predict the land use change in future based on business as usual and other possible scenarios, and (3) identify better land use policies interventions in the future in order to balance economic development and



Sources: Ministry of Forestry (1985-2012)

Figure 1 Forest cover condition in West Kalimantan (1985-2012) natural resource conservation. This research was conducted in West Kalimantan, Indonesia for several reasons. First, this province is the fifth largest area and one of the fastest growing oil palm plantations in Indonesia (Dinas Perkebunan Kalimantan Barat 2014). Secondly, this area is an important catchment area of Kapuas River system with approximately 1.5 million people depending on this river system (Hatta *et al.* 1997). Thirdly, most forested land in this area is also a part of Borneo Heart which is identified as important forest area for the island (WWF & PwC 2011).

MATERIALS AND METHODS

Data for System Dynamic Modeling

The reference data in the modeling was land use data of West Kalimantan based on satellite images released by the Department/Ministry of Forestry (Environment and Forests), especially for forest cover, oil palm plantation, and other non-forest category. The period of observation in this study was from 1992 to 2012 and simulation period was conducted from 2013 to 2030. The reason for this simulation until 2030 was to synchronize with government planning cycle and end of the sustainable development goals (SDGs) period. Field observation, key informant (village and local leaders) interviews and focus group discussions with several local stakeholder groups (local community organizers, researchers and local government officers) in West Kalimantan were conducted to obtain information on the trend of land use pattern in December 2015 to May 2016. The information gathered was used as input for designing causal loop diagram in system dynamics modeling.

System Dynamic Modeling

Land use and forest cover in the study area occurred through dynamic complex causes and factors. Observing these conditions, the system dynamics modeling was selected to understanding land use change system, especially to identify leverage factors and predict changes in the future. System dynamics is a methodology used to understand how systems change over time (Martin 1997) and a method for studying complex systems, based on the theory of non-linearity, dynamics and feedback control (Sterman 2000). Modeling of system dynamics is a cycle process, starting from the identification of problems of the system, the translation of the problems to the structure (from story to structure), modeling through stock flow diagram, simulation and validation, as well as sensitivity and policy analyses. Validation was conducted with the deforestation data in West Kalimantan which occurred between 1985-2012.

System dynamics modeling was conducted for provincial level due to limitation of time series data. The conceptual framework of the model was: "Increasing human population and global market demand for palm oil will encourage deforestation. Otherwise, afforestation can be conducted through reforestation and restoration initiatives. The declining of forest condition and function would result in externalities affecting the economy, which in turn will affect the poor. Poverty itself is identified as one of driving factor

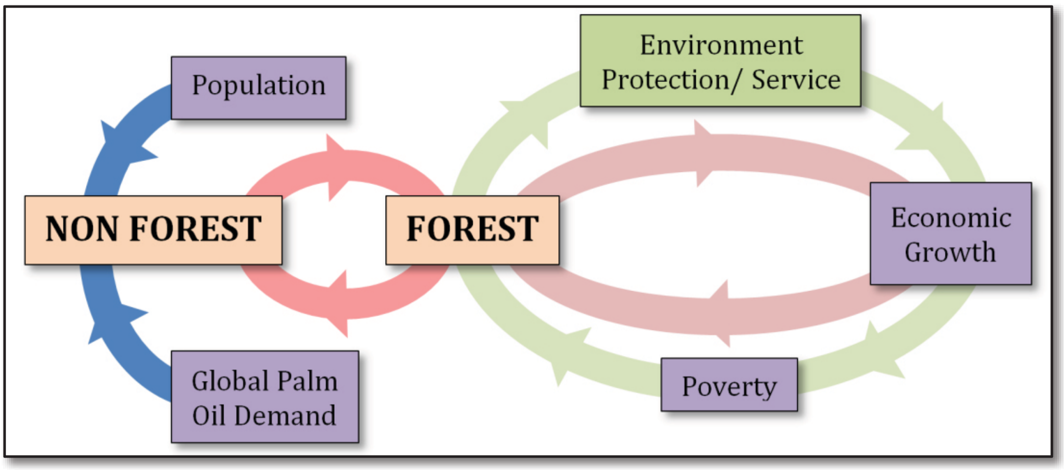


Figure 2 Conceptual framework of system dynamics model

of forest conversion. Forest conversion was conducted for pursuing economic growth. On the contrary, the high growth in regional economy will also hasten deforestation." The scheme of conceptual framework of the model can be seen in Fig. 2. System dynamics modeling was conducted with Powersim Studio 10 (License number PSSTUDIO-103365-1C4B1).

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RESULTS AND DISCUSSION

Land Use Change Pattern

Forest conversions within the study area were found to be mostly initiated by turning them into rain-fed paddy field (Ladang), although there were some areas of forest converted directly into rubber or oil palm plantation. Mostly direct conversion of forests into oil palm plantation occurred within the palm oil concession where the potential timber resources have been exploited. The transformation of rain-fed paddy field into other forms of land use was depended on the financial capital capacity of the land owner and legal status of the land itself. The legal status was referred to government for approval as a forest zone and non-forest/ development zone. The pattern, change direction and intensity of land use change within the study area can be seen in Fig. 3.

The rain-fed paddy field was located in non-forest zone and not within active plantation concessions, if the landowner has adequate financial capital, the land was more likely to be converted into palm oil or rubber plantations. However, if not, the land will be used as rain-fed paddy field and gradually planted with perennial trees, such as fruit and timber trees. Hence, after some time it will transform into agroforestry land and will not be used for unirrigated agricultural field. There were also many rain-fed paddy fields which later turned into scrubland, as neglected by their owners or damaged due to fires. The study has revealed that landowners transformed their rain-fed paddy fields, agroforestry land, scrubland or rubber plantation into oil palm plantation when they successfully accumulated enough financial capital or obtain loan from financial institutions, such as: credit union.

Oil palm plantations became the final land use within the research site. The study found it was rarely the case that, oil palm plantation turned into other land uses, even unproductive oil palm plantations have been replanted with new plant species. In the forest zone, local communities tend to use their land for rubber plantation or agroforestry, after being used as Ladang (rain-fed paddy field). They knew that oil palm plantation is not allowed in the forest zone. In some places, it was found that some communities maintained

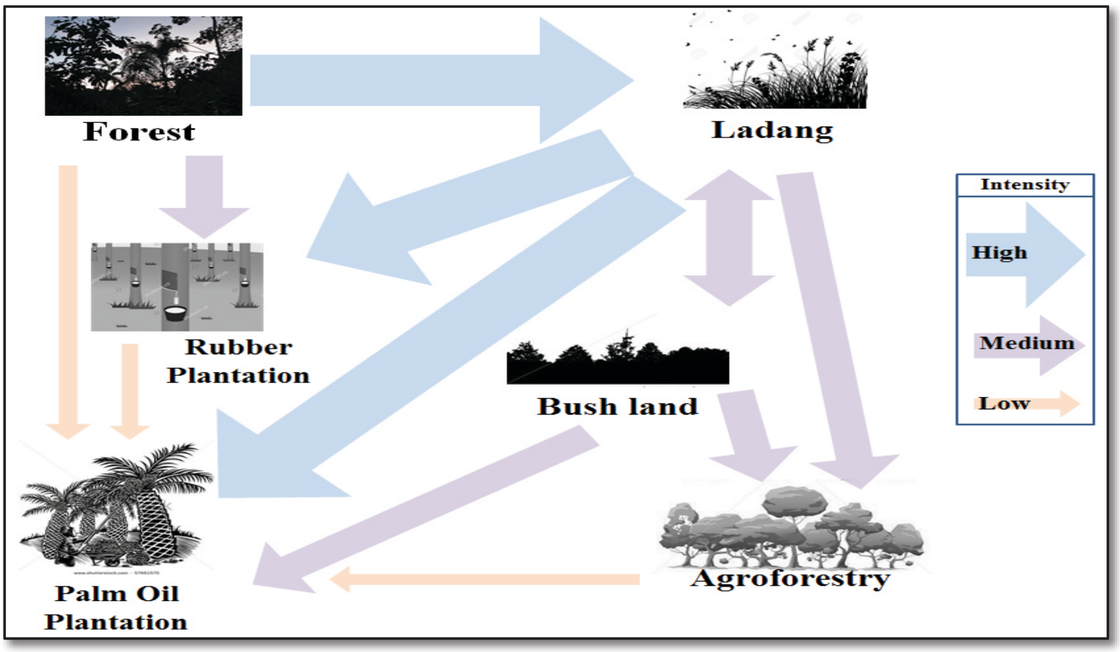


Figure 3 Pattern, change direction and intensity of land use change at community level in West Kalimantan

their Ladang due to cultural reason, in order to be eligible to participate in Gawai, a yearly cultural event to celebrate paddy harvesting. The products from Ladang and agroforestry were mostly consumed and traded locally. Timber from the forest were processed into sawn timber or plywood in the local industries, then traded locally or exported. Meanwhile, fresh fruit bunches (FFB) of palm oil and rubber sheets/ lumps were processed into intermediate materials for industries located near the production area. The intermediate materials, such as: crude palm oil (CPO), palm kernel oil (PKO) and ribbed smoke sheet (RSS) are exported to fulfill global demand.

System Dynamics Modeling Results

Land use pattern information was used in developing causal loop diagram (CLD) of the system dynamics modeling. The CLD of the model is shown in Fig. 4, with 2 balance loops and 1 reinforce loop. The first balance loop (B1) consists of the Forest-Environment, Protection-Economic, Growth-Poverty-Need of Land-Deforestation-Non Forest-Reforestation-Forest. The reinforce loop (R2) consists of Forest-Deforestation-Non Forest-Reforestation. Meanwhile, the second balance loop (R3) consists of Forest-Deforestation-Economic Growth-Poverty-Needs of Land-Deforestation-Non Forest-Reforestation-Forest.

The table and graph results of system dynamics modeling (Fig. 5A) were evaluated in two steps, namely visual and statistical validation. First in visual evaluation, the results showed similar behavior with the reference data. Then trough statistical validation, the model was valid because the mean absolute percentage error (MAPE) of the third reference data was less than 30% (Forest: 4%; Non Forest: 3%; and Oil palm plantation: 18%). The leverage points of the system are variables that had great effects on a system or environment with little effort to change. To identify leverage points of the system, some variables in the model were changed to observe the effects on the results. After several trial and errors exercises, it was concluded that, the leverage points were two variables, namely: national economic growth and global edible oil consumption per capita. The simulation results on identifying leverage points are shown in Fig. 5B.

In the next step of the system dynamics modeling, simulation with business as usual scenario was conducted to determine future condition by 2030. The simulation results showed that, forest cover will continue to decline to about 5,118,367 hectares or 35% of the area, otherwise non forested area will be expanded to 9,515,087 hectares or 65% of the total area. As predicted by some researchers, edible oil consumption will increase in the future resulting from the expansion of market distribution/consumer expansion, consumption behavior changes and biodiesel expansion (Obidzinski *et al.* 2012; Fitzherbert *et al.* 2008; United States Department

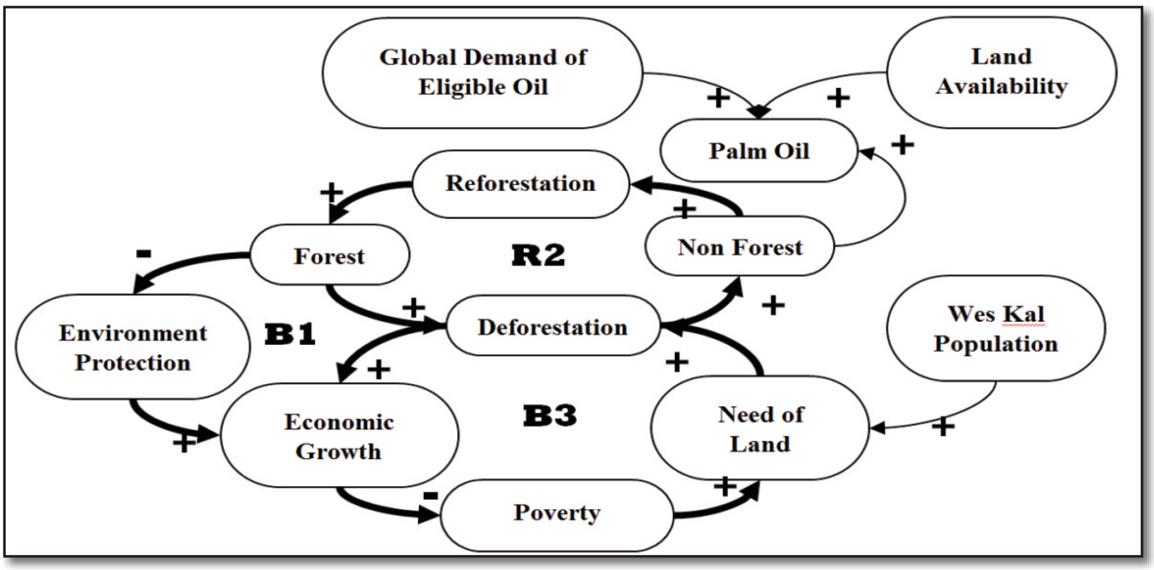
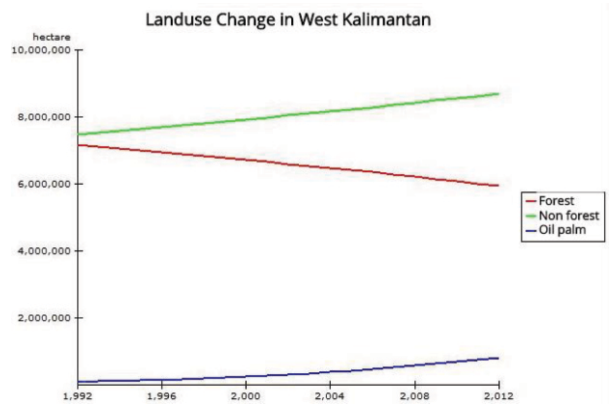


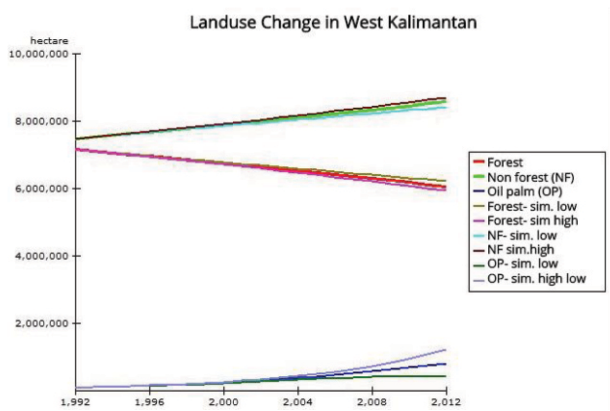
Figure 4 Causal loop diagram of system dynamics modeling

of Agriculture 2013). To anticipate this situation, simulation was conducted with different consumption rate, namely: the current level of consumption (0,025 tons/person/year), consumption increased by 40% (0,035tons/person/year), consumption increased by 60% (0.04 tons/person/year), consumption increased by 100% (0.05 tons/person/year), and consumption increased by 150% (0,075 tons /person/year). The simulation results on business as usual scenario is also shown in Fig. 5C. Based on business as usual scenario, it appeared increasing of edible oil demand in the global market will stimulate palm oil development in the observed location. Moreover, the palm oil expansion in the future can be greater than the remaining forest, especially when consumption increased by 100% or 150% (twice or triple of current consumption levels). This situation would negatively affect the existing environmental capacity. Simulation was again conducted, with national economic growth of 7% per year instead of 3.12% per year which is the average rate for the last twenty years. The 7% per year is a rate that Indonesia needed to move from middle incomestatus. The results showed forest cover in 2030 will be less than 139,094 hectares. It was concluded that, the condition of business as usual is not satisfactory and potentially threatens the sustainability conditions. It is therefore necessary to develop alternative and suitable interventions to mitigate deforestation.

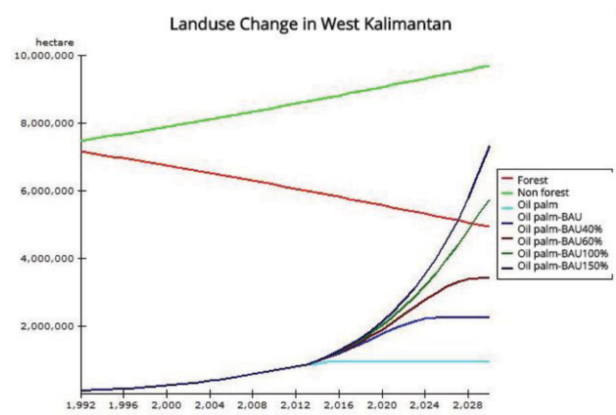
Two interventions which are necessary to achieve better condition in future were identified, namely: (1) increase reforestation activities with reforestation rate of 0.5% per year; and (2) limiting palm oil development with a maximum of 50% of non-forest zone (assuming no change of legal status). The first intervention was inspired by the phenomenon of community forests in Java for the last 20 years that successfully forested 800,000 hectares land between 1993-2003 (BPKH Region XI & FG-MFP II 2009). The target of 0.5% per year can be achieved through supportive government policies and capacity building activities to landowners. The simulation result of intervention is shown in



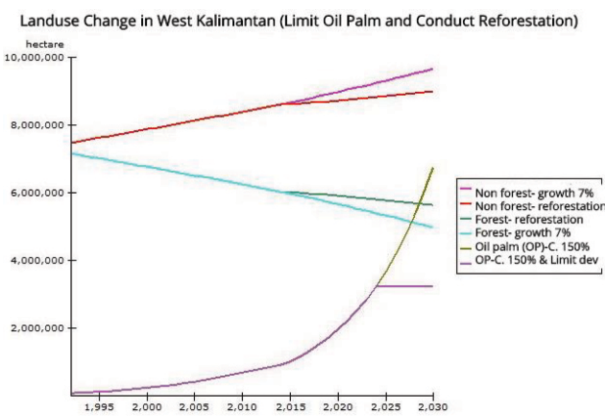
(A) Validation between deforestation data and simulation result



(B) Simulation to define leverage in the system



(C) Simulation of business as usual condition



(D) Simulation of suggested intervention

Figure 5 Simulation of graph results

Fig. 5D, it appears there will be additional forest cover of 515,334 hectares by 2030 compared to business as usual condition. Nonetheless, this area is still less than palm oil plantation area when consumption increased by 100% or 150%. To anticipate negative effect due to dominance of oil palm plantation, the second intervention must be implemented. The limitation of palm oil development in non-forest zone can determine the bearing capacity that will be used as a key device for measuring productive limit of a particular landscape. This condition is in line with Lane (2010), which emphasizes the need to define the limit of something massive to ensure sustainability in land use planning. The dominance of land use that occurred should be avoided, in order for landscapes to remain productive.

Based on the simulation results of the system dynamics modeling, the alternative composition of land use in West Kalimantan by 2030 is as follows:

1. Business as usual condition with edible oil consumption rate on the current conditions, i.e.: forest cover of 5,118,367 hectares, oil palm plantations of 946,517 hectares and other non forest area of 8,568,570 hectares.
2. Business as usual condition with edible oil consumption per capita increased by 150% and the national economic growth rate of 7%, i.e.: forest cover of 4,979,274 hectares, oil palm plantations of 6,744,308 hectares and other non forest area of 2,909,872 hectares.
3. Intervention condition (reforestation of 0.5% per year and limits the development of oil palm to a maximum of 50% development zone), i.e.: forest cover of 5,633,701 hectares, oil palm plantation of 3,241,159 hectares and other non forest area of 5,758,594 hectares.

Future Land Use Development Direction

Limitation of palm oil development will make local governments in the observed site unpopular due to politics and economic reasons. It needs strong policy endorsement from the central government of Indonesia. The implementation of limiting palm oil development needs to support the development of palm oil based advance processing industries within/ near production sites, in order to be able to withstand the added value and also to absorb labor force. Based on input-output analysis in 2010, the palm oil industry in West Kalimantan only has a forward linkage of 1.00 (Badan Pusat Statistik 2012), this value is still lower than the forward linkage palm oil processing industry in Malaysia, which is now about 2.39 (Jaafar *et al.* 2015). The opportunity of palm oil downstream industry development in West Kalimantan is very prospective since the government promoted biodiesel used as one of alternative energy source in future. The Ministry of Energy and Mineral Resources Number 12 Year 2015 is concerned with the Provision, Utilization, and Procedures of Commerce with biofuel as Other Fuel encouraged the use of biodiesel to about 30% of total national supply by 2025.

The economic productivity within the existing oil palm plantation needs to increase and can be improved by way of: (1) intensifying palm oil production, and (2) development of other economic activities within the existing oil palm plantation area. The former can be achieved through increased knowledge and capacity building for the oil palm plantation farmers. The results of the study showed that, the palm oil productivity (FFB: 11.32 tonnes/hectare) in the observed site is still lower compared to average national productivity (16.39 tonnes/hectare) or Malaysia (19.14 tonnes/hectare) (Dinas Perkebunan Kalimantan Barat 2014). Meanwhile, the development of other economic activities within the existing oil palm plantation area can be achieved through the planting of timber trees or livestock integration within oil palm plantation. The government actually has encouraged the cattle and palm oil integration program since 2007, but the program has not received full support from the companies and the local farmers. Only 15 out of 1,500 (1%) companies followed and implemented this program (Sawit Indonesia 2014). The program is expected to improve food security, through increased production of local cattle, and reduce production costs, through the provision of fertilizer, which is derived from wastes produced in the farms.

It's also considered that, there is a need to encourage the development of land use which provides good economic returns and environmentally friendly, such as: agroforestry. The agroforestry with combination of some fruit and timber plants can be an alternative land use development within the observed site. Planting timber plants in agroforestry programs can be a step to anticipate the scarcity of timber in the future. Small industrial processing of agroforestry produce, such as fruit processing, are also important to develop and support the use of the added value of the products. Suitability and capability of fruit-based agroforestry development to empower local community economy has been identified by several previous studies (Withrow-Robinson & Hibbs 2005; Roshetko & Purnomosidhi 2013). In addition, agroforestry is part of the forest garden system, which has genuine landscape utilization and has been implemented in Kalimantan (Salafsky 1994).

CONCLUSION

The main leverage factors in the land use change system in West Kalimantan were the desire to reach the expected economic growth and the increased per capita consumption of edible oil globally. In the business as usual modeling, it was found that, the increasing global demand of edible oil would lead to significant increment of oil palm plantation area; even the total area of plantation could be wider compare to that of the remaining forest area by 2030. Meanwhile, the key interventions that need to be considered in the future are to conduct reforestation (with reforestation rate of at least 0.5% per year) and limitations to oil palm plantation development to a maximum of 50% of developed areas. We suggested future strategies for land use development in West Kalimantan should only be not focused on the extent of oil palm plantation. It should be change to develop palm oil based advance processing industries within/ near production sites, and also introduce other economic activities within the existing oil palm plantation area and expansion of agroforestry.

ACKNOWLEDGEMENTS

This research was partially supported by Forum Orangutan Indonesia (Orangutan Indonesia Forum). We thank our colleagues from School of Environmental Science, Multidisciplinary Graduate Program, Universitas Indonesia, who provided insight and expertise that greatly assisted the research, although they may not agree with all the interpretations/ conclusions of this paper.

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