



**LAND USE GEOSPATIAL INDICES (LUGI) FOR
MEASURING URBAN SPRAWL IN ESTABLISHED
URBAN: A CASE STUDY OF KUALA LUMPUR**

BY

NUR AULIA BT ROSNI

**A thesis submitted in fulfilment of the requirement for the
degree of Doctor of Philosophy (Built Environment)**

**Kulliyyah of Architecture and Environmental Design
International Islamic University Malaysia**

JULY 2018

ABSTRACT

The term urban sprawl has a decades-long history in academic discourse, and yet there is still a lack of an integrated and comprehensive quantitative method to measure urban sprawl, especially in developing countries like Malaysia. Urban sprawl remains one of the unsolved urban issues and a major challenge for sustainable development concept. Many researchers have agreed that characterising urban sprawl using spatial measures requires the wide-ranging definition of urban sprawl principles. In this research, urban sprawl is defined as ineffective and dysfunctional urban growth that significantly interrupts the proper arrangement of land use, which in turn affects the sustainability of built environment elements, such as the degradation of the environment, and the deprivation of economic and social well-being. The aim of this research is to measure urban sprawl in the city of Kuala Lumpur city using five (5) components of Land Use Geospatial Indices (LUGI) with the application of remote sensing and GIS approach. The components of LUGI include i) segregated land use, ii) development planning consistency, iii) urban density, iv) strip development, and v) leapfrog development. The data used includes Landsat 5TM and Landsat 8 OLI-TIRS (30m resolution), as well as SPOT 5 and SPOT 6 (1.5m resolution) satellite images, which were used and combined with GIS database for change detection analysis and LUGI analysis. The city of Kuala Lumpur has been selected as a study area to examine the urban sprawl growth based on the land use patterns for the years 2005 and 2015. The urban sprawl measurement was conducted for each of Kuala Lumpur's strategic planning zones (SPZ), namely i) Sentul-Menjalara, ii) Wangsa Maju-Maluri, iii) City Centre, iv) Bandar Tun Razak-Sungai Besi, v) Bukit Jalil-Seputeh and vi) Damansara-Penchala. The findings of the LUGI calculation prove that Kuala Lumpur is currently facing a high index of segregated sprawl due to previous land use and zoning regulations enforced by local authorities. Strip and leapfrog geospatial indices also scored high on the index of sprawling in Kuala Lumpur; however, its occurrence can be justified by the compact in-fill development trend in Kuala Lumpur. Thus, this research found out that strip and leapfrog geospatial indices are more practical to measure sprawl in developing or sub-urban areas compared to already developed areas. Lastly, the lowest land use sprawl scores in Kuala Lumpur are development planning consistency sprawl and urban density sprawl, indicating that these types of geospatial indices sprawl are less likely to occur in Kuala Lumpur due to the strong enforcement of development plan that emphasises high-density development. This research focuses on the smaller but highly developed urban context, namely the city of Kuala Lumpur, where it was found that only three out of five geospatial indices are suitable to measure the sprawl index on the city scale. Therefore, the research agreed that the integration of LUGI urban sprawl with remote sensing and GIS was able to measure the formation of land use sprawl in a wider urban context, such as in metropolitan areas like Greater Kuala Lumpur that are currently going through a rapid development process. The research on the urban land use sprawl will give an opportunity for stakeholders to determine measures to be taken in solving urbanisation issues. Present research on the spatial analysis of remote sensing and GIS technology in urban planning has provided a new direction, not only in urban sprawl studies, but also complimenting urban indicators in the United Nation's Sustainable Development Goal, which is to "make cities inclusive, safe, resilient and sustainable".

خلاصة البحث

مصطلحات الزحف الحضري العشوائي لها تاريخ طويل من الزمن في الخطاب الأكاديمي، ومع يمتك مصطلح الامتداد العمراني تاريخاً طويلاً في الخطاب الأكاديمي، ومع ذلك لا يزال هناك نقص في طريقة كمية متكاملة وشاملة لقياس الامتداد العمراني، خاصة في الدول النامية مثل ماليزيا. ولا يزال الامتداد العمراني أحد القضايا الحضرية التي لم يتم حلها، ويمثل تحدياً كبيراً لمفهوم التنمية المستدامة. لقد اتفق العديد من الباحثين على أن توصيف الامتداد العمراني باستخدام المقاييس المكانية يتطلب تعريفاً واسع النطاق لمبادئ الامتداد العمراني. في هذا البحث، يُعرّف الامتداد العمراني على أنه نمو حضري غير فعال وغير فعال يقطع بشكل كبير الترتيب الصحيح لاستخدام الأراضي، والذي يؤثر بدوره على استدامة عناصر البيئة المبنية، مثل تدهور البيئة والحرمان الاقتصادي والاجتماعي والرفاه. الهدف من هذا البحث هو قياس الامتداد العمراني في مدينة كوالا لمبور باستخدام خمسة (5) مكونات لمؤشرات الأرض للاستخدام الجغرافي (LUGI) مع تطبيق أسلوب الاستشعار عن بعد ونظم المعلومات الجغرافية. وتشمل المكونات (LUGI أ) استخدام الأراضي المنفصلة، (ب) اتساق التخطيط التنموي، (ج) الكثافة الحضرية، (د) تطوير الشريط، (هـ) تطوير قفزة. وتشمل البيانات المستخدمة Landsat و Landsat 5TM و SPOT 5 و OLI-TIRS 8دقة 30م ، بالإضافة إلى صور الأقمار الصناعية SPOT 6 (دقة 1.5م ، والتي تم استخدامها وتضمها مع قاعدة بيانات GIS من أجل تحليل كشف التغيير وتحليل LUGI. تم اختيار مدينة كوالالمبور كمناطق دراسية لدراسة نمو الامتداد العمراني على أساس أنماط استخدام الأراضي لعامي 2005 و 2015. حيث تم إجراء قياس الامتداد العمراني لكل منطقة تخطيط استراتيجي في كوالا لمبور ، 1- سينتول مينجالارا (2) وانغسا ماجو - مالوري (3) سيتي سنتر ، (4) بندر تون رزاق - سونغاي بيسي ، (5) بوكيت جليل - سيوتيه و (6) دامانسارا - بنشالا. وتثبت النتائج التي توصلت إليها حسابات LUGI أن كوالالمبور تواجه حالياً مؤشراً كبيراً للتوسع الحضري المنفصل بسبب استخدامات سابقة لاستخدام الأراضي وتقسيم المناطق التي تفرضها السلطات المحلية. وسجلت المؤشرات الجغرافية والقفزية قفزة عالية في مؤشر الامتداد المترامي في كوالا لمبور. ومع ذلك ، يمكن أن يكون مبرراً حدوثه من خلال اتجاه التنمية المدمجة في ملء كوالا لمبور. وهكذا، فقد وجد هذا البحث أن استخدام القطاع والقفزات الجغرافية المكانية أكثر عملية لقياس الامتداد في المناطق النامية أو شبه الحضرية مقارنة بالمناطق المتقدمة بالفعل. وأخيراً، فإن أدنى نقاط الامتداد في استخدام الأراضي في كوالا لمبور هي التوسع في التخطيط التنموي للتوسعة والتمدد العمراني الكثيف، مما يشير إلى أن هذه الأنواع من الامتدادات الجغرافية المكانية تقل احتمالية حدوثها في كوالالمبور بسبب التنفيذ القوي لخطة التنمية التي تؤكد على كثافة عالية تطوير. يركز هذا البحث على السياق

الحضري الأصغر لكن المتطور للغاية ، وتحديداً مدينة كوالا لمبور ، حيث وجد أن ثلاثة مؤشرات من خمسة مؤشرات جغرافية مكانية تناسب قياس مؤشر الامتداد على نطاق المدينة. لذلك ، اتفق البحث على أن دمج LUGI في التوسع العمراني مع الاستشعار عن بعد ونظام المعلومات الجغرافية كان قادراً على قياس تشكيل الامتداد الذي يستغل الأرض في سياق حضري أوسع، كما هو الحال في المناطق الحضرية الكبرى مثل Greater Kuala Lumpur التي تمر حالياً بتطور سريع. سيعطي البحث عن التوسع العمراني في استخدام الأراضي فرصة لأصحاب المصلحة لتحديد التدابير الواجب اتخاذها لحل مسائل التحضر. قدمت الأبحاث الحالية عن التحليل المكاني للاستشعار عن بعد وتكنولوجيا نظم المعلومات الجغرافية في التخطيط الحضري توجهاً جديداً، ليس فقط في دراسات التوسع العمراني في المناطق الحضرية، بل وأيضاً تكمل المؤشرات الحضرية في هدف الأمم المتحدة للتنمية المستدامة، وهو "جعل المدن شاملة وآمنة. ومرنة ومستدامة."

APPROVAL PAGE

The thesis of Nur Aulia Bt Rosni has been approved by the following:

Norzailawati Mohd Noor
Supervisor

Alias Abdullah
Co-Supervisor

Mansor Ibrahim
Internal Examiner

Narimah Samat
External Examiner

Jamalunlaili Abdullah
External Examiner

Saim Kayadibi
Chairperson

DECLARATION

I hereby declare that this thesis is the result of my own investigations, except where otherwise stated. I also declare that it has not been previously or concurrently submitted as a whole for any other degrees at IIUM or other institutions.

Nur Aulia Bt Rosni

Signature.....

Date.....

INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA

**DECLARATION OF COPYRIGHT AND AFFIRMATION OF
FAIR USE OF UNPUBLISHED RESEARCH**

**LAND USE GEOSPATIAL INDICES (LUGI) FOR MEASURING
URBAN SPRAWL IN ESTABLISHED URBAN: A CASE STUDY
OF KUALA LUMPUR**

I declare that the copyright holders of this dissertation are jointly owned by the student and IIUM.

Copyright © 2018 Nur Aulia Bt Rosni and International Islamic University Malaysia. All rights reserved.

No part of this unpublished research may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording or otherwise without prior written permission of the copyright holder except as provided below

1. Any material contained in or derived from this unpublished research may be used by others in their writing with due acknowledgement.
2. IIUM or its library will have the right to make and transmit copies (print or electronic) for institutional and academic purposes.
3. The IIUM library will have the right to make, store in a retrieved system and supply copies of this unpublished research if requested by other universities and research libraries.

By signing this form, I acknowledged that I have read and understand the IIUM Intellectual Property Right and Commercialization Policy.

Affirmed by Nur Aulia Bt Rosni

.....
Signature

.....
Date

DEDICATION

To the most special person in my life

*Rosni Omar
Sofiah Ahmad*

My beloved family members

*Azeef Amerul Rosni
Ameer Aiman Rosni
Afeeq Azhan Rosni
Nur Alia Samsudin
Nurra Adeena Azeef Amerul*

My Supervisor and Co-Supervisors

Dr.Norzailawati Mohd Noor, Prof.Dato.Dr. Alias Abdullah, Prof.Dr. Setsuko Isoda
&
loyal friends whom supported me throughout this journey

The smallest act of kindness is worth more than the grandest intention.

Oscar Wilde

Kindness is the language which the deaf can hear and the blind can see.

Mark Twain

Thank you for the good times,
The days you filled with pleasure.
Thank you for fond memories,
And for feelings I'll always treasure

Karl Fuchs

The research is especially indebted to
Malaysia Remote Sensing Agency (ARSM) for the digital land use satellite imagery
database.

The authors would like to mention

**International Institute for Applied System Analysis (IIASA),
Academy of Sciences Malaysia (ASM)
Centre for Space and Remote Sensing Research, National Central University, Taiwan
Kumamoto National Institute of Technologies (KOSEN)**

for the opportunity to join their program thus provide knowledge and valuable experience
contributing to this research.

TABLE OF CONTENTS

Abstract	ii
Approval Page.....	v
Declaration	vi
Copyright Page.....	vii
Dedication.....	viii
List of Tables	xiii
List of Figures	xv
Abbreviation	xix
CHAPTER ONE : INTRODUCTION	1
1.1 Introduction.....	1
1.2 Research Background	1
1.3 Problem Statement.....	4
1.3.1 The Vagueness of Urban Sprawl Concept	4
1.3.1.1 Unavailability of precise definition to measure the term	4
1.3.1.2 Ambiguous ways in determining the urban sprawl concept....	5
1.3.1.3 Universality: Sprawl from a broader context	7
1.3.1.4 Other issues and problems associated with urban sprawl.....	7
1.3.2 Lack Utilisation of Remote Sensing & GIS	8
1.3.2.1 Availability of routinely update the database	8
1.3.2.2 Lack of synchronising tools/methods to control urban sprawl	9
1.3.3 Lack of Geospatial Indices Application.....	9
1.3.3.1 Distinguishing between urban development and urban sprawl	9
1.3.3.2 Limitation in capturing the characteristics of urban sprawl in	10
measurement.....	10
1.3.3.3 Managing urban sprawl from the different geographical	11
background	11
1.3.4 Less Research from Local Geographical Context.....	11
1.3.4.1 Excessive concentration on urban sprawl experience from the	11
specific context.....	11
1.4 Research Questions.....	13
1.5 Research Aim And Objectives.....	14
1.6 Research Scopes	15
1.7 Research Significance.....	19
1.7.1 Research Significance towards Urban Sprawl Studies	20
1.7.2 Research Significance towards Remote Sensing and GIS	21
1.7.3 Research Significance towards Geospatial Indices/ LUGI	22
1.7.4 Research Significance towards Study Area: The Local Context	23
1.8 Organisation Of The Research Chapters	24
1.9 Conclusion	26
CHAPTER TWO : LITERATURE REVIEW	27
2.1 Introduction.....	27
2.2 Theory Of Urban Sprawl	29

2.2.1	Definition of Urban Sprawl.....	31
2.2.1.1	Defined by Example	36
2.2.1.2	Defined as Aesthetic Judgement	38
2.2.1.3	Defined as Consequences/ Effects.....	40
2.2.1.4	Defined as Cause of Externality	41
2.2.1.5	Defined as Pattern of Development.....	42
2.2.1.6	Defined as Process of Development.....	44
2.2.2	Characteristics of Urban Sprawl	45
2.2.3	Factors and Causes of Urban Sprawl	47
2.2.3.1	Socio-Demographic	49
2.2.3.2	Economic	50
2.2.3.3	Political.....	52
2.2.3.4	Physical.....	53
2.2.3.5	Environment	54
2.2.3.6	Transportation.....	54
2.2.4	Effects of Urban Sprawl.....	55
2.2.4.1	The Good Side of Urban Sprawl	56
2.2.4.2	Adverse Effects of Urban Sprawl.....	57
2.2.5	Trends and Scenarios of Urban Sprawl.....	61
2.2.5.1	Scenarios around the World	61
2.2.5.2	Urban Sprawl Scenarios in Malaysia.....	63
2.3	Theory Of Remote Sensing And Gis	66
i.	Remote Sensing	66
ii.	Geographic Information Systems	67
2.3.1	The Applications of Remote Sensing and GIS	67
2.3.1.1	Image Visualisation	68
2.3.1.2	Mapping.....	70
2.3.1.3	Monitoring.....	70
2.3.1.4	Modelling	71
2.3.2	The Advantages of Remote Sensing and GIS	72
2.3.2.1	Valuable Tools for Urban Planning and Management	72
2.3.2.2	Assist in the Decision-Making Process	74
2.3.2.3	Offer Precise and Update Information for Research Purpose.....	75
2.3.3	Integrating Remote Sensing and GIS Applications in Urban Planning	76
2.3.4	Sensors, Systems and Software in Urban Planning Research.....	79
2.3.4.1	Landsat Satellite Imagery	80
2.3.4.2	SPOT Satellite Imagery	86
2.3.4.3	Geographic Information System (GIS).....	88
2.3.4.4	ERDAS Imagine Software	89
2.3.4.5	MapInfo Professional Software	90
2.3.4.6	ArcGIS Software	91
2.4	Theory Of Geospatial Indices	92
2.4.1	Introduction of Geospatial Indices	92
2.4.2	Land Use Geospatial Indices (LUGI)	94
2.4.2.1	Theories and Definitions of Segregated Land Use Sprawl....	96
2.4.2.2	Theories and Definitions of Development Planning Consistency Sprawl	98
2.4.2.3	Theories and Definitions of Urban Density Sprawl	100

2.4.2.4 Theories and Definitions of Strip Sprawl.....	103
2.4.2.5 Theories and Definitions of Leapfrog Development Sprawl	105
2.5 Conclusion	109
CHAPTER THREE : RESEARCH METHODOLOGY	110
3.1 Introduction.....	110
3.2 Data Collection Process	112
3.2.1 Primary Data	114
3.2.2 Secondary Data	120
3.3 Pre-Processing Stage	123
3.3.1 Pre-Processing of Remote Sensing Data.....	123
3.3.1.1 Radiometric and Geometric Correction.....	124
3.3.1.2 Image Enhancement and Pan-Sharpening	126
3.3.1.3 Image Subset and Clipping.....	128
3.3.2 Pre-Processing of GIS Data	128
3.3.2.1 Georeferencing and Visualisation	129
3.4 Main Processing Stage.....	129
3.4.1 Change Detection Analysis Technique	130
3.4.1.1 Image Classification: Supervised	132
3.4.1.2 Accuracy Assessment	134
3.4.2 Main Processing of GIS Data.....	136
3.4.2.1 Geoprocessing: Thematic Mapping.....	136
3.5 Case Study: Kuala Lumpur.....	137
3.5.1 Background of Case Study Area	137
3.5.1.1 Location	141
3.5.1.2 Historical Background.....	145
3.5.1.3 Socio-Economic Profile.....	147
3.5.2 Kuala Lumpur Physical Profile.....	149
3.5.2.1 Existing Land Use	149
3.6 Data Analysis Method	153
3.6.1 Land Use Geospatial Indices (LUGI) Measurement Techniques ..	153
3.6.1.1 Measuring Segregated Land Use Sprawl.....	155
3.6.1.2 Measuring Development Planning Consistency Sprawl	163
3.6.1.3 Measuring Urban Density Sprawl	168
3.6.1.4 Measuring Strip Sprawl.....	172
3.6.1.5 Measuring Leapfrog Development Sprawl.....	179
3.7 Conclusion	184
CHAPTER FOUR : ANALYSIS AND FINDINGS.....	185
4.1 Introduction.....	185
4.2 Pre-Processing Stage	185
4.2.1 Pre-Processing of Remote Sensing Data.....	186
4.2.1.1 Radiometric and Geometric Correction.....	186
4.2.1.2 Image Enhancement and Pan-Sharpening	188
4.2.1.3 Image Subset and Clipping.....	193
4.2.2 Pre-Processing of GIS Data	194
4.2.2.1 Georeferencing and Visualisation	194
4.3 Main Processing Stage.....	195

4.3.1 Change Detection Analysis Techniques.....	196
4.3.1.1 Supervised Classification	196
4.3.1.2 Accuracy Assessment	201
4.3.1.3 Post-Classification Comparison Land Cover Change Detection.....	204
4.3.2 Main Processing of GIS Data.....	213
4.3.2.1 Geoprocessing: Thematic Mapping.....	213
4.4 Data Analysis And Findings.....	216
4.4.1 Land Use Geospatial Indices (LUGI)	216
4.4.1.1 Segregated Land Use Sprawl Analysis and Findings	216
4.4.1.2 Development Planning Consistency Sprawl Analysis and Findings	220
4.4.1.3 Urban Density Sprawl Analysis and Findings.....	223
4.4.1.4 Strip Sprawl Analysis and Findings	226
4.4.1.5 Leapfrog Development Sprawl Analysis and Findings.....	228
4.5 Conclusion	230
CHAPTER FIVE : RESULTS AND DISCUSSION.....	231
5.1 Introduction.....	231
5.2 Change Detection Results And Discussion	232
5.3 Lugi Results And Discussion	233
5.3.1.1 Segregated Land Use Sprawl Results and Discussion	238
5.3.1.2 Development Planning Consistency Sprawl Results and Discussion.....	243
5.3.1.3 Urban Density Sprawl Results and Discussion	246
5.3.1.4 Strip Sprawl Results and Discussion.....	248
5.3.1.5 Leapfrog Development Sprawl Results and Discussion.....	253
5.4 Summary Of The Research Outcome	259
5.5 Conclusion	260
CHAPTER SIX : RECOMMENDATIONS AND CONCLUSION	261
6.1 Introduction.....	261
6.2 Crosstabulation Of Research Objectives And Chapters	262
6.2.1 Research Question and Objective 1	262
6.2.2 Research Question and Objective 2	263
6.2.3 Research Question and Objective 3	263
6.2.4 Research Question and Objective 4	264
6.3 Summary Of Research Contributions.....	265
6.3.1 Contributions for Urban Sprawl Studies	265
6.3.2 Contributions using Remote Sensing and GIS.....	266
6.3.3 Contributions for Geospatial Indices/LUGI.....	267
6.3.4 Contributions for Study Area: Local Context	268
6.4 Research Limitations	269
6.5 Recommendations And Potential Future Research	271
6.6 Conclusion	272
REFERENCES.....	274
RESEARCH PUBLICATIONS.....	295

LIST OF TABLES

Table 1.1	Studies on Urban Sprawl Topics According to Countries in 25 years (1991-2016)	12
Table 2.1	Publication on Urban Sprawl According to the Year 1996-2016	31
Table 2.2	Summary of Urban Sprawl Definition by Categories	35
Table 2.3	Collection of Studies on Urban Sprawl Factor and Causes	48
Table 2.4	Landsat 5 and Landsat 8 Satellite Description	81
Table 2.5	Landsat Application in Built Environment Fields	83
Table 2.6	Detail Description of Landsat 5 TM Spectral Resolution	84
Table 2.7	Detail Description of Landsat 8 OLI-TIRS Spectral Resolution	85
Table 2.8	SPOT 5 and SPOT 6 Satellite Description	87
Table 2.9	GIS Data Description	88
Table 3.1	Determining Data and Methods	112
Table 3.2	Types of Data Application for the Research	113
Table 3.3	Primary Research Materials	114
Table 3.4	Description of Satellite Raw Images for the Research	115
Table 3.5	Detail Specification of Landsat 5 MSS-TM and Landsat 8 OLI-TIRS Raw Data	116
Table 3.6	Detail Specification of Raw Satellite SPOT Imagery	117
Table 3.7	Geographic Information System Data of Kuala Lumpur	119
Table 3.8	Secondary Research Materials	121
Table 3.9	Findings from Secondary Research Materials	122
Table 3.10	Timeline History of Kuala Lumpur	147
Table 3.11	Kuala Lumpur Population Density Distribution	148
Table 3.12	Kuala Lumpur Land Use Proportion in 2015	150
Table 3.13	Parameters of Land Use Geospatial Indices	154

Table 3.14	Segregated Land Use Sprawl Indicators	158
Table 3.15	Development Planning Consistency Sprawl Indicators	165
Table 3.16	Urban Density Sprawl Indicators	169
Table 3.17	Kuala Lumpur Functional Road Hierarchy	173
Table 3.18	Strip Sprawl Indicators	175
Table 3.19	Leapfrog Development Sprawl Indicators	180
Table 4.1	Geometrically Corrected GIS Data	194
Table 4.2	Land Cover Classification Scheme used in the Research	197
Table 4.3	Accuracy Assessment of Kuala Lumpur Land Cover Classification	202
Table 4.4	Kuala Lumpur Land Cover Change Detection (2005-2015)	206
Table 4.5	Kuala Lumpur Land Use Change Detection (2005-2015)	209
Table 4.6	Kuala Lumpur Built Up Area Change Detection 2005-2015 by Strategic Zone	212
Table 4.7	Segregated Land Use Sprawl Distribution by Built Up Areas	218
Table 4.8	Segregated Land Use Sprawl Distribution by New Residential Area	219
Table 4.9	Findings of Development Planning Consistency Sprawl by Strategic Planning Zones	221
Table 4.10	Summary of Development Planning Consistency Sprawl Result	222
Table 4.11	Findings of Built up Residential Density Sprawl by Strategic Planning Zones	224
Table 4.12	Findings of Population Residential Density Sprawl by Strategic Planning Zones	225
Table 4.13	Findings of Residential Strip Sprawl by Strategic Planning Zones	227
Table 4.14	Findings of New Development (Residential and Commercial) Strip Sprawl by Strategic Planning Zones	228
Table 4.15	Findings of Leapfrog Development Sprawl Land Area by Strategic Planning Zones	229
Table 6.1	Main Component of Urban Sprawl Studies	266

LIST OF FIGURES

Figure 1.1	Geospatial Indices Urban Sprawl Components	17
Figure 1.2	Flowchart of General Research Framework	25
Figure 2.1	Literature Review Framework	28
Figure 2.2	Sprawl Characteristic Interpreted Into Categories of Geospatial Indices	46
Figure 2.3	General Framework of Remote Sensing and GIS Integration in LUGI Modelling	78
Figure 2.4	Illustration of Landsat 5 Satellite and Landsat 8 Satellite	80
Figure 2.5	Depiction of Segregated Land Use Sprawl	97
Figure 2.6	Depiction of Development Inconsistency Index Sprawl	99
Figure 2.7	Depiction of Urban Density Sprawl	101
Figure 2.8	Depiction of Strip Sprawl	104
Figure 2.9	Depiction of Leapfrog Development Sprawl	107
Figure 3.1	Flowchart of Research Methodology	111
Figure 3.2	SPOT Satellite Raw Imagery from Malaysia Remote Sensing Agency	118
Figure 3.3	Landsat Image Fusion and Colour Composite Process	127
Figure 3.4	Procedures for Remote Sensing Data Classification and Assessment	132
Figure 3.5	Data Geoprocessing	136
Figure 3.6	Peninsular Malaysia Growth Conurbation (KL City Plan 2020)	138
Figure 3.7	Regional Factor of Kuala Lumpur (KL City Plan 2020)	139
Figure 3.8	Key Plan and Location Plan of the Study Area	142
Figure 3.9	Site Plan of the Study Area	143
Figure 3.10	Site Plan of the Study Area (Google Earth Image 2017)	144

Figure 3.11	Historical Images of Kuala Lumpur City	146
Figure 3.12	Kuala Lumpur Existing Land Use 2015	151
Figure 3.13	Kuala Lumpur Residential Land Use Distribution 2015	152
Figure 3.14	Measurement Procedure for Segregated Land Use Sprawl according to the Built-up Area	160
Figure 3.15	Residential Segregated Sprawl Measurement Procedure	162
Figure 3.16	Residential Development Planning Consistency Sprawl Measurement Procedure	167
Figure 3.17	Horizontal and Vertical Built Up Density Sprawl Measurement Procedure	171
Figure 3.18	Population Density Sprawl Measurement Procedure	172
Figure 3.19	Cross Section of Selected Arterial Road for Strip Sprawl Measurement	174
Figure 3.20	Residential Strip Sprawl Measurement Procedure	177 Figure
Figure 3.21	New Development (Residential and Commercial) Strip Sprawl Measurement Procedure	178
Figure 3.22	Leapfrog Development Sprawl Measurement Procedure	183
Figure 4.1	Data Pre-Processing Procedure	186
Figure 4.2	Before (left) and After (right) Radiometric and Geometric Correction of the Satellite Images	187
Figure 4.3	Kuala Lumpur Landsat Satellite Images Bands Stacking Process	189
Figure 4.4	Landsat 5 TM Colour Composite and Contrast Enhancement to visualised Kuala Lumpur Built up Area	190
Figure 4.5	Landsat 8 OLI-TIRS Colour Composite and Contrast Enhancement to visualised Kuala Lumpur Built up Area	191
Figure 4.6	Kuala Lumpur SPOT Images Fusion Process	192
Figure 4.7	Kuala Lumpur Satellite Images Subset and Clipping	193
Figure 4.8	Geometrically corrected GIS data of Kuala Lumpur Urban Area	195

Figure 4.9	Main Processing Procedure and Analysis	196
Figure 4.10	Kuala Lumpur Land Use Classification for the Year 2005	199
Figure 4.11	Kuala Lumpur Land Use Classification for the Year 2015	200
Figure 4.12	Kuala Lumpur Land Use Classification (a.Built up area, b. Unbuilt area, c. Undevelopable area, d. Natural Features)	203
Figure 4.13	Kuala Lumpur Land Cover for the Year 2005	207
Figure 4.14	Kuala Lumpur Land Cover for the Year 2015	208
Figure 4.15	Kuala Lumpur land Cover Change Detection for the Year 2005-2015	210
Figure 4.16	Illustration of Selected Grid Cell for New Residential Development Patches	213
Figure 4.17	Kuala Lumpur Detail Land Use for the Year 2015 (Thematic Mapping)	214
Figure 4.18	Kuala Lumpur New Residential Patches in Year 2015	215
Figure 4.19	Segregated Land Use Sprawl Pattern (left) vs. Smart Growth (right)	217
Figure 4.20	Development Planning Consistency Sprawl Pattern (left) vs. Smart Growth (right)	220
Figure 4.21	Urban Density Sprawl Pattern (left) vs. Smart Growth (right)	224
Figure 4.22	Strip Sprawl Pattern (left) vs. Smart Growth (right)	226
Figure 4.23	Leapfrog Development Sprawl Pattern (left) vs. Smart Growth (right)	228
Figure 5.1	Diagrammatic Illustration of Kuala Lumpur Land Cover Loss and Gain in Acres	232
Figure 5.2	Summary of Land Use Geospatial Indices (LUGI) Analysis	235
Figure 5.3	Kuala Lumpur Land Cover Change Detection for the Year 2005-2015	237
Figure 5.4	Kuala Lumpur Segregated Land Use Sprawl by Strategic Planning Zones	240
Figure 5.5	Kuala Lumpur Segregated Land Use Sprawl by New Residential Area 2015	241

Figure 5.6	Kuala Lumpur Development Planning Consistency Sprawl	245
Figure 5.4	Kuala Lumpur Urban Density Sprawl	247
Figure 5.8	Kuala Lumpur Residential Strip Sprawl	250
Figure 5.9	Kuala Lumpur Residential & Commercial Strip Sprawl	252
Figure 5.10	Kuala Lumpur Leapfrog Development Sprawl	257

ABBREVIATION

CBD	Central Business District
CNES	Centre National <i>D'Etudes Spatiales</i>
EEA	European Environment Agency
EU	European Union
ES	Economic Sprawl
GIS	Geographic Information System
GIUS	Geospatial Indices of Urban Sprawl
GS	Geographic Sprawl
JKR	Public Works Department
KLCH	Kuala Lumpur City Hall
KLCP 2020	Kuala Lumpur City Plan 2020
LULC	Land Use Land Cover
LUGI	Land Use Geospatial Indices
MRSA	Malaysia Remote Sensing Agency
PLANMalaysia	Federal Department of Town and Country Planning, Malaysia
PCC	Post Classification Comparison
RS	Remote Sensing
RnD	Research and Development
SDG	Sustainable Development Goal
SME	Small Medium Enterprise
SPZ	Strategic Planning Zone
UN	United Nation
UNICEF	United Nations Children's Fund
USA	United States of America
USGS	United States Department of Geological Survey

CHAPTER ONE

INTRODUCTION

1.1 INTRODUCTION

The first chapter explains on the overview of research, highlighting the urban sprawl connotation with other relating terms of urban development such as urbanisation, urban growth, and sustainable development. This chapter later describes the research's problem statements, questions, aim, and objectives, scopes, purpose and significance as well as the organisation of the chapters. The chapter emphasises the researcher's attempt to develop Land Use Geospatial Indices (LUGI) for measuring urban sprawl growth in Kuala Lumpur, Malaysia with the application of Remote Sensing and Geographic Information System (GIS) techniques. The intention of this research is to quantify urban land use sprawl precisely so as to provide a meaningful insight of its growth process.

1.2 RESEARCH BACKGROUND

According to Ji et al. (2006), a city is a highly complex socioeconomic and spatial entities with a distinct hierarchical order. It is a hub of almost all human activities (Rajeshwari, 2006). Apart from physical forms, cities are shaped by various development forces such as economic, political, cultural and social, which later imposing themselves in physical forms and closely related to urban sprawl (Ardeshiri & Ardeshiri, 2011; Sudhira et al., 2004). In Western countries, an urban development characterised by two critical processes which are the inner-city decline and urban sprawl (Apostolos, 2007). These two processes are in fact entangled as that urban sprawl accelerates the inner-city decline.

Bhatta et al. (2010a) considered “Urban Growth” and “Urbanisation” are both the processes of “Urban Development.” UNICEF (2012) defined urban growth and urbanisation as “the increase in the number of people living in towns and cities” and “the proportion of a country that is urban.” Urban Development is a global phenomenon involving a process of spatial change like land use and land cover associated with the growth of population and economy. The process has a high impact on the environment such as depletion of natural resources, landscape deterioration, pollution and climate changes (Olujimi, 2009; Ramachandra, Bharath, & Sowmyashree, 2014; Shalaby & Tateishi, 2007; Weng, 2001). In this research, the term urban development will be used to represent the process of both urbanisation and urban growth.

Based on the growing awareness of the public on uncontrolled urban development issues, it is vital to improve understanding of this phenomenon (Rajeshwari, 2006; Verbeek, Boussauw, & Pisman, 2014). However, Steil et al. (2007) claimed that too many attention focuses on sprawl phenomena lead to neglecting the fact that suburban expansion has existed since the beginning of a city and will continue to expand as the population increase. They also added that suburban growth completes the insufficient spatial and functional requirement of the inner city. Undoubtedly, urban development cannot be stopped, but require shaping and controlling the growth as to lessen the negative impact on a more sustainable development.

In the modern urban studies, the spatial formation and the dynamics of urban development are the most important topics (Altieri, Cocchi, Pezzi, Scott, & Ventrucci, 2014). Bhatta et al. (2010a) also added that the occurrence of urban development is so general, and its implications are so vast, one of it is urban sprawl. Urban sprawl will

always continue to be the side effect of the urban development process and policies (Almeida, 2005). Also, Osman et al. (2008) and Zeng et al. (2015) believe that sprawl is associated with urban development regardless its growth in developed or developing countries.

Urban sprawl became one of the most important issues in the urban area around the world since the twenty-first century whose importance is still growing today (Altieri et al., 2014; Arribas-Bel, Nijkamp, & Scholten, 2011). Its rapid and uncontrolled expansion are alarming for urban specialists. Arribas-Bel et al. (2011) claimed that urban sprawl has to be placed in the broader context of urban and spatial dynamics in the industrialised world, in which cities are the nuclei of economic development. While Bruegmann (2015) mentioned, the urban sprawl concept has shifted over the years according to its original conditions and backgrounds in various parts of the world. Many researchers are accepting that urban sprawl as a broad and multidimensional concept which can be examined from several different points of views including Ewing et al. (2002) who have agreed upon sprawl as a real, measurable phenomenon with real implications for peoples' everyday lives.

On the contrary, sustainable development concept depicts the development that meets the requirements of the present without preventing the capability of upcoming generations to meet theirs (Ardeshiri & Ardeshiri, 2011; Tanguay, Rajaonson, Lefebvre, & Lanoie, 2010). This concept has become increasingly significant for creating a better future for the world, economically, socially and environmentally (Arbury, 2005; Stevens, Dragicevic, & Rothley, 2007). However, the sustainable development concept depends on the future role of urban planning in handling urban sprawl issues (Catalán et al., 2008; Yeh, 2002).

1.3 PROBLEM STATEMENT

There are issues in Malaysia urban development process. Despite extensive town planning regulations and practice has been enforced since 1976, urban sprawl is still a threat to many of its main cities. The urban sprawl problem has negatively impacted not only the urban society who live in the city but also the surrounding natural environment and the responsible government authority. In this subsection, some possible basis that contributes to the urban sprawl problem has been recognised.

Perhaps, research which investigates the urban sprawl growth through measurement of geospatial indices with the application of remote sensing and GIS could remedy the situation. This section draws attention to the available literature on the studies of urban sprawl issues as extracted from the bulk of the contemporary literature. There are four major challenges identified in this research. The issues and problems are relating to (i) urban sprawl, (ii) remote sensing and GIS, (iii) geospatial indices, lastly on (iv) diverse urban context. All of the problems identified stand as the research gap which indicated that there is a strong need for a more integrated and comprehensive quantitative method to measure urban sprawl in Malaysia.

1.3.1 The Vagueness of Urban Sprawl Concept

1.3.1.1 Unavailability of precise definition to measure the term

Urban sprawl is a term that has a long history in the academic and development practice. Nonetheless, it is still widely discussed as a major problem today (Coisnon, Oueslati, & Salani, 2014). Surprisingly, a standard and precise definition of urban sprawl are still not existed (Altieri et al., 2014; Bruegmann, 2015; Hasse & Kornbluh, 2004; Terzi & Kaya, 2008; Theobald, 2003; Wilson et al., 2003). Also, Bhatta et al. (2010b) claimed urban sprawl as a concept suffers from difficulties in the definition.

Hammer & Witten (2011) question if there is a single widely accepted definition of sprawl on which the majority of stakeholders can agree. Hasse & Kornbluh (2004) later added that there is a need for better defining the term to focus specifically on the undesirable and problematic development that many stakeholders are arguing. According to some researchers, most people especially professionals may recognise sprawl when they see it, but this may not help in practice especially in the rule or decision making (Ewing, 2008; Ewing et al., 2002; Galster et al., 2001). Currently, sprawl is defined loosely as dispersed and inefficient urban growth that always associates with characteristics such as low-density, decentralisation, and fragmentation (Farber & Li, 2013; Hasse & Lathrop, 2003).

Without a universal definition, quantification and modelling of urban sprawl are tough (Bhatta et al., 2010b; Wilson et al., 2003). Jaeger & Schwick (2014) added that every important method to measure the degree of urban sprawl needs to be based on a precise definition of “urban sprawl”. It needs to disentangle grounds and costs of urban sprawl from the phenomenon itself, as urban sprawl has different causes and effects in different regions and regulatory contexts. Moreover, Bruegmann (2015) also states that there has been a significant debate in academia on how to measure sprawl and to understand its dynamics. Thus a universal definition of urban sprawl is required.

1.3.1.2 Ambiguous ways in determining the urban sprawl concept

Urban sprawl is a critical issue in today’s world which is widely discussed but poorly understood (Wu, 2006). Other than a manifestation of development, it is known for its negative environmental and social impacts (Crawford, 2007; Feng, Du, Zhu, Luo, & Adaku, 2015).