Master Thesis

APPLICATION OF SYSTEM DYNAMICS MODEL FOR EVALUATION OF A TWO-YEAR MORATORIUM POLICY ON FOREST AND PEATLAND CONCESSIONS UNDER REDD-PLUS COOPERATION IN INDONESIA WITH CASE STUDY OF PALM OIL INDUSTRY SECTOR

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Application of System Dynamics Model for Evaluation of A Two-Year Moratorium Policy On Forest And Peatland Concessions Under REDD-Plus Cooperation in Indonesia With Case Study of Palm Oil Industry Sector

x + 101pages, 22 tables, 67 figures, 1 appendix

ABSTRACT

In this study, we aim to develop a system dynamics (SD) model to gain a better understanding about the impact of a two-year moratorium policy on the new forest and peatland concessions under REDD-plus cooperation in Indonesia's economy and the environment with a case study of the palm oil industry. A scenario-based approach was conducted using SD modeling to extrapolate two basic scenarios of business as usual (BAU) and moratorium policy (MP) scenarios. The result demonstrated that the MP noticeably reduces GHG emissions from deforestation, the highest GHG reduction is in 2013 which 60.5% below the BAU. However, the reduction is only temporary, and the emission trend under the MP scenario would eventually return to the BAU level. In environmental perspective, the moratorium policy solely has no significant impact on environmental improvement in the long term. By contrast, Indonesia would face a trade-off between emission reductions and economic growth. The average of annual decline of CPO production from 2010 to 2020 is estimated 0.7 Million Tons per year under MP scenario. It was calculated that the difference between the lost potential value and the financial compensation of REDD-plus Cooperation is around 6.6 Billion USD. In economic perspective, the MP is not economically viable for Indonesia since the potential economic loss cannot be offset by financial compensation. The policy is a good initiation to develop the next strategy for supporting MP. However, Indonesia should be readily prepared to weather the economic slowdown because of the policy implementation. Furthermore, the slowdown effect would last sufficiently long when compared to the policy period.

Keywords:*System dynamics, Indonesia moratorium policy, REDD-plus, GHG emissions, Palm oil.*

References: 63 (1961-2012)

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LIST OF ABREVIATIONS

BAU	Business As Usual
COP	Conference of the Parties
CO_2	Carbon Dioxide
CPO	Crude Palm Oil
FFB	Fresh Fruit Bunches
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GPO	Global Palm Oil
IPOC	The Indonesia Palm Oil Commission
IPOPA	Indonesia Palm Oil Plantation Area
IPO	IndonesiaPalm Oil
KP	Kyoto Protocol
LOI	Letter of Intent
LUC	Land Use Change
MAORI	Ministry of Agriculture Republic Indonesia
MP	Moratorium Policy
POC	Palm Oil Consumption
REDD-plus	Reducing Emissions From Deforestation And Forest Begradation
SD	System Dynamics
UNFCCC	United Nations Framework Convention on Climate Change
USDA-FAS	United States Department of Agriculture-Foreign Agricultural Service
USDA	United States Department Agriculture
USD	United States Dollar

CHAPTER I
INTRODUCTION

1.1 Background

1.1.1 International Agreement on Climate Change Policy

The concern on greenhouse gas (GHG) emissions associated with climate change issue has highly increased over the world; 1979 was the year of the first World Climate Conference and it continues until now. In 1997, there was a momentous event which taken place in Kyoto-Japan that linked to the United Nations Framework Convention on Climate Change (UNFCCC), it produced an international agreement, namely the Kyoto Protocol (KP) which set binding targets for industrialized countries and the European community for reducing GHG emissions [UNFCCC, 2012][1]. The KP has brought a new policy direction for climate protection using three market-based mechanisms: emission trading, the clean development mechanism, and joint implementation. Since then, emission trading became a widely discussed instrument for climate policy [Hansjurgents, 2005)][2]. 'GHG emissions - most prevalently Carbon dioxide (CO_2) - became a new commodity now' [UNFCCC, 2012][3]. Countries that bond with the target GHG emissions reductions in the KP can reach a portion of their targets using the three market-based mechanisms, that is, "it does not matter where the emissions are reduced, as long as the emissions are removed from the planet's atmosphere", for instance, they can develop green investments in developing countries to meet their reduction target. Regarding the international carbonmarket-based mechanisms for climate protection, the UNFCCC 13th Conference of the Parties (COP) in Bali-Indonesia 2007 produced the Bali Road Map to succeed the KP that represent the various negotiating tracks that are essential to achieve a secure climate in the future [UNFCCC, 2012][4]. A new framework of the various negotiating tracks for tackling the climate change is REDD. It then became RED-plus in the UNFCCC 14th COP, Poznan-Poland 2008. REDD-plus stands for 'reducing emissions from deforestation and forest degradation'. The REDD-plus framework

[1] UNFCCC. *Kyoto Protocol*. Retrieved February 12, 2012, from United Nations Framework Convention on Climate Change: http://unfccc.int/kyoto_protocol/items/2830.php, 2012.

[2] Hansjurgents, B. *Emissions Trading For Climate Policy, US and European Perspectives*. Cambridge: Cambridge University Press, 2005.

[3] UNFCCC. *Making those first steps count: An Introduction to the Kyoto Protocol*. Retrieved February 12, 2012, from United Nations Framework Convention on Climate Change: http://unfccc.int/essential_background/kyoto_protocol/items/6034.php, 2012.

[4] UNFCCC. *Bali Road Map*. Retrieved February 12, 2012, from United Nations Framework Convention on Climate Change: http://unfccc.int/key_documents/bali_road_map/items/6447.php, 2012

acknowledges the importance of forests in addressing climate change and emphasizes providing financial compensation to participating countries that effectively protect and conserve their forest [CIFOR, 2009][5].

1.1.2 Moratorium Policy of Indonesia

Indonesia was one of developing countries who declared a voluntary commitment on the reduction of GHG emission. Indonesia government is committed to reducing 26% until 41% of GHG emissions relative to the business as usual (BAU) level by 2020 [Yudhoyono, 2009][6]. A reduction of 26% of GHG emissions may be attained using Indonesia's national budget, whereas a reduction of 41% of GHG emissions can be completed with support from international partners. In accordance with the commitment, through the three market-based mechanisms and REDD-plus framework for climate protection, Indonesia and Norway signed Letter of Intent (LOI) for REDD-plus Cooperation in 2010 [Solheim and Natalegawa, 2010][7]. Norway intended to provide funds of up to USD$1for forest conservation programs to help significantly reduce deforestation-caused GHG emissions from in Indonesia. Under that agreement, Indonesia agreed to enact a 2-years suspension on all new concessions for the conversion of peatland and natural forest. The bilateral agreement finally came into force 1 year later, in May 2011, when the Indonesian president signed a Presidential Instruction No.10/2011, which enacted the 2-year suspension (termed the "moratorium policy (MP)") ;(Edward et al., 2011[8]; Yudhoyono and Astuti, 2011[9]). The implementation of MP from 2011 until 2013 raised negative opinions, mainly addressed to economic issue, on concerns such as that the policy would curb Indonesia's economic sectors that especilly rely on forest conversion and use, such as mining, timber/logging, palm oil and numerous agricultural industries, etc.

Before the implementation of a two-year moratorium, strong opposition arose from the palm oil industry sector, which was incorporated into the Indonesia Palm Oil Producers Association (GAPKI) and the Indonesia Palm Oil Commission (IPOC). They argued that the MP would

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[5]CIFOR. *Simply REDD-CIFOR's guide to forests, climate change and REDD.*Bogor: Center for International Forestry Research, 2009.

[6] Yudhoyono, S. *Intervention By H.E. Dr. Susilo Bambang Yudhoyono President of The Republic of Indonesia On Climate Change.*Pittsburgh:Forest Climate Center, 2009.

[7]Solheim, E. and Natalegawa, R.M.M.M. *Letter of intent between the Government of the Kingdom of Norway and the Government of the Republic of Indonesia on cooperation on reducing greenhouse gas emissions from deforestation and forest degradation.*Oslo: The Government of The Kingdom of Norway and The Government of The Republic of Indonesia, 2010.

[8] Edwards, D.P., Koh, L.P., Laurance W.F. Indonesia's REDD+ pact: Saving imperilled forests or business as usual?. *Biological Conservation*. Article in pers, 2011

[9]Yudhoyono, S.B.,and Astuti, R.P.B. *Presidential Instruction of Republic of Indonesia Number 10 of 2011 About Moratorium on the new permits and the Completion Governance of Primary Natural Forest And Peatland* .Jakarta: Sekretariat Kabinet RI, 2011.

hamper the industry's plan to double production by 2020 to meet the growing global demand of palm oil [The Jakarta Post, 2010][10]. They also suggested to the Indonesia's government that as a developing country, Indonesia must prioritize economic development over the environment. Moreover, Latul, J. and Chatterjee, N. [2010][11] reported concerns that the MP may stymie palm oil production, creating a perception of land scarcity in Indonesia and increasing land prices by 30%-50% over current levels.

1.1.3 Palm Oil of Indonesia

The origin of palm oil is believed from Africa. Nowadays, the palm oil gives the highest yields per hectare compares with other oil crops, it led to a rapidly expanding the industry which now based in the tropical areas of Asia, Africa and America. The most productive parts of the industry recently are in Indonesia and Malaysia which provide most of the palm oil in the international trade [Corley and Tinker, 2003][12] .

Regarding the Indonesia palm oil (IPO), the industry is a vital agricultural industry that plays a prominent role in the economic development of Indonesia. Since Indonesia became the largest producer of palm oil in the world which surpassed Malaysia in 2006 [USDA-FAS, 2007][13], it contributes up to 40% of global palm oil demand, and a figure that is continually increasing. The industry has always been the biggest and sole non-fossil fuel commodity (coal, oil and gas) of Indonesia in terms of export contribution [Alfian, 2011][14]. It contributes 6%-7% of Indonesia's gross domestic product (GDP), and approximetely 3.7 million people in Indonesia are involved in the industry, [RSPO,2011][15]. The Industry is mostly located in rural areas. Therefore, it revitalized a rural economy that enhancing welfare for the local population, especially by providing employment then it could also prevent the urbanization. The IPO industry has proved their contribution to great revenue for Indonesia which in turn will play an important role for economic development and enhancing the welfare of population. Hence, the industry becomes one pillar of Indonesia's national economy now.

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[10] The Jakarta Post. *CPO producers oppose moratorium*. Retrieved February 17, 2012, from The Jakarta Post: http://www.thejakartapost.com/news/2010/07/02/cpo-producers-oppose-moratorium.html, 2010.

[11] Latul, J. and Chatterjee, N. *Analysis: Indonesia forest moratorium to stymie palm oil firms*. Retrieved February 12, 2012, from Reuters: http://www.reuters.com/article/2010/08/12/us-indonesia-plantations-idUSTRE67B1J320100812, 2010.

[12] Corley, R.H.V. and Tinker, P.B. *The Oil Palm*. Malden-USA: Blackwell Science Ltd, 2003.

[13]Crutchfield, J. *Indonesia: Palm Oil Production Prospects Continue to Grow*. United States Department of Agriculture-Foreign Agricultural Service, 2007.

[14] Alfian. *Coal, CPO elevate exports to all-time high*. Retrieved February 17, 2012, from The Jakarta Post: http://www.thejakartapost.com/news/2011/01/04/coal-cpo-elevate-exports-alltime-high.html, 2011.

[15] RSPO. *Indonesia: Benchmark For Sustainable Palm Oil In Emerging Markets*. Retrieved September 28, 2011, from Roundtable on Sustainable Palm Oil (RSPO) : http://www.rspo.org/?q=content/indonesia-benchmark-sustainable-palm-oil-emerging-markets, 2011.

However, in addition to the economic advantages, the industry certainly has environmental impacts within all its phases that contribute to environmental degradation, specifically in the plantation phase. It relates to the extensive land required to establish the vast monoculture palm oil plantations, most of which are obtained by converting natural forest. As indicated by various documents, these issues include climate change (i.e., plummeting carbon stocks), loss of biodiversity, the extinction of endangered animals, soil erosion, and air, soil, and water pollution [Richardson, 2010[16]; Greenpeace, 2007[17], Brown and Jacobson, 2005[18]]. The relationship diagram of merits and demerits of the IPO from economic and environmental perspectives is shown in figure 1.

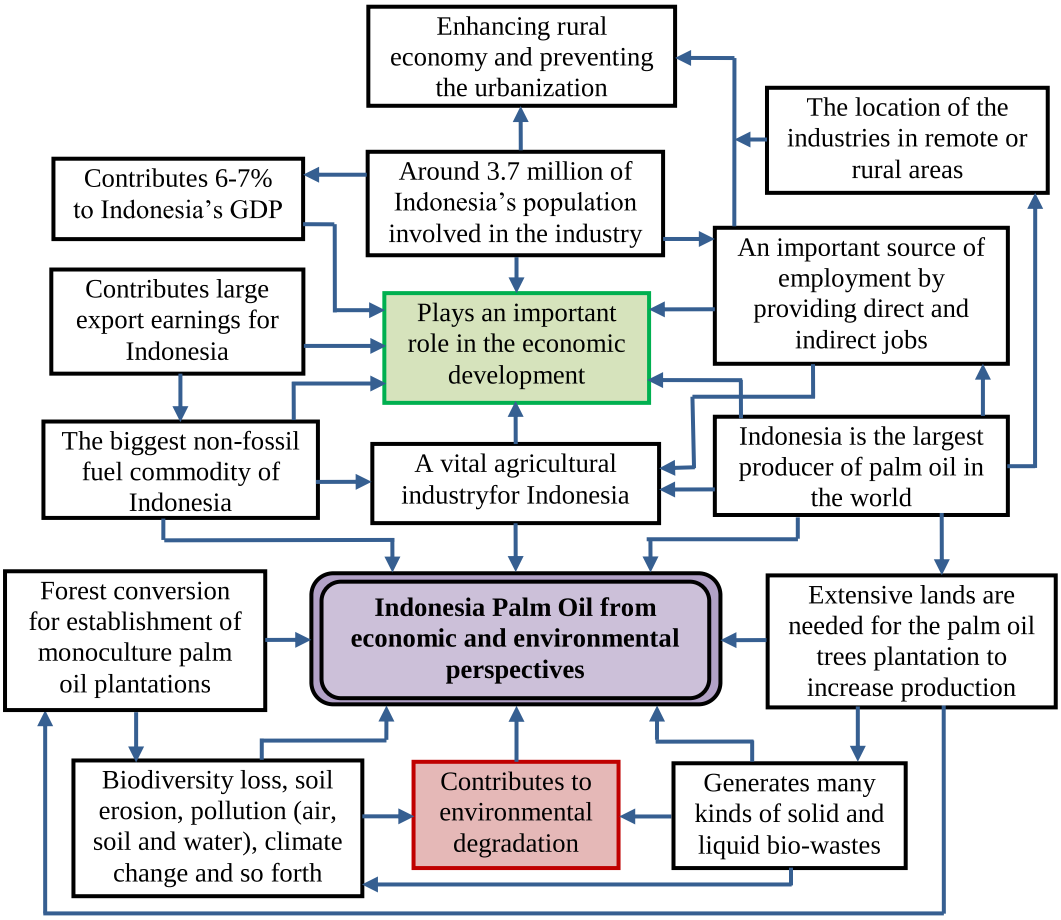

Figure 1-1. Relationship diagram of Indonesia palm oil from economic and environmental perspectives

16 Richardson, C. L. *Deforestation Due To Palm Oil Plantations In Indonesia.* Charlotte Louise Richardson 200431233, 2010.

17 Greenpeace. *How The Palm Oil Industry Is Cooking The Climate.* Amsterdam: Greenpeace International, 2007.

18 Brown, E and Jacobson, MF. *Cruel Oil-How Palm Oil Harms Health, Rainforest And Wildlife.*Washington, DC: Center for Science in the Public Interest, 2005.

1.1.4 Global Palm Oil Demand and Land Use Change in Indonesia

The population growth and rising income over time are the driver for the global demands for everything (food, feed, fuel and other raw materials). On the other hand, these demands have been creating economic opportunities for many developing countries to respond the demands by exploring their natural resources [Evans, 2009 ; Godfray et al., 2010 ; Rudel et al. 2009 ; cited in Koh et al., 2003][19].

With regard to the global palm oil (GPO) demand, Corley [2009][20] argued that the future GPO demand will increase due to growing world population and their consumption. It then consequently requires the additional area of palm oil plantations to meet the future demand. Same opinion also came from Tan et al. [2009] [21], because palm oil can be used as a versatile vegetable oil for a range of edible and non-edible products, including biofuel, it is the most highly demanded vegetable oil in the world. Thus, the expansion of palm oil plantation has been inevitable to meet the high demand of palm oil in the future. Hence, the demand of palm oil and land use change (LUC) is like two sides of the coin that cannot be separated.

Although, the terminology is different between demand and consumption. Where demand is prior to consumption logically, consumption is therefore predicated upon the exercise of demand. However, this fact itself does not imply anything when the final act of consumption will actually take place [Ludwig Von Mises Institute, 2009][22]. Thus, we could know the historical trend of GPO demand from the historical trend of GPO consumption. Figure 1-2 shows the historical data for the GPO demand, indicating that GPO demand in 2010 more than doubled compared to 2000, that is from 26.7 million tons in 2000 to 53.9 million tons in 2010 for an average growth rate of 6.9% per year.

Due to the law of supply and demand is naturally applied in the business world, the economic opportunity has affected to the land use change in Indonesia. Rising demand for palm oil triggers investment in the palm oil industry sector by establishing new palm oil plantations (i.e., expansion) to increase production to meet the demand. Figure 1-2 shows the historical data for the Indonesia palm oil plantation area (IPOPA). The IPOPA increased from 4.1 million hectares in 2000 to 7.8 million hectares in 2010 for an average growth rate of 6.7% per year.

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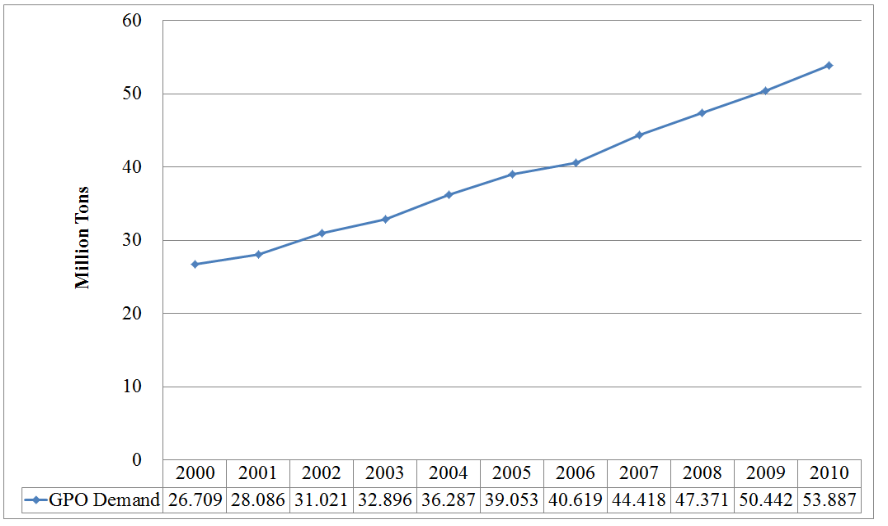
[19] Koh, L.P, Gibbs, H.k, Potapov, P.V, and Hansen, M.C. REDD calculator.com: a web-based decision-support tool for implementing Indonesia's forest moratorium. *Methods in Ecology and Evolution*, 3, 310-316, 2012.

[20]Corley, R. How much palm oil do we need?. *Environmental Science and Policy*, Vol.12, pp.134-139, 2009.

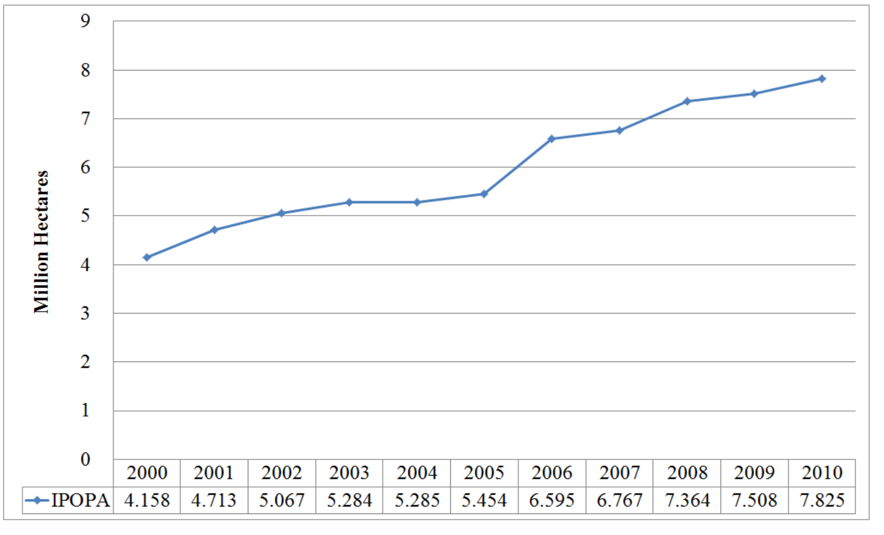
[21]Tan, K.T, Lee, K.T., A.R Mohamed, and Bhatia, S. (2009). Palm oil: Addressing issues and towards sustainable development. *Renewable and Sustainable Energy Reviews*, Vol.13, pp.420–427.

[22]Ludwig Von Mises Institute.*Chapter VI The Demand Side of The Market.* Retrieved September 12, 2012, from Ludwig Von Mises Institute: http://mises.org/PDF/Salerno_syllabus06/Shapiro_Ch6-7.pdf, 2009.



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
GPO Demand	26.709	28.086	31.021	32.896	36.287	39.053	40.619	44.418	47.371	50.442	53.887

Figure 1-2. Historical data of global palm oil (GPO) demand.
Source: USDA 2005[23], 2008[24], 2012[25]



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
IPOPA	4.158	4.713	5.067	5.284	5.285	5.454	6.595	6.767	7.364	7.508	7.825

Figure 1-3. Historical data of Indonesia palm oil plantation area (IPOPA).
Source: MAORI, 2010[26]

[23] United States Department of Agriculture. *Table47.xls World vegetable oils production, 2000/01-2004/05.* Retrieved March 22, 2012, from USDA Economics, Statistics, and Market Information System: http://usda.mannlib.cornell.edu/MannUsda/viewStaticPage.do?url=http://usda.mannlib.cornell.edu/usda/ers/89002/2006/../2005/index.html, 2005.

[24] United States Department of Agriculture. *Table47.xls World vegetable oils production, 2003/04-2007/08.* Retrieved March 22, 2012, from USDA Economics, Statistics, and Market Information System: http://usda.mannlib.cornell.edu/MannUsda/viewStaticPage.do?url=http://usda.mannlib.cornell.edu/usda/ers/89002/2008/index.html, 2008.

[25] United States Department of Agriculture. *Table47.xls World vegetable oils production, 2007/08-2011/12.* Retrieved March 22, 2012, from USDA Economics, Statistics, and Market Information System: http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1290, 2012.

[26] Ministry of Agriculture Republic Indonesia-Directorate General of Estate. *Area and Production by Category of Producers.* Retrieved August 21, 2011, from Ministry of Agriculture Republic Indonesia-Directorate General of Estate: http://ditjenbun.deptan.go.id/cigraph/index.php/viewstat/komoditiutama/8-Kelapa%20Sawit, 2010.

From both historical trends of GPO demand (figure 1-2) and IPOPA (figure 1-3), the data confirm that a relationship exists between GPO demand and IPOPA, that is, the GPO demand is set to determine the LUC in Indonesia related to palm oil plantation expansion. Furthermore, considering the analysis of the United States Department Agriculture-Foreign Agricultural Service (USDA-FAS, 2010), reliance on the IPO production to meet future GPO demand cannot be avoided. Hence, both GPO demand and IPOPA trends are predicted continue growing for the future. Hence, the key variables that we consider to be important variables that may depict the initial characterization of the problem are the GPO demand and the IPOPA.

1.2 Problem Definition

Sustainability can be seen as a triangle with each of its cornerstones representing economic, environmental and social perspectives. In order to attain the sustainable development, it is needed to give equal attention to those there elements of economy, environment and social. Due to the balance among these three elements is what we call as sustainable development [Sonnemann, et al., 2004][27]. Be consistent with the concept of sustainable development, Indonesia also has their own concept on green economy, which is believed as solution towards the full attainment of sustainable development. The green economy concept of Indonesia is as follows.

It should be conducted in the context of development that is pro-poor, pro-job, pro-growth and pro-environment, it subsequently should be translated into *policy* which aims at resources efficiency, eradicating poverty, creating decent jobs, and ensuring sustainable economic growth [Laksono,2011][28].

With regard to the moratorium policy under REDD-plus cooperation, the policy is expected as one effort to reduce GHG emission from deforestation. On the other hand, there are concerns that the policy will curb Indonesia economic sectors which especially rely on forest conversion and utilization, such as the mining industries, the agricultural industries,the palm oil industry, Timber/logging industry, etc.

1.2.1 Problem Statement

When the green economy concept of Indonesia is limited into pro-economic growth and pro-environmentonly. The moratorium policy seems pro-environment, but not pro-economic growth. Although, the statement is still unclear yet, since the validity period of the policy is

[27] Sonnemann, G., Castells, F., and Schuhmacher, M. *Integrated Life-Cycle And Risk Assessment For Industrial Processes.* Florida, the United States of America: CRC Press LLC, 2004.

[28] Laksono, H.R.A. *Benefits, Opportunities and Challenges of a Green Economy: Indonesia's Perspectives.*Nairobi: United Nations Environment Programme, 2011.

only 2 years, and Indonesia also will get the financial compensation from this REDD-plus cooperation. Hence, it is necessary to have an analysis to clarify the impact of moratorium policy on the economic growth and environmental situation of Indonesia, by focusing on one economic sector which rely on forest conversion and utilization for their business activities.

As had described previously, due to the IPO industry sector was considered as a vital agricultural industry that plays an important role in the economic development of Indonesia. Hence, author chose the IPO industry sector as case study.

The impacts of the policy must to be understood for future critical decisions. The dynamic problems presented previously that cover the economic and environmental perspectives can be modeled by using system dynamics approach.

1.2.2 Research Questions

The research question of this study is whether the moratorium policy in line with the green economy concept of Indonesia that is pro-economic growth and pro-environment?

1.2.3 Key variable

Based on the background and problem articulation, the key variable/concept that author consider to be an important variable that could depict the initial characterization of the problem above is GPO demand and IPOPA.

Global palm oil (GPO) demand: the GPO demand is defined as a variable of the future demand of palm oil which associated with extrapolation of world demographic and economic trends. The GPO demand then will automatically affect the IPO demand, in which the amount of IPO demand can be estimated by the percentage of IPO market share in the GPO market. Hence, the GPO demand eventually will determine the land use change (LUC) in Indonesia through IPO demand that is associated with the palm oil plantation expansion to increase production in order to meet the demand.

Indonesia palm oil plantation area (IPOPA): the IPOPA is defined as a variable of the existing area of palm oil plantation in Indonesia over time for all types of plantation (based on their classification: immature, mature, etc.). Increasing large area of palm oil plantation is determined by the demand of palm oil. Where increasing plantation area leads into two contradictory consequences, those are the environmental damage and economic growth.

1.2.4 Reference Mode and Time Horizon

Reference mode is a set of graphs and other descriptive data that showing the development of the problem over time. Modeler should always refer back to the reference mode throughout the modeling process since it is as an initial target pattern of our model behavior [Sterman, 2000][29]. According to Ford [2010][30], the reference mode will be known from historical data or it will be a relatively simple extension of the historical trend.

As had been stated previously, GPO demand and IPOPA were identified as key variables that could depict the initial characterization of the problem. The historical trends of the GPO demand (figure 1-2) and IPOPA (figure 1-3) since 2000 to 2010 have shown consistent increase exponentially at the similar average rate. Thus, the reference modes of GPO demand and IPOPA for future trend referred to their historical trends (figure 1-2 and 1-3).

The time horizon to observe the problem was set at 10 years that is from 2010 to 2020. Such long time is sufficient time to depict the problem and to see impacts. Since the moratorium policy is only 2 years, very long time horizon is feared will affect to the significance of the results, it then leads to wrong conclusion. On the other hand, Indonesia has own target on the GHG emissions reduction in 2020.

The Reference modes and time horizon for GPO demand and IPOPA were is sketched in figure 1-4. The reference modes for the two variables are same that is an exponential growth. Since it is an expected future trend, thus author didn't put the values on the vertical axis (Y axis).

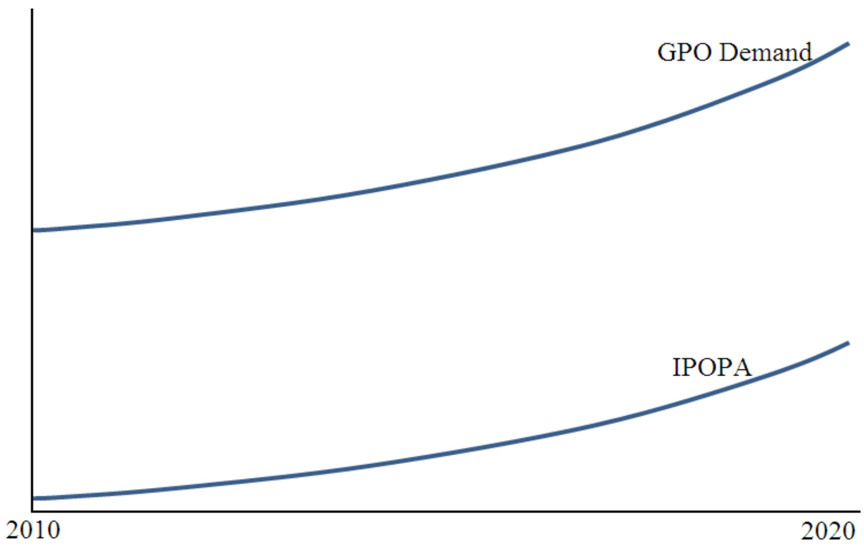


Figure 1-4. Reference mode for GPO demand and IPOPA

[29] Sterman, J. *Business Dynamics: Systems Thinking and Modeling for a Complex World.* Boston: McGraw-Hill Higher Education, 2000.

[30] Ford, A. *Modeling the Environment.* Washington, DC: Island Press, 2010.

1.3 Objective

1.3.1 General Objective

This study was undertaken to develop a system dynamics model, that clarifies the impact of a two-year moratorium policy under REDD-plus cooperation on the environment and the economy of Indonesia using a case study of the palm oil industry sector.

1.3.2 Specific Objectives

The specific aims of this study are,

(a) To develop a formal model by using system dynamics for policy analysis (by simulation) in order to,

   i) explore the moratorium policy associated with supply-demand systems of palm oil

   ii) evaluate the policy by using selected sustainability indicators, to see how the impacts of the policy on GHG emissions reduction and palm oil industry sector in Indonesia.

(b) To provide new insights into and understanding about the implementation of moratorium policy, also to propose policy actions for relevant policy maker and stakeholders.

1.4 Significance of Study

This study was expected to be one example of studies that demonstrate a trade-off between GHG emissions reduction and economic growth in a country who participates in REDD-plus framework for climate protection. Moreover, this study was expected to provide a future reference for students, researchers, policy maker and stakeholders on how to perform the evaluation of the trade-offs in accordance to sustainable development concept which gives an equal attention on all aspects.

1.5 Scope

The main limitation of this study is:

(a) In term of Sustainable development or green economy concept of Indonesia, it was limited into economic and environmental perspectives only.

(b) The focus of supply-demand systems under study lies at the interrelationships among palm oil demand, palm oil plantation area and moratorium policy. Thus the production processes of palm oil are limited in the plantation phase only.

Related to point b, Due to the approach of the REDD-plus to address the GHG emissions is focused on forest conservation programs. Also, there is clear evidence data that most palm oil plantations are located where there was formerly tropical forest and the conversion of tropical forests to palm oil plantations is still continuing [Reijnders and Huijbregts, 2008][31]. Author argued that to limit the production processes of palm oil that is in the plantation phase only is sufficient to gain insight and understanding about the policy intervention.

Furthermore, owing to this study used the methodology of system dynamics to meet the objectives, hence, detail limitations of this study will be described in each step of modeling process which specifically will be described in the Chapter 3 and 4.

1.6 Overview of Methodology

To meet the objectives, this study used a computer simulation modeling of SD to transform the descriptive scenarios of this study into a formal model. The SD is a computer-aided approach to policy analysis and design of dynamic problems which is characterized by interdependence, mutual interaction, information feedback, and circular causality [System Dynamics Society, 2011][32]. We used SD especially for mapping the interrelationships among variables of the scenarios in the stock and flow diagrams including its mathematical model and for conducting experiments (by simulation).

This study followed the methodology of SD which was given especially in Forrester [1961][33], Sterman [2000][34]and Ford [2010][35]. Based on those literatures, the author summarized, then made the methodology for this study. The methodology of this study in a flow chart can be seen in Figure 1-5. The colors of the flow chart (green, orange and purple) indicated the nature of a modeling process, whether it was a qualitative, a quantitave, or a combination between qualitative and quantitative.

The flow chart visually depicts the stages of a modeling proces of this study which divided in seven main stages as follows.

(a) Getting better acquainted with the problem and be specific with the key variables and its concepts that author must consider (problem identification).

(b) Making the scenario based on the description of real system (model conceptualization).

(c) Converting the scenario into SD model (model formulation).

[31]Reijnders, L. and Huijbregts, M.A.J. Palm Oil And The Emission of Carbon-Based Greenhouse Gases. *Journal of Cleaner Production*, Vol.16, pp. 477-482, 2008.

[32] System Dynamics Society.*The Field of System Dynamics*. Retrieved March 16, 2012, from System Dynamics Society: http://www.systemdynamics.org/what_is_system_dynamics.html#overview, 2011.

[33]Forrester, J.W.*Industrial Dynamics.*Massachusetts: The M.I.T. Press, 1961.

[34]Sterman, J.*Business Dynamics: Systems Thinking and Modeling for a Complex World.* Boston: McGraw-Hill Higher Education, 2000.

[35]Ford, A.*Modeling the Environment.* Washington, DC: Island Press, 2010.

(d) Conducting the experiments by the model (model simulation).
(e) Assigning the model with variation of policy designs for improvement (Model development).
(f) Testing the model to build confidence (model validation).
(g) Policy analysis in order to gain new insights into and understanding about the systems being studied (model use for policy analysis).

However, the iterative processes must be applied in each step of the modeling process above. Since the modeling process is iterative processes of trial and error [Ford, 2010][36]. It is not a linier sequence of steps, that is models go through constant iteration, continual questioning, testing, and refinement. Results of any step can yield insights that lead to revisions and redesigns in any earlier step [Sterman, 2000][37].

With regard to the model validation testing, actually, the best way to conduct it is in each step throughout the modeling process. Since the model validation step is too important to be to be left to the end [Ford, 2010][38]. To build confidence for the model of this study, several tests were conducted by following the model validation procedures that has been suggested by Sterman and Ford. The main purpose of model validation was to reveal its errors, flaws and shortcomings. Also, to make sure that the model is reasonable, realistic and robust, then it can be used for policy analysis.

1.7 Structure of Thesis

This thesis was organized in 7 chapters. *Chapter 1* introduces relevant backgrounds to the research. The problem is identified including the key variables and concepts which can depict the initial characterization of the problem. Thereafter, the objectives and scope of study were set. This chapter also introduces the methodology of system dynamics which depicts the modeling process of this study. *Chapter 2* is a literature review that presents briefly about the theories of system dynamics including its application for policy analysis which focus on environmental and energy systems. *Chapter 3* explains about model conceptualization which started by the framework of the study. The important elements of framework was described including major theories and assumption that were used to describe the system being studied. *Chapter 4* summarizes the concepts that had been described in previous chapter. It then describes the transformation process of the concepts into stock and flow diagram of SD including its mathematical model and the data that is inputted into the model. *Chapter 5* describes several model validation procedures that were imposed to the model in order to

[36] Ford, A.*Modeling the Environment.* Washington, DC: Island Press, 2010.

[37]Sterman, J.*Business Dynamics: Systems Thinking and Modeling for a Complex World.* Boston: McGraw-Hill Higher Education, 2000.

[38]Ford, A.*Modeling the Environment.* Washington, DC: Island Press, 2010.

build confidence that the model is useful and it can be used for gain insight into and understanding. *Chapter 6* shows and describes the simulation results of the model for both base run scenario and other alternative scenarios. Lessons learned from the model are discussed based on the simulation result. *Chapter 7* concludes the topic under study especially the main findings.

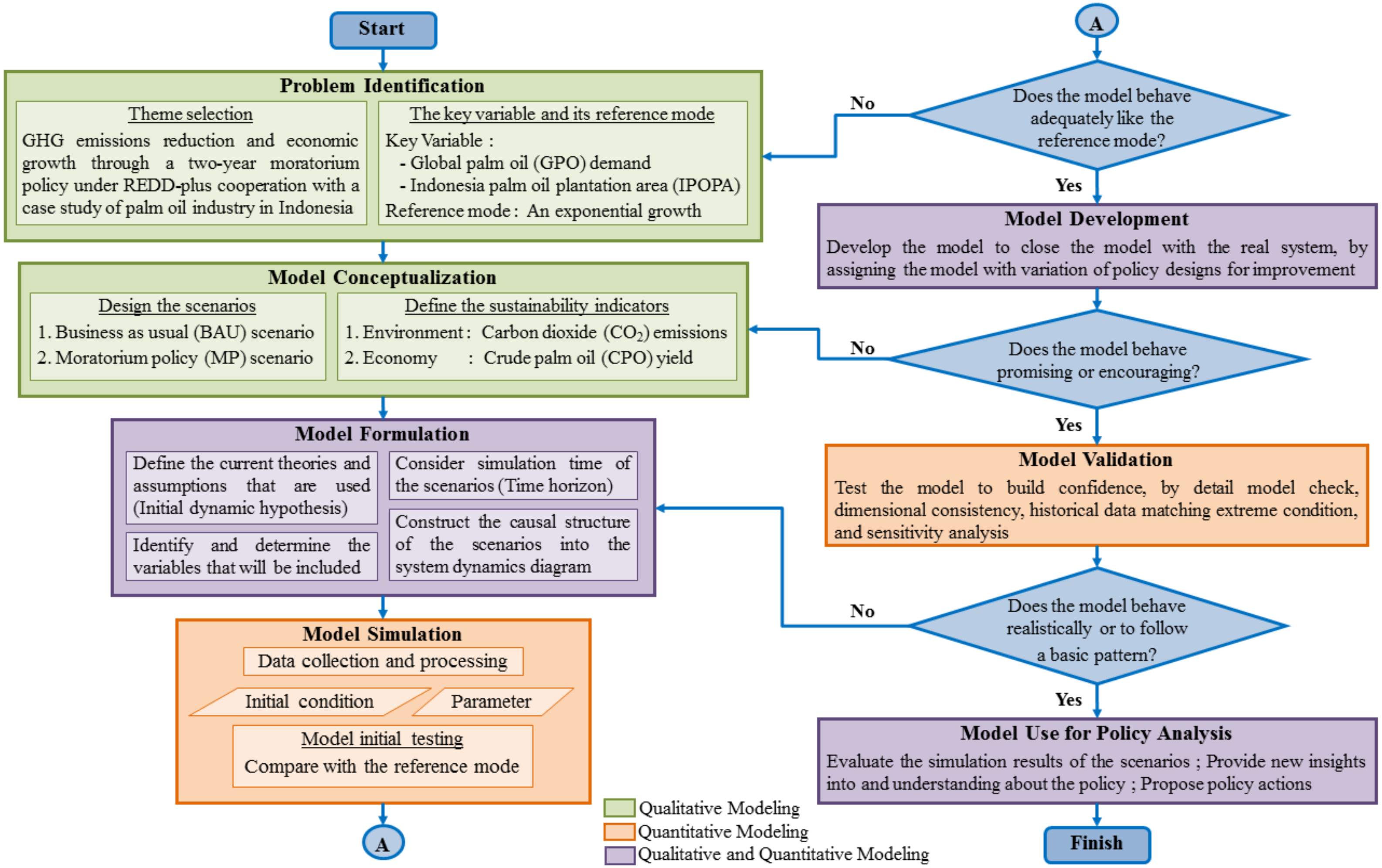


Figure 1-5.Methodology of the study.

CHAPTER II

SYSTEM DYNAMICS APPLICATION FOR POLICY ANALYSIS

2.1 Introduction

System dynamics (SD) has been acknowledged as an effective tool to depict complex and dynamic interactions among different systems. SD has been used for policy analysis and strategic planning in many fields. This chapter aims to introduce the SD approach which related to the important concept of the SD, and its applications for policy analysis. The literatures which presented in this chapter are focused on the application of SD for energy and environmental systems. The literatures were summarized and discussed. Subsequently, several appropriate concepts of the articles were used to be applied for this study.

2.2 Model

A model is a substitute for some real equipment or system, the value of a model arises from its improving the understanding of obscure behavior characteristics more effectively than could be done by observing the real system. Therefore, it can be a basis for experimental investigations at lower cost and in less time than trying changes in the actual system [Forrester, 1961][39]. Also, it is easier to work with a substitute than with the actual system since a model as a representation of some aspects in the real system [Ford, 2010][40]. Models have a long history as tools for helping to observe a phenomenon of the real system, hence the use of computational models is central to the regulatory decision-making process, to do prospective analyses of policies, including for estimating possible future effects on the environment, human health, and the economy [National Research Council, 2010][41].

To capture the key interrelationships in the systems, we should build a mathematical model then conduct experiments with the model. The mathematical model is often divided into two categories [Ford,1999][42],

(a) Static models, it helps us learn about behavior of a system at rest. For instance, in the engineering field, it is used to calculate the forces needed to keep an object at rest. In the economic field, such models are to calculate the price of a product that will motivate

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[39] Forrester, J.W. *Industrial Dynamics.* Massachusetts: The M.I.T. Press, 1961.

[40] Ford, A. *Modeling the Environment.* Washington, DC: Island Press, 2010.

[41] National Research Council. *Models in Environmental Regulatory Decision Making*. Washington, DC: The National Academies Press, 2010.

[42]Ford, A. *Modeling the Environment: An Introduction to System Dynamics Modeling Of Environmental Systems*. Washington, DC: Island Press, 1999.

producers to make exactly what the costumers wish to buy when the forces of supply and demand are in balance (market prices will be held constant over time).

(b) Dynamic models, it helps us think about how a system changes over time. For instance, a dynamic model may explain the physical forces needed to cause a rocket to accelerate or the economic forces needed to cause a nation's economy grow over time. Dynamic models also help us to understand the behavior of systems overtime, for instance, an ecologist might use a dynamic model to explain if the oscillations in predator populations will remain stable over time.

Ruth and Harrington in Suh [2009][43] stated that to examine human-environment interaction from a holistic perspective, it can be manifested in formal systems modeling including dynamic modeling. Boon et al. in Suh [2009][44] emphasized that such systems modeling not only increases the comprehensiveness of environmental analysis; it can also capture some of the interactions among the factors that drive the behavior of the system being studied. The computer simulation models help us to learn something new about the systems they represent, with new insights and better understanding then will come better instincts for managing environmental systems [Ford, 2010][45].

2.3 Brief History of System Dynamics

The SD was created during the mid-1950s by Jay W. Forrester, initially triggered by his involvement with the managers of General Electric to examine the employment instability in the company [Radzicki and Taylor, 1997][46)]. By his hand simulations (manual calculations) on the stock-flow-feedback structure of the General Electric plants which included the existing corporate decision-making structure for hiring and layoffs, he was able to show how the employment instability happens in the company. These hand simulations were the beginning of the field of system dynamics. Forrester published the first book of SD in 1961 with the title of Industrial Dynamics. At the first time of the SD appearance, SD was applied almost exclusively to corporate or managerial problems (the late 1950s to the late 1960s). Thereafter, the SD application continues to expand beyond corporate level, SD nowadays has been used in various fields including in environmental systems.

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[43] Suh, S. *Handbook of Input-Output Economics in Industrial Ecology*. London: Springer Science Business Media, 2009.

[44]Ibid.

[45]Ford, A. *Modeling the Environment.* Washington, DC: Island Press, 2010.

[46] Radzicki, M.J. and Taylor, R.A. *U.S. Department of Energy's Introduction to System Dynamics: A Systems Approach to Understanding Complex Policy Issues.* Retrieved June 12, 2012, from System Dynamics Society: http://www.systemdynamics.org/DL-IntroSysDyn/inside.htm, 1997.

2.4 The Concept of System Dynamics

SD emphasizes on system analysis in a holistic manner that viewing and considering something as parts of an overall system, rather than as separate parts. The system is a set of interacting or interdependent components forming an integrated whole, where its interactions or interdependence among the components is a feedback process. The fact is the most complex behaviors of systems usually arise from the feedbacks among the components of the system, not from the complexity of the components themselves [Sterman, 2000][47)]. Hence, the complex behaviors of systems are strongly determined by its feedback structure that depicts the interactions or interdependence among the components inside the system. Thus, SD approach is used to see the feedbacks that work in any systems. Some definitions of SD are quoted below to explain further information on the concept of SD:

- A powerful methodology and computer simulation modeling technique for framing, understanding, and discussing complex issues and problems [Radzicki and Taylor, 1997][48)].
- A method to enhance learning in complex systems [Sterman, 2000][49].
- A methodology for studying and managing complex systems that change over time [Ford, 2010][50].
- A computer-aided approach to policy analysis and design of dynamic problems which is characterized by interdependence, mutual interaction, information feedback, and circular causality [System Dynamics Society, 2011][51].

Thus, the concern of SD is to study the dynamics behavior of systems that are complex, nonlinear and change over time by using a computer model. For investigating, SD tries to translate the description of the real system into a formal model (SD model) by level and flow diagrams for the interrelationships among the variables including its mathematical equations. The SD diagrams including its description are presented in Table 1. As known, a model can be a basis for experimental investigations that are easier, lower in cost and lesser in time than trying changes in the actual system.

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[47] Sterman, J. *Business Dynamics: Systems Thinking and Modeling for a Complex World.* Boston: McGraw-Hill Higher Education, 2000.

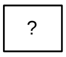
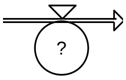
[48] Radzicki, M.J. and Taylor, R.A. (1997). *U.S. Department of Energy's Introduction to System Dynamics: A Systems Approach to Understanding Complex Policy Issues.* Retrieved June 12, 2012, from System Dynamics Society: http://www.systemdynamics.org/DL-IntroSysDyn/inside.htm, 1997.

[49] Sterman, J. *Business Dynamics: Systems Thinking and Modeling for a Complex World.* Boston: McGraw-Hill Higher Education, 2000.

[50] Ford, A. *Modeling the Environment.* Washington, DC: Island Press, 2010.

[51] System Dynamics Society. *The Field of System Dynamics*. Retrieved March 16, 2012, from System Dynamics Society: http://www.systemdynamics.org/what_is_system_dynamics.html#overview, 2011.

Table 2-1.Diagrams of system dynamics model.

Name and Symbols	Description
 Stock	A variable that represents the accumulation of changes in the system due to connected flows
 Flow	A variable that represents the rate of change in the level variable by adding (inflow) or subtracting the values (outflow)
 Auxiliary	A variable that contains calculations which associated with other variables
 Constant	A variable that contains constant/fixed value that used for miscellaneous calculations on other variables
 Information Linl	A connector that represents the relationship among variables within the system/model
 Cloud	A variable that represents the resource that will be used (a source) or have been used (a sink), It also represents the boundary of the system/model

2.5 System Dynamics Application for Policy Analysis

2.5.1 System Dynamics Action in Energy System

The energy model used at the United States (US) Department of Energy was created by Roger Naill in 1972, he made his model based on the life cycle theory of oil and gas discovery and production of M. King Hubbert (the petroleum geologist) [Radzicki and Taylor, 1997][52]. He then expanded the boundary of his model, namely the COAL1, COAL2 and FOSSIL1 models that included all major US energy sources (energy supply), as well as U.S energy consumption (energy demand). The scope of Roger Naill's models was a national level and designed to simulate policies that would aid the U.S to reduce its dependence on foreign oil (import) [Ford A., 1997][53].

However, Sterman [1983][54] argued that the energy models had been made previously were failure to incorporate the feedbacks or interactions between the energy and the macro-economy. The models only demonstrated how to satisfy the projected demand and to reduce

[52] Radzicki, M.J. and Taylor, R.A. *U.S. Department of Energy's Introduction to System Dynamics: A Systems Approach to Understanding Complex Policy Issues.* Retrieved June 12, 2012, from System Dynamics Society: http://www.systemdynamics.org/DL-IntroSysDyn/inside.htm, 1997.

[53]Ford, A. System Dynamics And The Electric Power Industry. *System Dynamics Review* , Vol.13, pp.57–85, 1997.

[54] Sterman, J. Economic Vulnerability And The Energy Transition. *Energy System and Policy*, Vol.7, pp.259-301, 1983.

the oil import. Sterman called his model as the second generation of the energy model that deals with the interactions between the energy and the macro-economy. In his paper, he proposed framework for energy policy analysis that integrates the dynamic effects of energy depletion and raises energy costs on economic growth, inflation, interest rate, and the standard of living. The model was used to analyze the macroeconomic effects of the energy transition and the effects of government subsidies for energy technologies.

The article of the energy system that got the 1996 Jay Wright Forrester Award is 'System Dynamics and the Electric Power Industry'[Ford, 1997][55]. The article contributed to a useful change for understanding the electric power industry system and reflections about the important and unique features of the system dynamics approach. On the issue about the electric power industry system, the author's model demonstrated the “death spiral” theory in the industry system. It is mainly the interrelationship among the need for capacity expansion to serve the growing demand, the industry who faces the financial challenge for the expansion, the regulators who normally allow the industry generate the allowed revenues and the consumers’ reaction to the electric rates/price. Concern to the important and unique features of the system dynamics approach, the author’s model believes that the SD approach has allowed the SD practitioners to make a useful and unique contribution to their field as long as they are able to see the feedbacks that work in the system being studied.

Recently, many studies in the energy sector have used SD to analyze the renewable energy policies associated with the potential reductions of Carbon emissions as studied by Trappey et al.[2012][56]. They proposed the formal methodology of cost-benefit analysis by SD approach to evaluate the feasibility of renewable energy policies by considering qualitative and quantitative factors for an administrative region. They used Penghu Island (Taiwan) as the case study to verify the proposed methodology. They analyzed the costs and related effects of the policy scenarios and evaluated the time varying impacts of the proposed solar energy strategies. There were four different policy scenarios that discussed in this article: (1) business as usual (without the renewable energy policy); (2) promoting wind power policies; (3) promoting solar application policies; (4) promoting long-term solar application policies. This article was intended to determine which renewable energy policies those were suitable for Penghu Island to achieve a stable Carbon emissions balance.

[55] Ford, A. System Dynamics and the Electric Power Industry. *System Dynamics Review*, Vol.13, pp.57–85, 1997.

[56]Trappey, A.J.C., Trappey, C.V., Lina, G.Y.P. and Yu-Sheng Chang, Y. The Analysis of Renewable Energy Policies for the Taiwan Penghu Island Administrative Region. *Renewable and Sustainable Energy Reviews*, Vol.16, pp.958– 965, 2012.

2.5.2 System Dynamics Action in Environmental System

The SD approach has been used widely in the environmental field. One of the books which is specially dedicated for the application of SD to the field is 'Modeling the Environment'. The book provides studies of modeling practice for the environmental policy analysis, such as the development of a policy model for understanding and managing the water flows in the Mono Basin of northern California, the growth and collapse of the deer herd on the Kaibab Plateau in northern Arizona, the long-term effects of the flow of DDT pesticides through the soil, air, and ocean and into the bodies of fish, etc [Cavana, 2003][57]. The Mono Basin is an important source of water supply for Los Angeles, but the lake gradually returns to unhealthy condition, then the California Water Resources Control Board ruled that the Los Angeles use of Mono Basin waters was restricted [Ford, 1999][58]. Hart in Ford [1999][59] said that the battle over the Mono Basin was one of longest and most fiercely contested conservation battles in U.S history. Ford [1999][60)] developed SD model of Mono Basin to project the future size of the lake by given different assumptions and to conduct experiments with different policies on the amount water exported to Los Angeles.

Sufian and Bala [2007][61] used SD to develop a model of urban solid waste management (UWSM) for Dhaka city, Bangladesh. The model divided into two sub-models that connected with each other, those were waste generation and waste management. The waste generation model consists of population, solid waste generation, electricity generation, public concern, composite index and stock levels of cleared, uncleared, treated, untreated, recyclable and non-recyclable wastes. The waste management model consists of waste collection, economics of waste collection and waste treatment issues. The descriptive scenario of this study included the electricity generation plant fueled by urban solid waste and scientific disposal facilities, although, in fact, the Dhaka city has no such facilities. The model was a theoretical framework for predicting solid waste generation and electrical energy recovery from the solid waste, for examining urban solid waste generation and its existing management system, for assessing potential electrical energy generation to meet the electrical energy consumption in the city, and also for assessing different policy options for the UWSM.

[57]Cavana, R. Modeling the Environment: An Introduction to System Dynamics Models of Environmental Systems. *System Dynamics Review (Book Review)*, Vol.19, pp.171-173, 2003.

[58] Ford, A. Water Flows in the Mono Basin. In A. Ford, *Modeling the Environment: An Introduction to System Dynamics Models of Environmental Systems* (pp. 33-50). Washington: Island Press, 1999.

[59] Ibid.

[60] Ibid.

[61] Sufian, M.A. and Bala, B.K. Modeling of Urban Solid Waste Management System: The Case of Dhaka City. *Waste Management*, Vol.27, pp.858–868, 2007.

Sandker, et al., 2007[62] used SD approach to simulate landscape dynamics in order to understand the trade-offs between conservation and development in case study of Malinau district, Kalimantan island of Indonesia. Malinau district which over 95% of its area still covered with forest declared as one of three conservation districts in Indonesia, but at the same time, the district has also welcomed to palm oil investments. Sandker, et al. explored and examined the scenario of potential conversion of 500000 ha of the forest into palm oil plantations and its impacts on land use change, potential migration as the result of employment created by such development and local economy (local livelihood income and district revenue). They emphasized their model was not a predictive model, but a scoping model (an exploratory model) which the primary use of the model was to stimulate discussion and promote dialog among different stakeholders (conservationists, development actors, and district authorities) who have different perspectives on the trade-off. This study was participatory modeling conducted from the initial stage of the modeling process through a discussion with researchers and staff of the district including the district head and a workshop that was attended by 12 representatives from the district agencies.

Han, J. and Hayashi, Y., [2008][63] developed a SD model for policy assessment and CO_2 mitigation potential analysis with a case study of the inter-city passenger transport in China. SD was used to look at the distribution of the expected growth under three policy scenarios and the external impacts of transport development on nonrenewable energy use and CO_2 emissions. For the model formulation, this study also used stepwise regression estimation to assess the role of possible determinants of modal share in inter-city passenger transport. The focus of this study was to determine which policy that is the most effective to reduce fuel consumption and to mitigate CO_2 emissions in inter-city passenger transport.

2.6 Conclusion

Literature studies showed that SD approach is an appropriate methodology for policy analysis and strategic planning for local, national, and international governmental levels. Also, SD could be used for various fields, since SD deals with,

- combination ideas from different fields (interdisciplinary),
- structural interconnectivity between variables from various systems including its internal feedback and time delays,
- system interactions that change over time and nonlinear.

[62] Sandker, M., Suwarno, A. and Campbell, B.M. Will Forests Remain in the Face of Oil Palm Expansion? Simulating Change in Malinau, Indonesia. *Ecology and Society*, Vol.12, Art.37, 2007.

[63] Han, J. and Hayashi, Y. A System Dynamics Model of CO_2 Mitigation in China's Inter-city Passenger Transport. *Transportation Research Part D*, Vol.13, pp.298‐305, 2008.

Moreover, the important and unique of the SD approach is the feedbacks feature. It enables us to make a useful and unique contribution to our field as long as we are able to see the feedbacks that work in the system being studied [Ford, 1997][64].

In this present study, the author tried to develop a model that represented the conceptualization of relationships among systems from different fields, for instance,

- ✓ economy (forecasting demand of global palm oil),
- ✓ environment (land use change related to the establishment of new palm oil plantations as response to meet the demand),
- ✓ policy applications (the implementation of a two-year moratorium on new forest and peatland concession),
- ✓ and quantitative impact study (their impacton the economic growth and environmental conditions in Indonesia).

Thus, to integrate the systems under study, to build a mathematical model from their interrelationships, and to conduct experiments (by simulation) for getting new insights and improving the understanding, the author needs to choose an appropriate method that was be able to facilitate it. The literatures have strengthened author's belief that the methodology of SD is an appropriate method to be employed in this study. Also, the study developed the model by adapting the concepts or stories including the variables that referred to the literatures. For example considering the socio-economic factors for the endogenous or exogenous variables, employing the SD management flight simulators for policy experimentation, and so forth.

[64] Ford, A. System Dynamics and the Electric Power Industry. *System Dynamics Review*, Vol.13, pp.57–85, 1997.

CHAPTER III
MODEL CONCEPTUALIZATION

3.1 Introduction

The scenarios are images of the future or alternatives of the future. It is based on set of assumptions or theories which are derived from understanding of both history and the current situation, they are neither predictions nor forecasts. However, the scenarios help us to improve the understanding of what the possible future developments of complex systems [IPPC, 2000][65].

This study was a scenario-based approach or a what-if approach, what might happen if certain conditions occur which was based on predefined conditions of the future image. This chapter aims to describe and construct conceptual foundation for the model of this study, before it is transformed into quantitative formal model of SD. The interrelationships between each element of concepts was mapped as conceptual framework of this study.

3.2 Framework

In order to analyze the impact of the moratorium policy, this study first determined the endpoint sustainability indicators for this study which based on both the REDD-plus and Indonesia own national concepts. This study then designed two different scenarios: (1) one scenario was describing the situation in the absence of the policy (business as usual scenario); (2) second scenario was describing the situation which implements the policy (moratorium policy scenario). Subsequently, the scenarios were transformed into formal model by using the SD computer modeling. After the model is developed and it has successfully passed the model validation procedures, the model was used for policy experimentation (i.e., simulation).

The business as usual (BAU) model was divided into 3 sub-model, those are palm oil demand sub-model, palm oil plantation sub-model, and impact sub-model. Impact sub-model divided into palm oil production model and carbon balance model. Each sub-model has main outputs that connect the relationship between sub-models. When the BAU model is imposed by MP sub-model, it becomes MP model.

To analyze the moratorium policy, the two scenarios were evaluated by comparing their simulation results. The selected sustainability indicators were used to measure the impacts of the moratorium policy. Finally, we describe insights and understanding about the policy

[65]IPPC-Nakicenovic, N. and Swart, R. (Eds.). *Emissions Scenarios.* Cambridge: Cambridge University Press, UK, 2000.

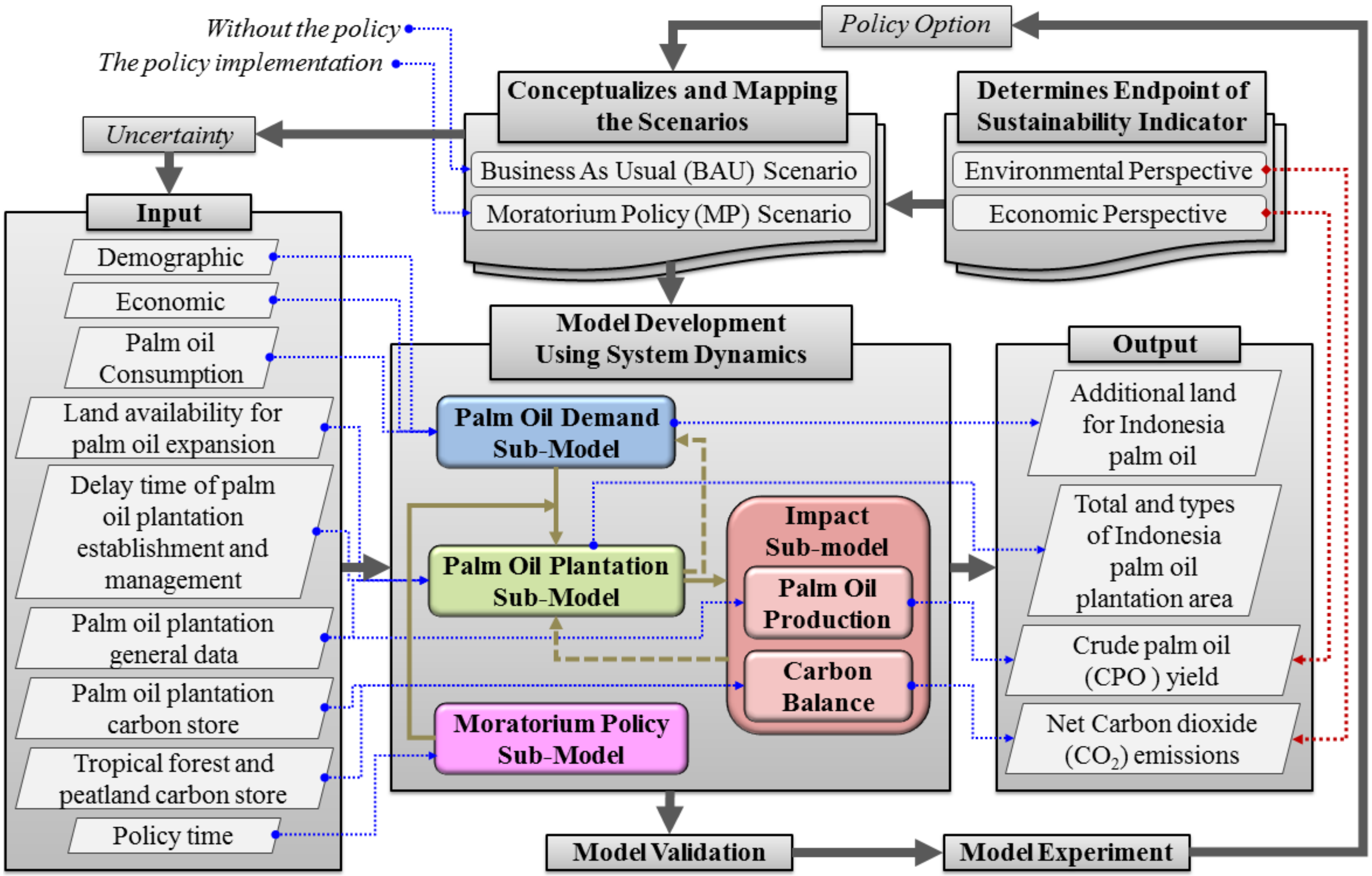


Figure 3-1. Framework of the study.

and proposed the policy actions for long and short term based on model experimentation. Figure 3-1 depicts the framework of this study that consists of the input, process, output, and feedback diagrams of the modeling process, including the model structure.

3.3 Sustainability Indicator

Determining the appropriate sustainability indicators for this study was based on both the REDD-plus concept and Indonesia own national concepts. Certainly, the Indonesia national concepts for environment in line with the global concept. Moreover, in this case, Indonesia has bound by the bilateral agreement with Norway on the REDD-plus cooperation. Owing to the REDD-plus framework is mitigation efforts to reduce GHG emissions from deforestation and forest degradation. Hence, GHG emissions is an important indicator to measure the effectiveness of the implementation of the moratorium policy as part of the bilateral agreement. According to UNFCCC [2012][66] there are six types of GHG as reduction target of Kyoto Protocol, namely: Carbon dioxide (CO_2), Methane (CH_4), Nitrous oxide (N_2O), Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs) and Sulphur hexafluoride (SF_6), however, the amount of emissions is measured in the equivalent of Carbon dioxide (CO_2e). Thus, this study only chose CO_2 emissions as environmental indicator which represents an environmental perspective of sustainable development for this study.

Also owing to the REDD-plus framework lingking the GHG emissions reduction with financial incentives to the countries that are willing and able to protect and conserve their forest. In this case, based on the bilateral agreement, Norway has an intention to provide funds of 1 billion USD to Indonesia for a significant achievement in emissions reduction from the deforestation. Hence, in line with the green economy concept of Indonesia (Chapter I, Laksono,2011[67]), it need to take into account the advantage of forest protection through the moratorium policy as part of the bilateral agreement compares to forest utilization and conversion for economic purposes. From economic sectors of Indonesia with rely on forest utilization and conversion, the author took up the palm oil industry as a case study, since the industry is a vital industry that plays an important role for economic development of Indonesia that described in Chapter I. Hence, this study selected the crude palm oil (CPO) yield that is produced by the IPO industry through their palm oil plantations as the economic indicator. Thus, the CPO yield was as indicator which represents an economic perspective of sustainable development for this study.

[66] UNFCCC. *Kyoto Protocol*. Retrieved April19, 2012, from United Nations Framework Convention on Climate Change: http://unfccc.int/kyoto_protocol/items/3145.php, 2012.

[67] Laksono, H.R.A. *Benefits, Opportunities and Challenges of a Green Economy: Indonesia's Perspectives.* Nairobi: United Nations Environment Programme, 2011.

3.4 Scenario

This study designed two scenarios of business as usual (BAU) and moratorium policy (MP). The MP scenario could be called as baseline scenario due to the government of Indonesia has already imposed a two-year moratorium policy since May 10, 2011. The MP scenario was our assumptions concerning the future continuation image of current policy intervention that was a two-year suspension on the new permits for use of primary natural forest and peatland (i.e. moratorium policy). Whereas the BAU scenario was our assumptions concerning the future image without the moratorium policy (in the absence of moratorium policy). Briefly,

- the BAU scenario is exploratory or descriptive scenario in the absence of the moratorium policy
- the MP scenario is exploratory or descriptive scenario of the implementation of the moratorium policy.

Thus, the difference between the two scenarios is only on the implementation of a two-years moratorium policy. The main assumption for the BAU and MP scenarios is as follows:

(a) The assumption for MP scenario was made in ideal situation, even lead to extreme situations for the model base run. That is, it was assumed that during the implementation of the policy there will be no expansion of the palm oil plantation area in Indonesia, and it will return tonormal conditions (permission for expansion is allowed) after the moratorium policy expires in 2013.

(b) The law of supply and demand is naturally applied in the business world. Thus, it was assumed that the IPO industry sector will always try to fulfill the future demand of palm oil. In order to fulfill the demand they will expand their plantations, the establisment of new plantations is on the forest and peatland areas.

The detail of theories and assumptions that were used for the scenarios will be described later in section 3.5.

We formalized the scenarios by using a computer simulation modeling of SD. We believed that the methodology of SD is an appropriate methodology to be employed in this study like we have described in chapter 2. Hence, the transformation process of the scenarios into a formal model and vice versa (for model experimentation) is to follow the methodology of system dynamics which had described in chapter I.

3.5 Major Theory and Assumption (Dynamic Hypothesis)

A dynamic hypothesis is a working theory of how the problem arose which guides us to focus on certain structures in the modeling efforts [Sterman, 2000][68]. Consciously or not, the mental

[68] Sterman, J. *Business Dynamics: Systems Thinking and Modeling for a Complex World.* Boston: McGraw-Hill Higher Education, 2000.

model always be used constantly to interpret the working theory of the problem arose around the people, a mental model is the images that can be carried in minds about deeply ingrained assumptions and generalizations that influence people to understand the real world and make decisions based on the understanding [Ford, 2010][69].

Considering all models are always wrong because it is simplified representations of the real world [Sterman, 2000], it is constrained by:

- computational systems of the model itself [National Research Council, 2007][70]
- and the mental model of the user in interpreting the working theory of the real world [Ford, 2010][71].

Thus, the model of real system can be a valid model if it is under certain assumptions [Longbin, 2007][72]. Hence, to develop a model of a real system, theories including assumptions to explain the real system that being studied, were needed to be formed.

The major theories and assumptions that were used for the model of this study are as follows.

(a) According to McCarthy et al. [2001][73], exploratory or descriptive scenario is describing how the future might unfold which according to known processes of change or extrapolations of past trends.

   ✓ The scenario of this study was exploratory or descriptive scenario, thus the approach for constructing the model was based on the extrapolation of current reference trend (historical data), to see how it might in the future if the trend continues to operate. Hence, it was assumed that those trends will not change over time.

(b) Corley [2009][74] argued that the future GPO demand will increase due to growing world population and their consumption. It then consequently requires the additional area of palm oil plantations to meet the future demand. Same opinion also came from Tan et al. [2009][75], because palm oil could potentially be the source of a versatile vegetable oil ranging from edible and non edible products to biofuel, have made it the most sought after vegetable oil in the world. In consequence, the expansion of palm oil plantation is

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[69] Ford, A. *Modeling the Environment.* Washington, DC: Island Press, 2010.

[70] National Research Council. *Models in Environmental Regulatory Decision Making.* Washington, DC: The National Academies Press, 2010.

[71] Ford, A. *Modeling the Environment.* Washington, DC: Island Press, 2010.

[72] Longbin, Z. *A System Dynamics Based Study of Policies on Reducing Energy Use and Energy Expense for Chinese Steel Industry.* Retrieved March 15, 2012, from Bergen Open Research Archive: https://bora.uib.no/bitstream/1956/2363/1/Masterthesis_Longbin.pdf, 2007.

[73] McCarthy, J.J., Canziani, O.F., Leary, N.A., Dokken, D.J. and White, K.S. *Climate Change 2001: Impacts, Adaptation, and Vulnerability.* Cambridge: The Press Syndicate of The University of Cambridge, 2001.

[74]Corley, R. How much palm oil do we need?.*Environmental Science and Policy*, Vol.12, pp.134-139, 2009.

[75]Tan, K.T, Lee, K.T., A.R Mohamed, and Bhatia, S. (2009). Palm oil: Addressing issues and towards sustainable development. *Renewable and Sustainable Energy Reviews*, Vol.13, pp.420–427.

inevitable in order to meet the high demand of palm oil in the future in line with world population growing.

As known, continued population growth is commonly used as the main factor that causes a change in every sector of human life. While the GDP is as the main tool for measuring the world economy. Author assumed that the world demographic and economic situations which are represented by world population and GDP will create the global demand in all sectores (food, fuel, etc) including palm oil. Thus, the growing of world population and GDP will increase future GPO demand which eventually will determine LUC on the other side of the world especially on the countries who are as producer of palm oil.

- ✓ The world population and GDP were chose as the main driver or the main exogenous variable that cause the GPO demand then will automatically affect the IPO demand and eventually will determine the LUC in Indonesia with regard to the expansion of the Palm Oil Plantations to meet the demand.

(c) By the variables of world population and GDP, the author could get the GDP per capita that was assumed as the variable to measure people income. People income will influence their consumption on palm oil product which was an increasing GPD per capita will increase the palm oil consumption (POC) per capita and conversely.

- ✓ Thus, it was assumed that the GDP per capita has an effecton the CPO per capita. A statistical technique of regression analysis was used for estimating the effect based on their historical data.

(d) With regard to the moratorium policy, the model base run for MP scenario was set as described previously, that is:

’*the moratorium policy will suspend the palm oil expansion for 2 years, during period 2011 to 2012, and the expansion will continue in 2013 after the moratorium policy is expired*’

- ✓ The assumtion above is as model base run for the MP scenario. Several assumptions related to the moratorium policy will be made for policy analysis.

(e) The law of supply and demand is naturally applied in the business world. Where increasing demand of palm oil will trigger investment in palm oil industry sector through establishing new palm oil plantations to increase production for fulfilling the demand.

- ✓ Thus, it was assumed that the IPO industry sector will always try to fulfill the future demand of palm oil.

(f) Most palm oil plantations are located where there was formerly tropical forest and the conversion of tropical forests to palm oil plantations is still continuing [Reijnders and

Huijbregts, 2008][76]. While, the deforestation on Peatland in Indonesia over reference year 1985 to 2005 was almost double than on non-Peatland area with the ratio of 1.3% per year : 0.7% per year, where the concessions for palm oil and timber plantations in Indonesia is greater planned on Peatland than on non-Peatland [Hooijer et al, 2006][77]. Each year, around 100.000 Hectares of peatland are drained and cleared for oil palm and timber plantations in Indonesia, from the data in 2008, Indonesia was the largest emitter of GHG from peatland that is around 500 million tons CO_2 [Butler , 2010][78]

- ✓ The author assumed that in order to fulfill the demand,the IPO industry will expand their plantations and the establisment of new plantations is on the tropical forest and peatland areas with the ratio of 14% : 86% (described in section 3.4.10).

(g) Increasing energy use from fossil fuels which is associated with climate change make switching to Biofuels are becoming a high priority, however converting native habitats to cropland to produce Biofuels releases Carbon to atmosphere (Carbon debt of land conversion), on the other hand the biofuels from the converted land will repay the Carbon debt if their production and combustion have net GHG emissions that are less than the life-cycle emissions of the fossil fuels that they displace [Fargione et al., 2008][79].

- ✓ The concept about "Carbon debt and repayment" is adopted and adapted for this study model. Thus, the assumption for the model is modified as follows.

  '*forest conversion to palm oil plantation releases Carbon to atmosphere, on the other hand, the growth of palm oil corps in the plantations or the process of new plantations become mature/established plantations will also absorp Carbon from atmosphere*'

- ✓ In this study, the amount of carbon emissions that is released as a result of the forest conversion is assumed to be equal to the amount of CO_2 emissions.

The dynamic hyphotesis above is the major theories and assumptions that is used to build the model, but for detail will be in every step of the modeling process.

3.6 Conclusion

This chapter described and depicted the framework of this study (figure 3-1) which is expected to provide a technical overview on how the study is conducted. Owing to the

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[76] Reijnders, L. and Huijbregts, M.A.J. Palm Oil And The Emission of Carbon-Based Greenhouse Gases. *Journal of Cleaner Production*, Vol.16, pp. 477-482, 2008.

[77] Hooijer, A., Silvius, M., Wösten, H. and Page, S. PEAT-CO2, Assessment of CO_2 emissions from drained Peatland in SE Asia. Netherlands: Delft Hydraulics, 2006.

[78] Butler, R.A. *Peatland Restoration Wins Support In Effort To Reduce Carbon Emissions*. Retrieved December 12, 2012, from mongabay.com: http://news.mongabay.com/2010/0610-Peatland.html, 2010.

[79] Fargione, F., Hill, J., Tilman, D., Polasky, S. and Hawthorne, P. *Land Clearing And The Biofuel Carbon Debt.* New York: The American Association for the Advancement of Science, 2008.

bilateral agreement linking the GHG emissions reduction with financial incentives, we determine the sustainability indicators from environmental and economic perspectives that are relevant to the theme of study. To evaluate the MP, CO_2 emissions was selected as an environmental indicator that measures the effectiveness of MP implementation. The CPO yield that is produced by the IPOPA was selected as the economic indicator for obtaining an overview of the advantage of forest protection with the MP compared to forest conversion and use for economic purposes. Understanding the impacts of the MP on the economy and environment of Indonesia lies in the relationship between the supply–-demand system of palm oil. The demand side covers palm oil demand on the international level (GPO demand), national level (IPO demand), and the total land required for it. The supply side covers the fulfillment of required land for the IPO industry sector in order to meet the IPO demand. The difference of predefined conditions between BAU and MP scenarios is only on the implementation of the moratorium policy. Theories and assumptions were formed as the conceptual foundation of the model for the next step of the modeling process.

CHAPTER IV
MODEL FORMULATION AND CONSTRUCTION

4.1 Introduction

Model formulation and construction is the process to translate the concepts which had been formed before into the stock and rate equations of a SD model. According to Forrester [1961][80], the proper formulation of a system dynamics model is the variables of the model should correspond to those in the real system being studied. The variables in the real system that will be included to the model can be identified and determined based on the key variable/concept (chapter 1) and dynamic hypothesis that were used to describe the system being studied (chapter 3).

Futhermore, due to the model is constructed based on descriptive scenario, that is based on the extrapolation of past trends. We should look back at the historical data of each variable to determine the numerical data that will be inputted into the model. Since SD is a mathematical model therefore the data for the model should be based on the best information that is readily available, but the modeling process should not be postponed until all pertinent parameter have been accurately measured, the value should be estimated when it necessary (Forrester, 1961)[81]. Thus, if there is data which was difficult to get, author used own assumption. The historical data of corresponding variables that will be included into the model are presented and described in appendix.

This chapter will describe the transformation process of the scenarios into formal model of SD in detail. The transformation process was including connecting interrelationships among variables within and between the system into SD diagram, mathematical equation of the interrelationships, and estimation data that is inputted into the model. Beforehand, author summarized the concepts which had been developed in previous chapter to make clear the model conceptualization of this study.

4.2 Scenario Formalization

4.2.1 Summary of Base Scenario

As described previously, this study compared two scenarios of the BAU scenario and the MP scenario which focus on CO_2 emission and CPO yield as endpoint indicators for comparison in order to analyze the moratorium policy. Furthermore, the difference between the two

[80] Forrester, J.W. *Industrial Dynamics.* Massachusetts: The M.I.T. Press, 1961.

[81] Ibid.

Table 4-1. A summary of scenario.

Model Component	Scenario	
	Business As Usual (BAU) Scenario	Moratorium Policy (MP) Scenario
Definition	Descriptive scenario in the absence of the moratorium policy	Descriptive scenario of the implementation of a two-year moratorium policy on new forest and peatland concessions
Driving Force		
Economic and demographic drivers	World population ; World GDP ; Palm oil consumption	
Policy driver	The continuation of current trend (without moratorium policy)	Will suspend the palm oil expansion for 2 years (during the period of the policy), the expansion will continue in after the moratorium policy expires
Palm oil industry driver	Always try to fulfill the palm oil demand	
Evaluation Indicator		
Environmental perspective	Carbon dioxide (CO_2) emissions	
Economic perspective	Crude Palm Oil (CPO)Yield	
Time		
Horizon time	2010-2010 (10 years)	
Base time	2010	
Policy time	-	2011-2013
Input Value for model base run		
Initial condition		
Parameter	As listed in table 4-4, 4-5, 4-6 and 4-7	

scenarios was only on the implementation of a two-years moratorium policy on new forest and peatland concessions. From the whole explanation that has been given previously, author summarized the two scenarios which is described in table 4-1.

4.2.2 Model Concept and Structure

Based on key variables, major theory and assumption that is used (dynamic hypothesis), and the selected variables of real system, author formulated the model concept (figure 4-1), with the description is as follows.

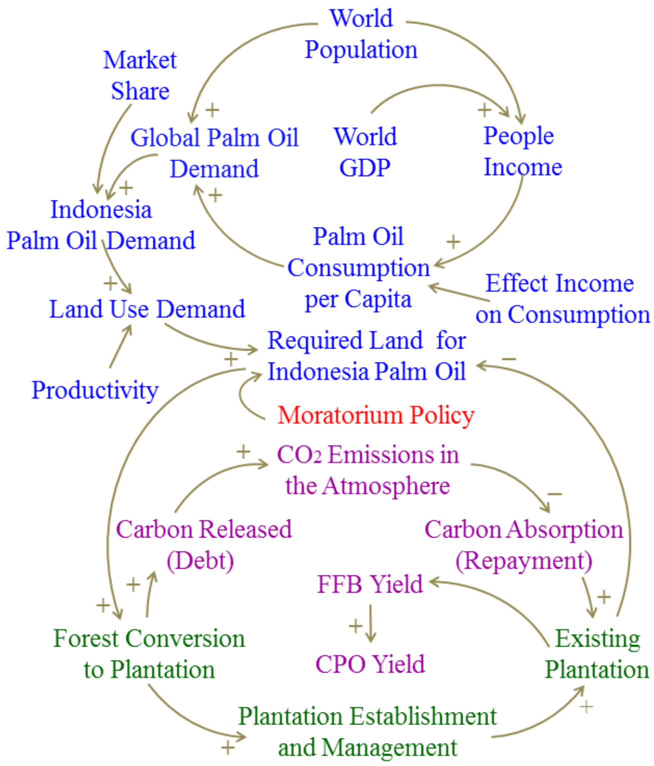

Figure 4-1. Structural relationships among system variables being studied.

(a) The world demographic and economic situations which are represented by growing population and GDP, respectively, create the GPO demand. The GPO demand is determined using global population and their consumption.

(b) The palm oil consumption (POC) per capita is influenced by personal income, which is measured using GDP per capita. Personal income is assumed to affect POC per capita, where an increasing GPD per capita will increase the POC per capita and conversely.

(c) Considering the analysis of the USDA that had been described in appendix section A.5 that is reliance on the IPO production to meet the future global demand of palm oil is something that cannot be avoided. Hence, the GPO demand automatically affects the IPO demand that is estimated using the IPO's market share in the palm oil global market.

(d) Owing to the law of supply and demand that is naturally applied in the business world. The IPO industry is assumed to always try to meet the IPO demand by expanding their plantation area to increase production. Thus, the IPO industry sector to meet the demand is focused on the fulfillment of required land that is required for the plantation area, or land use demand in order to meet the IPO demand that determines the LUC in Indonesia.

(e) The expansion of the plantation area is eventually added to the total of IPOPA. Thus, total IPOPA is supply-side or is a variable that balances the land use demand. By contrast increasing IPOPA also increases the aggregate yield of CPO that is by multiplying the mature plantation areas with the general data of palm oil plantation (section 3.4.9).

(f) Most palm oil plantations in Indonesia are located in former tropical forest, and the conversion of tropical forests to palm oil plantations continues to occur (Reijnders and Huijbregts, 2008). Thus, the establishment of new plantation areas is assumed to be in tropical forests and peatland areas. The new plantation establishment (forest conversion to palm oil plantation) releases carbon to the atmosphere (carbon debt). In contrast, the growth of palm oil crops in the plantation (new plantation area to established/mature plantation area) also absorbs carbon from the atmosphere (carbon repayment).

(g) With regard to MP, we assumed ideally to be extreme circumstance (e.g., no palm oil plantation expansion occurs during the MP implementation) for the implication of the policy implementation, that is the policy suspends the palm oil expansion for 2 year (from 2011 to 2012), and the expansion continues after the policy expires in 2013.

Where for the structure of the model is as shown in the framework of this study (figure 3-1) which divided into 4 sub-models in total: palm oil demand sub-models, palm oil plantation sub-model, impact sub-model (palm oil production model and carbon balance model) and moratorium policy sub-model. The interrelationships among the 4 sub-models including their main output are as shown in figure 4-1. Subsequently, the interrelationships among variables based on the model concept were transformed into stock and flow diagrams of SD.

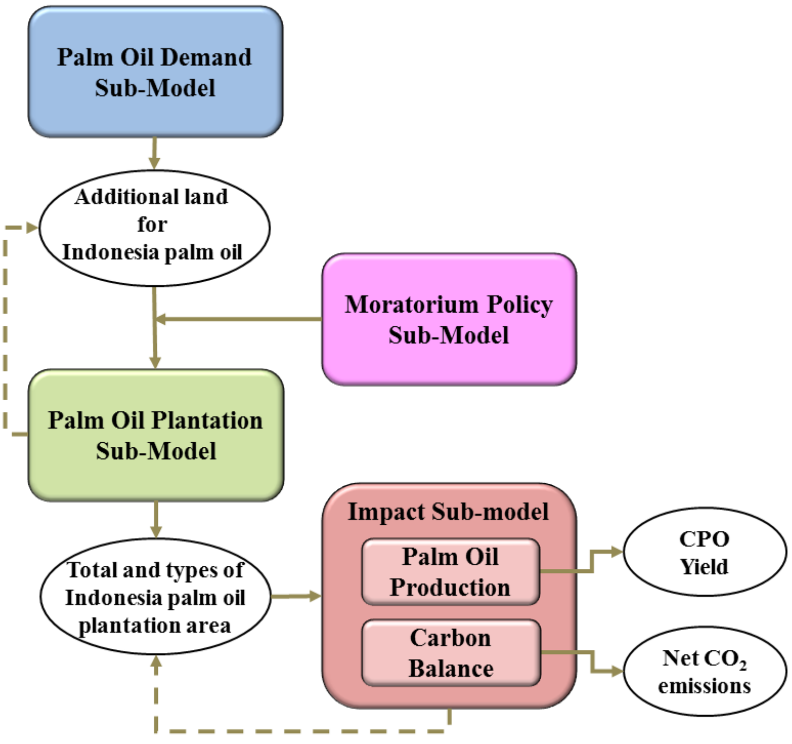

Figure 4-2. Model structure.

The detail of interrelationships among variables and its mathematical model including the input values for each sub-model will be described in next section.

4.2.3 Palm Oil Demand Sub-Model

The interrelationship among variables within the palm oil demand sub-model (blue color in figure 4-1) is as shown in figure 4-2. The main output of this model is the additional needed land for IPO.

As described previously, the variables of world population and world GDP are as the main driver that causes the GPO demand. By world population and world GDP variables, we could get GDP per capita that is assumed as variable to measure people income. People income will influence their consumption on palm oil product that is an increasing GPD per capita will increase the POC per capita and conversely. A mathematical equation of the effect of GDP per capita (as independent variable) on the POC per capita (as dependent variable) will be formulated by using a statistical technique of regression analysis. The GPO demand is obtained by multiplying the total population with the POC per capita. The GPO demand is used to calculate the IPO demand by the IPO's market share. The IPO demand then is used to calculate the land use demand for the IPO by the IPO's productivity per Hectare. The actual needed land or the additional land for the IPO is obtained by taking into account all existing

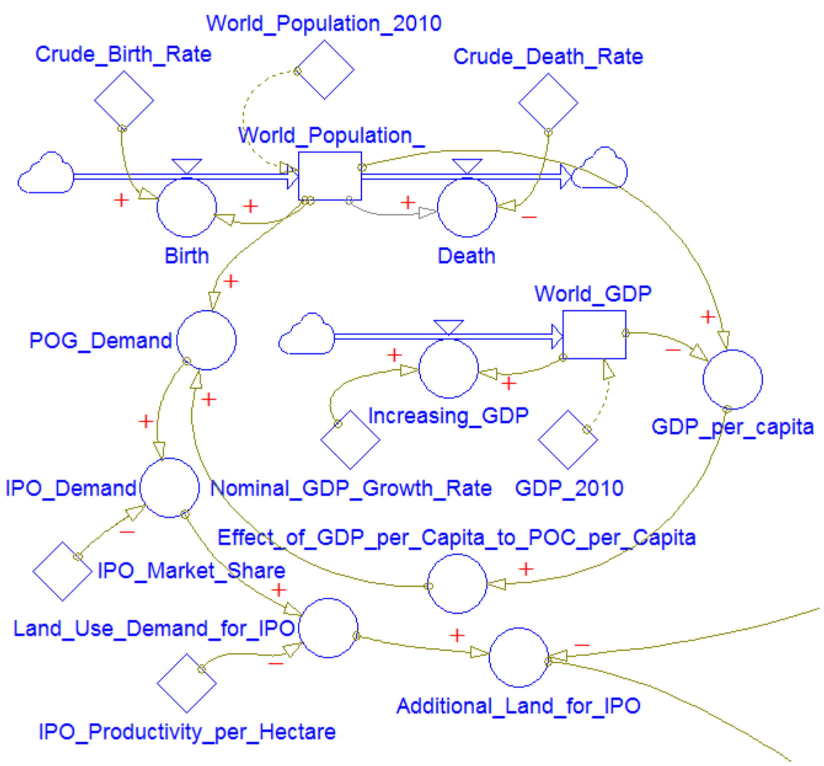

Figure 4-3. Interrelationships among variables within demand sub-model

palm oil plantations that already established in Indonesia (Total IPOPA). All mathematical equations and input data inside the demand sub-model including their explanations are as follows.

World Population

$$\text{Population (t)} = \text{World Population in 2010} + \int_{2010}^{t} \text{Births(s) ds} - \int_{2010}^{t} \text{Deaths(s)ds} \quad (4\text{-}1)$$

$$\text{Births (t)} = \text{Total World Population(t)} \cdot \text{Crude Birth Rate} \quad (4\text{-}2)$$

$$\text{Deaths (t)} = \text{Total World Population(t)} \cdot \text{Crude Death Rate} \quad (4\text{-}3)$$

Where the total *world population* at time *t* is w*orld population numbers* at initial time (t_0= 2010, i.e. world population in 2010) plus the integration value of *births* at any time *s* minus the integration value of *deaths* at any time *s* (time *s* is time between the initial time and the current/desired time). *Births* at time *t* is the total *world population* at time *t* multiplied by c*rude birth rate*, and *deaths* at time *t* is the total *world population* at time *t* multiplied by c*rude death rate*.

World GDP

$$\text{World GDP (t)} = \text{GDP in 2010} + \int_{2010}^{t} \text{Increasing GDP(s) ds} \quad (4\text{-}4)$$

$$\text{Increasing GDP (t)} = \text{World GDP(t)} \cdot \text{Nominal GDP Growth Rate} \quad (4\text{-}5)$$

Where the total *world GDP* at time *t* is the *GDP* at initial time (t_0= 2010) plus the integration value of *Increasing GDP* at any time *s*. *Increasing GDP* at time *t* is the total *World GDP* at time *t* multiplied by *Nominal GDP Growth Rate*.

GDP per Capita

$$\text{GDP per Capita (t)} = \frac{\text{World GDP(t)}}{\text{World Population(t)}} \quad (4\text{-}6)$$

Where the *GDP per Capita* at time *t* is the *World GDP* at time *t* divided by the *World Population* at time *t*.

Effect of GDP per Capita on Palm Oil Consumption (POC) per Capita

The effect of GDP per capita (as independent variable) on POC per capita (as dependent Variable) is represented by a mathematical equation that was obtained by using a statistical technique of regression analysis which based on their historical data (see appendix figure A-5 for GDP per capita and figure A-6 for POC per capita). The equation of simple linear regression model for two variables is as follows.

$$Y = a + bX$$

$$Y = \frac{\sum_{i=1}^{n} Y - b\left(\sum_{i=1}^{n} X\right)}{n} + \frac{n\sum_{i=1}^{n} XY - \left(\sum_{i=1}^{n} X\right)\left(\sum_{i=1}^{n} Y\right)}{n\left(\sum_{i=1}^{n} X^2\right) - \left(\sum_{i=1}^{n} X\right)^2} \cdot X$$

Where *Y* is *POC per Capita* and *X* is *GDP per Capita*.

By inputting numerical values that had been calculated based on the order that are listed in table 4-2, a mathematical equation of the effect of GDP per capita on POC per capita is as follows.

$$\text{POC per Capita (t)} = 0.000995136 + [7.08077 \cdot 10^{-7} \cdot \text{GDP per Capita (t)}] \quad (4\text{-}7)$$

Where the total *palm oil consumption per capita* at time *t* is 0.000995136 plus 7.08077E-07 multiplied by the *GDP per capita* at time *t*.

Table 4-2.Historical data and its numerical values of regression analysis.

Year	Y = POC [Ton/Person]	X = GDP per Capita [USD]	XY	X^2	Y^2
2001	0.0045332	5187.023	23.51365	26905205	2.05E-05
2002	0.0049456	5324.105	26.33085	28346096	2.45E-05
2003	0.0051811	5916.927	30.65644	35010019	2.68E-05
2004	0.0056468	6577.917	37.14432	43268994	3.19E-05
2005	0.0060052	7023.533	42.17779	49330019	3.61E-05
2006	0.0061726	7520.202	46.41912	56553443	3.81E-05
2007	0.0066709	8379.722	55.90031	70219742	4.45E-05
2008	0.0070313	9086.052	63.8865	82556340	4.94E-05
2009	0.0074007	8491.492	62.84291	72105430	5.48E-05
2010	0.0078161	9157.606	71.57657	83861746	6.11E-05
∑	0.0614035	72664.58	460.4485	5.48E+08	0.000388

Table 4-3.Numerical values for mean square error

Year	Y = POC [Ton/Person]	Y prediction	Y-Yprediction	$(\text{Y-Yprediction})^2$
2001	0.0045332	4.67E-03	-1.35E-04	1.82E-08
2002	0.0049456	4.77E-03	1.81E-04	3.26E-08
2003	0.0051811	5.18E-03	-3.63E-06	1.32E-11
2004	0.0056468	5.65E-03	-5.99E-06	3.58E-11
2005	0.0060052	5.97E-03	3.69E-05	1.36E-09
2006	0.0061726	6.32E-03	-1.47E-04	2.17E-08
2007	0.0066709	6.93E-03	-2.58E-04	6.64E-08
2008	0.0070313	7.43E-03	-3.97E-04	1.58E-07
2009	0.0074007	7.01E-03	3.93E-04	1.54E-07
2010	0.0078161	7.48E-03	3.37E-04	1.13E-07
∑	0.0614035			5.66E-07

By using the mathematical equation of the effect of GDP per capita on POC per capita, table 4-3 listed predictions of the POC per Capita ($Y_{prediction}$), and the mean square error (MSE) of the mathematical equation was obtained.

$$\text{MSE} = \frac{\sqrt{\left(\sum_{i=1}^{n} Y - Y_{prediction}\right)^2}}{n-2} = 0.000266$$

By MSE of 2.66E-04(small value), it can be said that the regression equation is good.

<u>Global Palm Oil (GPO) Demand</u>

$$\text{GPO Demand (t)} = \text{World Population(t)} \cdot \text{POC per Capita(t)} \qquad (4\text{-}8)$$

Where the total *palm oil global demand* at time *t* is the total w*orld population* at time *t* multiplied by *palm oil consumption per capita* at time *t.*

<u>Indonesia Palm Oil (IPO) Demand</u>

$$\text{IPO Demand (t)} = \text{POG Demand(t)} \cdot \text{IPO market share} \qquad (4\text{-}9)$$

Where the total *Indonesia palm oil* at time *t* is the total *POG demand* at time *t* multiplied by *market share of Indonesia palm oil* in the global pam oil market.

Land Use Demand for Indonesia Palm Oil (IPO)

$$\text{Land Use Demand for IPO (t)} = \frac{\text{IPO Demand(t)}}{\text{IPO Productivity per Hectare}} \tag{4-10}$$

Where the total *land use demand for Indonesia palm oil* at time *t* is the total *Indonesia palm oil demand* at time *t* divided by the *productivity of Indonesia palm oil*.

The Additional Land for IPO (to Fulfill the Land Use Demand)

The mathematical equation of the *land use demand for IPO* above is the total land use demand that is needed for the IPO industry to fulfill whole IPO demand. The actual needed land or the additional land for IPO is obtained by taking into account all existing types of palm oil plantation in Indonesia (Total IPOPA). Thus, a mathematical equation of the additional land for the IPO to fulfil the demand is as follow.

$$\text{Additional land for IPO (t)} = \text{Land Use Demand for IPO(t)} - \text{Total IPOPA(t)} \tag{4-11}$$

Where the total *additional land for Indonesia palm oil* at time *t* is the *land use demand for Indonesia palm oil* at time *t* minus the total *palm oil plantation area in Indonesia (IPOPA)* at time *t*.

Note: there is a mathematical logic function employed in the *additional land for Indonesia palm oil* variable to ensure the value of the variable is not negative value, that is ‘the arithmetic *IF* function’. Thus, the actual of mathematical equation for the *additional land for Indonesia palm oil* inside the SD model is as follows.

IF(Land Use Demand for IPO > Total IPOPA, Land Use Demand for IPO - Total IPOPA, 0)

Table 4-4. Input data for demand sub-model.

Variable	Value	Data Source
World Population in 2010	6894377794 Persons	World Bank, 2010 (Figure A-1)
Crude Birth Rate	20 per 1000 Persons	World Bank, 2010 (Figure A-2)
Crude Death Rate	8 per 1000 Persons	
World GDP in 2010	63135994837272.7 USD	World Bank, 2010 (Figure A-3)
Nominal GDP Growth Rate	7.08%	World Bank, 2010 (Figure A-4)
IPO market share	42.72%	USDA-FAS,2010 ; MARI, 2010 (Figure A-8)
IPO productivity per Hectare	2.631 Tons	MARI, 2010 (Figure A-10)

Where if the *land use demand for IPO* at time *t* is greater than *total IPOPA* at time *t*, the model will evaluate the *land use demand for IPO* at time *t* minus *total IPOPA*. Conversely, if the *land use demand for IPO* at time *t* is not greater than *total IPOPA* at time *t*, the model will evaluate *0 (zero)* as input value *which indicates that the IPO don't need to add or expand their plantation areas, since the existing IPOPA is still sufficient to fulfill the demand.*

All input data for the demand sub-model are listed in table 4-4. For more detail about the selected data is discussed in appendix, section A-1, A-2, A-3, A-4, A-5 and A-6.

4.2.4 Palm Oil Plantation Sub-Model

The interrelationship among variables within the palm oil plantation sub-model (green color in figure 4-1) is as shown in figure 4-3. The main output of this model is the palm oil plantation areas in Indonesia (IPOPA) for both the total area and the type of the plantation area. In the model, the type of the plantation area is split into new, immature, mature, unproductive plantations.

As have described previously, both CO_2 emissions and CPO yield that were chosen as indicators to measure the impacts of the moratorium policy and to evaluate the two scenarios

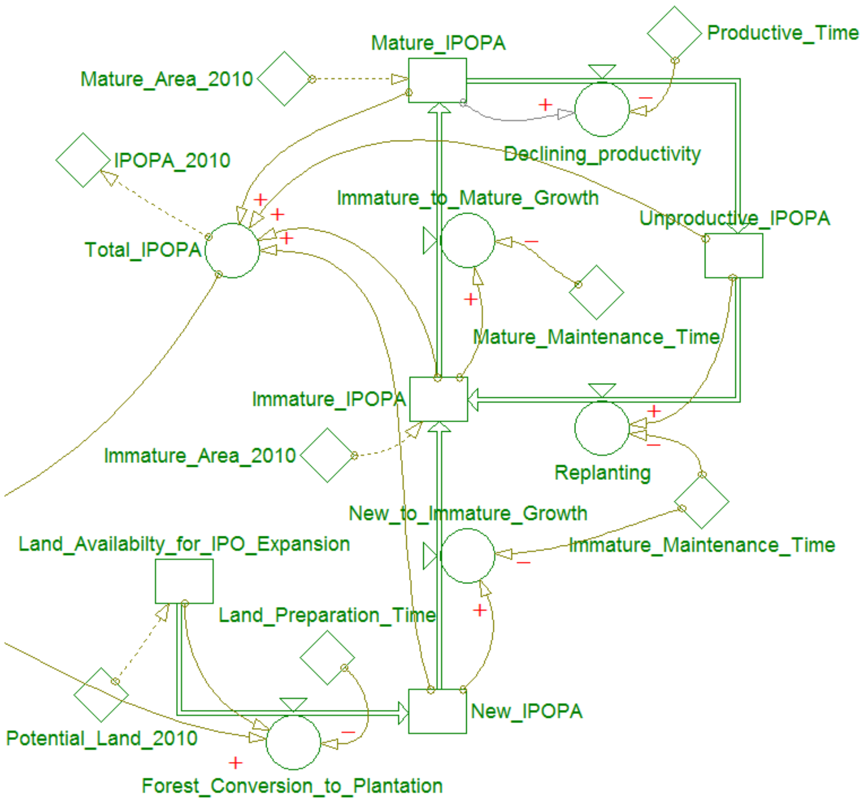

Figure 4-4. Interrelationships among variables within plantation sub-model.

associated with palm oil plantations. The new and mature plantation areas were used to calculate the net carbon emissions (carbon debt and repay). While to calculate CPO yield only used the mature plantation area.

The palm oil plantation sub-model (Figure 4-3) depicts the plantation establishment and management processes that were splited into five stocks.

- One stock is used to record the land availability for palm oil expansion.
- The other four stocks are used to keep track the plantation area types that described by the age of palm oil crop which started with a stock of the new IPOPA. The description of the four stocks are as follows,
  - (a) A new plantation refers to the period that the plantation land is still in preparation and under cultivation
  - (b) An immature plantation refers to the period that palm oil crops in the plantation is still growing, don't produce fresh fruit bunches (FFB) yet.
  - (c) A mature plantation refers to the period that the plantation begins to produce FFB
  - (d) An unproductive plantation refers to the period that the FFB production from the plantation begins to decline and they start to replace the unproductive crops with the new crops (replanting).

Author assumed that the management of palm oil plantation is a cyclical pattern in the same order, where palm oil crop will be replanted again when the crops in the mature plantations becomes unproductive, and it will follow the stages of the plantation management process (immature, mature, unproductive).

The four stocks of new, immature, mature and unproductive plantations are like a delay that provides stock of plantation in transit and moves them from one stage to the next stage based on their age. Owing to there are five stocks that represents the five stages of plantation establishment and management processes in the plantation sub-model and each stage contains a delay process. Thus, the model has five order delays in the total, since it is an interflow of five first-order delays together in series. The outflow from the stock of a first-order delay is always proportional to the stock [Sterman, 2000][82], the mathematical equations for the outflows (O) of each stock is as follows.

$$\text{Outflows of stock (O)} = \frac{\text{stock value (S)}}{\text{average delay time (D)}} \tag{4-12}$$

[82] Sterman, J. *Business Dynamics: Systems Thinking and Modeling for a Complex World.* Boston: McGraw-Hill Higher Education, 2000.

Where the *outflows (O) of each stock* are the *stock value (S)* divided by the *average delay time (D)*.

All mathematical equations and input data inside the plantation sub-model including their explanations are as follows.

Land Availability for IPO Expansion

$$\text{Land Availability for IPO Expansion (t)} = \text{Potential Land in 2010} - \int_{2010}^{t} \text{Forest Conversion to Plantation}(s)\,ds \quad (4\text{-}13)$$

$$\text{Forest Conversion to Plantation (t)} = \frac{\text{Additional Land for IPO(t)}}{\text{Land Preparation Time}} \quad (4\text{-}14)$$

Where the *land availability for Indonesia palm oil expansion* at time *t* is *potential land for Indonesia palm oil expansion* at initial time (t_0= 2010) minus the integration value of the *forest conversion for IPOPA* at any time *s*. The *forest conversion for IPOPA* at time *t* is the *additional land for Indonesia palm oil* at time *t* divided by *land preparation time*.

Note: there is a conditional function performed in the *forest conversion for IPOPA* equation, that is 'the *MIN* function'. Thus, the actual of mathematical equation inside the SD model is as follows.

MIN(Potential Land in 2010, Additional Land for IPO/Land Preparation Time)

The MIN fuction is to ensures the value of *land availabilty for IPO expansion* does not fall below zero or the value become minus even though the value of *forest conversion for IPOPA* is higher than the remain stock of *land availabilty for IPO expansion*.

New Indonesia Palm Oil Plantation Area (IPOPA)

$$\text{New IPOPA (t)} = \text{New Area in 2010} + \int_{2010}^{t} \text{Forest Conversion to plantation}(s)\,ds - \int_{2010}^{t} \text{New to Immature Growth}(s)\,ds \quad (4\text{-}15)$$

$$\text{New to Immature Growth (t)} = \frac{\text{New IPOPA(t)}}{\text{Immature Maintenance Time}} \quad (4\text{-}16)$$

Where the *new IPOPA* at time *t* is *new area of IPO in 2010* at initial time (t_0= 2010) plus the integration value of the *forest conversion for IPOPA* at any time *s* minus the integration value of the *immature growth* at any time *s*. The *new to immature growth* at time *t* is the *new IPOPA* at time *t* divided by *immature maintenance time*.

Immature Indonesia Palm Oil Plantation Area (IPOPA)

$$\text{Immature IPOPA (t)} = \text{Immature Area in 2010} + \int_{2010}^{t} \text{New to Immature Growth(s) ds} - \int_{2010}^{t} \text{Immature to Mature Growth(s) ds} + \int_{2010}^{t} \text{Replanting(s) ds} \quad (4\text{-}17)$$

$$\text{Immature to Mature Growth (t)} = \frac{\text{Immature IPOPA(t)}}{\text{Mature Maintenance Time}} \quad (4\text{-}18)$$

Where the *immature IPOPA* at time *t* is *immature area of IPO* at initial time (t_0=2010) plus the integration value of the *immature growth* at any time *s* minus the integration value of the *mature growth* at any time *s* plus the *replanting* at any time *s*. The *immature to mature growth* at time *t* is the *immature IPOPA* at time *t* divided by *mature maintenance time*.

Mature Indonesia Palm Oil Plantation Area (IPOPA)

$$\text{Mature IPOPA (t)} = \text{Mature Area in 2010} + \int_{2010}^{t} \text{Immature to Mature Growth(s) ds} - \int_{2010}^{t} \text{Declining Productivity(s) ds} \quad (4\text{-}19)$$

$$\text{Declining Productivity (t)} = \frac{\text{Mature IPOPA(t)}}{\text{Productive Time}} \quad (4\text{-}20)$$

Where the *mature IPOPA* at time *t* is *mature area of IPO* at initial time (t_0=2010) plus the integration value of the *immature to mature growth* at any time *s* minus the integration value of *declining productivity of palm oil crops on mature IPOPA* at any time *s*. The *declining productivity* at time *t* is the *mature IPOPA* at time *t* divided by *productive time of palm oil crops*.

Unproductive Indonesia Palm Oil Plantation Area (IPOPA)

$$\text{Unproductive IPOPA (t)} = \text{Unproductive Area in 2010} + \int_{2010}^{t} \text{Declining Productivity(s) ds} - \int_{2010}^{t} \text{Replanting(s) ds} \quad (4\text{-}21)$$

$$\text{Replanting (t)} = \frac{\text{Unproductive IPOPA(t)}}{\text{Immature Maintenance Time}} \quad (4\text{-}22)$$

Where the *unproductive IPOPA* at time *t* is *unproductive area of IPO* at initial time (t_0= 2010) plus the integration value of *declining productivity of palm oil crops on mature IPOPA* at any time *s* plus the integration value of *replanting palm oil crops* at any time *s*. The *replanting* at time *t* is the *unproductive IPOPA* at time *t* divided by *immature maintenance time*.

<u>Total Indonesia Palm Oil Plantation Area (IPOPA)</u>

$$\text{Total IPOPA (t)} = \sum \text{IPOPA Type}$$

$$= \text{New IPOPA(t)} + \text{Immature IPOPA(t)} + \text{Mature IPOPA(t)} + \text{Unproductive IPOPA(t)} \qquad (4\text{-}23)$$

Where the *established palm oil plantation area in Indonesia (IPOPA)* at time *t* is the sum of *all IPOPA types* at time *t*.

Refers to the Rankine and Fairhurst's Schematic plan for the establishment of a new palm oil plantation (appendix, table A-1), land preparation time for palm oil plantation is about 0.66 year, and the plantation management process for new plantation to mature plantation is about 1004 days or 2.75 years. While the average productive lifetime of palm oil crop to produce fresh fruit bunches (FFB) is around 22 to 27 years (appendix, table A-2).

(a) Since the process of of palm oil plantation establishment is notonly land preparation (surveying, roads and drains, land clearing, legume cover planting , lining), it is also needed a permission from government including to follow the reqired procedures, and to prepare and organize all resources that are needed for it. Thus, for the delay time of land preparation is assumed 365 days or 1 year.

(b) Since in the model there are 3 stocks between new plantation and mature plantation (new, immature and mature plantations). Thus, it was assumed that the delay time between each stock (new to immature and immature to mature) are a half of 1004 days that is 502 days or 1.38 years.

(c) The delay time for mature plantation to unproductive plantation is based on the average productive lifetime of palm crop to produce FFB, the lowest time that is 22 years was chosen for the model

USDA-FAS [2010][83] reported that the population of immature IPOPA is approximately 23% percent of total IPOPA. While the total IPOPA in 2010 from MARI Directorate General of Estate (figure 1-3) is 7,824,623 Hectares. Thus, it means that the mature IPOPA and immature IPOPA are 6,024,960 and 1,799,663 Hectares respectively. Those values were used as initial condition for the immature and mature IPOPAs. Due to there was difficulty in obtaining data for the number of new and unproductive IPOPAs. Thus, author assumed the initial condition

[83] USDA-FAS. *Indonesia: Rising Global Demand Fuels Palm Oil Expansion*. Retrieved March 23, 2012, from United States Department of Agriculture-Foreign Agricultural Service: http://www.pecad.fas.usda.gov/highlights/2010/10/Indonesia/, 2010.

Table 4-5. Input data for plantation sub-model.

Variable	Value	Data Source
Time intervals for Land preparation	365 Days or 1 Year	Assumption
Time intervals for immature Maintenance Time intervals for mature maintenance	502 Days or 1.38 Years 502 Days or 1.38 Years	The Rankine and Fairhurst's Schematic plan-cited in Corley dan Tinker, 2003 (Table A-1)
Time intervals for productive lifetime	22 Years	Hirsinger et al., 1995 and MPOB report, 2004-cited in Yusoff and Hansen, 2007 (Table A-2)
New IPOPA in 2010	0 Hectare	Assumption
Immature IPOPA in 2010 Mature IPOPA in 2010	1,799,663 Hectares 6,024,960 Hectares	USDA-FAS, 2010 ; MARI, 2010 (Figure 1-3)
Old IPOPA in 2010	0 Hectare	Assumption
Land availability for the palm oil expansion	45,846,329 Hectares	Dradjat, 2007 (Appendix, section 4-11)

for new and unproductive IPOPAs is zero. The delay time or time intervals for each process and the initial condition for each stock in the Plantation sub-model are listed in table 4-5.

4.2.5 Impact Sub-Model.

There are two models inside the impact sub-model (red color in figure 4-1), those are the carbon balance model and the palm oil production model. The main output of this model is the selected sustainability indicators (CO_2 emissions and CPO yield) that are used to measure the impacts of the moratorium policy.

4.2.5.1 Carbon Balance Model.

Figure 4-4 shows the interrelationships among variables within the carbon balance model. As have described previously (section 3.5 point g), the concept of the Carbon balance (carbon debt and repayment) is as follows.

The establishment of new plantation area will release carbon to atmosphere (carbon debt), and conversely, the plantations will also absorb the carbon from atmosphere over time during the growth of palm oil corps in the plantations (carbon repayment)

Also, it was assumed that the amount of carbon emissions that is released as a result of the forest conversion is equal to the amount of CO_2 emissions. The impact sub-model for CO_2 emissions only took into account:

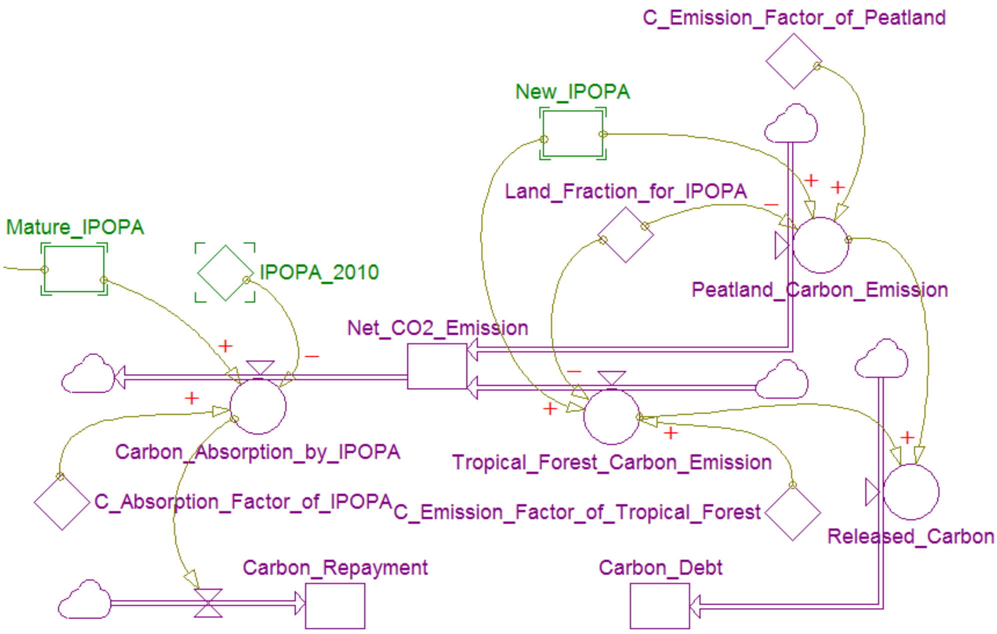

Figure 4-5. Interrelationships among variables within carbon balance model.

(a) The carbon that is released to atmosphere as a result of the IPOPA establisment after 2010 that was calculated by the stock of new IPOPA numbers (Carbon debt).

(b) The carbon that is absorbed by full-established plantations that began to establish after 2010. The full-established plantation that will be used for the calculation of CO_2 absorption that is the stock of mature IPOPA (Carbon repayment).

Thus, the model only took into account the Carbon balance as result of the palm oil plantation expansion after 2010. Hence, for equal or balance calculation, the total existing plantation areas in 2010 (initial value of plantation areas) was not used to calculate the absorption of carbon from atmosphere. In other word, the mature plantations that will absorb carbon are derived from the converted forest land itself.

Mathematical equation for CO_2 emissions balance and input data inside the model including their explanations are as follows.

$$\text{Net } CO_2 \text{ Emissions (t)} = CO_2 \text{ Emission in 2010} + \int_{2010}^{t} \text{Peatland Carbon Emissions}(s)\,ds + \int_{2010}^{t} \text{Tropical Forest Carbon Emissions}(s)\,ds - \int_{2010}^{t} \text{Carbon Absorption by IPOPA}(s)\,ds \quad (4\text{-}24)$$

$$\text{Peatland Carbon Emission (t)} = \text{New IPOPA(t)} \cdot \text{Land Fraction for IPOPA} \cdot \text{Carbon Emission Factor of Peatland} \quad (4\text{-}25)$$

$$\text{Tropical Forest Carbon Emission (t)} = \text{New IPOPA(t)} \cdot (1 - \text{Land Fraction for IPOPA}) \cdot \text{Carbon Emission Factor of Tropical Forest} \quad (4\text{-}26)$$

$$\text{Carbon Absorption by IPOPA (t)} = [\text{Mature IPOPA(t)} - \text{Total IPOPA in 2010}] \cdot \text{Carbon Absorption Factor of IPOPA} \quad (4\text{-}27)$$

Where the *CO_2 emission balance* at time *t* is *CO_2 emissions in 2010* at initial time (t_0=2010) plus the integration value of the *peatland Carbon emissions* at any time *s* and the integration value of the *tropical forest Carbon emissions* at any time *s* (we called Carbon debt). It then minus the integration value of the *Carbon absorption by IPOPA* at any time *s* (we called Carbon repayment). The *peatland Carbon emission* at time *t* is the *new IPOPA* at time *t* multiplied by *land fraction for IPOPA* and *carbon emission factor of peatland*. And so forth.

Note: there is a conditional function inputted in the *Carbon absorption by IPOPA* variable to ensure the value of *Mature IPOPA* is not negative value, that is 'the arithmetic *IF* function'. Thus, the actual of mathematical equation for *Carbon absorption by IPOPA* inside the SD model is as follows.

IF(Mature IPOPA(t)>IPOPA 2010, [Mature IPOPA(t) − IPOPA 201] x Carbon Absorption Factor of IPOPA, 0)

Where if the *mature of Indonesia palm oil Plantation Area* at time *t* is greater than *initial value of Indonesia palm oil Plantation Area (existing palm oil plantations in 2010)*, the model will evaluate the *mature of Indonesia palm oil Plantation Area* at time *t* minus *Indonesia palm oil plantation area* in *2010 multiplied by carbon absorption factor of Indonesia palm oil Plantation Area*. Conversely, if the *mature of Indonesia palm oil Plantation Area* is not greater than *initial value of Indonesia palm oil Plantation Area*, the model will evaluate *0 (zero)* as input value.

Table 4-6. Input data for carbon balance model.

Variable	**Value**	**Data Source**
Land fraction for IPOPA	14%	Hooijer et al., 2006 (Table A-3)
Carbon emission factor of peatland Carbon emission factor of tropical forest	3452 Tons C per Hectare 702 Tons C per Hectare	Fargione et al., 2008 (Table 4-5)
Carbon absorption factor of IPOPA	39 Tons C per Hectare	Dewi et al., 2009 (Table A-6)
CO_2 emissions in 2010	0 Ton	Assumption

The establishment of new plantation area is assumed on the tropical forest and peatland areas, with the concessions/permission ratio of 14% : 86% (i.e. 14% is on Peatland and 86% is on tropical forest). Thus, 14% was used as land fraction parameter to determine the origin of IPOPA (see appendix, section A-10). Due to the assumtion of the impact sub-model for CO_2 emissions that is the model only took into account the Carbon balance as result of the expansion of palm oil plantation after 2010. Thus, the initial value for CO_2 emissions (in 2010) was set zero. Furthermore, Fargione et al.'s data was used as parameter to calculated carbon that is released to atmosphere and Dewi et al.'s data was used to calculated carbon that is absorbed by the plantations (see appendix, section A-12).

4.2.5.2 Palm Oil Production Model

Figure 4-5 shows the interrelationships among variables within the palm oil production model, where the CPO yield was calculated based on the mature IPOPA.

Mathematical equation for CPO yield and input data inside the model including their explanations are as follows.

$$\text{CPO Yield of IPO (t)} = \text{FFB Yield of IPO(t)} \cdot \text{FFB to Produce CPO} \quad (4\text{-}28)$$

$$\text{FFB Yield of IPO (t)} = \text{IPO Crop(t)} \cdot \text{FFB per Palm Crop} \quad (4\text{-}29)$$

$$\text{IPO Crop (t)} = \text{Mature IPOPA(t)} \cdot \text{Palm Crop per Hectare} \quad (4\text{-}30)$$

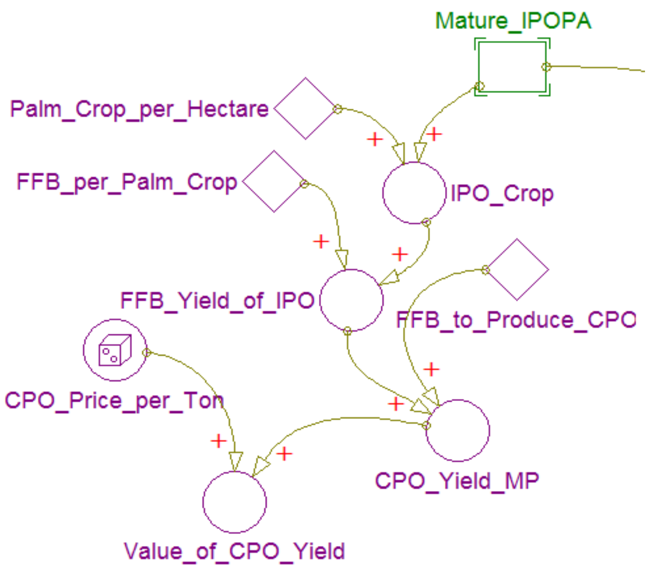

Figure 4-6. Interrelationships among variables within palm oil production model.

Where the *total crude palm oil yield of Indonesia palm oil* at time *t* is the total *fresh fruit bunch yield of Indonesia Palm Oil* at time *t* multiplied by the ratio of *fresh fruit bunch to produce crude palm oil*. The total *fresh fruit bunch yield of Indonesia Palm Oil* at time *t* is the total *IPO Crop in the mature plantation areas* at time *t* multiplied by the *fresh fruit bunch yield per palm oil crop*. The total *Indonesia palm oil Crop in the mature plantation areas* at time *t* is the *mature IPOPA* at time *t* multiplied by the *palm oil crop per Hectare*.

The calculation for the total value of CPO yield in USD is as follows.

$$\text{Value of CPO Yield (t)} = \text{CPO Yield of IPO(t)} \cdot \text{CPO price per Ton(t)} \qquad (4\text{-}28)$$

$$\text{CPO price per Ton(t)} = 914.44 \sim 1096.32 \text{ USD}$$

The total *value of crude palm oil yield* in USD at time *t* is the *total crude palm oil yield of IPO* at time *t* multiplied by *crude palm oil price per ton*.

Note: there is a conditional function inputted in the *CPO price per Ton* variable, that is 'the RANDOM function'. Where for *CPO price per Ton* was conducted in random simulation by using the interval price of 914.44 to 1096.32 USD. Thus, the actual of mathematical equation for *CPO price per Ton* inside the SD model is as follows.

RANDOM (914.44, 1096.32)

Where the model will select uniformly distributed random value of the *CPO price per Ton* between 914.44 USD (as minimum value) and 1096.32 USD (as maximum value) for calculation.

To estimate the total CPO yield of IPO and its value (in USD) were based on the general data of palm oil plantation (appendix, table A-2) and CPO price in global market (appendix, figure A-12), respectively.

Table 4-7. Input data for palm oil production model.

Variable	Value	Data Source
Palm oil crop per Hectare	140 palm crops	Hirsinger et al., 1995 and MPOB report, 2004-cited in Yusoff and Hansen, 2007 (Table A-2)
FFB per palm crop per year	0.140 Ton	
FFB to produce 1 Ton CPO	5 Ton	
CPO price in global market	914.44 - 1248.55 USD per Ton	Index Mundi, 2012 (Figure A-12)

4.2.6. Moratorium Policy Sub-Model.

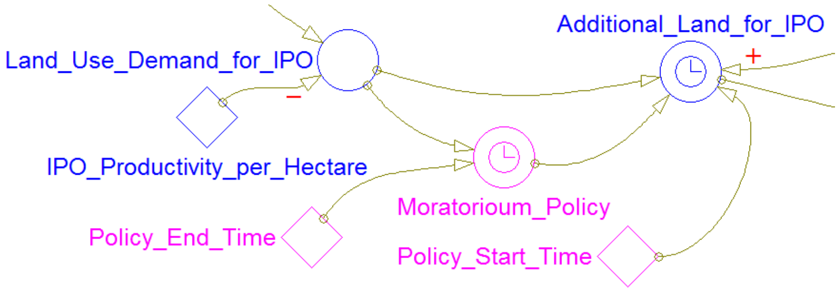

Figure 4-7. Moratorium policy sub-model.

Figure 4-6 shows moratorium sub-model, which is the interrelationship among variables within the moratorium policy sub-model (rosy/pink color in figure 4-1). The moratorium sub-model was put between demand sub-model and palm oil plantation sub-model. That is put between the variables of the land use demand for IPO and the additional needed land for IPO.

Based on the descriptive or assumption concerning the future image of moratorium policy (table 4.7) that was made in ideal situation or we also can say that the assumption is an extreme condition. The moratorium policy is perceived as variable that will suspend the forest conversion for palm oil plantations for 2 years. Hence, figure 4-20 can be described as follows.

- If the land use demand variable is perceived as material that will flow through the moratorium policy variable, thus the moratorium policy variable could be perceived as a process that captures and eliminates the material flow from the land use demand variable for 2 years, from 2011-2013.
- After 2013, it then will back to normal condition that the moratorium policy variable will transfer the material flow of the land use demand variable into the additional needed land variable for next calculation

An assumption of '*moratorium policy will suspend the palm oil expansion for 2 years (from 2011 to 2013), and the expansion will continue in 2014 after the moratorium policy is expired*' was modeled by using 'the STEP functions'. STEP function is a sudden increasing of value in the input from one rate to another. The mathematical equation is as follows.

Moratorium policy (t) = STEP (Land Use Demand for IPO (t), Policy End Time) (4-31)

Land Use Demand for IPO (t) = (see equation 4-10)

Policy End Time = 2013

Where the *moratorium policy* at time *t* is to make the input value of *land use demand for Indonesia palm oil* become zero if the time of simulation less than *policy end time (2013*).

Thus, the moratorium sub-model then will change the mathematical equation of the *additional needed land for IPO* variable (equation 4-11), the equation would be as follows.

Additional Needed Land for IPO (t)	=	IF(TIME < Policy Start Time, Land Use Demand for IPO(t)－Total IPOPA(t), IF(Moratorium Policy(t) > Total IPOPA(t), Moratorium Policy(t) － Total IPOPA(t), 0))

(4-32)

Policy Start Time	=	2011
Land Use Demand for IPO (t)	=	(see equation 4-10)
Total IPOPA(t)	=	(see equation 4-23)

Where if the *time of simulation* is less than *policy start time*, the model will evaluate the value of *land use demand for Indonesia palm oil* at time *t* minus *Indonesia palm oil plantation area* at time *t*. Conversely, if the *time of simulation* is not greater than or equal to *Policy Start Time*, the model will evaluate another ‘arithmetic If function'.

The another ‘arithmetic If function is if the value of moratorium policy at time *t* is greater than the *total Indonesia palm oil plantation area* at time *t*, the model will evaluate moratorium policy at time *t* minus the *total Indonesia palm oil plantation area* at time *t*. Conversely, if the value of moratorium policy at time *t* is not greater than the *total Indonesia palm oil plantation area* at time *t*, the model will evaluate zero as input value for *additional needed land for Indonesia palm oil* at time *t*.

4.3 Model Diagram

The whole model diagram of this study is as shown in figure 4-7. As have described previously in chapter III that the difference between the two scenarios of this study is only on the implementation of a two-years moratorium policy. Thus, the BAU model of this study is a combination of palm oil demand sub-model (section 4.2.3), palm oil plantation sub-model (section 4.2.4) and impact sub-model (section 4.2.5). When the BAU model is imposed or intervened by the moratorium sub-model, it becomes the MP model. Thus, the basic structure including its inputs between BAU and MP models is same, the diffrence is only there is a moratorium policy sub-model in the MP model.

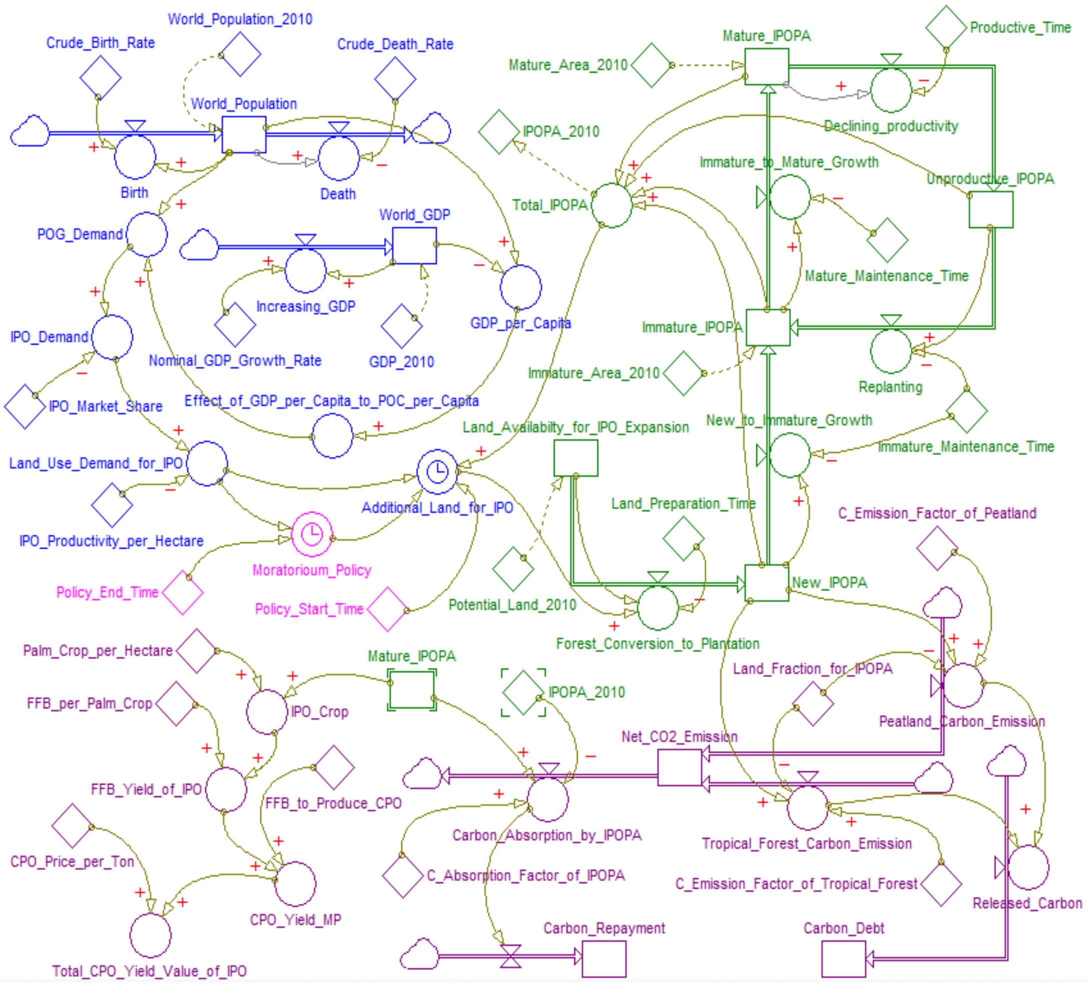

Figure 4-8. Model diagram.

4.4 Conclusion

Model formulation and construction focused on the transformation process of the concepts into SD model. The model is representing the interrelationships between policy intervention and supply-demand system of palm oil industry sector on national and international levels. The focus of supply side system of palm oil industry sector under study is at plantation phase only (see scope of study). Another important transformation process is how to translate the moratorium policy into mathematical model. After the formal quantitative model is built, the model has to pass the model validation testing before it is used for policy analysis.

CHAPTER V
MODEL VALIDATION

5.1 Introduction

Based on the purpose, an appropriate model was constructed. After that, the model should pass the model validation procedures before the model is used for experimentations (by simulation) in order to enhance our insight and understanding related to the themes being studied. With regard to the validation of models, many modelers have long recognized and argued that validation models is impossible in the sense of establishing truth [Sterman, 2000][84]. Although the model had been constructed by sophisticated software and high powered computer, but the model are still simplifications of the real system which being studied [Ford,1999][85]. However, the model validation procedures were designed to reveal errors, flaws and shortcomings of the model, it then could fix the model by revising the concepts and formulation of the model. Where the procedures are eventually intended to build confidence that the model is useful in order to enhance our insight and understanding related to the themes being studied. Sterman [2000][86] have summarized and described a wide variety of model validation procedure tests to uncover flaws and improve the model that had developed by SD modelers. Ford [2010][87] also have suggested several tests that were especially useful for environmental system.

To build confidence for the model in this study, several tests were conducted by following the model validation procedures that has been suggested by Sterman and Ford. The model validation that was carried out for BAU model as base run that includes dimensional consistency, reference mode behavior, historical data reproduction, extreme condition, and sensitivity analysis.

5.2 Dimensional Consistency

One principle of SD for model formulation that seems obvious and basic principles, but it has rather consistently been violated by modeler that is ‘the model variables should be measured

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[84] Sterman, J. *Business Dynamics: Systems Thinking and Modeling for a Complex World.* Boston: McGraw-Hill Higher Education, 2000.

[85] Ford, A. *Modeling the Environment: An Introduction to System Dynamics Modeling Of Environmental Systems*. Washington, DC: Island Press, 1999.

[86] Sterman, J. *Business Dynamics: Systems Thinking and Modeling for a Complex World.* Boston: McGraw-Hill Higher Education, 2000.

[87] Ford, A. *Modeling the Environment.* Washington, DC: Island Press, 2010.

in the same unit as the real variables [Forrester, 1961][88]. Checking the consistency of measurement unit for each variable is the most basic test for model validation [Sterman, 2000][89]. Hence, the errors in the units will be a fundamental flaw for a model. For this model, the measurement units of each variable followed the units that is used in the real system without the inclusion of scaling factors. In section 4.4 scaling factors were used for simplification in presenting the historical data of variables. For example, the world population will be counted in the unit of [person], not [million persons] as had been shown in the historical data (see appendix, figure A-1).

Mainly, there were 4 kind of measurement units that were used, those were Person (for population), USD (related to value or money), Percent (related to rate or fraction), Hectare (related to land or area), Ton (related to palm oil and emissions). Author could confirm that each initial value, parameter and equation that was inputted into the model was dimensionally consistent.

5.3 Reference Mode Reproduction Test

For matching the output of key variables that were produced by the model, the reference mode or target pattern of the model behavior was using as initial step of model testing (see chapter 1, section overview of Methodology), since the reference mode was an essential for the modeling process. Having the modeling without reference mode is like going for a trip but without knowing where to go [Ford, 2010][90].

As had been described in chapter 1 section 1.2.1, the key variables of the model are GPO demand and IPOPA, with an exponential growth as the reference mode for its future trend (figure 1-4). The model result for the GPO demand and IPOPA are as shown in figure 5-1 and 5-2 respectively.

The figure showed that the model result is to follow the reference mode or it has succeeded to reproduce an adequate behavior against the target pattern (exponential growth). Thus, author could confirm that the model had passed the initial testing procedure.

[88] Forrester, J.W. *Industrial Dynamics.* Massachusetts: The M.I.T. Press, 1961.

[89] Sterman, J. *Business Dynamics: Systems Thinking and Modeling for a Complex World.* Boston: McGraw-Hill Higher Education, 2000.

[90] Ford, A. *Modeling the Environment.* Washington, DC: Island Press, 2010.

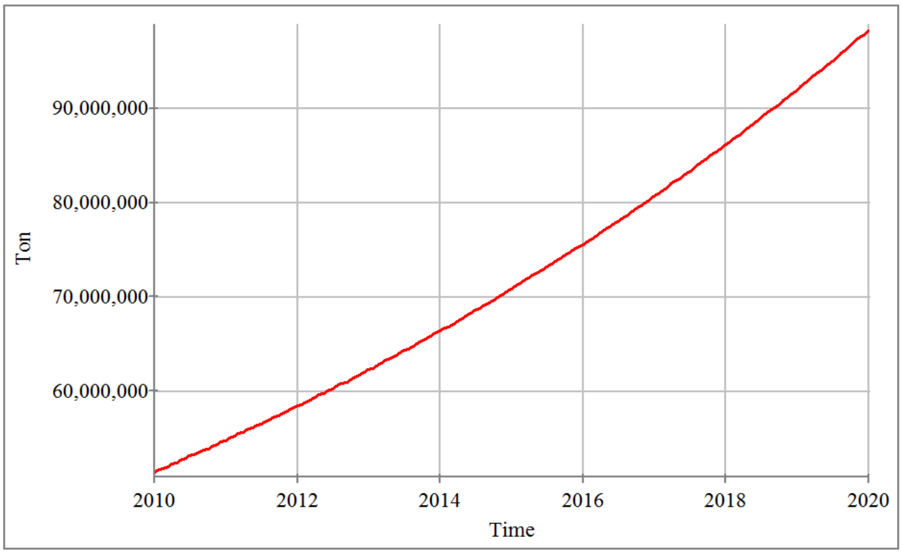

Figure 5-1. Extrapolation trend of global palm oil demand.

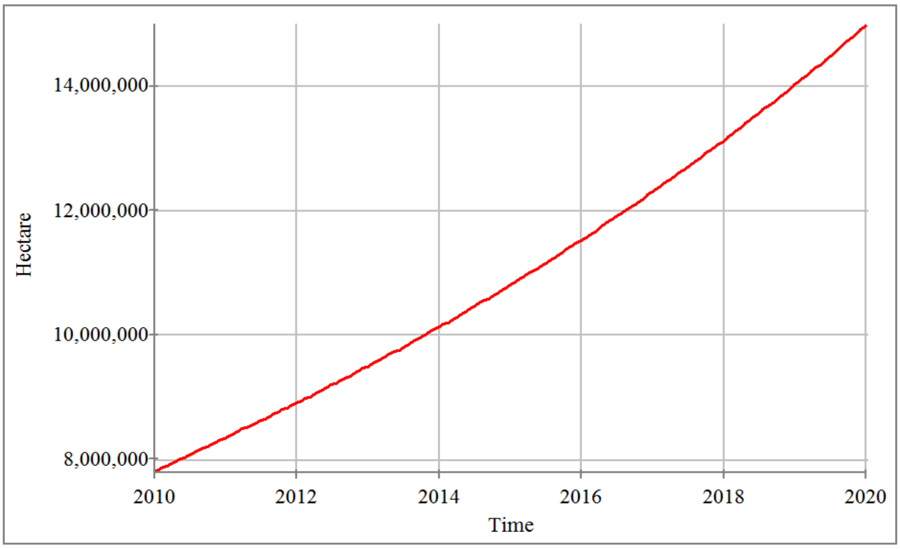

Figure 5-2. Extrapolation trend of Indonesia palm oil plantation area.

5.4 Historical Data Matching

To match the output of the model, using the historical data (data actual) is commonly used for model validation. For the historical data testing, author focused on the key variables (GPO demand and total IPOPA). The historical data series from 2001 to 2010 of both variables (figure 1-2 and figure 1-3) were used to verify the model in extrapolating the trend. Thus, the model was started in 2001 and ended in 2010 for this testing. Hence the initial condition/value of the model should be set at 2001, whereas for other parameters were fixed (base run). The changes in initial condition values for this testing is listed in Table 5-1. The descriptive statistics of Mean Absolute Percent Error (MAPE) was used for assessing the behavior reproduction of the model, whether the model output match with the historical data series. The MAPE formula is as following.

$$\text{Mean Absolute Percent Error (MAPE)} = \frac{1}{n}\sum \left| \frac{\text{Model Output(t)} - \text{Historical Data(t)}}{\text{Historical Data(t)}} \right| \cdot 100\% \qquad (5\text{-}1)$$

Where the *mean absolute percent error* is the sum total of the *model output* at time *t* minus the *historical data* at time *t* divided by the *historical data* at time *t* multiplied by *100%*, then it divided by the total number of horizon time.

Figure 5-3 and 5-4 showed a comparison data in scatter chart between the model output and the actual data for GPO demand and total IPOPA respectively. Where table 5-2 and table 5-3 show the MAPE for GPO demand and total IPOPA respectively.

The MAPE for both GPO demand and total IPOPA were under 6%. Thus, it indicated that the model was reasonable, since the model was able to reproduce the real system.

Table 5-1. Parameter changes for historical data testing purpose.

Variable	Value	Data Source
World Population in 2001	6195665261 Persons	World Bank, 2010 (Figure 4.3)
World GDP in 2001	32137056641076.10 USD	World Bank, 2010 (Figure 4.5)
Immature IPOPA in 2001 Mature IPOPA in 2001	1,084,090 Hectares 3629345 Hectares	USDA-FAS, 2010 ; MARI, 2010 (Figure 4.11)

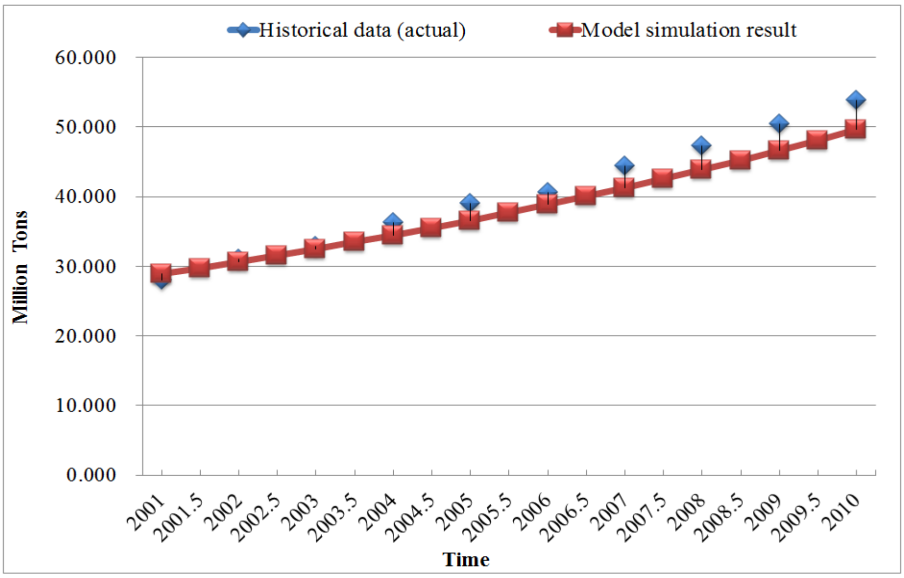

Figure 5-3. Historical data versus extrapolation of global palm oil demand for 2001 to 2010.

Table 5-2. Mean absolute percent error for Global palm oil demand.

Year	Global Palm Oil Demand (Million tons)		MAPE [%]
	Historical Data	Model Output	
2001	28.086	28.921	2.973
2002	31.021	30.650	1.197
2003	32.896	32.500	1.205
2004	36.287	34.479	4.981
2005	39.053	36.598	6.285
2006	40.619	38.867	4.313
2007	44.418	41.296	7.029
2008	47.371	43.896	7.335
2009	50.442	46.681	7.456
2010	53.887	49.663	7.838
Mean Absolute Percent Error (MAPE)			5.061

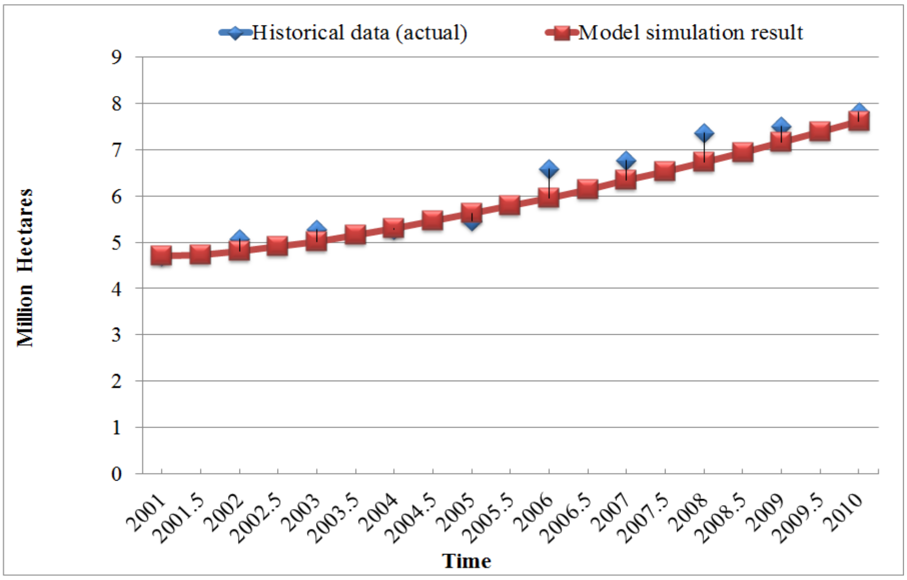

Figure 5-4. Historical data versus extrapolation of Indonesia palm oil plantation area for 2001 to 2010.

Table 5-3. Mean absolute percent error for the total of Indonesia palm oil plantation area.

Year	**Total Indonesia Palm Oil Plantation Area (hectare)**		**MAPE [%]**
	Historical Data	**Model Output**	
2001	4713435	4713435	0.000
2002	5067058	4801741.84	5.236
2003	5283557	5022145.74	4.948
2004	5284723	5302938.93	0.345
2005	5453817	5619559.78	3.039
2006	6594914	5964305.21	9.562
2007	6766836	6335551.31	6.374
2008	7363847	6733920.65	8.554
2009	7508023	7160923.49	4.623
2010	7824623	7618480.49	2.635
Mean Absolute Percent Error (MAPE)			4.531

5.4 Extreme condition

A proper model should be worked plausibly in all conditions although it is imposed by extreme conditions or unrealistic conditions. This testing was to check the basic logic of the concepts, equations, input values and policies of the model. The extreme condition testing for this model was focused on the main drivers (i.e. world population and GDP, see section 3.5 point b) that cause increasing or decreasing of the GPO demand which eventually have impacton both CO_2 emissions and CPO yield as the result of the establishment of palm oil plantations. Thus, scenario for extreme conditions might be like following:

'starting from 2015, there is no driving force that cause increasing the GPO demad, the number of world population and the world GDP will remain constant at 2015 level until 2020

Or

what should be happened when starting in 2015 there are no population growth and GDP growth?'

Actually, the purpose of testing was to isolate effect of the driving forces. For interactive experimentation, the parameters that will be under author's control to change base run scenario into extreme scenario was presented in simple SD management flight simulators, it was also as illustration to understand easily (see figure 5-5). Thus, the model was set:

1. Model will simulate base run before 2015, where there was no change in the input values.
2. In 2015, the parameters of crude birth rate, crude death rate and GDP growth rate were set to zero.

Figure 5-6 to 5-11 showed the variables under extreme condition and base run. The variables of world population (figure 5-6) and world GDP (figure 5-7) under extreme scenario kept at the level of 2015 until 2020. Since it was assumed that increasing people income will trigger more consumption in palm oil, therefore there should be no increasing of palm oil consumption per capita (figure 5-8). Also there should be no increasing of the GPO demand (figure 5-9), since it was estimated by multiplying the world population with the palm oil consumption per capita. Furthermore, net CO2 emissions and CPO yield trends will also correspond to the pattern.

Author ran other scenarios for extreme condition or impossible cases, in each case model could respond plausibly. The model had demonstrated that the model still could behave realistically although the model was imposed by extreme input values (in this case is zero). Such as has been shown in figure 5-13 to 5-18, those figures answered the question:

'what should be happened when starting in 2014 there is no GDP growth whereas the population growth continues as base run?'

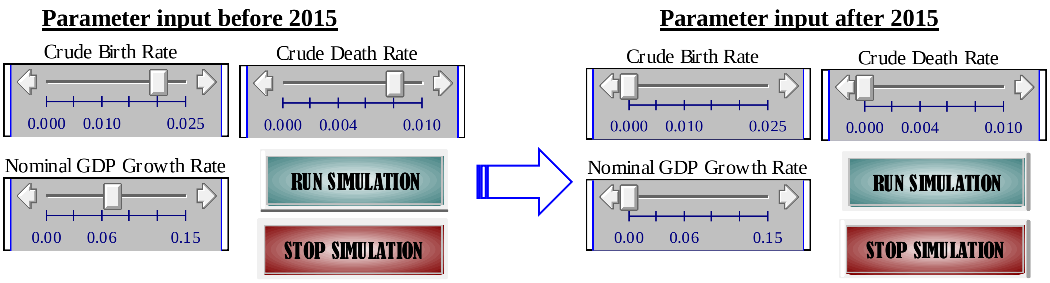

Figure 5-5. Simple SD management flight simulators for extrime condition testing-1.

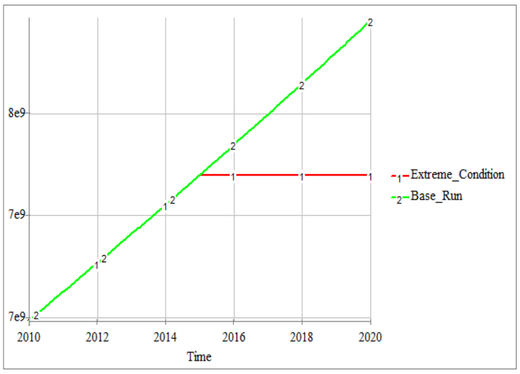

Figure 5-6. World population (person)

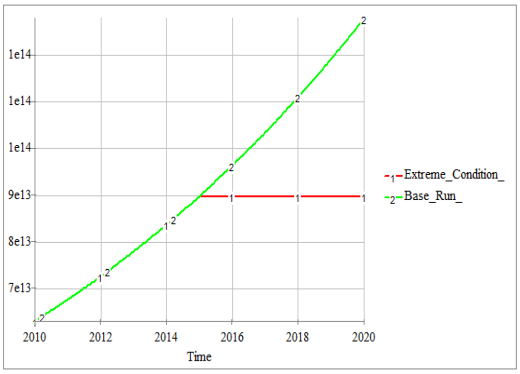

Figure 5-7. World GDP (USD)

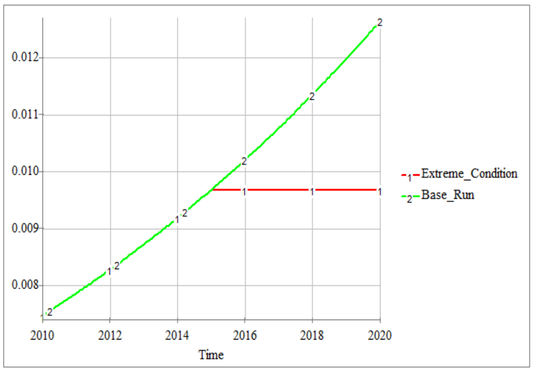

Figure 5-8. Palm oil consumption per capita (ton)

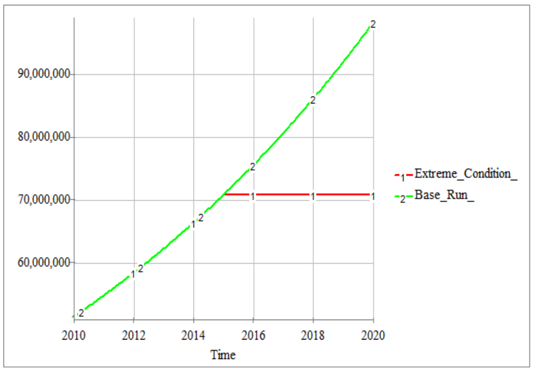

Figure 5-9. Global plam oil demand (ton)

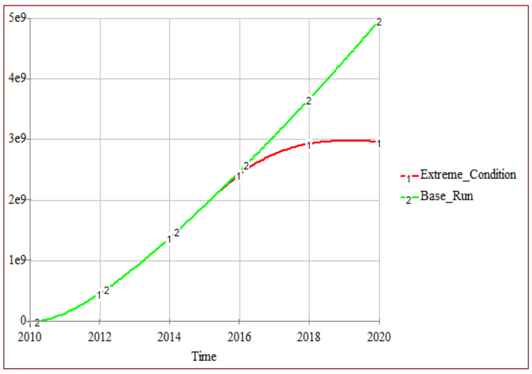

Figure 5-10. Net carbon dioxide emissions (ton)

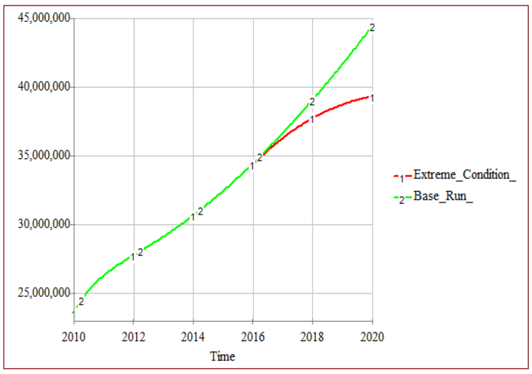

Figure 5-11. Crude palm oil yield (ton)

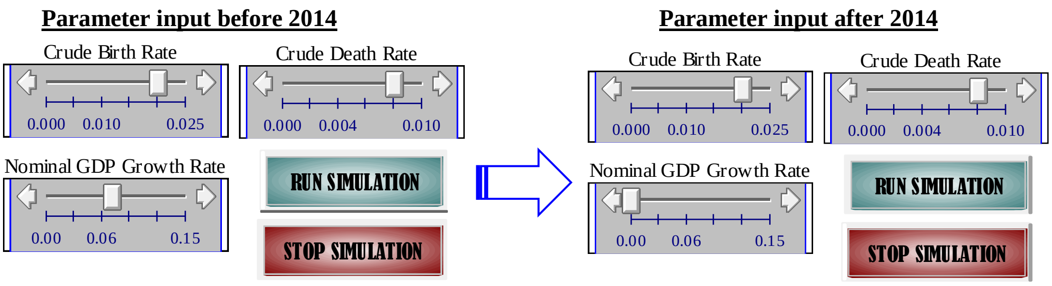

Figure 5-12. Simple SD management flight simulators for extrime condition testing-2.

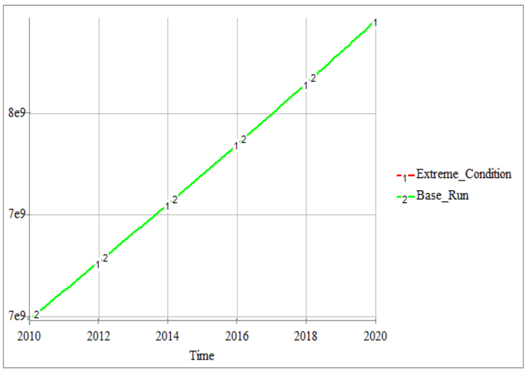

Figure 5-13. World population (person)

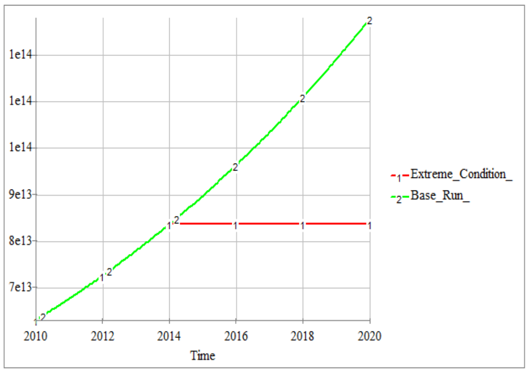

Figure 5-14. World GDP (USD)

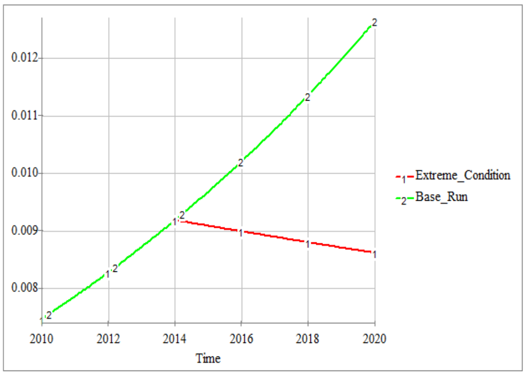

Figure 5-15. Palm oil consumption per capita (ton)

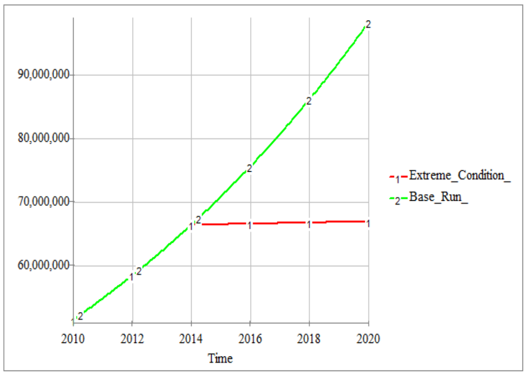

Figure 5-16. Global plam oil demand (ton)

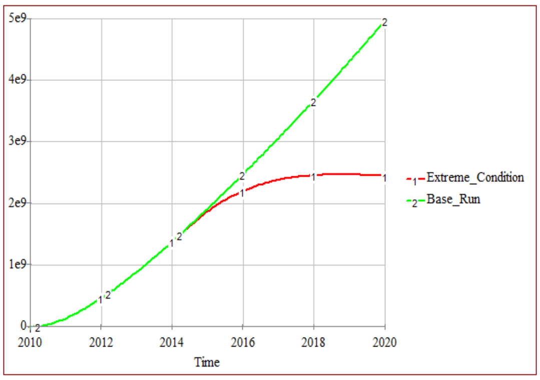

Figure 5-17. Net Carbon Dioxide emissions (ton)

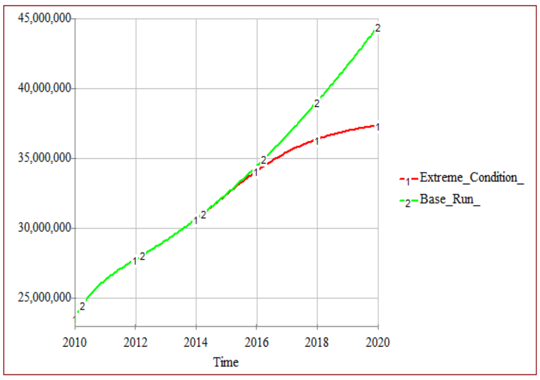

Figure 5-18. Crude palm oil yield (ton)

5.5 Sensitivity Analysis

Real system is full of uncertainties, the same thing certainly happens for a model that is made as a substitute of the real system. The uncertainties of the model comes from the uncertain parameter inputs, either constant value or function inputs which were as the modeler's argument to describe the real system. In this way of thinking, therefore we can convert the uncertainty of the model into the uncertainty of those parameter inputs [Morgan and Henrion, 1990][91]. Sensitivity analysis is a key testing in the modeling process of SD to reveal the uncertainty in many parameter inputs [Ford, 2010][92]. It is also used to determine how the sensitivity of a model to the changes, and to help the modeler understand the dynamics of the system being studied [Breierova and Choudhari, 2001][93]. However, sensitivity analysis requires much more than varying parameters under the plausible range of uncertainty. Actually, models are typically much more sensitive to assumptions about the boundary and formulations than to uncertainty in numerical input values [Sterman, 2000][94].

In this sensitivity analysis, author only focused on constant parameters. Since author is never to be able to estimate the parameters perfectly. In order to determine the plausible range of uncertainty for each parameter, author referred to their historical data (section 4.4). Owing to many modeler have argued that a comprehensive sensitivity testing that requires all combinations of assumptions testing is not possible. Hence, it makes sense to select only a few scenarios of special interest for examination [Morgan and Henrion, 1990][95]. This sensitivity analysis was conducted by parameter combination testing (multivariate) which was packaged in the form of best, base run, and worst scenarios.

The illustration of a comprehensive sensitive analysis is not possible is as follows. The model of this study has 59 of constant and function parameters in total. If author assumed that all of those parameters are uncertain inputs, author then want to test 3 possible combinations of the parameters, that is 3 combinations of parameters for the first test, 3 values for the second test, and so forth.

How many should author conduct simulation?

Total number of simulation is 3 to the 59th power (3^{59}) = 1.413×10^{28} simulations

Briefly, assumptions for worst and best scenarios are as follows.

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91 Morgan, M.G. and Henrion, M. *Uncertainty: A Guide to Dealing with Uncertainty in Quantitative Risk and Policy Analysis.* Cambridge: Cambridge University Press, 1990.

92 Ford, A. *Modeling the Environment.* Washington, DC: Island Press, 2010.

93 Lucia Breierova, L. and Choudhari, M.. *An Introduction to Sensitivity Analysis.*Massachusetts Institute of Technology, 2001.

94 Sterman, J. *Business Dynamics: Systems Thinking and Modeling for a Complex World.* Boston: McGraw-Hill Higher Education, 2000.

95Morgan, M.G. and Henrion, M.*Uncertainty: A Guide to Dealing with Uncertainty in Quantitative Risk and Policy Analysis.*Cambridge: Cambridge University Press, 1990.

- The worst case scenario might assume: the people income will not be so good which is indicated by world demographic and economic circumstances in the future. Where population growth will increase fast and GDP will grow at a slower rate. Also, the market share of Indonesia palm oil is small in the global palm oil market. Furthermore, somehow, it is needed longer time to establish full palm oil plantation area (mature plantation) which might be because it is caused by, for instance, it is difficult to get the permit for forest land conversion and utilization (concession), unfavorable weather for planting, plantation management which is not going well, so forth.
- The best case scenario might assume: the people income will be good overtime which is indicated by world population growth that will increase at a slower rate and world GDP that will grow faster. Also, the market share of Indonesia palm oil in the palm oil global market is quite big enough. Furthermore, the needed time to establish full palm oil plantation area (mature plantation) is faster than other scenarios, and the productive time of palm oil crop in the mature plantation is longer than other scenarios

The assumption and its parameter input values of best, base run, and worst scenarios for this sensitivity analysis testing are described in table 5-4.

The model simulation result (figure 5-20 to 5-23) have shown the pattern of behavior in the best and worst scenarios were same with base run that is exponential growth. However, the implications for future palm oil demand until the endpoint indicators (net CO2 emissions and CPO yield) were very different.

In the best scenario, a good circumstances in future will trigger higher palm oil consumption which also means faster palm oil demand. As a consequence, vast areas of forest will be converted into palm oil plantations to respond the demand. The impact is big amount Carbon will be realized to atmosphere as result of forest clearing. On the other hand, higher CPO also will be produced to fulfill the demand.

The worst scenario was opposite to the best scenario, the palm oil demand grows at slower rate since people depress their consumption on the palm oil. The differences in implication are apparenton both endpoint indicator graphs (figure 5-21 and 5-22), where increasing net CO_2 emission will be started after 2016 and CPO production will be stagnant then increased at a slower rate. It is because the existing Indonesia palm oil plantation area in 2010 is still enough to fulfill the demand until 2016 (figure 5-23) or in the ideal of the law of supply and demand, there will be no expansion in the palm oil industry sector until 2016.

Table 5-4. Best, base run, and worst scenarios for sensitivity analysis testing.

Parameters	**Worst Scenario**	**Base Run Scenario**	**Best Scenario**
World Population	population growth goes faster	population growth close to historical data	population growth goes slow
Initial Condition	6894377794 persons (Population Data in 2010 ; see figure 4-3)	6894377794 persons (Population Data in 2010 ; see figure 4-3)	6894377794 persons (Population Data in 2010 ; see figure 4-3)
Crude Birth Rate (CBR)	21 per 1000 persons (the highest data of historical data, i.e in 2001 ; see figure 4-4)	20 per 1000 persons (on average data of 2001 to 2010 ; see figure 4-4)	14 per 1000 persons (CBR is 70% of base run -assumption-)
Crude Death Rate (CDR)	8 per 1000 persons (on average data of 2001 to 2010 ; see figure 4-4)	8 per 1000 persons (on average data of 2001 to 2010 ; see figure 4-4)	8 per 1000 persons (on average data of 2001 to 2010 ; see figure 4-4)
World GDP	GDP growth goes slow	GDP growth close to historical data	GDP growth goes faster
Initial Condition	63.136E+12 USD (GDP data in 2010 ; see figure 4-5)	63.136E+12 USD (GDP data in 2010 ; see figure 4-5)	63.136E+12 USD (GDP data in 2010 ; see figure 4-5)
Nominal Growth Rate	5.31% (the nominal GDP growth rate is 75% of base run -assumption-)	7.08% (on average data of 2001 to 2010 ; see figure 4-6)	12.75% (the highest data of historical data, i.e. in 2007 ; see figure 4-6)
Market Share of Indonesia Palm Oil (IPO)	IPO Market share in the global market of palm oil is not good	IPO Market share in the global market of palm oil is quite good enough	It is same with base run
	29.85% (the lowest data of historical data, i.e. in 2004 ; see figure 4-10)	42.72% (the highest data of historical data, i.e. in 2006 ; see figure 4-10)	42.72% (the highest data of historical data, i.e. in 2006 ; see figure 4-10)
New Plantation Establishment	The process to full established plantation (mature plantation) will take longer than the base run. Whereas the productive time of mature plantation is same with base run	The process to full established plantation (mature plantation) will takes about 3.76 years. Whereas the productive time of mature plantation is 22 year	The process to full established plantation (mature plantation) will take shorter than the base run. Whereas the productive time of mature plantation is longer than base run
Land preparation time	1.5 years (assumption)	1 year (assumption)	0.66 year (see section 4.4.8, table 4-1)
Immature maintenance time	1.5 years (assumption)	1.38 year (see section 4.4.8, table 4-1)	1.38 year (see section 4.4.8, table 4-2)
Mature maintenance time	1.5 years (assumption)	1.38 year (see section 4.4.8, table 4-1)	1.38 year (see section 4.4.8, table 4-2)
Productive time	22 years (the shortest lifetime of Palm oil crop ; see table 4-2)	22 years (the shortest lifetime of Palm oil crop ; see table 4-2)	30 years (the longest lifetime of Palm oil crop ; see table 4-2)

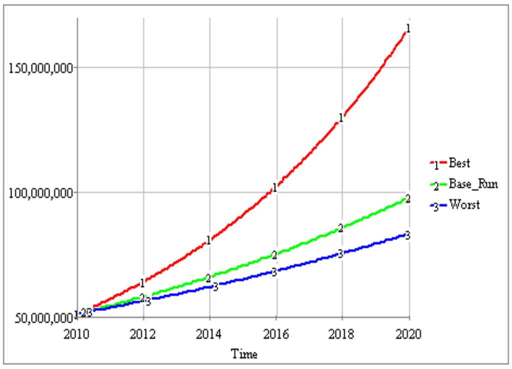

Figure 5-19. Global palm oil demand (ton)

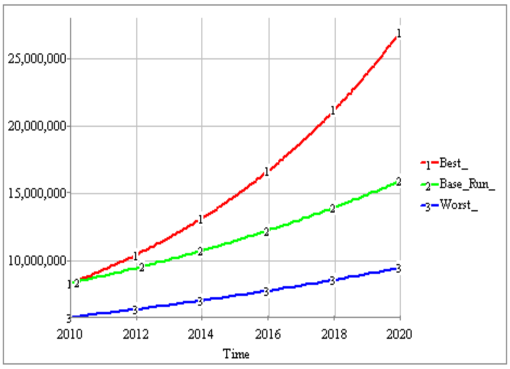

Figure 5-20. Land use demand for Indonesia palm oil (hectare)

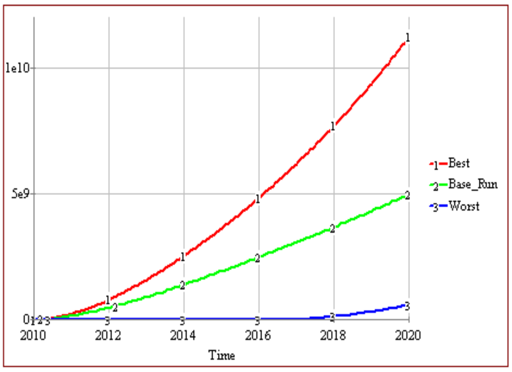

Figure 5-21. Net carbon dioxide emissions (ton)

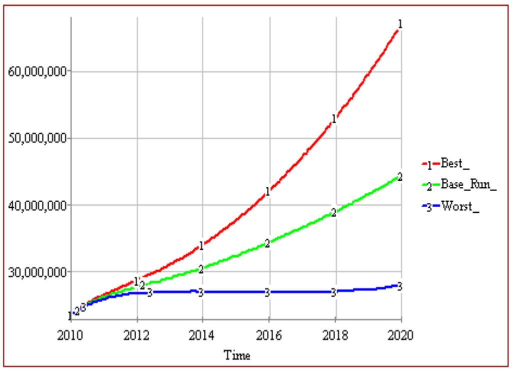

Figure 5-22. Crude palm oil yield (ton)

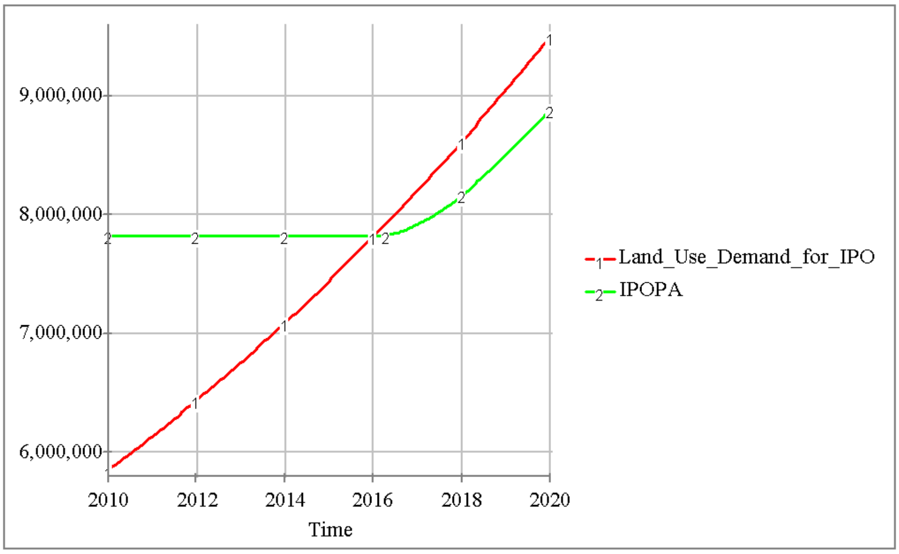

Figure 5-23. Comparison between land use demand and existing plantation areas of Indonesia palm oil (hectare)

According to Sterman [2000][96] and Ford [2010][97], sensitivity analysis testing is recognized as key testing to assess the robustness of the model, since the testing will answer whether the results or conclusions will be changed when we imposed the model by variation of assumptions that is still in the plausible range of uncertainty.

This testing has demonstrated the sensitivity analysis by using 8 combinations of constant parameters for each scenario. The result has showed that the model was able to produce the same pattern of behavior, it means the uncertainty in many parameter inputs will not change our conclusion. Thus, author could confirm that the model is robust and sensitive to the changes.

5.6 Conclusion

Several tests of the model validation procedures had been conducted to the model. The main purpose of those testing is to uncover errors, flaws and shortcomings. Author acknowledged that during model validation process, author found some mistakes in this model, it then lead to revisions at qualitative and or quantitative stages of the modeling process.

By several tests that were imposed, the results have shown that the model was able to produce realistic and reasonable behavior. Author could confirm that the model has passed the model validation testing especially for dimensional consistency, reference mode behavior, historical data reproduction, extreme condition, and sensitivity analysis. Moreover, the sensitivity analysis, the test that could reveal the uncertainty in many parameter inputs, had showed the robustness of our conclusions to uncertainty of our assumption. However, author will never be able to say that the model is true. However, in general, author could say that the model is useful to generate insight into and understanding including for policy analysis.

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[96]Sterman, J. *Business Dynamics: Systems Thinking and Modeling for a Complex World.* Boston: McGraw-Hill Higher Education, 2000.

[97]Ford, A.*Modeling the Environment.* Washington, DC: Island Press, 2010.

CHAPTER VI
SIMULATION RESULT AND DISCUSSION

6.1 Introduction

Author developed and applied the system dynamics model in order to understand the impacts of the moratorium policy on the economy and environment of Indonesia. To do so, author picked up one vital agricultural industry sector of Indonesia as case study (palm oil industry sector). The focus of study lies at the interrelationships between the supply-demand system of palm oil and the moratorium policy implementation. The demand side covers the demand of palm oil for international (global) and national level. The supply side is production process of palm oil which is limited in the plantation phase only.

Author argued that limiting the production processes of palm oil is only in the plantation phase is sufficient to gain insight and understanding about the policy intervention. Since the approach of the REDD-plus to address the GHG emissions is through forest conservation programs. Also, there is clear evidence data that most palm oil plantations are located where there was formerly tropical forest and the conversion of tropical forests to palm oil plantations is still continuing [Reijnders and Huijbregts, 2008][98]

The simulations were conducted in two scenarios which depicted 'without policy' (BAU) and 'with policy' (MP). The difference between the two scenarios is only on the implementation of a two-years moratorium policy on new forest and peatland concessions. Where, the assumption for MP scenario was made in ideal situation, even lead to extreme condition for the model base run (see table 4-7). Other alternatives of the MP scenario based on the story in real situation will also be simulated. Furthermore, CPO yield and net CO_2 emission were chosen as sustainability indicators to evaluate the policy which represent economic and environmental perspectives respectively. The simulation is run for a span of 10 years (horizon time of the model) starting from the year 2010 to 2020.

6.1 Model Base Run Result

The result of model base run here means the results that are based on the scenarios including assumptions which had been stated and described in chapter III and IV. Thus, the parameter inputs for the model either constant value or function were set based on that had been described in chapter IV. Hence, when there is need to change in the parameter inputs.

[98]Reijnders, L. and Huijbregts, M.A.J. Palm Oil And The Emission of Carbon-Based Greenhouse Gases. *Journal of Cleaner Production*, Vol.16, pp. 477-482, 2008.

6.1.1 Palm Oil and Land Use Demands

Future demand here is the projection of each important variable within the demand sub-model. The numerical simulation result for the projection of future world economic and demographic situations which are represented by population and GDP variables, and its effecton palm oil consumption which in turn is as the future global demand of palm oil (*variable name in the model: GPO Demand*) when the final act of consumption will actually take place are presented in time series in table 6-1.

In the year 2010, world population was 6.9 Billion person. It projected will be reached 7.8 Billion Person by the year 2020. It will be around 1.13 times higher than in 2010 or has increased by around 13% in total within 10 years (2010-2020).

The world GDP will reach 128 Trillion USD in 2020 or it is around 2 times higher than in 2010. This trend actualy is same with the period 2000 to 2010, that is 32 Trillion USD in 2000 grow to 63 Trillion USD in 2010.

The GDP per capita is projected will be 1.8 times higher than in 2010 that is approximately will be 16462 USD per Capita in 2020.

By using estimation the relationships between GDP per capita and POC per capita (see equation 4-7 for their relationships), with the level of income is estimated will affect to the amount of POC is around 0.0127 Ton per capita or 12.7 Kilogram per capita in 2020.

By the total of world population that will reach 7.8 Billion Person and the POC per person is around 12.5 Kilogram per capita in 2020. Thus, the total GPO demand in 2020 is projected nearly to 98.3 Million Ton.

Subsequently, depending on the percentage of market share and the national productivity per Hectare of IPO, the total palm oil demand for Indonesia (*variable name in the model: IPO*

Table 6-1.Projection of world economic and demographic situations and global palm oil demand

Time	World Population (person)	World GDP (USD)	GDP per Capita (USD per person)	POC per Capita (ton per person)	GPO Demand (ton)
2010	6.89E9	6.31E13	9157.61	0.0075	5.16E7
2011	6.98E9	6.78E13	9710.75	0.0079	5.49E7
2012	7.06E9	7.27E13	10297.3	0.0083	5.85E7
2013	7.15E9	7.8E13	10919.3	0.0087	6.24E7
2014	7.23E9	8.38E13	11578.8	0.0092	6.65E7
2015	7.32E9	8.99E13	12278.2	0.0097	7.09E7
2016	7.41E9	9.65E13	13019.8	0.0102	7.57E7
2017	7.5E9	1.04E14	13.806.3	0.0108	8.08E7
2018	7.59E9	1.11E14	14640.2	0.0114	8.62E7
2019	7.68E9	1.19E14	15524.5	0.012	9.21E7
2020	7.77E9	1.28E14	16462.2	0.0127	9.83E7

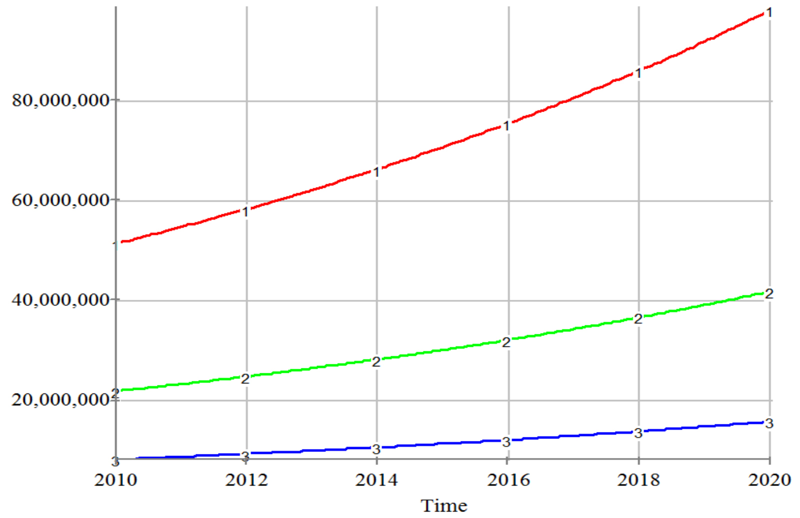


Figure 6-1. Palm oil demand for global and Indonesia levels, and land use demand for Indonesia palm oil.

demand) and the total required land that is needed to meet the demand (Land use demand for IPO) can be projected. The total IPO demand is around 42 Million Ton, while the total land use demand for IPO is around 15.9 Million Hectare in 2020. The simulation result graph for the GPO demand, the IPO demand, and the land use demand for IPO is shown in figure 6-1.

At this point, author emphasizes again that the 15.9 Million Hectare is the total palm oil plantations that should be owned by IPO Industry in 2020 in order to meet the total IPO demand. Hence, the IPO industry sector should estimate the additional land that is needed for expansion over time, which is by taking into account the total existing palm oil plantations that already established in Indonesia (*variable name in the model: Total IPOPA*). The extrapolation data of additional needed land for IPO for both scenarios are presented in table 6-2.

6.1.2 Forest Conversion to Plantation

With regard to the future demand of palm oil, the land use change (forest conversion to plantation) under the BAU and MP scenarios based on simulation result are presented and described as follows.

Numerical simulation result for comparison between the land use demand for IPO and the total IPOPA and its difference (the additional needed land to meet the demand) over time are presented in semiannual in table 6-2. By assumption, the additional needed land which is presented in table 6-2 is actually excuted by IPO industry sector by expanding their plantation on forest area. Thus, the rate of forest conversion to plantation in order to meet the demand under BAU and MP scenarios can be seen in figure 6-2.

Table 6-2. Total plantation area and additional needed land for BAU and MP Scenarios.

Time	Land Use Demand for IPO (hectare)	BAU Scenario		MP Scenario	
		Total IPOPA (hectare)	Additional Needed Land for IPO (hectare)	Total IPOPA (hectare)	Additional Needed Land for IPO (hectare)
2010	8.37E6	7.82E6	548234	7.82E6	548234
2010.5	8.64E6	8.1E6	543357	8.1E6	543357
2011	8.92E6	8.37E6	548059	8.37E6	0
2011.5	9.2E6	8.65E6	558749	8.37E6	0
2012	9.5E6	8.93E6	573295	8.37E6	0
2012.5	9.81E6	9.22E6	590434	8.37E6	0
2013	1.01E7	9.52E6	609424	8.37E6	1757642
2013.5	1.05E7	9.83E6	629833	9.14E6	1314997
2014	1.08E7	1.01E7	651413	9.74E6	1060264
2014.5	1.12E7	1.05E7	674030	1.02E7	917998
2015	1.15E7	108.E7	697614	1.07E7	843195
2015.5	1.19E7	1.12E7	722137	1.11E7	809008
2016	1.23E7	1.15E7	747595	1.15E7	799433
2016.5	1.27E7	1.19E7	773999	1.19E7	804931
2017	1.31E7	1.23E7	801370	1.23E7	819828
2017.5	1.35E7	1.27E7	829734	1.27E7	840748
2018	1.4E7	1.31E7	859122	1.31E7	865695
2018.5	1.45E7	1.36E7	889569	1.36E7	893491
2019	1.49E7	1.4E7	921110	1.4E7	923450
2019.5	1.54E7	1.45E7	953784	1.45E7	955180
2020	1.6E7	1.5E7	987631	1.5E7	988464

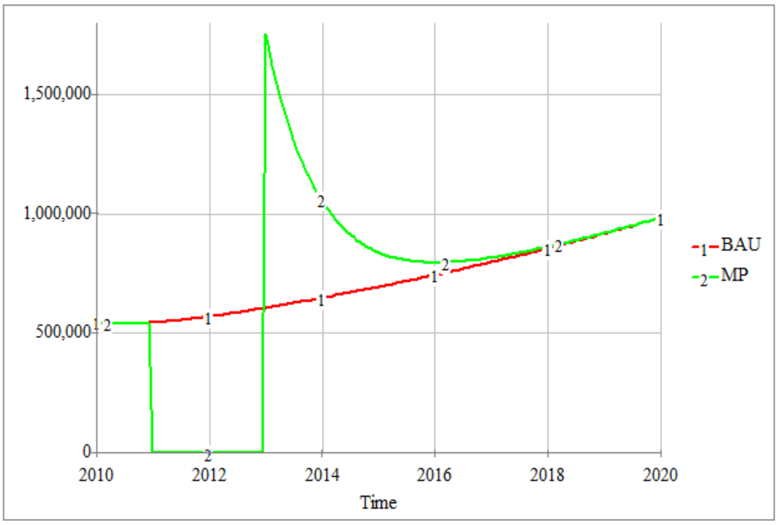


Figure 6-2. Forest conversion to palm oil plantation in order to meet the demand (hectare).

BAU scenario shows the forest conversion to plantation is gradually increasing over time in line with the demand. Whereas under MP scenario, the forest conversion to plantation grows exponentially at first, it then was interrupted by the moratorium policy which is shown by the line graph that dropped dramatically to zero during period 2011 to 2013. Thereafter, the forest conversion to plantation will be higher suddenly starting from 2013, followed by an exponential decline until MP reaches BAU level at around the period of 2019 to 2020.

A sudden peak happens in 2013 might be understood as follows: after the moratorium policy expires in 2013, the IPO industry sector will try to repay their lag for 2 years to meet demand, they then try add their production capacity by broosting the expansion to pursue the demand.

6.1.3 Palm Oil Plantation Area in Indonesia

After the forest conversion process (forest clearing)[99], the land would becomes new plantation area that is the type of plantation which is still in the stage of preparation and under cultivation processes. The model recorded physically the accumulation of the forest conversion to plantation in the new IPOPA stock. It then will continue to undergo the plantation establishment and management processes. Other results of the plantation establishment and management processes are shown in figure 6-3 to figure 6-6.

There is a marked difference in the line graph behavior between BAU and MP scenario in the four plantation types above. However, the general patterns for both scenarios are similar with the forest conversion to plantation (figure 6-2). The thing that makes different is only on the initial condition input value. Due to there is difficulty in obtaining the data, therefore the initial condition for the new and unproductive IPOPA were set zero.

The number of the new IPOPA under moratorium (figure 6-3) is increase at first, it then is decline during the implementation of moratorium policy. The decline is because there is suspension on the plantation expansions at the time and on the other hand the new IPOPA has growing into the immature IPOPA. Thereafter, the dramatic increase in number of the new IPOPA will happen in line with the effort of IPO industry sector to pursue the demand after the moratorium policy is expired.

The number of the immature IPOPA (figure 6-4) under both scenarios is decline at first time, then followed by increasing over time. This behave happens because the initial condition for the new IPOPA which was set zero. Consequently, there is no the new IPOPA that becomes the immature IPOPA at the first, and after that the number of the new IPOPA that becomes the immature IPOPA is increasing gradually.

Figure 6-5 clearly shows that the mature IPOPA growth is slower under MP scenario compare to BAU scenario. Although, it will be virtually identical (in the same level) in someday after 2020. Increasing number of the mature IPOPA grows slower under MP scenario is because

[99] The process of forest conversion to plantation area (forest clearing) is part or initial stage of the plantation establishment and management processes (see section 4.5.4 for detail)

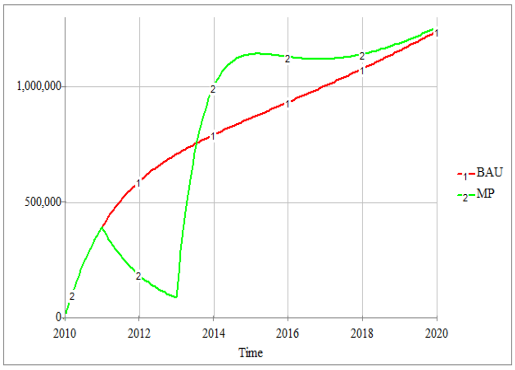


Figure 6-3. New Indonesia palm oil plantation area (hectare)

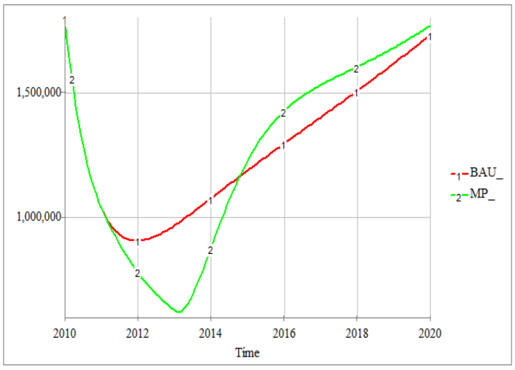


Figure 6-4. Immature Indonesia palm oil plantation area (hectare)

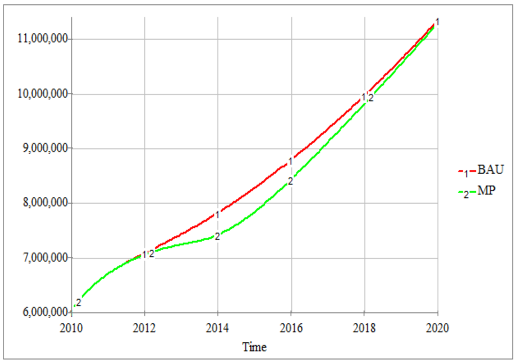


Figure 6-5. Mature Indonesia palm oil plantation area (hectare)

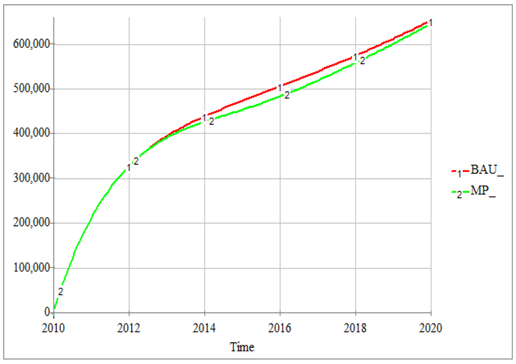


Figure 6-6. Unproductive Indonesia palm oil plantation area (hectare)

there is a temporary suspension on the plantation expansions as result of the implementation of the policy. Thus, the immature IPOPA which grows into the mature IPOPA is only from the stock of the immature IPOPA which is before the implementation of the policy

The similar thing also happen to the unproductive IPOPA (figure 6-6), that is the number of the unproductive IPOPA grows slower under MP scenario, since it depends on the the number of the mature IPOPA.

6.1.4 Endpoint of Sustainability Indicator

Author emphasizes that the CO_2 emissions that was estimated over time by the model is net CO_2 emissions, since it was taking into account both Carbon debt and Carbon repayment (see chapter 4, section 4.2.5.1). The annual carbon balance for BAU and MP scenarios are shown in figure 6-7 and 6-8 respectively. Figure 6-9 shows comparison result of annual net CO_2 emissions under BAU and MP scenarios. The comparison result of cumulative net CO_2 emissions under BAU and MP scenarios is presented in figure 6-10.

The figure 6-10 shows clearly there is a substantial increase in CO_2 emissions for both scenarios, due to IPO industry expansion. The moratorium policy has a positive impact on

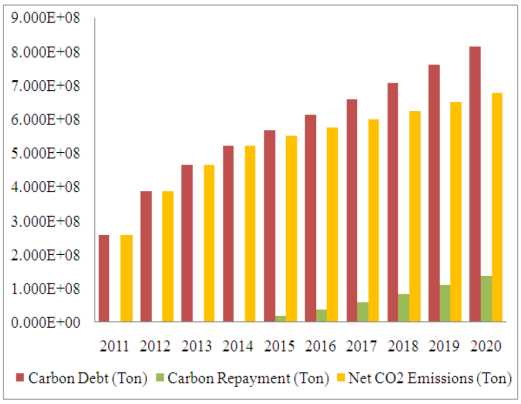


Figure 6-7. Annual carbon balance of BAU scenario (ton)

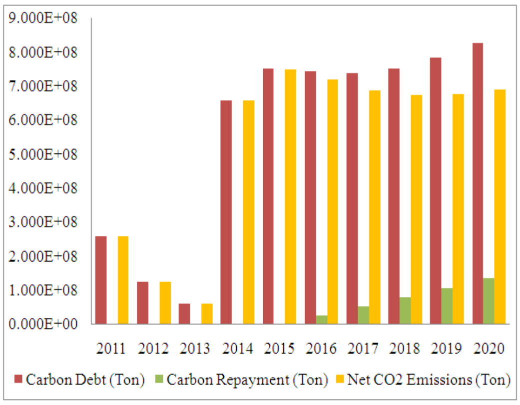
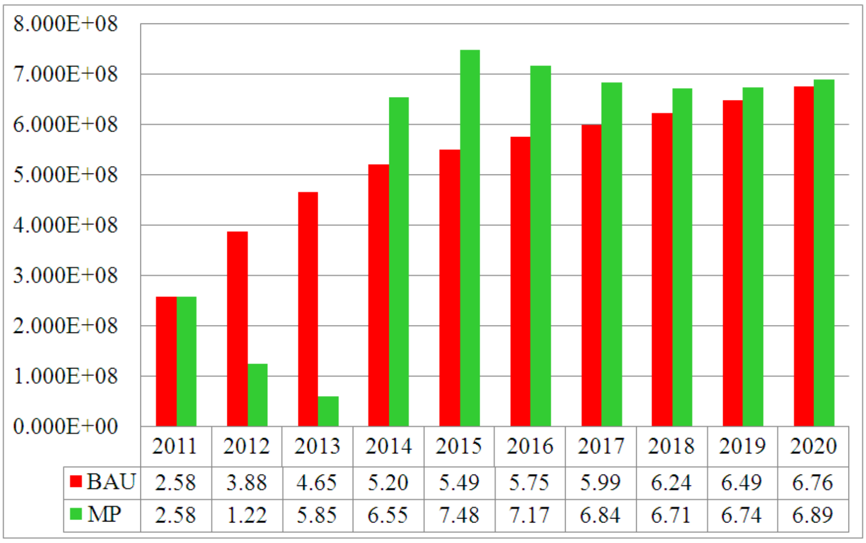


Figure 6-8. Annual carbon balance of MP scenario (ton)



	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
BAU	2.58	3.88	4.65	5.20	5.49	5.75	5.99	6.24	6.49	6.76
MP	2.58	1.22	5.85	6.55	7.48	7.17	6.84	6.71	6.74	6.89

Figure 6-9. Annual net carbon dioxide emissions for BAU and MP scenarios (ton).

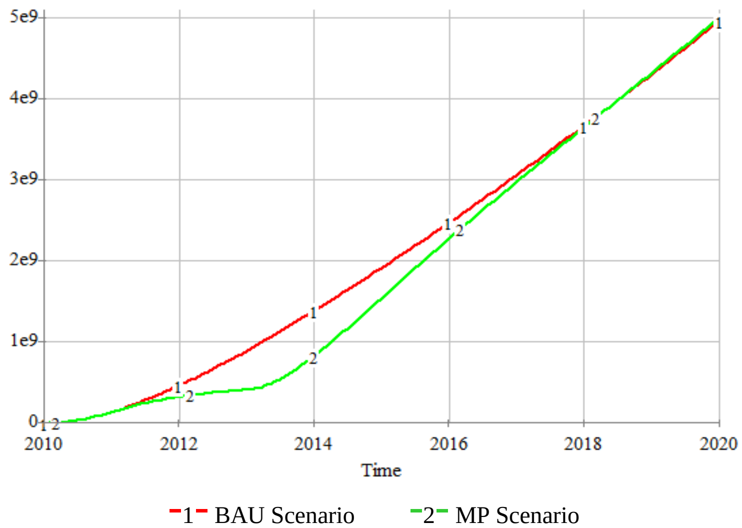


Figure 6-10. Cumulative net carbon dioxide emissions under BAU and MP scenarios (ton).

Table 6-3 Carbon balance for BAU and MP Scenarios.

Time	BAU Scenario				MP Scenario				Difference of Annual Net CO_2 Emissions (ton)	Difference of Cumulative Net CO_2 Emissions (ton)
	Carbon Debt (ton)	Carbon Repayment (ton)	Annual Net CO_2 Emissions (ton)	Cumulative Net CO_2 Emissions (ton)	Carbon Debt (ton)	Carbon Repayment (ton)	Annual Net CO_2 Emissions (ton)	Cumulative Net CO_2 Emissions (ton)		
2010	0	0	0	0	0	0	0	0	0	0
2011	2.580E8	0	2.580E8	2.580E8	2.580E8	0	2.580E8	2.580E8	0	0
2012	3.882E8	0	3.882E8	6.462E8	1.229E8	0	1.229E8	3.809E8	2.653E+08	2.653E8
2013	4.651E8	0	4.651E8	1.111E9	5.856E7	0	5.856E7	4.395E8	4.065E+08	6.718E8
2014	5.205E8	3.878E5	5.201E8	1.631E9	6.555E8	0	6.555E8	1.095E9	-1.354E+08	5.364E8
2015	5.678E8	1.809E7	5.497E8	2.181E9	7.492E8	9.598E5	7.482E8	1.843E9	-1.985E+08	3.379E8
2016	6.132E8	3.804E7	5.752E8	2.756E9	7.413E8	2.421E7	7.171E8	2.560E9	-1.419E+08	1.960E8
2017	6.594E8	6.003E7	5.994E8	3.356E9	7.353E8	5.054E7	6.848E8	3.245E9	-8.536E+07	1.106E8
2018	7.079E8	8.394E7	6.240E8	3.980E9	7.493E8	7.806E7	6.713E8	3.916E9	-4.730E+07	6.335E7
2019	7.594E8	1.098E8	6.496E8	4.629E9	7.810E8	1.064E8	6.747E8	4.591E9	-2.510E+07	3.825E7
2020	8.144E8	1.375E8	6.769E8	5.306E9	8.254E8	1.357E8	6.897E8	5.281E9	-1.280E+07	2.545E7

Note: Due to the model only took into account the Carbon balance as result of the palm oil plantation expansion after 2010 (see section 4.5.5). Hence, we could see that all values in 2010 is zero. Whereas the value of Carbon repayment that are still zero after 2010 could be understood that the planted palm oil crop on the plantation area are still in the process of growing. It takes time from new plantation becomes full-established plantations (mature plantation) that was used as parameter to calculate carbon repayment.

CO_2 emissions reduction (evironment). Although the two emission trends of BAU and MP are virtually identical in the end (after 2020). However, during the transition period from 2012 to 2020, CO_2 emissions is noticeably reduced by the implementation of a two-year moratorium policy. For more details, table 6-3 listed a numerical simulation result for the emission trends in a carbon balance perspective of this study. Under MP scenario, the average of annual reduction of CO_2 emissions from 2010 to 2020 is estimated around 2.3 Million Ton per year compare to BAU scenario.The amount reduction of cumulative CO_2 emissions is greatest in 2013, that is in the year when the moratorium ends. The cumulative CO_2 emissions under MP scenario in 2013 is nearly 60.5% below the BAU scenario. However,the precentage of reduction then will continue to decrease until the CO_2 emissions under MP scenario closes to BAU scenario (virtually identical). This is in line with the acceleration rate of the plantation expansion to pursue the demand. Thus, without further policy instruments which are as a continuation strategy to reduce emissions from deforestation, the moratorium policy on new forest concession which is only temporary for 2 years will be able to reduce CO_2 emissions which are only temporary as well.

The comparison result for CPO yield under BAU and MP scenarios is presented in figure 6-11 to 6-13. Consistent with the equilibrium of supply-demand, from the figure, we could see clearly that the moratorium policy has a negative impacton the IPO industry sector (economy). The policy will hamper the IPO industry sector to increase their capacity production in line with the demand.

Although in the end, the IPO industry will be able to increase smoothly their production capacity match with the BAU level. However, figure 6-13 clearly shows that the slowdown in production capacity as result of the moratorium policy seems still can not be paid by IPO industry even until 2020. It is still needed an additional time for the IPO industry to pursue their lag in production capacity in order to be equal with the BAU level.

The slowdown in production capacity is because the moratorium policy suspends the plantation expansions which automatically make the number of mature IPOPA grows slower

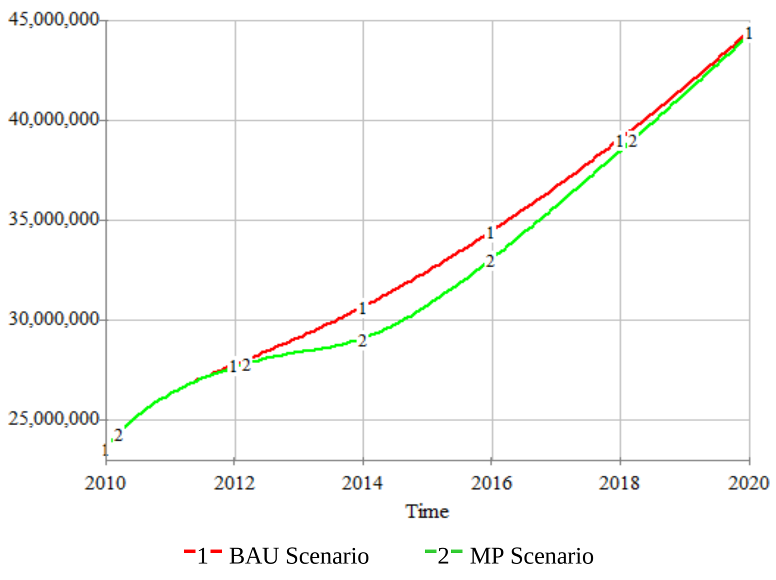
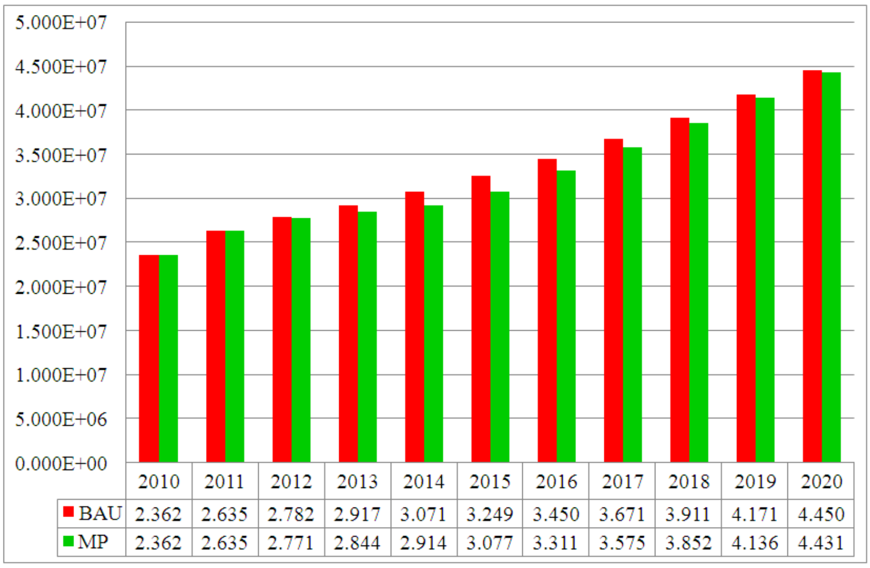


Figure 6-11. Annual crude palm oil yield under BAU and MP scenarios (ton).



	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
BAU	2.362	2.635	2.782	2.917	3.071	3.249	3.450	3.671	3.911	4.171	4.450
MP	2.362	2.635	2.771	2.844	2.914	3.077	3.311	3.575	3.852	4.136	4.431

Figure 6-12. Annual crude palm oil yield under BAU and MP scenarios (ton).

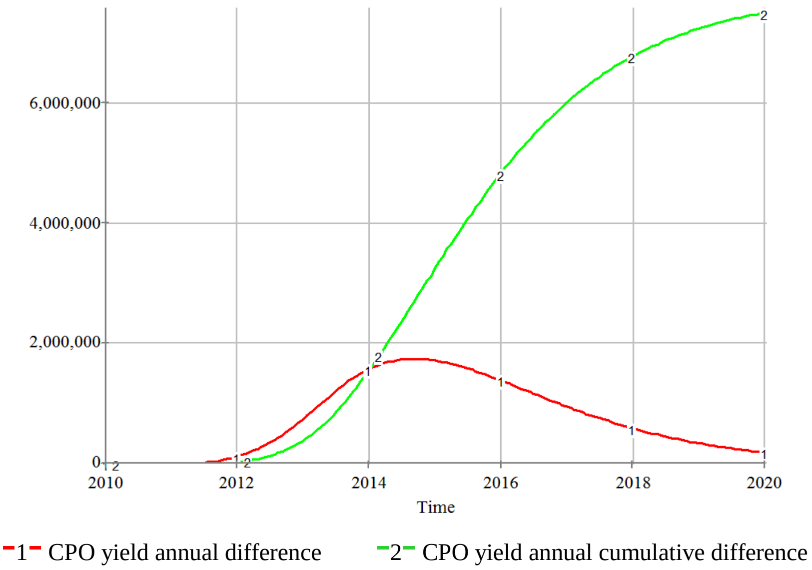


Figure 6-13. The difference yield of crude palm oil under BAU and MP scenarios (ton).

than BAU scenario (as has been described previously). Consequently, it will determines the production capacity of IPO.

Under MP scenario, the average of annual decline of CPO production from 2010 to 2020 is estimated will reach 0.7 Million tons per year compare to BAU scenario. The greatest decline in CPO production will be happened during periode from 2014 to 2016, that is in the range of 1.4 to 1.7 Million tons per year.

6.2 Policy Analysis

Policy analysis at this stage is intended to run the model with other plausible scenarios in order to get insight and understanding about the system being studied. What-if approach was used for this policy analysis. The scenarios for policy analysis will use different assumptions than base run scenario. Thus, It will change the parameter input either constant value or function. The simulation result of model base run and alternative scenario will be compared in model behavioral graphs.

6.2.1 Extending the Moratorium Policy Period

There is debate among stakeholders in Indonesia as result of the announcement of Indonesia's Forestry Minister that he will give a recommendation to the President that the moratorium policy should be extended when it expires in May 2013. The Ministry of Forestry will recommend extending the moratorium policy until the 2014 [Pasandaran, 2012][100]. Strong rejection came not only from industry association that rely on forest conversion and utilization, but also from parliament.

According to the House of Representatives forestry and agriculture commission: '*the reward (from REDD-plus cooperation) is not equal to the economic potential being lost in the forest sector*', for instance, Indonesia was losing too much money setting up reforestation projects, when it could be issuing more permits for palm oil plantations. Since the government receives nearly 300 applications for new palm oil plantations every year, it then approves around 70 to 80 concessions per year, where one plantation with the area of 10,000 hectare can provide work for entire villages in rural Indonesia.

By given dinamics of the situation above that the moratorium policy will be extended until 2014. Thus, the assumption for alternative policy of MP scenario is to follow the proposed recommendation. The alternative policy for MP scenario (called MP Alt.1)is as follows.

'*The moratorium policy will suspend the palm oil plantation expansion for 3 years started from 2011, the expansion will continue after the moratorium policy expires in 2014*'

As could be predicted (figure 6-16), if the period of moratorium policy is extended more 1 year, the trend of MP alternative-1 scenario is similar with MP scenario. Compares to MP scenario, the difference is, the amount of CO_2 emissions reduction will be higher and the slowdown in production capacity will be higher, moreover, it takes longer time for the IPO industry to pursue their lag in production capacity in order to be equal with the BAU level.

[100] Pasandaran, C. *Forest Ministry Pushes to Continue Deforestation Moratorium, House Pushes Back*. Retrieved January 13, 2013, from Jakarta Globe: http://www.thejakartaglobe.com/news/forest-ministry-pushes-to-continue-deforestation-moratorium-house-pushes-back/557849, 2012.

Figure 6-14. Simple SD management flight simulators for illustration.

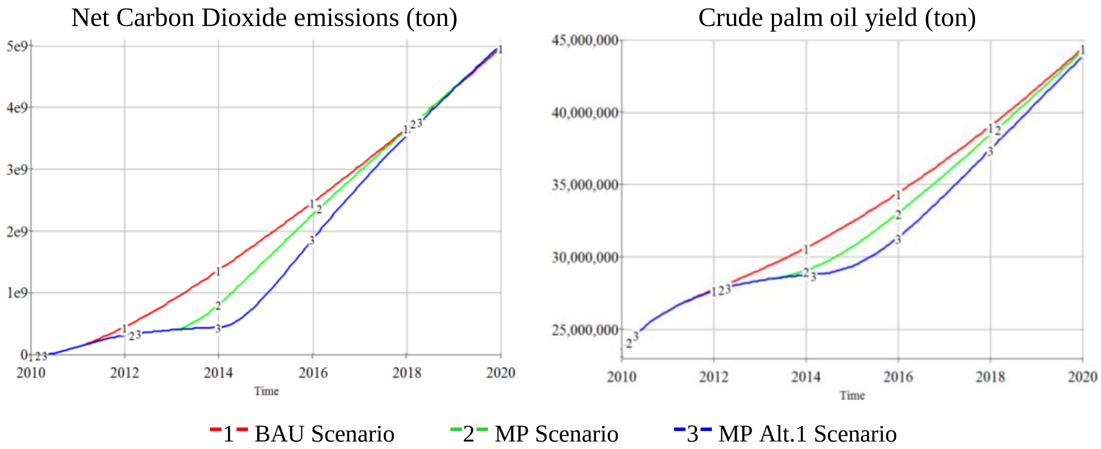


Figure 6-15. Comparison impacts under three scenarios of BAU, MP (base run) and MP alternative 1

6.2.2 Deforestation Still Continues Under the Moratorium Policy

The recent news reported that the deforestation in Indonesia is still continuing despite the implementation of the moratorium policy [Lang, 2012][101]. It is mainly caused by forest concessions that were issued before the moratorium policy was signed. Also law enforcement which is not going effective, for instance: the Indonesian State Audit Board has revealed that there was one palm oil company that conducted land-clearing operations without license from the Indonesia government.

By given circumstance above, the alternative policy for MP scenario (called MP Alt.2)is as follows.

’*The palm oil plantation expansion still continues during a two-year moratorium policy (from 2011 to 2013), but it is going slower than BAU scenario*’

Figure 6-15 to 6-16 show that if there is still forest conversion to palm oil plantation during the moratorium policy period, it reduces a sudden peak that will be happened in 2013 (after the moratorium policy expires). The implication is CO_2 emissions is also noticeably reduced by the implementation of the moratorium policy, nevertheless, it is not as much as under MP

[101] Lang, C. *Deforestation in Indonesia Continues, Despite The Moratorium*. Retrieved January 21, 2013, from redd-monitor.org: http://www.redd-monitor.org/2012/05/04/deforestation-in-indonesia-continues-despite-the-moratorium/, 2012.

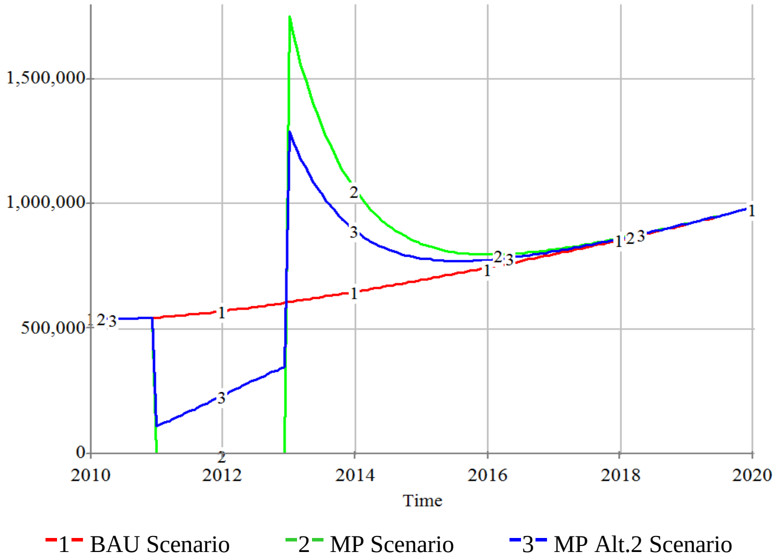


Figure 6-16. Forest conversion to palm oil plantation in order to meet the demand (hectare).

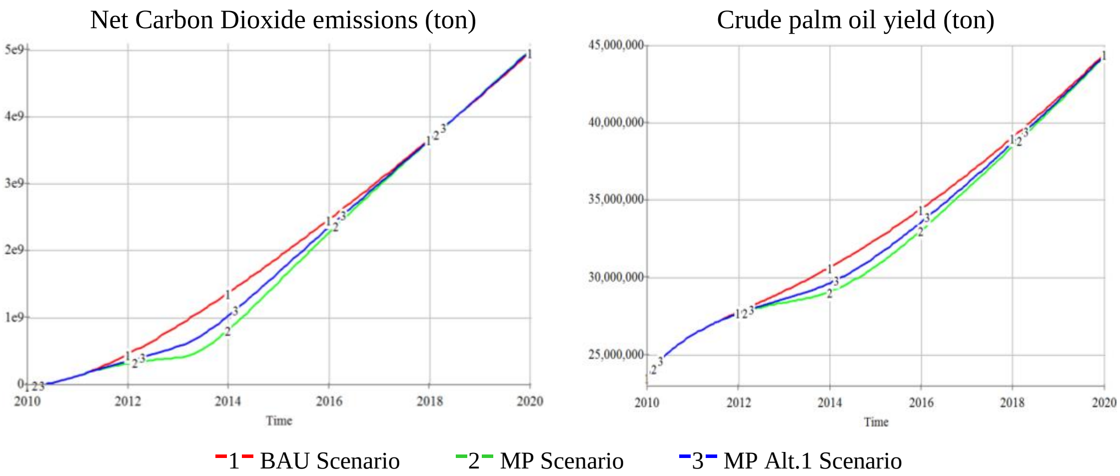


Figure 6-17. Comparison impacts under three scenarios of BAU, MP (base run) and MP alternative 2

scenario (base run: forest conversion is totally restricted/banned). In contrast, the temporary slowdown in the production capacity that will be faced by the IPO industry sector is lower compare to MP scenario.

This scenario that was derived from actual phenomena that happened, can also be used for futher policy options. That is as a temporary solution in the face of a choice between concern to the economic growth or concern to the environment improvement options, till proper solution is found to address the problem, for instance, how to increase the productivity of existing plantation areas.

6.2.3 Future Palm oil Yield Improvement

Corley [2009][102] stated that, '*Whether or not palm oil yields continue to improve in future is another important uncertainty*'. He argued that, there is plenty of scope for future yield improvement of palm oil, the plantation managers should play a role in improving the yield, for instance to take full advantage of the genetic yield potential of their planting material.

For base run model, the IPO productivity per Hectare was set 2.631 Tons and it is fix until 2020. Nonlinear of the IPO productivity will be simulated, we called BAU alternative scenario. The assumption for BAU alternative scenario is as follows.

'*The palm oil plantation management in Indonesia is going well over time, the productivity is successfully improved, that is from 2.631 Tons per Hectare in 2010 (actual data, see appendix, figure A-10), it then will gradually increase to 3 Tons per Hectare in 2020*'

Figure below shows the nonlinier IPO productivity for BAU alternative scenario until 2020. If the IPO industry sector could improve their productivity gradually become 3 Tons per Hectare nationally in 2020, it can reduce the additional needed land to meet the palm oil demand. Also, it automatically reduces CO_2 emissions as result of the forest conversion. Under BAU alternative scenario, until 2020, the total of additional needed land that will be reduced by productivity improvement is estimated around 24.7% compared to the BAU scenario. While, the total CO_2 emissions that will be reduced is estimated around 24.3%.

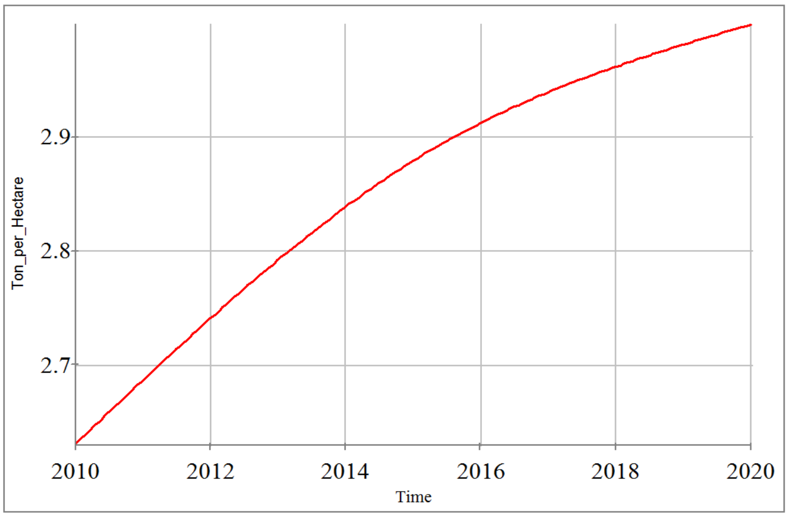


Figure 6-18. Improvement of productivity of Indonesia palm oil (ton per hectare)

Annual additional needed land for IPO (hectare) Cumulative Net Carbon Dioxide emissions (ton)

[102]Corley, R. How much palm oil do we need?.*Environmental Science and Policy*, Vol.12, pp.134-139, 2009.

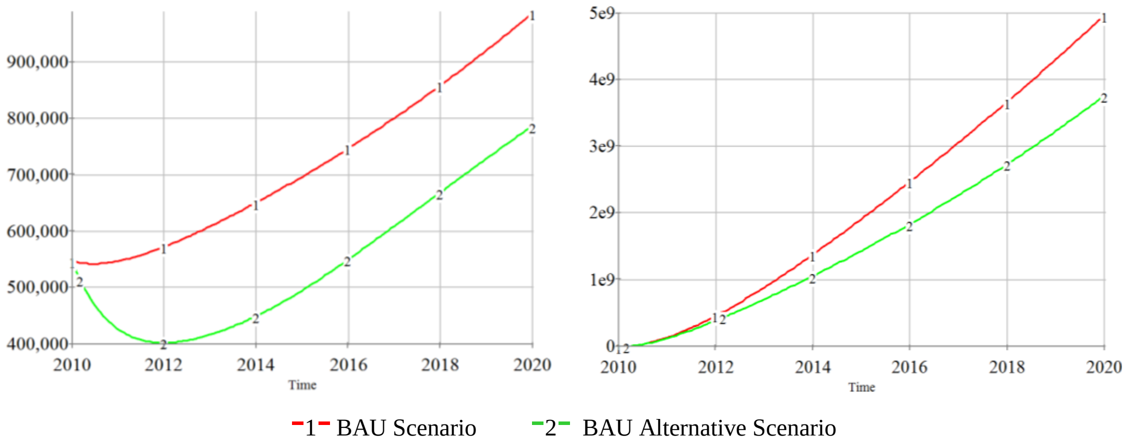


Figure 6-19. Comparison between BAU (base run) and BAU alternative scenarios for additional land (left) dan CO_2 emisson (right)

6.3 Result and Discussion

First of all, It should be noted that this model was made based on assumptions about the future palm oil demand, the plantation establishment and management processes, the impact model for both CO_2 emission and CPO yield, and moratorium policy. This model will never could represent those actual systems including to predict what actually happens to those systems in the future. Discussions based on model experiments are as follows.

Under environmental perspective, this study revealed that the only moratorium policy seems would not have significant impact for environment amelioration/improvement for long term. Although, the simulation result demonstrates that a two-year moratorium on forest and peatland concessions will reduce GHG emissions, but within several years the emission level will return to the BAU level. We can say that the moratorium policy solely without further strategy/policy is only halt temporary the environmental degradation or it only shifts the environmental degradation to the next period. Thus, further strategy and policy instruments which are as the continuation of the moratorium policy is absolutely necessary.

Carbon balance model of this study and other studies. It is necessary to have comparative result for the carbon balance model of this study and other studies. Since the CO_2 emissions is used as indicator to measure the impact of moratorium policy in environmental perspective. Koh et al. [2012] [103] developed a web-based decision-support tool for evaluating the implications and trade-offs of implementing Indonesia's forest moratorium in Kalimantan region (http://REDDcalculator.com). The web is spatially explicit tool that quantifies the

[103] Koh, L.P, Gibbs, H.k, Potapov, P.V, and Hansen, M.C. REDD calculator.com: a web-based decision-support tool for implementing Indonesia's forest moratorium. *Methods in Ecology and Evolution*, 3, 310-316, 2012.

moratorium's benefits for carbon conservation and its opportunity costs under alternative scenarios. They used Geographic information system (GIS) data for calculating the conserved carbon that is based on the type of the land area. We focus on their carbon conservation result, it will be compared to the result of the carbon balance model of this study. Based on the web, the summary outcome is as follows.

In in Kalimantan region, the moratorium policy will protect the total land areas of 9.131 Million hectares that include natural forest and peatland areas. It would conserve 7.06 Billion Tons of Carbon. Thus, if we calculate the conserved Carbon per Hectare is around 773.2 Ton per Hectare.

Using same unit (Ton Carbon per Hectare land) but in an opposite way of calculation, the result of this model was compared to Koh et al.'s model, to see the estimation of Carbon per Hectare for each model. The way to compare is by running simulation and then to match the amount of the total land areas that is converted to plantation areas (*variable in the model: forest conversion to plantations*) with the total protected land of Koh et al.'s model.

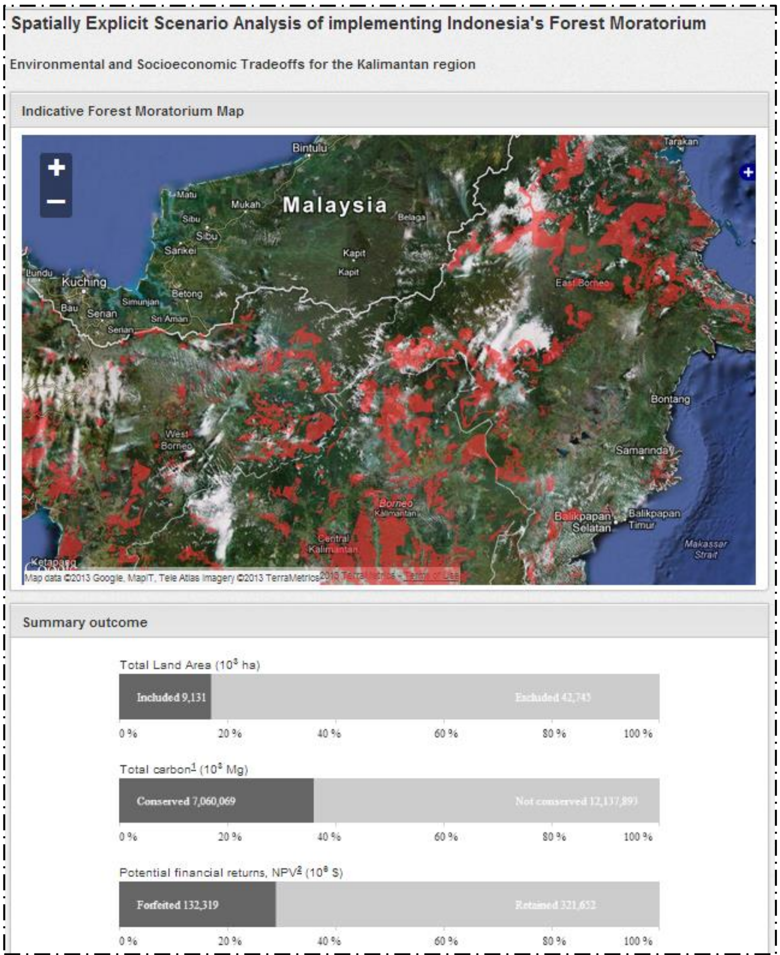


Figure 6-20. Webpage of REDDcalculator.com
Table 6-4 Simulation result of Carbon balance model of this study.

Time	Forest_Conversion_to_Plantation	Carbon_Debt	Ton_per_Hectare
2,021.84	9,117,555.30	6,964,741,007	763.88
2,021.84	9,121,949.43	6,968,364,592	763.91
2,021.85	9,126,344.77	6,971,989,168	763.94
2,021.85	9,130,741.31	6,975,614,735	763.97
2,021.86	9,135,139.05	6,979,241,293	764.00
2,021.86	9,139,537.99	6,982,868,843	764.03
2,021.86	9,143,938.14	6,986,497,384	764.06
2,021.87	9,148,339.49	6,990,126,917	764.09
2,021.87	9,152,742.04	6,993,757,443	764.12
2,021.88	9,157,145.79	6,997,388,961	764.15
2,021.88	9,161,550.76	7,001,021,472	764.17
2,021.88	9,165,956.92	7,004,654,976	764.20

Simulation result of Koh et al.'s model:

$$\frac{\text{Total conserved Carbon}}{\text{Total protected land under the morat.policy}} = \frac{7{,}060{,}069{,}000\ \text{Tons}}{9{,}131{,}000\ \text{Hectares}} = 773.2 \text{ Ton per Hectare}$$

For more clearly about the way of comparison, table 6-4 shows the simulation result of this model. The simulation time of 2021.85 is the year that has almost same in the amount of total converted land (9130741.31 Hectares) compare to the total protected land of Koh et al.'s model (9131000 Hectares). Thus, the simulation time of this model has been extended beyond the horizon time in order to match the amount of total land areas..

We can see that the comparation between the released Carbon per Hectare (this model) with the conserved Carbon per Hectare (Koh et al.'s model) is almost same with small difference amount, that is still acceptable (MAPE = 1.19 %).

Although, these two studies have difference approach in quantifying the carbon content per hectare, however it has same result. This was further proof that the model of this study is useful to analyze the moratorium policy. Also, with regard to carbon balance sub-model, it is appropriate model to evaluate the moratorium policy in environmental perspectives. Futhermore, it also confirms that SD approch is an effective tool to describe the real system and make it as a basis for experimental investigations at lower cost and in less time than trying changes in the actual system.

Under economic perspective, this study revealed that Indonesia will face economic slowdown as result of the implementation of the moratorium policy. It is mainly due to the declining productivity of the economic activities that rely on forest utilization and conversion. Although the period of moratorium policy is only 2 years, but it has long effect to Indonesia's economy.

In case of palm oil industry sector of Indonesia, the result demonstrates that the industry is still can not recover from the slowdown effect until 2020. It is still needed an additional time (exceed than 2020) for the industry to pursue their lag in production capacity in order to meet the demand. The policy will hamper IPO industry to meet the demand, lost opportunity to meet the market demand means lost opportunity to gain income.

Financial compensation from REDD-plus cooperation and the potential economic lost. With regard to the finding that Indonesia will face a slowdown in their economy as result of the moratorium policy. Hence, it is necessary to have an overview on the potential economic lost, that is because of the failure to capture the economic opportunities.

To get an overview of the potential economic lost, this study just simple calculated the value of the average palm oil yield that is potentialy lost during 2010 to 2020. As discussed previously that the potential productivity lost of IPO industry sector during 2010 to 2020 will reach 0.7 Million Ton per year. If the potential productivity lost is converted to the lost value in USD, that is multiplying it by the palm oil price. The total potential economic lost during 2010 to 2020 is around 7.6 Billion USD (figure 6-21). This value was obtained by random simulation using the higher and lower price of palm oil price that is 1248.55 USD per Ton and 914.44 USD per Ton respectively (Appendix, figure A-12).

Whereas the financial compensation that Indonesia got from the REDD-plus cooperation is just 1 billon USD. Thus, The gap difference between the lost potential value and the financial compensation is around 6.6 Billion USD. Futhermore, the total lost potential value is actually higher than that value, if we are considering other processes which related to forest conversion to plantation area, such as the forest concession fee, the timber value from the conversion (forest clearing), creating jobs, and so forth. Moreover, the payment of financial compensation depends on the achievement of Indonesia in reducing GHG emissions, it may

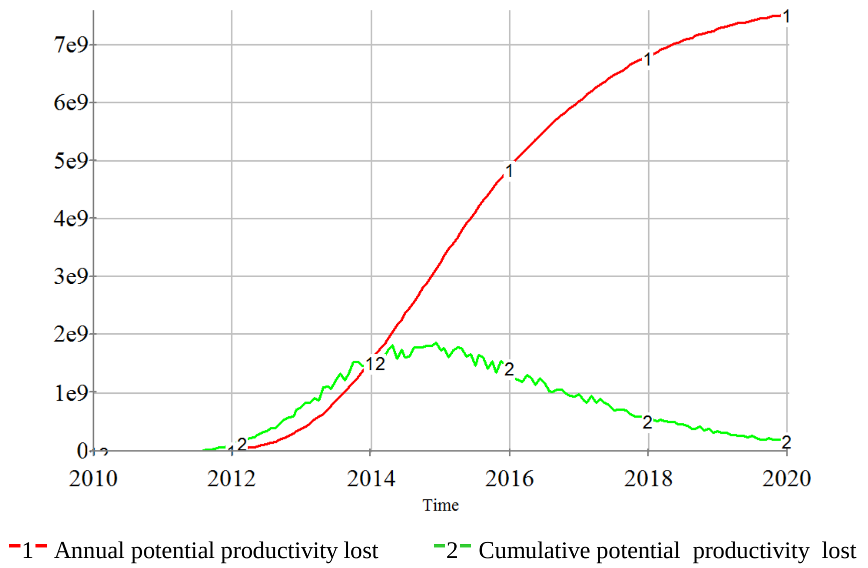


Figure 6-21. Potential productivity lost from palm oil industry sector until 2020 (USD).

not be paid until Indonesia can prove that reforestation efforts succeeded.

Thus, the bilateral agreementon REDD-plus cooperation is not in accordance with the green economy concept of Indonesia. It is not economically viable for Indonesia. From the illustration of calculation above, the potential economic lost cannot be offset by a financial compensation from the bilateral agreement.

Positive impacts of the moratorium policy, it can be an initial measure as a springboard for mitigating GHG emissions from deforesation and forest degradation. The 2 years during the implementation of the policy can be used for the preparation of further policy formulation including the facilities that are needed for it. For instance, seriously to draw up the degraded lands database and future palm oil plantation expansion will be placed at that land.

By placing the new concession of palm oil plantation at the degraded land, Indonesia will get two benefits atonce that is for both economy and environment (reforestation) purposes.

The moratorium policy could trigger the palm oil industry sector to shift their way in increasing the production. That is lead into the activities that can improve the productivity of existing plantations, rather than forest conversion activities. Model experiment had demostrated that by increasing the productivity of 0.37 Ton per Hectare from current level (2.631 Ton per Hectare), it can reduce the additional needed land nearly 24.7% compared to the BAU.

With regard to dynamic discourse about extending the period of moratorium policy, This study has revealed that extending the period of moratorium policy by 1 year will cause a significant impacton both GHG emissions reduction and economic slowdown. There may not be a problem for the GHG reduction, but how about the future economic condition of Indonesia. Since the simulation result had demonstrated that with the only 2 years moratorium has long effect to Indonesia's economy and the financial compensation is far enough to offset the potential economic lost. Thus, Indonesia goverment should be careful in taking a decission related to this issue.

CHAPTER VII
CONCLUSION

This study presents an SD application to assist with policy analysis of a trade-off between GHG emissions reduction and economic growth with regard to the implementation of the moratorium policy under REDD-plus cooperation in Indonesia. We conclude this study by reviewing the theme of study, findings, limitations and future work.

This model was built to enhance the understanding of the impacts of the moratorium policy implementation on new forest and peatland concessions on the economy and environment of Indonesia by using a case study of one economic sector of Indonesia which rely on forest conversion and utilization for their business activities. The palm oil industry sector was selected as case study. The impacts of the policy associated with the supply-demand systems of palm oil which is posed by increasing demand of palm oil in line with the growing of world population and economy. Scenarios and policies are tested as example images of future possible situations.

Since the model of this study has passed 5 model validation procedures, those are dimensional consistency, reference mode behavior, historical data reproduction, extreme condition and sensitivity analysis. Author can say that the prototype model has been built successfully.

Model Feature

The model is a simple model, however, author argues that this model still can capture the main structure of the real system being studied in accordance with the purpose of study. Simplified model structure is expected could help the readers get a better understanding without spending long time on digesting the structure of the model.

Model Findings

(a) The model has demonstrated that the moratorium policy noticeably reduce GHG emissions from deforestation. However, the trend of GHG reduction is only temporary, that is, using only the moratorium policy without further strategy and policy instruments which are as the continuation of the policy seems only to halt temporary environmental degradation or to shift the environmental degradation to the next period.

(b) Indonesia may face an economic slowdown as a result of the moratorium policy implementation. Furthermore, the slowdown effect will last sufficiently long compared to the period of the policy, mainly because of the declining productivity of the Indonesia economic sectors that rely on the forest.

(c) Referring to the results, the bilateral agreement on REDD-plus cooperation seems to not be in accordance with the green economy concept of Indonesia that provides equal attention to economic growth and the environment. Because the bilateral agreement is not economically viable for Indonesia, a payment for environmental services under the bilateral agreement is uncompetitive with the palm oil industry sector, which is only one of many economic sectors in Indonesia that rely on the forest.

Policy Suggestions

The moratorium policy can be an initial measure as a springboard for mitigating GHG emissions from deforestation and forest degradation. Thus, whether the MP has long-term positive impacts on both economy and environment of Indonesia depends on further strategy and policy instruments, which as a continuation of the MP are absolutely necessary and should be prepared before the policy expires.

The degraded lands database is most important things that should be ready when the moratorium policy is finished. By locating the future palm oil plantation expansion in this land, Indonesia will get two benefits at once, for both economic growth and environmental amelioration. Based upon the model experimentation, to improve the productivity per Hectare land has significant impact to reduce land use demand. Indonesia government along with the palm oil industry sector should play a role in improving the palm oil yield per Hectare.

With regard to dispute about extending or not extending the period of moratorium policy, Indonesia government should be careful in taking a decision related to this issue. However, based on this study, the current moratorium policy (2011-2013) is enough for Indonesia government to prepare everything that is needed to make future strategy to address this problems which in line with the green economy concept of Indonesia.

Limitation and Future Work

We address that the model is not meant to predict the future or to produce a quantitative projection, which may not match the actual situation in the future. This model is simplification of the real system, it was built based on the theories and assumptions in order to explain the real system. Both of them which mainly determine the limitations of this study that had been discussed in chapter 3 and 4.

The main objective of this study is to explore about trade-off between GHG emissions reduction and economic growth in a country who participates in REDD-plus framework for climate protection, also to see how effective the policy conservation help to reduce environmental degradation.

The future work can be extended to other production chain of palm oil industry, and more scenario alternatives with considering more policy instruments which related to the theme.

Appendix
Historical Data of Variable

This Appendix presents the historical data of the variables that was included into the model. The numerical data was used as the basis for model building that is as initial condition and constant parameter inputs for the model. Since SD is a mathematical model therefore the data for the model should be based on the best information that is readily available, but the modeling process should not be postponed until all pertinent parameter have been accurately measured, the value should be estimated when it necessary (Forrester, 1961)[104].

Author collected the data from sources that are readily available on internet and published papers (literature study). The statistics data of the variables of demand sub-model were mainly from the World Bank, the United States Department of Agriculture (USDA) and the Ministry of Agriculture Republic Indonesia (MOARI) databases. Thus, the data of this study was secondary data. The data that were needed for the model but it does not present in this appendix, it will be presented directly in each section that describes about it. The variables and its historical data are as follows.

A.1 World Population

The historical data of world's population, crude birth rate, and crude death rate that was derived from World Bank's data base are shown in figure A-1 and A-2. Based on the data, the total world population in 2010 is 6894.4 million Persons. The annual average of crude birth rate and crude death rate of the world population since 2001 until 2010 were 20.218 (≈ 20) and 8.391 (≈ 8) per thousand Persons respectively.

For the model, the author used the total world population data in 2010 is as initial condition and the annual average of crude birth and death rate is as parameter.

[104] Forrester, J.W. *Industrial Dynamics.* Massachusetts: The M.I.T. Press, 1961.

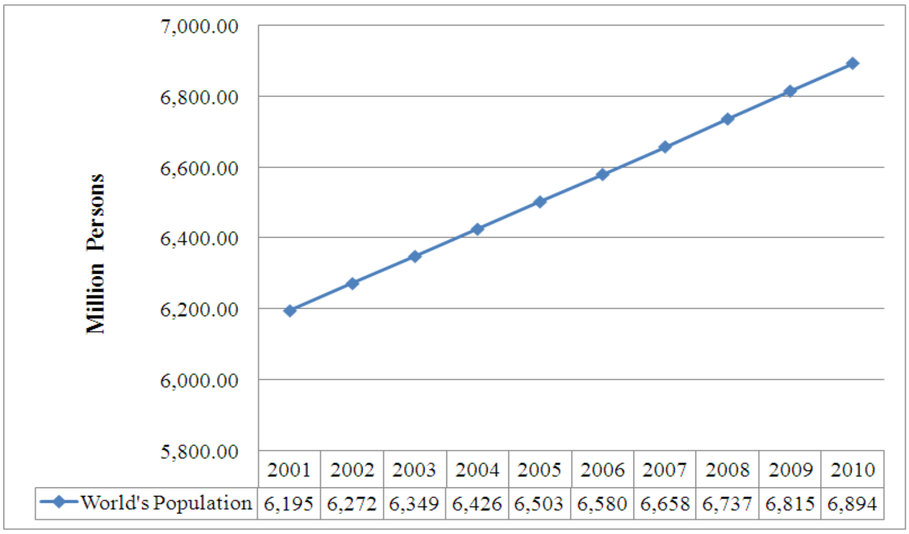


Figure A-1. Historical data of world population.
Source: World Bank, 2012[105]

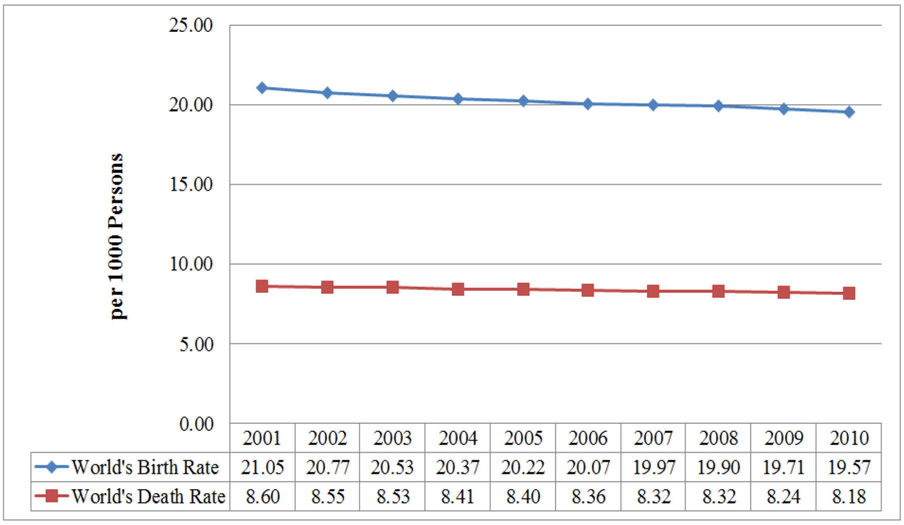


Figure A-2. Historical data of world crude birth and death rates.
Source: World Bank, 2012[106]

A.2 World Gross Domestic Product

The historical data of world GDP are shown in figure A-3. Based on the data, the total world GDP in 2010 is 63.136 trillion USD. By the data in figure A-3, we can get the historical data of the annual nominal growth rate of GDP that is as shown in figure A-4. During the period of 2001-2010, the highest and lowest of the increasing nominal rate of GDP were 12.75% and

[105] World Bank. World Bank Search. Retrieved March 22, 2012, from World Bank: http://search.worldbank.org/data?qterm=population&language=&format=, 2012.

[106] Ibid.

-5.45%, respectively. While increasing the average nominal rate of GDP growth from 2001 to 2010 was 7.08% annually.

For the model, the author used the world GDP data in 2010 as initial condition and the average annual increasing nominal rate of GDP from 2001 to 2010 as parameter.

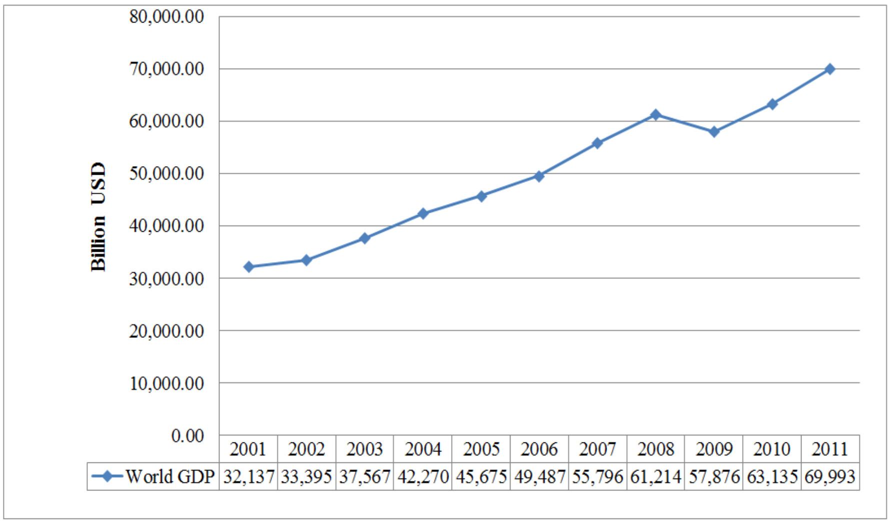


Figure A-3. Historical data of world GDP.
Source: World Bank, 2012[107]

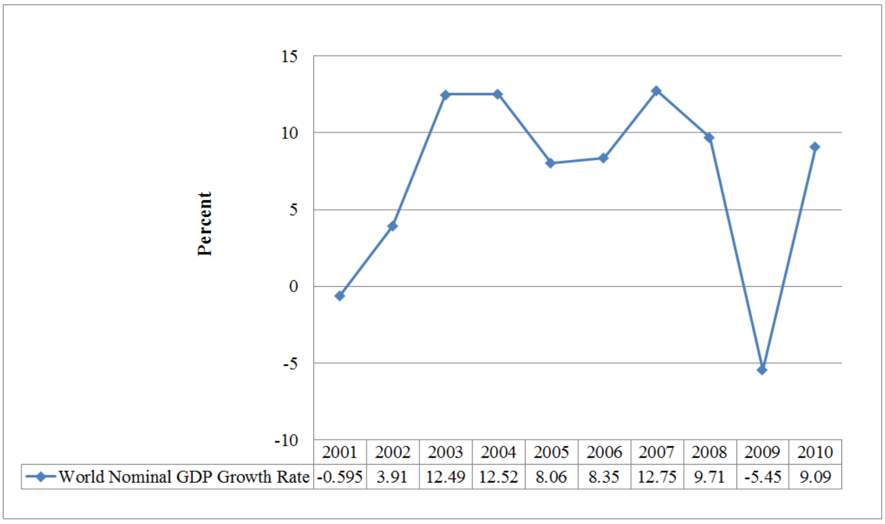


Figure A-4. Historical data of nominal growth rate of world GDP.

[107] World Bank. World Bank Search. Retrieved March 22, 2012, from World Bank: http://search.worldbank.org/data?qterm=GDP&language=&format=, 2012.

A.3 Gross Domestic Product Per Capita

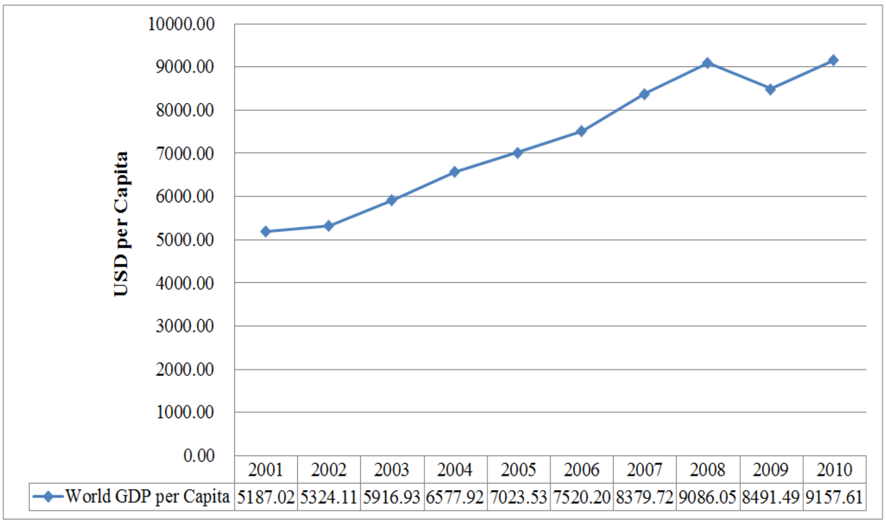


Figure A-5. Historical data of world GDP per capita.

The historical data of the world GDP per capita was obtained by calculating two historical data of the world GDP (figure A-3) as the numerator and the world population (figure A-1) as the denominator. The historical data of GDP per capita is shown in figure A-5.

For the model, the author inputted a mathematical equation of the relationships between GDP per capita (independent variable) and palm oil consumption per capita (dependent Variable). The mathematical model was obtained by using a statistical technique of regression analysis based on their historical data.

A.4 Global Palm Oil Consumption Per Capita

The historical data of the GPO consumption per capita was obtained by calculating two historical data of the GPO demand (figure 1-2) as the numerator and the world population (figure A-1) as the denominator. The historical data of GPO consumption per capita is shown in figure A-6. From the historical data (figure A-6), the palm oil consumption per capita in 2010 was 7.816 kilogram per Person. The average palm oil consumption per capita since 2001 until 2010 was 6.1404 kilogram annually, while the average increment of palm oil consumption per capita was 0.365 kilogram annually.

For the model, the author inputted a mathematical equation of the relationships between GDP per capita (as independent variable) and palm oil consumption per capita (as dependent Variable) by using a statistical technique of regression analysis based on their historical data.

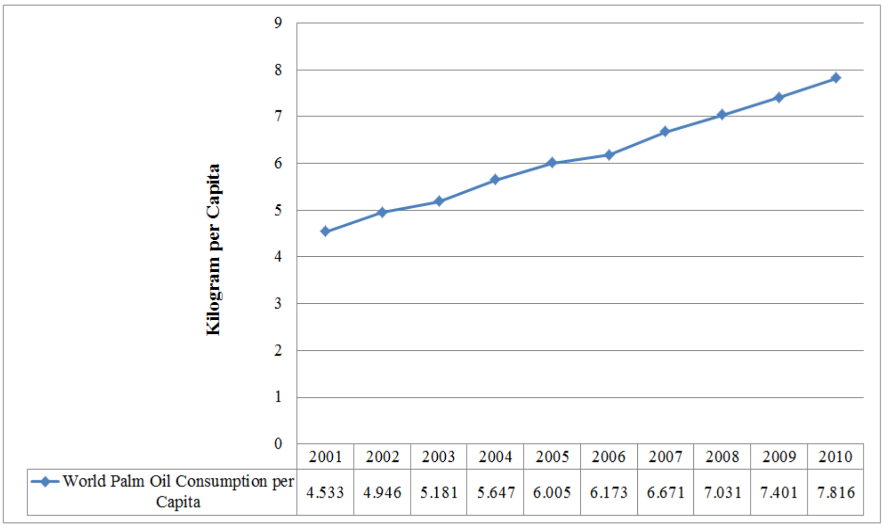


Figure A-6. Historical data of world palm oil consumption per capita.

During the period of 2001-2010, the highest and lowest nominal rate of the world GDP was 12.75% and -5.45%, respectively. Thus, an average nominal rate of GDP growth during the period was 7.08% annually.

A.5 Market Share of Indonesia Palm Oil

The historical data of the IPO contribution in the global palm oil market was obtained by comparing two historical data of the GPO demand as the denominator and the aggregate IPO production as the numerator (figure A-7). The historical data of the IPO contribution in the global palm oil market is as shown in figure A-8. The average IPO contribution in the global palm oil market (figure 4.10) since 2001 until 2010 was 34.74% annually. During the period of 2001-2010, the highest and lowest of the IPO contribution in the global palm oil market were 42.72% and 29.85% respectively. Author assumed the IPO contribution is as the IPO market share in the global market of palm oil.

USDA-FAS [2010][108] argued that if the trend growth of Palm oil global demand continues at current rates (2.5 million tons or 9.5% per year), by given that circumstance, there will be no combination of alternative producing countries who could increase production adequately to meet global demand, to rely on the IPO production is only expected to fulfill the demand. It is because:

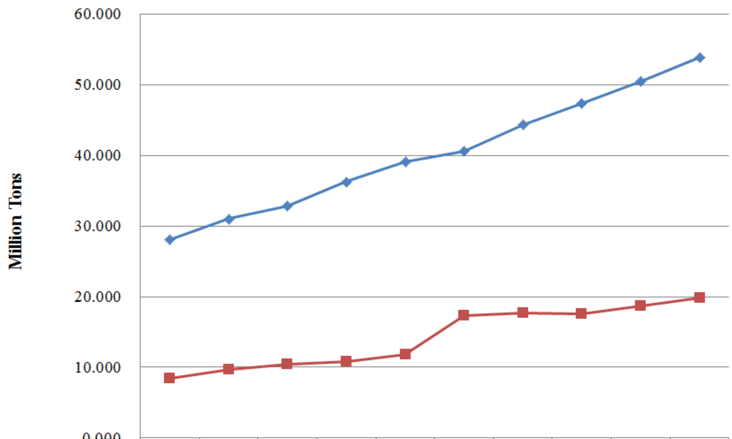
(a) Indonesia has excellent future growth prospects with a predominantly young tree population, increasing yields, and expanding plantation area.

(b) It is the only country known to be capable of reliably increasing production by 1.5 to 2.0 million tons a year over the foreseeable future

[108] USDA-FAS. *Indonesia: Rising Global Demand Fuels Palm Oil Expansion*. Retrieved March 23, 2012, from United States Department of Agriculture-Foreign Agricultural Service: http://www.pecad.fas.usda.gov/highlights/2010/10/Indonesia/, 2010.

(c) Compared to many other palm oil producing nations, Indonesia has the benefit of a stable political and economic environment, ample land resources and investment capital, appropriate climate, affordable labor, adequate infrastructure, experienced producers, and a well-organized and successful commercial palm oil industry.

By considering the commodity intelligence report of United States Department Agriculture-Foreign Agricultural Service (USDA-FAS), the highest of IPO market share that is in 2006 with the contribution of 42.72% was chose as parameter for the model.



	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Palm Oil Global Consumption	28.086	31.021	32.896	36.287	39.053	40.619	44.418	47.371	50.442	53.887
Indonesia Palm Oil Production	8.396	9.622	10.441	10.830	11.862	17.351	17.665	17.540	18.641	19.845

Figure A-7. Historical data of global palm oil consumption and Indonesia palm oil production.
Source: USDA, 2005[109],2008[110],2012[111] ; MAORI, 2011[112]

[109] United States Department of Agriculture. *Table47.xls World vegetable oils production, 2000/01-2004/05.* Retrieved March 22, 2012, from USDA Economics, Statistics, and Market Information System: http://usda.mannlib.cornell.edu/MannUsda/viewStaticPage.do?url=http://usda.mannlib.cornell.edu/usda/ers/89002/2006/../2005/index.html, 2005.

[110] United States Department of Agriculture. *Table47.xls World vegetable oils production, 2003/04-2007/08.* Retrieved March 22, 2012, from USDA Economics, Statistics, and Market Information System: http://usda.mannlib.cornell.edu/MannUsda/viewStaticPage.do?url=http://usda.mannlib.cornell.edu/usda/ers/89002/2008/index.html, 2008.

[111] United States Department of Agriculture. *Table47.xls World vegetable oils production, 2007/08-2011/12.* Retrieved March 22, 2012, from USDA Economics, Statistics, and Market Information System: http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1290, 2012.

[112] Ministry of Agriculture Republic Indonesia-Directorate General of Estate. *Area and Production by Category of Producers.* Retrieved August 21, 2011, from Ministry of Agriculture Republic Indonesia-Directorate General of Estate: http://ditjenbun.deptan.go.id/cigraph/index.php/viewstat/komoditiutama/8-Kelapa%20Sawit, 2011.

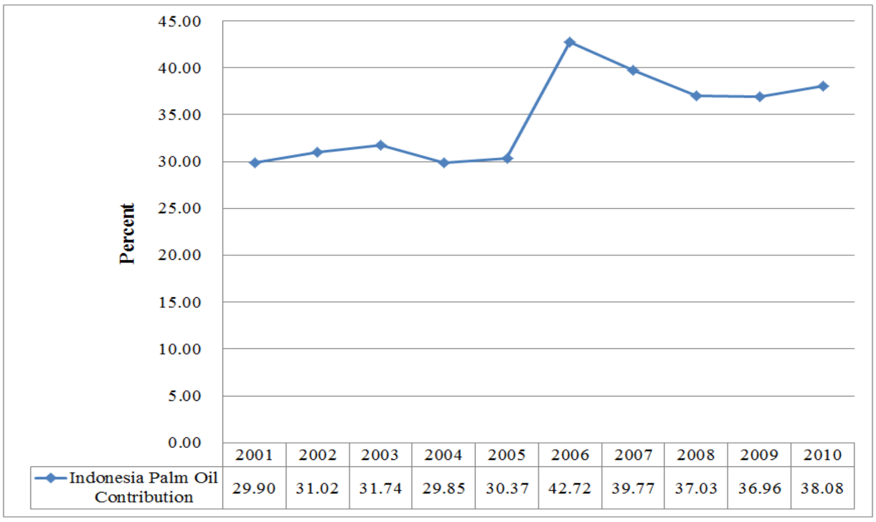


Figure A-8. Historical data of Indonesia palm oil market share in the palm oil global market.

A.6 Productivity of Indonesia Palm Oil

The historical data of the IPO yield per Hectare was obtained by comparing two historical data of the IPO aggregate production as the numerator and the total IPO plantation area as the denominator (figure A-9). Author called the IPO yield per Hectare as the IPO productivity per Hectare. The historical data of the IPO productivity per Hectare is as shown in figure A-10.

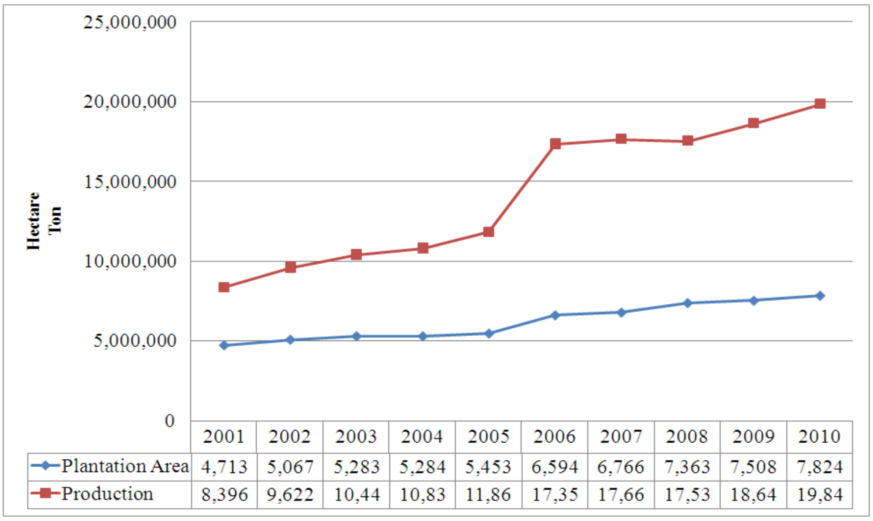


Figure A-9. Total production and plantation area of Indonesia palm oil.
Source: MOARI, 2010[113]

[113] Ministry of Agriculture Republic Indonesia-Directorate General of Estate. *Area and Production by Category of Producers*. Retrieved August 21, 2011, from Ministry of Agriculture Republic Indonesia-Directorate General of Estate: http://ditjenbun.deptan.go.id/cigraph/index.php/viewstat/komoditiutama/8-Kelapa%20Sawit, 2010.

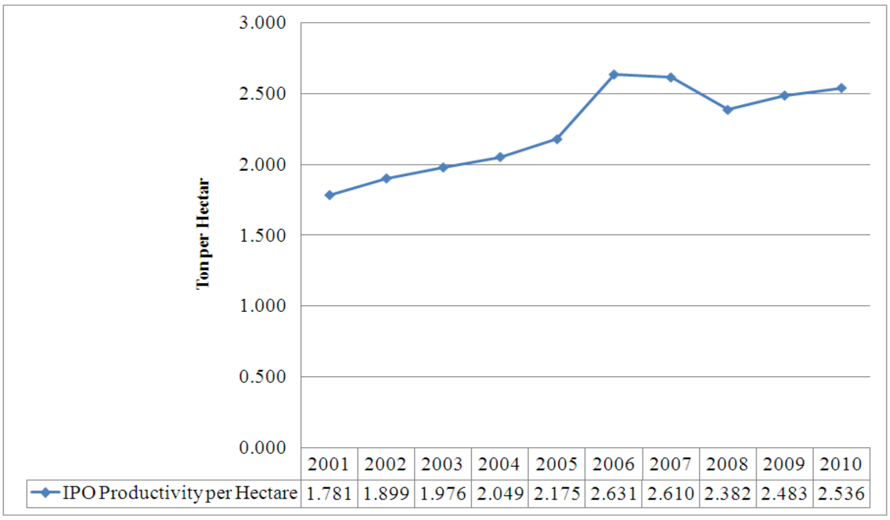


Figure A-10. Indonesia palm oil productivity per hectare.

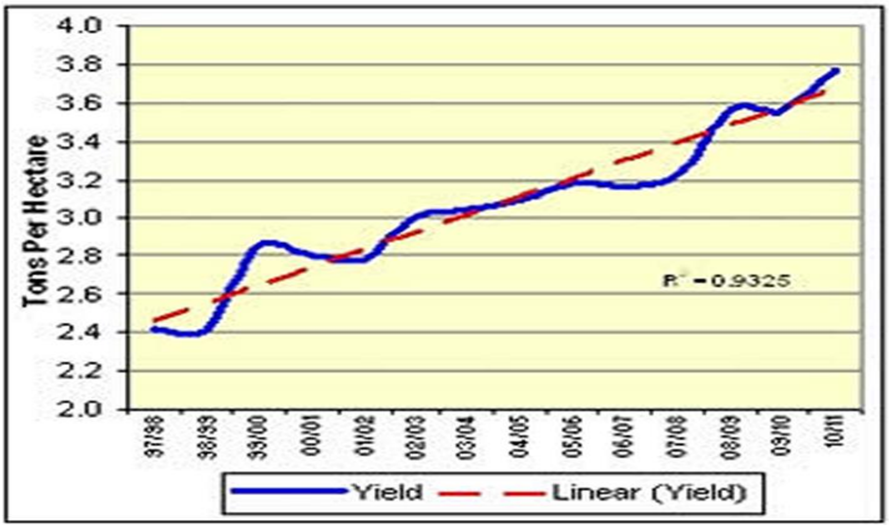


Figure A-11. Indonesia palm oil productivity per hectare (USDA version)
Source: USDA, 2010[114]

The IPO productivity since 2001 until 2010 (figure A-10) was in the range of 1.781 to 2.631 Tons per Hectare, with an average productivity of 2.252 Tons per Hectare annually. On the other hand, USDA-FAS [2010] also have their own historical data of the IPO productivity per Hectare (figure A-11) that during 2010-2011 the IPO productivity reached 3.7 Tons per Hectare. According to them, the figure has implied that the future trend of IPO yield is likely continuing to grow to be positive.

[114] USDA-FAS. *Indonesia: Rising Global Demand Fuels Palm Oil Expansion*. Retrieved March 23, 2012, from United States Department of Agriculture-Foreign Agricultural Service: http://www.pecad.fas.usda.gov/highlights/2010/10/Indonesia/, 2010.

Considering the two data sources of MOARI and USDA-FAS, the highest IPO productivity per Hectare in 2006 which based on the data of MOARI that is 2.631 Tons per Hectare was used as transforming parameter for the model to calculate the total land used demand for the IPO, if the IPO wants to fulfill the demand.

A.7 Crude Palm Oil Price

The historical price data of crude palm oil (CPO) in global market during period February 2011 until February 2012 is shown in figure A-12. On average, the CPO global price was 1096.32 USD per Ton. During the period, the higher price was1248.55USD per Ton and the lower price was 914.44 USD per Ton.

The interval between higher and lower price was used as transforming parameter for the model to calculate the value of CPO yield by using random function.

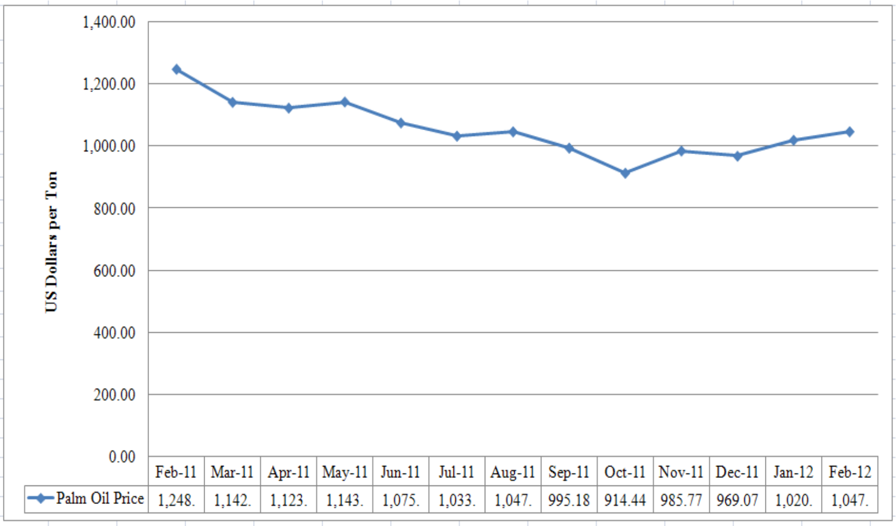


Figure A-12. Palm oil monthly price in the global market.
Source: Index Mundi, 2012[115]

A.8 Time For Establishment of New Palm Oil Plantation

According to Indonesia Investment Coordinating Board [2006] [116] the main production processes of palm oil in the plantation phase consist of opening and preparing land, seedlings and saplings, planting, plant care and maintenance, and harvesting. They also explained that the palm oil crop can be harvested for the first time after being planted when the crop reaches

[115] Index Mundi. *Palm oil Monthly Price - US Dollars per Metric Ton.* Retrieved March 25, 2012, from Index Mundi: http://www.indexmundi.com/commodities/?commodity=palm-oil&months=12, 2012.

[116] Indonesia Investment Coordinating Board. *Bab III Profil Komoditi Kelapa Sawit (Chapter III Commodity Profile of Palm Oil).* Retrieved April 5, 2012, from Indonesia Investment Coordinating Board: http://regionalinvestment.bkpm.go.id/newsipid/id/userfiles/komoditi/2/oilpalm_profilsingkat.pdf, 2006.

the age of 31 months or 2.5 years. Corley dan Tinker [2003][117] also had described in detail about the establisment process of new palm oil plantation.

In real system, to establish palm oil plantation certainly needs time. The time is required for all process of plantation management. According to Rankine and Fairhurst [cited in Corley dan Tinker 2003][118], the estimation time for the establishment of a new palm oil plantation is shown in table A-1. The Rankine and Fairhurst's Schematic plan may overlap for different processes. Thus, it is summarized into two major processes that are,

(a) Land preparation (surveying, land clearing, roads and drains, LCP, lining) which takes around 240 days or 0.66 years in total time.

(b) Plantation management process that is the process from a new plantation to a mature plantation (nursery processes, planting, care and maintenance, harvesting) which takes around 1004 days or 2.75 years in total time.

For more detailed structure of the model, such required time (delay time or interval time) was included into the model to represent the establishment and management processes of palm oil plantation.

Table A-1. Schematic plan for the establishment of a new palm oil plantation.

Task name	Days	2000 Q1	Q2	Q3	Q4	2001 Q1	Q2	Q3	Q4	2002 Q1	Q2	Q3	Q4	2003 Q1	Q2
Nursery preparation	30														
Nursery planting	3														
Nursery maintenance	300														
Final culling	2														
Surveying	30														
Roads and drains	120														
Land clearing	150														
LCP	130														
Lining	60														
Planting	70														
Supply planting	180														
Field maintenance	850														
Preharvest preparation	30														
Scout harvesting	210														

LCP = legume cover planting

Source: Corley dan Tinker, 2003

[117] Corley, R.H.V. and Tinker, P.B. (2003). The Oil Palm. Malden-USA: Blackwell Science Ltd, 2003.

[118] Ibid.

A.9 General Data of Palm Oil Plantation

Table A-2.General data of palm oil plantation.

Parameter	Value
Palm oil crop lifetime	25–30 years
FFB producing lifetime	22–27 years
Palm oil crop per Hectare	140 palm crops
FFB per palm crop per year	0.140 Ton
FFB to produce 1 Ton CPO	5 Ton

Source: Hirsinger et.al 1995 and MPOB report 2004
[cited in Yusoff and Hansen, 2007][119]

General data about palm oil plantation that was needed for plantation sub-model is listed in table A-2 depicts provides an overview of general plantation values. Based on the data, the lifetime of palm oil crop is generally at an average time of 25-30 years, whereas their productive lifetime to produce fresh fruit bunches (FFB) is at an average time of 22-27 years.

Author chose the sorthest time from the range that is 22 years as productive time parameter of mature plantation area for the model. For other constant parameters were to follow the general data in table A-2.

A.10 Palm Oil Plantation Concessions/Permission on Peatland

According to Hooijer et al. [2006][120], there are three main types of concessions in Indonesia, those are logging concessions (called HPH, i.e Hak Pengusahaan Hutan), timber plantation concessions (called HTI, i.e Hutan Tanaman Industri), and oil palm plantation concessions (called BHP, i.e Bahagian Pengurusan Hartanah). The concession data for the main peatland areas in Indonesia (Sumatra, Kalimantan and Papua islands) is as shown in table 4.3. These data cover both existing and planned developments. Based on the data, the total oil palm concession area on peatland is 28009 km^2 or 2.8 million hectares, therefore palm oil plantation concessions cover 14% of the total peatland area in Indonesia.

For the model, the percentage concession (14%) was used as fraction parameter for land type of palm oil expansion which split into two lands between tropical forest and peatland.

[119] Yusoff, S. and Hansen, S.B. (2007). Feasibility Study of Performing An Life Cycle Assessmenton Crude Palm Oil Production In Malaysia. *Life Cycle Assessment*, *12*(1), 50-58.

[120] Hooijer, A., Silvius, M., Wösten, H. and Page, S. PEAT-CO2, Assessment of CO2 emissions from drained Peatland in SE Asia. Netherlands: Delft Hydraulics, 2006.

Table A-3. Concessions on peatland in Indonesia.

Concessions in Indonesia		Logging		Timber plantation		Oil Palm plantation			
	Lowland peat area	HPH total~	HPH on lowland peat~	HTI total~	HTI on lowland peat~	BHP total~	BHP on lowland peat~	HTI+ BHP total~	HTI+ BHP on lowland peat~
	km²	*km²*	*km²*	*km²*	*km²*	*km²*	*km²*	*km²*	*km²*
Kalimantan		**124217**	**4451**	**27274**	**3104**	**50255**	**14725**		
Sumatra		**23601**	**6295**	**33544**	**11827**	**49513**	**12494**		
Papua		**95902**	**13686**	**14036**	**4992**	**3610**	**790**		
Total Kal + Sum + Pap		**243720**	**24432**	**74854**	**19923**	**103378**	**28009**	**178232**	**47932**
				as a percentage of total plantation area					
Kalimantan			**4**		**11**		**29**		
Sumatra			**27**		**35**		**25**		
Papua			**14**		**36**		**22**		
Total Kal + Sum + Pap			**10**		**27**		**27**		**27**
	km²	*% total area*	*% peat area*	*% total area*	*% peat area*	*% total area*	*% peat area*	*%peat area*	*%peat area*
Kalimantan	**58379**	**23**	**8**	**5**	**5**	**9**	**25**	**15**	**31**
C. Kalimantan	30951	28	5	2	2	18	41		
E. Kalimantan	6655	31	13	6	9	6	16		
W. Kalimantan	17569	11	12	7	11	6	5		
S. Kalimantan	3204	16	0	6	0	7	3		
Sumatra	**69317**	**5**	**9**	**7**	**17**	**11**	**18**	**18**	**35**
D.I. Aceh	2613	11	5	6	0	6	40		
N. Sumatera	3467	3	1	5	0	3	18		
Riau	38365	8	13	16	20	22	23		
Jambi	7076	8	9	5	2	17	8		
S. Sumatera	14015	1	1	10	29	5	6		
W. Sumatera	2096	8	11	1	2	22	23		
Papua	**75543**	**23**	**18**	**3**	**7**	**1**	**1**	**4**	**8**
Total Kal + Sum + Pap	**204156**	**16**	**12**	**5**	**10**	**7**	**14**	**11**	**23**

Source: Hooijer et al., 2006

A.11 Land Availability For Palm Oil Plantation Expansion

According to Tambunan [2006][121] the potential of land availability for palm oil plantation in Indonesia is about 26 million hectares scattering over the whole region of Indonesia (from Aceh to Papua province) that is as shown in table A-4.

Meanwhile, Lembaga Riset Perkebunan Indonesia (Indonesia Plantation Research Institute) reported that there were approximately 46,904,116 Hectares of potential land for oil palm plantation development in Indonesia which including high-potential land, moderate-potential land and low-potential land [Dradjat, 2007][122].

The data of Indonesia Plantation Research Institute were chose as initial condition for the model. Since the data is in 2007 while the time base of the model is in 2010. Thus, the land that had been used for the palm oil expansion during 2007 to 2009 should be calculated for getting the land availability in 2010. The land that had been used for the palm oil expansion during 2007 to 2009 (Figure 4.11) is 597,011; 144,176 and 316,600 Hectares respectively or

[121] Greenpeace. *How The Palm Oil Industry Is Cooking The Climate.* Amsterdam: Greenpeace International, 2007.

[122] Dradjat, B. Perkebunan Kelapa Sawit Indonesia Masih Berpotensi Dikembangkan (Indonesia Palm Oil Still Potentially Developed). *Warta Penelitian dan Pengembangan Pertanian Indonesia*, Vol. 29, No.2, pp.6-7, 2007.

Table A-4.Potential of Land Availability for Palm Plantation in Indonesia by Province.

Province	Area (hectare)
Nanggroe Aceh Darussalam	384,871
North Sumatera	37,000
West Sumatera	355,814
Riau	2,563,156
Jambi	1,818,118
South Sumatera	1,483,959
Bangka Belitung	593,038
Bengkulu	208,794
Lampung	336,872
Banten	63,742
West Jawa	224,708
West Kalimantan	1,681,186
Central Kalimantan	3,610,819
South Kalimantan	1,162,959
East Kalimantan	4,700,333
Central Sulawesi	256,238
South Sulawesi	192,370
Southeast Sulawesi	10,264
Papua	6,331,128
TOTAL	26,015,369

with the sum total of 1,057,787 Hectares. Therefore the land availability for the palm oil expansion in 2010 is,

46,904,116 Hectares - 1,057,787 Hectares = 45,846,329 Hectares.

We included this land availability for future palm oil expansion into the model to keep track the depletion of the land availability.

A.12 Carbon Stock In Tropical Forest, Peatland And Palm Oil Plantation

The carbon stock data in tropical forest, peatland and palm oil plantation were collected from several literatures. For instance, Fargione, et al. (2008)[123] had estimated carbon debts from conversion of native ecosystems for both tropical rainforest and peatland rainforest to monoculture palm oil plantations in Indonesia and Malaysia. They estimated carbon debts by calculating the amount of CO_2 released from belowground and aboveground of ecosystem biomass and soils. The result showed that converting native ecosystems would result carbon debt of 702 Tons Carbon per Hectare for tropical rainforest, and 1294 to 3452 Tons Carbon

[123] Fargione, F., Hill, J., Tilman, D., Polasky, S. and Hawthorne, P. *Land Clearing And The Biofuel Carbon Debt.* New York: The American Association for the Advancement of Science, 2008.

per Hectare for peatland rainforest. The table A-5 listed the data of carbon stock in tropical forest and peatland for both aboveground and belowground. The table A-6 listed the data of carbon stock in palm oil plantation for aboveground only.

The data was used as transforming parameter for the model to calculate the carbon balance as result of the establishment of palm oil plantations. The data of Fargione et al. and Dewi et al. were used for the model.

Table A-5. Carbon stock in tropical forest and peatland.

Source	Tropical Forest	Peatland Forest
Fargione et al. [2008][124]	702 Tons C ha^{-1}	1294~3452 Tons C ha^{-1}
Wahyunto et al. [2004][125]		26.6~7730.5 C ha^{-1}
IPPC [2000][126]	243.18 Tons C ha^{-1}	

Table A-6. Carbon stock in the palm oil plantation area.

Source	Palm Oil Plantation
Dewi et al. [2009][127]	39 Tons C ha^{-1}
Palm et al. 1999 [cited in Reijnders and Huijbregts, 2008][128]	48 Tons C ha^{-1}
Henson, 2003 [cited in Reijnders and Huijbregts, 2008][129]	36 Tons C ha^{-1}

[125] Wahyunto, Ritung, S., Suparto and Subagjo, H. Maps of Area of Peatland Distribution and Carbon Content in Kalimantan, 2000-2002. Bogor:Wetlands International-Indonesia Programme, 2004

[126] Intergovernmental Panel on Climate Change. *IPCC Special Report - Land Use, Land-Use Change, and Forestry.* The Intergovernmental Panel on Climate Change., 2000.

[127] Dewi, S., Khasanah, N., Rahayu, S., Ekadinata A. and van Noordwijk, M. *Carbon Footprint of Indonesian Palm Oil Production: a Pilot Study.* Bogor: World Agroforestry Centre, 2009.

[128] Reijnders, L. and M.A.J. Huijbregts, M.A.J. (2008). Palm Oil And The Emission of Carbon-Based Greenhouse Gases. *Journal of Cleaner Production*,Vol. 16, pp.477-482, 2008

[129] Ibid.

Reference

Alfian. *Coal, CPO elevate exports to all-time high*. Retrieved February 17, 2012, from The Jakarta Post: http://www.thejakartapost.com/news/2011/01/04/coal-cpo-elevate-exports-alltime-high.html, 2011.

Brown, E and Jacobson, MF. *Cruel Oil-How Palm Oil Harms Health, Rainforest And Wildlife.*Washington, DC: Center for Science in the Public Interest, 2005

Butler, R.A. *Peatland Restoration Wins Support In Effort To Reduce Carbon Emissions*. Retrieved December 12, 2012, from mongabay.com: http://news.mongabay.com/2010/0610-Peatland.html, 2010.

Cavana, R. Modeling the Environment: An Introduction to System Dynamics Models of Environmental Systems. *System Dynamics Review (Book Review)*, Vol.19, pp.171-173, 2003.

CIFOR. *Simply REDD-CIFOR's guide to forests, climate change and REDD.*Bogor: Center for International Forestry Research, 2009.

Corley, R. How much palm oil do we need?.*Environmental Science and Policy*, Vol.12, pp.134-139, 2009.

Corley, R.H.V. and Tinker, P.B. *The Oil Palm*. Malden-USA: Blackwell Science Ltd, 2003.

Crutchfield, J. *Indonesia: Palm Oil Production Prospects Continue to Grow*. United States Department of Agriculture-Foreign Agricultural Service, 2007.

Dewi, S., Khasanah, N., Rahayu, S., Ekadinata A. and van Noordwijk, M. *Carbon Footprint of Indonesian Palm Oil Production: a Pilot Study.* Bogor: World Agroforestry Centre, 2009.

Dradjat, B. Perkebunan Kelapa Sawit Indonesia Masih Berpotensi Dikembangkan (Indonesia Palm Oil Still Potentially Developed). *Warta Penelitian dan Pengembangan Pertanian Indonesia,* Vol. 29, No.2, pp.6-7, 2007.

Edwards, D.P., Koh, L.P., Laurance W.F. Indonesia's REDD+ pact: Saving imperilled forests or business as usual?. *Biological Conservation*. Article in pers, 2011.

Fargione, F., Hill, J., Tilman, D., Polasky, S. and Hawthorne, P. *Land Clearing And The Biofuel Carbon Debt.* New York: The American Association for the Advancement of Science, 2008.

Ford, A. *Modeling the Environment.* Washington, DC: Island Press, 2010.

Ford, A. *Modeling the Environment: An Introduction to System Dynamics Modeling Of Environmental Systems*. Washington, DC: Island Press, 1999.

Ford, A. System Dynamics And The Electric Power Industry. *System Dynamics Review* , Vol.13, pp.57–85, 1997.

Forrester, J.W.*Industrial Dynamics.*Massachusetts: The M.I.T. Press, 1961.

Greenpeace. *How The Palm Oil Industry Is Cooking The Climate.* Amsterdam: Greenpeace International, 2007.

Han, J. and Hayashi, Y. A System Dynamics Model of CO_2 Mitigation in China's Inter-city Passenger Transport. *Transportation Research Part D*, Vol.13, pp.298–305, 2008.

Hansjurgents, B. *Emissions Trading For Climate Policy, US and European Perspectives*. Cambridge: Cambridge University Press, 2005.

Hooijer, A., Silvius, M., Wösten, H. and Page, S. PEAT-CO2, Assessment of CO2 emissions from drained Peatland in SE Asia. Netherlands: Delft Hydraulics, 2006.

Index Mundi. *Palm oil Monthly Price - US Dollars per Metric Ton.* Retrieved March 25, 2012, from Index Mundi: http://www.indexmundi.com/commodities/?commodity=palm-oil&months=12, 2012.

Indonesia Investment Coordinating Board. *Bab III Profil Komoditi Kelapa Sawit (Chapter III Commodity Profile of Palm Oil).* Retrieved April 5, 2012, from Indonesia Investment Coordinating Board: http://regionalinvestment.bkpm.go.id/newsipid/id/userfiles/komoditi/2/oilpalm_profilsingkat.pdf, 2006.

Intergovernmental Panel on Climate Change. *IPCC Special Report - Land Use, Land-Use Change, and Forestry.* The Intergovernmental Panel on Climate Change., 2000.
IPPC-Nakicenovic, N. and Swart, R. (Eds.). *Emissions Scenarios.* Cambridge: Cambridge University Press, UK, 2000.

Koh, L.P, Gibbs, H.k, Potapov, P.V, and Hansen, M.C. REDD calculator.com: a web-based decision-support tool for implementing Indonesia's forest moratorium. *Methods in Ecology and Evolution*, 3, 310-316, 2012.

Laksono, H.R.A. *Benefits, Opportunities and Challenges of a Green Economy: Indonesia's Perspectives.*Nairobi: United Nations Environment Programme, 2011.

Lang, C. *Deforestation in Indonesia Continues, Despite The Moratorium*. Retrieved January 21, 2013, from redd-monitor.org: http://www.redd-monitor.org/2012/05/04/deforestation-in-indonesia-continues-despite-the-moratorium/, 2012.

Latul, J. and Chatterjee, N. *Analysis: Indonesia forest moratorium to stymie palm oil firms*. Retrieved February 12, 2012, from Reuters: http://www.reuters.com/article/2010/08/12/us-indonesia-plantations-idUSTRE67B1J320100812, 2010.

Longbin, Z. *A System Dynamics Based Study of Policies on Reducing Energy Use and Energy Expense for Chinese Steel Industry.* Retrieved March 15, 2012, from Bergen Open Research Archive: https://bora.uib.no/bitstream/1956/2363/1/Masterthesis_Longbin.pdf, 2007.

Lucia Breierova, L. and Choudhari, M.. *An Introduction to Sensitivity Analysis.*Massachusetts Institute of Technology, 2001.

Ludwig Von Mises Institute.*Chapter VI The Demand Side of The Market.* Retrieved September 12, 2012, from Ludwig Von Mises Institute: http://mises.org/PDF/Salerno_syllabus06/Shapiro_Ch6-7.pdf, 2009.

McCarthy, J.J., Canziani, O.F., Leary, N.A., Dokken, D.J. and White, K.S. *Climate Change 2001: Impacts, Adaptation, and Vulnerability.* Cambridge: The Press Syndicate of The University of Cambridge, 2001.

Ministry of Agriculture Republic Indonesia-Directorate General of Estate.*Area and Production by Category of Producers.* Retrieved August 21, 2011, from Ministry of Agriculture Republic Indonesia-Directorate General of Estate: http://ditjenbun.deptan.go.id/cigraph/index.php/viewstat/komoditiutama/8-Kelapa%20Sawit, 2010.

Morgan, M.G. and Henrion, M. *Uncertainty: A Guide to Dealing with Uncertainty in Quantitative Risk and Policy Analysis.* Cambridge: Cambridge University Press, 1990.

National Research Council. *Models in Environmental Regulatory Decision Making.* Washington, DC: The National Academies Press, 2010.

Pasandaran, C. *Forest Ministry Pushes to Continue Deforestation Moratorium, House Pushes Back*. Retrieved January 13, 2013, from Jakarta Globe: http://www.thejakartaglobe.com/news/forest-ministry-pushes-to-continue-deforestation-moratorium-house-pushes-back/557849, 2012.

Radzicki, M.J. and Taylor, R.A. *U.S. Department of Energy's Introduction to System Dynamics: A Systems Approach to Understanding Complex Policy Issues.* Retrieved June 12, 2012, from System Dynamics Society: http://www.systemdynamics.org/DL-IntroSysDyn/inside.htm, 1997.

Reijnders, L. and Huijbregts, M.A.J. Palm Oil And The Emission of Carbon-Based Greenhouse Gases. *Journal of Cleaner Production*, Vol.16, pp. 477-482, 2008.
Richardson, C. L. *Deforestation Due To Palm Oil Plantations In Indonesia.* Charlotte Louise Richardson 200431233, 2010.

RSPO. *Indonesia: Benchmark For Sustainable Palm Oil In Emerging Markets*. Retrieved September 28, 2011, from Roundtable on Sustainable Palm Oil (RSPO) : http://www.rspo.org/?q=content/indonesia-benchmark-sustainable-palm-oil-emerging-markets, 2011.

Sandker, M., Suwarno, A. and Campbell, B.M. Will Forests Remain in the Face of Oil Palm Expansion? Simulating Change in Malinau, Indonesia. *Ecology and Society*, Vol.12, Art.37, 2007.

Solheim, E. and Natalegawa, R.M.M.M. *Letter of intent between the Government of the Kingdom of Norway and the Government of the Republic of Indonesia on cooperation on reducing greenhouse gas emissions from deforestation and forest degradation.*Oslo: The Government of The Kingdom of Norway and The Government of The Republic of Indonesia, 2010.

Sonnemann, G., Castells, F., and Schuhmacher, M. *Integrated Life-Cycle And Risk Assessment For Industrial Processes.* Florida, the United States of America: CRC Press LLC, 2004.

Sterman, J. *Business Dynamics: Systems Thinking and Modeling for a Complex World.* Boston: McGraw-Hill Higher Education, 2000.

Sterman, J. Economic Vulnerability And The Energy Transition. *Energy System and Policy*, Vol.7, pp.259-301, 1983.

Sufian, M.A. and Bala, B.K. Modeling of Urban Solid Waste Management System: The Case of Dhaka City. *Waste Management*, Vol.27, pp.858–868, 2007.
Suh, S. *Handbook of Input-Output Economics in Industrial Ecology*. London: Springer Science Business Media, 2009.

System Dynamics Society.*The Field of System Dynamics*. Retrieved March 16, 2012, from System Dynamics Society: http://www.systemdynamics.org/what_is_system_dynamics.html#overview, 2011.

Tan, K.T, Lee, K.T., A.R Mohamed, and Bhatia, S. (2009). Palm oil: Addressing issues and towards sustainable development. *Renewable and Sustainable Energy Reviews*, Vol.13, pp.420–427.

The Jakarta Post. *CPO producers oppose moratorium*. Retrieved February 17, 2012, from The Jakarta Post: http://www.thejakartapost.com/news/2010/07/02/cpo-producers-oppose-moratorium.html, 2010.

Trappey, A.J.C., Trappey, C.V., Lina, G.Y.P. and Yu-Sheng Chang, Y. The Analysis of Renewable Energy Policies for the Taiwan Penghu Island Administrative Region. *Renewable and Sustainable Energy Reviews*, Vol.16, pp.958– 965, 2012.

UNFCCC. *Bali Road Map*. Retrieved February 12, 2012, from United Nations Framework Convention on Climate Change: http://unfccc.int/key_documents/bali_road_map/items/6447.php, 2012

UNFCCC. *Kyoto Protocol*. Retrieved February 12, 2012, from United Nations Framework Convention on Climate Change: http://unfccc.int/kyoto_protocol/items/2830.php, 2012.

UNFCCC. *Making those first steps count: An Introduction to the Kyoto Protocol*. Retrieved February 12, 2012, from United Nations Framework Convention on Climate Change: http://unfccc.int/essential_background/kyoto_protocol/items/6034.php, 2012.

United States Department of Agriculture. *Table47.xls World vegetable oils production, 2000/01-2004/05.* Retrieved March 22, 2012, from USDA Economics, Statistics, and Market Information System: http://usda.mannlib.cornell.edu/MannUsda/viewStaticPage.do?url=http://usda.mannlib.cornell.edu/usda/ers/89002/2006/../2005/index.html, 2005.

United States Department of Agriculture. *Table47.xls World vegetable oils production, 2000/01-2004/05.* Retrieved March 22, 2012, from USDA Economics, Statistics, and Market Information System: http://usda.mannlib.cornell.edu/MannUsda/viewStaticPage.do?url=http://usda.mannlib.cornell.edu/usda/ers/89002/2006/../2005/index.html, 2005.

United States Department of Agriculture. *Table47.xls World vegetable oils production, 2003/04-2007/08.* Retrieved March 22, 2012, from USDA Economics, Statistics, and Market Information System: http://usda.mannlib.cornell.edu/MannUsda/viewStaticPage.do?url=http://usda.mannlib.cornell.edu/usda/ers/89002/2008/index.html, 2008.

United States Department of Agriculture. *Table47.xls World vegetable oils production, 2007/08-2011/12.* Retrieved March 22, 2012, from USDA Economics, Statistics, and Market Information System: http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1290, 2012.

USDA-FAS. *Indonesia: Rising Global Demand Fuels Palm Oil Expansion*. Retrieved March 23, 2012, from United States Department of Agriculture-Foreign Agricultural Service: http://www.pecad.fas.usda.gov/highlights/2010/10/Indonesia/, 2010.

Wahyunto, Ritung, S., Suparto and Subagjo, H. Maps of Area of Peatland Distribution and Carbon Content in Kalimantan, 2000-2002. Bogor:Wetlands International-Indonesia Programme, 2004

World Bank. *Population*. Retrieved March 22, 2012, from World Bank: http://search.worldbank.org/data?qterm=population&language=&format=, 2012.

World Bank. GDP. Retrieved March 22, 2012, from World Bank: http://search.worldbank.org/data?qterm=GDP&language=&format=, 2012.

Yudhoyono, S. *Intervention By H.E. Dr. Susilo Bambang Yudhoyono President of The Republic of Indonesia On Climate Change.*Pittsburgh:Forest Climate Center, 2009.

Yudhoyono, S.B.,and Astuti, R.P.B. *Presidential Instruction of Republic of Indonesia Number 10 of 2011 About Moratorium on the new permits and the Completion Governance of Primary Natural Forest And Peatland* .Jakarta: Sekretariat Kabinet RI, 2011.

Yusoff, S. and Hansen, S.B. (2007). Feasibility Study of Performing An Life Cycle Assessmenton Crude Palm Oil Production In Malaysia. *Life Cycle Assessment, 12*(1), 50-58.

in order to shorten payback period of Carbon debt.

This confirms the statement of Edwards et al. [2011]: "it is far too soon to declare this a victory for the environment after several delays in the implementation“. The environmental benefits that will be gotten by implementing the policy might be smaller than be expected.

The impacts of the implementation of moratorium policy based on the simulation result are as follows.

It has confirmed the concerns of Indonesia Palm Oil Producers Association before the implementation of moratorium policy that is the policy will stymie palm oil production [The Jakarta Post, 2010]

Due to the mature IPOPA is the main parameter which will be used to estimate the CPO yield in this model.

The comparison result of the two indicators under BAU and MP scenarios is presented in figure 6-7 for Net CO2 emission and in fegure 6-8 for CPO yield for Net CO2 emission.

to see the impact of moratorium policy on

Later on, several assumptions related to the moratorium policy will be made to explore the policy for policy analysis

The comparison With the projected demand

Whereas for the increasing number of established palm oil plantations overtime as result of the palm oil plantation expansions (based on the additional land that is needed for IPO to fulfill the demand, please see equation 4-11) including its processes will be explained in next session. The

Owing to palm oil nowadays is an essential vegetable oil which notonly for foods, but also for non-food including as source of alternative fuel [Sheil et Al., 2009][130].

For the extrapolation number of actual or additional land that is needed for IPO over time to fulfill the demand can be seen in table 6-2.

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http://reddinfo.wordpress.com/2011/07/19/indonesia%E2%80%99s-forest-moratorium-a-decent-deal-for-palm-oil/

[130] Sheil, D., Casson, A., Meijaard, E., van Nordwijk, M. Gaskell, J., Sunderland-Groves, J.,Wertz, K. and Kanninen, M.*The impacts and opportunities of oil palm in Southeast Asia:What do we know and what do we need to know?.* Bogor: Center for International Forestry Research, 2009.

Still, prior to the issuance of the moratorium, concerns have been growing that Norway's contribution to conservation efforts will not offset the losses if palm oil development is jeopardized.

J2007_Will Forests Remain in the Face of PO Expansion

Luas lahan yang di protek compare to insentive yg dikasih Norway

Author used qualitative data to verify the error of the model result. The qualitative data is as follows.

'*the GAPKI and IPOC argued that a two-year moratorium would hamper the industry's plan to double production into 40 million tons by 2020 to meet the growing global demand of the palm oil commodity*'(Chapter I)

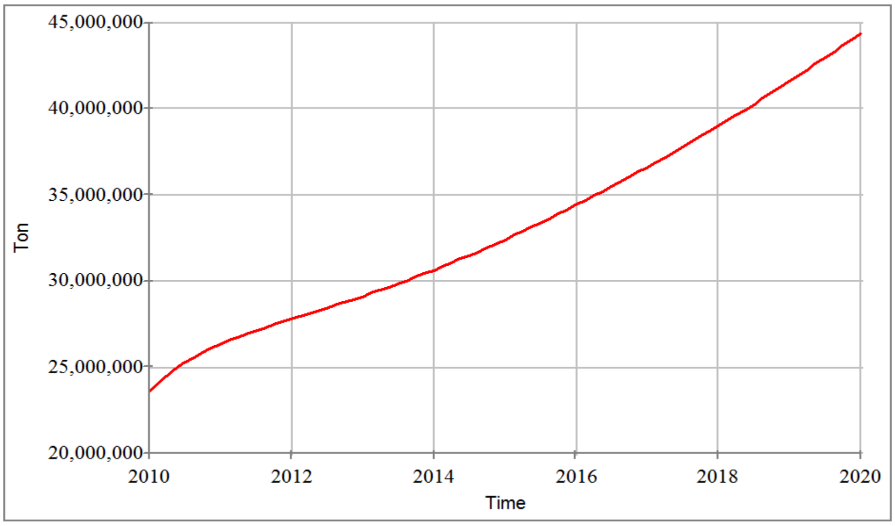

Figure 5-2. Extrapolation of crude palm oil production of Indonesia.

Author highlighted their target in 2020 that they have planned to produce palm oil up to 40 million tons. The model result for CPO production in 2020 is as shown in figure 5-2. We calculated the absolute error by the following equation:

$$\text{Absolute error (t)} = \left| \frac{\text{Quantitative or Qualitative data(t)} - \text{Model result(t)}}{\text{Quantitative or Qualitative data(t)}} \, x \; 100\% \right| \quad (5\text{-}1)$$

Where the *absolute error* at time *t* is the *qualitative or quantitative data* at time *t* minus *model simulation result* divided by the *qualitative or quantitative data* then multiplied by *100%*.

Thus the absolute error for CPO Production in 2020 (t = 2020) is as follows.

$$\text{Absolute error of CPO Production}_{(2020)} = \left| \frac{40 \text{ million} - 43596339}{40 \text{ million}} \; x \; 100\% \right| = 8.99\%$$

From the figure 5-1 and the absolute error for CPO Production in 2020 that was under 10%, we could say that the model result is to follow the reference mode or succeeded to produce an adequate behavior of the target pattern.