EFFECTS OF POLICY CHANGES ON AGRICULTURAL PRACTICES RELATED TO SELECTED CROPS IN MALAYSIA

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By

ABDULLA IBRAGIMOV GAFURJANOVICH

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirements for the Degree of Doctor of Philosophy

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DEDICATION

I dedicate my dissertation work to my family and many friends. A special feeling of gratitude to my loving parents whose, words of encouragement and push for tenacity ring in my ears. My brothers have never left my side and are very special. I will always appreciate all they have done. I dedicate this work and give special thanks to my wife and my son for being there for me throughout the entire doctorate program. Both of you have been my best cheerleaders.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the Degree of Doctor of Philosophy

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August 2017

Chairman : Professor Datin Paduka Fatimah Bt Mohamed Arshad, PhD
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The agricultural sector growth in Malaysia may not be sustainable in the future as agriculture and food sectors are continuously challenged by shifting fundamentals, resource constraints and climate change. The "business as usual" stance for agriculture may be detrimental to Malaysia in terms of opportunity cost, inefficient use of resources, food insecurity and outflow of foreign exchange for imports. The Malaysian agriculture is biased towards industrial crops, such as palm oil, rubber and cocoa. As in 2015, palm oil accounted for about 4% of the gross domestic product (GDP) and 0.53% for rubber. The share of industrial crops in the land use has increased from 68.5% in 1960 to over 80% in 2015. On the other hand, the land use for the food crops shows an opposite trend. If this trend persists, the food security of the country may be affected.

The agriculture is beset with a number of development issues which remain unaddressed despite the rapid industrialization. These include sectoral division between the industrial crops (palm oil and rubber) and the food commodities (fruits and vegetables, livestock and fisheries). While industrial crops are continuously supported by the government, the food sector is largely marginalized with the exception of paddy and rice sector. Within these sectors, there is another dichotomy between the estates and the smallholders with a significant gap in terms of productivity and returns. Due to higher returns in the palm oil industry, the returns in the rubber and cocoa industries have shrunk significantly (production and area) with most of the farms run by the smallholders i.e. 95% in the rubber and 95% in cocoa sectors). The big gap between the estates and smallholders clearly indicates poor technology transfer and coordination, which calls for improvement in technology transfer, structural and institutional readjustments.

Towards these ends, the study has adopted the system dynamics methodology to capture the circular causality between variables in the crop production system as well as delays and non-linearities.

The general objective of the study is to identify the key policy interventions towards revitalization of the agriculture sector with respect to primary production growth, equity and sustainability. The specific objectives are: (i) To determine structural and institutional factors that lead to the crop mix shift and slow growth in production; (ii) To determine structural and institutional factors that lead to the low income to the farmers and their uncertain livelihoods; (iii) To develop a system dynamics model to capture causal relationship between major structural elements in the sector that lead to the overall poor performance; (iv) To identify the key policy interventions to revitalize and sustain the agriculture sector with respect to primary production growth, equity and sustainability based on the developed system dynamics model. The findings indicate that funding for R&D for development of high yielding varieties, gradual transition to automation and mechanization, local input production along with accelerated replanting hold big promise towards productivity enhancement, cost reduction, thus, higher return particularly to the smallholders. These in turn result in an equitable income distribution among participants both in the industrial and food crop sectors which contributes to an optimal mix of crops and sustainability of the agriculture sector at large.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Doktor Falsafah

KESAN PERUBAHAN POLISI KE ATAS AMALAN PERTANIAN TANAMAN TERPILIH DI MALAYSIA

Oleh

ABDULLA IBRAGIMOV GAFURJANOVICH

Ogos 2017

Pengerusi : Profesor Datin Paduka Fatimah Bt Mohamed Arshad, PhD
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Pertumbuhan sektor pertanian di Malaysia berhadapan dengan isu kelestarian pada masa hadapan. Hal ini didorong oleh sektor pertanian dan makanan yang sentiasa dicabar oleh perubahan fundamental, kekangan sumber dan perubahan iklim. Keadaan "situasi seperti biasa" (*business as usual*) dalam sektor pertanian mungkin menimbulkan masalah kepada Malaysia dari segi kos masa lepas, penggunaan sumber yang tidak cekap, ketidakjaminan bekalan makanan dan aliran keluar tukaran matawang asing bagi sektor import. Pertanian di Malaysia lebih menjurus kepada tanaman industri seperti kelapa sawit, getah dan koko. Pada tahun 2015, kelapa sawit dan getah masing-masing mencatatkan pendapatan lebih kurang 4% dan 0.53% daripada Keluaran Dalam Negara Kasar (KDNK). Pecahan penggunaan tanah bagi tanaman industri telah meningkat kepada 80% pada tahun 2015 berbanding 68.5% pada tahun 1960. Walau bagaimanapun, penggunaan tanah bagi tanaman makanan menunjukkan trend yang bertentangan. Jika situasi ini berterusan, maka bekalan makanan di Malaysia mungkin akan terjejas.

Sektor pertanian dilanda beberapa isu pembangunan yang masih belum diatasi walaupun industri bertumbuh dengan pesat. Hal ini termasuklah jurang antara sektor tanaman industri (kelapa sawit dan getah) dan sektor komoditi makanan (buah-buahan dan sayur-sayuran, ternakan serta perikanan). Tatkala tanaman industri menerima sokongan yang berterusan oleh kerajaan, sektor makanan pula terpinggir secara signifikan kecuali sektor padi dan beras. Dalam kedua-dua sektor tersebut, terdapat pembahagian antara ladang dan pekebun kecil dengan jurang yang ketara dari segi daya pengeluaran dan pulangan. Disebabkan oleh pulangan yang lebih tinggi dalam industri kelapa sawit, pulangan dalam industri getah dan koko pula merosot dengan ketara

(pengeluaran dan keluasan tanaman) dan sebahagian besar tanah dikendalikan oleh pekebun kecil (95% pekebun kecil dalam sektor getah dan 95% pekebun kecil dalam sektor koko). Jurang yang besar antara ladang dan pekebun kecil jelas menunjukkan kelemahan pemindahan dan penyelarasan teknologi yang memerlukan penambahbaikan dari segi penggunaan teknologi serta pelarasan semula struktur dan institusi. Bagi mencapai matlamat tersebut, kajian ini telah menggunakan kaedah sistem dinamik untuk memahami hubungan sebab-akibat dalam pusingan (*circular causality*) antara pembolehubah dalam sistem pengeluaran tanaman serta kelengahan (*delay*) dan ketidaklinearan(*non-linearities*).

Objektif umum kajian ini adalah untuk mengenal pasti dasar intervensi utama ke arah pengukuhan semula sektor pertanian berhubung dengan pertumbuhan pengeluaran primer, kesetaraan dan kelestarian. Objektif khusus adalah: (i) Untuk menentukan faktor struktur dan institusi yang menjurus kepada perubahan dalam campuran tanaman dan pertumbuhan perlahan dalam pengeluaran; (ii) Untuk menentukan faktor struktur dan institusi yang menyebabkan pendapatan petani yang rendah serta punca pendapatan yang tidak menentu; (iii) Untuk membangunkan model sistem dinamik bagi mengenal pasti hubungan sebab-akibat antara struktur elemen utama dalam sektor yang menjurus kepada prestasi keseluruhan sektor pertanian yang perlahan; dan (iv) Untuk mengenal pasti dasar intervensi utama demi meningkatkan dan melestarikan pertumbuhan sektor pertanian berhubung dengan pengeluaran komoditi utama, kesetaraan dan kelestarian berdasarkan model sistem dinamik yang telah dibangunkan. Dapatan kajian ini menunjukkan bahawa pelaburan dalam penyelidikan dan pembangunan (R&D) bagi pembangunan jenis berhasil tinggi (*high yielding varieties*), peningkatan automasi dan mekanisasi secara beransur, pengeluaran input tempatan dan penggiatan penanaman semula menjanjikan daya pengeluaran yang lebih tinggi dan kos yang lebih rendah lantas meningkatkan pulangan yang lebih tinggi terutamanya kepada pekebun kecil. Perubahan ini membawa kepada agihan pendapatan yang saksama dalam kalangan peserta dalam sektor tanaman industri dan tanaman makanan yang akan menyumbang kepada campuran tanaman yang seimbang dan kelestarian sektor pertanian pada umumnya.

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The members of my committee spent many hours reviewing the work. I could not have completed this study without the firm support, constant encouragement, and guidance of Professor Fatimah Mohamed Arshad. In spite of her extremely busy schedule, she has always found time to read my voluminous drafts and make valuable suggestions. Her pragmatic outlook and constant emphasis on relating the research to the real world gently pushed me towards enriching the empirical content in this study that has made it far livelier than it would have been otherwise.

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I would like to express my sincere gratitude to Universiti Putra Malaysia for making the *International Graduate Research Fellowship* possible. I was thrilled to learn of my selection for this honour and I am deeply appreciative of the support. Thank you again for your generosity and support.

I certify that a Thesis Examination Committee has met on 24 August 2017 to conduct the final examination of Abdulla Ibragimov Gafurjanovich on his thesis entitled "Effects of Policy Changes on Agricultural Practices Related to Selected Crops in Malaysia" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Doctor of Philosophy.

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This thesis was submitted to the Senate of the Universiti Putra Malaysia and has been accepted as fulfillment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

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Declaration by graduate student

I hereby confirm that:

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Declaration by Members of Supervisory Committee

This is to confirm that:

- the research conducted and the writing of this thesis was under our supervision;
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LIST OF ABBREVIATIONS AND ACRONYMS

ANRPC	Association of Natural Rubber Producing Countries
B	Balancing Loop
BERNAS	Padiberas Nasional
Bn	billion
CAPRI	Common Agricultural Policy Regionalised Impact
CGE	Computational General Equilibrium
CLD	Causal Loop Diagram
CPO	Crude Palm Oil
DAP	Diammonium Phosphate
DoSM	Department of Statistics Malaysia
E.g.	Exempli Gratia
EPP	Entry Point Projects
EPU	Economic Planning Unit
ETP	Economic Transformation Plan
EU	European Union
FAO	Food and Agriculture Organization
FAPRI	Food and Agricultural Policy Research Institute
FELCRA	Federal Land Consolidation and Rehabilitation Authority
FELDA	Federal Land Development Authority
FFB	Fresh Fruit Bunches
FOB	Free on Board
GDP	Gross Domestic Product
GIS	Geographic Information System

GMP	Guaranteed Minimum Price
GNI	Gross National Income
HIC	High Income Countries
HYV	High Yielding Varieties
IADP	Integrated Agricultural Development Projects
ICT	Information and Communications Technology
IFAD	International Fund for Agricultural Development
IFPRI	International Food Policy Research Institute
IHL	Institutes of Higher Learning
IIASA	International Institute for Applied Systems Analysis
IMF	International Monetary Fund
I-O	Input-Output
JPS	Jabatan Pertanian Sarawak
IRPA	Intensified Research Priority Area
LIC	Low Income Countries
LITS	Low Intensity Tapping System
LMIC	Lower Middle-Income Countries
MARA	Majlis Amanah Rakyat
MNC	Multi National Corporation
MoA	Ministry of Agriculture
MOP	Muriate of Potash
MP	Malaysia Plan
MPOB	Malaysian Palm Oil Board
MPOC	Malaysian Palm Oil Council
MRB	Malaysian Rubber Board

NAP	National Agricultural Policy
NKEA	National Key Economic Area
NPK	Nitrogen, Phosphorous, and Potassium
NPRB	North Pacific Research Board
NR	Natural Rubber
OER	Oil Extraction Rate
OLS	Ordinary Least Squares
PEMANDU	Performance Management and Delivery Unit
PORIM	Palm Oil Research Institute of Malaysia
PPP	Purchasing Power Parity
R	Reinforcing Loop
R&D	Research and Development
RIDA	Rural Industrial Development Authority
RISDA	Rubber Industry Smallholders Development Authority
RM	Ringgit of Malaysia
RRIM	Rubber Research Institute of Malaya
SAM	Social Accounting Matrices
SD	System Dynamics
SF	Stock and Flow
SMR	Standard Malaysian Rubber
SNA	System of National Account
SRIB	Sabah Rubber Industry Board
UMIC	Upper Middle-Income Countries
UN DESA	United Nations Department of Economic and Social Affairs
UNEP	United Nations Environment Programme

CHAPTER 1

INTRODUCTION

1.1 Background

Agriculture is an important component, and plays a key role in Malaysian economy. Although the share of the agriculture sector on the country's GDP has declined from about 30% in the 1970s to about 8.07% in 2016, in terms of absolute value it has grown in value from RM10.6 bn in 1980 to RM27.5 bn in 2010 (DoSM, 2011). Similarly, the number of people employed in the sector has declined from more than half to only 11.5% during the said period (MITI, 2012). This is a natural evolution as the country moves towards industrialization where sectors like manufacturing and services earn bigger share. The industrialization was made possible partly through the release of production factors such as labour, capital and land from the agriculture sector. This imbalanced growth may not be sustainable in the future as agriculture and food sectors are being challenged by shifting fundamentals, resource constraints and climate change. The "business as usual" stance for agriculture may be detrimental to Malaysia in terms opportunity lost, inefficient use of resources, food insecurity and outflow of foreign exchange for imports.

The Malaysian agriculture is biased towards industrial crop such as palm oil, rubber and cocoa (DOS, 2016). As in 2015, palm oil accounted for about 4% of the gross domestic product (GDP) and rubber is accounted for 0.53% of the GDP. The share of industrial crop to the total land has increased from 68.5 in 1960 to 83.7% in 2005. On the other hand, the food crops show an opposite trend. If this trend continues, the food security of the country may be affected.

For instance, the intensive land openings for palm oil areas in the 1980s have resulted in exponential growth in areas and production. However, due to land constraint, urbanization and industrialization, the rate of growth has somewhat slowed down in the 1990s and beyond. The production of rubber suggests an "overshoot" behaviour where it peaked in the 1970s and 1980s and began to decline in the 1990s. A similar behaviour is observed for cocoa. An S-shaped rice production curve is observed where during the Green Revolution era, the rate of growth was much higher than those achieved in the last decade.

The production of agriculture sector showed a relatively higher rate of growth during the 1960s and 1970s and began to decline in the 1990s and beyond, indicating a logistic growth in 1960 - 2010. Most of agricultural productivity growth (palm oil, cocoa, and paddy) has declined during the said period. This non-linear agricultural production behaviour over time implies a structural change that has occurred in the sector.

1.2 Problem Statement

Agriculture is back into most of the countries agenda in the world. The reasons for this include: firstly; the growing importance of the sector lately and in the future as reflected in its multi-functionality as opposed to its conventional roles as food and fiber producer, provider of employment and export income. The functions of agriculture go beyond that, i.e., encompassing food security, environmental, resource sustainability and preservation of rural landscape (Anderson, 2001, Burrel, 2001, Renting et al. 2009). The growing concern of climate change manifested in extreme weather in the last decade is already challenging agricultural and food production worldwide. Secondly, recent decades saw an unprecedented volatility of commodity and food prices as a result of the convergence of multi-dimensional factors: fundamental and technical factors (FAO, 2008). The increase in demand for agricultural commodities and food cannot be matched by the supply sector due to overstressed resources in particular land and water and serious under investment in the developing countries. The food crisis in 2008 clearly revealed the vulnerability of Malaysia to the world market volatility despite being classified as "middle income nation" with adequate foreign exchange to source food from the world market. The world food crisis, though short-lived, was unprecedented in scale and a manifestation of what the world market may endure in the future as volatility continues. Thirdly, the continuous dependence on crude oil energy as well as petroleum-based fertilizer may prove unsustainable in the long-term due to the increase in price as well as volatility and evidences of damages to soil and environment. In view of these factors, it would be useful for Malaysia to relook at this sector again to seek better policy options.

The sector is beset with a number of development issues which remained unaddressed despite the rapid industrialization. These include: sectoral division between the industrial crops (palm oil and rubber) and the food crops and commodities (paddy, fruits and vegetables, livestock and fisheries). The definition of "food crop" is that the crop is grown primarily for food, even though some farmers may sell part or their entire crop for cash (FAO, 2003). While industrial crops are defined as those which are not grown for food and whose production potentially competes with food crops for land, water, labour and capital. A wider definition might also include crops that undergo considerable processing, even if the end product is a food (FAO, 2010). Within these sectors there is another dichotomy between the estates and the smallholders with a significant gap in terms productivity and returns. A similar division exists between the highly commercialized farms (horticultural produce) and the small-scale farms and big fishing boat operators versus the small-scale fisheries. Due to higher returns in the palm oil industry, the rubber and cocoa industries have shrunk significantly (production and area) with most of the farms left run by the smallholders (95% in the rubber and 95 % in cocoa sectors).

Secondly, the country is a net importer of food with deficits growing larger with time with no signs of slowing down. Food trade deficits enlarged from RM1bn in 1990 to almost RM15 bn in 2015 (EPU, 2016). The food balance of trade plan devised in 2001 aimed at achieving a surplus of RM1.2 bn in 2010 was unachievable and hence abandoned. Examination of the country's import composition indicates that it depends for imports for most of its food items such as rice and cereals, feedstuff, fruits and vegetables, beef, mutton, dairy products, processed food as well as agricultural inputs such as feedstuffs, fertilizers, chemicals, seeds, machines and even labour (EPU, 2016). Malaysia's export items are live chickens, poultry meat, eggs, fisheries, cocoa-based products and processed food. However, the surplus in export is offset by a big deficit in trade. Over dependence on the food imports has recently proved risky to the country's food security as proven in the 2008's crisis.

Thirdly, due to the limited innovations in mechanization and automation, the agricultural sector remains highly labour intensive from farm to the later stage of the supply chain (DOS, 2016). The higher wage in the industrial sector caused a massive outflow of human resource from the agricultural sector creating a big void in particular the estate sector. Hence, shortage of labour is a serious issue which threatens the competitiveness of the sector in the future.

Fourthly, the value-added contribution of the sector comes from three major sectors, palm oil (36.6% in 2010), fisheries (14.1%) and sawn timber (10%). In fact, the industrial crops accounted for 56.4% of the total value added in agriculture.

Under the new Agro-food Policy (2011-2020), a number of policy directions and strategies were identified to rejuvenate the sector in terms of growth and value-added contributions. This time around, efforts will be mobilized towards increasing income and ensuring food security to the country. The main thrusts of the strategies are to ensure competitiveness and sustainability. These are achieved through strengthening R&D, improving supply chain, greater private sector role, increasing production and productivity, exploring high value agricultural commodities; all intended to improve competitiveness of the sector. In ensuring sustainability, the following strategies are laid out; encouraging healthy diet, human resource development, biomass and waste management, environmental-friendly practices and addressing climate change. The institutional restructuring includes: a new MoA incorporated concept, implementation of agricultural flagship projects, enhancement of farmers and fisheries institutions, and rationalization of the government agencies (MoA, 2011). The ministry has set a number of targets to be achieved by 2020 as guidelines for objectives realization.

Besides the Agro-food Policy, under the Economic Transformation Plan (ETP), the government has identified the palm oil sector and the agriculture sector as two of the National Key Economic Area (NKEAs) besides other sectors such as services and energy (ETP, 2016). The palm oil industry is targeted to contribute a total of RM125bn (or 11%) to the country's GNI in the year 2020 while agriculture contribution is expected to reach RM29 bn (or 2%). As for agriculture, a total of 16 Entry Point Projects (EPPs) and 11 Business Opportunities have been identified to spearhead the development. The EPPs include among others: unlocking value from Malaysia's biodiversity through high-value herbal products, expanding the production of swift let nests, venturing into commercial scale seaweed farming in Sabah, farming through integrated cage aquaculture systems, rearing cattle in oil palm estate, replicating integrated aquaculture model to tap market for premium shrimp and others (PEMANDU, 2012).

With many strategies and targets, it would be useful to examine whether some of the major targets are achievable given the resources available and the macro-environment faced by the industry. The system dynamics model is the appropriate methodology to examine "what ifs" scenarios in the future to be compared to the current set up, structurally and institutionally (Sterman, 2004). The model also is able to give some indications on the trade-offs between the short and long term's objectives.

Overall problem is stagnant and losing ground in domestic production and producer welfare and sustainable livelihoods. Shift in the crop composition driven by profitability and world price change. Despite the dynamic shift in composition, the overall growth of the agriculture sector is low relative to other sectors. Inequitable distribution of profit and income along the supply chain especially the food producers. The industry exhibits a non-linear behaviour and circular causal interactions between policies and impact and vice versa. Under such a system, a system dynamics approach is the most suitable method to understand the relationship between structure and its impact on behaviour, non-linear relationship between elements or variables, delays in the system as well as simulating the impact of changes in policies on the system. This research seeks to address the following questions:

1) What are the structural and institutional factors and policy paradigms that drive the crop mix change?
2) What causes low agricultural production and productivity?
3) What are the structural factors that cause the inequity throughout the agriculture?

4) What are the key policy intervention towards revitalization of the agriculture sector with respect to primary production growth, equity and sustainability?

1.3 Objectives of the Study

The general objective of the study is to identify the key policy interventions towards revitalization of the agriculture sector with respect to primary production growth, equity and sustainability.

The specific objectives are:

(i) To determine structural and institutional factors that lead to the crop mix shift and slow growth in production;
(ii) To determine structural and institutional factors that lead to the low income to the farmers and their uncertain livelihoods;
(iii) To develop a system dynamics model to capture causal relationship between major structural elements in the sector that lead to the overall poor performance;
(iv) To identify the key policy interventions to revitalize and sustain the agriculture sector with respect to primary production growth, equity and sustainability based on the system dynamics model developed above.

1.4 Novelty of the Study

So far only a handful of studies have analysed the agricultural issues within the SD-in-mean framework. Mainly, literature analyses the issue of agriculture within the individual crop framework. According to these conventional approaches, agricultural policies are analysed using econometric models or other standard statistical formulae and employing various estimation methods ranging from OLS to co-integration techniques. However, this study attempts to analyse the agricultural policy implications as a system employing SD modelling. To do this, a system is represented by feedback loops which simulate the dynamic behaviour of the system. The problem or system (e.g., political system, mechanical system, or plantation area) is first represented as causal loop diagram as well as a stock and flow diagram. Thus, all variables of interest are included in one whole system. Main advantage of this approach is it provides a foundation for constructing computer models to do what the human mind cannot do that is rationally analyse the structure, the interactions and mode of behaviour of complex socioeconomic, technological, and environmental systems. System dynamics methodology is based on feedback concepts and multi loop nonlinear and time lagged complex systems can be handled easily. Fully capturing the nonlinear dynamic relationships is exceedingly difficult with traditional econometric techniques. There is a dearth of system dynamics analysis of the agricultural sector at large in Malaysia. This is a first attempt to study the agricultural sector using system dynamics approach in Malaysia. It is hoped that this study will provide the starting point for a much more comprehensive and advanced application of system dynamics to complex problems in the agricultural sector as well as other industries.

1.5 Scope, Relevance and Limitations

The scope of the thesis confines to the effects of policy changes on dynamics behaviour of selected agricultural crops in Malaysia with relevance to primary production, costs of production, income distribution and crop mix shift.

The major problems of the Malaysian agricultural sector can be summarized as follow:

(i) Rapid urbanization and industrialization is stressing on agricultural factors such as land, input and capital. The outflow of these resources from the agriculture sector will further lead to shrinkage of the sector;

(ii) Yield improvement is mainly due to increase in factor intensity as fertilizer application or irrigation. The level of automation and mechanization is minimal;

(iii) The productivity growth in all crops has been slow or stagnant, so the crop production growth, if any, is largely due to crop area expansion (and crop value growth is more related to its economic value in the world market) and cheap labour.

To this end, the research has applied systems approach that can be used to study and understand the behaviour of a complex system over time which is characterized by interdependence. As Richardson (1999) notes that system dynamics (SD) is a computer-aided approach to policy analysis and design. This approach can be applied to complex dynamic problems of agricultural, biological, environmental, social, managerial, economic, or ecological systems, literally any type of dynamic systems characterized by interdependence, mutual interaction, information feedback, and circular causality.

The findings of the system dynamics analyses may provide some policy lessons to policy makers as well as industry players particularly in evaluating the trade-offs between the short-term benefits and long-term losses. The focus on oil palm plantation may increase production in the medium term but the country is susceptible to both economic and ecological risks due to the hazard of mono-cropping and not diversification. For instance, heavy subsidies may improve productivity in the short term but the fiscal burden cannot be sustained for long.

Besides, the heavy use of fossil based fertiliser is detrimental to soil and water resources as proven in many parts of the world. The reliance on cheap labour solves the shortage issue but it may back fire in the long term as mechanisation and automation are left unattended.

The limitations of the model will also limit the scope of the analysis. The following limitations as well as the substantive assumption of the model given in Chapter four should be kept in view while evaluating this policy analysis.

1. The model used for policy analysis has largely been qualitatively and quantitatively validated with respect to its feedback structure, its internal tendency, and its response to exogenous policy. Thus, while an argument is made for the model being a valid representation of Malaysia's agricultural crop production system, the model is not claimed as an instrument of quantitative forecasting.
2. The growth of agricultural production shown by the model is low to maintain the current degree of self-sufficiency in all policy experiments. This is unrealistic and occurs because of ignoring technological growth and underestimating the impact of exogenous shocks to be strictly fixed.
3. The origins of the policies and the way government may influence their implementation (e.g. Roundtable on Sustainable Palm Oil certification) are outside the scope of the model. Interests of various economic and political groups play significant roles in initiating and directing development programs while the model assumes programs can be implemented independently of the influence of the various power groups.
4. Population growth rate is exogenously specified and no assumptions are made about a possible demographic transition or about changes in population growth rates related with the changes in resources per capita as manifested in many economic theories. Although such processes are controversial, their effects must be recognized.

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APPENDICES

Appendix 1 : List of Equations for Oil Palm

Production Cost=(Production Cost per ha*Total Planted Area)*SMOOTH(1-"A&M Effect on Cost", 7) ~ RM/Year

A&M Effect on Workforce= IF THEN ELSE(Time>=2016, 0.5, 0)

Workforce in Oil Palm=(Total Planted Area/Average Labor Per Hectare)*SMOOTH((1-"A&M Effect on Workforce")/7) ~ worker

Average Labor Per Hectare= 12 ~ ha/worker

Total Mature Crop Area= ("Aged-Tree Area"+Mature Tree Area+Young Tree Area) ~ha

Total Planted Area=(Immature Tree Area+Total Mature Crop Area) ~ ha

Mature Crop Productivity=24 ~ ton/ha/Year

FFB Yield=Implemented Potential Yield+SMOOTH("R&D Policy for yield", 6)

~ ton/ha

Young Crop Productivity= 20 ~ ton/ha/Year

Old Crop Productivity= 14 ~ ton/ha/Year

production=Total Mature Crop Area* FFB Yield ~ton/year

Change in Potential Yield=Desired Productivity Change*"R&D"/Potential Yield Adjustment Delay ~ ton/(Year*ha)

"R&D Policy for yield"= RAMP(6.87, 2016, 2017)

Profit= "Oil Palm Income (RM/yr)"-Production Cost ~ RM/Year

Production Cost per ha= WITH LOOKUP (Time, ([(1980,1220)-(2050,2000)] ,(1980,1220),(1992.42,1469.74),(2011.47,1692.11),(2029.24\,1870), (2050,2000))) ~ RM/ha/Year

Expected Profitability of Oil Palm=("Oil Palm Income (RM/yr)"-Production Cost)/Production Cost

"Oil Palm Income (RM/yr)"=CPO Price*Total FFB ~ RM/Year

Yield Gap=MAX(0,Maximum Economic Yield- FFB Yield)~ton/ha

Implemented Potential Yield=SMOOTH(Potential Yield, Time to Implement New Variety) ~ ton/ha

Desired Productivity Change=Yield Gap~ton/ha

Time to Implement New Variety= 1 ~ Year

Maximum Economic Yield=26~ton/ha

Potential Yield Adjustment Delay=6~Year

Potential Yield= INTEG (Change in Potential Yield,17)~ton/ha

Relative CPO Price=Expected Price/"Reference CPO Farm Price (1980)"~1

"Conversion to Other Sectors (COS)"=Abandoned Area*Normal COS Fraction~ha/Yr

Abandoned Area= INTEG (Decay-"Conversion to Other Sectors (COS)"

Replanting,60000) ~ha

Price Effect on Clear and Cutting= WITH LOOKUP (Relative CPO Price, ([(0,0.78)(3.5,1.33)],(0,1.32035),(0.27682,1.21421),(0.556575,1.11531),(1,1), (1.47706\,0.927149),(2.10856,0.871667),(2.79358,0.828246),(3.45731,0.787 237)))

Decay="Aged-Tree Area"/Normal Life Span*Price Effect on Clear and Cutting~ha/Year

CPO Price= WITH LOOKUP (Time,([(1980,0)-(2050,6000)],(1980,715) ,(1991.77,1815.79),(2005.47,2815.79),(2020.46,3736.84\),(2033.09,4394.74) , (2050,5000))) ~RM/ton

RL Effect on New Planting= WITH LOOKUP (Normalized RL,([(0,0)-(1,1)],(0,0),(0.03,0.16),(0.13,0.39),(0.22,0.55),(0.34,0.7),(0.52,0.84),(0.66\,0.9 1),(0.83,0.96),(1,1)))

~dmnl

Price Effect on Conversion= WITH LOOKUP (Relative CPO Price,([(0,0)-(3.5,2)],(0,0),(0.47,0.22807),(0.78,0.307018),(1,0.359649),(1.35933,0.447368 \),(1.85168,0.552632),(2.35474,0.701754),(2.96,0.903509),(3.5,1.32456)))~dmnl

Normalized RL="Remaining Land (RL)"/Initial RL~1

Early Maturation=Immature Tree Area/EMP ~ha/Year

Initial RL=5.32669e+006~ha

Conversion=Normal Conversion Fraction*OCA Effect on Conversion*Immature Tree Area*Price Effect on Conversion~ha

Normalized OCA="Other Crop Area (OCA)"/Initial OCA~1

Initial OCA=379992~ha

New Planting=Normal New Planting Fraction*RL Effect on New Planting*Immature Tree Area*Price Effect on New Planting ~ha/Year

FFB per Mature Crop Area=Mature Tree Area*Mature Crop Productivity~ton/Year

FFB per Old Crop Area=Old Crop Productivity*"Aged-Tree Area"~ton/Year

FFB per Young Crop Area=Young Tree Area*Young Crop Productivity~ton/Year

Total FFB=FFB per Young Crop Area+FFB per Mature Crop Area+FFB per Old Crop Area~ton/Year

Immature Tree Area= INTEG (New Planting+Conversion+Replanting-Early Maturation,

294000)~ha

Price Effect on New Planting= WITH LOOKUP (Relative CPO Price,([(0,0)-(3.5,2)],(0,0),(0.35,0.3),(0.68,0.6),(1,1),(1.35,1.28),(2.05,1.6),(2.62,1.79\),(3.01,1.92),(3.5,2)))~dmnl

Normal Replanting Fraction=0.6 ~dmnl

Replanting=Abandoned Area*Normal Replanting Fraction*Price Effect on Replanting

~ha

"Remaining Land (RL)"= INTEG (-New Planting,4.32669e+006)~ha

Price Effect on Replanting= WITH LOOKUP (Relative CPO Price,([(0,0)-(3.5,3)],(0,0),(0.406728,0.157895),(0.759939,0.631579),(1,1),(1.12385,1.60526\),(1.47706,2.11842),(2.03364,2.53947),(2.60092,2.78947),(3.5,3)))~dmnl

"Other Crop Area (OCA)"= INTEG (-Conversion,670303) ~ha

Initial Value for Other crop area = Cocoa Area + Rubber Area (1980)

"Reference CPO Farm Price (1980)"=719 ~RM/ton

Ageing=Mature Tree Area/Ageing Period ~ha/Year

Late Maturation=Young Tree Area/Late Maturation Period~ha/Year

Mature Tree Area= INTEG (Late Maturation-Ageing, 400000) ~ha

"Aged-Tree Area"= INTEG (Ageing-Decay, 130000) ~ha

Young Tree Area= INTEG (Early Maturation-Late Maturation,199000) ~ha

Appendix 2 : List of Equations for Rubber

Total Mature Area=(Young Tree Area+Mature Tree Area+"Aged-Tree Area") ~ha

"A&M Effect on Cost"=IF THEN ELSE(Time>=2016, 0.56, 0)

Production Cost=Production Cost per ha*Total Planted Area*SMOOTH(1-"A&M

Effect on Cost", 7) ~RM/Year

"A&M Effect on Workforce"=IF THEN ELSE(Time>=2016, 0.6, 0)

Workforce in Rubber=(Total Planted Area/Average Labor Per Hectare)*SMOOTH((1-

"A&M Effect on Workforce")\, 7) ~worker

Average Labor Per Hectare=6 ~ha/worker

"R&D Policy"=RAMP(1, 2016, 2017)

Change Fraction=0.025

Change in Potential Yield=Desired Productivity Change*Change Fraction/Potential

Yield Adjustment Delay ~ton/(Year*ha)

Rubber Yield=Implemented Potential Yield*Effect of Tapping on Yield+SMOOTH("R&D Policy", 6) ~ton/ha

Expected CPO Price=SMOOTH(CPO Price, Time to Adjust Expected CPO Price)~RM/ton

CPO Price=919~RM/ton

Total Planted Area=Immature Tree Area+Total Mature Area ~ha

Rubber Income="Natural Rubber (NR) Price"*Total Production ~RM/Year

Production Cost per ha= WITH LOOKUP (Time,([(1980,2200)-(2050,8000)], (1980,2200), (1996.06,4140.35),(2014.25,5719.3),(2030.52,\6982.46),

(2050,8000))) ~RM/ha/Year

Expected Profitability of Rubber=(Rubber Income-Production Cost)/Production Cost

Profit= Rubber Income-Production Cost ~RM/Year

Labour=12 ~person/ha/Year

Relative Rainy Days=" Yearly Rainy Days (days/yr)"/"Average Yearly Rainy Days (days/yr)"

Relative Tapping=Normal Tapping*Tapping Intentsity

Normal Tapping=0.9

"Average Yearly Rainy Days (days/yr)"=2000 ~ mm/Year

Time to Implement New Variety=1 ~Year

Effect of Tapping on Yield= WITH LOOKUP (Relative Tapping,([(0,0)-(1,2)],(0,0),(0.232416,0.27193),(0.495413,0.578947),(0.733945,0.736842),(0.98471\,1.00921)))

Desired Productivity Change=Yield Gap ~ton/ha

Yield Gap=Maximum Economic Yield- Rubber Yield ~ton/ha

Maximum Economic Yield=3 ~ton/ha

Effect of Rainy Days on Tapping= WITH LOOKUP (Relative Rainy Days,([(0,0)(1,1)],(0,0),(0.24159,0.381579),(0.498471,0.653509),(0.733945,0.881579),(1,\1)))

Effect of Relative Labour on Tapping= WITH LOOKUP (Relative Labour,([(0,0)-(1,1)],(0,0),(0.24,0.25),(0.49,0.5),(0.74,0.75),(1,1)))

Relative Labour= Labour/"Normal Labour (person/ha)"~1

"Normal Labour (person/ha)"=12 ~person/ha/Year

Potential Yield= INTEG (Change in Potential Yield, 1.2) ~ton/ha

Potential Yield Adjustment Delay=6 ~Year

Implemented Potential Yield=SMOOTH(Potential Yield, Time to Implement New Variety) ~ton/ha

Tapping Intentsity=1*Effect of Rainy Days on Tapping*Effect of Relative Labour on Tapping

Expected NR Price=SMOOTH("Natural Rubber (NR) Price", Time to Adjust Expected NR Price) ~RM/ton

Relative NR Price=Expected NR Price/Reference NR Price~1

Relative Price Ratio=Relative NR Price/Relative CPO Price

Replanting=Abandoned Area*Normal Replanting Fraction

*Price Effect on Replanting ~ ha

Decay="Aged-Tree Area"/Normal Life Span*Price Effect on Life Span ~ha/Year

Price Effect on Replanting= WITH LOOKUP (Relative Price Ratio,([(0,0)-(1,1)],(0,0),(1,1)))

Reference CPO Price=919 ~RM/ton

Reference NR Price=2737 ~RM/ton

Relative CPO Price=Expected CPO Price/Reference CPO Price ~1

Price Effect on New Planting= WITH LOOKUP (Relative Price Ratio,([(0,0)-(2,2)],(0,0),(1,1),(2,1.5)))

Time to Adjust Expected CPO Price=1

"Natural Rubber (NR) Price"= WITH LOOKUP (Time,([(1980,2737)-(2050,12000)],(1980,2737),(1994.34,5743.41),(2014.25,8302.93),(2032.45\,10456.2),(2050,12000)))

~RM/ton

Price Effect on Life Span= WITH LOOKUP (Relative Price Ratio, ([(0,0)-(2,2)],(0,0),(1,1),(2,1.5)))

Time to Adjust Expected NR Price=1

New Planting=Normal New Planting Fraction*Price Effect on New Planting ~ha/Year

Immature Tree Area= INTEG (New Planting+Replanting-Early Maturation,323000)

~ha

Abandoned Area= INTEG (Decay-"Conversion to Other Sectors (COS)"-Replanting,

1000) ~ha

Latex per Mature Crop Area=Mature Tree Area*Mature Crop Productivity ~ton/Year

Latex per Old Crop Area=Old Crop Productivity*"Aged-Tree Area" ~ton/Year

Latex per Young Crop Area=Young Tree Area*Young Crop Productivity ~ton/Year

Old Crop Productivity=0.35 ~ton/ha/Year

Total Production=Latex per Young Crop Area+Latex per Mature Crop Area+Latex per Old Crop Area ~ton/Year

Mature Crop Productivity=1.5~ton/ha/Year

Ageing=Mature Tree Area/Ageing Period ~ha/Year

Late Maturation=Young Tree Area/Late Maturation Period~ha/Year

Mature Tree Area= INTEG (Late Maturation-Ageing,500000) ~ha

"Aged-Tree Area"= INTEG (Ageing-Decay,100000) ~ha

Young Tree Area= INTEG (Early Maturation-Late Maturation,692000) ~ha

Appendix 3 : List of Equations for Cocoa

Total Mature Crop Area=(Young Tree Area+Mature Tree Area+"Aged-Tree Area") ~ ha

Average Labor Per Hectare=4 ~ha/worker

A&M Effect on Workforce=IF THEN ELSE(Time>=2016, 0.3, 0)

Workforce in Cocoa=(Total Planted Area/Average Labor Per Hectare)*SMOOTH((1-"A&M Effect on Workforce")\, 7) ~worker

LIP Effect on Cost=IF THEN ELSE(Time>=2016, 0.3, 0)

Production Cost=Production Cost per ha*Total Planted Area*SMOOTH(1-LIP Effect on Cost, 7) ~ RM/Year

Cocoa Yield=Implemented Potential Yield*Effect of Insect Attack Intensification*Intensifiaction Effect*Effect of Fertlizer*Effect of Labor ~ton/ha

"R&D Policy for yield"= RAMP(4.62, 2016, 2017)

Total Planted Area=Immature Tree Area+Total Mature Crop Area~ha

RnD Effect=IF THEN ELSE(Time>=2016, 0.92, 0)

Production=Cocoa Yield*Total Mature Crop Area

New Planting=Normal New Planting Fraction*Price Effect on New Planting+Land Policy ~ha/Year

Land Policy=IF THEN ELSE(Time>2020, 3000, 0)

Mature Crop Productivity=1.4 ~ton/ha/Year

Young Crop Productivity=0.7 ~ton/ha/Year

Old Crop Productivity=0.3 ~ton/ha/Year

Cocoa Income=Total Production*Cocoa Beans Price ~RM/Year

Expected Profitability of Cocoa=(Cocoa Income-Production Cost)/Production Cost

Profit= Cocoa Income-Production Cost ~RM/Year

Production Cost per ha= WITH LOOKUP (Time,([(1980,1300)-(2050,2900)],(1980,1300),(1993.06,1847.37),(2011.25,2268.42),(2031.16,2661.4),(2050,2900)))

~ RM/ha/Year

Yield Gap=Maximum Economic Yield- Cocoa Yield ~ton/ha

Fertilizer Application500= WITH LOOKUP (Time,([(1980,0)-(2014,600)],(1980,500),(1981.98,307.895),(1983.02,236.842),(1986.13,205.263),(1988.21,192.105),(2003.29,181.579),(2014,157.895)))~kg/ha/Year

"Labor (person/ha)"= WITH LOOKUP (Time,([(1980,0)-(2014,2)],(1980,2),(1981.77,1.76316),(1981.77,1.42105),(1986.13,0.5),(1990.4,0.263158),(1994.87,0.175439),(2003.29,0.192982),(2008.8,0.201754),(2010.26,0.0701754),(2011.3,0.0526316),(2013.06,0.0526316))) ~person/ha/Year

Relative Labor="Labor (person/ha)"/"Normal Labor (person/ha)"~1

Effect of Fertlizer= WITH LOOKUP (Relative Fertilizer Use,([(0,0)-(1,1)],(0,0),(0.2,0.3), (0.28,0.54),(0.4,0.75),(0.6,0.86),(0.78,0.93),(1,1))) ~dmnl

"Normal Labor (person/ha)"=2 ~ person/ha/Year

"Average Fertilizer Requirement (kg/ha/yr)"=500 ~kg/ha/Year

Change in Potential Yield=Desired Productivity Change*"Effect of R&D Subsidy"/Potential Yield Adjustment Delay ~ton/(Year*ha)

Thinning Intensification Rate=Thinning Normal Growth*Thinning Decision

Potential Yield= INTEG (Change in Potential Yield, 1.02) ~ton/ha

Potential Yield Adjustment Delay=6 ~Year

Implemented Potential Yield=SMOOTH(Potential Yield, Time to Implement New Variety) ~ ton/ha

Insect Attack Growth Rate=Insect Multiplication*Insect Normal Growth

Insect Attack Intensification= INTEG (Insect Attack Growth Rate, 0)~dmnl

Insect Multiplication= WITH LOOKUP (Shading Tree Removal Intensification,([(0,0)-(1,1)],(0,1),(1,0)))

Intensifiaction Effect= WITH LOOKUP (Shading Tree Removal Intensification,([(0,0)-(1,1)],(0,0),(1,1)))

Thinning Decision= WITH LOOKUP (Cocoa Yield,([(0,0)-(1,1)],(0,1),(1,0)))

Thinning Normal Growth=0.001~dmnl

Desired Productivity Change=Yield Gap ~ton/ha

Maximum Economic Yield=5 ~ton/ha

Relative Fertilizer Use=Fertilizer Application/"Average Fertilizer Requirement (kg/ha/yr)" ~1

Effect of Insect Attack Intensification= WITH LOOKUP (Insect Attack Intensification,([(0,0)-(1,1)],(0,1),(0.2,0.9),(0.4,0.8),(0.63,0.6),(0.82,0.35),(1,0)))~dmnl

Effect of Labor= WITH LOOKUP (Relative Labor,([(0,0)-(1,1)],(0,0),(0.17,0.16), (0.33,0.32),(0.5,0.48),(0.67,0.64),(0.83,0.8),(1,1)))~dmnl

"Effect of R&D Subsidy"= WITH LOOKUP ("R&D Subsidy",([(0,0.8)-(1,1)],(0,0.9), (1,1)))~dmnl

Shading Tree Removal Intensification= INTEG (Thinning Intensification Rate,1)

Time to Implement New Variety=1~Year

Insect Normal Growth= 0.003 ~dmnl/Year

Abandoned Area= INTEG (Decay-"Conversion to Other Sectors (COS)"-Replanting, 100) ~ha

Relative CPO Price=Expected CPO Price/Reference CPO Price ~1

Decay=Normal Life Span*"Aged-Tree Area"*Price Effect on Clear and Cutting ~ha/Year

Cocoa Beans Price4400= WITH LOOKUP (Time,([(1980,4400)-(2050,15000)],(1980,4400),(1993.06,8212.28),(2017.03,9095.61),(2028.59,13186.8),(2050, 15000))) ~RM/ton

Expected Cocoa bean Price=SMOOTH (Cocoa Beans Price4400, Time to Adjust Expected Cocoa Bean Price)~RM/ton

Price Effect on Clear and Cutting= WITH LOOKUP (Relative Price Ratio,([(0,0)-(1,1)],(0,0),(1,1))) ~dmnl

Price Effect on Conversion= WITH LOOKUP (Relative Price Ratio,([(0,0)-(1,1)],(0,1),(1,0))) ~dmnl

CPO Price=919 ~RM/ton

Price Effect on Replanting= WITH LOOKUP (Relative Price Ratio,([(0,0)-(1,1)],(0,0),(1,1))) ~dmnl

Reference Cocoa Bean Price=4400 ~RM/ton

Reference CPO Price=919 ~RM/ton

Relative Cocoa Bean Price=Expected Cocoa bean Price/Reference Cocoa Bean Price ~1

Immature Tree Area= INTEG (New Planting+Replanting-Early Maturation, 10425)

~ha

Relative Price Ratio=Relative Cocoa Bean Price/Relative CPO Price ~1

Time to Adjust Expected Cocoa Bean Price=1

Expected CPO Price=SMOOTH(CPO Price, Time to Adjust Expected CPO Price) ~RM/ton

Price Effect on New Planting= WITH LOOKUP (Relative Price Ratio,([(0,0)-(1,1)],(0,0),(1,1))) ~dmnl

Time to Adjust Expected CPO Price=1~Year

Replanting=Abandoned Area*Normal Replanting Fraction*Price Effect on Replanting ~ha

"Conversion to Other Sectors (COS)"=Abandoned Area*Normal COS Fraction*Price Effect on Conversion ~ha/Year

Mature Tree Area= INTEG (Late Maturation-Ageing-d1,14325) ~ha

Young Tree Area= INTEG (Early Maturation-d2-Late Maturation, 5000)~ha

Normal Life Span=7~Year

Early Maturation=Immature Tree Area/EMP ~ha/Year

Cocoa Beans Production per Mature Crop Area=Mature Tree Area*Mature Crop Productivity ~ton/Year

Cocoa Beans Production per Old Crop Area=Old Crop Productivity*"Aged-Tree Area" ~ton/Year

Cocoa Beans per Young Crop Area=Young Tree Area*Young Crop Productivity ~ton/Year

Cocoa Production=Cocoa Beans per Young Crop Area+Cocoa Beans Production per Mature Crop Area+Cocoa Beans Production per Old Crop Area ~ton/Year

Ageing=Mature Tree Area/Ageing Period ~ha/Year

Late Maturation=Young Tree Area/Late Maturation Period~ha/Year

"Aged-Tree Area"= INTEG (Ageing-Decay, 5000)~ha

Appendix 4 : List of Equations for Paddy

Total Paddy Area=Rice Area~ha

Workforce in Paddy=Total Paddy Area*Average Labor Per Hectare*SMOOTH((1-"A&M Effect on Workforce"), 7) ~worker

Paddy Yield=Implemented Potential Yield*Land Degradation ~ton/ha

"A&M Effect on Workforce"=IF THEN ELSE(Time>=2016, 0.4, 0) ~dmnl

Average Labor Per Hectare=1.46 ~worker/ha

LIP Effect on Cost=IF THEN ELSE(Time>=2016, 0.18, 0)

Production Cost=Total Paddy Area*Production Cost per ha*SMOOTH(1-LIP Effect on Cost, 7) ~RM/Year

Change in Potential Yield=Desired Productivity Change*Change/Potential Yield Adjustment Delay ~ton/(Year*ha)

Total Paddy Production=Paddy Yield*Total Paddy Area ~ton/Year

Production Cost per ha= WITH LOOKUP (Time,([(1980,900)-(2050,2000)],(1980,954),(1985.99,1252.19),(1993.27,1474.12),(2001.41,1647.81),(2011.25,1780.7),(2020.89,1879.39),(2031.16,1933.33),(2050,2000))) ~RM/ha/Year

Paddy Income=Rice Price*Total Paddy Production~RM/Year

Expected Profitability of Paddy=(Paddy Income-Production Cost)/Production Cost

Profit= Paddy Income-Production Cost ~RM/Year

Rice Area Discrad Rate=Normal Discard Fraction*Rice Area*Effect of Profit on Discard Rate ~ha

Relative Profitability=Rice Price/Cash Crop Price ~1

Desired Rice Area= Rice Demand/Paddy Yield ~ha

Paddy Yield= 2.6 ~ton/ha

Cash Crop Price=919~RM/ton

Rice Area= INTEG (Rice Area Increase Rate-Rice Area Discrad Rate,716800) ~ha

Development Time=1~Year

Rice Price= WITH LOOKUP (Time,([(1980,0)-(2050,2000)],(1980,480),(1990.92,508.772), (1997.34,552.632),(2001.41,640.351),(2006.97,824.561),(2011.9,1000),(2015.11,1078.95),(2020.03,1219.3),(2026.45,1315.79),(2035.02,1385.96),(2050,1500))) ~RM/ton

Rice Area Increase Rate=Government Support Decision for Land

Development*Desired Rice Area /Development Time ~ha/Year

Regenaration=Land Degradation*Regenaration Factor

Land Degradation= INTEG (Regenaration-Degenaration, 1)

Degenaration Factor=0.015

Regenaration Factor= 0.005

Degenaration=Land Degradation*Degenaration Factor

Desired Productivity Change=Yield Gap ~ton/ha

Potential Yield Adjustment Delay=3~Year

Yield Gap=Maximum Economic Yield- Paddy Yield~ton/ha

Maximum Economic Yield=7.2 ~ton/ha

Potential Paddy Yield= INTEG (Change in Potential Yield,2.85) ~ton/ha

Implemented Potential Yield=SMOOTH(Potential Paddy Yield, Time to Implement New Variety)~ton/ha

Time to Implement New Variety=5 ~Year

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