MODELLING BIOENVIRONMENTAL FACTORS FOR OIL PALM PLANTATIONS IN RIAU INDONESIA TOWARDS FRESH FRUIT BUNCH PRODUCTIVITY

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UNIVERSITI TEKNOLOGI MALAYSIA

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Specially dedicated to *My beloved family*

I really miss all of you.

Al-Fatihah

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ABSTRACT

Productivity of *Fresh Fruit Bunch* (FFB) varies in each country. Indonesia is the largest oil palm plantation country, but it has the lowest FFB productivity due to bioenvironmental factors. This study identified bioenvironmental factors that affect FFB productivity, and explored a new model for prediction of FFB productivity. To identify the factors, data were collected from literature, survey, focus group discussion, and field observation of 200 blocks of oil palm plantation in an area of 2,300 hectares in the Riau province. Correlation among bioenvironmental factors and FFB productivity was statistically analysed using linear regression. From the findings, a model was developed based on multiple regression of the Cobb Douglas function. The new model was simulated using Dynamic System software (Stella 9.0.2) to define the relationship between factors and estimate the FFB productivity of oil palm until it reaches its productive age. Simulations were conducted and verified by comparing the results with previous related studies. Besides, results were also validated using a Chi Square test from field survey in oil palm plantations. The statistical results confirmed that FFB productivity was affected by ten groups of bioenvironmental factors. These factors that can increase FFB productivity by nearly 7.58% include good management of oil palm biophysics, bioagent, water conservation, soil conservation, fertilizer, topography, and climate. On the contrary, management of pest, diseases, and herbicide can decrease FFB productivity by nearly 0.31%. Furthermore, simulation results indicated that the optimum productive oil palm was 30 years old, and that there were no significant differences in the validation results between the field survey and simulation, showing that the model is sustainable. These results have shown that the model can be used as support for FFB productivity management based on bioenvironmental factors.

ABSTRAK

Produktiviti Tandan Buah Segar (FFB) berbeza di setiap negara. Indonesia merupakan negara penanam kelapa sawit yang terbesar, namun mempunyai produktiviti FFB yang rendah disebabkan oleh faktor biopersekitaran. Kajian ini mengenal pasti faktor-faktor biopersekitaran yang memberi kesan kepada produktiviti FFB, dan meneroka model baharu untuk ramalan produktiviti FFB. Bagi mengenal pasti faktor-faktor tersebut, data dikumpulkan daripada literatur, kajian, perbincangan kumpulan fokus, dan pemerhatian lapangan ke atas 200 blok ladang kelapa sawit di kawasan seluas 2,300 hektar di wilayah Riau. Korelasi antara faktor biopersekitaran dengan produktiviti FFB dianalisis menggunakan regresi linear. Daripada hasil kajian, sebuah model dibangunkan berdasarkan regresi fungsi Cobb Douglas. Model baharu tersebut disimulasikan menggunakan perisian Sistem Dinamik (Stella 9.0.2) bagi menentukan hubungan antara faktor dan menganggarkan produktiviti FFB kelapa sawit sehingga mencapai umur produktif. Simulasi yang dijalankan telah disahkan dengan membandingkan hasilnya dengan kajian-kajian yang dijalankan sebelum ini. Di samping itu, hasil kajian juga telah disahkan dengan menggunakan ujian khi kuasa dua melalui kajian lapangan di ladang-ladang kelapa sawit. Keputusan statistik mengesahkan bahawa produktiviti FFB dipengaruhi oleh sepuluh set faktor biopersekitaran. Faktor-faktor tersebut yang boleh meningkatkan produktiviti FFB hampir 7.58% termasuk pengurusan biofizik kelapa sawit yang baik, bioagen, pemuliharaan air, pemuliharaan tanah, baja, topografi, dan iklim. Selain itu, pengurusan serangga perosak, penyakit, dan racun herba boleh mengurangkan produktiviti FFB hampir 0.31%. Selain itu, hasil simulasi menunjukkan bahawa tempoh produktif optimum kelapa sawit adalah 30 tahun, dan tidak terdapat perbezaan yang signifikan antara hasil pengesahan kajian lapangan dengan simulasi maka ini menunjukkan bahawa model tersebut adalah mampan. Hasil kajian ini menunjukkan bahawa model tersebut boleh digunakan sebagai sokongan terhadap pengurusan produktiviti FFB berdasarkan faktor-faktor biopersekitaran.

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LIST OF ABBREVIATIONS

FFB	-	Fresh Fruit Bunch
SOE	-	State Owned Enterprise
SLS	-	Sari Lembah Subur
CPO	-	Crude Palm Oil
FGD	-	Focus Group Discussion
LSU	-	Leave Sample Unit
D	-	Dura
P	-	Pisifera
T	-	Tenera
LCC	-	Legume Cover Crops
N	-	Nitrogen
P	-	Posphate
K	-	Kalium
Mg	-	Magnesium
Ca	-	Calcium
Mn	-	Manganese
Cu	-	Copper
Fe	-	Ferrum
B	-	Boron
Zn	-	Zinc
BSR	-	Basal Stem Rot
USR	-	Upper Stem Rot
DBR	-	Dry Basal Rot
SR	-	Spear Rot
BMP	-	Best Management Practice
WCED	-	World Commission on Environment and Development
BN	-	Bunch Number
ABW	-	Average Bunch Weight

SPH	-	Stand Per Hectare
EFB	-	Empty Fruit Bunch
CLD	-	Cousal Loop Diagram
SFD	-	Stock Flow Diagram
VIF	-	Variance Inflation Factor
PR	-	Smallholders
PBN	-	State Own Enterprise (SOE)
PBS	-	Private Enterprise
LN	-	Logarithm Natural
SPSS	-	The Statistical Package for the Social Science
KS	-	Kolmorove Smirnov
A	-	Age
AP	-	Antigonon Plant
TA	-	Tyto Alba
T	-	Turnera
Tr	-	Trench
ID	-	Infield Drain
RS	-	Rain Slot
MF	-	Manual Furrow
Cv	-	Celvort
Nl	-	Nephrolepis
Mu	-	Mucuna
Ma	-	Manure
S	-	Solid
BA	-	Boiler Ash
OS	-	Organic Slot
FA	-	Form Area
pH	-	hydrogen Peroxide
BS	-	Base Saturation
SiL	-	Sloping Land
StL	-	Suitability Land
Rf	-	Rainfall
Rd	-	Rainday
Cp	-	Caterpillar

Bw	-	Bagworm
R	-	Rat
O	-	Orycties
C	-	Curvignathus
Gly	-	Gliphosate
Prq	-	Paraquate
Mms	-	Metasulfuron

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CHAPTER 1

INTRODUCTION

1.1 Research Background

Oil palm plants are shaped like trees and consiost of fibrous root, stems covered with midrib, compound leaves, and fruit clustered in bunches on each midrib. The most popular part of the oil palm plant is its fruit that is known as Fresh Fruit Bunch (FFB). To obtain highly productive FFB, sustainable management is an important when developing oil palm plantations. Due to the long life cycle of oil palms, plantations require a management system involving the nursery, planting, canopy management, fertilization, plant protection and harvesting (Pahan, 2012a).

Oil palm is an important commodity in global trade. It is a major source of foreign exchange for some developing countries. Oil palm is an important industrial plant that produces cooking oil, industrial oil, and fuel (biodiesel). In addition, palm oil is used as raw material for soaps, cosmetics, industrial steel, wire, radio, leather and pharmaceuticals. Palm oil is processed into several products due to its excellent characteristics, including its oxidation resistance in high pressure conditions, the ability to dissolve chemicals that are insoluble in other solvents, and not causing skin irritation when used in cosmetic products. The advantages of palm oil are its low selling prices, low cholesterol content, and high carotene content (Ministry of trade Indonesia, 2014).

The largest oil palm plantations in the world are located in Indonesia. These plantations consist of State-Owned Enterprises (SOE), private enterprises and smallholders. There are around 50 large private companies that dominate oil palm plantations in Indonesia. They are mostly located in the Riau Province. This study was conducted in one of the largest oil palm companies in the Riau Province. The

plantation in this province already possessed good management for crops, ecologically, economiclly, and socially.

Figure 1.1 below shows that FFB production in Indonesia is the lowest in the world even though Indonesia has the largest oil palm plantations in the world. Therefore, proper oil palm plantation management urgently needs to be applied in Indonesia's oil palm plantations.

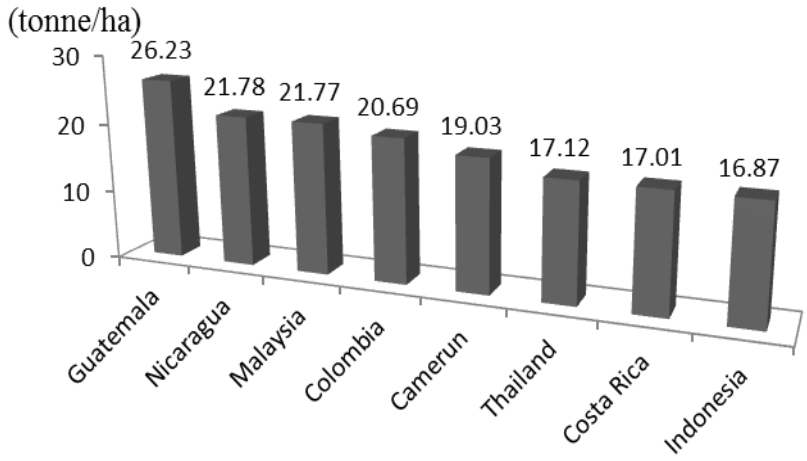

Figure 1.1: The largest FFB producer countries in the world, average value from 2008 till 2012 (Indarti, 2014)

Indonesia's palm oil production centers are mainly located in 6 (six) provinces which account for 75.26% of the total palm oil production in Indonesia. The Riau and North Sumatra provinces are the largest CPO production centers in Indonesia and contribute 26.31% and 16.05% of total production, respectively. The next mosty productive provinces are South Sumatra, Central Kalimantan, Jambi and West Kalimantan with respective contributions of 10.02%, 10.00%, 7.12% and 5.77% total production, respectfully.

The Riau Province has the largest palm oil production center in Indonesia and is spread over 7 districts. The district with the largest palm oil production is Kampar with 1,090,681 tonnes of total palm oil production. The next most productive districts are Rokan Hulu with 1,006,505 tonnes, Pelalawan with 813,126 tonnes, Rokan Hilir with 798,257 tonnes, Siak with 792,777 tonnes, Indragiri Hilir with 596,371 tonnes, and Bengkalis with 460,469 tonnes (Indarti, 2014).

There are numerous factors that affecting the productivity of FFB, life cycle long time process and the variety of land conditions. These factors lead to the importance of oil palm plantation management. A factor that is directly related to the productivity of FFB is bioenvironmental factor. Bioenvironmental factor is the study of human resources and the environment that contributes to the ecology and conservation (Reiss and Chapman, 2000) includes production plants, land conservation, climate, weeds, pests, diseases, and the application of chemicals (David and Susan-Pimentel, 1980). In addition, an integrated evaluation of bioenvironmental factors become a standard to prevent weeds, pests and diseases as well as to respond to the use of pesticides (Haferkamp, 1988).

However, each bioenvironmental factor relationship is very complex and interdependent. To explain those complex and dynamic relationships, dynamic systems analysis is used in this study. To optimize the relationship complexity between the factors that is influencing each other, dynamic system modeling could be performed (Forrester, 1968; Sterman, 2000). The dynamic system framework is used to generate a simulation, due to the ability of a dynamic system in representing the physical and information flow. This benefit allows us to understand the behavior of non-linear dynamics in uncertain conditions (Astrom and Murray, 2006). Dynamic System is a mathematical model to express the relationship between historical data toward changing from time to time, and then predict the future by using a mathematical model approach (Fucs, 2006). This study are expected to predict the FFB productivity by bioenvironmental factors in oil palm plantations.

1.2 Problem Statement

The factors that affecting the productivity of FFB depend on region, climate, and oil palm plantation management. Those factors, including the quality of planting material, age of the plant, fertilization, land condition, rainfall, pest and disease, and harvesting activities (Fairhurst, *et al.*, 2010; Lubis and Widanarko, 2011). Moreover, temperature, exposure time, relative humidity, evaporation, soil moisture, harvest cycles, type of the land, practical management, and pollinator also included in the factors that affecting the productivity of FFB (Stenek and Connell, 2011).

Furthermore, inappropriate and ineffective management, unskillful labor, and marginal area are significantly affecting the productivity of FFB (Yik Nam, 2011). Therefore, it is important to identify the specific factors that are related to the bioenvironmental through literature review. The factors that affecting the productivity of FFB are an important thing that must be considered by every oil palm plantation management. However, it is important to identify which factor that mostly affecting the productivity of FFB.

Most of the studies that have been done only focused on Crude Palm Oil (CPO) mills (Jatmika, 2007), replanting (Zanariah, 2009), biophysical, economic (profit), and social (people) factors (Mandung *et al.*, 2013). It is necessary that factors affecting the productivity of FFB be analyses in an integrated manner. This is because statistical analysis, if conducted separately, may show different results. The relationship between the factors affecting oil palm plantations on FFB are very important to know clearly. Therefore, it is very important to integrate all of the bioenvironmental factors to obtain higher FFB production.

However, combining these factors in an integrative manner is still relatively limited. Syukur and Lubis, (1989) used to predict the growth rate of oil production short term, while Estes *et al.*, (2013) predict crop productivity implication for ecological forecasting. The dynamics of all the factors that affecting the productivity of FFB are necessary to be known to estimate the sustainability of fruit production until the plants are capable to produce optimally (Hidayatno *et al.*, 2011). Bioenvironmental factors that have been in analysed statistically can be used to predict the future FFB productivity. Model bioenvironmental factors need to be verified and validated on oil palm plantations.

1.3 Research Objective

The objective of this study are:

i. To identify bioenvironmental factors which affects the FFB productivity in oil palm plantations

ii. To develop a new model to predict FFB productivity based on bioenvironmental factors.
iii. To verify and validate the model with field survey and statistic analysis.

1.4 Research Scope

The study was focusing on oil palm plant and bioenvironmental factors that affecting the productivity of FFB in Riau Province. A preliminary study was divided into two parts, namely literature review and observation. Literature review activity was aimed to collect the data about factors that affecting the productivity of FFB and the management plan for developing oil palm plantation. There were two observation method that was conducted in this research, namely field observation and focus group discussion. Observation activity was aimed to understand the process in the plantation and to obtain the information needed by using a case study approach. The information obtained from those activities, including the plantation environmental condition, the development activity that has been conducted by the company, and the plantation management system. This activity became a consideration in deciding the research location, in determining which data that would be collected during the research and in determining which bioenvironmental factors that affecting the productivity of FFB.

The next step was data collection. The data includes land survey maps, FFB production, fertilization, planting age, planting area, planting space, weeds, pests and diseases, rainfall and rainy days, land topography, soil and water conservation, herbicides, LSU (leaf sample unit) results, and biological agents.

To create a bioenvironmental factors model in oil palm plantations, Stella simulation with dynamic system analysis was chosen. This study proposes a model based on the bioenvironmental management of FFB productivity in oil palm plantations. Results of statistical analysis used in simulating bioenvironmental factors to predict FFB productivity in oil palm plantations. To find the complex relationship between each factor in the model, a simulation of the Stella software

was used. After that, the model proposed was verified and validated with field survey and Chi Square Test.

1.5 Significance of Study

The finding from this study is expected to give contributions to oil palm plantations farmer and companies. Bioenvironmental factors and their relation with FFB productivity are clearly defined.

Improving the productivity of FFB had been becoming a main priority for every oil palm companies. Therefore, the current study was trying to solve that issue by using a dynamic system modeling. By using this model, it was expected to facilitate the farmer and companies in making policies and creating a sustainable oil palm plantation management. Moreover, based on the analysis performed, it was possible for oil palm companies to save cost both the labor and save material.

Moreover, it also provides a construction bioenvironmental factors model that affects the FFB productivity in oil palm plantation. Therefore, these findings would generate an optimum productivity of FFB, a sustainable oil palm plantation management, and an effective and efficient oil palm plantation management. The finding will benefit to improve the oil palm productivity not only in Riau but also globally.

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