UNIVERSITI PUTRA MALAYSIA

SPATIO-TEMPORAL DYNAMICS OF AGRICULTURAL LAND USE AND LAND USE CHANGE IN SELANGOR, MALAYSIA USING DYNA-CLUE MODEL

OLANIYI AKEEM OLAWALE

FPAS 2013 22

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OLANIYI AKEEM OLAWALE

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

August 2013

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DEDICATION

This work is dedicated to the ONE and ONLY ALLAH (SWT) the owner and bestower of knowledge. "… only HIM do I worship, and from HIM alone do I seek assistance". I really appreciate HIS divine guidance and support for me. There is nothing I can offer that can be equivalent to HIS love, mercy and guidance on me, my households and endeavours. I prayed for HIS continuous guidance and mercy for the rest of my life, my soul and those of my entire generations till the end of time (Amin).

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirements for the degree of Doctor of Philosophy

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By

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August 2013

Chairman: Associate Professor Ahmad Makmom Abdullah, PhD

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Selangor is one of the most economically developed states in Malaysia. For some decades now, the contribution of the agricultural sector to the economy of the state had been overtaken by the manufacturing and the services sectors. Therefore, it becomes important to assess the trend, the drivers and predict future agricultural land uses under different scenarios and evaluate the implications of the agricultural land use change for food security. Data applied in this study were collected from the relevant agencies of the Malaysian government and the data were transformed into the formats that made them suitable for statistical analysis with excel spreadsheet, ArcGIS 9.2, MatLab and SPSS (version 19) softwares.

Eighty eight spatially explicit independent variables hypothesized to influence agricultural land use decision in the study area were disaggregated from where twenty

eight most significant variables driving agricultural land use were selected. Principal Component Analysis (PCA) was used to aggregate the 28 independent variables into seven important factors influencing agricultural land use decision. Scenarios of agricultural land use demands were projected with trend analysis using data of 1990 as the baseline. DynaCLUE model was utilised to allocate different agricultural land use demands under two separate spatial policies (restricted and unrestricted agricultural land use policies). The performance of the model (DynaCLUE) was evaluated with the use of Kappa statistics. Hotspots of agricultural land use change were mapped and the food security scenarios were assessed.

This study found that agricultural land use in the study area will continue to decline until 2030 except under RED scenario. The agricultural land use in the study area were determined by urbanization, availability of agricultural labour, aging, sectoral competition for labour, climatic factors, accessibilities and availability of suitable agricultural land. Moreso, this research found peat swamp in the north eastern part and coastal areas of Selangor as the hotspots of land use change under the Business – as – Usual/Rapid Economic Development and Environmental Conservation scenarios respectively and that food security will be mostly assured under RED scenario.

Though the ECs scenario could be attractive because of its positive impact on environment, however, it choice as an economic pathway may be unfavourable because of its social and economic implications. Whereas, the RED scenario signifies improvement in the general wellbeing of the citizen but could cause negative impact on the sensitive ecosystems. In conclusion, this research has been able to predict the trend,

identify the drivers and hotspots of agricultural land use change and assess the food security implication of different developmental scenarios in the study area.

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

SPATIAL-TEMPORAL PENGGUNAAN TANAH PERTANIAN DAN PERUBAHAN PENGGUNANAAN TANAH DI SELANGOR, MALAYSIA MENGGUNAKAN MODEL DYNA-CLUE

Oleh

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Fakulti: Pengajian Alam Sekitar

Selangor adalah antara negeri yang termaju dalam aspek ekonomi di Malaysia. Dalam beberapa dekad kini, sumbangan sektor pertanian kepada ekonomi negara lebih tertumpu kepada sektor pembuatan dan perkhidmatan. Oleh itu, adalah penting untuk menilai corak perubahan, faktor-faktor serta ramalan pengunaan tanah pertanian pada masa hadapan di bawah situasi yang berbeza dan menilai implikasi perubahan penggunaan tanah pertanian bagi tujuan kelestarian bekalan makanan. Data yang digunakan dalam kajian ini diperolehi dari agensi-agensi berkaitan dari kerajaan Malaysia dan data tersebut telah diformat mengikut kesesuaian untuk analisis statistik dengan excel spreadsheet, ArcGIS 9.2, MATLAB dan perisian SPSS (versi 19) .

Lapan puluh lapan pembolehubah yang dimanipulasi bagi hipotesis untuk

mempengaruhi keputusan pertanian guna tanah di kawasan kajian telah dikategorikan kepada dua puluh lapan pembolehubah yang paling penting sebagai faktor penggunaan tanah pertanian. Prinsipal komponen analisisa (PCA) telah digunakan untuk agregat 28 pembolehubah yang dimanipulasikan kepada tujuh faktor penting yang mempengaruhi keputusan pertanian penggunaan tanah. Senario tuntutan penggunaan tanah pertanian pula diramalkan dengan menganalisis data pada tahun1990 sebagai data asas kepada model. Model DynaCLUE adalah model yang digunakan untuk mengkaji faktor penggunaan tanah pertanian yang di bawahdua polisi yang berasingan (dasar penggunaan tanah pertanian terhad dan tidak terbatas). Prestasi model (DynaCLUE) telah dinilai dengan menggunakan Kappa statistik. Kawasan tumpuan penggunaan tanah pertanian telah dipetakan dan senario kelestarian bekalan makanan telah dinilai.

Kajian ini mendapati bahawa penggunaan tanah pertanian di kawasan kajian akan terus merosot sehingga 2030 kecuali di bawah senario RED. Penggunaan tanah pertanian di kawasan kajian telah ditentukan oleh perbandaran, buruh pertanian, penuaan, persaingan sektor bagi buruh, faktor-faktor iklim dan faktor tanah pertanian yang sesuai. Tambahan pula, kajian ini mendapati paya gambut di utara bahagian timur dan kawasan pantai Selangor sebagai kawasan tumpuan bagi perubahan penggunaan tanah di bawah perniagaan sebagai Pembangunan Ekonomi Biasa/Rapid dan senario Pemuliharaan Alam Sekitar masing-masing dan bahawa kelestarian bekalan makanan Kebanya kannya dijamin di bawah RED senario.

Walaupun senario EC itu boleh menjadi perhatian kerana kesan positifnya terhadap alam sekitar, jika ia menjadi pilihan sebagai laluan ekonomi, ia mungkin tidak

menguntungkan kerana implikasinya terhadap sosial dan ekonomi. Manakala, senario RED menandakan peningkatan dalam kesejahteraan umum masyarakat tetapi boleh menyebabkan kesan negatif kepada ekosistem yang sensitif. Kesimpulannya, kajian ini telah berjaya membuat ramalan, mengenal pasti faktor-faktor dan kawasan tumpuan bagi perubahan penggunaan tanah pertanian dan menilai implikasi simpanan makanan terhadap pembangunan yang berbeza di kawasan kajian.

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I certify that a Thesis Examination Committee has met on 1 August 2013 to conduct the final examination of Olaniyi Akeem Olawale on his thesis entitled "Spatio-Temporal Dynamics of Agricultural Land Use and Land Use Change in Selangor, Malaysia, using Dyna-Clue Model" 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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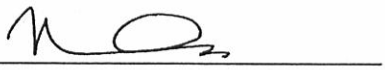

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfillment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

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DECLARATION

I hereby confirm that:

- this thesis is my original work
- quotations, illustrations and citations have been duly referenced
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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,
- supervision responsibilities as slated in Rule 41 in Rules 2003 (Revision 2012-2013) were adhered to.

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TABLE OF CONTENTS

LISTS OF TABLES

LISTS OF FIGURES

LIST OF ABBREVATIONS

ACDA	Agricultural Concentrated Development Area
AEZ	Agro Ecological Zones
AIC	Akaike Information Criterion
ALU	Agricultural Land Use
ALUC	Agricultural Land Use Categories
ALUT	Agricultural Land Use Types
ANOVA	Analysis of Variance
ASDP	Area Specific Development Project
ASCII	American Standard Code for Information Interchange
AUC	Area under Curve
Avr	Average
BAU	Business–as–Usual
BMLR	Binomial Multiple Logistic Regression
CA	Cellular Automata
CAP	Common Agricultural Policy
CDA	Cluster Development Approach
CEC	Cation Exchangeable Capacity
DynaCLUE	Conversions of Land and its Effects
DVs	Dependent Variables
ECs	Environmental Conservation Scenarios
FAO	Food and Agriculture Organization
FELCRA	Federal Land Consolidation and Rehabilitation Authority

FELDA	Federal Land Development Authority
GATT	General Agreement on Tariffs and Trade
GDP	Gross Domestic Product
GFP	Good Farming Practices
GIS	Geographic Information System
GLMs	Generalized Linear Models
GRASP	Generalized Regression Analysis and Spatial Predictions
IVs	Independent Variables
JUPEM	Jabatan Ukur Dan Pemetaan Malaysia (Department of Survey and Mapping Malaysia)
JMG	Jabatan Minera dan Geosians (Department of Mineral and Geoscience)
LU	Land Use
LUC	Land Use Change
LUCAM	Land Use Change Analysis and Modeling
LUCC	Land Use and Cover Change
LULUC	Land Use and Land Use Change
MARA	Council of Trust for the Indigenous People
MatLab	Mathematical Laboratory Software
MCA	Markov Chain Analysis
MCM	Markov Chain Model
MDoA	Malaysian Department of Agriculture
MDoS	Malaysian Department of Statistics
MMD	Malaysian Meteorological Department
MNLR	Multinomial Logistic Regression

MF	Modern Farm
MP	Malaysian Plan
Nag	Nagelkerke
NAP	National Agricultural Policy
NaU	Non–Agricultural Uses
NDP	National Development Policy
NEP	New Economic Policy
NRS	National Remote Sensing Centre
OPP	Outline Perspective Plan
OR	Odd Ratio
PCA	Principal Component Analysis
PFPP	Permanent Food Production Park
PV	Predictor Variables
RED	Rapid Economic Development
RISDA	Rural Industrial Development Authority
ROC	Receiver Operating Characteristics
RV	Response Variables
SC	Schwarz Criterion
SPSS	Statistical Package for Social Scientists
Vision2020	Vision 2020

CHAPTER ONE

INTRODUCTION

1.1 Background of Study

Land use change is a common feature of economic development all over world (Laymon, 2003; Lausch and Herzog, 2002). Most of this change is concentrated in the capital cities where concern for 'ecological footprint' and sustainable livelihood is very high (Rees, 1992). In Malaysia, land use change in the wake of economic development have been documented by various researchers (Abdullah and Hezri, 2008; Abdullah and Nakaghozi, 2007; Abdullah and Nakaghozi, 2006). The change occurmostly in Selangor (Figure. 1) where the strategic location of the state for socio-economic and political activities have brought about significant transformation of the agricultural landscape to urban built-up (Olaniyi et al. 2012; Abdullah and Hezri, 2008; Abdullah and Nakaghozi, 2007; Abdullah and Nakaghozi, 2006; Saharudin et al. 2004).

Aside the locational advantage of Selangor which makes it a hotspot of agricultural land use change, the state (Selangor) houses the old (Kuala Lumpur) and the new (Putrajaya) federal administrative capital cities and the country's international airport thus giving the state opportunity to offer off-farm employment that are attractive to the international and local migrants. The demand for specific type of food, housing and other socio – economic infrastructures by the migrants and the locals further increase the dynamism of agricultural and non-agricultural land use in the state over time (Abdullah and Hezri, 2008).

At the early stage of economic development in Malaysia and of course, Selangor, agricultural productivities was accorded the highest priority through policy intervention and agriculturally biased budgetary allocation (Arshad et al. 2007). For example, during the first Malaysian Plan (1965 – 1960), agricultural sector received the highest allocation (about 26%) of the total annual budget (Arshad et al. 2007). Other policy interventions such as the establishment of agricultural based agencies e.g Rural Industrial Development Authority (RISDA), Council of Trust for the Indigenous People (MARA) led to the promotion of commercial farming (Tamin, 1991; EPU, 1981). The launch of the National Economic Policy (NEP) and the First Outline Perspective Plan (OPP) between 1970 and 1990 that sought to reduce the rural poverty through direct investment (irrigation facilities and rural road networks) in the agricultural development increase the agricultural land use further (Olaniyi et al. 2013).

Futhermore the agrarian reform through land development and resettlement programmes marked the turning point in Malaysian agricultural development. Resettlement programmes such as Federal Land Development Authority (FELDA) (1956); Federal Land Consolidation and Rehabilitation Authority (FELCRA) (1966) and (RISDA) (1972) led to the relocation, rehabilitation and consolidation of farmers from overcrowded and non-economic holdings to commercial farming schemes 10th Malaysian Plan (MP).

Food security policy of the 1980's is another important policy programme that shaped the direction of Malaysian agricultural land use. Issues of food security became the

focus of the government because of unpredictable supply from food exporting countries. Therefore, during the first and the second Malaysian Plans, the cultivation of paddy for food security attracted political attention through heavy investments in irrigation and drainage facilities (Arshad et al. 2007). National paddy and rice price control act were implemented to remove structural deficiencies and market imperfections caused by the intermediaries and to ensure that farmers are adequately compensated for their farming activities. These interventions increase agricultural productivities and consequently increase agricultural land use (Arshad et al. 2007).

Crop diversification policy was embarked upon because of reduction in national income from rubber exportation due to a fall in global price of rubber latex (Olaniyi et al. 2013). This policy led to the introduction of oil palm, cocoa, pineapples, pepper, fruits and vegetables into Malaysian agricultural landscape. This diversification policy resulted in increased the acreage of oil palm from 2.1% in 1960to 63.4% of total agricultural land by 2005 (Arshad et al. 2007).

In 1978, Malaysia adopted the FAO recommended Integrated Agricultural Development Projects (IADPs) guidelines in rural areas through the creation of dams for rice production, replanting of rubber, coconut, pineapple, oil palm and cocoa (Arshad, 2007; Arshad, 1997). In 1984 and 1992, National Agricultural Policy (NAP 1 & 2) (1986 – 1990) were launched to provide a policy direction for the agricultural sector so that it could match up with the other sectors (manufacturing and the services) of the economy in terms of productivities and return on investments. These policies provided

opportunity for the establishment of agro based industries for value addition to rubber, oil palm, food and wood before exportation (EPU, 1984). The increase in the rate of return on agricultural investment due to the implementation of these policies subsequently brought about increase in agricultural land use.

However, the implementation of the National Development Policy (NDP) and several other National Plans (1991 - 2010) in Malaysia brought a setback to further extensification of the agricultural sector. The NDP and other MPs from (1991 - 2010) were introduced to transform Malaysia into a highly developed economy by the year 2020 (EPU, 1996; Doraisami, 2004). Under these policies, the agricultural sector was accorded lesser national priority. Thus, the sector (agricultural) was overtaken by the manufacturing and services sectors in its contribution to the GDP, employment and foreign exchange earnings.

The associated urbanization that accompanied industrialization further increased labour shortages in the agricultural sector such that the agricultural sector found it difficult to compete with the other sectors for investments (land, labour and capital). The comparative better condition of service offered to labour in the manufacturing sector compared to the other sectors caused theoutflow of labour in the agricultural sector and this caused a major setback for sustained agricultural expansion. However, this scenario had been experienced in Korea, China, USA, UK, Japan, Hong Kong and Taiwan during their economic transformations (Sun et al. 2007; Deng et al. 2006; Huang, 1993).

1.2 Problem Statement

Agricultural land use is declining in major economies of the world as well as in Malaysia (Lambin et al. 2003). Much of this change is asa result of globalization, where countries of the world are positioning themselves to exploit new opportunities in the global markets. This situation caused competitions between economic sectors for investments. Since investors are rational decision makers (will make investment where such attract the highest returns). The current lower rates of return on agricultural investment compared to the manufacturing and the services sectors have resulted to the withdrawal and diversion of investments from the agricultural sector thuscausing reduction in agricultural land uses (Olaniyi et al. 2013).

The global increase in the prices of major food crops pose social security challenges for the food importing countries. The major cause of the food security crisis were suboptimal harvests, stock reduction, commodities speculation, increasing non-food demand for agricultural commodities and the conversion of agricultural land into non agricultural uses as a result of industrialization and urbanization (Figure 1.1). This global food crisis has led the rich countries to increase their investments in arable land of the other (land) rich countries in order to secure their food and non-food demands for agricultural commodities. However, as industrialization and urbanization increase in the land rich countries, the available agricultural land is been quickly replaced by urban development.

The publications of the Malaysian Department of Agriculture (ie NAP3) have related the barriers of agricultural land use to the country's biophysical challenges.Moreso, agricultural land use in Malaysia is fast changing as a result of changes in local food preferences and regional trade agreements. For example, the urbanization witnessed at the wake of industrialization led to increased standard of living through increased income. This increased income raised the health awareness and caused a shift from consumption of starchy food to highly proteinous food (Arshad et al. 2007). These shifts in local food preferences subsequently influence agricultural land use for growing of fruits, vegetables, pastures, orchard and fish ponds (Fox et al. 2008; Fujita and Phanvilay, 2008; Padoch et al. 2007; Fox and Vogler, 2005; Xu et al. 2005; Thongmanivong et al. 2005).

The determination of the Malaysian government to transform Malaysia to a highly developed nation leads to the conversion of agricultural lands, to industrial sites and build up areas. The economic focus on industrial development led to the encroachment of the existing arable land. As arable land becomes scarce and food imports increases, the need to assess the trends, identify and quantify the drivers of agricultural land use dynamics for hotpots analysis and to highlight the implications of arable land conversion on food security in Malaysia becomes necessary in order to make relevant data available for land use planning and management.

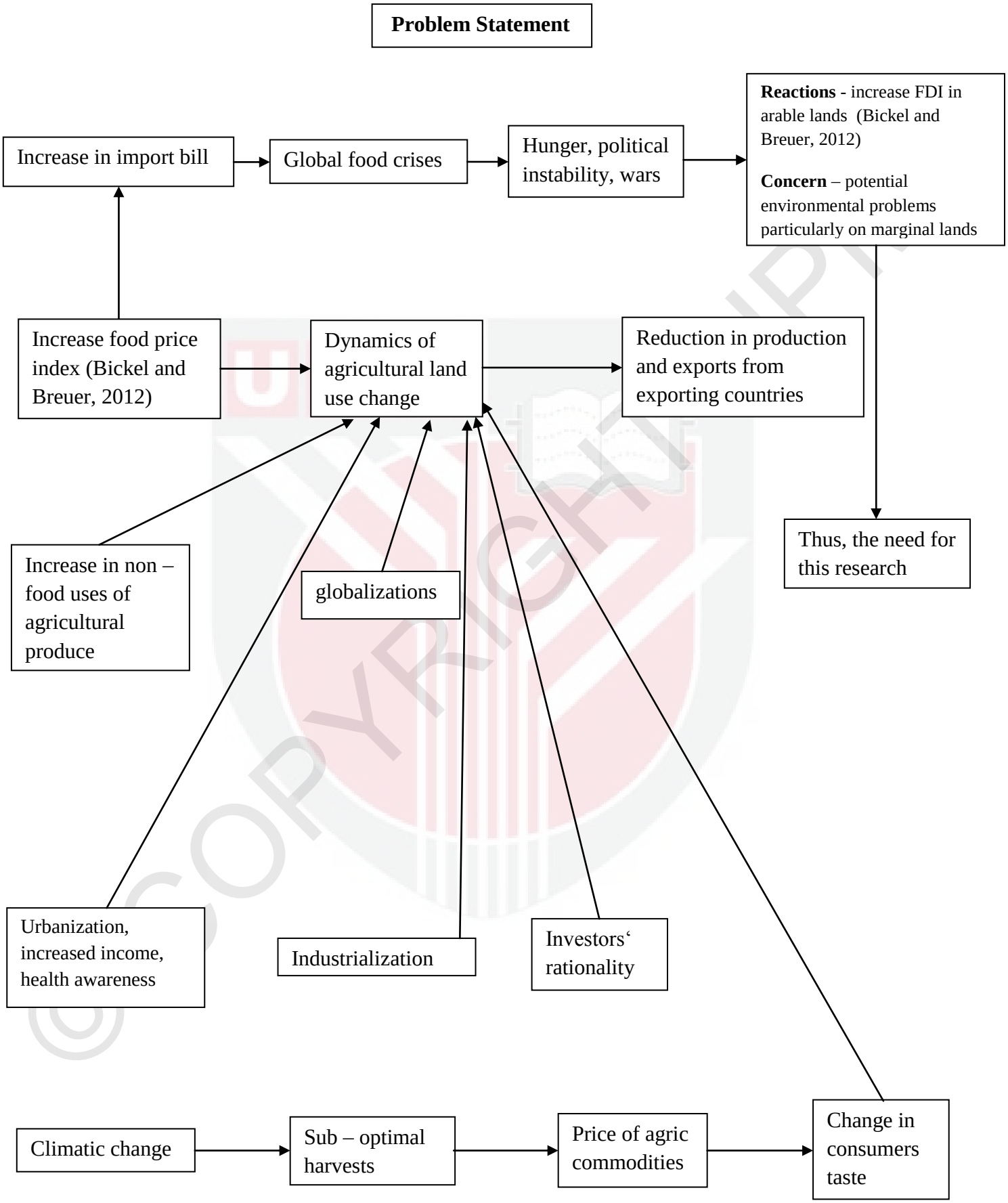

Figure 1.1. Problem Statement

There exist complex interactions between environmental and socio-economic factors influencing agricultural land use. The analysis of these factors, their relationships and dynamics are useful in understanding the past land use changes from where the future direction of the change could be established.

1.3 Study Objectives

The aim of this study is to assess the trend, identify the drivers, identify the hotspots of future agricultural land use change and project the implications of the agricultural land use dynamics for food security in Selangor, Malaysia.

The specific objectives of this study are:

(1) to analyse the dynamics of agricultural land use and land use change (spatio – temporally) in the study area.
(2) to identify and quantify the main biophysical and socio economic drivers of agricultural land use.
(3) to identify the hotspots of future agricultural lands use change in the study area.
(4) to estimate the potential effects of agricultural land use change on food security.

1.4 Research Questions

The research questions for this study were drawn after extensive literature review of related studies. This research is borne out of the need to critically examine (i) whether

the trend of agricultural land use in Selangor had been increasing or decreasing (ii) the driving factors of agricultural land use change (iii) the hotspots of agricultural land change (iv) the implications of agricultural land use change for food security in Selangor. Therefore, this research hope to answer the following research questions :

Research Question 1: has agricultural land use in Selangor changes spatially ?

Research Question 2: has agricultural land use in Selangor changes temporally ?

Research Question 3: is agricultural land use change in Selangor influenced by socio – economic and or biophysical factors ?

Research Question 4: which of the agricultural land use driver is more significant than the other ?

Research Question 5: what are the trends of agricultural land use dynamics in Selangor ?

Research Question 6: what are the effects of spatial policies on the dynamics of agricultural land use change in Selangor ?

Research Question 7 what implication does agricultural land use dynamics has on food security ?

1.5 Significance of the Study

Available evidences showed that Selangor is at brink of major land use change, the land use professionals and the policy makers are uncertain about the direction and the likely implications of these changes on the people and the environment. An assessment of agricultural land use in Selangor, will give an insight of the driving factors, the likely trend and the implications the land use change will have for for food security such that if the quantity of agricultural land to be converted to non agricultural uses under a certain policy scenario is too high in a way to negatively impact food security, (Brown, 1995), a

policy reversal that will maintain a balance between socio – economic development and food security may be advocated (Xiangzheng et al. 2010).

Studies of the agricultural land use dynamics are important in order to assess the potential for agricultural land expansion in production of currently cultivated land through spatially referenced datasets. This information becomes useful for mapping sustainable agricultural land uses and to make relevant information available to the local communities, investors and the government on locations where investments will bring higher returns and to steer investors away from fragile or marginal lands where agricultural investments could have adverseeconomic and environmental impacts.

Moreso, information on productive capacity of land could help local communities as well as governmental institutions in appreciating alternative options for land use planning and to guide them to an evidenced based judgement for land use decisions. Moreover, information about land use is important for the assessment of the environmental impacts of land use (Maitima et al. 2004) and to evaluate the resilience and vulnerability of land use under different scenarios (Yecui et al. 2013; Forbes et al. 1995).

Spatially explicit analysis of land use change will facilitate spatially explicit maps that will enable the policy makers to formulate and implement geographically targeted intervention policies. Scenarios result will suggest potential locations of agricultural land use changes for hotspots analysis.

1.6 Organization of the Thesis

This thesis is organized into five chapters viz:

Chapter one discusses the socio–economic and political background of the study area. The implication of these for agricultural land use dynamics, the objectives of the study and the limitations in land use analysis and modeling.

Chapter two elaborates the significance of land use change analysis in environmental studies, the methodologies and approaches used, the driving factors as well as the models that have been successfully implemented in land use change analysis and modeling.The principles of land use allocation in DynaCLUE model were highlighted.

Chapter three focuses on the descriptions of the study area, data acquisitions, data formatting for statistical analysis and the empirical analysis of the drivers of agricultural land use change. Methodologies for estimating future land demands, potential hotspots of land use change and food security indices were also discussed in this chapter.

Chapter four describes the results obtained from this study. This chapter also presents the land use dynamics, food security indices and the hotspots of agricultural land use change under different scenarios and the findings were linked to the experiences in other transiting economies.

Chapter five elaborates on the major findings of the study, shortcomings in the study and also presents recommendations for future studies.

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