On Palm Oil and Deforestation in Borneo: A Step-Wise Model-Based Policy Analysis

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ABSTRACT

Deforestation due to the increasing palm oil demand has been a major environmental issue in Indonesia, especially in Kalimantan on Borneo Island, where the growth of oil palm plantation is the highest. As the potential for oil palm plantations in Sumatra Island has been reached, expansion has moved to Kalimantan where forest coverage is still relatively high. Besides logging trees, land is cleared by burning the forest without proper procedures and neglecting the environmental surroundings of the forest. Consequently, the fire spreads and affects surrounding areas. This study attempts to explore the long-term dynamics of the forest coverage in Kalimantan and to design policies to reduce the damage caused by this expansion. Using a model-based adaptive robust design approach, we show that it is possible to reduce the percentage of simulation runs which forest coverage in 2100 is smaller than 15 million hectares from more than 80% to less than 15%. Ultimately, the percentage of simulation runs which forest coverage is less than 10 million hectares is even smaller than 2% after the final policies are executed.

Keywords: palm oil, Borneo, deforestation, system dynamics, deep uncertainty, adaptive robust design

I. BACKGROUND

Palm oil constitutes the largest share of vegetable oil produced in the world because palm tree has the biggest yield of oil extraction compared to other crops. Based on data from the United States Department of Agriculture (2016), the worldwide production volume keeps increasing following the world demand trend in palm oil usage from 24 million tons in 2001 to 61.7 million tons in 2015. The fact that Indonesia and Malaysia are situated at around 10 degrees north and south of the equator makes these two countries the major players in the palm oil industry. In fact, Indonesia and Malaysia have become the biggest suppliers of palm oil since 1966. Their share increased to 85% in 2014 (United States Department of Agriculture, 2016; Wetlands International, 2013; Sime Darby Plantation, 2014). Currently Indonesia has already supplied 50% of total world palm oil demand (Statistics, Sub Directorate of Estate Crops, 2015) and this number has been increasing throughout the years as can be seen in Figure 1. Nowadays, the majority of palm oil plantations are located in Sumatra and Borneo Island. These islands are the home of elephants, Sumatran tigers, Borneo dwarf elephants, orang utans and also thousands of variety flora and fauna (BAPPENAS, 2016).

This paper focuses on Kalimantan, the Indonesian area jurisdiction of Borneo Island, which in recent years has become the place where the biggest expansion in palm oil plantations in Indonesia happens. The expansion has affected the biodiversity in the island due to monoculture palm trees plantation that alters the biodiversity balance in the area. Two methods of land clearing, namely logging and burning, damage the forest in this area. These methods have been largely criticized by environmental groups (Indonesia-Investments, 2016). In addition, most of Indonesia palm oil plantations do not comply with sustainability standards set by Roundtable on Sustainable Palm Oil (RSPO) certification. Furthermore, the nature of palm trees that absorb water and degrade soil fertility more than the capability of the land affects the quality of the land and causes land degradation once the palm tree plantation cycle has ended (PTPN5 BUMN, 2015). Eventually, palm oil industries prefer clearing other forest area for new plantations instead of rehabilitating the current abandoned land.

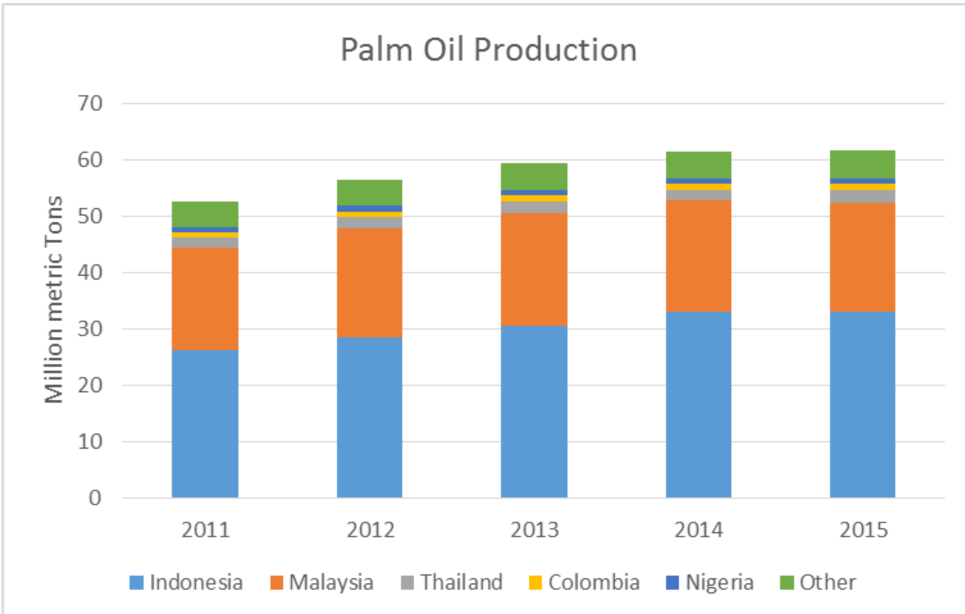

FIGURE 1 WORLD PALM OIL PRODUCTION (UNITED STATES DEPARTMENT OF AGRICULTURE, 2016)

Current actions from Indonesia government as stated in Government Work Plan are reforestation and reducing deforestation and forest degradation (Indonesian Government, 2016). Although the effort has not been maximized, Indonesian government has already done some measures to counter the issues of fire and logging through (i) creating sub department such as the National Forest Fire Control Centre (PUSDALKARHUTNAS), the Province Forest Fire Control Centre (PUSKALDARHUTDA) and fire extinguishment brigades around the forest area, (ii) equipping them with tools, guidelines and technical instructions to control and prevent forest fires, (iii) training the officials, plantation employees and communities to handle fires, (vi) conducting campaign and patrol on forest fires and illegal logging control, and (v) applying strict sanction to illegal logger and fires initiator (Soemarsono, 1997).

Similar research has been performed by Medrilzam (2013) who modeled the drivers of deforestation and forest degradation in the peatland ecosystem of Kalimantan. He looked at factors affecting local community’s decision on land conversion. However, his study only focuses on an ex-Mega Rice Project, a peatland area in Central Kalimantan. The plan was launched in the early 1990 with 2 goals: driving country revenues from large scale timber harvesting and covering national food security by converting peatland into rice fields. The project has been stopped since 1999 due to extensive peatland fires over the previous 15 years.

Another work by Ibragimov, Arshad, Bala, Kusairi, & Tasrif (2014) focuses on palm oil export duties of Malaysian palm oil industry. They modeled the dynamics of Malaysian palm oil industry by incorporating palm oil plantation cycle and supply-demand system of the economic sector.

In this paper, high level approach is used to understand the dynamics of the forest area due to the expansion of palm tree plantation in Kalimantan and to design effective policies to prevent further damage to the forest. The model focuses on the interrelation of causalities between palm oil plantation development, global palm oil demand trend and the Government's measures to preserve Borneo Forest.

In the remainder of the paper, model description and model based policy design for preventing further damage on forest area will be discussed. First, the methodology used in the paper is explained. Second, a conceptual model which explain the boundary and the line of thought on the model decisions is discussed. Third, detailed model and sub-systems explanation is provided. Fourth, business as usual simulation results and the behavior of the model are deliberated. Finally, exploration of promising policies based on the Adaptive Robust Design framework is executed.

II. METHODOLOGY

The model was made using System Dynamics modeling methodology. System Dynamics (SD) is a method to understand the structure and the dynamics of a complex system, through simulating the behavior over time of the system (Forrester, 1961; Sterman, 2000). A core underlying assumption of SD is that the structure of a model/system determines its own behavior. The structure of the system contains information and policies which are important for decision-making process in a complex problem setting (Roberts, 1988). Thus, structural change is needed to improve undesirable behaviors in the system and SD enables to test and identify the impact of system changes through 'virtual laboratory' (Pruyt, 2013).

Firstly, the conceptual model is made through Casual Loop Diagram (CLD) to identify main feedback loops and sub-systems affecting the system. Afterward, detailed stock-flow diagram (SFD) is developed to model the system followed by the determination of the model equations and parameter values.

Afterwards, this study follows Adaptive Robust Design (ARD) Framework as shown in Figure 2. The major difference between ARD and normal policy design in system dynamics is on what basis the policies are derived. While the normal system dynamics approach designs policy by analyzing the feedback loops, ARD tries to analyze the set of values of uncertain exogenous variables that strongly drive the behavior of the system to undesired direction. Consequently, ARD begins by assuming that some of the exogenous variables' values are not exactly known in nature as they are uncertain. ARD takes a specific possible range of values for each uncertain exogenous variables, then run the simulation for hundreds or thousands replications. Each replication has its own unique set of values of uncertain variables since in each replication a specific value is sampled for all variables. ARD then searches for troublesome region of output (outputs which end values are not desirable) and selects the range of some exogenous variables that typify this region by applying statistical data mining technique. The policy is then designed to manage the selected exogenous variables so that the number of the troublesome outputs is suppressed. The steps above are repeated several times until the modeler and the stakeholders are satisfied with the result of the designed policies (Hamarat, Kwakkel, & Pruyt, 2013).

In short, ARD employs an iterative approach of policy design by analyzing sets of uncertain exogenous variables that strongly drive the outcomes of the system's performance indicator to undesired direction, and designs policies based on these selected set of uncertainties. ARD computational approach is executed by using python based Exploratory Modeling and Analysis (EMA) workbench. The workbench generates combinations of plausible futures that encompass a broad range of uncertain variables (Hamarat, Kwakkel, & Pruyt, 2013). In order to find the troublesome and promising regions of the simulation runs, ARD employs the Patient Rule Induction Method (PRIM), a statistical data mining technique (Friedman & Fisher, 1999). PRIM allows identification of troublesome subspaces in the multidimensional uncertainties and has been extensively used in combination with EMA to translate the problematic region into qualitative scenarios that can be presented to decision maker for adaptive policy design and monitoring systems (Groves & Lempert, 2007; Hamarat, Kwakkel, & Pruyt, 2013).

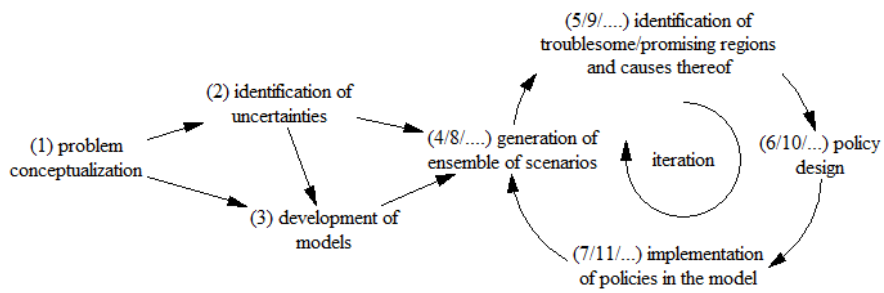

FIGURE 2 ADAPTIVE ROBUST DESIGN FRAMEWORK, ADAPTED FROM (HAMARAT, KWAKKEL, & PRUYT, 2013)

The initial value of the model was collected from various sources, mainly Indonesian government statistics Bureau; Badan Pusat Statistik (BPS), United States Department of Agriculture (USDA) and other sources. Nevertheless, the deep uncertainty nature of some variables are also addressed by specifying plausible value ranges of the uncertain variables as displayed in Appendix I.

III. MODEL DESCRIPTION

A. Model Boundaries

Deforestation and palm oil industry are complex sociotechnical systems which consist of multiple interrelated elements. Obviously, not all elements are modeled in this study because then the model will get extremely complex and the insights generation from the model run will become hard. Therefore, some elements are considered in this study while some other elements are disregarded as can be seen in Figure 3. This subchapter will focus the discussion on exogenous variables and omitted variables.

The drivers of forest land opening for palm oil plantation are the global palm oil demand and the percentage of global demand fulfilled by Kalimantan. The increasing trend of the global demand and Kalimantan fulfillment rate are considered as exogenous variables since Indonesia is less likely to have political and market power to shift the trend. Global palm oil demand for instance is largely influenced by the development of cleaner technology, environmental issue, world politics and also increasing demand of food supply to cater global population growth, which are beyond the scope of the study. The Government currently has allocated budget on forestry management, which is considered to be fixed in this study. Lastly, this study also considers the uncertain el nino cycle, an irregular variation of wind and sea surface temperature that influences the occurrence of natural forest fires as an external variable.

This study, on the other hand does not include the geographical distribution of forest and palm oil plantation in Kalimantan. For instance, forest area is modeled as one bulk stock in the model instead of the real geographical location which is usually studied by Geographical Information System (GIS). Palm oil plantation development is also influenced by the socioeconomic condition of its surroundings, namely the Kalimantan inhabitants. These socioeconomic drivers are omitted in this study because it is assumed that the palm oil plantation opening is dominantly influenced by a shift in global demand, instead of the conditions of Kalimantan inhabitants. Finally, this study only considers deforestation due to palm oil plantation expansion. This study does not consider the land opening for other purposes such as housing construction and open pit mining field development.

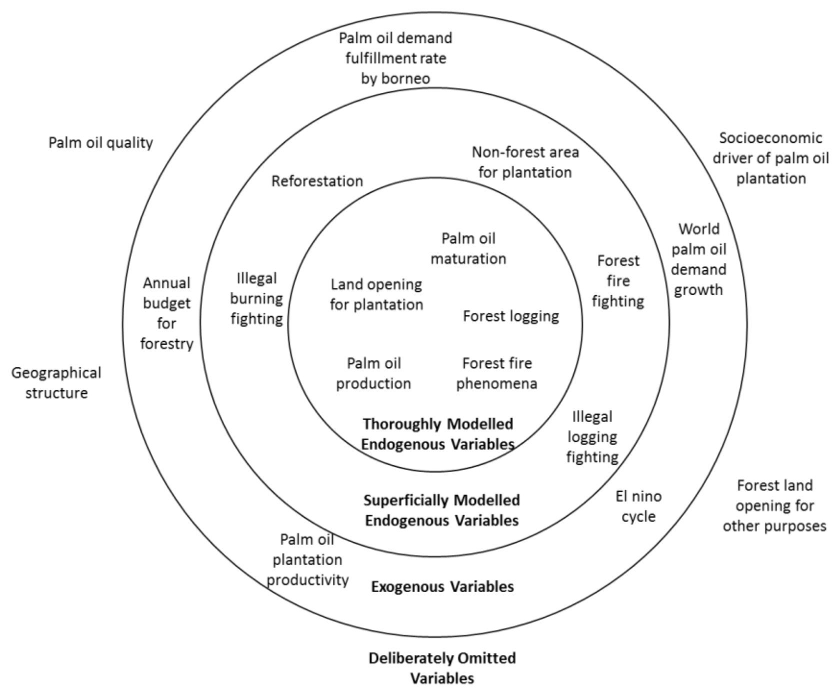

FIGURE 3 BULL'S EYE DIAGRAM

B. Main Feedback Loops

The main interest in this model is to show the increasing trend of forest land usage in Kalimantan for palm tree plantation due to the increasing world demand for palm oil usage. The model intention is to show the "tragedy of the commons" phenomenon of the increasing demand of palm oil to the forest area in Kalimantan. The increasing deforestation for palm plantation will eventually deplete the forest area after some decades. The aggregated CLD in Figure 4 shows the overview of six main feedback loops.

There are six important feedback loop in this study:

[1] Forest conversion to palm oil plantation: the more forest area converted into palm oil plantation, the more deforestation occurs, thus palm oil plantation area is increased.

[2] Reforestation from palm oil plantation: after the cycle of palm oil plantation, the land can turn into the forest again after some time through reforestation.

[3] Natural forest fire: the impact of climate change together with the natural temperature *el nino* cycle increase the natural forest fires occurrence.

[4] Unintended illegal burning and logging activities: smaller forest area results in smaller approval of land opening, thus businesses tend to do illegal land opening practices which decrease the forest area even more.

[5] Forest land opening approval limitation: there is a limit on the size of the forest area which affects the approval quota that the Government can give, smaller forest area results in smaller number of permits the Government can approve.

[6] Vicious cycle of land opening: When demand increases, the need for palm supply triggers the company to request additional land opening permits, thus affecting the forest area through land opening by burning and logging.

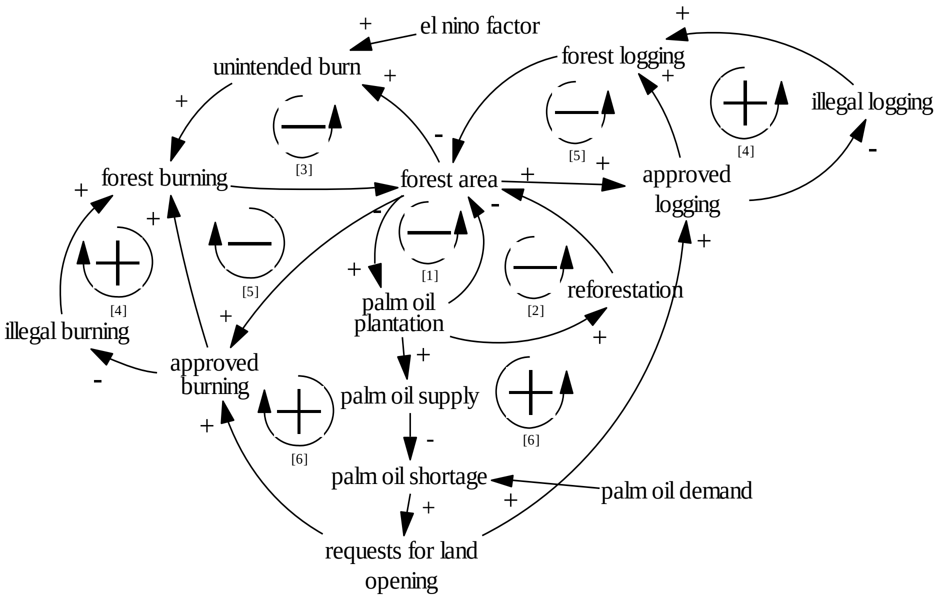

FIGURE 4 AGGREGATED CAUSAL LOOP DIAGRAM

IV. THE SIMULATION MODEL

The flow starts from world demand on palm oil where a fraction of the demand is fulfilled by palm oil plantation in Kalimantan. In order to produce more palm oil to fulfill the demand gap, plantation owners request the Government for forest area land opening approval. The initial size of forest area in Kalimantan by 2000 was around 45 million hectares. Among this forest, there is protected forest area of around 32% total forest which should not be used for land opening (Badan Pusat Statistik, 2013; Statistics, Sub Directorate of Estate Crops, 2008).

There are two types of plantation owners; small-scale plantation owners and big-scale plantation owners. The assumption of average request size by small-scale plantation owners is on average 3 hectares while big-scale plantation owner on average requests 16,200 hectares (Global Forest Watch, 2015; Badan Pusat Statistik, 2013). The approval rate is not exactly known in nature, due to the political factors and bribery practices which influence the approval rate of land usage. Plantation owners who have legal permit will convert the land into proper land for plantation through logging and burning activities, with a bigger fraction on burning activities as it is cheaper compared to logging. The improper burning practice sometimes cause the fire to spill to another part of the area. Intertwined with the cyclical nature from *el nino* and *la nina* phenomena, the burning activities create unintended forest fire. As for the plantation owners whose request is rejected, some fraction of them will pursue illegal action to obtain the area and to harvest timber through illegal burning and logging practices. Palm oil trees are then planted after the process of land clearing is done.

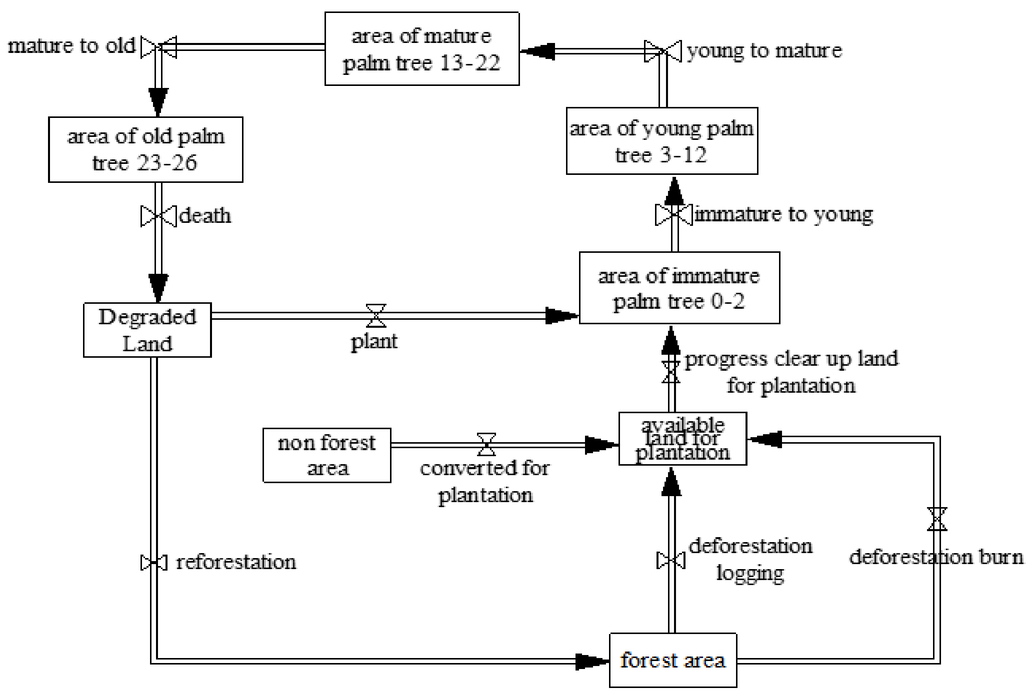

FIGURE 5 STOCK FLOW DIAGRAM FOREST & PLANTATION

As shown in Figure 5, in this model the palm tree plantation is distributed into four categories based on the distinction of the production yield: immature, young, mature and old. During immature period the palm tree cannot produce palm tree oil. The production yield increases once it gets older and reaches its peak when it matures, producing the highest yield in its lifetime. From there on the production yield starts to decline and in this model the palm tree enters unproductive phase after plantation age around 26 years old (Sutarta & Rahutomo, 2010; Lubis A. , 2008). By that time, the plants need to be replaced and the fertility of land will decrease, resulting in an area of degraded land. As for the fruit bunch harvest, the bunch is sent into production facilities and converted into palm oil to fulfill the global market demand.

The land can be replanted into palm plantation or can be turned back into forest with the reforestation method after increasing the fertility of the land. Palm plantation owners have the tendency to open forest area as the land fertility of forest area is still high although the degraded land can alternatively be utilized by swapping the allocation of the forest area with degraded land (Rosenbarger, Alisjahbana, & Anderson, 2013).

V. MODEL BEHAVIOR AND STEPWISE POLICY DESIGN

A. Business as Usual

The business as usual model corresponds to the current situation of handling deforestation in Kalimantan. For instance, the Government supports palm oil plantation by accepting land opening from Kalimantan forests on a limited basis. The unaccepted land opening requests might instead go for illegal burning or illegal logging. The Government then spends a fixed amount of budget to counter illegal actions and to extinguish forest fire, reducing the illegal actions and unintended forest fire. Besides that, the Government does not apply any other proactive measure to maintain the forest area.

The model is then simulated 5000 times across the uncertainty ranges as listed in Appendix I in order to apprehend as many plausible scenarios as possible. Each scenario represents a unique set of combination of uncertain variables which are automatically sampled by applying Latin Hypercube Sampling method in the EMA Workbench. The full spectrum of results of the 5000 runs can be seen in Figure 6.

The left-side graph of Figure 6 presents the behavior over time of the forest area from the 5000 simulation runs. While each ensemble of scenario produces different behavior over time, all of the simulation runs reside within the blue envelopes of the graph. The right-side graph of Figure 6 displays the kernel density, which plots the distribution density of the terminal values of all the 5000 simulation runs. For instance, the kernel density can be seen as a histogram distribution of the 5000 points of forest area by the end of the simulation run.

It can be seen that in some cases, the forest area of Kalimantan by the end of simulation run still exceeds 30 million hectares. However, Figure 6 shows that these cases are extreme cases since the density of this area is very small. It shows that there is only a small set of combinations of uncertain variables which the forest area by 2100 is still more than half of the forest area in 2000. Moreover, there are two peaks of kernel density distribution: one resides at about 15 million hectares and the other one resides at 0 hectare. This bimodal distribution of the kernel density is mainly caused by the different possible specifications of global palm oil demand development and fulfillment rate of this demand by Borneo plantation. When the trend of these variables is increasing, such as the second specification possibility of these variables as shown in Appendix II, the forest area is depleted. On the other hand, the second peak at 15 million hectares is mainly caused by steady trend of the palm oil demand and Borneo fulfillment rate. This fact also implies that either most of the simulation runs end at leaving the forest area to around 15 million hectares or that there will be no more forest in Kalimantan by the end of 2100. It can also clearly be seen that the peak at 0 hectare is higher than the peak at 15 million hectares. Therefore, in the broad ensembles of uncertain variables, there are a lot of permutations of scenarios that can defoliate the Kalimantan forest.

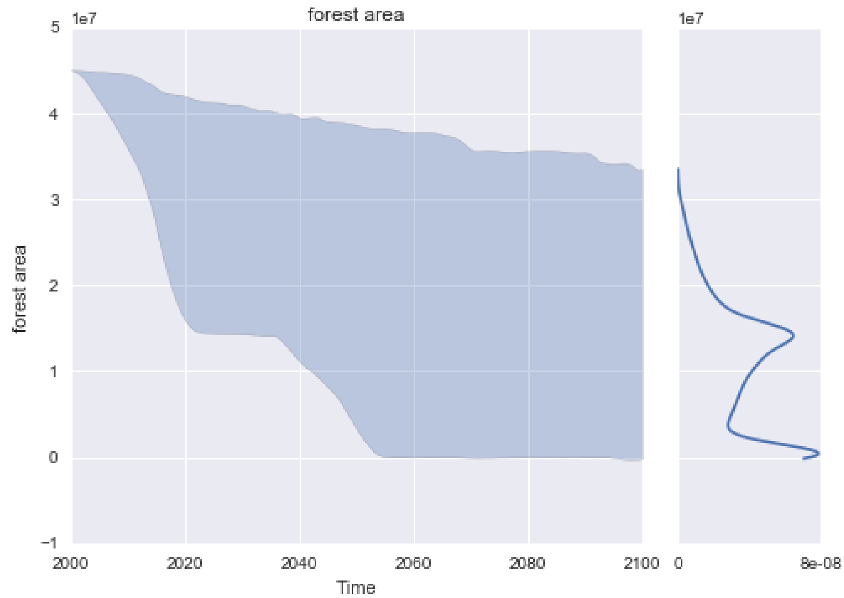

FIGURE 6 BUSINESS AS USUAL SIMULATION RESULTS

Although in the meantime the Government has conducted some policies to avoid major deforestation, the business as usual exploratory runs show that the current measures are not enough. The reasons correspond to the current issues in Indonesia, such as continuing illegal logging or illegal burning of fires, and corrupted local or central Governments who accept more land opening requests than the allowed threshold based on the constitution. Although the regulation strictly limits land opening if the forest area has fallen below 32% of the total area, illegal activities are still ubiquitous, making the forest area keeps decreasing.

In order to identify an effective measure, PRIM analysis is conducted to the business as usual simulation runs. Forest area is set as an indicator with the threshold value of 15 million hectares (32% of the forest area). PRIM analysis clusters the simulation runs which forest area falls below this threshold and identify the set of uncertain variables that typifies this cluster. Eventually, 4157 out of 5000 simulation runs belong to this undesirable category. The result of the PRIM analysis can be shown in Table 1.

TABLE 1 PRIM RESULT FOR BAU RUNS WITH FOREST AREA < 15 MILLION HECTARES

	PRIM Result		Initial Range
	Min	Max	
fulfillment rate switch	{0,1,2}	{0,1,2}	{0,1,2,3}
conversion yield	0.08	0.206	0.08-0.22
reforestation rate	25.84	79.99	20-80

PRIM identifies three uncertain variables that strongly drive the result of the forest area below 15 million hectares. Three out of four possible developments of Kalimantan's fulfillment rate of world palm oil demand are the most influencing drivers. Switch 0, 1, and 2 are switches where the fulfillment rate shows an increasing pattern, whereas the unselected switch 3 is the scenario where the fulfillment rate is relatively constant. Keeping Kalimantan as the main source of palm oil will eventually lead to forest devastation. The second most influencing factor is the relatively poor performance of conversion yield while the last factor is relatively high reforestation rate. The first policy then has to tackle these variables.

B. First Iteration: Improving Conversion Yield of Palm Oil Plantation

Based on the suggestion made by PRIM analysis, the first policy will try to improve the three identified uncertain variables. The first iteration of ARD selects conversion yield as a focus due to the easiness of influencing this variable compared to the other two variables. Basically, conversion yield is the amount of palm oil extracted per ton of palm fruit bunch. For instance, one ton of palm fruit bunch may contain 0.08 to 0.22 ton of palm oil. The value differs per palm oil plantation because the yield depends on the quality of the palm trees, the fertility of the soil, the adequacy of the fertilizer, and the plantation and irrigation methods.

The first policy will try to improve the performance of the palm oil plantation which ultimately will increase the production of palm oil. Intensification of palm oil production is expected to improve the overall production of Kalimantan palm oil plantations. Therefore, business actors do not necessarily need to open up new land in order to cope with the increasing global demand for palm oil. In order to improve the productivity of palm oil plantations, the Government has several means. Subsidy for better fertilizers and herbicides can be distributed. Another mean is by giving public counseling and training in cooperation with RSPO expert for palm oil farmers regarding palm oil best practices that comply with the RSPO certification and procedures. The Government can also invest in palm oil research and development with specific context of Kalimantan, then publicize the result to the farmers. Any of these available options will lead to higher production of palm oil per ton of palm fruit bunch.

On the other hand, the Government faces a budget limitation in executing this policy. Especially in Indonesia, almost all ministries are inquiring higher budget for their own problems since different sectors face different (urgent) challenges. As a consequence, additional budget allocation is not preferred in this study. In order to conduct this policy, the Government will have to sacrifice a portion of its annual budget for forestry. The forestry budget in the business as usual case is initially allocated for two posts, which are fighting illegal logging and burning and extinguishing forest fire. By applying this policy, the annual forestry budget is then split into three posts, taking into account the 'Plantation Best Practice Training' policy. The portion mix of these three posts are randomized as displayed in Appendix I.

The first policy is then simulated for 5000 replications and the results can be seen in Figure 7. The first policy has made the kernel density at the terminal value shifts upward. The kernel density now only has one dominant peak at about 15 million hectares. The concentration of simulation runs that reside in zero hectare has also been significantly reduced by a factor of roughly around four. Moreover, the tail of the upper side of the density graph, specifically the area above 20 million hectares, has become thicker compared to the Business as Usual case.

FIGURE 7 FIRST ITERATION SIMULATION RESULTS

The figure suggests that modifying annual forestry budget allocation by adding part of the budget for productivity improvement program, without needing to increase the absolute amount of the budget itself, can reduce the magnitude of deforestation to some extent. Nevertheless, it is also important to realize that the share of simulation runs that leads to undesirable outcome (forest area smaller than 15 million hectares) is still big. PRIM analysis shows that there are 2844 cases of interest out of 5000 simulation runs. The uncertain variables that drive this behavior are exactly the same as the previous PRIM analysis. The detailed range of these variables is presented in Table 2.

TABLE 2 PRIM RESULT FOR POLICY 1 RUNS WITH FOREST AREA < 15 MILLION HECTARES

	PRIM Result		Initial Range
	Min	Max	
fulfillment rate switch	{1,2}	{1,2}	{0,1,2,3}
conversion yield	0.08	0.206	0.08-0.22
reforestation rate	23.03	79.99	20-80

C. Second Iteration: Reforestation Obligation for Land Opening

Since the conversion yield has been addressed in the first policy, the next most feasible policy is to reduce the reforestation time so that the abandoned land transforms into forest area faster. Normally, abandoned land with plant and tree seeds needs approximately 50 years before the trees regrow and the land transforms into forest. The number might vary due to natural factors such as fertility of the land, rain intensity, drought intensity, etc. Proactive human-made reforestation is obviously a possible option to accelerate the natural reforestation process. Intensive reforestation effort might reduce the reforestation time up to 20 years.

In order to conduct intensive proactive reforestation, the Government apparently needs additional fund. The already limited annual forestry budget is evidently not sufficient to finance the second policy. As a workaround to increase the reforestation rate, 'Reforestation Obligation for Land Opening' is proposed. The idea of this policy is that any firm who wants to open new land, either by logging or by burning, is also obliged to conduct proactive reforestation on other abandoned lands as their corporate social responsibility program. Firms will have to fulfill a compulsory reforestation of 25% area of the new land they open for plantation.

Due to the higher cost of land opening from a business point of view, the consequence of this policy is the reduction of Kalimantan attractiveness for palm oil business. The global demand fulfillment rate of Kalimantan is then decreased, resulting in lower trade volume for Indonesia. Since the magnitude of this impact is unknown, a range of fulfillment rate decrease between 10% until 50% is considered in the simulation runs.

Similar to previous cases, the second iteration case is simulated 5000 times. Since the second iteration is a continuation of the first policy, the red line in Figure 8 denotes the performance of the combination of Policy 1 and Policy 2. The second iteration case has managed to shift the kernel density upward even more. While the dominant peak of the kernel density distribution still dwells at around 15 million hectares, the density of forest area below 15 million hectares has been greatly reduced compared to the first iteration and the business as usual case. On the other side of the spectrum, the density of forest area above 15 million hectares are considerably increasing.

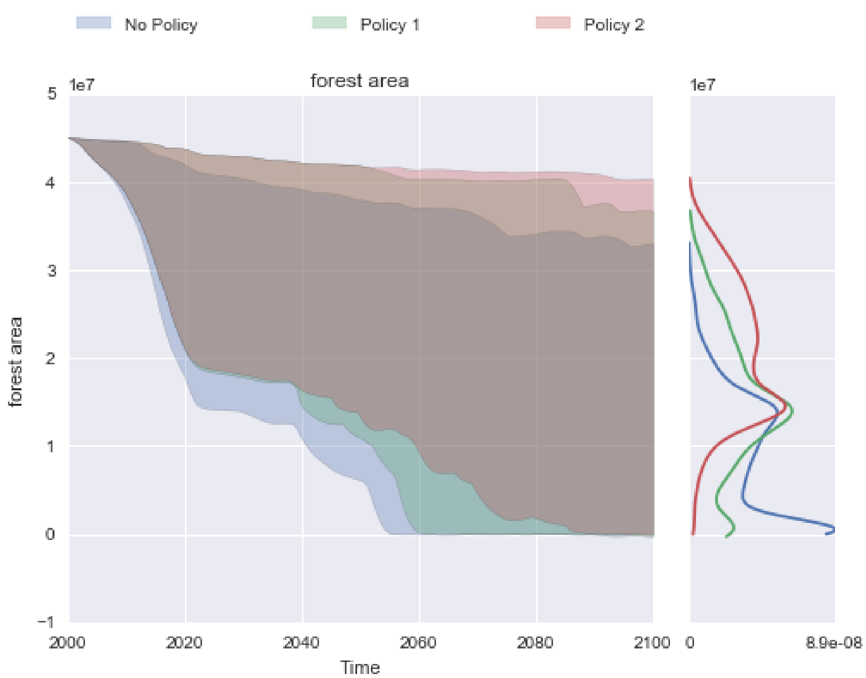

FIGURE 8 SECOND ITERATION SIMULATION RESULTS

The combination of the first and the second policy has resulted in a better robustness of deforestation mitigation. The reasons are straightforward: obligatory land opening increases the number of forest area and the second policy hampers the increasing trend of global palm oil demand fulfillment rate by Kalimantan. The fact that there is still some noticeable area below the peak of the kernel density implies that there is still a lot of cases where the deforestation cuts down forest area drastically. On the other hand, it signals a room for improvement by performing another iteration of ARD.

The PRIM analysis shows that the second iteration has halved the number of cases of interest (simulation runs where the forest area is smaller than 15 million hectares), specifically to 1363 out of 5000 total runs. Figure 9 shows the result of the PRIM analysis in graph form, instead of in table form. In Figure 9 it can be seen that surprisingly, the PRIM analysis also indicates that the same uncertain variables are responsible for this undesired region, except that the reforestation rate is not there anymore. The two variables that strongly influence the outcome are: fulfilment switch; indicated by the three dots which imply that the basic scenario, the first scenario and the second scenario of fulfillment rate by Kalimantan cause low number of forest area, and conversion yield; indicated by a continuous line that ends before it reaches 1 which implies that high conversion yield is needed to save the trees.

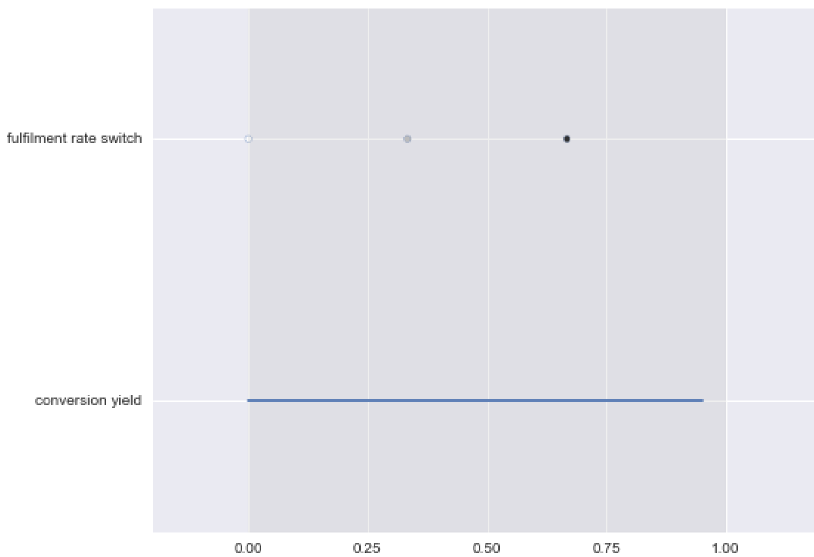

FIGURE 9 PRIM RESULT FOR THE SECOND ITERATION

D. Third Iteration: Responsive Tax of Land Opening

As the PRIM analysis suggests, the third iteration will have to reduce the fulfillment rate of palm oil demand by Kalimantan. The second policy has indirectly influenced the fulfillment rate by introducing obligatory corporate social responsibility program for firms that want to open new land. Reducing the attractiveness of Kalimantan further can be accomplished by introducing additional costs for firm to open new lands. However, the reason for including additional costs should be justifiable, else the proposed policy will not be applicable. It is because palm oil is one of the major exporting commodity that greatly contributes to Indonesia's GDP. Introducing additional cost out of the thin air will trigger resistance from some stakeholders.

To confront this issue, the third policy will establish a responsive tax of land opening based on the supply-demand gap of palm oil in Kalimantan. The Government assesses the total supply and demand of palm oil on an annual basis. Based on this information, the Government then sets a responsive land opening tax for the consequent year based on the supply-demand gap of the current year. This approach is justifiable in the sense that during the condition of palm oil scarcity (demand gap is positive), the attractiveness of investing in palm oil rises. In accordance to standard economic logic, introducing additional cost (in this case the land opening tax) is acceptable if the demand to invest is relatively high.

This policy is expected to be effective due to two motives. First, applying tax will reduce the attractiveness of investing in Kalimantan to a certain degree. Coupled with the responsive nature of the tax, in absolute term, this policy will not reduce the income of Indonesia from palm oil trades because the tax will only be applied if the demand gap is large enough. The tax functions as a feedback control mechanism of Indonesia to reduce the desire of quick win from land opening, overlooking the environmental consequence of the decision. Second, the collected tax can be utilized for annual forestry budget. The increase of the annual forestry budget will then increase the magnitude of illegal actions fighting, forest fire fighting, and palm oil best practice training.

The purple line in Figure 10 exhibits the density distribution of the third iteration, which is a combination of Policy 1, Policy 2 and Policy 3. There are two interesting features exhibited by the third iteration simulation runs. The peak at around 15 million hectares does not dominate the density distribution anymore. There is a big mountain-shaped distribution above the area of 15 million hectares which is now dominating the kernel density. It also indicates that most of the simulation runs now end with forest area larger than 15 million hectares. Furthermore, the density of forest area below 10 million hectares is very small. The number of cases with forest area below threshold value is 746 cases. Among the 746 cases, only 61 of them have value lower than 10 million hectares.

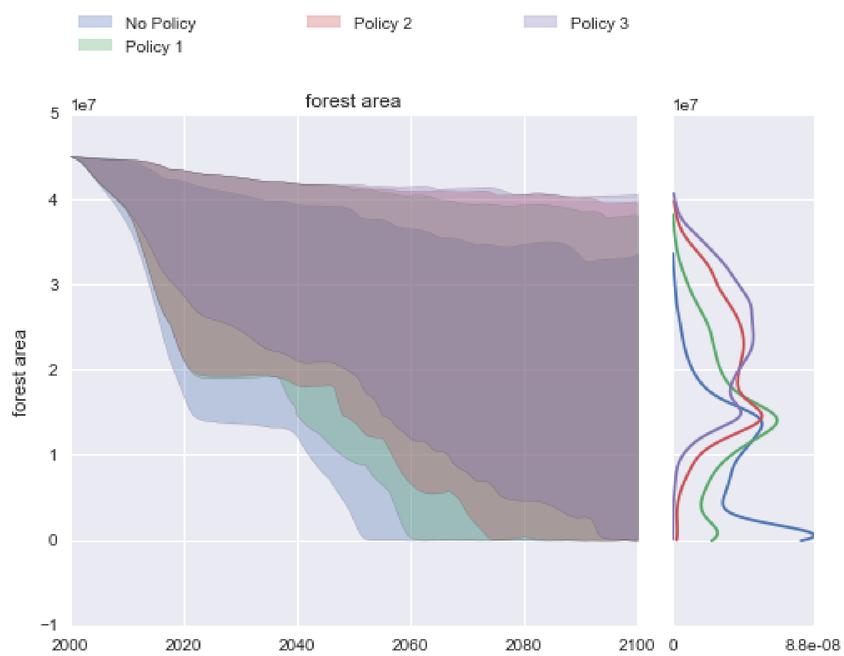

FIGURE 10 THIRD ITERATION SIMULATION RESULTS

The third iteration has shown a very promising result to avoid major deforestation in 2100. Therefore, the third iteration is determined as the last iteration because further analysis will not be cost efficient.

VI. CONCLUSION & RECOMMENDATIONS

As one of the biggest CO_2 absorber country in the world, it can be said that Kalimantan forest is one of the lungs of our earth. On the other hand, the richness of fertile soil on Kalimantan island also becomes an economically sounds reason to exploit its forests. Consequently, tragedy of the commons occurs and major deforestation befalls. The business as usual simulation runs have indicated that the current measures applied by the government are far than sufficient to avoid devastating deforestation by 2100.

This paper has utilized the Adaptive Robust Design framework to challenge the deforestation issue from system-structure perspective. By identifying the most statistically influential factors that characterize the undesired region of the simulation results, policies were iteratively designed by confronting those factors. The iterative policy design process has developed two static policies (improvement of palm oil yield and reforestation obligation for land opening) and one adaptive policy (responsive tax based on demand gap).

The ARD framework also enables the inclusion of deep uncertainty into the analysis, which is important for dealing with the deforestation problem under uncertainties. For instance, the *el nino* and *la nina* phenomena, which are two of the driving factor of the forest fire, is uncertain in nature. The degree of acceptance of land opening requests by local government and central government is also uncertain due to the ubiquitous corruption and bribing practices. The two examples above are only small slices of the whole uncertainties in deforestation problem which have been considered in this study.

In combination, these three policies have become an orchestrated robust policy to prevent major deforestation. By setting the threshold value of the PRIM analysis to 15 million hectares of forest area in 2100, the final iteration of ARD has squeezed the number of undesired simulation results from 4157 out of 5000 cases during the business as usual scenario to only 746 out of 5000 cases. In addition, the number of simulation runs whose forest area's final value is less than 10 million hectares is less than 2% of the total simulation runs.

Though the result of the policies suggested by this paper is promising, it is not without limitation. Firstly, the applicability of the policy is only assessed to a limited extent. Only small number of discussions and deliberations with stakeholders and experts were conducted throughout the study. Second, the model used in this study is an elegant, high-level, aggregated model that omits many details of the forest land use change and is based on some deliberate assumptions. For instance, the model does not differentiate primary forest and secondary forest. The model doesn't dive deeper into socioeconomic factors that drive small oil palm plantation owners to open new land. The model also assumes that the policy design should exclude policies which demand additional cost for its execution. Hence, the limitations mentioned above open room for further research in this topic. Nevertheless, this paper has given high-level recommendations of how to prevent vast deforestation in Kalimantan.

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APPENDIX I: Ranges of Uncertain Variables

PARAMETER	VALUE	INTERVAL	SOURCES
FULFILMENT RATE SWITCH	0	(0,1,2,3)	(Statistics, Sub Directorate of Estate Crops, 2007-2015)
DEMAND WORLD SWITCH	0	(0,1,2,3)	(Statistics, Sub Directorate of Estate Crops, 2007-2015), (United States Department of Agriculture, 2016)
CLIMATE CHANGE FACTOR SWITCH	0	(0,1,2,3,4,5)	(World Meteorological Organization, 2014)
APPROVAL TIME RATE	1.5	(0.5,2.5)	Assumed
RATIO APPROVAL TO USE DEGRADED LAND	0.7	(0.3,0.9)	Assumed
FRUIT DAMAGE RATE	0.05	(0.02,0.2)	(Mohamad, Manaf, & Chuprat, 2012)
AVERAGE PRODUCTION OF YOUNG PALM TREES	15	(10,30)	(Sutarta & Rahutomo, 2010), (Lubis A. , 2008), (Badan Pusat Statistik, 2013)
AVERAGE PRODUCTION OF MATURE PALM TREES	23	(20,45)	
AVERAGE PRODUCTION OF OLD PALM TREES	12	(7,22)	
CONVERSION YIELD	0.12	(0.08,0.22)	(Badan Pusat Statistik, 2013), (Statistics, Sub Directorate of Estate Crops, 2007-2015)
SIZE OF NATURAL CYCLIC FOREST BURN	100000	(30000, 300000)	(Badan Nasional Penanggulangan Bencana-Indonesian Government, 2015)
RATIO DEMAND FULFILLED BY SMALL PLANTATION	0.28	(0.15,0.6)	Assumed
AVERAGE AREA BIG PLANTATION REQUEST	16200	(13000, 30000)	(Global Forest Watch, 2015) and (Badan Pusat Statistik, 2013)
AVERAGE AREA SMALL PLANTATION REQUEST	3	(1,10)	
CLEARING RATE	2	(1.5,4)	
REFORESTATION RATE	50	(20,80)	Assumed
LEGAL BURN OVER LOGGING RATIO FOR SMALL SCALE	0.9	(0.5,0.95)	Assumed
LEGAL BURN OVER LOGGING RATIO FOR BIG SCALE	0.7	(0.1,0.5)	Assumed
ILLEGAL BURN OVER LOGGING RATIO FOR SMALL SCALE	0.95	(0.5,0.95)	Assumed

ILLEGAL BURN OVER LOGGING RATIO FOR BIG SCALE	0.2	(0.1,0.4)	Assumed
PERCENTAGE ACCEPTANCE SMALL PLANTATION BY LOCAL PROVINCE GOV	0.8	(0.5,0.9)	Assumed
PERCENTAGE ACCEPTANCE APPROVAL BIG PLANTATION	0.7	(0.5,0.9)	Assumed
FIRE SPILLOVERS FROM INTENDED BURNING	0.2	(0.05,0.4)	Assumed
BUDGET PORTION FOR ILLEGAL FIGHTING	0.8	(0.1,0.9)	(Ministry of Finance Goverment of Indonesia, 2015)
ILLEGAL FIGHTING EFFECTIVENESS	0.4	(0.1,0.9)	Assumed
FIRE FIGHTING EFFECTIVENESS	0.5	(0.1,0.9)	Assumed
PREFERENCE OF TRAINING OVER FIRE FIGHTING	0.8	(0.6,0.9)	Assumed
EFFECT OF REFORESTATION OBLIGATION TO BORNEO ATTRACTIVENESS	0.3	(0.1,0.5)	Assumed
EFFECTIVENESS OF TAX COLLECTION	0.7	(0.5,0.9)	Assumed
INITIAL PREFERENCE ON FOREST AREA	0.9	(0.5,0.9)	Assumed

APPENDIX II: Different Uncertainties of Lookup Variables

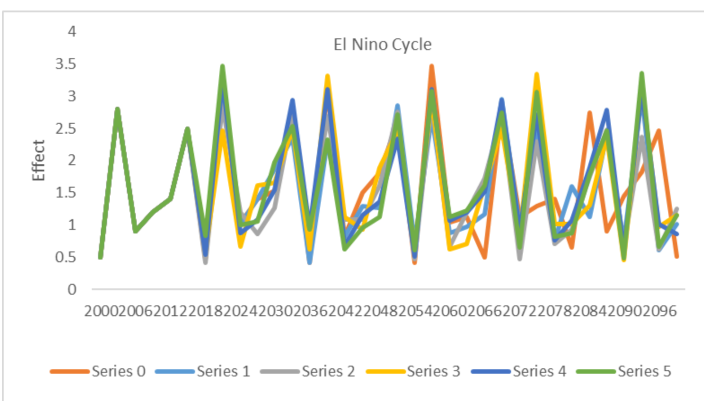

FIGURE 11 FIVE EL NINO CYCLE ODDS

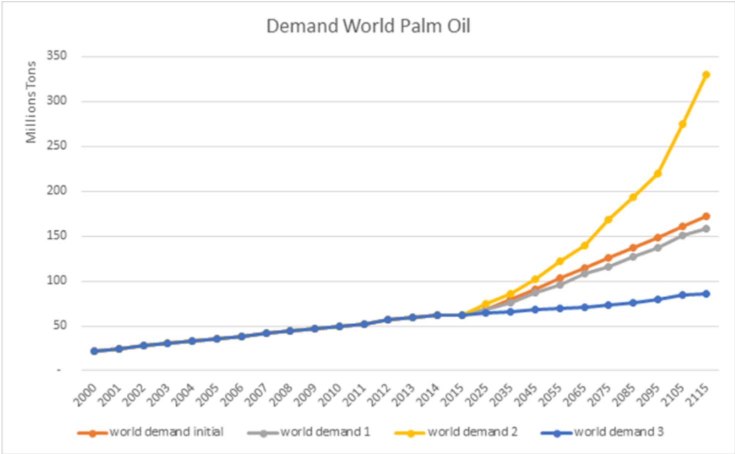

FIGURE 12 FOUR PALM OIL GLOBAL DEMAND DEVELOPMENT

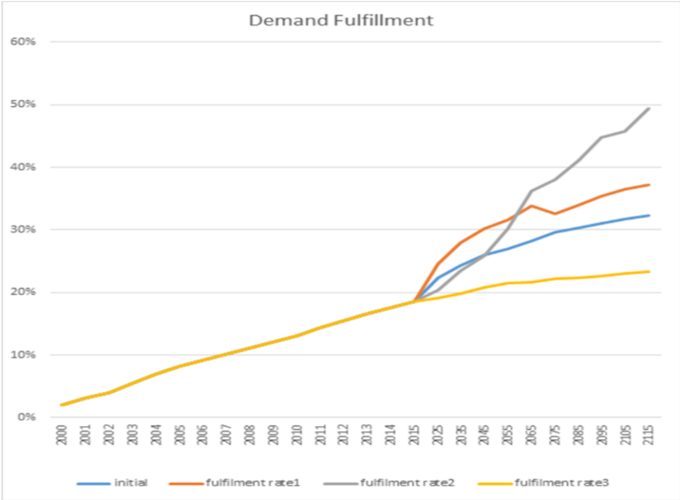

FIGURE 13 FOUR GLOBAL DEMAND FULFILLMENT BY KALIMANTAN POSSIBILITIES