



**UNIVERSITI PUTRA MALAYSIA**

**PREDICTION AND SIMULATION OF SPATIAL PATTERN FOR URBAN  
GROWTH AND CHANGE IN LAND USE IN SANA'A CITY, YEMEN**

**MOHAMED ABDULLAH AL-SHALABI**

**FK 2007 77**

**PREDICTION AND SIMULATION OF SPATIAL  
PATTERN FOR URBAN GROWTH AND  
CHANGE IN LAND USE IN SANA'A CITY,  
YEMEN**

**MOHAMED ABDULLAH SALEH AL-SHALABI**

**DOCTOR OF PHILOSOPHY  
UNIVERSITI PUTRA MALAYSIA**

**2007**



**PREDICTION AND SIMULATION OF SPATIAL PATTERN FOR URBAN  
GROWTH AND CHANGE IN LAND USE IN SANA'A CITY, YEMEN**

**By**

**MOHAMED ABDULLAH AL-SHALABI**

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

**November 2007**



## **DEDICATION**

I dedicate this work to my family – my great father, who supported me by financing me with the necessary amounts to buy satellite images and other related materials. To my mother, who supported me to a great extent with her prayers. My lovely brothers and sisters, my loyal wife and my cute kids ; Amani, Nora, Nada, Ayman, Norhan and my son Osama who suffered a lot in my absence– for their love, understanding, encouragement, and never failing support during all these years.



Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

**PREDICTION AND SIMULATION OF SPATIAL PATTERN FOR URBAN GROWTH AND CHANGE IN LAND USE IN SANA'A CITY, YEMEN**

By

**MOHAMED ABDULLAH SALEH AL-SHALABI**

**November 2007**

**Chairman: Professor Shattri Bin Mansor, PhD**

**Faculty: Engineering**

In this study, Sana'a master plans were evaluated and analyzed to verify whether their implementations corresponded with the actual spatial urban development. The result shows that until the present time there is still lack of clear policy that controls and guides urban development. It also shows that about 40% of the growth occurred in unplanned areas, green areas and reserved land without suitable protection and regulations.

GIS, remote sensing techniques and field survey were used to study the spatial pattern growth for the spontaneous areas in Sana'a city as well as the physical, socio-economic, and environmental conditions. There is no specific planning pattern was found in these settlements. Development has taken place randomly in unplanned areas, following the pattern of topography and concentrating along main roads.

The study has successfully developed a model for locating suitable land for urban development in Sana'a by integrating GIS and Multi-criteria Analysis and Cellular



Automata methods. The potential suitable lands were generated and the validation of the model was done by overlaying the generated suitability map on the potential land for residential development proposed by 1999 Sana'a master plan. The result shows the areas for future development proposed by the master plan corresponded well with the high to very high suitability zones except for illegal areas.

The prediction and simulation of the urban growth and land use change were done successfully in GIS-based CA model which output "managed growth scenario". Based on the land suitability assessment produced by the model, the demand for land for urban development during the period from 2004 to 2020 was then estimated using statistical tools. Then, the candidature of a cell by adopting again MCA method was evaluated. It provides dynamic transition rule for land use conversion at each time step of the simulation model based on the following factors used: land suitability, proximity to existing developed areas, proximity to prioritized land, and current land use. Variable calculation produces land use conversion probabilities for each cell. The rules are updated at each time step in order to reflect the land dynamics of the previous step. The result was validated through the process of running the model for the period from 1994 to 2003. The result gives an overall accuracy of 99.6%, producer's accuracy of 83.3% and the user's accuracy of 83.6%.

In this study the SLEUTH model was also used to predict the urban growth and land use change. It was calibrated using 35-year time series dataset compiled from interpreted historical topographical maps, aerial photographs and satellite imageries for the entire study area to identify the parameters that influenced the urban growth

in Sana'a city. Results from the calibration modes- coarse, fine, and final represented the top five scorings from thousands of iterations. The composite results of the optimum values for the diffusion, spread, slope and road gravity parameters show successive improvements in the parameters that control the behavior of the system. In the mechanism of self-modification rules, parameters averaging on the best results from the final calibration were used. The prediction mode of the SLEUTH model uses the best fit growth rule parameters from the calibration to begin the process of “growing” urban settlements, starting at the most recent urban data layer. The resulting forecast of future urban growth outputs a probability map where individual grid cells are being urbanized at some future date, assuming the same unique “urban growth signature” is still in effect as it was in the past. The final results of the model are annual layers map of future urban growth and land use change (2004–2020).

Based on the analysis the comparison between GIS-based CA model and SLEUTH model carried out and the strong and weak points of them were highlighted. This study benefits decision makers and planners in carrying out future urban growth planning and it gives them the opportunity to know the advantages and consequences for each growth scenario in order to promote the continuity and sustainability of urban development in the Sana'a city.



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

**RAMALAN DAN SIMULASI CORAK RUANG UNTUK PERTUMBUHAN  
PEMBANDARAN DAN PERUBAHAN DALAM GUNATANAH  
BAGI BANDARAYA SANA'A , YEMEN**

Oleh

**MOHAMED ABDULLAH AL-SHALABI**

**November, 2007**

**Pengerusi: Profesor Shattri bin Mansor, PhD**

**Fakulti: Kejuruteraan**

Dalam kajian ini, pelan-pelan induk Sana'a telah di dinilai dan dinalisakan untuk menentukan samaada perlaksanaannya adalah sejejar dengan pembangunan ruang pembandaran yang sebenar berlaku. Kajian dapat menunjukkan bahawa setakat sekarang masih terdapat pula kekurangan polisi ketara yang mengawal dan memandu pembangunan pembandaran. Kajian menunjukkan juga bahawa kira-kira 40 % pertumbuhan berlaku pada kawasan yang tidak dirancang, kawasan hijau dan kawasan simpanan dengan tiada perlindungan dan peraturan yang sesuai.

Sistem Maklumat Geografi (GIS), penderiaan jauh dan kerja lapangan telah digunakan untuk mengkaji corak pertumbuhan ruang di kawasan penempatan spontan dalam bandaraya Sana'a, termasuk juga keadaan fizikal, sosio-ekonomi dan alam sekitar. Adalah didapati kawasan penempatan ini tiada corak perancangan spesifik. Pembangunan telah berlangsung secara rawak di kawasan-kawasan yang tidak dirancang, mengikut corak topografi dan tertumpu pada jalan raya utama.



Kajian ini telah berjaya membangunkan sesuatu model untuk menentukan lokasi kawasan yang sesuai bagi tujuan pembangunan pambandaran di Sana'a dengan menggunakan GIS, Analisa Pelbagai Kriteria (MCA) dan Cellular Automata Methods. Peta kawasan berpotensi sesuai telah dihasilkan dan pengesahan model dapat dijalankan dengan penindihan peta ini ke atas peta kawasan potensi pembangunan perumahan yang dicadangkan dalam Pelan Induk Sana'a tahun 1999. Hasil pertindihan ini menunjukkan bahawa kawasan-kawasan yang disyorkan dalam pelan induk untuk pembangunan masa depan terjatuh pada zon-zon sesuai ke sangat sesuai kecuali kawasan penempatan haram.

Ramalan dan simulasi pertumbuhan pambandaran dan perubahan gunatanah telah dijalankan dengan jayanya dengan penggunaan model CA berasaskan GIS, yang dapat menghasilkan "senario pertumbuhan yang diurus". Berasaskan penilaian kesesuaian tanah yang dihasilkan oleh model, permintaan tanah pambandaran bagi tempoh 2004-2020 dapat dianggarkan dengan penggunaan kaedah statistik. Kemudian calonan sel dapat dinilai dengan penggunaan MCA sekali lagi. Ia telah memberikan satu peraturan perubahan dinamik untuk penukaran gunatanah pada setiap langkah masa model simulasi berasaskan faktor-faktor berikut : kesesuaian tanah, kedekatan kepada kawasan yang telah dibangun, kedekatan kepada kawasan keutamaan dan gunatanah semasa. Perkiraan angkubah menghasilkan kebarangkalian perubahan gunatanah bagi setiap sel. Peraturan-peraturan dikemaskinikan bagi setiap langkah masa untuk mencerminkan status dinamik tanah bagi langkah yang lalu. Keputusan ini dapat disahkan melalui proses pengoperasian model bagi tempoh dari

tahun 1994 ke tahun 2003. Ia telah memberikan ketepatan menyeluruh 99.6%, ketepatan pengeluar 82.6% dan ketepatan pengguna 82.2%.

Dalam kajian ini model SLUETH telah digunakan juga untuk meramalkan pertumbuhan pempadaran dan perubahan gunatanah. Kalibrasi model dapat dijalankan dengan penggunaan data yang dikumpulkan selama 35 tahun daripada peta topografi yang lalu, gambar foto udara dan data satelit bagi seluruh kawasan kajian untuk mengenalpasti faktor-faktor yang mempengaruhi pertumbuhan pempadaran Sana'a. Keputusan daripada mod-mod kalibrasi, iaitu, kasar, halus dan akhir, mewakili lima markah tertinggi dari beberapa ribu ulangan. Keputusan gabungan nilai-nilai optima daripada parameter-parameter penyerapan, pengedaran, kecerunan dan graviti jalan menunjukkan peningkatan berterusan kawalan parameter terhadap kelakuan sistem. Dalam mekanisme aturan ubahsuaian-sendiri purata parameter berasaskan keputusan terbaik daripada proses kalibrasi terakhir digunakan. Mod ramalan model SLUETH menggunakan parameter-parameter aturan pembangunan paling padan dari kalibrasi untuk memulakan proses "pertumbuhan" penempatan pempadaran, mulai dari data pempadaran yang terkini. Hasil ramalan pertumbuhan pempadaran masa depan adalah peta kebarangkalian yang mana setiap sel grid mempunyai nilai kebarangkalian pempadaran masa depan dengan andaian "tandatangan pertumbuhan pempadaran" yang khas ini adalah sama seperti dalam tahun-tahun lalu. Keputusan terakhir model merupakan peta-peta tahunan pertumbuhan pempadaran dan perubahan gunatanah masa depan (2004-2020).

Berasaskan analisa yang dijalankan, kelebihan dan kekurangan model-model yang digunakan dapat diutarakan. Kajian ini memanfaatkan pembuat-pembuat keputusan dan perancang-perancang perancangan pertumbuhan pempbandaran masa depan dan memberi kesempatan untuk mengetahui kebaikan serta akibat setiap senario pertumbuhan supaya dapat mempromosi keterusan dan kelestarian pertumbuhan pempbandaran di bandaraya Sana'a.

## ACKNOWLEDGEMENTS

All praise to **Allah**, most Gracious, Most Merciful, Who, Alone brings forgiveness and light and new life to those who call upon Him; and to Him is the dedication of this thesis.

*“Read! In the Name of your Lord Who has created (all that exist).  
He has created man from a clot.  
Read! And your Lord as the Most Generous.  
Who has taught (the writing) by the pen.  
He has taught man that which he knew not.”*  
Qur’an 96: 1-5

We praise Allah for His great loving kindness, which has brought us all together to tell and encourage each other and mankind with stories of His care, and leading. In so doing, I also thank those who answered His call, who have started their journey upon the Straight Path of Allah. All respect for our Holy Prophet (Peace be upon him), who guided us to identify our creator

I am whole-heartedly thankful to my research supervisor, Prof. Dr. Shattri bin Mansor for his encouragement, exceptional ideas, and tireless optimism that have kept me going. Without his guidance, this work wouldn’t see the light. He has exerted a lot of efforts and lighted the dark for me.

I am thankful to Associate Professor Dr Nordin bin Ahmed who kindly guided me and provided me with positive and valuable suggestions about my research. I am really grateful to him as long as I breathe.



My thanks are extended to Associate Professor Dr. Abdul Rashid Mohamed Shariff, who has encouraged me a lot and guided me with his unforgettable and exceptional ideas.

Sincere thanks are due to my brother Ahmed Al-Shalabi and my friends Mr. Ali Almwari, Mr. Fua'ad Abdulrazzak, Mr. Mohamed Alkawani, Mr. Ali Alsharafi, and Mr. Tarek Alahdel who allowed me to use their computers to do the SLEUTH Calibration processing at the Laboratory of computer science for more than two months. I here acknowledge that without their help the process wouldn't be a success. Finally, I would like to thank everybody who supported me especially in the process of collecting the data, a matter which was a difficulty as Yemen lack that kind of data. Among these people were Mr. Kahtan Alhadda, Mr. Abdulghani Alansi, and others who leave no effort in providing me with the necessary data I needed for my research. I also thank Mr. Mohammed M. Abdulkhaleq for leaving no effort and time in revising this work linguistically.



I certify that an Examination Committee has met on \_\_\_\_\_ to conduct the final examination of Mohamed Abdullah Saleh Al-Shalabi on his Doctor of Philosophy thesis entitled “PREDICTION AND SIMULATION OF SPATIAL PATTERN FOR URBAN GROWTH AND LAND USE CHANGE OF SANA’A CITY, YEMEN” in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

**Chairman, PhD**

Professor  
Faculty of Graduate Studies  
Universiti Putra Malaysia  
(Chairman)

**Examiner 1, PhD**

Professor  
Faculty of Graduate Studies  
Universiti Putra Malaysia  
(Internal Examiner)

**Examiner 2, PhD**

Professor  
Faculty of Graduate Studies  
Universiti Putra Malaysia  
(Internal Examiner)

**External Examiner, PhD**

Professor  
Faculty of Graduate Studies  
Universiti Putra Malaysia  
(External Examiner)

---

**HASANAH MOHD GHAZALI, PhD**

Professor/Deputy Dean  
School of Graduate Studies  
Universiti Putra Malaysia

Date:



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

**Shattri Bin Mansor, PhD**  
Professor  
Faculty of Engineering  
Universiti Putra Malaysia  
(Chairman)

**Noordin Bin Ahmad, PhD**  
Lecturer  
Faculty of Engineering  
Universiti Putra Malaysia  
(Member)

**Abdul Rashid Mohamed Shariff, PhD**  
Associate Professor  
Faculty of Engineering  
Universiti Putra Malaysia  
(Member)

---

**AINI IDERIS, PhD**  
Professor and Dean  
School of Graduate Studies  
Universiti Putra Malaysia

Date: 10 April 2008



## **DECLARATION**

I hereby declare that the thesis is based on my original work except for quotations and citations, which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any degree at UPM or other institutions.

---

**MOHAMED ABDULLAH AL-SHALABI**

Date:



## TABLE OF CONTENTS

	<b>Page</b>
<b>DEDICATION</b>	ii
<b>ABSTRACT</b>	iii
<b>ABSTRAK</b>	vi
<b>ACKNOWLEDGEMENTS</b>	x
<b>APPROVAL</b>	xii
<b>DECLARATION</b>	xiv
<b>LIST OF TABLES</b>	xviii
<b>LIST OF FIGURES</b>	xx
<b>CHAPTER</b>	
1	<b>INTRODUCTION</b> 1.1
1.1	Introduction 1.1
1.2	Problem Statement 1.3
1.3	Research Goal and Objectives 1.4
1.4	Significance of the Study 1.5
1.5	Thesis Organization 1.6
2	<b>LITERATURE REVIEW</b> 2.1
2.1	Introduction 2.1
2.2	Urban Development 2.1
2.3	Land Use Planning 2.3
2.3.1	Factors Affecting Urban Development and Land Use Planning 2.6
2.4	The Spontaneous Urban Growth 2.16
2.4.1	Spontaneous Settlements in Yemen 2.18
2.5	Factors Causing the Growth of Spontaneous Settlements 2.20
2.5.1	Urbanization 2.20
2.5.2	Poverty 2.21
2.5.3	Urban Management and Policies 2.23
2.6	Influence of the Growing Spontaneous Settlements on the policy in Yemen 2.24
2.7	Spontaneous Growing Settlements in Sana'a City 2.26
2.8	The Spontaneous Settlements Upgrading Approach 2.28
2.8.1	Development of Upgrading Interests 2.28
2.8.2	Constraints Facing Upgrading 2.29
2.9	Spatial Information Technology Application in Land use Planning 2.31
2.10	Modeling the Urban Growth 2.35
2.10.1	Cellular Automata Models (CA) 2.38
2.10.2	GIS-based CA Model 2.56
3	<b>METHODOLOGY</b> 3.1
3.1	Introduction 3.1
3.2	Study Area 3.1



	3.2.1	Data Collection	3.2
3.3		Comparison between Master plans and existing situation	3.4
3.4		Spontaneous Growth in Sana'a City	3.4
	3.4.1	Data Preparation	3.5
	3.4.2	Field Survey	3.6
	3.4.3	Madbah Spontaneous Settlement	3.7
	3.4.4	Alkafji Spontaneous Settlement	3.7
3.5		Modeling Urban Growth	3.8
	3.5.1	Data Preparation	3.9
	3.5.2	Prediction of Urban Growth Using GIS-based CA Model	3.10
	3.5.3	Using SLEUTH Model to Predict Urban Growth	3.22
	3.5.4	SLEUTH Model Prediction	3.36
<b>4</b>		<b>RESULTS</b>	<b>4.1</b>
	4.1	Introduction	4.1
	4.2	Urbanization	4.1
	4.3	Result of the Land Use Classification and Change Detection 1994-2003	4.2
	4.4	Master Plan and Urban Policies in Sana'a City	4.6
	4.4.1	Background Analysis of the Master Plan 1978	4.6
	4.4.2	The Regional Vision	4.7
	4.4.3	Population and Economic Projections	4.8
	4.4.4	Urban Planning Issues	4.10
	4.4.5	The 1978 Master Plan Methodology	4.11
	4.4.6	Plan and development Phases	4.14
	4.4.7	The limitation of the Master Plan 1978	4.18
	4.4.8	Updating Sana'a Master Plan 1999	4.19
	4.4.9	Associating the Current Situation with Master Plans	4.28
	4.5	Result of Spontaneous Settlement	4.33
	4.5.1	Madbah Area	4.34
	4.5.2	Alkafji Area	4.42
	4.6	Results of the GIS-Based CA Model	4.48
	4.6.1	The Criteria and Constraint Maps	4.49
	4.6.2	The Constraints	4.54
	4.6.3	Calculation of the Criterion Weight for Land Suitability Analysis	4.57
	4.6.4	Using GIS-based CA Transition Rule to Predict Urban Growth and Land Use Change	4.66
	4.6.5	Validation of the GIS-based CA Model	4.72
	4.7	Results of the SLEUTH Urban Growth Model	4.76
	4.7.1	Calibration Result	4.76
	4.7.2	Self- Modification	4.79
	4.7.3	Prediction Result	4.81

4.7.4	Comparison between the Prediction of GIS- Based CA Model and SLEUTH Model	4.87
5	<b>CONCLUSION AND RECOMMENDATION</b>	5.1
5.1	Conclusion	5.1
5.2	Recommendations for Future Work	5.5
	<b>REFERENCES</b>	R.1
	<b>APPENDICES</b>	A.1
	<b>BIODATA OF THE AUTHOR</b>	D.1



## LIST OF TABLES

<b>Table</b>		<b>Page</b>
2.1	Population and Growth Rate in Sana'a City	2.10
2.2	Summary of Growth Rules, Growth Parameters Defined in the SLEUTH Model	2.51
2.3	Scale and Pairwise Comparison	2.72
2.4	Pairwise Comparison Matrix	2.72
3.1	Criterion Score for Elevation Factor	3.12
3.2	Criterion Score for Slopes Factor	3.13
3.3	Criterion Score for Aspect Factor	3.14
3.4	Criterion Score for Road Networks Factor	3.16
3.5	The Parameters of the Coarse, Fine, Final Calibration (10 Meter Pixel Size)	3.34
4.1	The Population Growth in Sana'a City (1962—2004)	4.2
4.2	Pairwise Comparison Matrix for the Evaluation Criteria	4.57
4.3	Normalized Pairwise Comparison Matrix	4.58
4.4	Pairwise Comparison Matrix and Weights of Importance for the Evaluation Criteria	4.59
4.5	Consistency Ratio Limits	4.60
4.6	The Area of Potential Suitable Land for Urban Development	4.62
4.7	Prediction the Demand of Land for Spatial Urban Growth in Sana'a City 2004-2020	4.66
4.8	The Factors and Scores Effect the Transition Rule	4.68
4.9	The Land Use Change for the Year 2010	4.69
4.10	Validation Result of the GIS-based CA Prediction Model for the Year 2003	4.72



4.11	Average Coefficient Values After the “Derive Forecasting Coefficients Phase” for Historical Data	4.80
4.12	Prediction of the Demand of Land for Spatial Urban Growth in Sana’a City 2004-2020	4.82
4.13	The Annual Land Use Transition Probabilities	4.83
4.14	The Land Use Class per Pixel Transition	4.84



## LIST OF FIGURES

Figure		Page
2.1	The example of four growth types implemented in the SLEUTH model.	2.53
2.2	Decision flowchart for spatial multicriteria analysis	2.64
2.3	Example of simple cell evolution using transition rule adopted from the Game of Life.	2.77
3.1	Location Map of Sana'a City	3.3
3.2	QuickBird Satellite Image of Madbah – Sana'a city, 2003, with Distinct Patterns of Planned and the Spontaneous Settlements	3.6
3.3	General Structure of the SLEUTH Model	3.23
3.4	SLEUTH Model Run Using Brute Force Calibration Approach	3.30
4.1	The Land Use Map 1994	4.4
4.2	The Land Use Map 2003	4.5
4.3	Land Use Change 1994-2003	4.6
4.4	Population Projection of 1978 Master Plan	4.9
4.5	Alternative Development Concept in master plan 1978	4.13
4.6	Master Plan of 1978: Plan for Sana'a in 2000	4.16
4.7	The Development Phases in Master Plan 1978	4.17
4.8	The Potential Areas for Development in Master plan 1999	4.22
4.9	The Community Facilities in the Sectors and Potential areas for Development	4.23
4.10	Master Plan Development -First Stage 2000-2005	4.24
4.11	Master Plan Development- Second Stage 2005-2010	4.25
4.12	The Master Plan Development – Third Stage 2010-2020	4.26

4.13	Master Plan 1999: The Land Use Map 1996	4.27
4.14	Conform the Master plans 1978 and 1999 with existing spatial urban growth	4.31
4.15	The Critical Slope in Madbah Area	4.35
4.16	The Pattern Growth of the Spontaneous Houses in Madbah Area from 1994-2003	4.37
4.17	View of the House Size and Building Material	4.38
4.18	The Unpaved and Narrow Street in Madbah Area	4.39
4.19	Narrow Street in Madbah Area	4.40
4.20	View of the Spread of Garbage in the Madbah Area	4.40
4.21	View of Land Erosion in Madbah Area	4.41
4.22	The Pattern of Growth in the Spontaneous Houses in Alkafji Area from 1994-2003	4.42
4.23	The Residents' Income in Madbah and Alkafji Areas	4.43
4.24	The Roads in the Alkafji Settlement	4.45
4.25	The Water Resources in Madbah and Alkafji Areas	4.45
4.26	The Sewage System in Madbah and Alkafji Areas	4.46
4.27	Slope Suitability Map	4.51
4.28	Elevation Suitability Map	4.52
4.29	Aspect Suitability Map	4.53
4.30	Road Network Suitability Map	4.55
4.31	The Constraint Factors Maps	4.56
4.32	Potential Land Suitability for Urban Development	4.63
4.33	Overlay the Master Plan Proposed Areas for Development with Potentially Suitable Land for Urban Development	4.65
4.34	The Predicted Spatial Urban Growth 2010 (GIS-Based CA Model)	4.70



4.35	The Change in Land Use from 2003- 2010 (GIS-Based CA Model)	4.71
4.36	The Actual Built Up Area for the Year 2003	4.73
4.37	The GIS-based CA Predicted Model for the Year 2003	4.74
4.38	Overlay of the Actual and Predicted Areas for the Year 2003	4.75
4.39	The Behavior of the Study Area, Sana'a City, to the Growth Coefficients	4.77
4.40	The Predicted Areas 2010 Using SLEUTH Urban Growth Model	4.85
4.41	The Land Use Change in SLEUTH Model for the Year 2010	4.86
4.42	The Pattern of Urban Growth in GIS-based CA Model and SLEUTH Model	4.88
4.43	Comparison of GIS-Based CA Model and SLEUTH Model for Future Land Use Change Predictions in Sana'a City	4.89





# CHAPTER 1

## INTRODUCTION

### 1.1 Introduction

Cities or urban areas are the symbol of modernization. Urban activities are the wheel of a country's economy. The city is a magnet; it is a home and recreational center for city residents; it is a market place and shopping center for rural dwellers; it offers work and job opportunities to the unemployed and criminals; it is a source of souvenirs for tourists, visitors and foreigners. If it is a capital, major national policies are made and decisions are taken there; it is the home of major financial and economic institutes; it is a transportation hub. On the other hand cities are the source of complex problems. They need special attention from the whole fabric of society, particularly urban planners and decision-makers, who are responsible for the planning and management of the cities.

Urban areas comprise a relatively small portion of the earth's surface, but it is a major type of land use and land cover change in the human history and contains a disproportionate share of the earth's total population. The United Nations (2004) estimated that nearly half of the world's population lived and worked in urban areas. In addition to population pressure, urban areas are subjected to intensive usage from industrial production, commercial developments, and transportation and communication infrastructure. Such intense land usage often translates into social and environmental impacts that extend well beyond the spatial limits of the city itself.

