

# **MEASURING URBAN MORPHOLOGY FOR ADAPTATION TO CLIMATE CHANGE IN HO CHI MINH CITY**

A thesis approved by the Faculty of Environmental Sciences and Process Engineering at the Brandenburg University of Technology in Cottbus in partial fulfilment of the requirement for the award of the academic degree of Doctor of Philosophy (Ph.D.) in Environmental Sciences.

by

**M.A. LE THANH HOA**

from Ho Chi Minh City, Vietnam

Supervisor: Professor Dr. Dr. h.c. Michael Schmidt

Supervisor: V.-Prof. Dipl.-Ing. Frank Schwartze

Day of the oral examination: 11.10.2013

# **EVALUATION STÄDTISCHER STRUKTUREN ZUR FESTSTELLUNG DER ANPASSUNGSKAPAZITÄT AN DEN KLIMAWANDEL AM BEISPIEL VON HO CHI MINH CITY**

Von der Fakultät für Umweltwissenschaften und Verfahrenstechnik der  
Brandenburgischen Technischen Universität Cottbus zur Erlangung des  
Akademischen Grades eines Doktors der Philosophie (Ph.D.) in  
Umweltwissenschaften genehmigte Dissertation

vorgelegt von

**M.A. LE THANH HOA**

aus Ho Chi Minh City, Vietnam

Gutachter: Professor Dr. Dr. h.c. Michael Schmidt

Gutachter: V.-Prof. Dipl.-Ing. Frank Schwartze

Tag der mündlichen Prüfung: 11.10.2013



## ACKNOWLEDGEMENT

My dissertation is “Measuring Urban Morphology for Adaptation to Climate Change in Ho Chi Minh City”. The scholarship is funded by the BMBF-DAAD program “Study and Research Scholarships of Today for the Megacities of Tomorrow”, under the main supervision of Professor Dr. Dr. h.c. Michael Schmidt, Dean of Faculty of Environmental Sciences and Process Engineering, Head of the Department of Environmental Planning, Brandenburg University of Technology Cottbus-Senftenberg, and Director of Megacity Research Project in Ho Chi Minh City.

I would like to acknowledge Professor Dr. Dr. h.c. Michael Schmidt, Head of the Department of Environmental Planning, Brandenburg University of Technology Cottbus-Senftenberg, Director of the Megacity Research Project in Ho Chi Minh City, my first supervisor; V.-Prof. Dipl.-Ing. Frank Schwartze, Department of Urban Planning and Spatial Design, my second supervisor; and Dr. Harry Storch, the Megacity Project Coordinator, who supported me to finish proposal writing, conduct the results and fulfill the writing, as well as evaluate every scholarship period.

I would like to acknowledge the DAAD, German Academic Exchange Service, who supported me the scholarship that provide me all support for my PhD study. I am very grateful to Mrs. Irmgard Kasperek, who has wholeheartedly supported me through all procedure processes for studying and living in German.

I also would like to thank for all of the supports from other coordinators of the Megacity Project Ho Chi Minh City, Nigel Keith Downes and Antje Katzschner; and the Department Secretary, Mrs. Christine Melchet, who helped me to fulfill all procedures for visa extension, scholarship and study extension in both German and Vietnam sides.

On the Vietnamese side, I would like to thank Dr. Ho Long Phi, who gave the remarkable comments about the flooding situation in Ho Chi Minh City for me to finish my study.

I also would like to thank to Mr. Bang Anh Tuan, Head of USSH International Relation Office, who had supported me to fulfill all study extension procedures with the HCMC University of Social Sciences and Humanities.

My heartfelt thanks to my parents, brothers and sisters, whose prayers and love always be of help to boost up my spirit in finishing my study. Finally, I give thanks to Jesus Christ my Lord and Mother Mary, who have abundantly granted graces to help me all the time.

Le Thanh Hoa

Brandenburg University of Technology Cottbus-Senftenberg, Germany

## DECLARATION

I declare that the results in this dissertation “Measuring Urban Morphology for Adaptation to Climate Change in Ho Chi Minh City“ are my own. I worked out the doctoral thesis by myself and that all used aid is listed in the doctoral thesis. This dissertation has never been presented or submitted for any degree in this or any other University or Institution at national and international level.

-----

Le Thanh Hoa

## ABSTRACT

Urban morphology is used in many developed countries to classify and manage the distribution of urban functions. In urban planning, it helps to identify the emerging problems and solve the disorder of urban functions. The megacity Ho Chi Minh City has faced many problems with uncontrollable urbanization, urban management and planning. It has received increasing tropical storms and cyclones which caused more heavy rains in recent decades. Rapid urbanization has caused the increase of built-up coverage with disordered typologies, incomplete infrastructure and urban-peripheral instability. In the flooding context, these problems have increased more seriously with flooding impacts and caused uncontrollable planning and management in the city. This study applies the urban morphology method to measure flood impacts on urban functions and develop the adaptive solutions for flooding adaptation for Ho Chi Minh City.

The methods in this study are based on applying fractal geometry, GIS and Remote Sensing on large-scale maps for measuring the urban morphology. The land-use map and the building footprints map of 2010 were founded to analyze the distribution of urban areas by high resolution of satellite images and large scale GIS data. The fractal geometry was a setting based on Avenue program of Arcview GIS to measure the urban morphology. This formed a key input for the multi-criteria analysis (MCA) method that investigated the cause of flood impacts and suggested the solution for flooding adaptation. In addition, alterations of lakes, ponds and watercourse from 1995 to 2009 were explored.

The study showed HCMC had problems on irrational development in residential densities areas and urban functions, and the uneven development of population and residential density between the urban areas: too much in the urban districts (about 300 to 500 persons per hectare per block and coverage ratio 0.7 - 0.9). This pushed the increasing demand on built-up area and filled-up rivers and canals (About 80 percent of original ponds and lakes in inner-center were filled-up in the past; and 63 percent of ponds and lakes have been filled-up in Sub-Districts and new-urban-development areas).

It made the imbalance between the permeability of land surface and the run-off water flows; then leads the inundation to increase. This is the main reason for reducing the water-storage capacity in rainy season. Flooding in urban residential area was more impacted than in rural residential area, higher level and longer flood time; while flooding in the rainy season due to high tides, heavy rains or both was the emerging and uncontrollable problems. For flooding adaptation, urban morphology analysis helped to figure out the potential areas in the city could be used for reducing flooding impacts in urban areas. There are many low-density residential areas in above 1.5 meter AMSL areas in

the North, Northwest and Northeast areas of the city which could be developed with complete infrastructure and urban services to attract people from high-density residential areas impacted deeply by floods in the center. These potential areas could be the long-term strategic solution to flooding adaptation for HCMC. The results also suggested that some current flooded areas would be re-planned or returned to be the water-storage and permeable areas (such as green parks, ponds and lakes). This re-planning would improve the city landscape and increase the permeable surface, green spaces and open spaces to HCMC. More green spaces, lakes and ponds will also help to reduce the temperature of urban center in the dry season. This adaptation solution would reduce at least 25 percent of current flooded areas in urban center. The protection and constructed restriction of current agricultural areas in peri-urban Districts would maintain the infiltration and green-tree areas. Furthermore, the complete drainage system would help to reduce better flood for these areas. Finally, fully dredging river and canal system of the city would reduce about 25 to 30 percent of current flooded areas.

**Keywords:** *Urban morphology, Climate change, Flooding, Fractal geometry, Urban area*

## ZUSAMMENFASSUNG

Stadtmorphologie wird in vielen entwickelten Ländern zur Klassifizierung und Verwaltung von städtischen Funktionen genutzt. Innerhalb der Stadtplanung können so entstehende Probleme identifiziert und gelöst und dadurch die Störung der städtischen Funktionen verhindert werden. Die Millionenstadt Ho-Chi-Minh-Stadt hat große Probleme mit einem unkontrollierbaren Urbanisierungsdruck, dem Stadtmanagement und der Stadtplanung. Zunehmend wird die Stadt in den letzten Jahrzehnten durch tropische Stürme und Wirbelstürme, die wiederum schwerere Regenfälle verursachen, heimgesucht. Die schnelle Urbanisierung hat eine Zunahme der bebauten Flächen mit ungeordneten Typologien, einer unvollständigen Infrastruktur und Instabilität besonders an den Stadträndern verursacht. In Anbetracht der verstärkten und häufigeren Überschwemmungen haben sich diese Probleme noch weiter verstärkt und zur unkontrollierbaren Planung und Verwaltung der Stadt beigetragen. Die Stadtmorphologie-Methode wird in dieser Studie angewendet um die Auswirkungen von Hochwasser und Überflutung auf die städtischen Funktionen zu messen und Lösungen zur Anpassung an Überflutungen für Ho-Chi-Minh-Stadt zu entwickeln.

Die Methoden in dieser Studie basieren auf der Anwendung der fraktalen Geometrie, GIS und der Fernerkundung auf großen Karten für die Messung der städtischen Morphologie. Die Landnutzungskarte und eine Karte der Gebäudegrundrisse aus dem Jahre 2010 wurden entwickelt, um damit die Verteilung der städtischen Gebiete mit Hilfe von hochaufgelösten Satellitenbildern und großen GIS-Daten zu analysieren. Die fraktale Geometrie war eine Einstellung zur Messung der Stadtmorphologie auf der Grundlage des Programms ArcView GIS. Die Daten waren dabei ausschlaggebend für die Multi-Kriterien-Analyse (MCA)-Methode, die Ursache der Hochwasserauswirkungen untersucht und Lösungsvorschläge für die Anpassung an Überschwemmungen macht. Des Weiteren wurden Veränderungen von Seen, Teichen und Wasserläufen zwischen 1995 bis 2009 untersucht.

Die Studie zeigt, dass Ho-Chi-Minh-Stadt Probleme mit der informellen, unkontrollierten Entwicklung dicht besiedelter Wohngebiete und dessen städtischen Funktionen hat. Es gibt des Weiteren eine ungleiche Entwicklung der Bevölkerung sowie der Wohndichte der einzelnen Stadtgebiete: einige Stadtteile haben einen Besiedlungsgrad von 0,7 - 0,9; 300 bis 500 Personen leben dort pro Hektar und Block. Dies führte zu einer steigende Nachfrage nach bebaubaren Flächen wie beispielsweise auf verfüllten Flüssen und Kanälen (über 80% der ursprünglichen Teiche und Seen im Stadtkern wurden in der Vergangenheit verfüllt und 63% der Teiche und Seen sind in

den Außenbezirken und neuen Stadtentwicklungsgebieten in bebaubare Fläche umgewandelt worden).

Das Verfüllen der Gewässer führt zu einem Ungleichgewicht zwischen der Durchlässigkeit des Bodens und dem Oberflächenabfluss des Wassers. Dies wiederum führt zu einer Erhöhung der Überflutungsgefahr. Auch ist dies der Hauptgrund für die Verringerung der Wasserspeicherkapazität des Bodens in der Regenzeit. Die Hochwassergefahr und das Hochwasser steigen in den städtischen Wohngebieten signifikanter als in ländlichen Wohngebieten. Das Hochwasser ist höher und hält längere Zeit an. Überschwemmungen in der Regenzeit durch Tiedehochwasser, starke Regenfälle oder beides führen weiter zu neuen und unkontrollierbaren Problemen. Die Stadtmorphologie-Analyse hilft bei der Anpassung an häufiger auftretende Überschwemmungen. So kann herausgefunden werden, welche Bereiche der Stadt sich besonders eignen, um die negativen Auswirkungen einzugrenzen.

Es gibt zahlreiche weniger dicht besiedelte Wohngebiete mit über 1,5 Meter ü. d. Meeresspiegel in den Nord-, Nordwest- und Nordostgebieten der Stadt. Diese Areale könnten mit kompletter Infrastruktur und städtischen Dienstleistungen entwickelt werden, um Menschen aus Wohngebieten mit hoher Dichte und Hochwassergefährdung neuen Lebensraum zu bieten. Diese potentiellen neuen Wohngebiete könnten die langfristige strategische Lösung zur Anpassung an Überschwemmungen in Ho-Chi-Minh-Stadt darstellen. Die Ergebnisse zeigen auch, dass einige aktuell von Überflutung gefährdeten Gebiete neu geplant werden könnten und durch eine Umwandlung in Parks, Teiche oder Seen wieder als Wasserspeicher – oder wasserdurchlässige Bereiche dienen könnten. Diese Umplanung würde die Stadtlandschaft verbessern und die durchlässige Oberfläche von Grünflächen und Freiräumen um Ho-Chi-Minh-Stadt erweitern. Eine Zunahme an Grünflächen, Seen und Teichen wird auch helfen, die Temperatur des Stadtzentrums in der Trockenzeit deutlich zu reduzieren. Die beschriebenen Anpassungen würden mindestens 25% der aktuellen Hochwassergebiete im Stadtkern reduzieren. Der Schutz und Baurestriktionen der aktuellen Landwirtschaft genutzten Flächen in den Stadtrandbezirken würde die Versickerung sicherstellen und Grünflächen erhalten. Darüber hinaus würde ein ausgereifteres Entwässerungssystem helfen, Hochwasserereignisse für diese Bereiche zu reduzieren. Schließlich würde eine optimale Beräumung des städtischen Fluss- und Kanalsystems durch Ausbaggern zu einer Reduktion der Überflutungsfläche um 25% bis 30% führen.

**Stichwörter:** Stadtmorphologie, Klimawandel, Hochwasser, fraktale Geometrie, Stadtgebiet

## **TABLE OF CONTENTS**

<b>ACKNOWLEDGEMENT</b> .....	<b>3</b>
<b>DECLARATION</b> .....	<b>4</b>
<b>ABSTRACT</b> .....	<b>5</b>
<b>ZUSAMMENFASSUNG</b> .....	<b>7</b>
<b>TABLE OF CONTENTS</b> .....	<b>9</b>
<b>LIST OF MAPS</b> .....	<b>14</b>
<b>LIST OF TABLES</b> .....	<b>15</b>
<b>LIST OF FIGURES</b> .....	<b>17</b>
<b>LIST OF ABBREVIATIONS</b> .....	<b>19</b>
<b>1 INTRODUCTION</b> .....	<b>21</b>
1.1 Background.....	21
1.2 Research Hypothesis .....	22
1.3 Research Objectives .....	22
1.4 Research Questions .....	23
1.5 Research Scopes .....	23
1.6 Reality and Application.....	23
1.7 Thesis Structure .....	24
1.8 Summary for Chapter One.....	25
<b>2 URBAN MORPHOLOGY AND ITS ROLES IN URBAN PLANNING AND FLOODING ADAPTATION</b> .....	<b>26</b>
2.1 Urban Morphology as an Emerging Interdisciplinary Field.....	26
2.1.1 Understanding about Urban Morphology.....	26
2.1.2 History of Urban Morphology .....	26
2.1.3 Urban Morphological Research as an Interdisciplinary Field .....	27
2.2 The Key Findings of Urban Morphology Analysis.....	28
2.2.1 Principles of Urban Morphology.....	28
2.2.2 The Roles in Urban Planning .....	29

2.2.3	Role of Urban Morphology in Dynamic Megacities.....	29
2.3	Urban Morphology on Urban Climate and Flooding Adaptation .....	31
2.3.1	Studies on Urban Climate.....	31
2.3.2	Using Urban Morphology for Flooding Adaptation.....	31
2.4	Urban Morphology Analysis .....	33
2.4.1	Processes of Urban Morphological Analysis .....	33
2.4.2	Scales in Urban Morphological Analysis .....	33
2.4.3	The Principles for Residential Density.....	34
2.5	Fractal Analysis in Urban Morphology Processes .....	35
2.6	Summary for Chapter Two .....	37
<b>3</b>	<b>RESEARCH METHODOLOGY.....</b>	<b>38</b>
3.1	Research Framework.....	38
3.2	Data Preparation and Compilation .....	39
3.3	Study Area.....	41
3.4	Classification of Land-use and Building Types .....	41
3.4.1	Technical Approach for Land-use and Building Types Classification .....	41
3.4.2	Land-use and Buildings Classification Process.....	42
3.5	Fractal Geometry Analysis .....	43
3.6	Urban Morphological Analysis .....	46
3.7	Potential Areas Analysis for Flooding Adaptation.....	49
3.8	Summary for Chapter Three.....	50
<b>4</b>	<b>URBAN DEVELOPMENT AND FLOODING PROBLEMS IN HO CHI MINH CITY .....</b>	<b>52</b>
4.1	Dynamic Development and Land-use Change .....	52
4.1.1	Urban Expansion and Disorder of Urban Function Areas.....	52
4.1.2	The Urban-Peripheral Linkage and Land-use Change .....	53
4.1.3	Flooding Problems of Land-use in HCMC .....	55
4.2	Mass Occupation of Urban Built-up Coverage and Flooding Problems.....	56
4.2.1	Expanding Residential Areas and Various Housing Typologies .....	56
4.2.2	Growing Built-up Coverage and Flooding Expansion .....	56



---

4.3	Inadequate Urban Infrastructure and Services in Flooding Context of HCMC ..	57
4.3.1	Overloaded and Narrowing of Natural Drainage .....	57
4.3.2	Carrying Capacity of Constructed Drainage System.....	59
4.4	Flooding Hazard and Demand for Urban Natural Resource Protection.....	60
4.4.1	The Infiltration and Evaporation with Flooding of HCMC.....	60
4.4.2	Resilient Land and Water Resources in Flooding Context of HCMC .....	61
4.5	Summary for Chapter Four.....	63
<b>5</b>	<b>SATELLITE IMAGES INTERPRETATION FOR LAND-USE AND BUILDINGS IN 2010 IN HO CHI MINH CITY .....</b>	<b>64</b>
5.1	Why Landsat and High-Resolution Images Were Interpreted for Land-use and Buildings in HCMC? .....	64
5.2	Mapping of Land-use 2010 .....	66
5.2.1	Data Input for Satellite Images Processing .....	66
5.2.2	Interpretation of Landsat ETM <sup>+</sup> Images for Land-use Mapping.....	67
5.2.3	The Accuracy Evaluation for Land-use 2010.....	69
5.2.4	Interpretation Results of Land-use 2010 .....	70
5.2.5	Land-use Change 2005-2010.....	72
5.3	Interpretation for Building 2010 and Building Types Change 2005-2010.....	75
5.3.1	Using Data for Building Update.....	75
5.3.2	Geo Referencing for Interpretation of Building .....	75
5.3.3	Buildings Classification.....	76
5.3.4	Buildings Update Results and Building Change for HCMC 2005-2010 .....	79
5.4	Summary for Chapter Five .....	86
<b>6</b>	<b>MEASURING URBAN MORPHOLOGY IN HO CHI MINH CITY .....</b>	<b>87</b>
6.1	The Necessity of Urban Morphology Map and Urban Function Map .....	87
6.2	Program Tool for Fractal Geometry Analysis .....	88
6.3	Spatial and Density Relation of Urban - Peripheral Areas in HCMC.....	89
6.3.1	Spatial and Density Distribution of Urban - Peripheral Areas in HCMC .....	90
6.3.2	Trend of Spatial and Density Distribution of Built-up Areas in HCMC.....	95
6.3.3	Trend of Spatial Distribution of Residential Areas in HCMC .....	96

6.4	Spatial and Density Distribution of Building Types in HCMC .....	97
6.5	Vertical and Horizontal Distribution of Urban Density in HCMC .....	100
6.5.1	Distribution of Population Density on Land-use Block in HCMC .....	100
6.5.2	Distribution of Building Coverage and Floorspace Ratio on Land-use Block in HCMC .....	104
6.6	The Relation between Buildings Coverage and Floorspace of 2005 and 2010 on Land-use Blocks in HCMC .....	111
6.6.1	The Changing between Buildings Coverage and Land-use Blocks in 2005- 2010 .....	111
6.6.2	The Changing Between Floorspaces and Land-use Blocks in 2005-2010 .....	115
6.7	Summary for Chapter Six .....	118
<b>7</b>	<b>FLOODING IMPACTS ON URBAN MORPHOLOGY IN HO CHI MINH CITY .....</b>	<b>119</b>
7.1	Identification Approach to Flooding Analysis in HCMC .....	119
7.1.1	Identification Approach Based on Flooding Information in HCMC.....	119
7.1.2	Methods of Flooding Identification for HCMC .....	120
7.2	Flooding Impacts in HCMC .....	121
7.2.1	Flood Areas in Flood Types and Geographical Elevation in HCMC.....	121
7.2.2	Reason Identification of Flooding in HCMC .....	123
7.3	Flood Impact on Residential Areas in HCMC .....	128
7.3.1	Flooding in Residential Areas in HCMC .....	128
7.3.2	Reason Identification of Flooding in Residential Areas in HCMC.....	132
7.4	Summary for Chapter Seven .....	135
<b>8</b>	<b>POTENTIAL AREAS FOR FLOODING ADAPTATION IN HO CHI MINH CITY .....</b>	<b>136</b>
8.1	Identification Approach to Flooding Adaptation in HCMC.....	136
8.2	Method for Flooding Adaptaion in HCMC .....	137
8.3	Flooding Adaptation to Urban Residential Areas .....	138
8.4	Increasing the Run-off Water Collection for Flooding Adaptation.....	141
8.4.1	Flooding Adaptation to Permeable Surface to Ho Chi Minh City-The Green Space.....	141

---

8.4.2	Flooding Adaptation to Water-Infiltration Areas for Agriculture in Peri-Districts.....	144
8.5	Flooding Adaptation to Water-Storage Areas-Lakes and Ponds.....	147
8.6	Restoration of Rivers and Canals System to Flooding Mitigation .....	150
8.7	Summary for Chapter Eight.....	153
<b>9</b>	<b>CONCLUSION .....</b>	<b>154</b>
9.1	Conclusion.....	154
9.2	Limitation of Study.....	158
<b>10</b>	<b>REFERENCES .....</b>	<b>159</b>
<b>11</b>	<b>APPENDIX .....</b>	<b>173</b>
11.1	General Statistics Data of Flooded Locations 2010 of HCMC .....	173
11.2	Source Program .....	185

## LIST OF MAPS

Map 5.1	Interpretation Result of Land-use 2010 of HCMC.....	71
Map 5.2	Land-use Change 2005-2010 of HCMC .....	74
Map 5.3	The Result Classification Building Types of HCM 2010 .....	81
Map 5.4	Buildings Change 2005-2010 of HCMC.....	82
Map 6.1	Urban Morphology of HCMC 2010.....	91
Map 6.2	The Urban Function of HCMC .....	92
Map 6.3	Population Densities on Land-use Block of HCM 2010.....	102
Map 6.4	Building Coverage on Land-use Block of HCM 2010.....	107
Map 6.5	Floor Area Ratio on Land-use Block of HCMC 2010.....	110
Map 6.6	The Changing Building Coverage 2005-2010 on Land-use Block of HCMC .....	114
Map 6.7	The Changing Floor Spaces 2005-2010 on Land-use Block of HCMC .....	117
Map 7.1	Flooded Map of HCMC 2010 .....	122
Map 7.2	The Changes State of Drainage Canals in Inner City (1995-2009).....	125
Map 7.3	The Changes State of the Natural Ponds and Lakes in Inner City (1995- 2009).....	127
Map 7.4	Flooded Impacts on Urban Residential Areas of HCMC.....	131
Map 7.5	Buildings Types Flooded Areas .....	134
Map 8.1	The Result of Flooding Adaptation to Urban Residential Areas of HCMC	140
Map 8.2	Restoration of Parks and Green Spaces to Flooding Adaptation of HCMC	146
Map 8.3	Restoration of Lakes and Ponds to Flooding Adaptation of HCMC.....	149
Map 8.4	Restoration of Drainage Canals System to Flooding Mitigation of HCMC	152

## LIST OF TABLES

Table 2.1 The Standard of Residential Density Ranges for the Study Area .....	35
Table 3.1 Maps and Data Sources Used for the Analysis of Research .....	40
Table 3.2 Satellite Imagery Used for the Classification of HCMC Land-use and Building Types .....	40
Table 4.1 Land-use Change of HCMC (2000-2010).....	54
Table 5.1 Key Sampling for Each Class of Land-use Types.....	68
Table 5.2 Land-use Classification Accuracy Confusion Matrix and Kappa Constant...	69
Table 5.3 Area and Percentage of Change in each Land-use Class and Annual Rate of Change between 2005 and 2010 .....	72
Table 5.4 Describes the Keys Sampling of Building Types for Classification .....	77
Table 5.5 Buildings Change in 2005-2010.....	79
Table 5.6 Building Types Changed in 2005-2010 of HCMC .....	84
Table 6.1 Dimensions Associated with Partial Building Densities.....	90
Table 6.2 Overall Fractal Geometry of Particular Building Categories in HCMC .....	98
Table 6.3 Percent of Ground Floor of Building on Land-use Block.....	106
Table 6.4 Percent of Floorspace on Land-use Block.....	109
Table 6.5 The Changing of Building Coverage 2005-2010 on Land-use Blocks.....	113
Table 6.6 The Changing Floorspaces 2005-2010 on Land-use Blocks .....	115
Table 7.1 Flooded Impacts Areas 2010 of HCMC.....	123
Table 7.2 Flooded Impacts on Residential Areas of HCMC.....	130
Table 7.3 Population in Flooded Areas .....	132
Table 7.4 Number of Buildings in Flooded Areas of HCMC .....	133
Table 8.1 List of the Multi-Criteria for Flooding Adaptation .....	138
Table 8.2 The Potential Residential Areas for Flooding Adaptation in Northwest and Northeast Districts of HCMC.....	139
Table 8.3 The Potential Areas of Urban Green Spaces for Flooding Adaptation of HCMC .....	143

---

Table 8.4 The Analysis Results of Agriculture Areas and the Permeable Surface for Flooding Adaptation of HCMC.....	145
Table 8.5 The Potential Areas of Lakes and Ponds as the Water Storage for Flooding Adaptation of HCMC.....	148
Table 8.6 The Restoration of Canals and Ditches as the Water Storage for Flooding Adaptation of HCMC .....	151

## LIST OF FIGURES

Figure 3.1	Flow Chart Approach.....	39
Figure 3.2	Hierarchical Segmentation of Classified Urban Categories .....	43
Figure 3.3	The Transfer of Classified Thematic Categories into Fractal Geometry Cumulative and Density Profiles .....	46
Figure 3.4	The Use of the MCA to Optimize Urban Functions .....	48
Figure 3.5	Flooding Adaptive Process to HCMC .....	50
Figure 4.1	Urban Development and Flooding Impact Problems of HCMC .....	62
Figure 5.1	The Methodological Framework for Land-use and Buildings Analyses .....	65
Figure 5.2	The Landsat EMT+ (image a), and GeoEye-1 images (image b) 2010 .....	67
Figure 5.3	Detail of Building Updated from Ikonos, GeoEye-1, Worldview-2 Images 2010.....	80
Figure 6.1	Morphologist Tool Based on ArcView 3.3 .....	88
Figure 6.2	The Construction of the Morphology Tool in Arcview .....	89
Figure 6.3	Cumulative Count Profiles of the Urban and Built-up Categories of HCMC.....	95
Figure 6.4	Density Profiles of the Urban and Built-up Categories of HCMC .....	96
Figure 6.5	Cumulative Count Profiles of the Residential and Non-Residential Categories of HCMC .....	97
Figure 6.6	Cumulative Count Profiles of the Building Categories of HCMC .....	99
Figure 6.7	Population of Residential Density on Blocks of HCMC .....	103
Figure 6.8	Total Blocks of Residential Density of HCMC .....	103
Figure 6.9	Area of Residential Density of HCMC .....	104
Figure 6.10	The Changing of Dong Khoi park to Vincom Building in Center 2005- 2010.....	112
Figure 7.1	GIS Analysis Framework Developed in Flooding Impacts on Urban Function .....	120
Figure 8.1	Flowchart of Potential for Flooding Adaptation in Urban Area .....	137
Figure 8.2	Illustration of Built-up Parks with less Greenspace of HCMC.....	142

---

Figure 8.3 Illustration of Filled-up Pond in District 7 for Apartment Building ..... 147

Figure 8.4 Illustration of One Filled-up Branch of Tau Hu-Ben Nghe Canal for  
Residential Area..... 151



## LIST OF ABBREVIATIONS

ADB	Asian Development Bank
AMSL	Above Mean Sea Level
BCR	Building Coverage Ratio
CBD	Central Business District
DoC	Department of Construction
DoNRE	Department of Natural Resources and Environment
DoPA	Department of Architect and Planning
DoT	Department of Transportation
ETM	Enhancement Thematic Mapper
ENVI	Environment for Visualizing Images
FAR	Floor Area Ratio
GIS	Geographic Information Systems
GPS	Global Positioning System
GUI	Graphical User Interface
HCMC	Ho Chi Minh City
HIDS	HCMC Institute for Development Studies
IDW	Inverse-Distance-Weighting
IIED	International Institute for Environment and Development
IPCC	Intergovernmental Panel on Climate Change
MLC	Maximum Likelihood Classification
MCA	Multi Criteria Analysis
MOC	Ministry of Construction
MSA	Multi Spatial Analysis
PSO	HCMC Statistic Office
RS	Remote Sensing
SDA	Spatial Data Analysis
SCES	Steering Committee for Environmental Sanitation

---

SCFC	Steering Centres of Flooding Control Program
SIHYMETE	Sub-Institute of Hydrometeorology and Environment of South Vietnam
UM	Urban Morphology
UTM	Universal Transverse Mercator
UNDP	United Nations Development Programmers
UNEP	United Nation Environmental Program
UN-Habitat	United Nations Human Settlements Programme
UN-VN	United Nation – Vietnam
VNPM	Vietnam Prime Minister
WB	World Bank

# 1 INTRODUCTION

## 1.1 Background

When world industrialization has boomed, the anthropogenic industrial gas emission rapid increased has caused the greenhouse effect and affected the global climate (Meinshausen, 2009). It results in global warming and sea level rise. The global annual temperature, oceans and continents are increasingly changed (IPCC, 2007a; Meinshausen et al., 2009<sup>1</sup>; Pierce & Barnett, 2009<sup>2</sup>; Senga, 2009<sup>3</sup>). The increasing of global temperature can be searched as the widespread melting of snow and ice. These result in sea level increase. Over the past 100 years, the global temperature is around 10<sup>o</sup>c warmer and the sea level is around 2 meter higher. Those rising signals were not regularly increased each decade or year, though. They have increasingly trends in recent decades (IPCC, 2007a; Peter & Forest, 2007; Roggema, 2009).

Global climate change is an external force on HCMC climate change because of the increasing of sea level, tidal flows, storms, and heavy rains (World Vision, 2009; UN-VN, 2009). According to ADB report (2010), HCMC has more storms and heavy rains affected over the last 60 years since Vietnam has received more tropical storms and cyclones. Otherwise, HCMC is a coastal city in Southeast Asia with high slopes and low elevations (61% of total surface area is below 2.0 m above mean sea level). Therefore, when storm and heavy rains come, the city receives large amounts of run-off water at the same time. And they cause the temporary floods in the large surface. And when the sea level rises, it can be seen as tidal flows, along with prolong heavy rains, and the larger areas have been flooded permanently.

HCMC is one of the top five cities in the world with high population growth (Nicholls et al., 2008). During last ten years, many housing projects and programs have been implemented in central and sub-urban areas<sup>4</sup>. However, the housing demand is still a big problem in HCMC. Many agriculture lands have been used for built-up areas and urban expanding. This has caused the land-use change in HCMC.

---

<sup>1</sup> Meinshausen et al. (2009) said that global warming has led the earth temperature up to 2<sup>o</sup>C or below relative to pre-industrial level. And the global temperature will be increasing in the next 50 years but not higher than.

<sup>2</sup> For Pierce & Barnett (2009), the surface layers of the ocean have been increased 0.3<sup>o</sup>C over the past 40 years.

<sup>3</sup> Senga's report (2009), the temperature in Asia continent has been increased from 1-3<sup>o</sup>C during the last 100 years.

<sup>4</sup> Sources: HCMC Cadastry and Housing Land Department (2001); HCMC Department of Construction (DoC), (2005 & 2010).

Because of loose of urban management of built-up areas without planning leads to the lacking of infrastructure and urban services, such as drainage systems and sanitation. The built-up areas have swallowed streams and canals, trees and parks, and open spaces of the city. These results increase of soil sealing and reducing of water infiltration and evaporation. Thus, when heavy rains and storms come as well as sea level rise, the inadequate drainage system and the large amount of soil sealing have caused the big flooding in HCMC. The flooding lasts for a long time and may cause the micro climate change in the city.

Therefore, it is necessity to analyze the urban morphology for the current land-use in the situation of flood impact by climate change. This may help the city adapt to climate change for the future development.

## 1.2 Research Hypothesis

Land-use, buildings, and population are three main factors in urban morphological analysis. Measuring urban morphology can figure out the distribution of urban functions of the city, such as the distributions of built-up density, residential density, and green space, etc. the inappropriate distribution of urban functions may cause flooding problems to the city. Therefore, the hypothesis of this study is as follow:

Urban morphology analyses will advance the understanding of the causes and impacts of flooding in the urban residential areas of HCMC.

## 1.3 Research Objectives

To implement the research and find out the results, the main objective and strategic objectives must be involved.

### **Main objective:**

Measuring urban morphology is to analyze flooding impacts for flooding adaptation in Ho Chi Minh City.

### **Strategic objectives:**

- To build an urban morphology map based on land-use and urban-categories for flooding analysis in HCMC
- To analyze flood impacts on urban-function areas based on urban morphology (in current floods level)
- To estimate flood-impacted areas on the urban morphology (in current floods level)
- To suggest the potential of different urban areas for adapting to flood impacted in HCMC.

## 1.4 Research Questions

According to the above objectives, the research questions may be the followings:

- a. How to build the urban morphology map for flooding analysis in HCMC?
- b. How are the current urban flooding impacts related to current urban development processes?
- c. Where are the hotspot areas for floods located in the city?
- d. What are the potential or suitable areas to aid the adaptation to flooding impacts?

## 1.5 Research Scopes

### *Scope of research field:*

To analyze the morphology for Ho Chi Minh City, it is necessary to have all view of the city. Then it can be understood why its urban fields are located and the rate of urban center to its peripheral area. And when analyses with the flooding, the total impact area can be displayed.

### *Scope of scientific research:*

The climate change may come from many reasons and it also impacts on several aspects on the surface of Ho Chi Minh City. In this research, the flooding impact is mainly concentrated. And city's land-use has been analyzed by morphology on the flood areas. It is supposed that, if without adaptation for flooding expanding, the flood would be exposed in the next 10 years. When the urban morphology is integrated on the flood 2010, the urban morphology will be described among the urban districts areas and peri-urban districts areas of the fractal geometry analysis. In order to assess the impacts of flood 2010 and the adaptation capabilities in this City are analyzed the results of urban morphology map.

## 1.6 Reality and Application

### *Reality*

Ho Chi Minh City is in the coastal area of Southeast Asia. The increasing of flooding impact by climate change and urbanization in this HCMC is foreseeable. The dynamic development and the changing of urban fabric are still going on. In case of current high flooding in HCMC, urban morphology analysis will help to identify the improper distribution of the main urban function areas, where have been flooded. This will be the big problems for urban development of HCMC in the future. The results of research help to describe the urban morphology base on land-use impacted by flood and in the future.

Urban morphology analysis on urban residential areas can aid the understanding of flooding impacts and its drivers for HCMC

### *Application*

Urban morphology identifies the distribution of different functions in a city. Especially model of fractal geometry can apply to measure the spatial structure of urban areas such as residential density, built-up density, and open spaces, etc.

Urban morphology analysis offers the potential areas to flooding adaptation. Flooding impact evaluation on urban functions in these analysis processes helps to find out the appropriate potential areas for flooding adaptation and mitigation, and support for urban planning in HCMC.

## **1.7 Thesis Structure**

Chapter One provides the background information and discusses the problem of HCMC. This chapter discusses the main concepts based on which the hypothesis, the objectives and research questions are identified.

Chapter Two gives information about the relevant study. It explains the theoretical basis of the research. This part will provide a thorough background and knowledge in the subject area of urban morphology, not only to understand the concept itself but also to develop an understanding of various aspects of urban morphology. Theoretically, urban morphology should be considered as an interdisciplinary field as it involves numerous scientific and technical areas, e.g. Geographical Information Science (GIS), Remote Sensing (RS), urban geography, complexity theory, land-use, fractal geometry, etc.

Chapter Three presents the research framework within which three work packages were carried out. It discusses the schematic presentation of study approach explained the process of research.

Chapter Four presents the information of flooding problems in HCMC. The chapter also presents these problems of urban development push flooding in HCMC.

Chapter Five presents the results and discussion of the study in terms of the strategic objectives. It first analysis stakeholders needs assessment followed and discussion of other objectives the development of the urban morphology map. It presents the results on the object-pointed satellite image analysis such as land-use, building footprints.

Chapter Six presents one of the main objectives of study. The discussions focus on the potentials of fractal geometry concepts in urban morphology. It helps to explain the growth rate of urbanization and the density distribution of urban function areas, especially the megacity of HCMC with a long time of dynamic urbanization.

Chapter Seven presents the identification of flooded areas base on the flooding data. The results focus on the impacts of the flooding in urban function areas. The impact evaluation of flooding will be analyzed in cases of current flood in HCMC.

Chapter Eight provides the results of potential areas for flooding adaptation of the main research findings. It then goes on to suggest the potential function areas for flooding adaptation in current flood level and considers adaptation solutions to reduce flood impacts in HCMC

Chapter Nine gives a summary of the main research findings based on the hypothesis and objectives of study. It makes recommendations for further research work.

## **1.8 Summary for Chapter One**

HCMC is in crisis of flooding because of climate change impacts and rapid urbanization forces. The City is in the coastal area where is affected by tropical cyclones and more heavy rains in rainy season. More run-off water has caused longer flood in the ground surface. Furthermore, urbanization has brought many problems with disorder development and uncontrolled planning. These resulted in the widespread expansion of urban function areas, such as the sprawling of residential areas, public and urban services. Many lowland areas were occupied for urban development. These caused the increase of flooded and flood-prone areas in the city.

Urban morphology analysis with the roles of analyzing and identifying the urban function areas and their problems for planning supports. It can be used for analyzing flooding problems and suggesting the solutions for adapting and mitigating to flooding in HCMC. Therefore, the hypothesis of this study is “Measuring urban morphology will advance the understanding of the causes and impacts of flooding in the urban residential areas of HCMC, and find out solutions for flooding adaptation of Ho Chi Minh City”

From the hypothesis, the main objective and strategic objectives as well as research questions were developed to conduct the research. The research scopes for the field and scientific research were also developed to identify the study area. Finally, the main structure of the study was summarized in chapters for the short introduction of the entire thesis.

## **2 URBAN MORPHOLOGY AND ITS ROLES IN URBAN PLANNING AND FLOODING ADAPTATION**

This chapter gives information about the relevant studies. The gathered data and information had been analyzed under five main aims: Urban morphology as an emerging interdisciplinary field, the key findings of urban morphology analysis, urban morphology on urban climate and flooding adaptation, urban morphology analysis, and fractal analysis in urban morphology processes.

### **2.1 Urban Morphology as an Emerging Interdisciplinary Field**

#### **2.1.1 Understanding about Urban Morphology**

The definition of Larkham (1991) about urban morphology is the study of the physical or built fabric of urban form, and the people and process shaping it. According to Kubin (1992), urban morphology is the functional relations and physical structure is both integrated within city structure. Batty (2001) had the clear definition, that morphology is the study of form and process, growth and form, form and function. Other definitions from Bengui et al. (2001), state that cities are physical objects for display of extreme variety of size and morphology.

The above definitions focus on the urban form and the changes of urban form and functions in the cities. There are definitions closely mentioned on physical geography of the urban. Urban form is known as urban morphology or landscape. It simply defined as the study of the physical characteristics of towns and cities resulting from an evolutionary process of urban activities and planning action (Gu, 2001).

Adolphe (2001a) said that urban morphology is state that performance of various urban forms referred to the interaction between urban morphology and climatic condition and laws covering the complexity of urban morphology. Urban morphology inquires forms and relations between causes and effects of the social forces within, while the urban form and structure consisted of various compositions of physical and spatial elements (Lynch & Rodwin, 1958).

#### **2.1.2 History of Urban Morphology**

The history of geographical urban morphology during the first half of the twentieth century, and its diverse research traditions, has been the subject of substantial inquiry (Slater, 1990a; Whitehand, 2005). Although much of this work has been concerned with urban morphogenetic tradition and the central role played in it by Conzen (1968). Howev-



er, they were less interested in conceptualizations of process than in description and classification.

The primary concern of urban morphology was the structure of urban form. Therefore, it may be defined as "Urban Morphology was concerned with plan and built form of the habitat, viewed and interpreted in terms of its origin, growth and function" (Dickinson, 1968).

The study of urban morphology is rooted in Evolutionary theory and borrowed from the zoological and biological sciences, which was sought to develop phylogenetic classifications to account for the interdependencies between different animal species form to generating process (Longley & Mesev, 2000).

Urban theory has variously considered densities of population and densities of economic activity across urban areas, to devise measures of efficiency of urban form in term such as transportation (Bengui et al., 1991), residential development, retail and industrial planning, and access to public open space (Longley et al., 2001).

Generally urban morphology is taken synonymous to urban land-use, urban landscape or townscape. In specific terms the urban morphology includes all the structural patterns, growth and related functional characteristics of an urban area. So, if an understanding of internal structure is essential to successful 'manipulation' of a material, urban morphology is essential to urbanism and urban design (Whitehand, 2005).

### **2.1.3 Urban Morphological Research as an Interdisciplinary Field**

Urban morphology has useful insights to offer to the various disciplines concerned with the formation of the built environment and it has used in many fields of urban study, such as urban planning, regional planning, urban design, urban geography, urban environment, urban buildings and architecture, etc. (Moudon, 1997; Samuels, 2000; Rashed et al., 2003; Larkham, 2006; Batistae Silva & Sá Marques, 2010). It not only focuses on the above urban study's disciplines, it but also studies on urban climate and climate adaptation (Adolphe, 2001b; Curdes, 2010).

In economic field, urban morphology researches on the economic patterns such as trade and commercial areas, markets, industrial and processing zones, etc. (Mesev et al., 1995; Longley & Mesev, 2000).

In social field, it has been studied on urban life, culture and heritage as well as the distribution of population groups (such as rich and poor groups in different areas) etc (Moudon, 1997; Satoh, 1997; Longley & Mesev, 2002; Vincente et al., 2006; Filicaia, 2007). And it should be prepared to do this even at the cost of a littler popularization of its message (Samuels, 2000).

On the other hand, urban morphology focuses on tangible results of social and economic forces. They shape on the ground and mould our cities. Buildings, gardens, streets, parks, and monuments are the main elements of urban morphological analysis. These elements, however, are considered as organisms which are constantly used and hence transformed through time. Build structures are shaping and being shaped by open space around them (Moudon, 1997).

## **2.2 The Key Findings of Urban Morphology Analysis**

### **2.2.1 Principles of Urban Morphology**

Urban morphology can be analyzed to understand through the medium of its physical form or urban form. And at its most elemental level, urban morphological analysis is based on three principles (Moudon, 1997; Conzen, 2001):

- There are three fundamental physical elements to define the urban form and city pattern: building footprints and their related open spaces, plots or blocks, and streets in its urban area.
- Urban form can be analyzed at different levels of resolutions. There are four commonly levels corresponding to the building/lot, the street/block, local scale, and the regional scale.
- The historically understanding of urban form can be analyzed only when its elements is directly changed the urban land-use and city pattern in urban morphology.

Therefore, the original level of a morphology analysis on which interest is based on three fundamentals components: form, resolution, and time:

- **Form:** It relates to the social, cultural, and economic factors, settlement habits, and historical development of the urban area. They all form the urban space and structure; locate the urban functions, as well as building typologies and residential densities on land-use types.
- **Resolution:** It relates to scales of the areas in analyzing urban morphology. The different scales can be regional, city/urban, and block levels. The resolution can be used to analyze the built-up densities of residential density and other urban functions at different scales.
- **Time:** It relates to the historical development of urban form and the transformation of spaces and places in urban area, such as the increase or decrease of open-space, or the increase or decrease of agriculture land in urban area.

### **2.2.2 The Roles in Urban Planning**

Urban planning, urban design, urban geography, and urban architecture, etc. are different research fields, though; they are in combination to the process of urban planning. The urban typography, nature landscapes, geography, astronomy, and geometry etc. have shaped the nature form of cities. However, social economic elements such as population, demography, and economic activities, etc. have transformed the cities and shaped the new forms and patterns (Longley & Mesev, 2002; and Timber, 2009). Concise explanations of the important findings of urban morphology in planning have been identified as follows:

Urban morphology focuses on concrete results of social and economic forces. It helps urban planning to shape on the ground and mold cities. Buildings, gardens, streets, parks, public works and monuments are the main elements of urban morphological analysis. These elements, however, are considered as organisms which are constantly used and hence transformed through time. Build structures are shaping and being shaped by open space around them (Moudon, 1997).

The changes of social and economic purposes have posed enormous new challenges to understanding of emergent urban morphologies and processes that underpin change. The better understanding of process requires better understanding of spatial morphology and form, and that this in turn must be founded upon better inventory measures of urban developments. The ‘better’ most obviously means more timely, detailed, relevant, and comprehensive. It also entails the creation of measures that are transferable across space and time (Mesev et al., 1995; Longley & Mesev, 2002).

In the cities’ development processes, urban morphology has analyzed and evaluated the dynamic changes of physical, social and economic elements which have transformed the urban form and new structures of urban patterns with inappropriate ways through the planning processes (Larkham, 2006; Caliskan, 2010). The population growth has often posed the increasing of housing and buildings, expanding residential areas, changing open spaces, and the growing of traffic. Fractal and urban morphology analyses helped to analyze the effect radiuses and zones and try to maintain the urban patterns as well as set the new appropriate structures for city’s stable development (Satoh, 1997; Ryan, 2006; Hern, 2008).

### **2.2.3 Role of Urban Morphology in Dynamic Megacities**

The disparity between rural and urban areas has pushed a wave of immigration to dynamic cities. There have been strong effects on the transformative processes of city-wide structure in these cities with urban sprawl out the rural and agricultural areas. The dynamics of social and economic activities have increased the urban functions and affected on the patterns’ changes (Satoh, 1997; Longley & Mesev, 2002; Rashed, 2005;

Ryan, 2006; Dias-Coelho, 2010). The trends of these changes are the increases of residential and housing areas, density of low- and high-rise buildings; the increasing patterns of commercials, retails, and industrial, etc. And these have strong effects on transformative processes of open spaces and green trees in urban areas (Choi, 2010; Srivanit & Kazunori, 2011). Then cities have changed their shapes and imbalance between housing and open spaces, plots or lots, and streets (Mesev et al., 1995; Moudon, 1997; Longley & Mesev, 2002). Urban morphology helps to show these transformations and remark for planning control and management (Longley & Mesev, 2002; Batistae Silva & Sá Marques, 2010; Caliskan, 2010).

The spatial change in city-wide structure has weakened the rural peripheral area in urban-rural linkage (Hainc, 2010). It has caused the transformation of rural-agriculture areas into urban- and peri-districts for residential and public areas (Hainc, 2010). However, the spatial changes are not only in widespread areas, but also occur within classes. They are vertical growth of buildings, increase in housing density, and decrease in open spaces; and are reflected by an aggregation of land cover and urban materials (Rashed et al., 2005; Vincente et al., 2006; Banik-Schweitzer, 2010). These changes without planning and controlling may encroach inappropriately the urban geography and landscape. And they may bring some negative impacts into the cities, and flooding or sediment is example. Fractal analysis in urban morphology can identify the dynamic changes between the linkage and the density distribution within this linkage to support the planning adjustment, population policies as well as social economic management (Bérubé and Jébrak, 1999).

The distribution or location and its trend of poor settlement or poor housing of the poor have been identified by urban morphology and fractal dimension in developed and developing big cities, such as in Metro-Manila of Philippines (Vincente et al., 2006) and in London Borough of Islington (Filicaia, 2007). The poor housing distribution has related to the poor condition of public patterns of commercial, transportation and infrastructure, and other urban services.

In cultural heritage as well, urban morphology can figure out the negative effects of modern transformative processes which impact on the space of cultural architecture and propose the schemes for new structures necessary to urban improvement as well as cultural conservation (Satoh, 1997).

## **2.3 Urban Morphology on Urban Climate and Flooding Adaptation**

### **2.3.1 Studies on Urban Climate**

Urban geography and urban landscape show the physical elements, such as geographical, geological, ecological, astronomical, and typological, etc., which shape the form of the city. Studies have also have evidence that city configuration is the result from the above physical characteristics and the social economic elements. And the variation of these elements has shaped the different urban fabrics (Adolphe, 2001b). Different land-use, land-use patterns, and urban fabrics have different the weather condition of the place. And the changes of urban land-use and fabrics would change the micro climate in urban area (Daneke & Oßenbrügge, 2010).

The different form and morphology has disparities of outdoor and indoor climates: wide range of dry air temperature, wind speed, the heat radiation exchanged with the sky volt, and the available natural lighting (Adolphe, 2001b; Langkamp et al., 2010). The changes in building patterns and densities have changed the outdoor temperature, increased the heat island, and decreased ventilation (Gill et al., 2007; Srivanit and Kazunori, 2011). The change of buildings (various typologies, high-rise and high density) could increase urban pollutants and affect on the ventilation of urban air (Weber et al., 2001; Hsie, 2008; Hee et al., 2010).

Therefore, understanding of urban morphology and its relation to urban climate would simulate this relation and adjust the urban climate (Adolphe<sup>5</sup>, 2001b; Hsie & Ward, 2006; Buttstädt et al., 2010; Daneke & Oßenbrügge, 2010; Curdes, 2010).

### **2.3.2 Using Urban Morphology for Flooding Adaptation**

As the Fourth Assessment of the Intergovernmental Panel on Climate Change (IPCC, 2007b) notes, urban area and the infrastructure they concentrate and the residential areas that are a key part of many such centers' economic bases are often capable of considerable adaptation from the direct and indirect impacts of flooding. All large urban areas have had to make very large 'adaptations' to environmental conditions, site characteristics, natural resources availability and environmental hazards to be able to function for instance, creating stable sites for building types, putting in place the urban function that all cities require, and controlling provision for flooding and surface run-off (Levina & Tirpak, 2006).

---

<sup>5</sup> Adolphe (2001b) researched on urban morphology to simulate the urban climate at micro-and intermediate scales for neighborhood in Blagnac, France.

Urbanization and dynamic development in urban areas have caused many changes on urban morphology and pushed the urban climate problems as mentioned in the above Sections of 2.2.3 and 2.3.1. Global climate change has brought more climate crisis on urban areas. Flooding is one of the big climate problems in big cities, especial cities in coastal areas and in developing countries. Beside of the high volume of water from heavy rains, the increasing of run-off water on the ground was result of built-up coverage increase and surface sealing, and related to infiltrated space decrease during the urban development (Handley & Carter, 2006; Handley, 2007; Friesecke et al., 2012). The transformative analyses of urban patterns by urban morphological analysis in the climate change situation can applied for flooding impact analysis, adaptation and mitigation (Genovese, 2006; Gill, 2006; Gill et al., 2007; Roggema, 2009).

Therefore, adapting urban flood considerations into urban morphology in HCMC is already an intricate decision-marking problem which expects the careful examination of the question, related to particular places and residential areas. Adaptation actions are more prevalent on the local level. These actions are measures aiming at reducing “unavoidable impacts of climate change in the short and medium terms” (Davoudi et al., 2009).

Urban morphology could plan flooding-related impacts out of urban expansion by obviating the sites most at risk and by ensuring that building types and residential areas for new developments can deal with extreme flooding (Roggema, 2009). Returning open spaces and green spaces occupied by urban sprawl and developing the new green spaces for increasing impermeable and infiltrated areas are the important solutions for flooding adaptation (Silander et al., 2006 & 2007; Handley & Carter, 2006; Handley, 2007; Gill, 2006; Gill et al., 2007; Roggema, 2009). The solution of increasing areas of lakes and ponds is to enhance the water storage for flooding mitigation in urban areas (Petroy et al., 2005; Silander et al., 2006 & 2007).

Urban morphological analysis in urban temperature in combination of temperature modeling could figure out the flooding adaptive solutions (Cavan, 2012). Some studies on urban morphology had suggested the new structure of building codes, flooding defences, and infrastructure for adaptation and mitigation (Kazmierczak & Kenng, 2011; and Friesecke et al., 2012). And green-infrastructure to infiltrate the run-off water of flooding in urban areas is one of examples (Gill, 2006; Gill et al., 2007; and Roggema, 2009).

Measuring urban morphology to flooding impacts has very large implications for the competence and capacity to support locally appropriate land-use for building types development and subdivision regulations; this improves building types conditions and greatly extends housing possibilities for new settlements (Roggema, 2009).

## **2.4 Urban Morphology Analysis**

### **2.4.1 Processes of Urban Morphological Analysis**

These concepts of urban morphology analyses are based on the definitions of urban morphology. The development of a better theory of urban land-use or growth and change is fundamentally premised upon clearer conception, better measurement and more appropriate analysis of urban phenomena (Longley et al., 2001). It helps to link the science viewpoint to analyze urban morphology in researches.

First, an urban pattern of homocentric surround with different land-use types and a central business district. It involves block, typology, urban form, and residential form, central business district. This concept has been related to large scale of urban morphology effects. They are referring the association between distribution of function areas and pattern of city level. The values can be more significant when they are used for the purpose of comparative analysis, such as different urban land-use patterns (Batty & Longley, 1994)

Secondly, most analyses of urban morphology have been performed with the relationship between size of location and form, relation between land-use blocks and physical structure. This pattern of urban morphology was modified by specific development along blocks density. Compared with residential areas, fringe belts have considerably larger average plot sizes, less hard surface and fewer road crossings: they are less permeable to traffic (Whitehand & Morton, 2003).

Finally, an uneven of urban patterns was formed by the complex functions of urban specialized land-use activities. According to Conzen (2001) geographical dimension of urban form includes the study of collectivities, ensembles, and grouping of material forms and their layout within and in relation to larger spatial framework of city.

Understanding the urban morphology by determining the development of urban areas can assist in understanding not only their historical development, but also their future. GIS and fractal analysis represent techniques to study urban morphology that go outside specified description. Fractal analysis combined with GIS is now an indispensable tool in the field of urban study. Their use is extremely useful in understanding the spatial distributions of the urban morphology. The next section will cover the detailed analysis of fractal from an analytical point of view.

### **2.4.2 Scales in Urban Morphological Analysis**

Cities have trends to become larger and modern in many countries (Satoh, 1997; Choi, 2010; Hee et al., 2010; Batistae Silva & Sá Marques, 2010; Srivanit & Kazunori, 2011). The dynamic development results the big changes (or disorder) of urban morphology

and urban fabrics in short time. The locations of households or human individuals should be keys to creation of data models of spatial distributions in urban areas. In GIS terms, humans are represented as mobile point referenced events and, as a medium to long term goal, their activity patterns (residence, but also work and leisure) should be represented (Longley & Mesev, 2002). Therefore, better spatial analysis in different scales and in large scales can identify and assess clearly the smaller transformation of cities (Longley & Mesev, 2002; Timm et al., 2003; Tannier & Puain, 2011).

Measures of surface reflectance characteristics have provided barely acceptable functional classifications of urban land cover, and stop well short of spatially detailed inventories of land-use, hence urban function (Longley & Mesev, 2002). Quantification and alleviation of scale and aggregation effects has preoccupied some research fields. However, spatial analyses in better scales could minimize the depressing and inevitable conclusion. And they must be analyzed upon such building blocks as are available (Longley & Mesev, 2002; and Timm et al., 2003).

Furthermore, the development of better theories of urban land-use or growth and change is fundamentally premised upon clearer conception, better measurement and more appropriate analysis of urban developments (Longley et al., 2001). And in the future, new methods will be quested to build better time-space models of density in urban systems (Longley & Mesev, 2002).

### **2.4.3 The Principles for Residential Density**

In urban morphology and fractal geometry analyses, most of the currently used measures for describing urban patterns are based on the notion of density (Longley and Mesev, 2002). To describe the density in urban morphology, it is necessary to introduce some concepts of density and identify the density measures for urban residential areas.

There are several measures of residential density depending on the scales of given areas (Forsyth, 2003; Hess et al., 2007; and Cardew, 1996). However, the density measures for the residential area excluding the non-local residential areas such as parks, schools, and open space, etc. are widely accepted in residential planning. The widely accepted measures for planning and managing the residential areas are site residential density (only the residential component of the land area) and net residential density (Landcom, 2011). In identifying the residential density in urban morphology map, density is usually calculated by dividing an overlapping (e.g. the built-up area of land-use) by the surface on which this overlapping is localized and which agrees as reference (e.g. the total area of the land-use).

In other aspect, to understand more about the residential density some important measures are identified, especially in urban residential area, such as: net residential density on land-use block, site residential density on land-use block, housing/building types



on land-use block, and residential population (including person and household size on land-use block, etc. (Forsyth, 2003). In which, the net density is used at the individual block level either as a measure of total building types per block or as a statistical evaluates of residential amount. This measure is basically used to analyze the floor-area-ratio (FAR), building-coverage-ratio (BCR) and population density per land-use block for this study. The aim of urban morphological analysis in this study is to identify the residential density based on the two indicators of number of building footprints and the land-use area per hectare. In this, the fractal geometry was applied to identify the density of building footprints on land-use block. From then the distribution of building density in different urban residential areas were analyzed and compared to flood impacts in the areas.

Ho Chi Minh City did not have the category of residential density. And specially, there was no previous research about residential density analysis on land-use block for this city. This category was also unclear in some developing countries to analyze urban density, while there were many researches with residential density analysis in high-, medium-, and low levels (Landcom, 2011; UN-Habitat, 2004). To analyze the distribution of residential density on urban morphology map for Ho Chi Minh City, this study applied the categories of residential density of Western Australian Planning Commission (2012). This category is likely to appropriate to the distribution of residential density in Ho Chi Minh City (Table 2.1)

Table 2.1: The Standard of Residential Density Ranges for the Study Area

Residential density category	Number of building footprints (per ha)
High residential density	> 50 building footprints per ha
Medium residential density	21-50 building footprints per ha
Low residential density	≤ 20 building footprints per ha

*Source: Department of Planning - Western Australian Planning Commission*

## 2.5 Fractal Analysis in Urban Morphology Processes

Mandelbrot (1977) defined that fractal is generic name for graphic forms, structures and phenomena that have no length characteristics. In that field of application, fractal can be related to important features of urban morphology just as easily as to the evolution of urban systems. Recently, analytical urban modeling has shown that planned and designed spatial objects such as urban morphology can also be treated as fractals (Batty & Longley, 1994; Frankhauser, 2000). It is considered that fractal geometry is one of the few concepts that are directly relevant to the problem of urban complexity (White &

Engelen, 1993). Actually, its formalization is compatible with many characteristics of the urban systems: self-similarity in clustering and fragmentation of spatial patterns at different scales, rank organization, complex of borders, and distributive density. Adolphe (2001a) has described urban pattern by measuring urban morphology indicators computed by MapInfo. Measurement of urban morphologies led to the invention of urban models which imitate urban areas and are able to consider the unreasonable developments of the urban spatial patterns.

The combination of GIS and fractal geometry, as well as massive increase of computational power available to research communities, are upgrading modes of urban morphology (Timm et al., 2003; Haghani & Larkham, 2010). It makes with mathematical targets which show properties of self-similarity and are useful for describing spatial forms which are not regular in the sense of Euclidean geometry. With the relationship between GIS and Remote Sensing data, fractal analysis is based on algorithmic program. And the study of urban morphology has been planned to make important changes to the approach (Batty & Kim, 1992). Although many of applications precede the use of digital data for morphology analysis, the range of quite different urban applications indicates that the corresponding digital database may need to be application specific, there are nevertheless many areas of urban analysis in which urban theory requires improves data for rich and defensible empirical application. Such consistency will enable comparative urban morphologies to be investigated across a range of scales: at the macro scale, entailing the comparison of the overall morphology of different settlements at the meso-scale, focusing upon the morphological make-up of different areas of single settlement; and at large scale, in which effect of individual activity patterns upon the make-up of urban areas might be investigated (Orford, 1999).

One further important effect of innovation of fractal geometry has been the beginning of space-filling 'norms' against which the density gradients of real-world cities can be compared. Mesev (1998) was found that the estimates of population and residential densities obtained from remote sensing sources are essentially 'first estimates', which may be further refined through the integration of socio-economic data sources into land-use algorithms. A range of urban data models are used to combine with integrated data sets which are usable in the measurement and classification of urban residential and the outlooks are hopeful for development of spatially extensive models of urban morphology.

According to Watt et al. (2003), possible adaptation measures for urban flooding are includes: pipe replacement (under a normal maintenance program); disconnect impervious areas (parking areas); increase surface storage (lakes and ponds); reduction in rate of tide rise input (reduce surcharge to sewer system); increase pond volume (availability of land); infiltration (depending on surface conditions). These problems concerning urban areas' flooding adaptation are considered the independent of current flood and ur-

ban morphology, it is easy to conceive of certain HCMC, larger urban centers and peri-districts face far more serious impacts than others; but it is also possible to envisage HCMC adaptation strategies that support urban development away from the area's most from flood related impacts.

## 2.6 Summary for Chapter Two

UM is the study of form and process, growth and form, form and function. It has useful insights to offer to the various disciplines concerned with the formation of the built environment. And it has used in many fields of urban study, such as urban planning, regional planning, urban design, urban geography, urban environment, urban buildings and architecture, etc. Furthermore, it not only focuses on the above urban study's disciplines, but it also studies on urban climate and climate adaptation. In flooding research, UM can identify the flooding impacts on urban function areas and find out the adaptive solutions for flooding problems. And the solutions will support to urban planning as well as flood control programs.

The methods for urban morphological analysis must be based on GIS (Geographic Information System) and RS (Remote Sensing) techniques and their tools. One special GIS tool in this process is fractal dimension or fractal geometry. The combinations of GIS and fractal geometry, as well as massive increase of computational power available to research communities, are upgrading modes of UM. It makes with mathematical targets which show properties of self-similarity and are useful for describing spatial forms. With the relationship between GIS and RS data, fractal analysis is based on algorithmic programs, and has been planned to make important changes to the approach.

One of successful achievement of urban morphological analysis or measure is to work at various scales of field areas, especially large scale such as block level. The locations of households or human individuals should be keys to creation of data models of spatial distributions in urban areas. Therefore, better spatial analysis in different scales and large scales can identify and determine clearly the smaller transformation of urban areas. Moreover, spatial analyses in better scales could minimize the depressing and inevitable conclusion. And they must be analyzed upon such building blocks as are available.

### **3 RESEARCH METHODOLOGY**

#### **3.1 Research Framework**

The research framework described the whole processes of study. It consisted of main methods, concepts, tools and data set applied for the whole research. All applied methods and tools were based on the urban morphology analysis processed and the necessary data for urban flooding evaluation. The technique tools using in the research are fractal geometry, RS and spatial analysis (of GIS). The flow chart in Figure 3.1 summarized three work packages and their relation in research. The results of previous package would be applied for the processes of following packages to find out results for the whole study.

Work package one started with data inputs of satellite images (Landsat and Ikonos images) for finalizing land-use and urban categories by the remote sensing technique. The images were interpreted to identify the types of land-use, buildings and categories of urban functions in HCMC. Land-use interpretation explained the spatial distribution of land categories of the city. From satellite images, the urban buildings were identified in spatial distribution and classified in various typologies. And urban categories, such as urban or rural, residential or non-residential, built-up or non-built-up areas were also interpreted from the images. All results in this package were the data inputs for work package two.

In work package two, data inputs from work package one combined with the statistic data of city population at commune level for the processes of urban morphology analysis. In this part, GIS techniques and fractal geometry were applied for finalizing the urban morphology map and urban function map of the city. The urban function map described the spatial distribution of urban function areas. And the urban morphology map described the density distribution of urban functions. Population data was integrated to evaluate the carrying capacity of urban functions (such as high- or low-density of residential areas, or high- or low-density of built-up areas, etc.). And the results of this part were input for identified flooding impacts of the city in work package three.

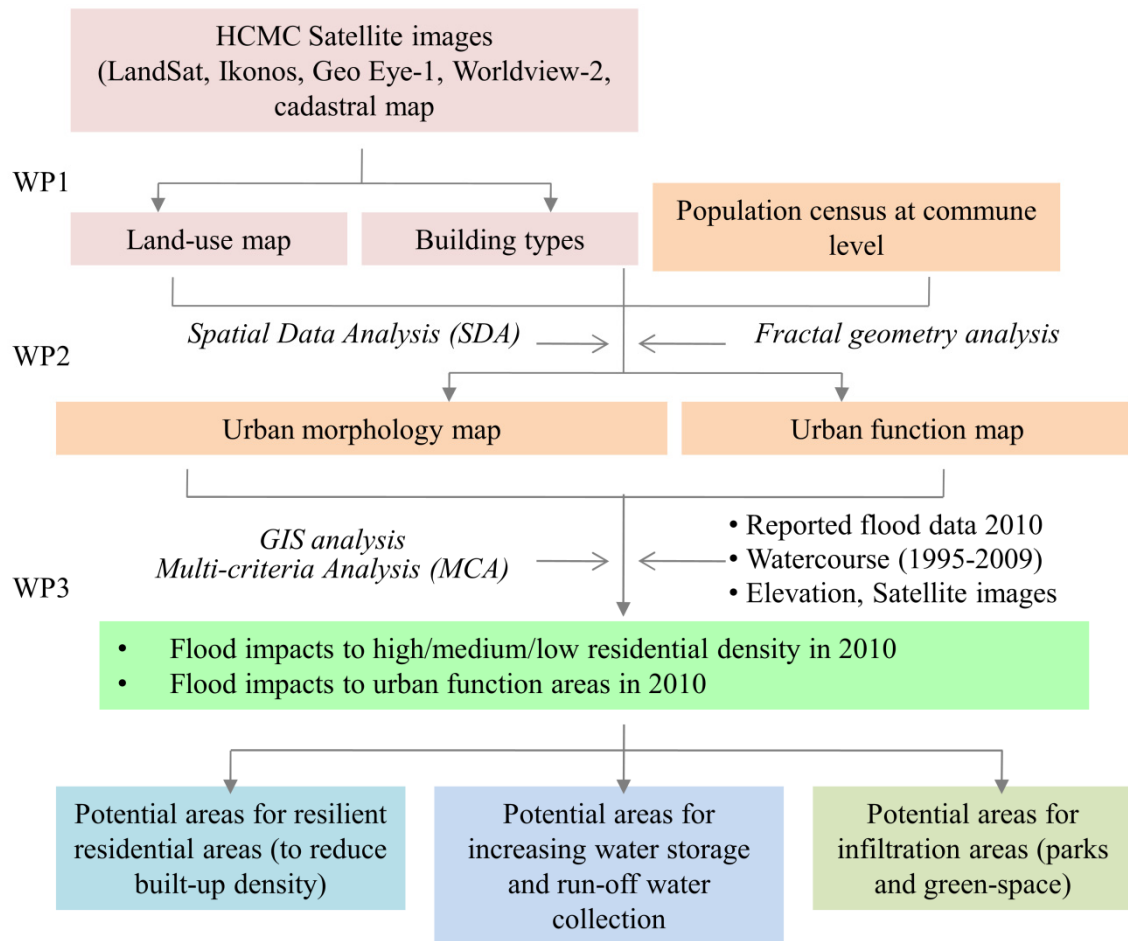


Figure 3.1: Flow Chart Approach

In work package three, the statistic flood data 2010 of the city was put in the base map to create flood map 2010. This flood map was overlaid with all-results layers from work package two to analyze the impacts of flooding on urban function areas. Based on these results, urban morphology map helped to find the flooding reasons, and from then, figure out the potential areas for flooding mitigation and adaptation in HCMC.

### 3.2 Data Preparation and Compilation

All data of Table 3.1 used for analysis is available and up-to-date. The study obtained most of the data from municipal statistics of HCMC Statistic Office (population census 2010). Land-use and primary map data were compiled using the Department of Resources and Environment (DoNRE in 1995, 2005 and 2010, scale: 1/2,000-1/25,000) and additional building topographic map (1/2,000) which were digitized on-screen. The number and type of land-use classes chosen in research correspond to the spatial scale of preparatory building types used in urban morphology map. Population data in the form of statistical available for each municipal commune in the city's annual census was disaggregated to the building types of the residential land-use cover in order to exactly determine where people live. For the analysis from urban morphology were con-

verted into a raster format using Arcview 3.2 with a grid cell size of  $1 \times 1$  m. Fractal geometry was settings based on Arcview by Avenue program for urban morphology tool. These criteria of flooding adaptation were either derived directly from the morphology map information or taken from the reported flood data of 2010.

Table 3.1: Maps and Data Sources Used for the Analysis of Research.

Cartography	Format	Scale	Projection	Date	Source
Elevation map	vector	1/2,000	UTM; WGS 84	2007	DoNRE
Base map	--	--	--	1995; 2009	--
Watercourse map	--	--	--	1995; 2009	--
Land-use 2005	--	1/25,000	--	2005	--
Land-use 2010	--	--	--	2010	--
Population census	statistical			2010	HCMC PSO
Reported flood data	statistical			2010	HCMC SCFC

In Table 3.2, satellite images were used to classify the buildings and land-use types. After inputting into the ENVI program, satellite images was initially registered and ortho-rectified with projection UTM Zone 48, WGS-84 coordinates. The ground control points (GCPs) from a digital terrain model (DTM) is used to generate the base maps at 1/2,000 scale. During preprocessing, the output pixel size was not changed and the nearest neighbor algorithm was used for intensity resampling. The resulting image produces an output product that can be effectively utilized at scales of 1/5,000-1/25,000.

Table 3.2: Satellite Imagery Used for the Classification of HCMC Land-use and Building Types

Satellite	Format	Band	Resolution (m)	Data of capture
Landsat ETM <sup>+</sup>	Raster	6	30	02/04/2010
Ikonos	--	3	1	16/01/1999
Ikonos	--	3	1	02/01/2010
GeoEye-1	--	3	0.5	27/03/2009
Worldview-2	--	3	0.5	24/04/2010

### **3.3 Study Area**

HCMC has 209,554.48 ha and includes a variety of land-use associated with a complex mix of land cover. The urbanized areas are located at the center of the scene. In these areas, residential use is often mixed with commercial, public, and sometimes “light” industrial uses within the same block. However, variations can easily be observed between: (a) affluent residential areas with ‘relatively’ lower density of population (11,773 people/km<sup>2</sup>); (b) less affluent residential areas in the old part of the city with higher density (26,528 people/km<sup>2</sup>); (c) the central business district (CBD) of the city; and (d) newly developed lands and informal settlements on the urban/rural.

Based on the interpretation of these satellite imageries, and supporting by field observation and secondary data, population of census communes and districts, census maps and survey of HCM maps, the growth of the city during 2005-2010 will be studied. HCMC could be divided into three geographical zones (urban districts, peri-districts, and rural), primarily on the basis of built-up area characteristics like land-use pattern, built-up density, population density and their functional characteristics like residential areas, commercial areas, green space, recreational areas, agriculture, industrial, etc.

The merging of remote sensing and GPS technologies goes far beyond the level of increasing fieldwork efficiency, enabling data integration directly in the field. Assess the accuracy of the urban morphology mapping. For example: built-up, residential, non-residential, detached, semi-detached, terraced, and apartment, etc.

### **3.4 Classification of Land-use and Building Types**

#### **3.4.1 Technical Approach for Land-use and Building Types Classification**

Landsat ETM+ image, high resolution images and buildings data were integrated for land-use classification in this research. The process was done with several stages of pre-classification, during classification, and post classification to precisely identify land-use.

Building information was extracted from the map data at block level, and building density was calculated by dividing building footprint units in block area. To combine buildings into Landsat ETM+ image, buildings data was converted to raster format. In this study, the centroids of blocks were identified with the aid of ArcGIS, and then Inverse-Distance-Weighting (IDW) interpolation was used to generate a building surface. The smooth and continuous building surface derived from the centroids of blocks using IDW enabled conversion of spatial data from irregular zonal units (blocks) into regular units (surface cells or pixels) that had a similar format as the ETM+ image (Goodchild et al., 1999). One important characteristic of this study was to preserve the total building

units (Mesev, 1998). In contrast, the rasterized building density was not continuous; cell values were the same within a block, but it preserved most of the original building density of the blocks. Both were integrated with the ETM+ image as extra layers by stacking them on Landsat ETM+ six bands for further classification.

A traditional supervised classification (specifically, the maximum-likelihood classifier) was used to classify the Landsat ETM+ image using its light-reflective bands. Before implementing image classification, selection of good-quality training samples was critical.

Maximum likelihood classification assumed that the statistics for each class in each band were normally distributed and calculates the probability that a given pixel belongs to a specific class.

Richards (1986) implemented the maximum likelihood classification by calculating the following discriminant functions for each pixel in the image:

$$g_i(x) = \ln p(\omega_i) - \frac{1}{2} \ln |\Sigma_i| - \frac{1}{2} (x - m_i)^t \Sigma_i^{-1} (x - m_i) \quad (1)$$

Where:

$i$  = class

$x$  = n-dimensional data (where  $n$  is the number of bands)

$p(\omega_i)$  = probability that class  $\omega_i$  occurs in the image and is assumed the same for all classes

$|\Sigma_i|$  = determinant of the covariance matrix of the data in class  $\omega_i$

$\Sigma_i^{-1}$  = its inverse matrix

$m_i$  = mean vector

Equation (1) was the first step of the whole urban morphological analysis process of this study and was applied for analyzing in work package one.

### 3.4.2 Land-use and Buildings Classification Process

In this research, building density, zoning data and high spatial-resolution satellite images were used to assist the identification of training samples of different urban land-use classes. The ETM+ image was classified initially into classes (i.e., industrial, water, urban residential, rural, bare soil, cropland, agriculture, and forest, etc.). These classes then were merged into classes by combining commercial, transportation, and industrial as urban (non-residential, residential) and combining crop and fallow as agricultural land. Figure 3.2 explained the classification processes for land-use and buildings in



HCMC. The Landsat, Ikonos, and high-resolution images were in the RS technique for geometric correction. They then were in the pre-processing process for filtering and enhancing the quality of images. The next step was to input images into the process of interpretation in combination with key sampling from field observations and land-use 2005. After this step, the interpreted images produced the land-use map 2010 and identified the urban categories at several levels: urban and rural areas; built-up and non-built-up in rural and urban areas; residential, non-residential, and other in built-up areas. At the residential level, and still in the RS technique, the buildings map 2005 was overlaid to high resolution images 2010 to interpret buildings categories of 2010 (such as Terraced, Detached, Semi-detached, and Apartment, etc.). The results of urban categories and buildings categories were input for fractal geometric analysis in work package two of this study.

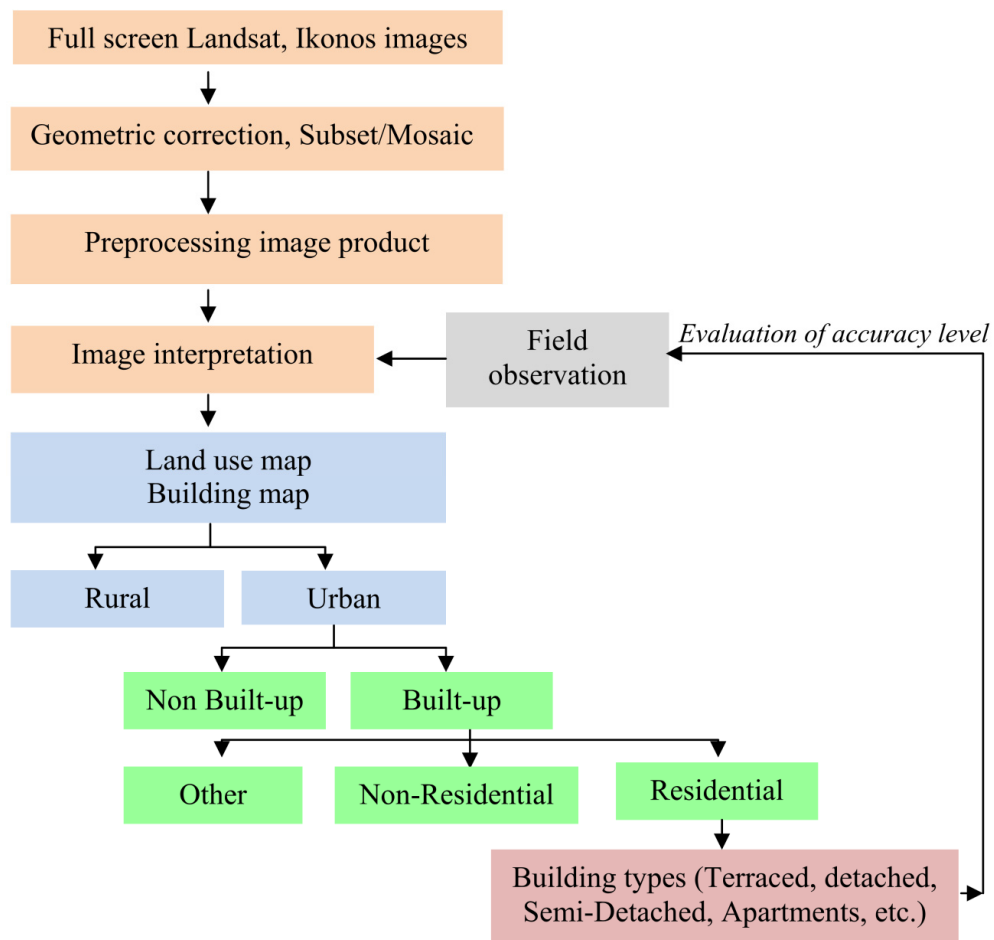


Figure 3.2: Hierarchical Segmentation for Urban Categories Classification

### 3.5 Fractal Geometry Analysis

Measuring the urban morphology based on the raster, vector data structure of a GIS to generate graphical output such as thematic maps (Pesaresi, et al., 2001). Especially,

large scale data and population census were used together for urban morphology detection. Overlay and variable analysis by using GIS technique help to identify the relationship between population and urban areas (Raford et al., 2003).

Therefore, the fractal geometry method was used to analyse the urban morphology to HCMC. The input data was the results of work package one included the land-use map and building types map. Base on fractal analyses, the residential densities of different scales could be counted. The residential density of land-use blocks provides information about the concentration of the number of building types per land-use block. Then the built-up coverage ratio was computed. These results were used to evaluate the development level and relate to flood impacts in the urban area of HCMC. Fractal geometry not only represents the average value of area of building types on every land-use block, but it also explains the relation between densities of building-type area on land-use block. They are actually the results of the complex overlapping of each type of building on each land-use block (block size). In the science of fractal geometry, Batty and Kim (1992) had analyzed the fractal geometry to identify the residential density on land-use block. Therefore, this study applied the Batty and Kim's fractal formula to identify residential densities to HCMC. The formula is the following:

$$N(R) = kr^D \quad (2)$$

Where:

$N(R)$  is the count of buildings of each building type overlapping the feature of block (per unit area of building types, in square meters)

$r$  is perimeter meters of land-use block

To analyze D values, the function of natural log (formula 3) was used to transfer the above formula 2 as follow:

$$D = \ln N(R) / \ln(r) \quad (3)$$

In this case  $\ln N(R)$  refers the density of each building type of land-use block, and  $\ln(r)$  is the size of land-use blocks (block of an observation). D is the fractal geometry.

With the formula 3, the fractal geometry "D" can measure a rate of the identity distribution of mean building count of a block as block density, and the constant k is 1.0 related to the mean connection of urban morphology map.

The value D is as the parameter to measure the identity of building types, residential density, and the values of built-up density on land-use block. When the D value is larger, the density on land-use block is larger as well as the identity of each building type (the same construction the number of building type on block). And D can explain the

level of block for the most complex, cumulation of the number of building types with plane-filling perimeters as well. The analysis results of fractal geometry of this study were categorized in three degrees of residential density based on the category on Table 2.1.

From the analysis results on urban morphology map, the value of building footprints density was integrated onto land-use block combined with population data to compute the population density on land-use block. Population values of land-use block were calculated from census data at the commune level. The general equation can be written as follows:

$$P_{bl} = P_{co} * U_{bl} / U_{co} \quad (4)$$

Where  $P_{bl}$  = population of land-use block;  $P_{co}$  = population communes;  $U_{bl}$  = residential areas of land-use blocks;  $U_{co}$  = total residential areas of commune.

To estimate the residential population densities of land-use block based on the result of equation 4, it can be calculated as follows:

$$P_{RD} = P_{bl} / U_R \quad (5)$$

Where:  $P_{RD}$  = residential population densities;  $U_R$  = areas of land-use block (housing or building footprints areas).

In other hand, to clarify more the urban density, the parameter of Building Coverage Ratio (BCR) and Floor Area Ratio (FAR) were applied in this study as the followings:

*Building Coverage Ratio (BCR)* - Area of ground floor footprint of building divided by land-use block. This measure indicates the amount of open space left on the block. (6)

*Floor Area Ratio (FAR)* - Built floor area on all floors divided by land-use block. (7)

Step (2) to step (7) of this part was in the second part of the whole urban morphological analysis process, and was applied for the first part of work package two of this study.

The analysis process from step (2) to step (7) in work package two of the study was summarily explained in Figure 3.3 below. In this process, the population data from population census, land-use, and building layers were input in the computer as the codes in the binary system (with 0 was unoccupied, and 1 was occupied). This binary system was presented in one matrix and was analyzed by fractal geometry for counting profiles. The results of this process were the density profiles of urban area for finalizing the urban morphology and urban function in the next steps in work package two.

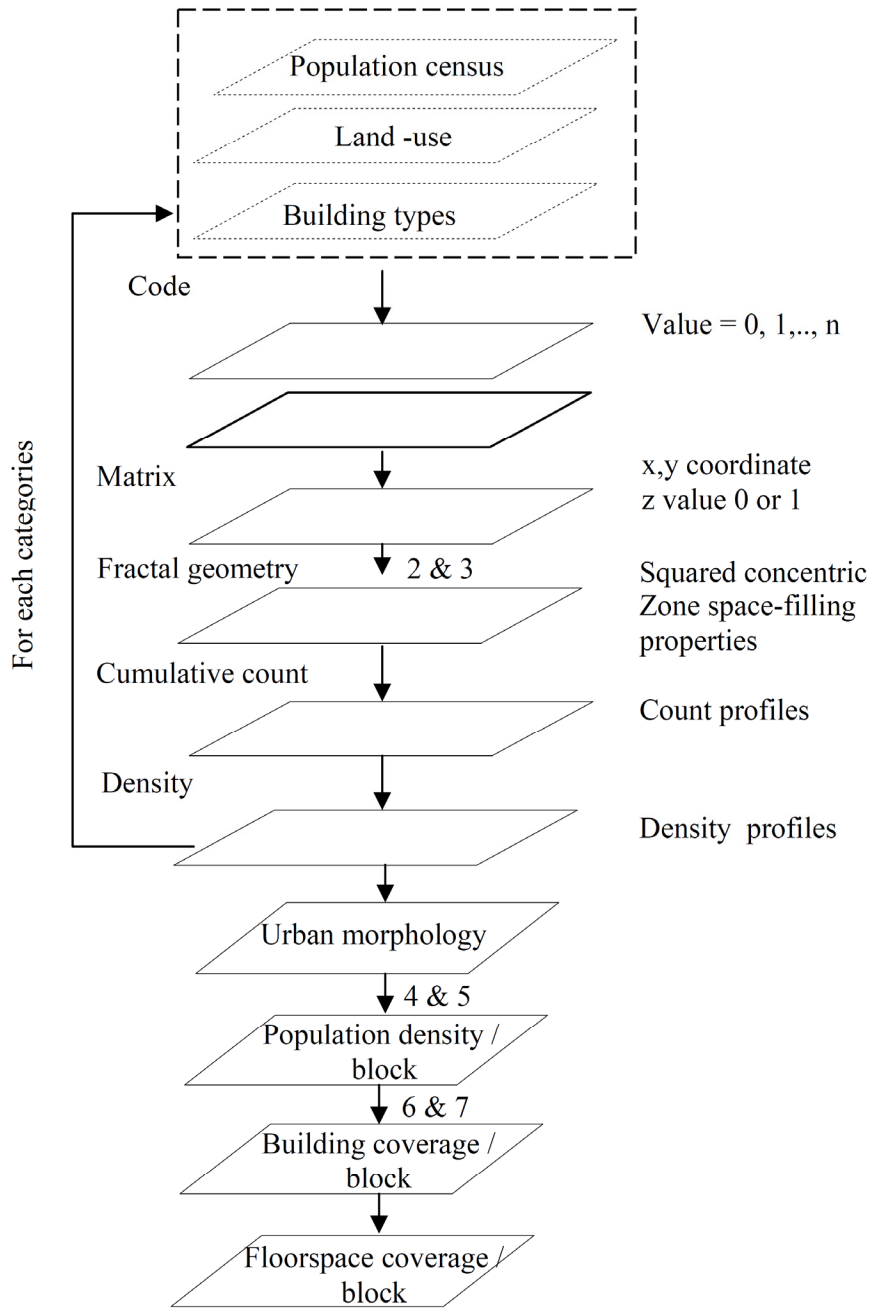


Figure 3.3: The Transfer of Classified Thematic Categories into Fractal Geometry Cumulative and Density Profiles

### 3.6 Urban Morphological Analysis

In case of urban analysis, the adoption of GIS has given the strong impression that the discipline embraces space in modeling. It notes that, however, the statistical models underlying urban analysis remain, for the most parts, a spatial missing (Landis & Zhang, 1998a-b). Thus, they sometimes ignore some important issues such as the failure of most conventional statistics to adequately summaries of location information, the lack of independence and inherent stickiness of spatial data (e.g. spatial association), the

differential effects in spatial processes, and the implications of shape and representation in spatial analysis (Griffith, 1988).

The solution to this spatial problem in GIS environment inevitably was based on the special character of spatial data (Anselin, 1995). This was called Spatial Data Analysis (SDA) (Burrough, 1986). This has two areas: statistical and computer base, that count the existence to the refinements of spatial data. In fact, several well-known GIS provide functions, modules, or macro languages that allow for modest analytical capabilities (such as ArcGis and Arcview).

However, spatial analysis is more difficult than it looks. It demands a good knowledge of the content of the databases. There are a variety of techniques that can make the performance of a spatial analysis easier. These techniques help the decision-maker to formulate the problem, create an appropriate model, and evaluate the results of the model. Decision-support tools can be used to assist in the urban morphology analysis; however they do not perform the analysis or make decisions themselves (Jones, 1997).

The most suitable and available technique to solve the above problems is the multi-criteria analysis (MCA) technique in GIS. This technique for important urban application is to calculate the change of an urban development that represents the exposure of different areas in maps. To estimate the exposure of the urban area, the alteration of the values of the different urban aspects (such as land-use, building footprints and openspace, etc.) caused through the changes in the urban morphology (e.g. building a new road) is measured.

MCA can also be used to support environmental or urban planning by making suitability maps for different land-use types. An impact assessment or a suitability analysis normally takes different criteria into account in order to analyze these complex questions and problems. The characteristic that makes MCA special is that it enables the decision-maker to assign different degrees of importance to the different factors.

Once the values are ranked on a scale, the different criteria need to be compared. This is done by an overlay of the different maps. The arithmetic manipulation of these different layers is a simple addition. Each criterion can have a different contribution to the solution, meaning that one criterion can be more important than another can. Therefore, the different criteria need to be assigned a numeric weight that indicates their relative importance (Eastman, 1999). The overlay operation on the different criteria then is expressed as follows:

$$S = \sum_{i=1}^n (W_i \times X_i) \quad (8)$$

$S$  = suitability index

$W_i$  = weight assigned to criterion  $i$

$X_i$  = factor score

Step (8) of this part was applied for the second part of work package two of this study. The measure of integration is one of the principal empirical measures used in the space syntactic characterization of urban morphology. Almost all locations in urban spatial land-use can be reached immediately from the strongly integrated places. It means that the integrated measure can answer how many locations in the urban areas are relatively strongly integrated and how many others are less integrated and probably belonging to the urban morphology (Hillier, 2002). Therefore, Multi Criteria Analysis (MCA) is used to define the most suitable areas for a certain land-use. When an area needs to be divided according to the most suitable locations for specific land-use and building types, the MCA technique was used to create suitability maps for the different land-use types and urban functions.

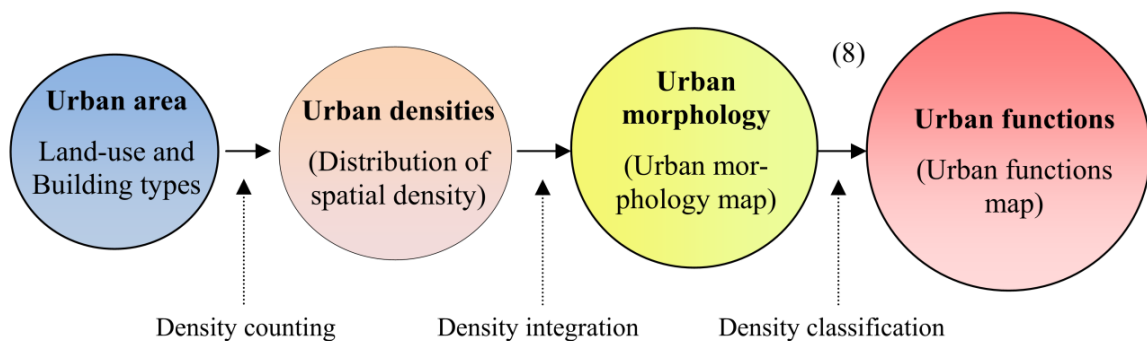


Figure 3.4: The Use of the MCA to Optimize Urban Functions

The MCA process for finalizing the urban functions was summarily described in Figure 3.4 above. The input data for this process was interpreted land-use and buildings in work package one of this study. These data layers were overlaid for counting the cumulative density. The MCA counted the spatial codes with the similar spatial characteristics. The similar density codes were integrated into groups. The spatial distributions of density data combined with the land-use types to finalize the urban morphology map. And then they were classified for urban functions to develop the urban function map. These maps were overlaid on flood map to identify flooding impacts on urban morphology and urban functions in work package three of this study.

### 3.7 Potential Areas Analysis for Flooding Adaptation

Adaptation to urban flooding refers to efforts for resilient city. The process was to finalize the flood-impact areas and find or suggest the solutions and potential areas to reduce floods such as: The solutions for urban function areas in the current flood; the potential areas for increasing the run-off water collection and evaporation; potential function areas for flooding adaptation in current flood level (Shaw et al., 2007). Based on the general criteria developed by The UNEP (1998) and IIED (2007) for flooding adaptation, the principles below were applied to adapt for urban flooding in HCMC:

- a. Adaptation to short-term flood variability and extreme events is included as a basis for reducing impact to longer-term of urban flooding;
- b. Adaptation potential and measures are assessed in a development context of urban; Land building diversions reduce losses and restore the sustainability of existing low lands; and
- c. Adaptation occurs at different levels of urban areas to reduce impacts of flooding in affected areas.

In this process, the informative layers on flooding impacts were overlaid. GIS for spatial interrogation and other participatory and quantitative assessments were used for analysis the target variables to locate potential (or negative) impact. These various overlays will assist in identifying hotspots where adaptation activities should be focused (Jones, 1997).

Once again, the MCA method was applied for this process. The major criteria for evaluating the operation of various methods were: data requirement, their linkage with GIS, and their interpretability. This allowed options to be evaluated using a range of criteria that included the analysis of unquantifiable factors, especially when distributional implications need to be considered. The purpose of using MCA was to support for the decision-making process for the most sensible way of setting a solution (Eastman, 1999). It was useful in assessing options for flooding adaptation as many factors need to be considered, including equity, efficiency, short- or long-term stabilizations as well as many other the relevant factors (Carter, 2007).

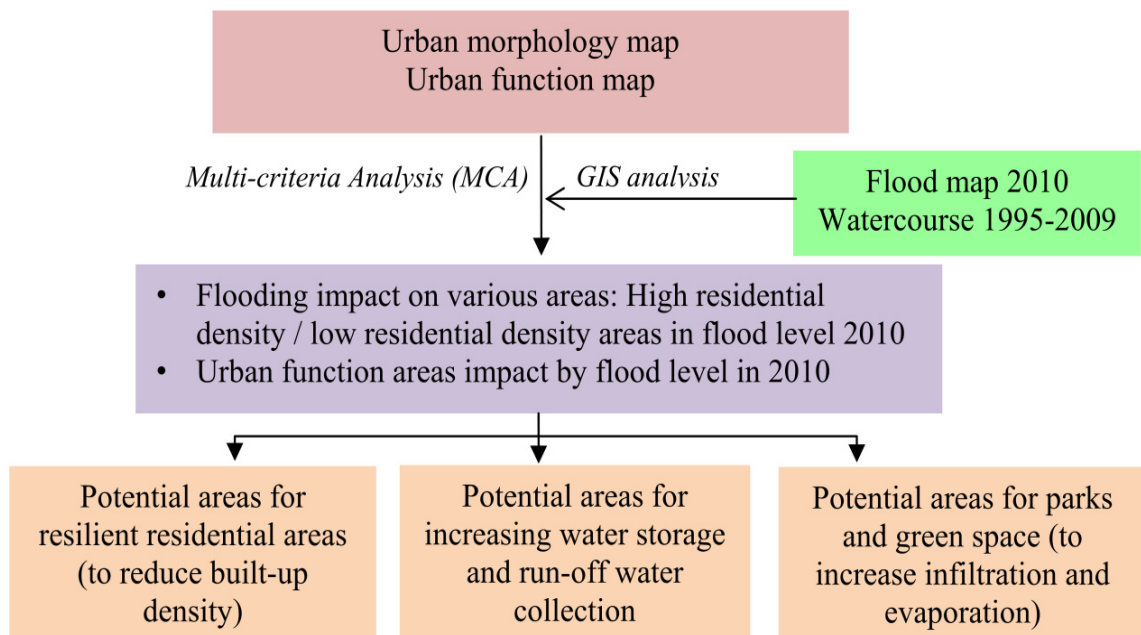


Figure 3.5: Flooding Adaptive Process to HCMC

The adaptive process of this study was summarized in Figure 3.5. It was the last part of work package three of this study. The morphological map provided a solid basis to evaluate particular flood impacts and identified the consequences of flood areas (Roggema, 2009). For every typology, the impacts and effects could get differently. Based on urban morphology's results and the particular impact analyses, different solutions for flooding adaptation were to decide on every part of urban areas in substance, arrangement in a rational way of building footprints, and the potential areas for increasing the run-off water collection and evaporation.

### 3.8 Summary for Chapter Three

Measuring urban morphology in this study required the entry of GIS (Geographical Information System) and RS (Remote Sensing) techniques and their tools. RS technique was used to pre-process and interpret satellite images for land-use and buildings (urban categories). The results of land-use and buildings were used for fractal geometric analysis and Multi-Criteria-Analysis (MCA) for urban morphological analysis on land-use and urban function maps. All of these results were inputs for analyzing flooding impacts and flooding adaptation for HCMC.

By using RS, the Landsat images, Ikonos images, and high-resolution images of HCMC were used in the process (in work package one). RS and high-resolution images were in the finalizing process for building categories (such as Terraced, Detached, Semi-detached, and Apartment, etc.). In combination to population census data, the GIS technique was used to finalize urban morphology map and urban function map (in work



package two). In this process, several algorithms were applied in GIS to conduct the results, such as counting the similar characteristics of spatial data for integrate density distribution; finalizing the urban functions (including: urban and rural or peripheral areas; built-up and non-built-up areas; residential and non-residential areas), and figuring out the flood impacts on urban functions for flooding adaptation (in work package three).

And during the study processes, many other primary and secondary data were used to support the analysis processes as well as to clarify the results. Such as: the taken photos and notes from field observation for classifying and integrating building categories and urban functions; referent documents, reports, and photos, etc. were used for analyzing flooding impacts and suggesting the adaptive solutions. The results in this study can be the references for further urban planning and flood control programs in HCMC.

## **4 URBAN DEVELOPMENT AND FLOODING PROBLEMS IN HO CHI MINH CITY**

The development process in HCMC has brought many changes on urban surface, land-use and landscape, and urban functions. The demand for development sometime causes disorders and problems in the city. In the context of climate change, lack or loose in urban planning and management had caused more problems of flooding in HCMC.

### **4.1 Dynamic Development and Land-use Change**

#### **4.1.1 Urban Expansion and Disorder of Urban Function Areas**

HCMC has the highest urbanization rate in Vietnam with more than 80% of urban people, while other cities have the average rate only 40%. Because it is the biggest city with the important center of economics, finance, science, and education of Vietnam, people want to come here for working, studying, and living. It has attracted many rural immigrants from rural areas and neighbor provinces. Therefore the immigration rate in this city was higher than the natural growth rate in last more than ten years (Trinh & Nguyen, 2001; Le, 2005; DoPA, 2010). In 2011, the immigration rate was two times higher than the natural growth rate (PSO, 2012)<sup>6</sup>. The increase of population has led the growing of housing and urban services.

There is the increasing of housing area and urban service in this city. The center has been expanded for more urban services. In 1976, the center was in District 1, but now it invades in four districts (VNPM, 2010). The housing area must move out to other districts and sub-districts. Up to now, the size of the city is two times and a half larger than in 1975 (Vu, 2010). In developmental history, City has many times sprawled out to rural areas. Recently, many sub-urban, rural agricultural, as well as non-urban areas have been used for new-urban sectors (Vu, 2010; VNPM, 2010). Some of them are planned by city government; most of them are spontaneously expanded. It has caused disorder in housing structure and rapid increasing the built-up area.

In developing process, HCMC had expanded and occupied suburban areas several times to have more districts and sub-districts (Ho, 2007; Luong, 2008). The expansion was mostly for residential areas. The basic infrastructure (as drainage and transportation systems) and urban services (as water and power supplies) as well as urban function

---

<sup>6</sup> According to HCMC Statistic Office (2012), the net-emigration rate in 2011 was 1.9% and the natural growth rate was 0.9%.

areas (such as administrative and commercial centers, markets, hospitals, education, parks and green trees, etc.) were provisioned for people in these areas.

Since housing demand increased, many houses were built in unplanned areas of sub-urban. Because of the loosing in urban management, there has been mass encroachment on rivers and canals, lakes and ponds in inner districts; low and agricultural lands in rural areas for housing with low condition of infrastructure since 1986<sup>7</sup>. Many squatters were raised in urban center and slums along rivers and canals. City government had to raise big fund for many housing programs and resettlement projects in 2000s (HCMC Cadastry and Housing Land Department. 2001a, b&c).

Urban planning run after economic development has ignored the planning of social welfare, such as green trees, parks and open spaces. Many agriculture lands were replaced for industrial and processing zones, and for residential areas. Most of them are in flood-prone of low land and water storage areas of the city. Low capacity of local planning did not take into account the flood risk and skip the water infiltration and water storage in district planning (DoNRE, 2013). Rapid urbanization, in other aspects, has caused the rapid decrease of green areas (DoT, 2010). The green tree area has the important role in receiving and evaporating the run-off water in urban area. Its decline pushes the climate change and flooding increasing in the city.

#### **4.1.2 The Urban-Peripheral Linkage and Land-use Change**

In the economic-trend-city, rural area has a weak role in the urban-peripheral relation. The big disparity of infrastructure and job opportunities between urban and rural areas attracted more labors from rural to urban area (Le, 2005; Trinh, 2008; Vu, 2010; DoPA, 2010). The city developing strategies oriented industrialization and modernization has occupied agricultural and rural lands for industrial and processing zones for economic development. The industrial process without environmental protection caused the strong pollution on water resource and low quality of irrigative water for agriculture (Vo, 2009). It resulted in low agricultural production and strong transfer from rural land to industrial and residential areas. Since housing development programs in 2000<sup>8</sup>, many big residential projects were developed in sub-urban and in low-land areas. The Phu My Hung project was one example with more than seven hundred hectares in low-land area of the Southeast of HCMC, the main water storage area of the city. This project had filled up many tributaries of Nha Be River in this area.

Along with the new urban areas in sub-urban, many high-rise buildings projects in urban center for offices and residential were replaced for squatter and slum areas. Some

---

<sup>7</sup> Since 1986, the 'Doi Moi' Policy Reform for open-economic development in HCMC, the labor attraction had increased the housing boom and high demand on urban infrastructure and services in HCMC

<sup>8</sup> HCMC Cadastry and Housing Land Department. 2001a and b

were for commercial and service areas. Instead of reducing population in the center, these projects brought new people to the new residential buildings in centers. The resettled people go into the center everyday for working and cause more traffic problems. The high-rise buildings in the center increased more built-up coverage and invaded open space, parks and green-tree areas (DoT, 2010). This is the big reason for flooding problem in the urban center (Luong, 2008; Ho, 2008). Furthermore, high buildings in city center and along the rivers had broken the city view and landscape (DoPA, 2010), prevented the air flows into the center, and caused higher temperature to the city (Luong, 2008).

In recent years, the phenomena of sprawling on the buffer area and the run-off water gates of the city become popular, such as the Phu My Hung new urban in District 7 (750 ha)<sup>9</sup>, the Hiep Phuong new urban in Nha Be Sub-district (3,000 ha) (DoPA, 2010). Most of these areas are in the low-land and can receive, store, and evaporate large amount of run-off water for the city. The disappearance of these areas has caused the accumulation of run-off water on the ground surface when heavy rains come; or when letting water out from the water reservoirs; etc. and resulted in the flooding in the city.

Table 4.1: Land-use Change of HCMC (2000 – 2010)

Criterion	2000 (*)		2005 (**)		2010 (**)	
	(ha)	(%)	(ha)	(%)	(ha)	(%)
Agricultural land (1)	130,719.9	62.4	123,517.0	58.9	118,051.9	56.3
- Agriculture	91,139.2	69.7	77,954.9	63.1	72,143.3	61.1
- Forestation	33,472.2	25.6	33,857.9	27.4	34,116.5	28.8
- Aquaculture	4,149.3	3.2	9,767.31	7.9	9,441.2	8.0
- Salt marsh	1,959.2	1.5	1,469.09	1.2	1,943.30	1.7
- Other agricultural land			467.8	0.4	407.6	0.4
Non-agricultural land (2)	74,367.4	35.5	83,773.8	39.9	90,867.6	43.4
- Residential land	16,685.6	22.45	20,614.3	24.5	23,666.2	26.0
- Public land	19,601.7	26.45	28,534.9	34.1	32,973.9	36.3
- Religious land			400.3	0.5	410.4	0.5
- Cemetery	997.9	1.3	924.6	1.1	951.0	1.04
- Rivers and lakes	36,163.2	48.6	33,156.40	39.6	32,812.5	36.1
- Other non-agricultural land	919.0	1.2	143.3	0.2	53.6	0.06
Unused land (3)	4,414.5	2.1	2,263.7	1.2	635.4	0.30
Total land (1+2+3)	209,501.8	100.0	209,554.5	100.0	209,554.9	100.0

Source: (\*) DoNRE (2000) cited from HIDS (2010); (\*\*) DoNRE (2013)

<sup>9</sup> The information is on Phu My Hung website: <http://www.phumyhung.com.vn>

Table 4.1 above showed the land-use change in 2000 to 2010 in HCMC. In the table, the areas of agriculture, rivers and lakes, and unused land were strongly reduced for increasing of residential and public lands. The public land was much increased (about 13,372 hectares) in ten years for infrastructure, industrial and processing areas, etc. There was a very strong change of unused land in this period with 85.6% of transfer for developing. The breadth wise development of the city has used the land resources ineffectively and lost the reserved land for future development. It causes disorder of city landscapes and affects urban morphology as well as increases the flood risk of the city.

#### **4.1.3 Flooding Problems of Land-use in HCMC**

Urban development has decreased infiltration and causes localized flooding. There is mounting evidence that the heat island effect is changing the city's climate and that urbanization has contributed significantly to increasing temperature, rainfall, and flooding over the last two decades. Land subsidence has also been observed at a number of locations and there is evidence to suggest that it is increasing. Increased land subsidence will make HCMC more sensitive to flooding (ADB, 2010).

The typography of city is sloping gently to the Southeast and down to the Sea of Bien Dong. Most of city is located under the 1.5m altitude (Ho, 2007; Nguyen & Duong, 2007; Trinh, 2008). At present, some areas in the city had been highly flooded at the 1.3m to 1.5m above-mean-sea-level in the rainy season. Therefore if the 1.5m flood would come, it would impact most of the urban centers and urban function areas of the city (Ho, 2007).

The Asian Development Bank (2010) had searched between 1997 and 2000, that almost all of districts of HCMC were directly affected by natural disasters. Most of the damage was concentrated in the vulnerable rural districts of Can Gio and Nha Be, toward the mouth of the Dong Nai River. With the 1.5m above-mean-sea-level flood, more centers and urban function areas of districts and sub-districts would be flooded.

Because of population growth and high demand of economic development, the expansion moves forward to the Southeast area of city with many important public areas such as industrial and processing zones, compact technical and residential as well as tourism areas, etc. Lately, Vietnam's Prime Minister had approved the new regional planning for HCMC and the Southeast area of Vietnam with the expansion of HCMC out to the neighbor Provinces to have new satellites (VNPM, 2012). With the widthwise development as mentioned above in Section 4.1.2 and the development trend down to the low-land areas of Southeast city (Trinh, 2008), city is in the high risk of flooding and even the solutions for adaptation would be more difficult.

## **4.2 Mass Occupation of Urban Built-up Coverage and Flooding Problems**

The dynamic development with disordered urban function areas in HCMC has brought problems with landscape and architecture, more flooding and risk of micro climate change. The expansion of built-up coverage would reduce the infiltration surface and may invade the water storage in low-land areas of the city.

### **4.2.1 Expanding Residential Areas and Various Housing Typologies**

When the housing policy promulgated for housing development in 2000s, many housing and housing projects were constructed to meet the housing demand in HCMC (HCMC Cadastry and Housing Land Department, 2001 a&b; Vu, 2010). With the above high housing need, city government has agreed to develop 900 housing projects with 7,500 ha. In the near future, some new urban areas will be finished with at least 10,000 hectares (DoPA, 2010).

The uncontrolled development in this period resulted in the breadth wise expanding of residential areas with various housing typologies. And they were mixed together in the same land-use block. Without urban design, high-rise houses and buildings are with low-rise houses in disordered architecture of the same area (DoPA, 2010).

The housing projects upgraded from the squatters and slums in center districts were normally constructed high-rise buildings for more people living in. Though the squatters and slums were disappeared, these new buildings were intermixed with the current houses like the patches in urban fabric and they made unsightly landscapes in the urban center. This disordered landscape has come again in many new urban areas in sub-urban- and peri-districts. The high-building residential areas in peri-districts would hide the center and decline the city viewpoints (DoPA, 2010). The expansion of housing increased built-up areas. High density of soil-ceiling had decreased the evaporation and infiltration of ground surface.

### **4.2.2 Growing Built-up Coverage and Flooding Expansion**

Table 4.1 in Section 4.1.2 highlighted the expansion of built-up areas of housing residential and public areas in last decade. It meant that the evaporated and infiltrated areas of green and open spaces were reduced. The soil-ceiling of built-up coverage caused the increase of heat radiation and city temperature in urban center (Luong, 2008). The low infiltration of urban surface kept the run-off water longer in the ground surface and caused flooding more serious.

Another important reason of raising the built-up coverage in urban center is the land price in urban center much is higher than in sub-urban areas. It resulted in the occupa-

tion of public areas, filling up of rivers and canals, lakes and ponds, parks and green trees for housing building. This led the strong reduction of water storage and permeable areas for solving the flooding problem in urban area. Urban development with loosing urban planning and management had resulted in the inadequate infrastructure and living condition to people in HCMC.

### **4.3 Inadequate Urban Infrastructure and Services in Flooding Context of HCMC**

HCMC had several times of expansion in the past as mentioned in Section 4.1.1 above. Many residential and urban function areas were developed. However, the city infrastructure and urban services are still insufficient and they are not comprehensively planned throughout the time. The urban center planned before 1975 now is inadequate and overloaded, such as the drainage system, electricity and water supply, etc. The infrastructure system in new urban areas of sub-urban and peri-districts is even incomplete. And they are reasonable reasons of flooding increase in HCMC.

#### **4.3.1 Overloaded and Narrowing of Natural Drainage**

The water drainage system in HCMC consists of natural drainage of rivers and canals, and constructed drainage pipes in residential areas. It was not long-time upgraded and rebuilt to carry the amount of wastewater of the growing population. It has now a new mission of collecting and storing flood water of the city. Understanding the current problems of drainage system would have the proper solutions for future planning and flooding adaptation to HCMC.

The city is located in the basin of Dong Nai and Saigon river system. These two rivers are merged at Cat Lai confluence into Nha Be River situated in the Southeast of HCMC. This widespread system covers almost all districts and sub-districts of the city. This system receives and adjusts water from the upstream of Dong Nai River and pours down into the two estuaries of Long Tau and Soai Rap, the two largest run-off water gates of the city. These gates are also heavily impacted by the tidal flows, salinity, storms, and sea level each year (SCFC, 2010)

This river system for many years has the important role of receiving the rain water and drainage water of the city. There are five canals and ditches in this system being a main nature drainage system to receive waste water from the second drainage system of the

city and all rain water of the area<sup>10</sup>. The dense network of rivers/canals in the study area involves five following main river systems:

- Tan Hoa - Lo Gom canal
- Tau Hu - Kenh Te - Ben Nghe canal
- Ben Nghe canal
- Nhieu Loc - Thi Nghe Canal
- Tham Luong - Ben Cat river - Vam Thuat canal

The length of the main streams and branches of these river systems are 55.6 kilometers and 56.4 kilometers, respectively. The density of the stream is about 4m/ha. These river systems are responsible for drainage and are wastewater-receiving sources of HCMC. They are highly influenced by tide.

The river system is effected by three opposite driving forces: (1) the upstream driving force of water adjust from the water reservoirs; (2) the tidal flow and sea level from Bien Dong Sea; and (3) the rain water. The water levels in the large rivers are strong affected by the first two driving forces, while the smaller rivers are mostly affected by the local rains. The increase of rain volume and rain intensity have caused the high run-off water when these rivers' widths and depths are being remarkable narrowed. This will have the "domino effect" to all drainage systems.

By times, these canals and ditches have been narrowed and accumulated with sludge and sediment. These result in the decrease of their drainage capacity (Le, 2009). According to the HCMC Steering Center of Flooding Control Program (SCFC), there are about 121 rivers and ditches with 226 kilometers length need to be dredged their beds for drainage work. However, there are just only 7 rivers and ditches that are dredged and 29 of them are planned to be dredged. Others still receive sludge and sediment, though they are the important drainage outlets and store the rain water when tidal flows. Even in the main natural drainage rivers of Nhieu Loc - Thi Nghe, Tham Luong, and Tau Hu - Ben Nghe, which have been planned for cleaning in many years, they just have been partly dredged.

The exceeding of the river system has occurred. It creates more the high flooding points in the center. One considerable reason which causes the narrow of rivers is the filling-up of houses on the river banks during urbanization. In 2006 there were 182 places on this system filled-up by housing; most of them are in new districts and sub-districts (To,

---

<sup>10</sup> According to the HCMC Company of Urban Drainage System (1995), the canals and ditches of the river network are categorized to be the first drainage system to receive all waste water and rain water of the city and then pour into the big rivers' mouths. The second, third, and fourth drainage systems are made from bricks and cement or from iron with slow down sizes to receive rain water and all waste water from households and other urban sectors for the first drainage system.



2008)<sup>11</sup>. The filled-up rivers and canals for housing are still increasing in center districts and peri-districts of HCMC. This has caused flooding even in the dry season when the tidal flow come (ADB, 2010).

In the first years of 2000s, the city government has implemented the four big upgrading projects on four main drainage canals. However, these projects are not finished yet up to now. During the implementing, they require to close many drainage outlets (SCES, 2010). This contributes to increase flooding over the past ten years.

#### **4.3.2 Carrying Capacity of Constructed Drainage System**

The city drainage system was built in different stages and conditions. The drainage area which has a main role in collecting run-off water of the city is concentrated in District 1 and 5 and has been built since 1954. The main material was brick. From 1954 to 1975 it has expanded to the surrounding districts (currently, the central districts). The main material for this stage was iron pipe. After 1975, this system has been developed in other districts and sub-districts. However, in this stage, this part of system was built unsystematically, especially from the households to the main network, depended on the expansion of the housing area in the urbanization process. According to Department of Transportation (2008), very little area in sub-districts has drainage system. And the city drainage system has just connected to only 60% of city population (SCFC, 2010).

For many years, the parts of system built before 1975 was ruined and damaged. The city government has just built for new housing area, but not any activities for repair or rebuilding in the ruined drainage parts. Furthermore, this system has received bulky rubbish after the rains without removing for many years. The dredge to remove these trash-es has just been concerned in recent years when flooding becomes serious. However, this activity is not totally implemented. And the upgrading on the damaged drainage has already been done in a very small part.

In 2001-2010 HCMC has rebuilt many parts of drainage system along the streets, where flooding was serious. To do this, the drainage lines here were built in higher level than the old system along with the higher streets. The aim of these projects is to ensure the transportation totally safe under the heavy rains. However, these higher-level drainage parts led the stronger flood in where the drainage lines are in lower level and cause more flooding areas in city. Most of the lower areas are housing. These projects not only reduce flooding, but they also cause the flooding increasing.

According to HCMC SCFC, the surveyed positions of flooding in the city showed that, most of the flooded places were in the high altitude areas of above 2 meter. These were

---

<sup>11</sup> To(2008). Drainages in Ho Chi Minh City. Retrieved June 15, 2013 from <http://www.vncold.vn/Web/Content.aspx?distid=136>.

about three-fourths of total surveyed positions. Only one-fourths of them were in 1.5 meter or lower altitude. Flooding in the high altitude may have some reasons: they are in the lowland area, lower than the surround areas; or the drainage system in there was not capable to collect all run-off water in these areas. The over-carrying capacity of the drainage system can be caused by the followings: the partly or totally damage of the drainage; the long-time sedimentation of waste in the drainage; and the technical mistakes of the drainage (Ho, 2008).

One other important reason, the lack of urban management results in the encroachment of public land in this city is more popular. Many households built their houses on the city drainage lines and outlets. This causes the drainage dredging or upgrading more difficult.

## **4.4 Flooding Hazard and Demand for Urban Natural Resource Protection**

### **4.4.1 The Infiltration and Evaporation with Flooding of HCMC**

Evaporation in HCMC may be affected by some factors: temperature, moisture, green space, etc. In comparison with the mean temperature of Mekong Delta, the HCMC's temperature has remarkable change with  $0.02^{\circ}\text{C}$  increasing per year. However this value was dramatically increased in recent years along with the climate change features. It was  $0.5^{\circ}\text{C}$  or  $0.03^{\circ}\text{C}$  in 1991 to 2005 (Luong, 2008; SIHYMETE, 2008; 2011).

The moisture, however, is indifferent. When the Mekong Delta's moisture is increasing, the city moisture is decreasing, about 0.081% per year. The climate change has also affected on this feature and made it faster decrease, about 3.2% per year in the period of 1991 to 2005. With the high temperature above, steam cannot move up higher and make the evaporation process become more difficult (Luong, 2008). In flooding situation of HCMC, low evaporation capacity would keep run-off water longer and bring more flooding hazard on the ground surface.

Green space in the city has many important functions. They can keep the run-off water and evaporate it. In developing process, green space density is not enough for city population (DoT, 2010). Even when the urbanization rapid increased, green space was encroached and replaced for housing development. Urbanization also resulted in the increase of built-up areas. It has raised highly impermeable surfaces and restrains the evaporation (Luong, 2008; Ho, 2008; 2010).

After 1986, the built-up areas has rapid increased in HCMC. The research in 1989-2002 proved the velocity of built-up area was 1.84% per year. The HCMC statistic data on

construction area showed its velocity in 1997 to 2004 was 3.63% per year (Luong, 2008). This results in the compelled shortcut of green space, the sealed zones increase, and other sealed construction materials, etc. The slow-down of evaporation leads the rising-up of temperature and causes the micro climate change in the city. In flooding time, when more heavy rains and high tide come, the decrease of evaporation and infiltration will cause the increase of flooding in HCMC.

#### **4.4.2 Resilient Land and Water Resources in Flooding Context of HCMC**

Flooding in monsoon regime would visit many areas of HCMC one or two times a day. Low evaporation and longer time of flooding would leave waste and sediment on the ground surface. It would pollute land surface and living environment.

High density of built-up coverage in urban areas and the encroachment of infiltration areas such as green parks and green trees, and unused land had prevented the supplement of ground water resource. It would lead the water insufficiency for future water supply. The pollute land surface by waste and sediment would bring the pollution to the ground water resource. And on the other hand, the insufficiency of ground water may cause the land subsidence an impact on urban land resource (Jha et al., 2011).

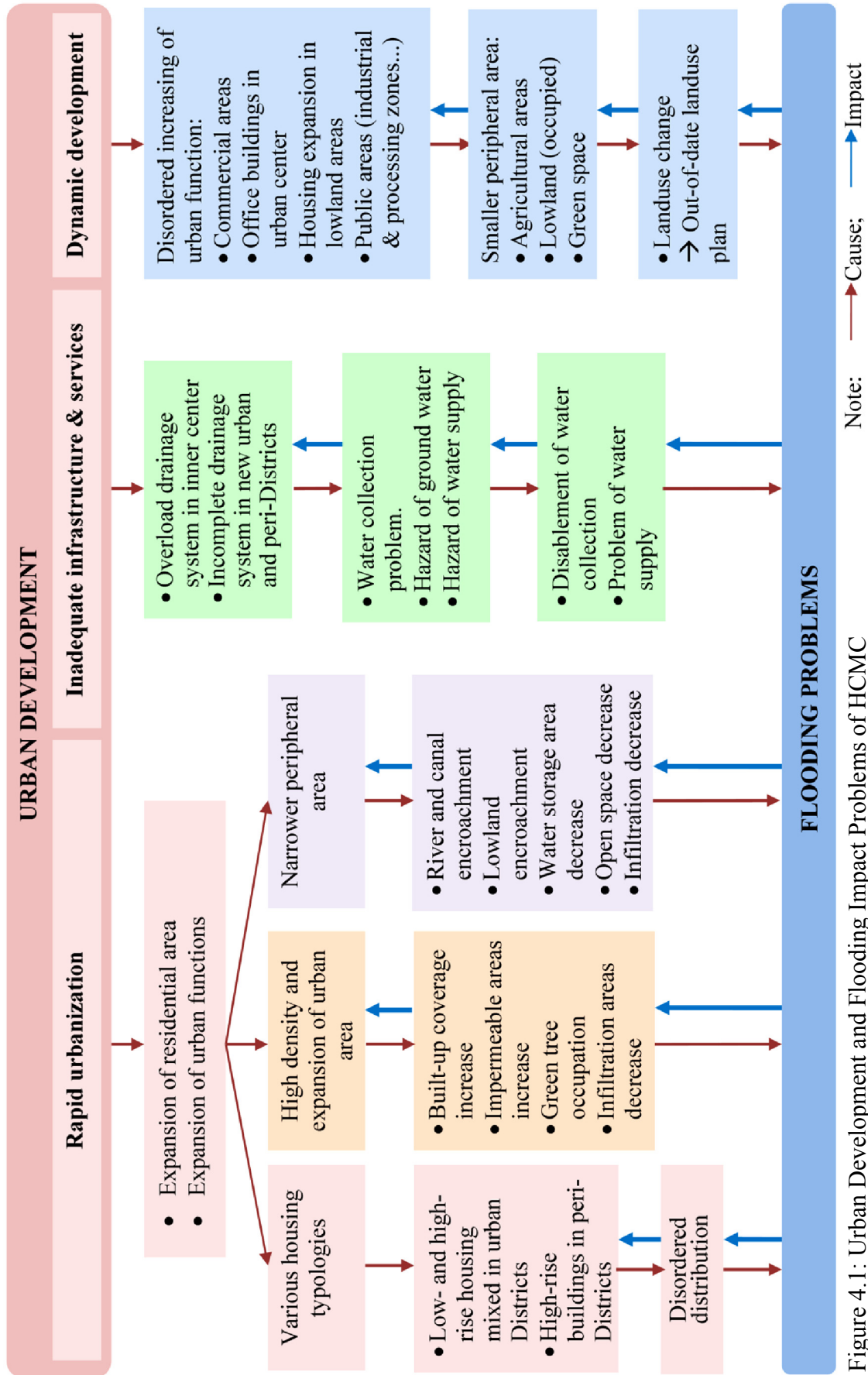


Figure 4.1: Urban Developed and Flooding Impact Problems of HCMC

(Source: Framework developed for Chapter Four of this thesis)

## 4.5 Summary for Chapter Four

A large city such as HCMC with high opportunities of economic developing, working and education, etc. has attracted more people and increased the demands of residential areas, urban function and services. Rural and agricultural areas were invaded for new residential and public areas. Loosing in urban planning and management caused the breadth wise expansion of the city and land-use changes. They also led the raising of various types of housing without urban design in the old center as well as in new urban areas of sub-urban and peri-districts.

The old and new housing buildings, low- and high-rise housing mixed together as the patches in the urban fabrics caused disorder in urban landscapes and effect on urban morphology. The invasion on rural and agricultural land led the smaller role of peripheral area in the peri-urban linkage and the lost of reversed land for future development. The trend of urban expansion moves forward to the city's Southeast areas, the big low-land areas for water storage of the city. Many tributaries of rivers and canals, natural lakes and ponds, parks and green trees were even occupied for developing demands. These have reduced the infiltration and permeability in urban areas and water storage areas for flood control.

Because of urban expansion down to the low-land areas of city, many new important urban functions are in the flood prone areas. Either in the center, high density of built-up coverage has increased the impermeable surface and reduced the infiltration as well as evaporation areas for adjusting large amount of run-off water of flooding. Furthermore, the overload of infrastructure in the old center; and the incomplete infrastructure in new urban areas caused flooding more serious in HCMC. Flooding in HCMC not only causes many problems on land-use, urban morphology and social economic aspects, it also brings problems on protecting urban land and water resources.

## **5 SATELLITE IMAGES INTERPRETATION FOR LAND-USE AND BUILDINGS IN 2010 IN HO CHI MINH CITY**

### **5.1 Why Landsat and High-Resolution Images Were Interpreted for Land-use and Buildings in HCMC?**

Development of Remote Sensing (RS) technology and Geographic Information System (GIS) altered the method for studying urban morphology. Remote sensing satellite imagery represents an important source of information for urban analysis (Jensen and Cowen, 1999; Donnay et al., 2001). This chapter aimed to interpret land-use and buildings for HCMC by using urban remote sensing combined to scale-sensitive measures. It also showed the important roles of GIS and RS technologies in classifying the city land-use and building types through interpreting Landsat ETM<sup>+</sup> (Thematic Mapper) and high resolution images with different methods. Until now, urban remote sensing is still the best method to objects' classification as the last product of data modeling. However, it needs to have the appropriate spatial analytical methods to measure the spatial morphology of land-use and building classifications.

HCMC is the appropriate case to apply RS and GIS technologies as tools for analyzing urban morphology based on land-use. This process produced the urban morphology map to assess flooding impacts on city areas. Urban morphology maps also help to figure out the solutions for flooding adaptation in different areas of HCMC. Application of RS and GIS to urban morphology is the new approach to urban study, especially in flooding adaptation, in HCMC.

Scientifically, the urban remote sensing technique is available to extract the urban information from the high resolution images and the prospective techniques such as: GeoEye-1, Worldview-2 and Ikonos images. As the geospatial feature extraction for topographic mapping, Baltasvias et al. (2001a) and Fraser et al. (2002) presented their results on building extraction from Ikonos digital images. One of the most extensively-used applications of remote sensing technology in urban morphologies focused on characterization, identification, classification and quantification of urban construction materials, shape and structure.

Many urban studies have started automatic solutions for urban land-use classification based on digital imagery, but there are many approaches that remain unsolved, such as image understanding and shape recognition. Therefore visual interpretation is still a reliable solution and is applied in this study for the creation of land-use/buildings map,

especially when high resolution image, the land-use and building in 2005-2010 are used together for change detection (Martin, 1989). Overlay and variable analysis by using GIS technique was showed the relationship between land-use change and building foot-prints change in 2005-2010.

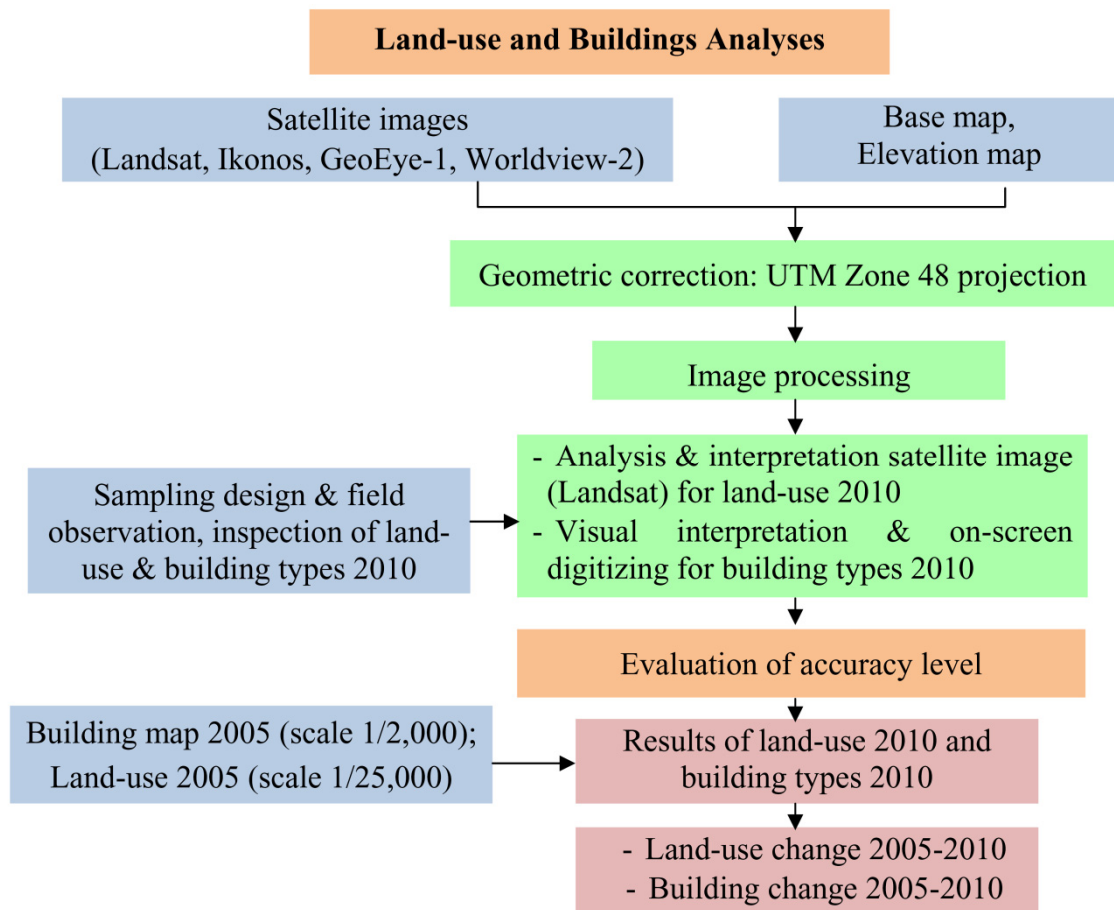


Figure 5.1: The Methodological Framework for Land-use and Buildings Analyses

Therefore, the methodological steps for land-use and buildings analyses were described in Figure 5.1. This methodological process needed data collection from both primary and secondary sources. The primary data included the city's satellite images (Landsat and Ikonos) and high-resolution images (GeoEye-1 and Worldview-2), sampling design collected from field observation, and the inspection of city land-use and building maps of 2005. The main secondary data were the city topographic and thematic maps. The satellite images of year 2010 were with the topographic map, base maps in the geometric correction process for UTM Zone 48 projection. After geometric correction, these images were in the processing step for clearer images. Then the clearer Landsat image was input to analyze and interpret for land-use 2010. And the clearer Ikonos and high-resolution images were input for visual interpretation and on-screen digitizing to finalize the building layer 2010. Then the sampling design, field observation, land-use and

building maps of year 2010 were integrated into land-use and building layers of 2010 to evaluate the accuracy of interpreted processes. After that, the building map 2005 (scale 1/2,000) and land-use map 2005 (scale 1/25,000) were overlaid with land-use and buildings layers 2010 to establish land-use and building maps of year 2010. Again, the land-use and building maps 2010 were compared to land-use and building maps 2005 for developing land-use change map and building change maps of 2005-2010. These maps were used for the next steps of urban morphological analysis, spatial pattern analysis for UM map and urban function map in the next Chapter Six and for flooding analysis in Chapter Seven of this study.

## **5.2 Mapping of Land-use 2010**

### **5.2.1 Data Input for Satellite Images Processing**

RS is very important technique for UM researching. The Landsat EMT+, GeoEye-1, Ikonos and Worldview-2 images (illustrated in Figure 5.2 below) were signaled in the best seasons for HCMC, from January to April. The building map, base map and land-use map of 2005 were created by the HCMC Department of Natural Resources and Environment (DoNRE) through the support of various districts, communes and considerable fieldwork. The images were geo-referenced to a UTM (WGS 84-zone 48N) coordinate system, requiring the total of 27 ground control points that produced a root mean square (RMS) error of less than 0.5 pixels.

During pre-processing, the output pixel size was reduced to 15m and a nearest neighbor algorithm was used for intensity resembling. The resulting image produces an output product that could be effectively utilized at scales of 1/5,000-1/25,000. This could be the best accuracy for this research. Secondary sources included cadastral map, elevation map, and base map.



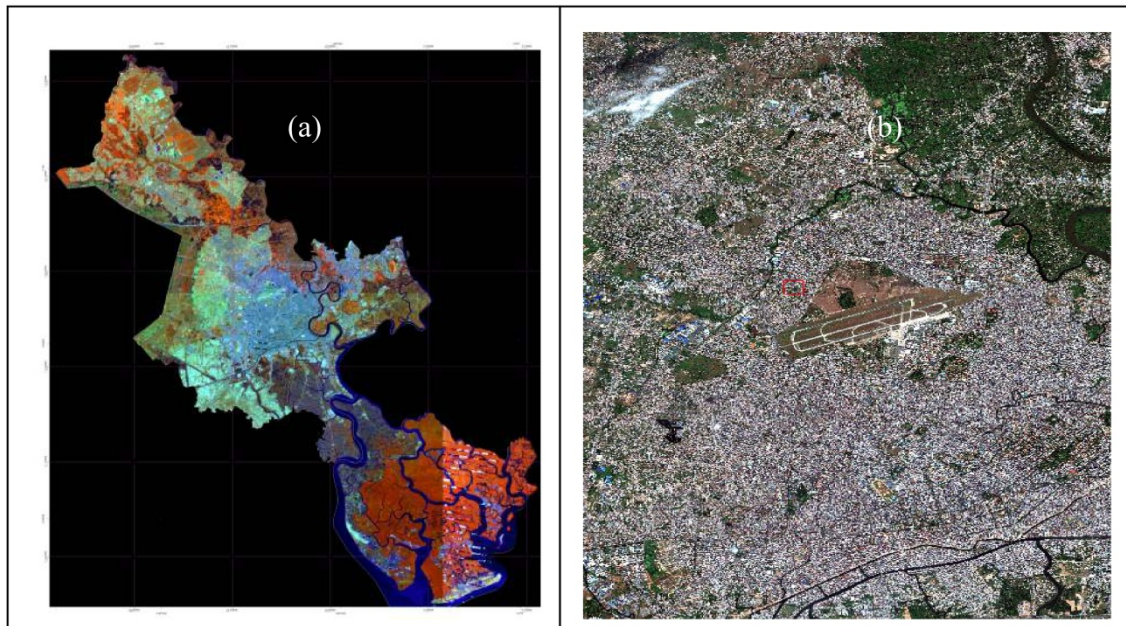


Figure 5.2: The Landsat EMT+ (image a), and GeoEye-1 images (image b) (2010)

### 5.2.2 Interpretation of Landsat ETM<sup>+</sup> Images for Land-use Mapping

For certain type of urban land-use categories, utilizing spectral information from Landsat ETM+ image 2010 was necessary to identify the principal objects of urban. In this research, the Maximum Likelihood Classification (MLC) algorithm (Equation 1) was used to classify urban land-use, which ensured classification accuracy requirement, while saving significantly processing time. The powers of MLC algorithm was evaluated based on their classification accuracies measured by Kappa coefficient (Cohen, 1960).

The key samplings were identified during site survey period by GPS, combined to the GeoEye-1 and land-use map 2005, covering initially 13 land-use types (urban residential, rural residential, public office, industry, production and business, rice, crop, grass, forest, aquaculture, bare soil, salt, water) (see Table 5.1 below). The ground truth image was made from screen digitizing the satellite image. This was less than optimal approach, though; the digitizing was performed independently from training areas by a well trained person that was not involved in the classification.

The averages of key sampling for each class were selected in about 15 points. A window size of 4x4 pixels was identified to extract the classification value for each key. This classification layer was generated using a conventional approach. For Landsat ETM<sup>+</sup>, six bands of spectral data were selected because they provided complementary information (Martin, 1989). The red visible band exhibited low noise and provided good delineation of non-vegetated surfaces while the two infrared bands allowed for good discrimination among vegetation classes. Each cluster was labeled by visually compar-

ing the spatial distribution of its member pixels with ground reference data and assigning a label matching to the estimated prevalent thematic class.

Table 5.1: Key Sampling for Each Class of Land-use Types

Class	Land-use types	Description
1	Urban residential	Flats and houses, located as blocks of housing
2	Public office	High density built-up, high buildings
3	Industry	Medium density, manufactories with unique design, height, size, and located in net blocks
4	Rural residential	Medium and low density residential, mixed with green trees
5	Business	High density (1-4 floors), mixed with residential areas
6	Rice	In rural areas, distribution as rice fields
7	Crop	In rural areas, distribution as vegetable-rows fields
8	Grass	In suburban area, distribution as green space with no border
9	Forest	Forests or mangrove in sub-districts of Cu Chi, Binh Chanh, Nha Be, and Can Gio.
10	Aquaculture	Aqua-ponds with borders in sub-districts of Can Gio, Nha Be, and Cu Chi.
11	Bare soil	Blank land with scattered grasses
12	Salt	Salt fields in coastal Can Gio
13	Watercourse	Rivers and canals system and ponds

*(Source: The result processing of Landsat image 2010)*

In case of HCMC, the maximum likelihood classification algorithm was applied to classify separate image into thirteen layers, clumping a classified image and a distance image. Maximum likelihood classification assumed that the statistics for each class in each band were normally distributed and calculated by the probability that a given pixel belongs to a specific class. ENVI software implements maximum likelihood classification by calculating the following discriminate functions for each pixel in the Landsat ETM+ image. Kernels or image windows containing specific spatially distributed combinations of classified pixels have been suggested as a way to infer urban land-use (Barnsley & Barr, 1996).

### 5.2.3 The Accuracy Evaluation for Land-use 2010

Table 5.2 presented the confusion matrix (Mather, 2004) for the results of an accuracy assessment based on classification results with different channels and a digitized ground truth image. For a statistic comparison, the classified image was masked with administrative borders. The accuracy of the ground truth image was found to be sufficient due to numerous ground truth samples, GeoEye-1 and photographs taken in the area on the April 2011 field trip.

Before using the classification results for change detection, this result assessed their validity by testing the results against ground truth data. Error matrices were used to assess classification accuracy and results were summarized in Table 5.2. The overall (average) training class accuracy for land-use 2010 achieved by the MLC classification was 93.99%, with Kappa statistics of 93.44%. User's and producer's accuracies of individual classes were consistently high, ranging from 53%, to 100%. Rice, crop, grass, forest, aquaculture, bare soil, salt, and water classes were all characterized by the highest classification accuracy. This was because the integration of the results of visual interpretation and supervised classification, which allowed the study to correct the misclassified pixels. Overall Accuracy = 93.99%; Kappa coefficient = 93.44%

Table 5.2: Land-use Classification Accuracy, Confusion Matrix and Kappa Constant

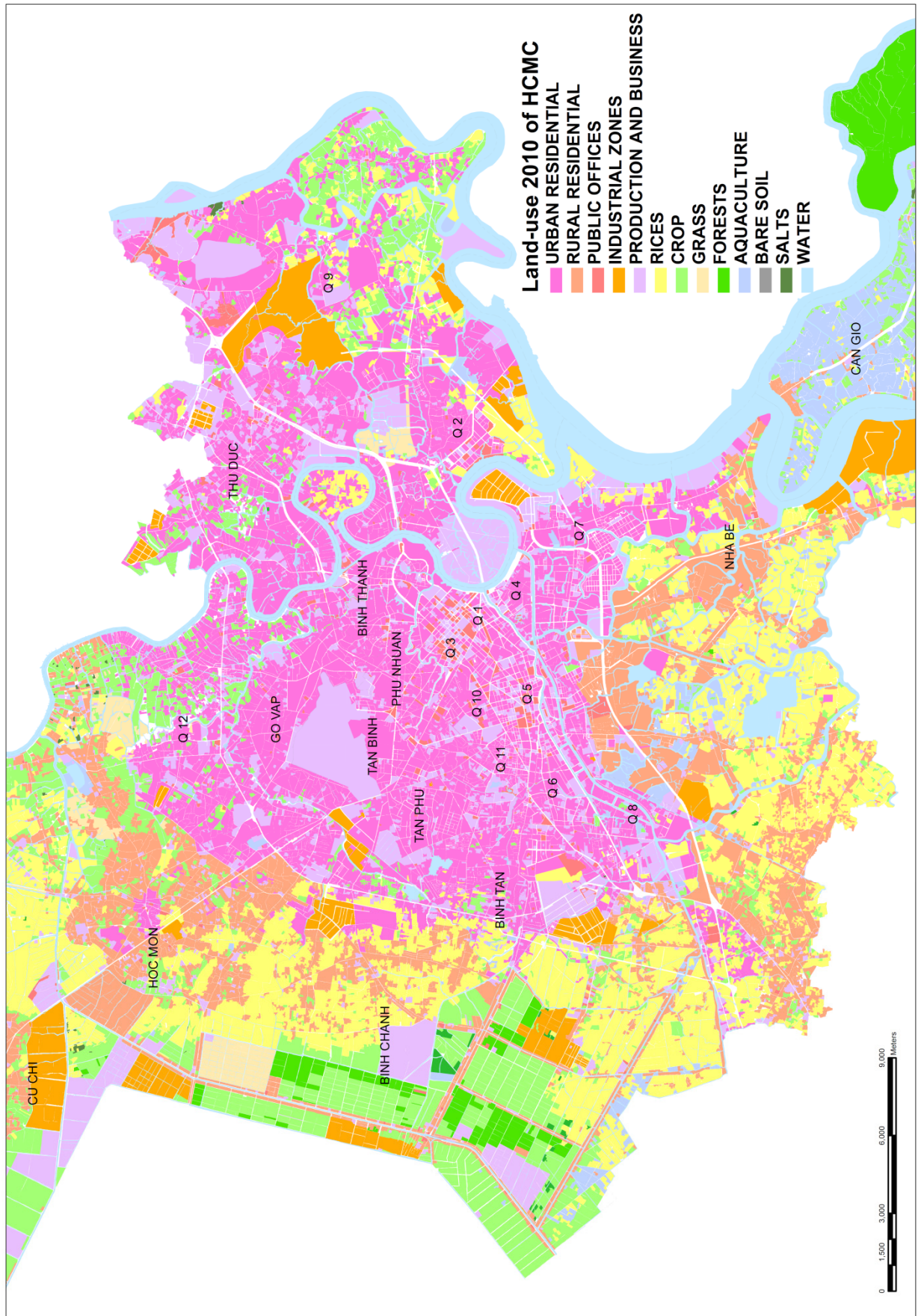
		Ground references													User's	Kappa		
Data classification	Class	1	2	3	4	5	6	7	8	9	10	11	12	13	Total	Accuracy	coefficient	
	1	65	2	0	0	0	0	0	0	0	0	0	0	0	0	72	97.0	0.97
	2	12	59	4	0	0	0	0	0	0	0	0	0	0	74	78.7	0.78	
	3	0	5	55	3	0	0	0	0	0	0	0	0	0	68	87.3	0.86	
	4	0	2	9	14	1	0	0	0	0	0	0	0	0	20	53.8	0.53	
	5	0	2	1	1	15	0	0	0	0	0	0	0	0	16	78.9	0.78	
	6	0	0	0	0	0	65	0	0	0	0	0	0	0	65	100	1.00	
	7	0	0	0	0	0	0	40	0	0	0	0	0	0	40	100	1.00	
	8	0	0	0	0	0	0	0	47	0	0	0	0	0	47	100	1.00	
	9	0	0	0	0	0	0	0	0	62	0	0	0	0	62	100	1.00	
	10	0	0	0	0	0	0	0	0	0	64	0	0	0	64	100	1.00	
	11	0	0	0	0	0	0	0	0	0	0	63	0	0	63	100	1.00	
	12	0	0	0	0	0	0	0	0	0	0	0	48	0	48	100	1.00	
	13	0	0	0	0	0	0	0	0	0	0	0	0	60	60	100	1.00	
	Total	77	70	69	18	16	65	40	47	62	64	63	48	60	699			
Producer's Accuracy	84.4	84.3	79.7	77.8	93.8	100	100	100	100	100	100	100	100					

(Source: data analysis from land-use classification accuracy, confusion matrix and Kappa constant of Landsat image 2010)

#### **5.2.4 Interpretation Results of Land-use 2010**

The classification results had figured out 13 land-use types identified in Map 5.1 in the next page. In which, the built-up areas included the areas of urban residential, rural residential, industrial, business and production, and public; the non-built-up areas included the areas of rice, crop, grass, forest, aquaculture, bare soil, salt, and watercourse. The total areas of these land-use types were described in the following Table 5.3. Map 5.1 showed the widespread distribution of urban residential areas and public area among them. This large distribution of urban residential areas had increased the sealing surface of built-up coverage and decreased the greenspaces and openspaces in urban areas. And this was one of reasons caused the micro climate change and flooding increase in HCMC (Luong, 2008; Ho, 2010).

Map 5.1 also demonstrated the non-built-up areas distributed in peri and rural areas mixed with areas of industrial zones, production and business, agriculture and aquaculture, etc. Especially, the Map indicated the industrial areas and production and business areas had tended to occupy the rural and agriculture areas. From these trends, the rural residential areas have increased, and the agriculture areas have been decreased. The built-up areas increased in peri and rural areas, mostly in lowland areas, was the reason for increasing the flooded and flood-prone areas in HCMC.



Map 5.1: Interpretation Result of Land-use 2010 of HCMC  
 (Source: Classification from Landsat image 2010)



### 5.2.5 Land-use Change 2005-2010

The data in Table 5.3 and Map 5.2 represented respectively the rate and the total area of each land-use class of 2010 in comparison with statistics of 2005. In 2010, urban residential was the largest class, occupied 18,233.35 hectares of the total land-use categories. It increased 18.94% in comparison to 2005 of the study area. The spatial interpretation of these results indicated the increase of rural residential area mainly came from conversion of rice, crop classes (about 34.47% of the change rate).

Table 5.3: Area and Percentage of Change in each Land- use Class and Annual Rate of Change between 2005 and 2010

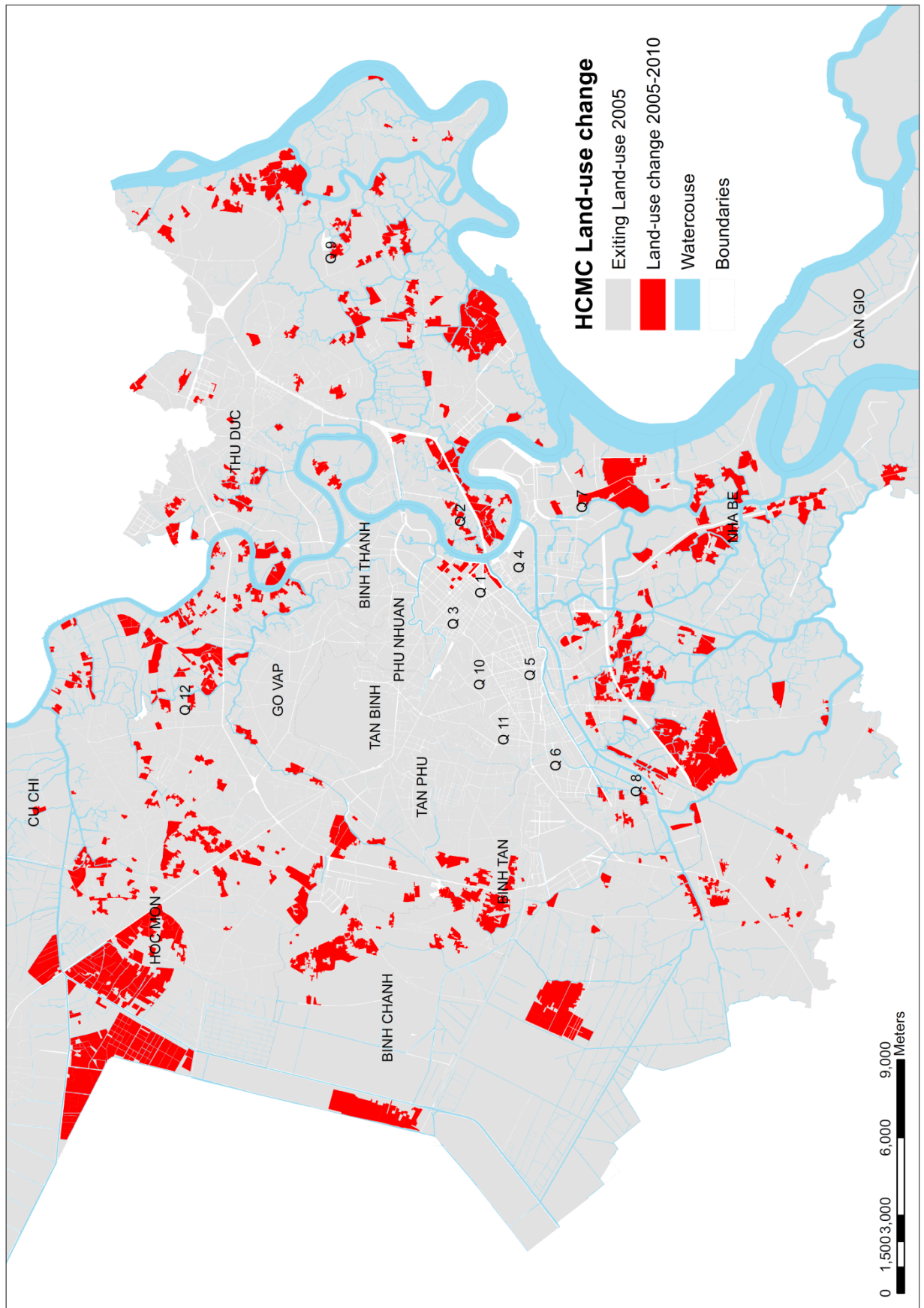
Land-use types	Class	Area statistics from (DoNRE) 2005 (ha) (1)	Area statistics from (DoNRE) 2010 (ha) (2)	Area of the classified image 2010 (ha) (3)	Change rate (%) (3&1)	Change rate (%) (2&1)
Urban residential	1	15,329.87	16,090.85	18,233.35	18.94	4.96
Rural residential	2	5,284.38	7,575.19	7,105.91	34.47	43.35
Public office	3	883.78	1,009.57	1,177.20	33.20	14.23
Industry zones	4	3,274.18	4,817.81	4,825.38	47.38	47.15
Production and business	5	9,657.69	11,000.73	10,130.92	4.90	13.91
Rice	6	35,555.48	27,795.86	27,364.85	-23.04	-21.82
Crop	7	45,935.57	39,983.25	37,089.29	-19.26	-12.96
Grass	8	1,533.81	2,228.14	1,852.84	20.80	45.27
Forest	9	33,731.28	33,284.85	33,032.09	-2.07	-1.32
Aquaculture	10	10,073.89	9,442.05	10,007.74	-0.66	-6.27
Bare soil	11	2,262.61	2,043.63	2,189.29	-3.24	-9.68
Salt	12	1,469.09	1,943.37	1,827.59	24.40	32.28
Watercourse	13	33,160.25	32,812.54	31,671.35	-4.49	-1.05

(Source: Data analysis from Landsat image 2010, land-use statistics of DoNRE 2005, 2010)

In 2010, total rural residential area was 7,105.91 hectares increased 1,821.53 hectares (34.47%) in comparison with 2005. It depended on three main factors: period of time (2005-2010), GDP per capita (increased 12.05%/year), the urban population (increased 16.12%), urban area, and housing developed from 12.2% (2005) to 18.9% (2010). Overall, 4,825.38 hectares of industrial areas transferred from crop and bare soil. Forest and water were accounted with the lowest percentage of the total land-use categories in this study.

In comparison between DoNRE statistic data in 2005-2010 and the results of classification image in 2010, there were many similar points in land-use change as well as growing land for urban residential, rural residential, industrial and public areas. The data of land-use change in 2005-2010 from DoNRE and from the results of classification image was nearly the same. Areas for rice, crop, forestry and aquaculture had decreased. On the contrary, land for residential, industrial, public office areas had increased. In consideration of macroscopic, this was changing tendency following the urbanization of HCMC.

The rural built-up areas were rapidly expanded, especially from 2005. This expansion had encroached on agriculture land in rural areas for non-agriculture one (for new-urban area, new rural residential areas, industrial zones, and processing zones, etc.). As a matter of fact, when the government had a good planning, this land could be returned and conserved for agricultural purpose and for green space development. However, it was like the potential land for growing demand of urbanization and economic development. Therefore, the process of industrialization, modernization and urbanization has led the big change of land-use and reduction of agriculture and rural land in HCM.



Map 5.2: Land-use Change 2005 – 2010 of HCMC

(Source: Analysis from land-use maps of 2005-2010)



### **5.3 Interpretation for Building 2010 and Building Types Change 2005-2010**

The purpose of this part was to update the building map and produce the range type map via joining them. The latest available building map was produced by DoNRE published in 2005, underscoring on fieldwork. To update database for building types, it was necessary to detect the changed building types in HCMC. High resolution images were important input data for the changed detection.

Many studies have developed automatic solutions for urban classification based on digital imagery, but there are many aspects which remain unsolved, such as image understanding and pattern recognition. For residential areas, where buildings systems involved complex social and economic activities, visual interpretation is still the most reliable method for classification. An on-screen digitizing advance using the ArcGis package is selected for visual interpretation because of the comfortable transition of data between the ArcGis and Envi 4.7 formats.

Digital Ikonos, GeoEye-1 and Worldview-2 images were also necessary part of strategy to update other layer of building types for HCMC. Therefore the features represented on DoNRE geospatial database and deducible maps were in year 2010.

In the HCMC case, the changed building types were directly digitized from the images. These were done by overlaying Ikonos, GeoEye-1 and Worldview-2 images on building types digital data in the scale of 1/2,000 and comparing some of their details with using visual interpretation.

#### **5.3.1 Using Data for Building Update**

The primary data sources include GeoEye-1, Worldview-2 and Ikonos images with building types map of the same scales. Data integration is the requirement to create spatial layers consistent in time, space and content. Apart from the necessary spatial and image processing, visual interpretation is very important to guarantee the accuracy and consistence of data by applying exact, experiment and identical technical specifications.

#### **5.3.2 Geo Referencing for Interpretation of Building**

After input GeoEye-1, Worldview-2 and Ikonos images to the ENVI program, it was initially registered and Ortho-rectified with projection UTM Zone 48N, WGS-84 coordinates using ground control points (GCPs) from a digital terrain model (DTM) 0.5 meter, generated from base maps at 1/2,000 scale. This is very important, as for registration of the image with the digital data they have to originate in the same reference. In the Ortho rectification module of Environment for Visualizing Images (ENVI 4.7) well distributed control points in the image and the corresponding control points in the digi-

tal data were selected. A projective transformation was used with a sigma of 0.5 pixels (0.5 meter), which is acceptable regarding to the scale of the housing digital data.






### **5.3.3 Buildings Classification**

Buildings classification was the processes of identifying housing typologies in HCMC and developing the buildings map 2010. This map was used to analyze the housing density and their relation to flooding impacts in HCMC (in the following chapters). Therefore, the buildings map 2010 and land-use 2010 were the very important steps for UM analysis in this study.

#### **5.3.3.1 Keys Sampling of Building Types**

The classification scheme was designed to follow the Vietnam standards 353-2005 (MOC, 2005). These standards included additional categories for research requirements. The key sampling was represented at 11 classes of generalization and had been checked during site-observation period and combined to the high resolution images and building types map 2005 (contented most details of 11 building types). Table 5.4 below described the keys sampling of building types in processing of images data such as: Apartment; Building; Office building; Detached house; Semi-detached house; Terraced house; Villas; Wood-framed, Thatch-roofed house; Temporarily-built and other houses; Hotels; Markets.

Table 5.4: Description the Keys Sampling of Building Types for Classification (continued)

Typologies	Figures	Building types	Description
1		Apartment	High buildings for housing with 5 to 9 floors, each apartment has each balcony, apartment's size from $1,000\text{m}^2$ ÷ $5,000\text{m}^2$ of ground floor.
2		Building	Very high buildings for offices, commercial and housing with 9 to 20 floors, building's size from $500\text{m}^2$ ÷ $3,000\text{m}^2$ of ground floor.
3		Office building	Office building with 10 to 40 floors normally located in the centers or main streets. Its building is about $200\text{m}^2$ ÷ $1,000\text{m}^2$ of ground floor. Excluded are buildings used for housing.
4		Detached house	Single flats or house, less than $50\text{m}^2$ of ground floor, with 0 to 4 floors and various designs.
5		Semi – detached house	Single flats or house, less than $30\text{m}^2$ of ground floor, with 0 to 1 floors and various designs, located in old residential areas or rural areas.

(Source: From GeoEye-1, Worldview-2 and Ikonos image, fieldtrip photo in April, 2011)

Table 5.4: Description the Keys Sampling of Building Types for Classification

Typologies	Figures	Building types	Description
6		Terraced house	Houses built in rows of three or more units of which each has a common wall or walls adjoining with the next house. Each house is about 80m <sup>2</sup> ÷160m <sup>2</sup> of ground floor with 1 to 5 floors.
7		Villas	Located in new districts or sub-districts, where has large land for building a house with surrounded garden. Each house is about 200m <sup>2</sup> ÷500m <sup>2</sup> of ground floor, depended on the detailed planning of each area.
8		Hotels	Include all entities whose function is to provide a service that is a short stay, about 150m <sup>2</sup> ÷1,500m <sup>2</sup> of ground floor with more than 7 floors, located along the main/large streets in the center.
9		Markets	Traditional markets or supermarkets, about 400m <sup>2</sup> ÷1,500m <sup>2</sup> of ground floor with 1 to 2 floors, and located in centers of districts or peri-districts.
10		Wood-framed, thatched-roofed house	House with simple materials (wood wall, iron or coconut-leaves roof, etc.), about 20 m <sup>2</sup> ÷40m <sup>2</sup> of ground floor, located in small alleys (1 – 2m width), most are in District 4, 7, and 8.
11		Temporarily-built and other houses	One-floor house with very simple materials (wood or leaves), about 25m <sup>2</sup> ÷40m <sup>2</sup> of ground floor, located in small alleys or roads.

(Source: From GeoEye-1, Worldview-2 and Ikonos image, fieldtrip photo in April, 2011)

### 5.3.3.2 Overlaying and Change Detection of Buildings Update

After identified clustering, the GeoEye-1, Worldview-2 and Ikonos images 2010 and building layer 2005 were overlaid together. In the next stage, appropriate spectral and spatial transformations such as contrast enhancement, rationing, color composites and image fusion were carried out on the images. As a result the building types which were somehow a change recognized. ENVI software, having the satellite image as setting formats of image with overlaying the building layer 2005, the changes was on-screen digitized in a new layer and the digital data has been updated. Object delineation by hand requires interpreters with good visual interpretation skills and very detail description of the interpretation key to standardize interpretation among interpreters working on the same projection as well as to make it possible to repeat the process elsewhere or on a new set of images (Tullis & Jensen, 2003)

### 5.3.4 Buildings Update Results and Buildings Change for HCMC 2005-2010

From the above introduction on images interpretation process for buildings update, this section detailed the results of the new building layer 2010. From the building layers of 2005 and 2010, the new layer for building-change 2005-2010 was developed to understand the changes in this period.

#### 5.3.4.1 The Technical Results of Building Update and Changes in HCMC 2010

Figure 5.3 detail of the building updated from the Ikonos, GeoEye-1, and Worldview-2 image 2010 of HCMC. Left side: result of digital object-oriented classification. Right side: visual interpretation and on-screen digitizing. By displaying the multispectral bands in different colors on a computer screen, one gets a colored image (color composite). The colors for display can be chosen to suit interpretation.

Table 5.5: Buildings Change in 2005-2010

	Buildings data (2005)	Buildings data update (2010)	Increase in numbers	Percent increase (%)
Number of building foot- prints	613,232	802,077	188,845	30.79
Area (ha)	7,238.20	11,838.23	4,600.03	63.56

(Source: Data analysis base on building maps 2005 - 2010)



Figure 5.3: Detail of Building Updated from Ikonos, GeoEye-1, Worldview-2 Images 2010

*(Source: The result of visual interpretation)*

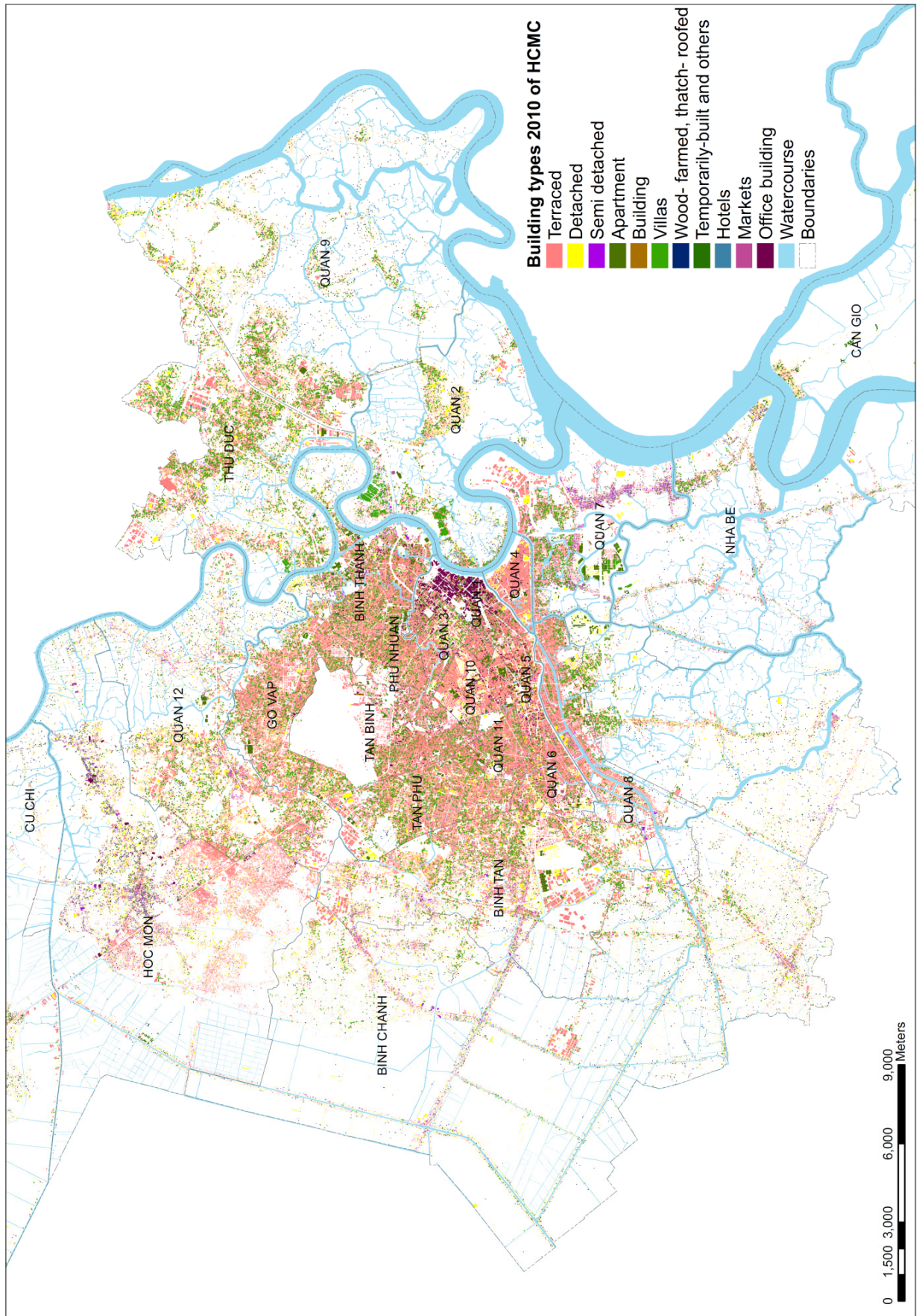
In Table 5.5, the numbers of building increased to 2010 were 188,845 buildings; and it increased 30.79% within 5 years (2005-2010). However, this number just demonstrated the numbers of new buildings in the new building layer 2010. There were various typologies of buildings dynamically changed within this period; and there was the replacement of the old types into the new types among building areas. These were explained in details in the following section.

#### 5.3.4.2 Buildings Result 2010 and Buildings Change 2005-2010

The building type classification has been executed on GeoEye-1, Worldview-2 and Ikonos images 2010. This classification consists of marking the boundaries of areas representing single cover housing units on the building types layer 2005 using on-screen digitizing to update attribute of building types, as well as extrapolating the demonstrated depiction and identification of different parts showing similar characteristics.

In urban areas, both buildings and pavements are made of concrete, bricks and asphalt, making it difficult to classify pixels based on just color. Therefore, the basic interpretation keys were tone, texture, pattern, shape, size, shadow, location, GPS and 200 sampling survey of object in the classification process, they were carried out to achieve a general knowledge and overall view from 11 building types. This gives much better results for interpretation of high resolution optical image. The following building type classification was adopted for the building map of 2010, which was already in digital format (Shp format). These digitized shapes of building types are combined with the building map 2005 from DoNRE to detect the new constructions (Map 5.3 and Table 5.6).

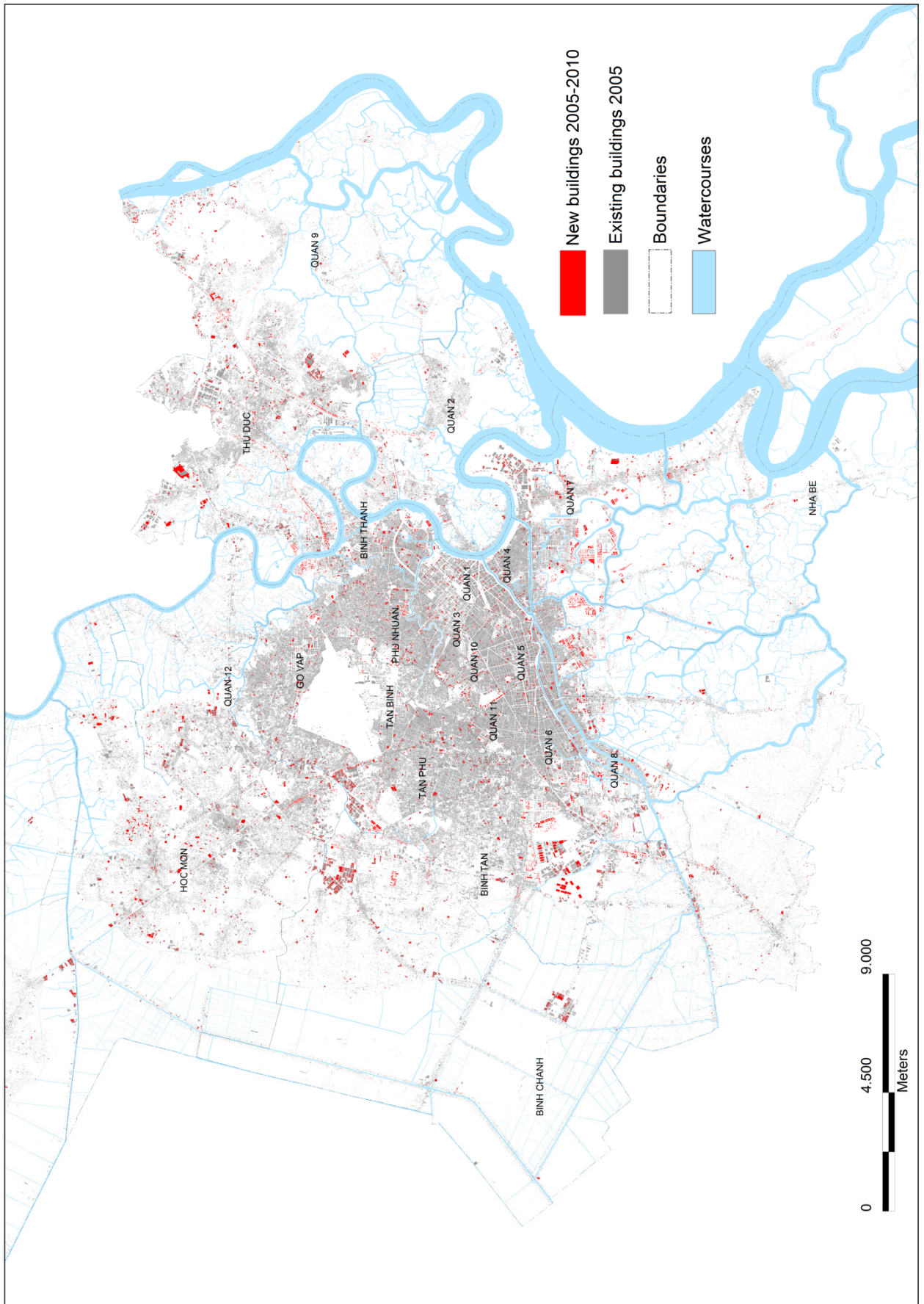




Map 5.3: The Result Classification Building Types of HCMC 2010

(Source: Interpretation from high resolution images)





Map 5.4: Buildings Change 2005-2010 of HCMC

(Source: Analysis from building types map 2005-2010)



Map 5.3 above drew the housing fabric on 2010 with the widespread housing expanding in the city. The Map showed the Terraced type was main occupied in inner center of the city, while detached and semi-detached (with smaller areas) were widespread mostly in new urban, peri-districts and in rural areas. Apartments and Buildings were the new housing types in recent decades in this city and distributed in groups in planned areas, mostly in new urban of peri-districts. Other types of Office-buildings, Hotels, and Markets were mixed with Terraced in urban center. And Villas were located in peri-districts and surround river areas. The total numbers of building types were described in Table 5.6 below.

To understand about buildings change, the Map 5.3 also explained the trends of building types in the near future. In this Map 5.3, the housing area trended to expand into peri-districts and rural areas. Terraced trended to concentrate in urban center and replace for Detached and Semi-detached. The Detached trended to move out to peri-district and rural areas and replace for Semi-detached in peri-districts. Semi-detached now was mostly in rural areas and trended to replace for Temporarily-built, Wood-framed, and Thatch-rooted types in rural areas. Generally, building layer of the city trends to expand and it has a growing quality of housing.

Map 5.4 explained clearer the expanding directions of housing fabric of the city. There were two strong directions of extension: the Northwest and the Southeast directions. In which, the Southeast direction had housing expansion in spontaneous way; while the Northwest direction had housing expansion in better planning. Other two directions of Southwest and Northeast were in weaker expanded directions.

Results from satellite images interpretation merged with housing data (Map 5.4 and Table 5.6) showed that, the apartment (typology 1) had the highest proportion from 2005 to 2010, mostly built in districts of 2, 4, 7, 11, Tan Binh, Thu Duc, Binh Tan, and Tan Phu. During this time, there were 591 apartment buildings raised (more than 58.23% of total in comparison to 2005). And the built area for this typology was of course increased (about 47.68% in comparison to 2005). This type of housing trended to rise up rapidly in HCMC. It could supply a large number of housing units for the big housing demand in the small construction land in this HCMC (DoC, 2010). City government was trying to lift the housing standard up to 14 square meters per person (DoNRE). If housing supply was the one-floor houses or flats, City would need at least 8500 ha for construction. However, with the four or five or higher floors apartment buildings, then less land would be used.

Table 5.6: Building Types Changed in 2005-2010 of HCMC

Building types	2005		2010		Increase	
	Number of building footprints	Area (ha)	Number of building footprints	Area (ha)	Rate of buildings (%)	Rate of areas (%)
Apartment	1,015	112.68	1,606	166.41	58.23	47.68
Building	487	18.60	589	28.17	20.94	51.45
Detached	274,221	2,149.32	332,829	2,872.45	21.37	33.64
Semi detached	19,090	316.72	24,816	457.97	29.99	44.60
Temporarily-built and others	3,169	37.36	2,028	17.35	-36.01	-53.56
Terraced	255,055	3,495.63	380,921	7,154.27	49.35	104.66
Villas	30,459	893.20	31,076	896.69	2.03	0.39
Wood- framed, thatch- roofed	25,317	54.48	23,298	51.74	-7.97	-5.03
<b>Total</b>	<b>608,813</b>	<b>7,077.99</b>	<b>797,163</b>	<b>11,645.05</b>	<b>30.94</b>	<b>64.52</b>
<b>Commercial types</b>						
Markets	59	8.24	103	17.15	74.58	108.13
Hotels	1,531	39.03	1579	45.11	3.14	15.58
Office building	2,829	112.94	3,232	130.92	14.25	15.92
<b>Total</b>	<b>4,419</b>	<b>160.21</b>	<b>4,914</b>	<b>193.18</b>	<b>11.20</b>	<b>20.58</b>

(Source: data analysis from classification of building map 2010 and building map 2005)

The terraced and detached houses became common in HCMC. They were 86.72% of total housing in 2005. In 2010, they were 89.36% of total. Most terraced houses were in the urban-districts (Districts of 1, 2, 3, 7, Phu Nhuan, and Tan Binh) and Phu My Hung new urban. While detached houses were mostly in the new urban districts (Districts of 9, 12, Thu Duc, and Nha Be) with low density, or scattered in the old residential areas (Go Vap and Binh Thanh Districts).

The semi-detached house was also rapidly increased in recent years. In 2010 it was about 30% more than in 2005 and its land increased 44.6%. This typology much occurred in spontaneous residential areas. Most of these areas were not planned yet. They were mostly in rural or agriculture land in peri-districts (Thu Duc, Binh Tan, Tan Phu,

District 9, and Binh Chanh). This type was also located in spots in inner districts (in District 4, 8, 9, 11, Binh Thanh, and Go Vap) with lower density.

Building typology increased 20.94% in 2005-2010. The new buildings were just increased partly in areas; however, their land was remarkable increased, about 51.45 % higher than in 2005. With this trend, this typology would continue rising up in the coming years. Beside the existed buildings in District 1, many new buildings continued to be constructed in inert centers (such as in District 1, 3, 4, and 5) and in urban districts of Tan Binh, and Phu Nhuan. Most of new buildings in the center were built on the evacuated areas of old or ruined housing or slums. They were often built in the compact buildings including the high quality apartments, commercial areas and services, or with office buildings.

Otherwise, villas typology dramatically appeared in last ten years in the well-planned areas. This land was mostly speculated for a long time. But in 2000 to 2005, they were rapidly increased to 30,459 villas. And five years later (2006 to 2010) they just increased 2.03% (about 31,076 villas in total). The villa area in 2010 was 896.69 hectares, mostly in new districts of 2, 7, and 9 and some in the inert districts.

In contrast, the temporarily-built housing was remarkably decreased in both proportions of quantity and area. In comparison to 2005, the decreases of quantity and area to 2010 were -36.01% and -53.56%. Most of them were disappeared from old or ruined housing or slum in the districts' centers for urban upgrading projects, such as: the Dong - Tay Highway project in District 4, 8, and Binh Chanh Sub-district; the Nhieu Loc - Thi Nghe sanitation project in Districts 1, Phu Nhuan, Binh Thanh, and Tan Binh, etc. However, this typology still occupies the large area of 17 hectares with about 2,000 units scattered in the low-income housing areas in HCMC.

The Wood-framed and thatch-roofed housing typologies also trended rising down. But they were not as much decreased as the temporarily-built housing, just -5.03 % of area. These types were easily seen in rural and peri-districts such as Binh Chanh, Nha Be, Hoc Mon, Thu Duc, and Can Gio and some in the low-income housing area in the inert districts.

In the commercial typologies, they were categorized into 3 types: market/supermarket, hotel, and office building. In which, the number of markets in 2005 was 59 with 8.24 hectares. To 2010 it was 103 markets with 17.15 hectares. The markets/supermarkets increased 74.58% but their area had increased to 108.13%. This shows that the system expanded to provide products for the growing population of this city.

The area of hotels and office buildings in the commercial typologies increased 15% in 2005-2010. However, in comparison among them, the number of office buildings was five time higher than hotels. Most of office buildings increased in the urban district cen-

ters such as District 1, 3, 4, 5, and 10, because these districts were concentrated with commercial and urban services of HCMC.

#### **5.4 Summary for Chapter Five**

By techniques of GIS and remote-sensing with high-resolution images, the thirteen land-use units and eleven building types of HCMC in year 2010 were interpreted and identified at scale of 1/2,000. The results were compared to the results of year 2005 to show their dynamic changes as presented and explained in above. And importantly, all of these results were used as the based data for urban morphological analysis in the following Chapters. Therefore, they were checked and compared to DoNRE's statistic data to have the precise data sources. These data sources were used for mapping the land-use map 2010, building map 2010, land-use-change map 2005-2010, and building-change map 2005-2010 in the following Chapter.

## **6 MEASURING URBAN MORPHOLOGY IN HO CHI MINH CITY**

### **6.1 The Necessity of Urban Morphology Map and Urban Function Map**

Fractal geometry, was described in details in Chapter Three of this study, is one important part in urban morphology analysis. Fractal geometry is used to measure the densities of patterns of urban districts and peri-districts in HCMC. The results of fractal analysis were urban morphological structures of the city. And these structures helped to show the densities of patterns at different levels, such as densities of housing, buildings, residential areas, parks and green trees, etc.

The breadthways expansion and high density of built-up coverage had close relation to density of open spaces and growing population. Fractal geometry shaped the city from the sources (satellite images, vector GIS data and city census) and identified the areas of urban districts and peri-districts. This shape was discovered on computer screens and in the city density (Batty & Longley, 1986). One of the special characteristics from fractal analysis was described by a no integer dimension. The mathematics of fractal geometry have allowed for practicable tools as a variety of scientific conditions (Gerosa, 1999). It presents the characteristics of urban built-up at a large scale. The large scale was compared to that of density and it demonstrated the meaning and utility of fractal geometry (Mesev, Longley & Batty, 1995). This is the basics to calculate fractal geometry, and it can forecast a development direction at the same time.

Each units of urban morphology is characterized by typical urban density values and, as result, urban morphology as spatial units interconnect buildings and related land-use and population. Large-scale parameters for land-use and building types, as well as population density parameters are both based on large scale and statistical data that can be attributed to urban morphology types (Batty & Longley, 1994).

This is an important and necessary step in order to illustrate the effects of urban density on building types elements and urban functions. The resulting “Urban morphology map” allows calculation of resource urban land-use and urban functions at city level, for districts, communes.

## 6.2 Program Tool for Fractal Geometry Analysis

The morphology of HCMC urban was analyzed following principle from fractal geometry. Based on the equations of section 3.5, fractal analysis was carried out using the population, land-use 2010 and building types 2010 of GIS database for HCMC about the different areas of centre and peripheral. The program that was applied for finding the fractal geometry of HCMC was Arcview 3.3 (Environmental Systems Research Institute, Inc. ESRI, 2002). ArcView was preferred because of its user-friendly GUI (Graphical User Interface) and its potential to extend spatial analysis by using the inherent Avenue language (see Appendix 11.2). The analytical tool is followed as an Arcview project in this research (Figure 6.1).

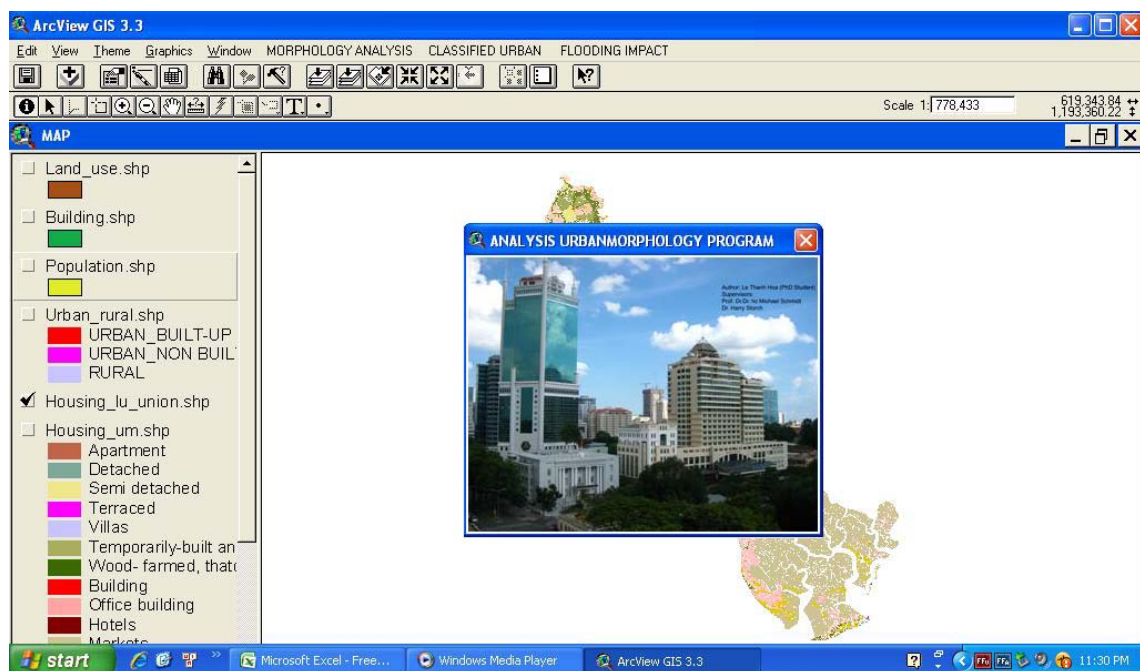


Figure 6.1: Morphologist Tool Based on ArcView 3.3

*(Source: The result setting of morphologist tool)*

The effectuation of an analytical morphologist tool within GIS provides some significant rewards from both computational and in case of this study. Containing model in GIS encourages both GIS and urban morphology research. Moreover, it increases GIS practicality in spatial analysis into the field of urban morphological analysis. But then, GIS provides rich geo-referenced data, spatial data analysis and visualization potentialities for urban morphological research. The development of the morphology tool is based on the raster, vector data structure of a GIS in order to the ability to generate graphical output such as thematic maps, which are able numerical data.

The construction of the morphology tool in Arcview is contributed in Figure 6.2, they have two main functions to set up as morphology analysis, classified urban. The two

functions are implemented using Avenue scripts with close ties modules: interpolating with objects, calculation with raster, vector data and table, and analysis with table and chart. All these Avenue scripts are compacted to Arcview as a project named “urban\_projects.apr”.

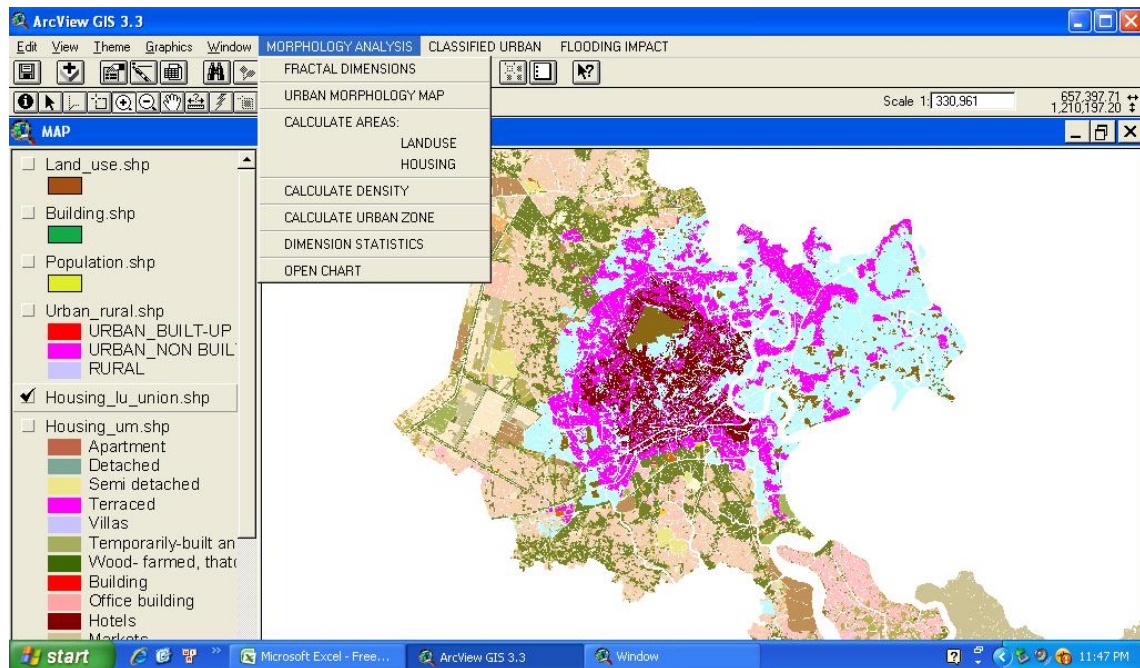


Figure 6.2: The Construction of the Morphology Tool in Arcview

(Source: From urban morphology tool analysis)

A group of morphological examines can be done with the project fractal geometry tools allow users to analysis raters and polygons on an attribution data or an Arcview feature theme. Statistical tools calculate various space insertion parameters, based on a property record, including connectivity, control value, and local and space integrating. Calculated results are stored in a table matching to the morphology map or polygon theme. The results can search data from different views, or analysis mentioned data, density rate or urban functions, which can be related with the logarithm analysis.

### 6.3 Spatial and Density Relation of Urban – Peripheral Areas in HCMC

In this part, the calculation of density is calculated by using the morphology tool based on the Arcview GIS. The input and conversion of vector and raster data from another GIS - RS software such as ArcGis, ENVI are demanded. In the case of urban morphology, the information geometry is calculated by an Avenue programming language.

### 6.3.1 Spatial and Density Distribution of Urban-Peripheral Areas in HCMC

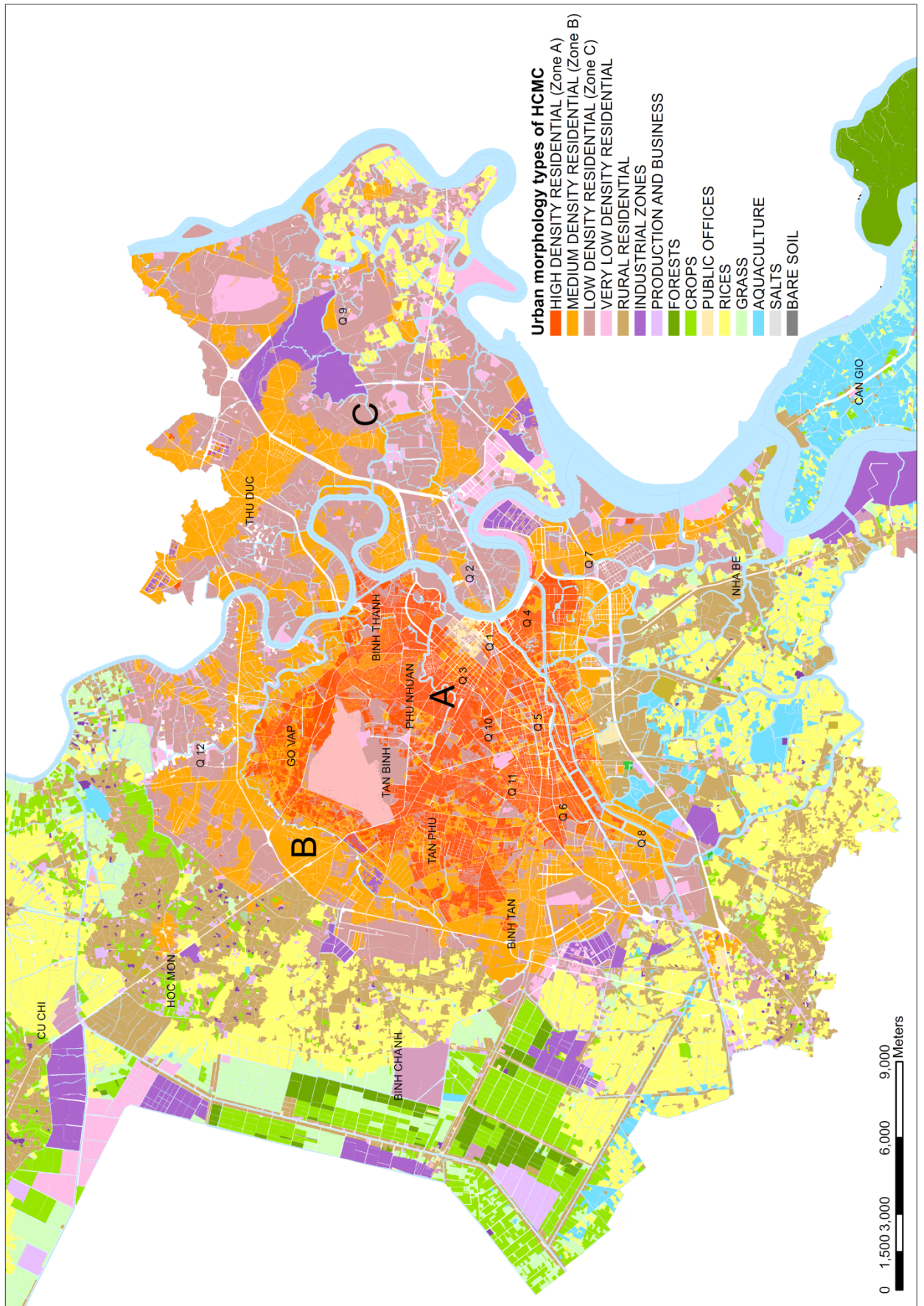
Based on the theoretical mentioned in Chapter Two and the spatial density analyzed by program tool for fractal geometry analysis, the results are shown in Table 6.1, Map 6.1 and Map 6.2

Table 6.1: Dimensions Associated with Partial Building Densities

Range	Zone	Area (ha)	Number of building footprints	Building footprints density (#/ha)	ln(area)	Dimensions D
High	A	1,721.22	260,245	151	7.45	1.67
Medium	B	5,413.64	268,701	49	8.60	1.45
Low	C	14,022.73	273,131	19	9.55	1.31
Total		21,157.59	802,077			

(Source: Data analysis from morphologist tool)

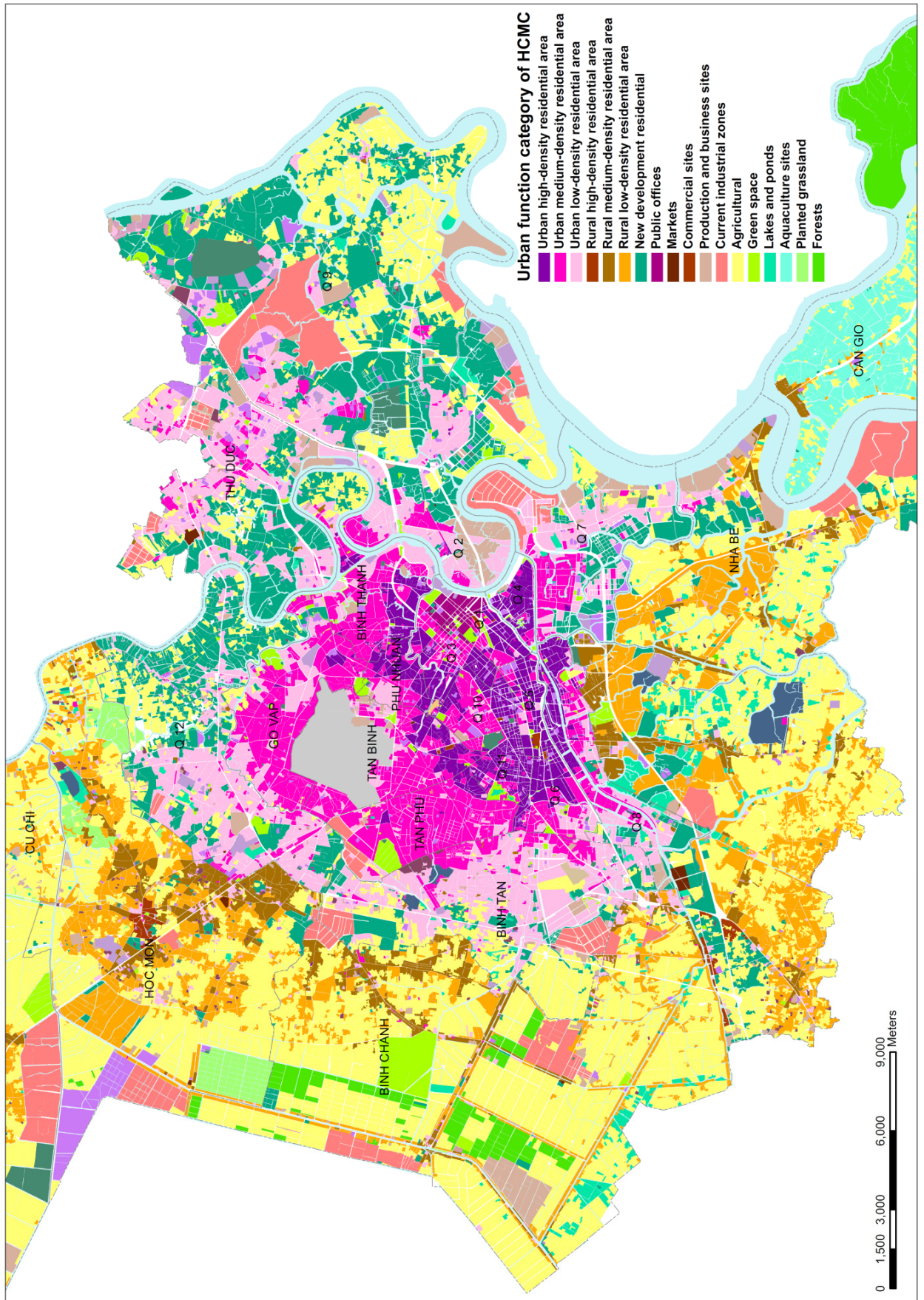




Map 6.1: Urban Morphology of HCMC 2010

(Source: Data analysis from morphologist tool)





Map 6.2: Urban Function of HCMC

(Source: Analysis from fractal geometry)

Table 6.1 shows all fractal geometry of urban density and building footprints density in three range values (high, medium and low). It shows that the fractal geometry (D) is estimating 1.31 to 1.67 synonymous with urban densities and buildings. Corresponding density profiles for the same are shown 1.7 for residential area, 1.8 for build-up area (Longley & Mesev, 2001).

The results from fractal geometry analysis show the numbers of buildings in these zones are nearly the same. However, there are big differences of buildings densities among three buildings zones - A (high density), B (medium density), and C (low density) in the city. Zone A has buildings density three times higher than of zone B, and eight times higher than of zone C. But the building areas are in converse, the area of zone A is about three times less than zone B and eight times less than zone C (see more in the above Table 6.1). This contrast shows the inequality distribution of buildings among the zones. People living in the high density of buildings zone A have to share smaller land urban services, otherwise, people living in larger building area of zone C still have place for more open space and other urban services.

By interpolated analysis and GIS analysis from fractal geometry, Map 6.1 shows the buildings density for the urban residential 2010 in HCMC. The research has found out the followings of some important results in buildings distribution of these three building densities zones.

Buildings in the high density of zone A are mostly distributed in the urban districts (includes districts of 3, 4, 5, 6, 8, 10, 11, Phu Nhuan, Binh Thanh, Tan Binh, Go Vap and part of District 1). Because District 1 is the city center, it has most land for buildings and office buildings. Therefore building is occupied partly with very high density. Currently, there is no more land for housing in these areas. To have more living spaces, these districts should change their housing typologies from terraced and detached types to apartment buildings. To do this, the slums and ghettos should be replaced into the apartments. This also helps to rearrange the housing area and center landscape as well as to have space for more infrastructures and urban services.

Buildings in zone B have the medium density distribution with about 49 units in one hectare. They are mostly in the new-urban districts of 2, 7, 12, Tan Phu, Binh Tan; some in the center of District 9; and someplace in North of Nha Be, Thu Duc. In consideration on aspect of terrain and urban space, these areas can be seen as the peripheral area of the city, where is used to relocate the urban functions of the center and the housing area.

Zone C is the lowest density of building areas of the city with only 19 building units per hectare. It consists of peri-urban district areas and rural areas (including District 2, District 9, District 12, District 7, Tan Phu, Thu Duc and a part of Nha Be, Binh Chanh, Hoc Mon). This is the peri-urban districts and rural area of the new development urban are-

as. However, this area is being rapidly urbanized and growing with many temporarily housing typologies such as detached, semi-detached, wood-framed, thatch-roofed-houses, etc. In the near future, this rural area will be transferred into the new-urban area.

Map 6.2 shows the residential density in HCMC made by the above mentioned method. The built-up area extended behind the northeastern and the southern parts of the city. In the center of the city, the density is the highest and it is gradually higher towards the fringes of the city as is clearly shown on the Map 6.1. HCMC is mainly situated on the alluvial fan sloped Northeastern, which was built by the Saigon river. Seemingly, there were many morphological elements that disturbed the development of the city. The city is the site of the prefectural office and is the administrative, educational, economical, and cultural center of District 1. HCMC was planned in front of the castle and the inner has been extended outwards. The highest house density is seen along streets in the center, which was already a central shopping center. The density is also high in the shopping streets located in District 1 and 5. These areas were developed after the planning of city in 1995.

However, in 2000 the city set the present zoning system in the built up area to promote the city planning. The zoning, of course, does not show the actual land-use but shows a standard for forbidding chaotic development of the built-up areas and an unplanned land-use (HCMC Cadastry and Housing Land Department, 2001a). But the zoning system in some measure was set on the basis of generalizing the actual land-use; therefore, it is considered that the zoning map on the whole agrees with the actual land-use. In this research, I analyze the relation between the land-use and the distribution of the house density.

The land-use pattern in HCMC shows that the commercial district is located in the central part of the city and the residential areas around it, and detached and semi detached in districts are located around the northern part of the center district and on the periphery of the built-up area. Radial extension of commercial district into the residential areas reflects the existence of the peripheral.

The land-use and the house density are closely related. For example, in most of the commercial districts, the house density is 61% and more, and the highest density of 81% and more is exclusively in the commercial district. The exceptional area of 41-60% density in the commercial district is the area in which there is public office. On the other hand, the densities in the peripheral housing beside streets in residential districts are 41-60%, far lower than in the central shopping street, the percentage is equivalent to that in the residential districts. The density in the residential district is less than 60% with some exceptional areas. The area of 41-60% located in the eastern part of the city was originally developed as a residential area after 2005, and now the area has been well developed (HCMC Cadastry and Housing Land Department. 2001c). These values seem rep-

representative of well developed residential districts of big size cities like HCMC. However, a slightly higher density is seen within the residential districts where rather low density is widely spread. Such are smaller housing streets scattered in residential districts.

An isolated low density area seen in the north part of the city is an old housing or hamlet. Its density is about 15%. This is a general value as the density in a village. On the other hand, an area with very high density is observed in the residential districts in the southwest part of the city, in some part of which the values exceed 71%. This district is often regarded as a slum. So, it is necessary to devise some measure to remove the quality.

### 6.3.2 Trend of Spatial and Density Distribution of Built-up Areas in HCMC

Using classified urban tools in this study, the fractal analysis process described the spatial distribution of HCMC's urban function areas such as urban built-up, non built-up, residential, non-residential, peripheral, and rural. Each land-use type or building types was coded as a binary surface. The classified tool in ArcView was used to calculate fractal geometry and to create the cumulative count profiles. The diagrams in Figure 6.3 to Figure 6.4 below described the cumulative-count profile densities and spatial distributions for urban and built-up types in HCMC in 2010.

Figure 6.3 explained the cumulative-count profile of urban and built-up categories in year 2010. These categories continue to develop in urban areas. The built-up category trends to fill up the urban category in urban areas. The Figure 6.3 showed the spatial distributions of these two categories were close together. However, there were still non-residential areas among urban areas, mostly in peri-districts.

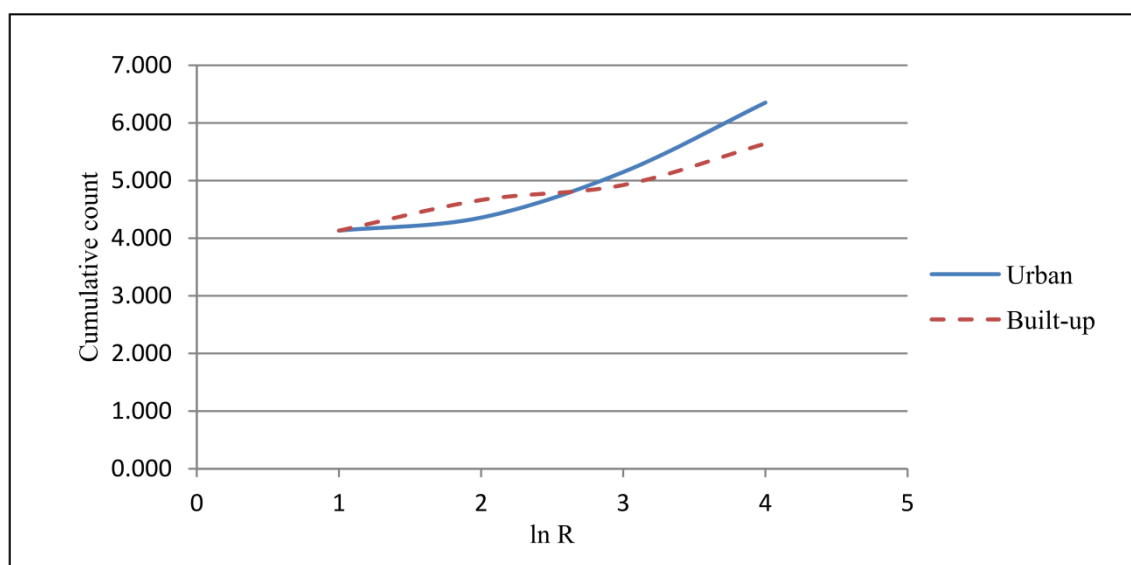


Figure 6.3: Cumulative Count Profiles of the Urban and Built-up Categories of HCMC  
(Source: data analysis from morphologist tool)

In comparison of built-up density and urban density in urban areas, the Figure 6.4 showed these two density categories seemed to be overlapped. It meant the built-up areas nearly filled all spaces of urban areas with less green space and open space in the center. Corresponding density profiles for the same categories of land-use are show in Figure 6.4.

The first of these suggests instability in the density of the urban and built up categories until  $\ln(R) \approx 4.5$ . This is logical with the urban density slopes within the "complete" part of urban residential remain constant as a settlement grow and leave significantly from these space filling averages only in the external growth zones of residential in which growth is still taking place. Therefore, the green trees and open spaces in peri-districts were trending to be filled up for residential and public areas.

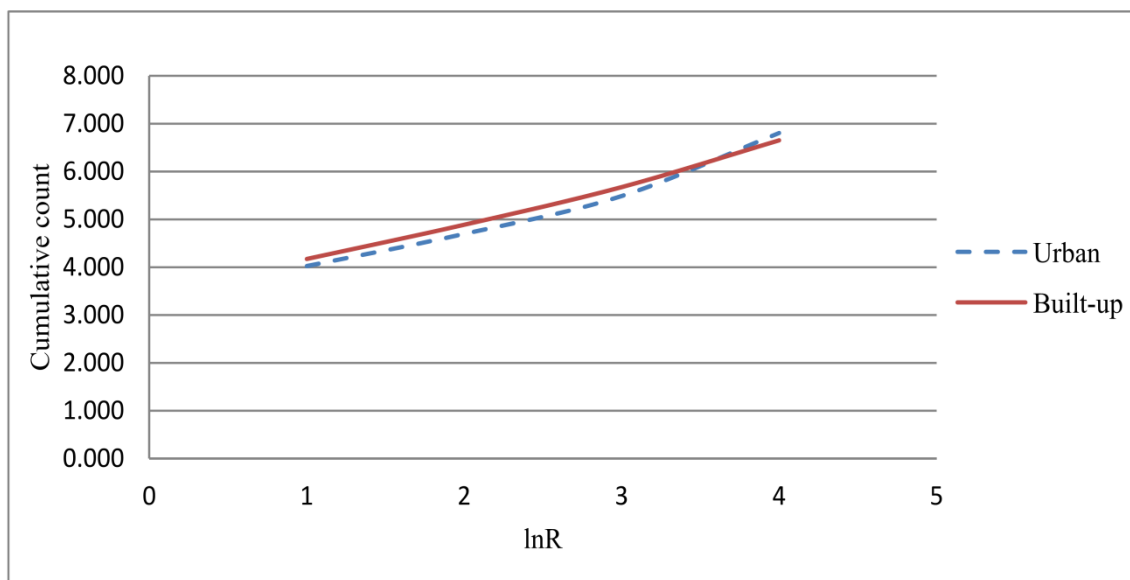


Figure 6.4: Density Profiles of the Urban and Built-up Categories of HCMC

(Source: The result analysis of morphologist tool)

### 6.3.3 Trend of Spatial Distribution of Residential Areas in HCMC

The residential category in Figure 6.5 was quite far above the non-residential category. It meant the non-residential category had less advantage to develop in urban areas and tend to be replaced by the residential category. In reality, there were many lakes and ponds, green trees and parks, and many small tributaries filled-up in urban areas (as mentioned in Chapter Four, Sections 4.2 and 4.3). Moreover, in urban developing processes, without appropriate planning or lack of planning control, more non-residential areas would be invaded for built development.



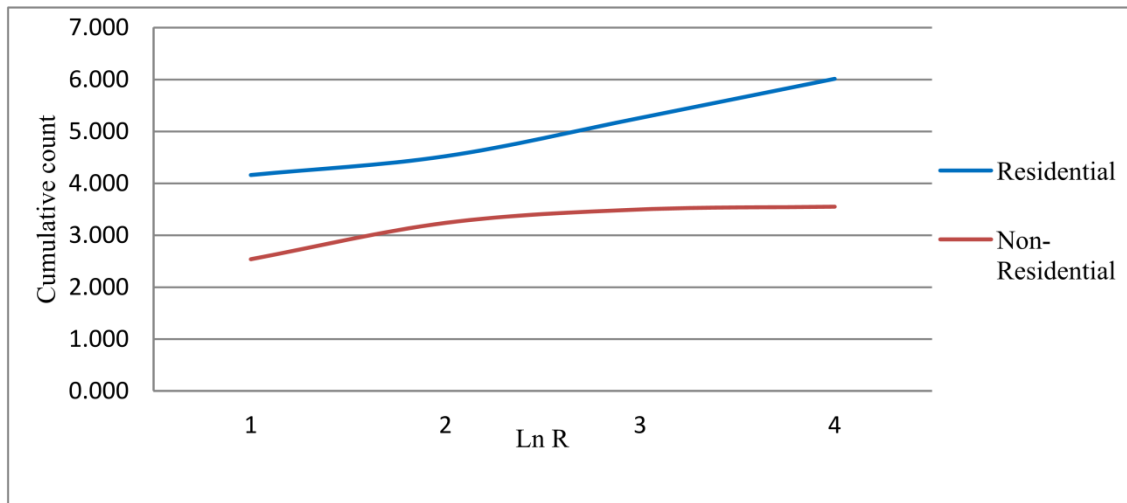


Figure 6.5: Cumulative Count Profiles of the Residential and Non-Residential Categories of HCMC

(Source: Data analysis from morphologist tool)

## 6.4 Spatial and Density Distribution of Building Types in HCMC

This section was used only for the scale ranges indicated in Table 6.2 and separate regressions were fitted for the scale ranges separated by ticks marked in figure 6.6. The Table 6.2 below described the values of “D” fractal geometry of building types and urban, built-up, residential and non-residential areas.

Amongst the building types, the apartment and building had the highest values ( $D = 1.902-1.907$ ) in residential areas. These said that they had high density and high level of identity on land-use block. However, in comparison between values  $D$  and  $r$ , the two building types had the differences in the size and the number of land-use block. The size of blocks of apartment was smaller than of building ( $r$  of apartment block smaller than  $r$  of building) while the density of apartment block was higher than of building block ( $\ln(R)$  of apartment block higher than  $\ln(R)$  of building block). And the blocks of apartment were scattered distribution in the new urban (as in District 2, 7, Tan phu and Tan Binh District). By contrast, blocks of building were closely clustered with larger size, and concentrated in the center area as the groups of high blocks in District 1, 3, 4, 5, 6, and 10.

The  $D$  values of terraced and detached were almost the same on land-use block. However, the size ‘ $r$ ’ and the density ‘ $\ln(R)$ ’ of terraced on each land-use block were bigger than of detached. This said that terraced had more occupation both in area and number.

The result also showed the  $D$  value of villa smaller than the above building types. It was almost in peri-districts, where they have many undeveloped areas, low built-up density, and the large size of land-use blocks (normally were the blocks of former agriculture).

The two types of temporarily-built and wood-framed had the lowest D values, because they had the small sizes (less than 35 square meters per building type on average) and low density on land-use block. They were mostly in rural residential areas or scattered in some urban areas.

The analyses of fractal geometry also indicated the very high D values of urban density and built-up density in urban areas ( $\ln(R) \approx 4.7$ ). They showed the value of urban density of center districts come closely to the quite tailing off of value, because of the fulfilled residential areas ( $D = 1.842$ ). Therefore, the new residential areas had to develop in new urban areas, because the D value of built-up density (ranked from 1.842 to 1.996) was higher than the D value of residential density ( $D = 1.776$ ). This was the main reason to continue the expansion of residential areas in peri-district and rural areas.

Table 6.2: Overall Fractal Geometry of Partial Building Categories in HCMC

Types	$\ln(R)$	D	$r^2$
Apartment	3.3392 - 3.5794	1.907	0.781
Building	3.0891 - 3.4849	1.902	0.976
Detached	2.3805 - 2.7094	1.819	0.962
Hotels	2.0756 - 2.1972	1.825	0.972
Markets	2.2997 - 2.3978	1.893	0.927
Office building	2.1925 - 2.3025	1.942	0.910
Semi detached	2.0914 - 2.3862	1.738	0.892
Temporarily - built and others	0.8065 - 1.0914	0.968	0.712
Terraced	2.9832 - 3.0459	1.819	0.967
Villas	2.3078 - 2.5946	1.291	0.949
Wood- framed, thatch - roofed	0.3662 - 1.0465	0.881	0.759
Urban	3.1320 - 4.3534	1.776	0.883
Built-up	4.3120 - 4.6412	1.996	0.910
Residential	4.1581 - 4.3024	1.842	0.905
Non-Residential	0.4522 - 1.8031	0.779	0.647

(Source: Data analysis from morphologist tool)



About building typologies, the diagram in Figure 6.6 illustrated the spatial distributions among building typologies in urban areas. There were distributions of apartments, buildings, terraces, office buildings, detached, semi-detached, and markets close together in groups in the above space of the diagram. It meant that these categories were advantageously developed in urban areas. And profiles of other types were distantly distributed in below. And among this close group, apartments, buildings, and terraced had the most advantage in developing. The terraced houses were widespread distributions in urban districts rather than detached and semi-detached. As well, detached replaced semi-detached in peri-districts. The categories of temporary houses (temporarily-built houses) and wood-framed houses distributed in the bottom of diagram meant that, they had no more advantage to develop in urban areas. And they were trending to be replaced by detached and semi-detached. This Figure also showed the current trends of high-rise building types (apartment and building) were replacing the low-rise building types in large areas (such as semi-detached, temporarily-built houses and wood-framed houses). This trend would help to eliminate the densities of residential and built-up areas, and may lessen the flood exposure in urban center.

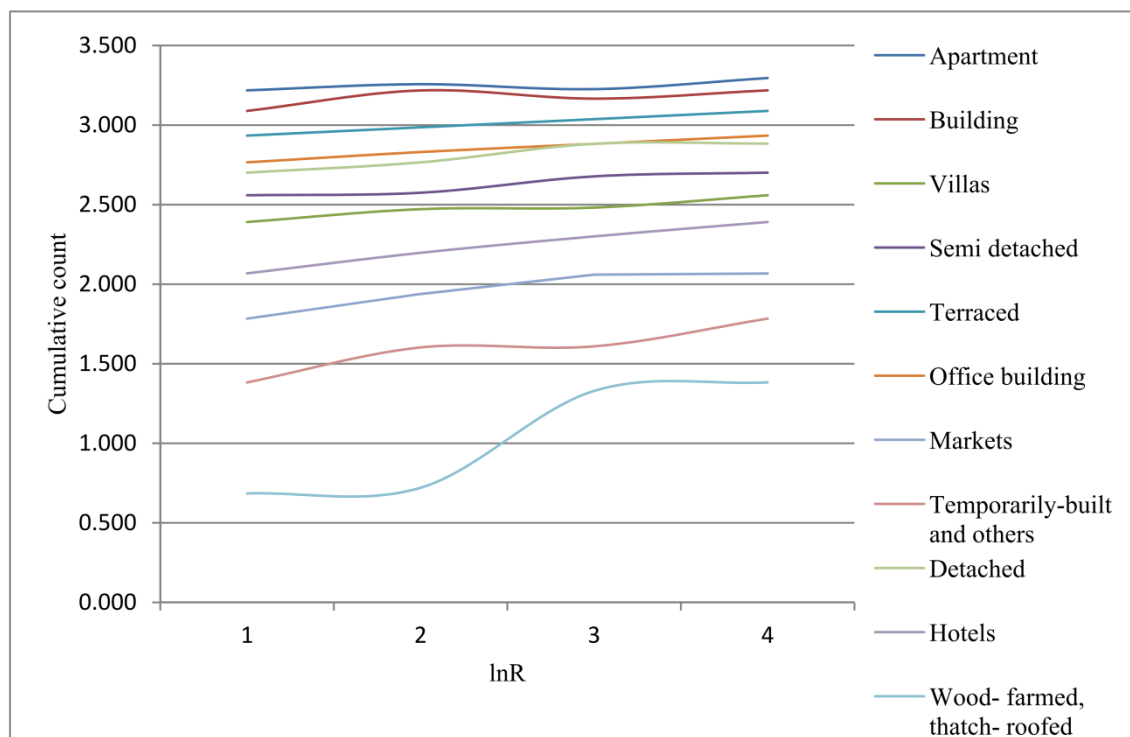


Figure 6.6: Cumulative Count Profiles of the Building Categories of HCMC

(Source: Data analysis from morphologist tool)

## **6.5 Vertical and Horizontal Distribution of Urban Density in HCMC**

### **6.5.1 Distribution of Population Density on Land-use Block in HCMC**

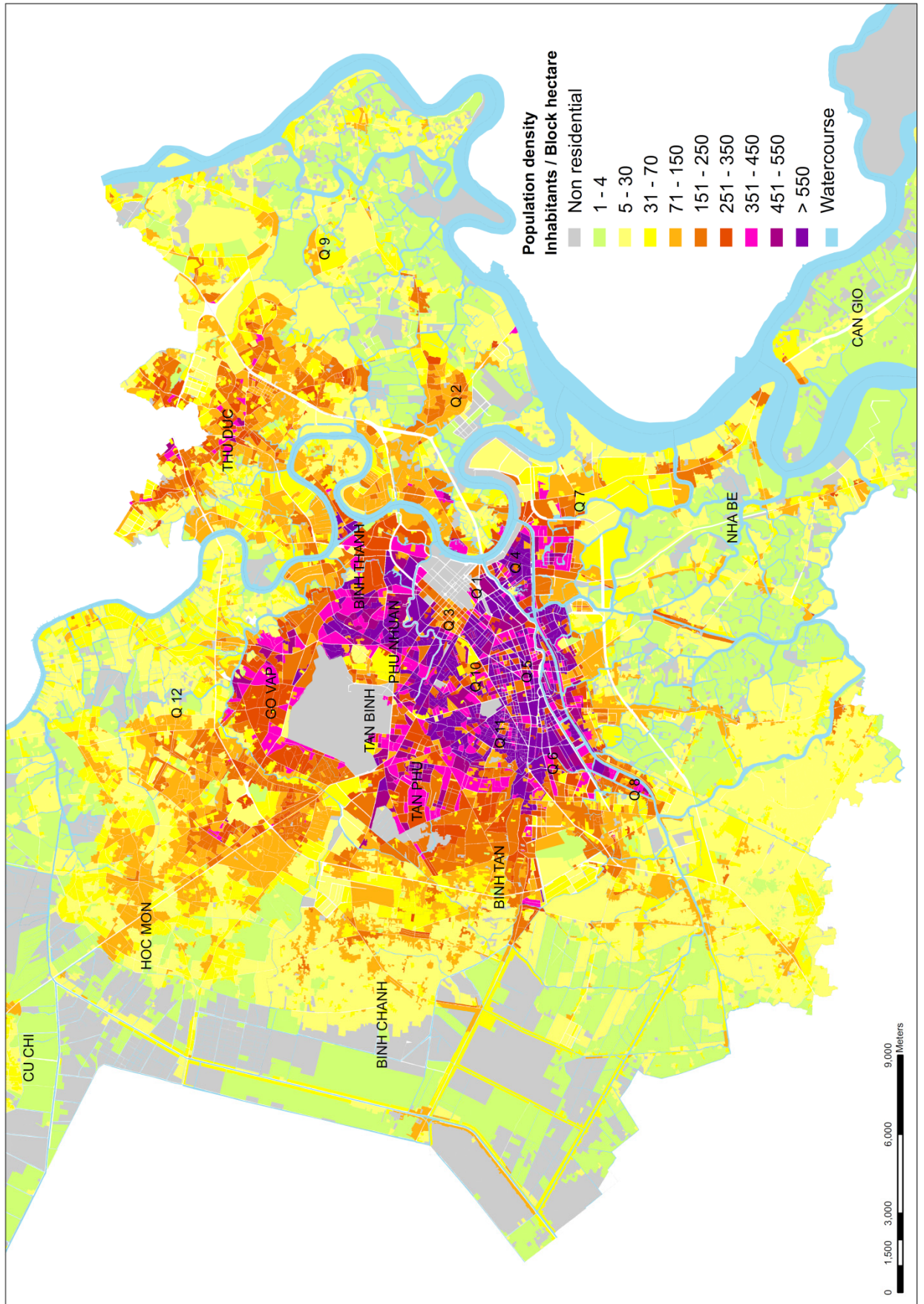
Transferring data from one set of population communes to another set of land-use blocks or building is often necessary in spatial density analysis. Based on the equations 4-5 of Section 3.5, research used GIS data of people living and building types within communes to estimate the number of people in a smaller area within the land-use block, or an area. This is defined as “the transfer of data from one set (source units) to a second set (target units) of overlapping, non-hierarchical, areal units. Area interpolation is closely related to population densities on each block (Langford et al., 1994)

The amount of population estimated to be in the intersecting block is assumed to be proportional to the amount of area in the land-use or building against commune areas. The ratio of area of land-use block to commune areas is then applied to population in the communes to yield the population total in the land-use block. Three datasets were used for this analysis: population census 2010, land-use 2010 and building 2010. Database calculated by the above analysis results contains exhaustive data at building types attributes, residential area, and land-use units.

The result showed in Map 6.3 that the population density on land-use blocks. HCMC is characterized by a heterogeneous structure between districts center such as area of District 1 and other district centers. There are large differences between population densities and block areas. Some small blocks with more than 550 persons/ha were found like in District 4, 5, 6, 8, 10, 11, Binh Thanh, Tan Binh, Phu Nhuan, Go Vap. Some high-rise buildings in large land-use blocks in District 7, 11, 10, Tan Phu and Tan Binh have high density with 350 to 550 persons/ha. The low density areas are mostly in rural with 5 to 70 persons/ha as in Cu Chi and Hoc Mon. Typical for urban peripheral is comparatively thinly populated settlements with 150 to 250 persons/ha as in Nha Be, Thu Duc, Binh Tan and District 12. This is unreasonable with the urban density in HCMC because the principle of population density increases from the city edge to the inner city (DoPA, 2010).

From the population density map, it allowed to calculate the areas, blocks, and population of residential areas in HCMC. The urban-high-density residential areas have 2,004,010 persons on 3,606 hectares (Figure 6.7 and Figure 6.9). The total blocks in these areas are 1,357 (Figure 6.8). It is a very high density residential area that has caused so many problems of drainage system and high sealed zone in the centre and led serious problems of flooding in rainy season. Some areas in here have been developed on the catchment of rivers' tributaries and small canals, and on the nature ponds such as in District 6, 8 and Binh Thanh District. These parts have been affected heavily by tide

and tidal flow in rainy season. It is a very high density residential area that has caused so many problems of drainage system and high sealed zone in the centre and led serious problems of flooding in rainy season. Some areas in here have been developed on the catchment of rivers' tributaries and small canals, and on the nature ponds such as in District 6, 8 and Binh Thanh District. These parts have been affected heavily by tide and tidal flow in rainy season.



Map 6.3: Population Densities on Land-use Block of HCM 2010

(Source: Analysis from fractal geometry)

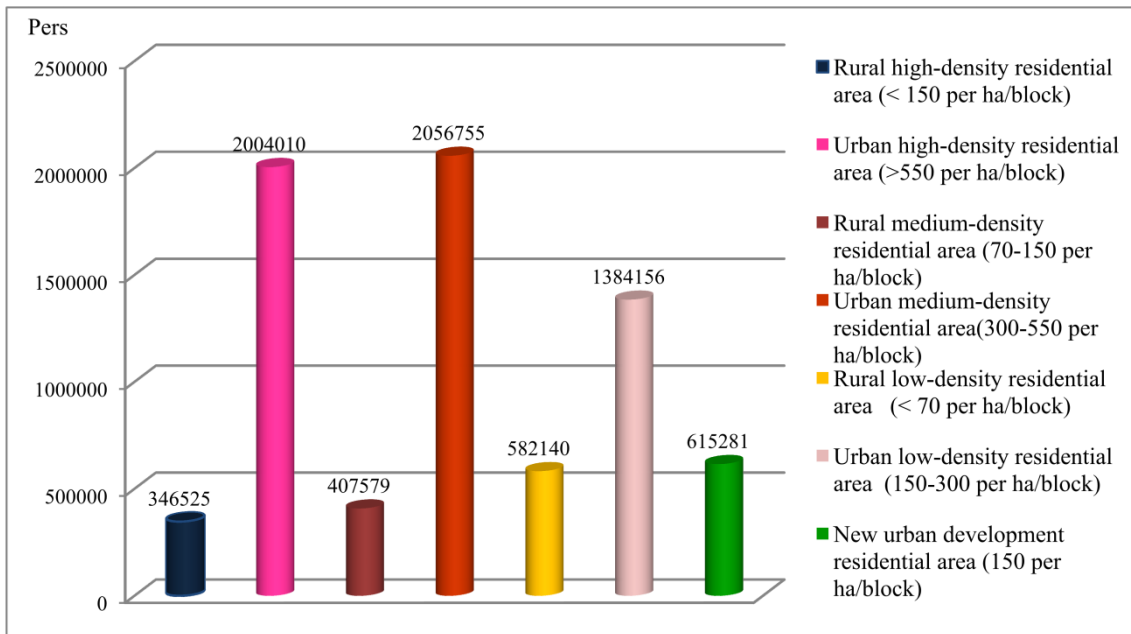


Figure 6.7: Population of Residential Density on Blocks of HCMC

(Source: Data analysis from population density map)

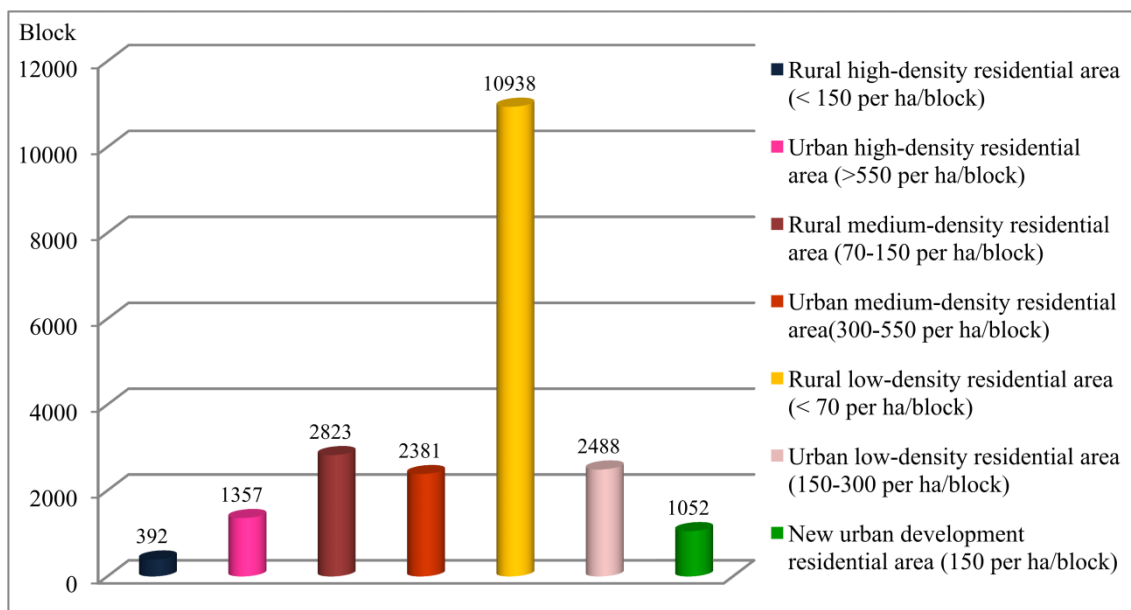


Figure 6.8: Total Blocks of Residential Density of HCMC

(Source: Data analysis from urban function map)

In the urban-medium-density residential area, the population is nearly to the urban high density residential area (about 2,056,755 persons). However, the number of land-use blocks is two times higher (Figure 6.8). This medium density areas were developed with the spontaneous residential areas in 1985 to 2005 in the District 6, 7, 11, and 12; in the North parts of Tan Binh District, Go Vap District, and Binh Thanh District. The urban planning did not calculate for long time of development and urban management did not

strictly control. These lead to the filling-up of so many natural ponds and lakes, natural drainage rivers and canals. The water storage areas in rainy season were reduced. The run-off water and tidal water cannot move down to the canals and rivers of the city. This has caused the long lasting of high inundation. The following chapter will have more explanation on this part.

The population density in urban-low-density residential areas is just 150 to 300 persons per hectare. These areas are as the transition of urban and rural areas of the city. They consist of District 2, 7 and 9; and the districts of Tan Phu, Binh Tan, and Thu Duc. This area is 8,113 hectares; and the population is 1,384,156 pers (Figure 6.9). These areas are much lower than the above residential categories. It means there are more green land and open spaces in these areas. Therefore, they can be the stored areas for re-planning and upgrading of the urban centre.

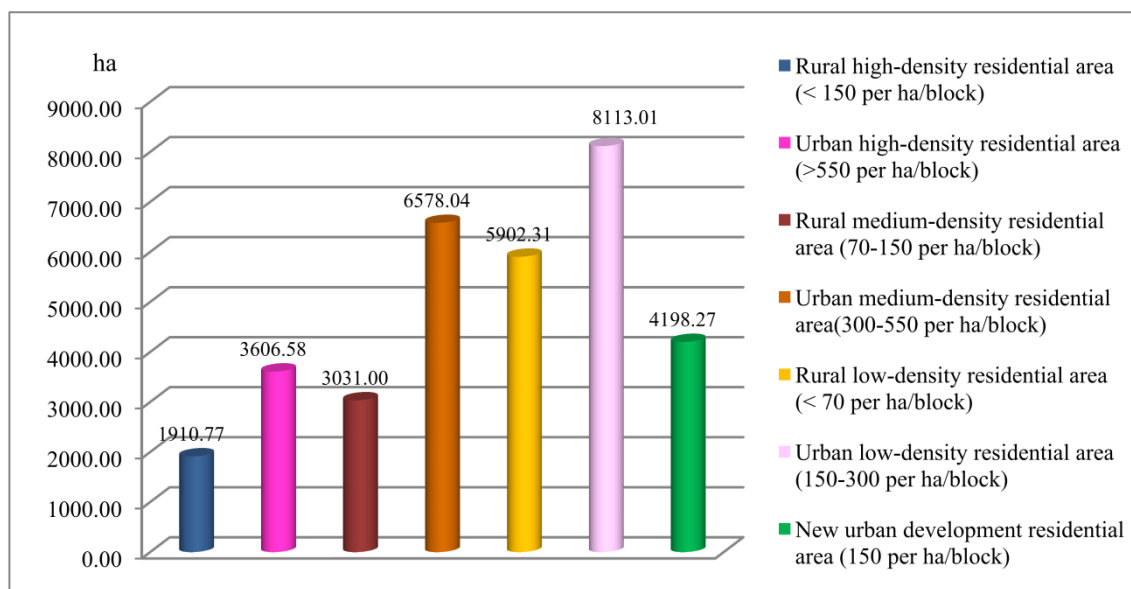


Figure 6.9: Area of Residential Density of HCMC

(Source: Data analysis from coverage ratio map)

In summation, the above results showed the city has a trend to develop new urban areas down to the low land area along the rivers of Saigon, Nha Be, and Dong Nai with the elevation lower 1.5 meter (in District 2, 7, 9, and 12). These areas in long time will be strongly impacted by inundation if the strategy for waste-water drainage and storm-water drainage systems would not be integrated into the master plan (Ho, 2008).

### 6.5.2 Distribution of Building Coverage and Floorspace Ratio on Land-use Block in HCMC

To understand the spatial distribution of building coverage and floorspace ratio in urban areas, this section used the equations (6) and (7) described in Section 3.5 of Chapter

Three to calculate the building coverage and floorspace ratio on land-use block. These results helped to identify the appropriate distribution between built-up areas and green space as well as open space in urban areas, and on land-use block. The vertical distribution of floorspace on land-use block help to understand the appropriate areas for building types distribution by the spacing-filling norms. The results on this section were based on the land-use and buildings interpretations at large scales in Chapter Five. The results at large scales with high accuracy helped to identify the small changes in urban areas at land-use block.

#### 6.5.2.1 Distribution of Building Coverage on Land-use Block in HCMC

The spatial distribution of building coverage on land-use block in HCMC was described in Table 6.3 of this section. The result figured out ten ratio categories of built-up area of buildings on land-use block ranked from 0.1 to nearly 1.0. This distribution was also demonstrated on Map 6.4 in the next page.

The ratio category at 0.1 meant the large amount of greenspace existed on land-use block. These blocks were in rural areas; or the agriculture areas existed in peri-districts as in District 7, 9, 12, and Thu Duc. This category was in rural areas, therefore, the built-up coverage of building on land-use block was very small, just 6.7% of total built-up areas of the city.

The ratio categories from 0.2 to 0.4 had about 29% of total land-use blocks of the city. These blocks had about 45% of total built-up coverage of buildings. They were mostly in rural and new urban areas. The ratio categories from 0.5 to 0.6 were in peri-districts as District 7, 12, Binh Tan, Tan Phu, and Go Vap. The blocks were only 6.8% of total but the built-up coverage was about 25% of total built-up areas. These were the new development areas with many new urban areas built in.

About the ratio categories from 0.7 to 0.8, these land-use blocks were in urban districts (as in District 1, 3, 4, 6, 8, 10, Tan Binh, Phu Nhuan, and Binh Thanh). They were about 5.4% of total blocks but the building coverage was 19.1% of total built-up areas of city. And the last two ratio categories of 0.9 and 1.0, the land-use blocks were in urban center (as in District 1, 5, 6, and 11). They were just 1.5% of total land-use blocks but the built-up coverage was 3.6% of total built-up areas.

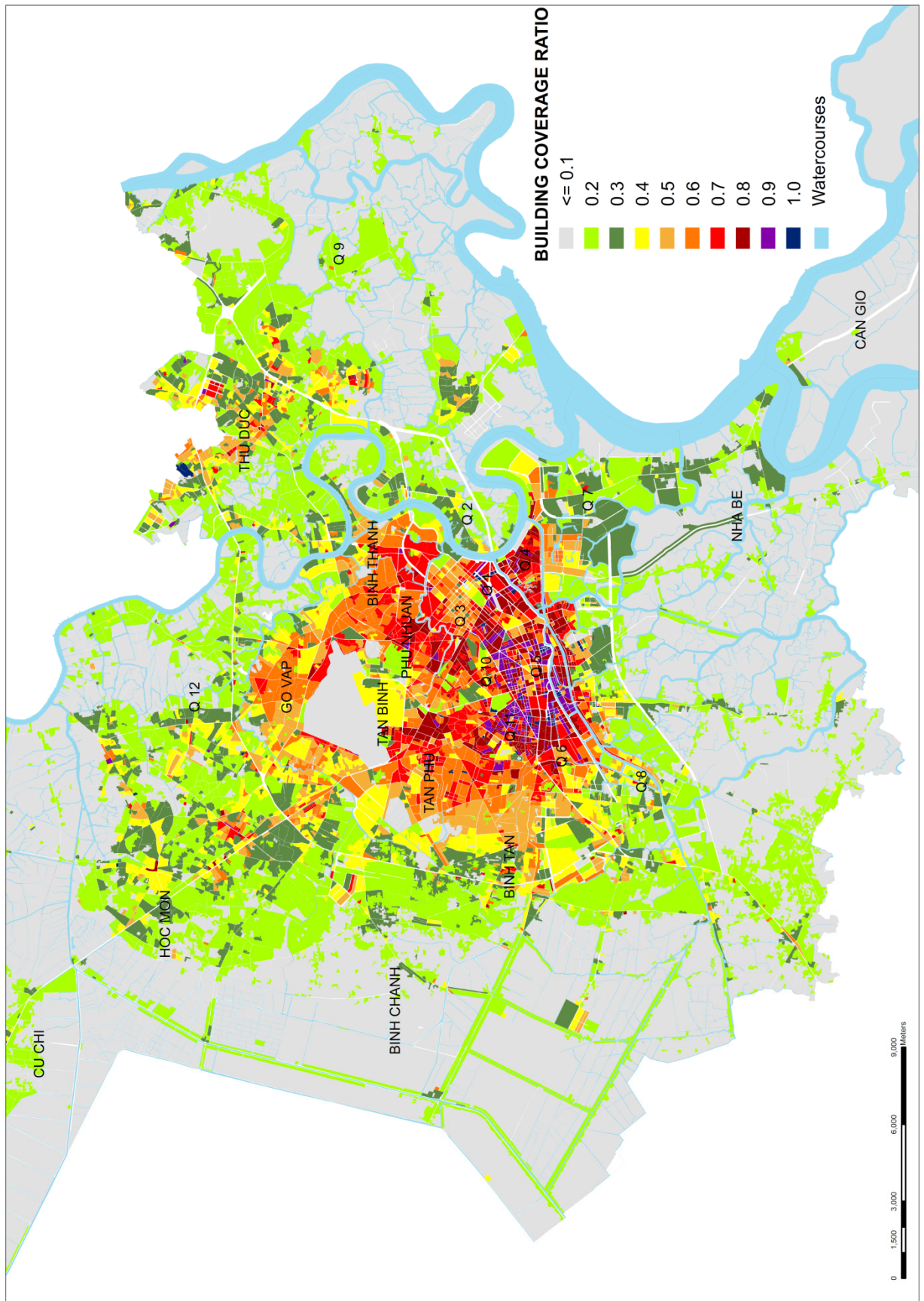
In summation, the results indicated that the built-up coverage was concentrated densely in the inner center and slow down to urban districts, peri-districts, and rural areas. There were many land-use blocks with high ratio from 0.7 to 1.0 in the center. This said that the inner center had no more openspace for urban expansion. This distribution was also demonstrated on Map 6.4 in the next page.

Table 6.3: Percent of Ground Floor of Building on Land-use Block

Building cover- age/blocks	Numbers of land-use block (%)	Numbers of building on land-use block (%)	Areas of building on land-use block (% ha)
<= 0.1	56.3	10.4	6.7
0.2	18.9	24.7	20.1
0.3	5.9	12.9	12.8
0.4	4.2	10.6	12.6
0.5	3.3	8.6	10.5
0.6	3.5	12.7	14.6
0.7	2.8	10.1	11.2
0.8	2.6	7.4	7.9
0.9	1.7	2.3	2.8
≈ 1.0	0.8	0.3	0.8
<b>Total</b>	<b>100</b>	<b>100</b>	<b>100</b>

(Source: Data analysis from building maps 2005-2010 and land-use map)





Map 6.4: Building Coverage on Land-use Block of HCMC 2010

(Source: Analysis from fractal geometry)

### 6.5.2.2 Distribution of Floorspace Ratio on Land-use Block of HCMC

The results in this section explained the relations between floorspace ratios to building coverage on land-use block in HCMC. The result presented in Table 6.4 showed the correspondence between floorspace and building coverage on land-use block. However, more details in this table and results on Map 6.5 of this section indicated some critical information as follows:

In the category of floorspace ratio on block (floorspace ratio/block) was less than 0.05: the spatial distribution was quiet low as in the first ratio category of building coverage on land-use block (ratio category was 0.1). When counting in percentage of total city, the total floors and floor-areas were very low, just 1.6% of total floors and 1.2% of total floorspace of the city. The floorspace in these areas was very low because most of Detached, Semi-detached, Temporarily-built, and Wood-framed houses were distributed in here.

The categories of floorspace ratio on block ranked from 0.2 to 1.0 had about 47.5% of total land-use blocks, and the percentages of floor and floor area were quiet high (about 52.5% of total floors and 44% of total floor areas). These areas were mostly in rural and peri-districts. And the common building types were Terraced, Detached, and Semi-detached with floor number from 0 to 1 floor. Some new urban areas here were planned for Villas terraced with 0 to 1 floor as in District 2 and District 7.

The categories of floorspace ratio on block ranked from 1.1 to 5.0 had 13% of total land-use blocks, but they had 45.7% of total floors and 53.4% of total floor areas. The common type of building was Terraced distributed in urban center and urban districts (as in District 3, 4, 5, 6, 7, 8, Tan Binh, Binh Thanh, Go Vap, and Tan Phu).

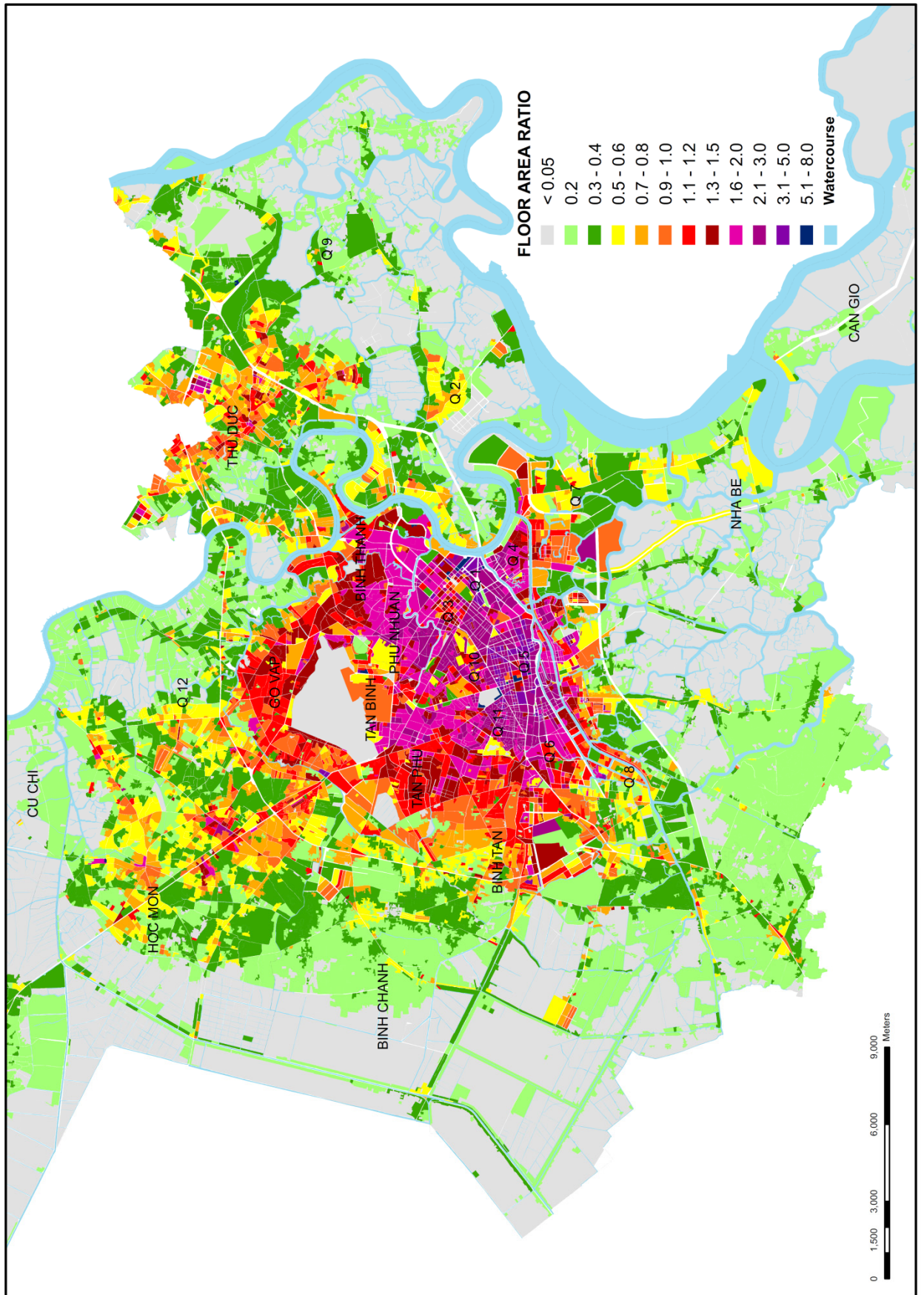
And the last category of floorspace ratio on block over 5.0 occupied very little land-use (about 0.12% of total blocks) and had less floor and floor area either. It was Office buildings and high-rise buildings in District 1, 2, 5, 7, and some in District 10 and 11. Some were Apartments and high-rise buildings in new urban of peri-districts.

These results indicated that, the urban center trended to increase the floor numbers of buildings in the small built-up areas. And the peri-districts and rural areas had lower buildings and housing. Some land-use blocks in peri-districts with high-floor-ratio on block up to 5.0 were the planned areas for new urban residential areas with the type of high-rise buildings. These results were also demonstrated on Map 6.5 in the next page.

Table 6.4: Percent of Floorspace on Land-use Block

Floorspace/block ratio	Numbers of block (%)	Numbers of floorspace on block (%)	Area of floorspace on block (% ha)
< 0.05	38.95	1.66	1.26
0.2 - 1	47.56	52.46	44.16
1.1 - 2	8.88	30.90	37.17
2.1 - 3	3.60	12.81	13.36
3.1 - 5	0.89	2.03	2.87
> 5	0.12	0.14	1.18
Total	100	100	100

*(Source: Data analysis from building maps 2005-2010 and Land-use map)*



Map 6.5: Floor Area Ratio on Land-use Block of HCMC 2010

(Source: Analysis from fractal geometry)



## **6.6 The Relation between Buildings Coverage and Floorspace of 2005 and 2010 on Land-use Blocks in HCMC**

The above Section 6.4 showed in details the density distributions of population, buildings coverage, and floor-spaces on each land-use block. These densities had explained the imbalances of urban functions, such as residential, commercial, official, and industrial areas, in development of the megacity (with over 7.5 million persons). And the result of these disordered developments was flood increase. This Section wanted to explain more on the changes of buildings coverage and floor-space on land-use block between 2005 and 2010 to clearly understand the development processes of the city.

To analyze the relation of buildings coverage and floor-space on land-use block, the multi-spatial analysis (MSA) of GIS technique was worked on different layers in different periods of time (Alexander, 1993). And in this case of HCMC, two different times was in 2005 and 2010. These layers were joined with the attributes of buildings coverage and floor-space to land-use block to see the various densities and areas of buildings coverage and floor-spaces within land-use block.

### **6.6.1 The Changing between Buildings Coverage and Land-use Blocks in 2005-2010**

Map 6.6 showed the developing trend of the city through the changes of buildings coverage area on each land-use block in the period time of 2005-2010. In Table 6.5, the changes of this relation were classified in six categories and were explained as follows:

Category 1 - On the land-use block which buildings coverage was increased up 10%: the total increased area was 224 hectares with the increase of 11,294 buildings. These areas were mostly in District 9 (partly) and rural areas of Cu Chi, Hoc Mon, Binh Chanh, and Nha Be. This increased area was the transformation of agriculture area into residential area and partly industrial area. This category was also seen very little in center districts of 3, 4, 10, and Phu Nhuan District by the transformation of open space and green space into residential area.

Category 2 - On the land-use block which buildings coverage was increased from 11% up to 20%, and Category 3: from 21 to 30%. The total increased areas of Category 2 and 3 were about 2,000 hectares (about 45% of total increased areas). The increased buildings of these categories were about 65% of total increased buildings (71,945 buildings of Category 2 and 51,052 buildings of Category 3). The increased areas in these categories were transformed from the agriculture blocks, and the blocks with residential low-density. They were normally seen in peri-districts (District 2, 7, 9, and 12, Binh Tan District) and partly rural areas of Cu Chi, Hoc Mon, Binh Chanh, and Nha Be. This transformation was for the new residential areas with various typologies of building, terraced, detached, villas, and apartment (from 2 to 3 floors). Most of these areas were

developed on low land below 1.5 meter AMSL with many tributaries surround, low quality of infrastructure, and high risk of flooding.

Category 4 - On the land-use block which buildings coverage was increased from 31% up to 40%, and Category 5: from 41 to 50%. The total increased areas of Category 4 and 5 were about 1,800 hectares (about 39% of total increased areas). The increased buildings of these categories were about 25% of total increased buildings (17,944 buildings of Category 4 and 30,165 buildings of Category 5). These blocks were planned to develop the new residential areas since 2000, therefore; the increase rate of buildings coverage was quite high. About 30 to 50% of these increased areas were seen in center districts (in District 6, 7, 8, 12, Binh Thanh, Go Vap, Tan Phu, and Binh Tan)<sup>12</sup>.

Category 6 - On the land-use block which buildings coverage was increased over 50%: the total increased area was 467 hectares (about 10% of total increased areas) with the increase of 6,445 buildings (about 3% of total increased buildings). The increased areas were in most part of peri-districts, where the new-high-rise-residential areas were planned, such as Phu My Hung, Phu My, and Him Lam in District 7; new residential areas in Wards of An Phu and Binh Trung Dong in District 2. Some open space and parks in center districts were occupied for high-rise residential areas or commercial buildings (about 2.5% of 467 increased hectares), such as new residential areas in Wards of 11, 12, and 17 of Binh Thanh District; and in Ward 10 of District 6. These open spaces and parks were very little existed in center area. And they are now over-used for high-rise buildings. The Vincom Plaza, the commercial building in Dong Khoi Street (District 1), was built on the area of green park in the urban center (See the illustrations in Figure 6.10).



Figure 6.10: The Change of Dong Khoi Park to Vincom Plaza in 2005-2010

(Source: <http://saigonphoto.net/sg/Forums/viewtopic/t=1677.html>;

<http://chothuediaoc.vn/upload/2012102523004763.jpg>

---

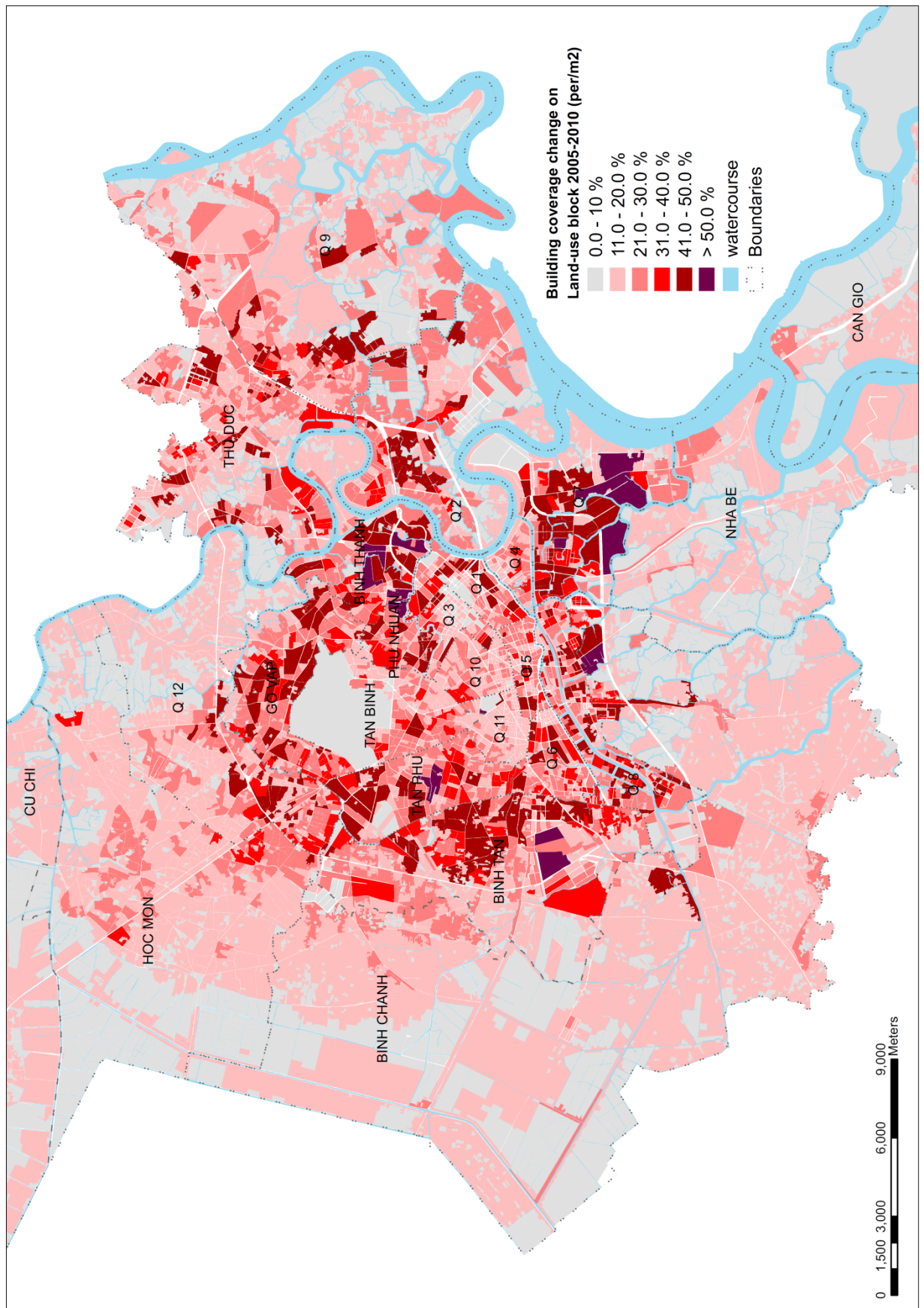
<sup>12</sup> Some new-planned residential areas such as: Rach Lao, Rach U Cay, and Hong Quang in District 8; E-City, Saigon West Villas, Manhattan City, Tan Tao A of Binh Tan District; Celadon City of Tan Phu District; City Land Garden Hills, An Hoi of Go Vap District; Binh Trung Dong – Cat Lai of District 2; the Ward-12-Residential area of Binh Thanh District; Exim Garden, Topia Garden, River Terrace of District 9; Thu Duc Garden Homes of Thu Duc District; Carillon City, Nam Phu Villas, Phu My Hung, Him Lam, Tan Hung of District 7; etc.

Table 6.5: The Changing of Building Coverage 2005-2010 on Land-use Blocks

Category	Buildings/land-use block change (%)	Increased area (ha)	Increased buildings (number)
1	0-10	224.40	11,294
2	11-20	1,021.40	71,945
3	21-30	1,074.20	51,052
4	31-40	951.70	17,944
5	41-50	860.90	30,165
6	>50	467.70	6,445
	Total	4,600.3	188,845

(Source: Data analysis from building maps 2005-2010 and land-use map)

In summation, the changes of buildings coverage on each land-use block in 2005-2010 were quite different between urban-districts, peri-districts, and rural areas. In urban districts, this change was very little: some new-high-rise housing developed on the existing residential areas in Category 1, and some open spaces and green parks occupied for high-rise buildings as in Category 6. The peri-districts and rural areas had a big change of buildings coverage on land-use block. Because of the planning strategy directed downward the South and Southwest, the change of building coverage on block in the South and southwest was higher than in the North and Northeast of HCMC (Storch et al., 2012).



Map 6.6: The Changing Building Coverage 2005-2010 on Land-use Block of HCMC

(Source: From building maps 2005-2010 and Land-use map)



### 6.6.2 The Changing Between Floorspaces and Land-use Blocks in 2005-2010

The results in Table 6.6 described the increased areas and numbers of floorspaces on land-use block in HCMC (also classified into six categories). Map 6.7 showed that, the increased area of floor-space on land-use block from 0 to 10% (Category 1) was distributed in rural areas (about 329.4 hectares), with 1.0 floor increased. The total number of increased floor-spaces was 11,261 floors (about 2.2% of total increased floor areas). The unused land in this rural area is still high, therefore; the increase rate of floors was still small. The increased area of floor-space on land-use block from 11 to 30% (Category 2 and 3) identified on Map 6.7 was distributed in the areas between peri-districts (of District 2, 7, 9, 12, and Thu Duc) and rural areas (of Binh Chanh, Hoc Mon, and Nha Be). The increased floors were various among these areas, because of inconsistent planning in HCMC.

Map 6.7 showed the increased area of floor-space on land-use block from 31 to 50% (Category 4 and 5). The location of these blocks was mostly in planned areas with good infrastructure, such as in District 2 (Thao Dien Ward), 7 (Phu My Hung), 6, 8, 9, Binh Thanh, Tan Phu, and Binh Tan. The common typologies on these blocks were Terraced (3-5 floors), Villas (2-3 floors), Office buildings (4-5 floors), and Apartments (5-6 floors). These types are being developed to have more housing in HCMC. However, they have caused the big problems of increasing encroachment on low land (such as lakes and ponds, rivers and canals), where were the water storage areas of the city. And they led the increase of flooded and flood-prone areas in HCMC.

Blocks which had an increased area of floor-space on land-use block over 50% (Category 6) was distributed in the center (for office and commercial buildings) and urban-districts (for high-rise residential buildings). They were in District 1, 2, 7, 10, 11, Tan Binh, Binh Thanh.

Table 6.6: The Changing Floorspaces 2005-2010 on Land-use Blocks

Category	Floor-space/land-use block changes (%)	Areas increase (ha)	Number of floor-space increased	Average of floors increase on land-use block
1	0-10	329.41	11,261	1.0
2	11-20	2,212.63	108,735	1.5
3	21-30	2,189.05	129,595	2.5
4	31-40	2,275.93	94,813	5.3
5	41-50	3,154.34	112,834	3.7
6	>50	2,235.80	45,691	7.1
Total		12,397.16	502,929	

(Source: Data analysis from building maps 2005-2010 and Land-use map)

In summation, the results of this Section showed that the high-density of built-up areas in the center seemed to have no more land for new development and no more land for new park and green trees. The urban development has trend downward to the South and Southwest, where the low-land area (below 1.5 meter AMSL) largely distributed. And many green trees and open spaces exist in these areas. If city government has no good planning strategies from now, these low-land areas would be invaded for new development. And city would face to the high-risk of widespread flooding, as in the high-flood areas of current center.



## 6.7 Summary for Chapter Six

The results of this chapter have developed the important links between spatial analysis and the results of combination Remote Sensing and GIS, especially in the result of fractal geometry. Fractal geometry highlighted the spatial distribution and density of built-up, non built-up areas in urban, peri-urban and rural districts. These links offer the prospect of enhancing our understanding of how urban morphology produced from classified urban land-use types and building types can describe, and hence prescribe, change in the morphological and functional characteristics of settlement.

The relationship between densities of population, building footprints and floor-space showed that the areas with high population density correspond with high densities of building footprints and floor-space. In contrast, the area with low population density had low densities of building footprints and floor-space.

Urban morphology analysis identified the improper distribution of urban functions (residential, commercials, officials, industrial, green space, and open space, etc.):

- In urban districts 61% of total land is for residential use.
- Only 1.3% of total land in urban districts is reserved as green space.

There is a need to explore more deeply the way in which fractal geometry can be used in the spatial analysis of urban areas, and how fractal measurement might be used to assess the way in which patterns of urban land-use vary across space.

The final point is that measuring the residential density in HCMC is a basis of the study of urban morphology and it will extend a basic material for urban planning. This part is a timely application of new analysis methods to tractable and relevant function problem in HCMC. Urban morphology analysis on urban residential areas can aid the understanding of flooding impacts and its drivers for HCMC.

On the other hand, this part found an easier way of measurement of urban morphology and applied it in the research of HCMC. It found, based on this analysis, that the distribution of the residential density is closely related to development of the city as well as the pattern of land-use. And it impressed out differences between the urban function in HCMC and the actual density of urban residential (Luong, 2008). These results highlighting the importance of urban density indicators for flood risk assessment.

## **7 FLOODING IMPACTS ON URBAN MORPHOLOGY IN HO CHI MINH CITY**

According to the result of Chapter Six, it provided densities on urban morphology in HCMC, including urban densities, rural densities, open spaces, and building types. It showed that HCMC has the problems of the irrational development in residential densities areas and urban functions. For this reason, urban floods have occurred in the city recently, besides the causes that were mentioned in Chapter Four. Ho. L. P (2008) showed that flooding in HCMC is not only in the low density areas, but also in the high density areas.

This chapter aims to identify the flooded areas based on the flooding data (statistic data, elevation map, base map, and morphology map), analyze and assess the flooding impacts to urban functions in HCMC.

### **7.1 Identification Approach to Flooding Analysis in HCMC**

#### **7.1.1 Identification Approach Based on Flooding Information in HCMC**

As descriptions of urban development factors and flooding problems caused the flooding increase in HCMC mentioned in Chapter Four, Section 4.1 and 4.2, long time urbanization has caused the following serious problems:

- There is the expansion of built-up area from urban districts to rural and peri – districts for developing housing, residential areas and public works. High demand on urban land led to the occupation of open spaces, parks and green trees in urban center. These areas have roles of infiltration and evaporation for center city.
- The rural immigration has resulted in the increases of houses in unplanned areas, slums and squatters in low-land areas, and along the canals and rivers. This expansion without planning led to the low quality of infrastructure, especially drainage system to collect waste water and run-off water in these areas.
- During the expanding process, the blowing-up of built-up coverage has filled up many small streams and tributaries, natural lakes and ponds in low-land areas. These areas have important roles for collecting and storing the run-off water of the whole city. Therefore, when they were decreased, the flood-prone areas were increased. The water storage, therefore, has been narrowed and the run-off water has increased on the ground surface. In the rainy season, it causes more inundation and flooding.

- The dynamics of development has caused problems on city planning and management. They have brought disorder in housing typologies, urban functions. The city planning could not follow the urbanization process, especially infrastructure and drainage systems.

### 7.1.2 Methods of Flooding Identification for HCMC

In the data system for flooding identification, besides the elevation map, statistic flooding data, and the flooding map 2010; the statistical maps of original ponds, lakes, rivers and canals before filled-up (maps of 1995 and 2009) are very important and necessary to find out the flooding reason. And one more important data is the urban function map of HCMC in 2010. The use of ranking impact severity and weighting impact significance is described by various authors such as Sadar & Dirsch (1996), Biswas & Agarwala (1992). Therefore, all the data layers to identify for flooding impact base on GIS are described in the Figure below.

To do the analysis process on Figure 7.1 below, the method of multi-criteria analyses (MCA) along with analysis tool of ArcGis area used to estimate the flooding impacts on the urban morphology map in the city. This is done by an overlay of the different maps (Eastman, 1999). The intersect tool of ArcGis is used with data on maps of watercourse in 1995 and 2009 map of topography, and satellite image 2010 to prove the result of filling up rivers and canals as well as ponds and lakes during the urbanization period 1995-2010. This is one of the important reasons which lead the flooding increase in HCMC.

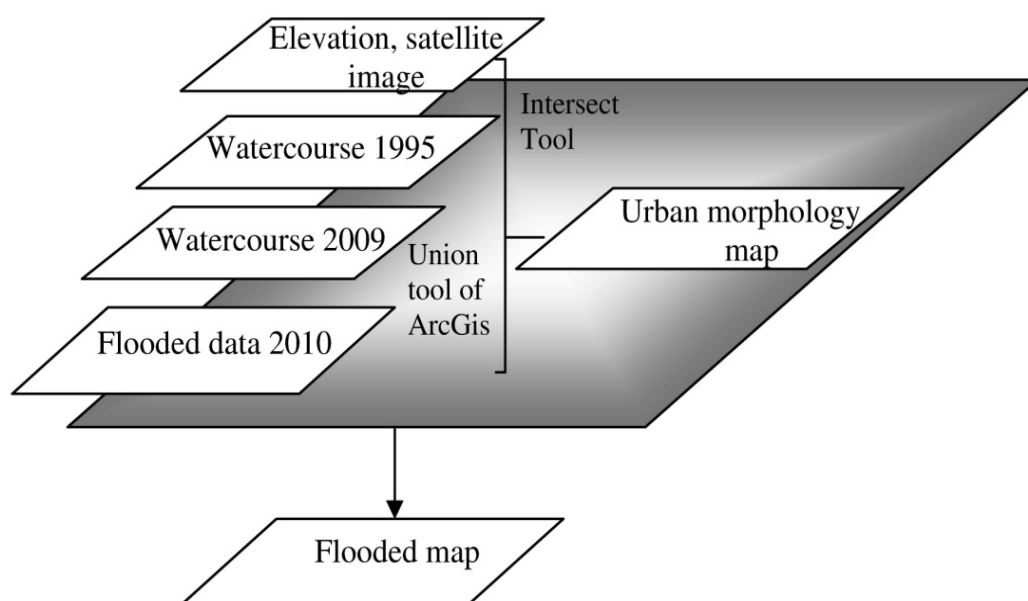


Figure 7.1: GIS analysis framework developed in flooding impacts on urban morphology

The entire above flooding database integrated with the results of urban morphology analysis presented in Chapter Six, helps to understand the impacts of flooding on the specific areas of urban functions such as on residential areas, building types, and land-use blocks, etc.

## **7.2 Flooding Impacts in HCMC**

### **7.2.1 Flood Areas in Flood Types and Geographical Elevation in HCMC**

From reported flood data in 2010 (see Appendix 11.1), flooding map of HCMC of the Steering Center for Urban Flood Control Program (SCFC) and urban morphology map (in Map 7.1), it showed the impact of flooding on the area, its reasons and expansion by months of year 2010. All data was integrated into GIS to analyze the flooding impacts to urban morphology.

By the results, flooding in HCMC came about from three reasons of rain and tide and it happened in three types of floods: (1) flooded by rain; (2) flooded by tide; and (3) flooded by both rain and tide (Ho, 2010).

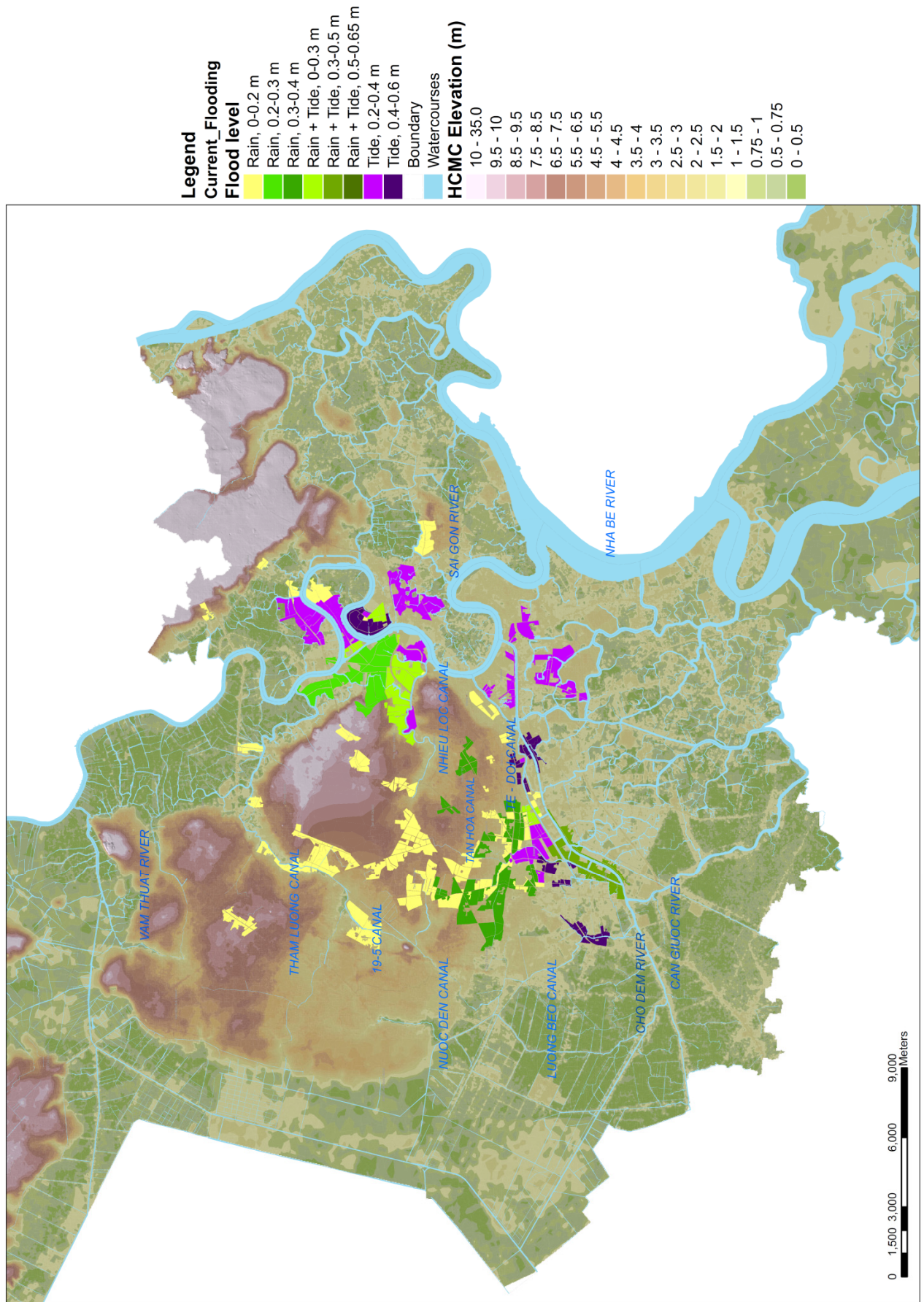
Flooding by rain usually visit HCMC from June to November every year. Depending on rain intensity, flooding may be more or less. The flood level is from 10 to 30 cm in 20 to 60 minutes. When the rain intensity is more than 50 mm, flood level is higher (SIHYMETE, 2011).

Flooding by tide comes to city even in dry season, about four to six times per year. The flooding statistic data explained when tidal flow had risen up to 1.35 m; the catchment of rivers and canals in below 1.0 m or areas below 1.0 m without drainage system would be flooded. The average flood level in these areas is around 20 to 60 cm. And flooding comes two times a day: from 5 to 8 in the morning; and from 16 to 20 in the evening.

Flooding by both rain and tide normally happens in the rainy season. The flooding time lasts longer and the water level is 25 to 60 cm in average. (SIHYMETE, 2008 & Ho, 2010).

The research results in Table 7.1 had described the flooded areas affected by three flood types in HCMC. Flooding by rain occupied the largest area with 2,031.95 hectares. By tide is 1,076.29 hectares and by both rain and tide is 454.14 hectares. As explained in the above Section 7.2.1, most of the flooded-by-rain areas have a high built-up density, old and overload drainage, and the high filling-up of canals or ditches or lakes in urban areas.





Map 7.1: Flooded Map of HCMC 2010

(Source: SCFC - HCMC Steering Center of Flooding Control Program, 2010)



Table 7.1: Flooded Impact Areas 2010 of HCMC

Flooded impact areas	Rain (ha)	Rain & Tide (ha)	Tide (ha)
Urban areas	2,031.95	454.14	1,076.29
Rural areas	29.74		12.48
Total	2,061.69	454.14	1,088.77

(Source: Data analysis from flood map and urban morphology map)

The flood by tide mostly occupied the urban areas were developed after 1995. These areas had high frequency of filling ponds and lakes, small streams around the canals and rivers. They are in the low land area; therefore they are affected easily by tide. Another important reason of flooding here is the sediment of solid waste on the canals that leads the canals narrower and shallower. The canal beds have been considerably dredged or not dredged for long time. This leads to accumulation of huge quantity of pollutants from wastewater and solid waste dumped which causes sludge and adverse effects on city drainage. The small and slow water flow on the canals has caused the longer inundation in these areas.

The flood areas by both rain and tide happen only when the high tidal flow in the heavy rain (over 90mm of rain intensity) (ADB, 2010). They are the transition area between the flooded-by-tide and flooded-by-rain areas.

In rural, flooding mostly visits in the new rural residential areas. The flooded areas by rain and tide are not much, and in shorter time of flooding; because the land has low-constructed density and can be highly permeable. The main reason of flooding here is because of the incomplete drainage system.

## 7.2.2 Reason Identification of Flooding in HCMC

### 7.2.2.1 The Relations between Filling-up of River and Canals to Flooding in HCMC

According to the statistic data from DoNRE (2013), all areas of HCMC have 27 main networks of canals and ditches with the length of more than 310 kilometers. In which, the length of mainstreams and branches of these river systems are 55.6 kilometers and 36.4 kilometers, respectively. The density of stream is about 4 m/ha. These river systems are responsible for drainage and are wastewater-receiving sources of HCMC. They are highly influenced by tide. Almost all canals and ditches in the inner city were narrowed by the illegal housing and constructed area (Le, 2009). Those are canal systems of Nhieu Loc-Thi Nghe, Tan Hoa-Lo Gom, Tau Hu-Ben Nghe, Kenh Doi-Kenh Te and Tham Luong-Ben Cat whose bottoms are gradually shallower by the waste matter, trash

from houses, and constructions. While canals in sub-urban areas are relatively good, they are natural or artificial canals for the rural agricultural land.

In the new-development districts of 7, 9, 12, and Thu Duc, canals and ditches were filled-up to develop the new urban areas. Such as Phu My Hung area in District 7 (about 700 hectares) is located in the low-land of canal catchment of Kenh Doi-Kenh Te. This leads to the water drainage becoming much more difficult. In the long run, local flooding and inundation would be increased in these areas and the time of flooding would be longer (Ho, 2007).

On the other side, the analytical results from the map of canals and ditches in Map 7.1 showed the big changes of this system during 1995-2009. There were 23.96 kilometers of canals and ditches filled up during this period. Especially, the inner-center (districts of 4, 6, 8, 11, Binh Thanh and Tan Phu), more than 8 kilometers of canals were totally filled-up. Many areas in the elevation below 1.5 m in District 2, 7, 9, 12, Binh Tan, and Thu Duc, the area of canals and ditches were filled-up to 160 hectares in the length of 16 kilometers. In 2006 there were 182 places on this system filled-up by housing; most of them are in new districts and sub-districts (To, 2008).

Most of these canals and ditches are small with 2 to 5 m width; however, they have the important role in water storing and water drainage from the residential areas into the main rivers and main drainage system (To, 2008). Therefore, the flooded areas by rain and tide have more impacts because of this reason. The increase of run-off water causes the longer inundation and higher flooding.



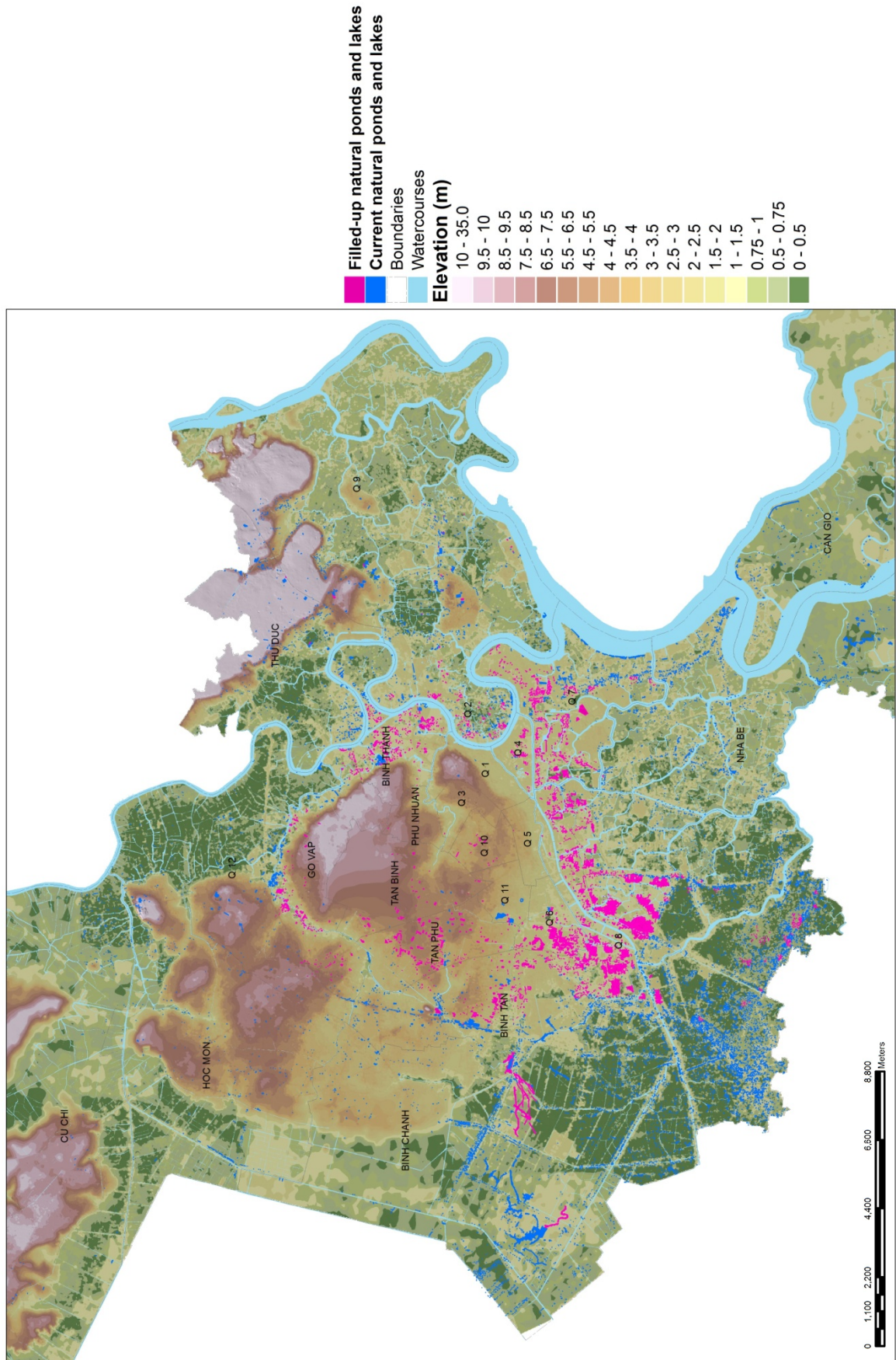
### 7.2.2.2 The Relations between Filling-up of Natural Lakes and Ponds to Flooding in HCMC

To the natural ponds and lakes, there were about 1,500 hectares that were filled up during 1995 – 2009 of the whole city. In which, the inner center was about 496.9 hectares, mostly in districts of 4, 6, 8, 11, Binh Thanh, and Go Vap (see Map 7.3). In sub-urban and new-development districts, the filled-up area is up to 932.1 hectares, including District 2, 7, 9, 12, Thu Duc, Binh Tan, and partly Binh Chanh Sub-district. Most of them were in low-land areas below 1.5 m. These lakes and ponds were the natural water storages of the city to adjust water in the rainy season or the reservoirs from the up-stream areas.

In comparison between the land-use map 2010 and buildings map 2010, these filled-up lakes and ponds were replaced by the new urban residential areas. Especially, these located in the South of Tau hu Canal and had the role as water storage areas when flood and tide come. And this explained why flood is increasing seriously in District 8.

In District 6, 11, Binh Tan and Tan Phu, the increasing of filling-up natural lakes and ponds caused the widespread flooding. Especially in District 6, 11 and Binh Tan, when many new residential projects were being constructed, flooding would be more serious.





Map 7.3: The Changes State of the Natural Ponds and Lakes in Inner City (1995-2009)

(Source: Analysis from watercourse maps 1995 -2009 of DoNRE)

### 7.2.2.3 Urban Expansion and Flooding in HCMC

The urban expansion in HCMC was discussed in many parts of previous chapters (as in Section 4.1 and 4.2 in Chapter Four, and the analysis results in Chapter Five and Six). The spontaneous urbanization since the Doi Moi period in 1986 had resulted in the urban expansion into peri-areas, in rural and agriculture areas (Le, 2009; Nguyen & Duong, 2007; Luong, 2008; Vu, 2010). Urban development in uncontrollable planning and management caused disorder distributions of urban function areas, residential areas, and housing typologies (DoPA, 2010). And especially, urban sprawl had filled up many river tributaries, natural lakes and ponds, and caused rapid decrease of greenspace and openspace in urban areas (DoPA, 2010; DoT, 2010). The disappearance of these greenspace and openspace, lakes and ponds caused the decreases of infiltrated and permeable areas, and water storage areas in the city.

The results of the land-use map and buildings map 2010 in Chapter Five had demonstrated the expansion of residential areas and increase of built-up coverage; and the decreases of agriculture and rural areas in the city. These enhanced the sealing surface and growing flows of run-off water in the ground surface. Furthermore, the inappropriate and disordered distribution of spatial density of urban residential areas as discussed results in Chapter Six (Section 6.3 and 6.4) had driven flooding increasing in the city. Therefore, the widespread expansion of urban residential areas was one remarkable reason of flooding in HCMC. And this will be strong discussed in the next section of this chapter.

## 7.3 Flood Impact on Residential Areas in HCMC

Sections 7.1 and 7.2 described most of the flooding areas are in the urban districts, the residential areas. Flooding has impacted buildings of many housing typologies and people living in there, etc. Flooding has left the impacts on urban functions and caused the remarkable barriers to urban development (Gill et al., 2010). This section analyzes in detail the flooding impacts on residential areas, population sector, building sector in HCMC.

### 7.3.1 Flooding in Residential Areas in HCMC

In the GIS analysis's results in Table 7.2 and Map 7.4, the flooded residential area has expanded to 3,562.38 hectares (19.5%) in the total urban residential area of 18,233.35 hectares. In which, flooding in high-density residential area was 738.42 hectares; in medium-density residential area was 1,582.05 hectares; in low-density residential area was 887.49 hectares; and in new-urban-area was 354.42 hectares. And the flooded area in rural residential area was 42.22 hectares (0.6%) in the total 7,105.91 hectares, with

medium-density residential area was 36.52 hectares; and low-density residential area was 5.7 hectares.

In the urban high-density residential area of urban area (over 550 persons per hectare per block), flooded area was 20.4% of total 3,606.58 hectares of high-density residential area, and 20.7% of total urban flooded area. It consists of districts in the old central urban (District 3, 4, 5, 6, 8, 10, and 11). It has flooded area by rain with a water level from 30 to 40 cm in District 6, 8, 10, and 11. And the flooded area by tide and by both rain and tide located along the Kenh Doi-Kenh Te Canal, where they had the high filling-up of ditches in the past. Its flood level was from 50 to 65 cm (Nguyen et al., 2007).

To the urban medium-density residential area (about 300 to 550 persons per hectare per block), flooded area was 24% of total 6,578.04 hectares, but it was about 44% of total urban flooded area. In which, flooded area by rain was 17.27% (1,136.18 hectares) with water level from 10 to 20 cm; by tide was 4.88%; and by both rain and tide was 1.89%. The flood level of the last two types was 20 to 40 cm. This residential area had the water level lower than in the high-density residential area and located in districts of Go Vap, Tan Binh, Tan Phu, Binh Tan, and Binh Thanh.

The urban low-density residential area (about 150 to 300 persons per hectare per block) has mostly been developed from agricultural land since 1998. The green-tree density here is still high; however, flooding still visits in 10.94% (887.49 hectares) of total area in the rain season, because of the incomplete infrastructure system here. The level of flood by rain was from 20 to 30 cm; and by tide or by both rain and tide was from 20 to 40 cm. Some areas are in the catchment of Sai Gon River as in District 2, 7, and Thu Duc.

And to the new-development residential area, developed since 2000, the average population density is 150 persons per hectare per block and the built-up density is less than 0.5. Because it is in the below 1.5 m elevation, flooding by tide (6.78%) was higher than by rain (1.71%). The filling-up of canals and ditches in here has made the flooding more serious in the future. Flooding in rural area was much less impacted to the urban area. It was just flooded in the short time and in small scattered areas.

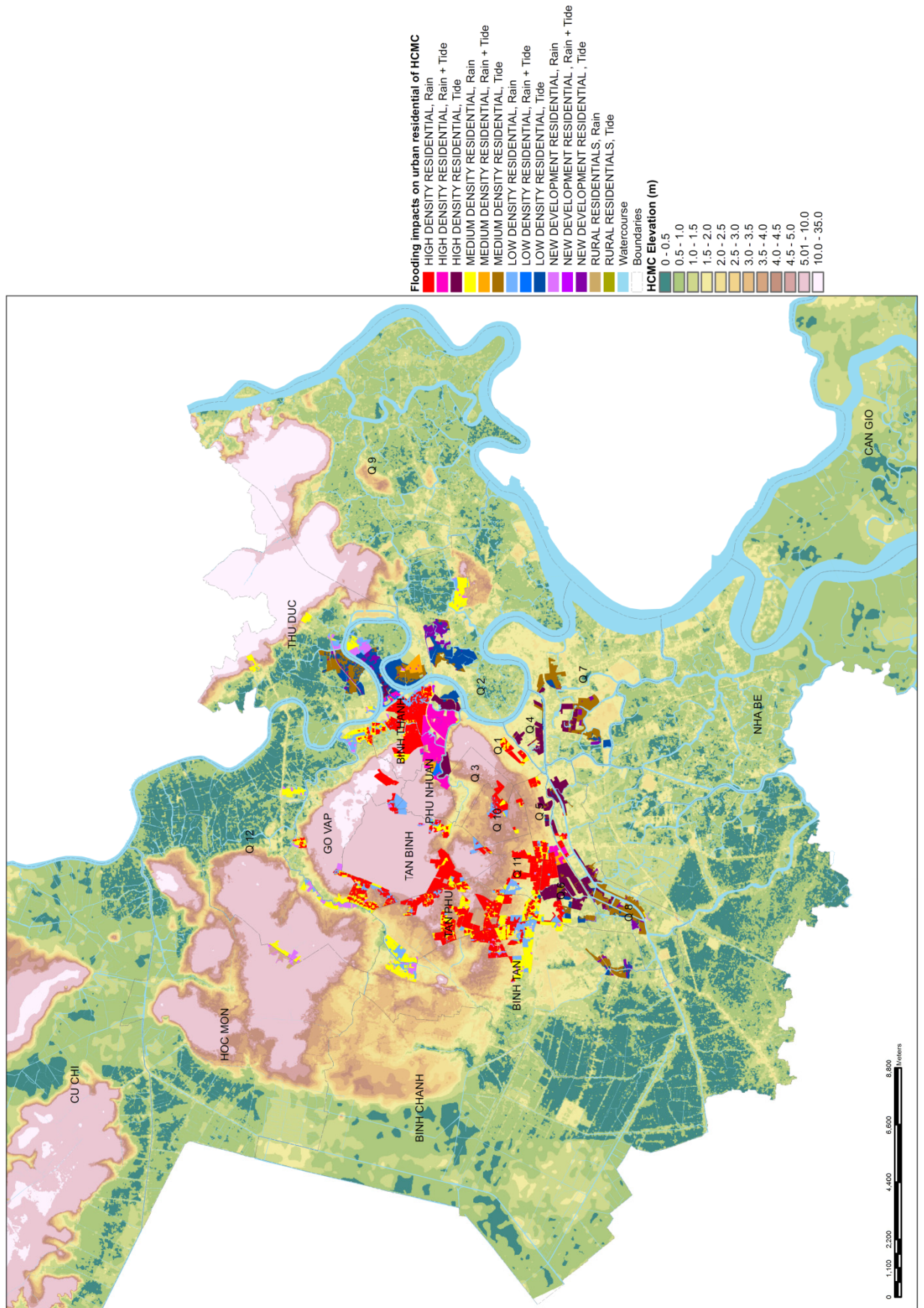
In summation, flooding in the urban residential area was more impacted than in rural residential area, having higher flood levels and longer flooding time. It has caused the tangible and intangible impacts on social and economic aspects and on the environment, such as traffic transportation, pollution, housing downgrading and difficult living, etc. (Muller, 2007).

Table 7.2: Flooded Impacts on Residential Areas of HCMC

Residential areas in HCMC	Rain (ha)	Rain & Tide (ha)	Tide (ha)	Total Flooded impact (ha)	Total Urban & rural residential areas (ha)
Urban high-density residential area (> 550 per ha/block)	322.25 8.93%	212.68 5.89%	203.49 5.64%	738.42 20.47%	3,606.58
Urban medium-density residential area (300- 550 per ha/block)	1136.18 17.27%	124.58 1.89%	321.30 4.88%	1,582.05 24.05%	6,578.04
Urban low-density resi- dential area (150-300 per ha/block)	501.59 6.18%	109.07 1.34%	276.83 3.41%	887.49 10.94%	8,113.01
New urban develop- ment residential area (150 per ha/block)	71.92 1.71%	7.82 0.19%	274.68 6.54%	354.42 8.44%	4,198.27
Rural medium-density residential area (70-150 per ha/block)	29.74 0.98%	-	6.78 0.22%	36.52 1.2%	3,031.00
Rural low-density resi- dential area (< 70 per ha/block)	-	-	5.70 0.10%	5.70 0.10%	5,902.31
<b>Total</b>	<b>2,061.69</b>	<b>454.14</b>	<b>1,088.77</b>	<b>3,604.60</b> 11.47%	<b>31,429.21</b>

(Source: Data analysis from flood map on urban function map)





Map 7.4: Flooding Impacts on Urban Residential Areas of HCMC

(Source: Analysis from flood map and urban function map)

### 7.3.2 Reason Identification of Flooding in Residential Areas in HCMC

#### 7.3.2.1 Relation of Population Density on Urban Morphology to Flooding in HCMC

Flooding has many impacts on residents in HCMC. The population who was directly impacted from flooding came up to over 424,000 persons. More than 171,000 persons were impacted by rain in high-residential area; and more than 170 thousand persons in medium-residential areas. And the many others have been indirectly impacted by flooding through the daily social and economic activities in the city (Wilbanks et al., 2007).

Population was affected by flooding types in different-density-residential areas was explained in Table 7.3. And along with the flooding reasons described in Section 7.1, it has shown the problems on the master plan, urban management and planning of the city. The water-storing areas and infrastructure, especially drainage systems were not strictly control during development.

Table 7.3: Population in Flooded Areas

Residential areas in HCMC	Rain (Pers.)	Rain & Tide (Pers.)	Tide (Pers.)	Total (Pers.)
Urban high-density residential area (>550 per ha/block)	83,978	47,547	39,942	171,467
Urban medium-density residential area (301-550 per ha/block)	123,879	18,182	28,662	170,723
Urban low-density residential area (151-300 per ha/block)	33,528	6,928	18,559	59,015
New development residential area (150 per ha/block)	6,353	2,644	8,010	17,007
Rural medium-density residential area (71-150 per ha/block)	4,217		1,381	5,598
Rural low-density residential area (< 70 per ha/block)			413	413
<b>Total</b>	<b>251,955</b>	<b>75,301</b>	<b>96,967</b>	<b>424,223</b>

(Source: Data analysis from flood map and population density map)

### 7.3.2.2 Relation of Buildings Density on Urban Morphology to Flooding in HCMC

The results from Table 7.4 and Map 7.5 below analyzed by using the intersect tool in ArcGIS 10.01 showed the impacts of flooding to the urban residential area of HCMC.

More than 74,000 buildings in HCMC were impacted in the flooded areas by rain. They mostly were terraced and detached housing. The urban medium-density residential area had the largest number of flooded building with 41,035 buildings; two time higher than in urban high-density residential area. But the flood level was lower than in urban high-density residential area. And therefore, building damages and property loss in urban high-density residential area were much higher than in the urban medium-density residential area. It is because this area is in the urban center where the business and commercial activities are concentrated.

On the other hand, the urban high-density residential area had 16,000 buildings impacted by tidal flood. They consist of terraced, wood-framed, thatch-roofed, temporarily-built houses and villas. These building types have often been seen in the catchment of rivers and canals, where the drainage system is incomplete to access to the residential area (Meliefste et al., 2008).

In urban low-density residential area, there were 13,542 buildings had been flooded by rain (including detached, terraced, and semi-detached houses) and 5,685 buildings had been flooded by tide (including detached, villas).

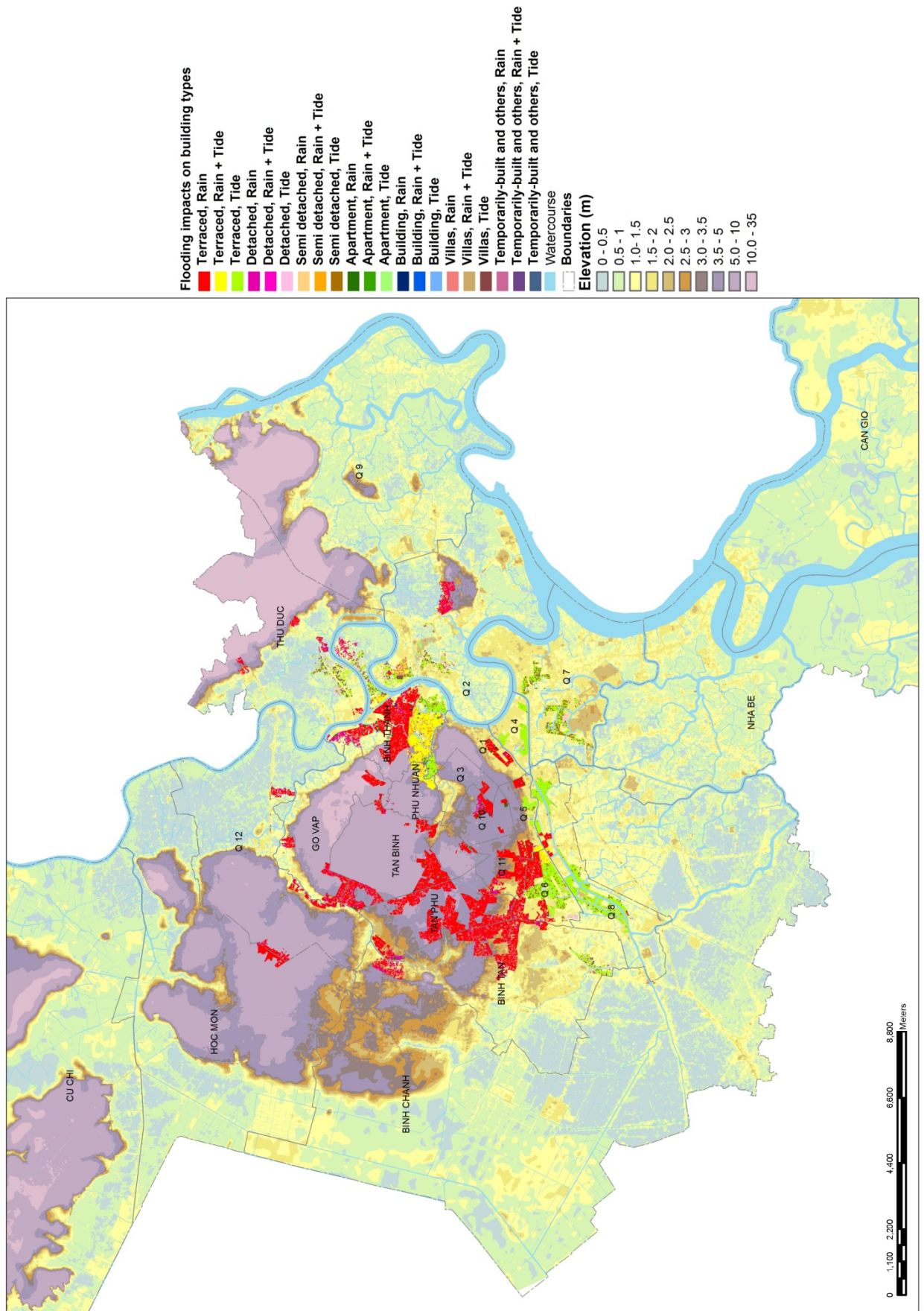
Buildings in the new development residential area were less impacted than others. It was about 1,909 buildings flooded by tide, mostly villas and detached. And about 1,031 buildings such as terraced, detached and villa was flooded by rain in this area.

Table 7.4: Number of Building Footprints in Flooded Areas of HCMC

Residential areas	Rain (No)	Rain & Tide (No)	Tide (No)
Urban high-density residential area (>550 per ha/block)	17,504	11,165	8,760
Urban medium-density residential area (301-550 per ha/block)	41,035	3,926	8,143
Urban low-density residential area (151-300 per ha/block)	13,542	2,431	5,685
New development residential area (150 per ha/block)	1,031	210	1,909
Rural medium-density residential area (71-150 per ha/block)	918		126
Rural low-density residential area (< 70 per ha/block)			54
<b>Total</b>	<b>74,030</b>	<b>17,732</b>	<b>24,677</b>

(Source: Data analysis from flood map and urban morphology map)





Map7.5: Building Types in Flooded Areas

(Source: Analysis from flood map and building map 2010)

## 7.4 Summary for Chapter Seven

From all of the above results, it helps to understand that flooding in HCMC was not by climate change totally, however, by urbanization. The results from urban morphology analysis showed the uneven development of population and residential density between the urban areas: too much in the inner center. This requires more land for built-up area and demand of filling up rivers and canals. It made the imbalance between the permeability of land surface and the run-off water flows; then leads the inundation increasing. The master plan could not follow the strategic plans in the flooding area and resulted in the master plan failing. It was about 19% of urban residential area, 0.6% of rural residential area, and 116,438 building footprints impacted by flood caused by rain, tide and by both rain and tide.

The results also showed the importance of how rivers and canals, ponds and lakes filled-up during the urbanization. It is the main reason to reduce the water-storage capacity during flooding and in rain season. Therefore it is necessary to return these rivers and canals, ponds and lakes to their original states (Jha et al., 2011).

## **8 POTENTIAL AREAS FOR FLOODING ADAPTATION IN HO CHI MINH CITY**

### **8.1 Identification Approach to Flooding Adaptation in HCMC**

The results of Chapter Seven proved that flooding mainly impacted residential areas in the urban center of HCMC, including 3,207.96 hectares. The main reasons were the high residential density in high coverage density (about 300 to 500 persons per hectare per block and coverage ratio 0.7-0.9). These reasons have increased the impervious surface in this area. About 80% of original ponds and lakes in the urban-center were filled-up in the past; and 63% of ponds and lakes have been filled-up in peri-districts and new-urban-development areas. The results also showed 23% of agricultural land reduced in 2005 to 2010. And in 1995 to 2009, there were 23.96 kilometers of rivers' tributaries filled-up. In which, the filled-up tributaries in center was 8 kilometers.

By these results, flooding in HCMC was not the process of sea level rise by climate change. Most of flooding areas were in high elevation areas, above 1.5 meters. And no matter how the high or low tidal level was at the Phu An meteorological station, only with the rain fall of 50mm, there were about 70% of flooding points in these elevated areas (Ho, 2010). It means that, most of the flooding points in HCMC are not mainly by the low geographical elevation or the increase of tidal level of Saigon River, but by rapid urbanization and the irrational development of urban residential areas.

The potential area for flooding adaptation mapping is based on work overlaid by multi-factors and objects (Janssen, 2000). The combination of this, with the surface cover analysis developed by Lamond et al. (2012), provides a useful basis for further flooded analyses of the urban residential areas. Based on the results of urban morphology analysis in Chapter Six and flooding impact analysis on urban function in Chapter Seven, the main following adaptive solutions in this research are suggested for flooding adaptation to HCMC:

1. To identify the potential function residential areas for flooding adaptation.
2. Increasing the run-off water collection for flooding adaptation (water-storage areas-lakes and ponds and water-infiltration areas-green space).
3. Restoration of rivers and canals system to flooding mitigation.

## 8.2 Method for Flooding Adaptaion in HCMC

To reduce flooding impact, the potential urban areas in HCMC for flooding adaptation were mapped in this research by using the accessing criterion (such as: population density, urban residential, floor-area ratio, flooded area and elevation map, etc.) in analyzing urban morphology. An appropriate application for analyzing the adaptive areas is the multi-criteria analysis (MCA). It helps to determine the adaptive process to the potential areas. The mapping analysis will finalize the potentials of different urban areas in HCMC.

To estimate the flooding adaptation of the areas, the measurable factors such as population density, urban function area, floor-area ratio, flooded area and elevation map are combined into maps to identify the potential areas for residential development (Mukheibir & Ziervogel, 2007). The important advantage of the MCA method is the ability to analyze the different factors at different levels of elevations to finalize the potential areas for flooding adaptation (see more in Section 3.7 of Chapter Three). Every measure of urban morphology, urban residential, building coverage ratio, floor area ratio, flood impact and elevation, etc. applied into thematic maps to evaluate the data-values they represented.

The flowchart in Figure 8.1 was developed to present the steps of information of different criterion used in analyzing process. This flowchart indicates the thematic maps of criterion as the input data for the process of finalizing the results.

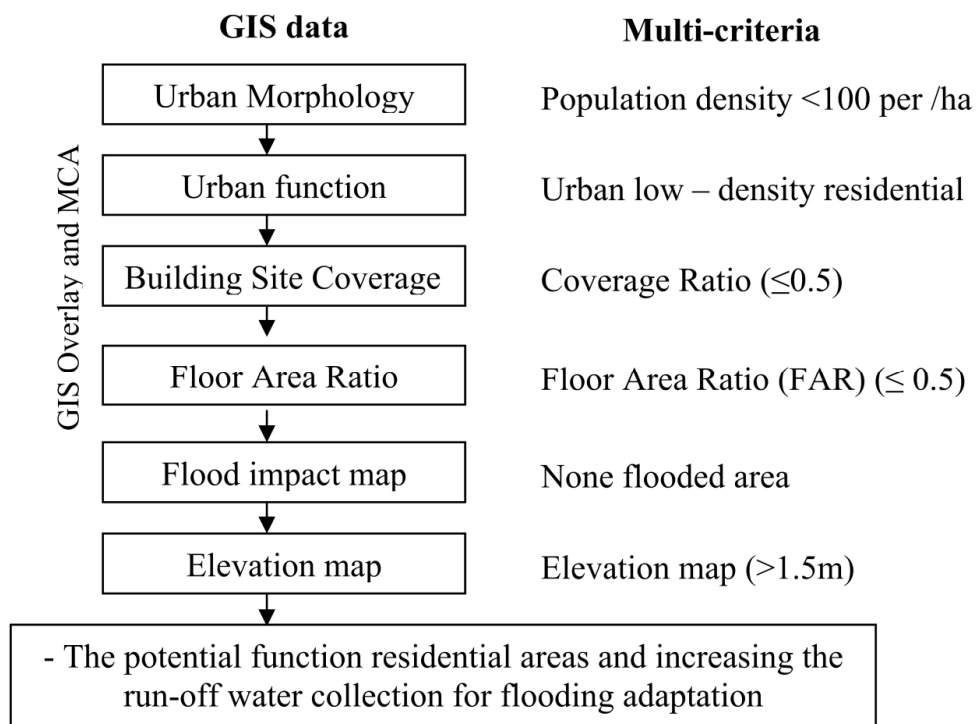


Figure 8.1: Flowchart of Potential Flooding Adaptation in Urban Areas

To find a quantification of potential areas for flooding adaptation of the advanced location alternatives, six intermediate layers were considered in this research: urban morphology, urban function, building coverage, floor area ratio, flooded impact and elevation map. A general approach was used to determine the potential areas of these established adaptation criteria (Table 8.1):

Table 8.1: List of Multi-Criteria for Flooding Adaptation

	Multi-criteria of the potential areas for flooding adaptation	Description
1	Population density < 100 per / ha	Relatively low
2	Urban low-density residential area	Relatively low to moderate; Buildings density: 20 -50 (# / ha)
3	Coverage ratio ( $\leq 0.5$ )	Relatively moderate
4	Floor Area Ratio (FAR) ( $\leq 0.5$ )	Relatively low
5	Non flooded area	Areas without impact of flooded residential
6	Elevation map ( $> 1.5\text{m}$ )	Areas with elevation $> 1.5\text{m}$ are less flood areas

### 8.3 Flooding Adaptation to Urban Residential Areas

The results of the creation of the potential areas for flooding adaptation were composed from the six layers used as discussed above. The flooding adaptation had been evaluated to include the exposure criteria and viewed these criteria as part of the adaptation criteria for urban flooding.

Map 8.1 on the next page was the result of the MCA method. The results showed that about 5,473.9 hectares of potential urban areas would be the places for flooding adaptation in HCMC (see Table 8.2). They are in six districts of Binh Tan (1,808.65 hectares), District 12 (1,436.08 hectares), District 9 (977.39 hectares), Thu Duc (780.06 hectares), District 2 (453.41 hectares), and Tan Phu (18.37 hectares) with 42 communes included. These districts are the new planning for urban development, therefore, the infrastructure and urban services in these areas are incomplete.

The areas in Binh Tan District and District 12 located in the West and North-West of the city have the geographical elevation above 1.5 meter AMSL. There are many undeveloped lands there with large areas. And the undeveloped land in Tan Phu District is about 18 hectares. The coverage density and residential density here are quite low. Therefore, they could be the new adaptive urban residential areas.

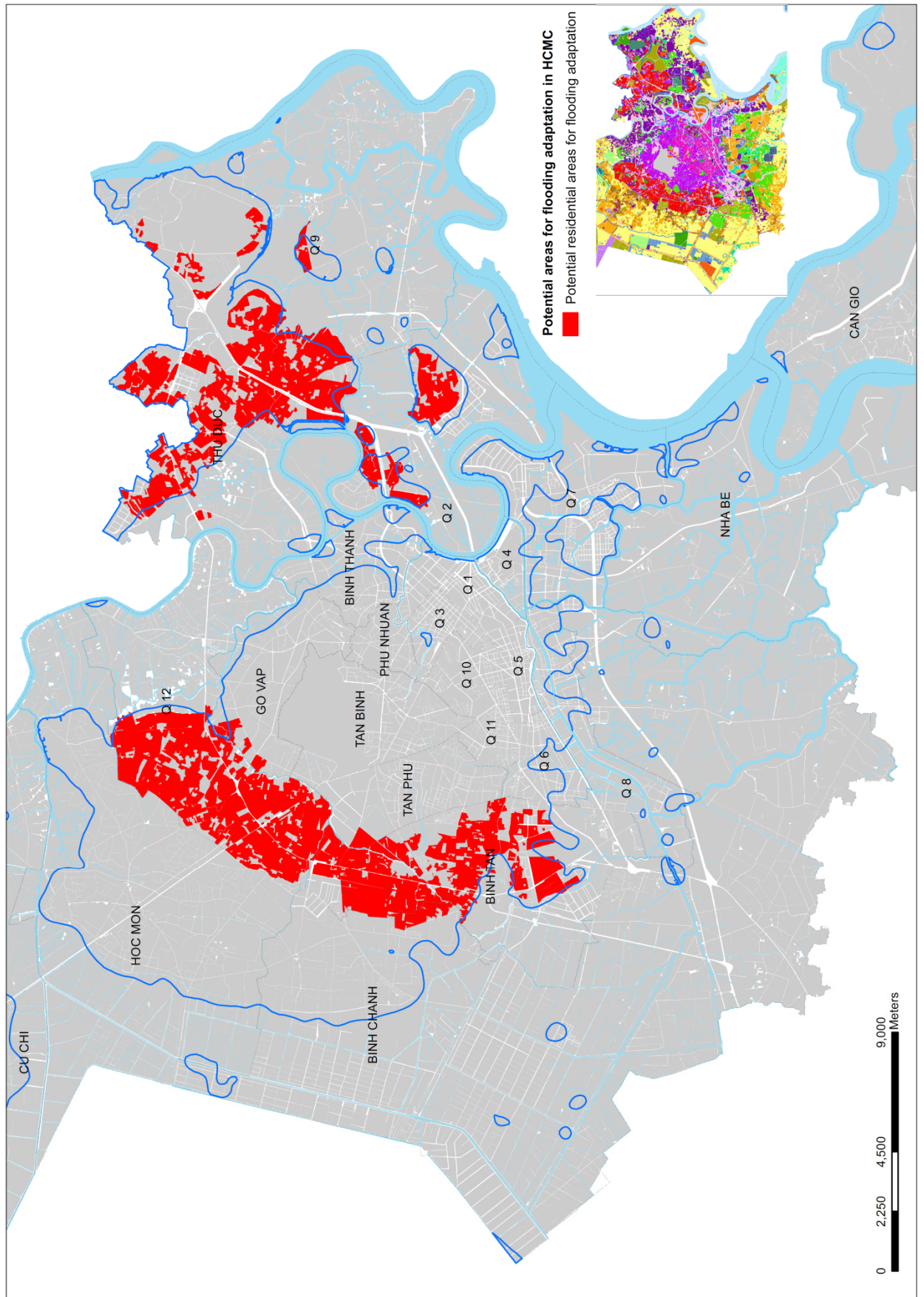


The results also showed the areas in the East and North-East of the city in District 9, 2, and Thu Duc, where that has some strips of land above 1.5 meter AMSL with low coverage density and residential density would be appropriate to the criterion of flooding adaptation.

Table 8.2: The Potential Residential Areas for Flooding Adaptation in Northwest and Northeast Districts of HCMC

Districts	Communes	Areas (ha)
Districts (a)	Districts in the Northwest	
12	7 Communes	1,436.08
Binh Tan	9 Communes	1,808.64
Tan Phu	1 Communes	18.37
Total (a)		3,263.09
Districts (b)	Districts in the Northeast	
2	7 Communes	453.41
9	7 Communes	977.38
Thu Duc	11 Communes	780.07
Total (b)		2,210.86
Total (a+b)		5,473.95

(Source: Data statistics from MCA on urban function map)



Map 8.1: The Results of Flooding Adaptation to Urban Residential Areas of HCMC

(Source: Analysis from MCA)

The analyzed data for the areas identified above showed that they would be the most potential areas with all appropriate conditions for adapting the current-flooded-residential areas (see Map 8.1). Now, if city government would have the proper master plan and support policies to people moving out by themselves from the flooded areas to the potential residential areas with lower built-up density, the city would reduce floods in the current flooding areas (Jha et al., 2011). The new residential areas should have an available infrastructure system (such as: transport system, altitude basis for construction and drainage system) and urban services (such as: housing infrastructure, schools and markets, etc.) to attract people in the current-flooded-residential areas of the inner city with high population density, and people in the filled-up rivers, ponds and lakes of the center areas (such as the areas in District 6, 8 and Binh Thanh District).

The current flooded residential areas, then, would reduce the terraces to develop the water-storage areas and permeable areas, such as green parks, green trees, ponds and lakes, etc. This re-planning would improve the city landscape and increase green spaces and open spaces to HCMC. The green spaces, lakes and ponds will help to reduce the temperature of urban center in the dry season. And especially, these adaptation solutions would reduce at least 25% of current flooded areas in urban center (Sheltair, 2003).

However, these proposed solutions require the coordination of government at levels, responsible departments and institutions, such as Department of Natural Resources and Environment (DoNRE), Department of Architecture and Planning (DoAP), Department of Transportation (DoT), Department of Construction (DoC), Sub-Institute of Hydrometeorology and Environment of South Vietnam (SIHYMETE), Institution of Irrigation and Planning, etc. as well as social organizations to have the comprehensive solutions for the planning.

## **8.4 Increasing the Run-off Water Collection for Flooding Adaptation**

The results of Chapter Seven explained the urbanization was the main driven factor of flooding in HCMC. The urbanization has narrowed the agricultural land, green space and open space. It has also caused the filled-up process of rivers and canals, lakes and ponds, where were the water storages and permeable areas of HCMC. Therefore, the group of adaptive solutions is to increase the permeable surface, restore and conserve lake and pond systems in the city (Jha et al., 2011).

### **8.4.1 Flooding Adaptation to Permeable Surface to Ho Chi Minh City – The Green Space**

The GIS analysis results from the urban morphology map and urban function map in Table 8.3 showed the total areas of parks and green trees in urban districts and peri-

districts (peripheral area) were 187.99 hectares and 542.53 hectares. In urban districts, the average ratio of green trees per person was very low, about 0.47 square meters per person. The average area of eighty-six parks and green spaces in these areas was from 0.15 to 25 hectares (DoT, 2010). However, about 30% to 40% of these parks were constructed with high impermeable surface (see Figure 8.2). The average area of green trees in peri-districts was 2.45 square meters per person. And the average area of ninety-six parks and greenspaces in these areas was from 0.75 to 125 hectares.



Figure 8.2: Illustrations of Built-up Parks with less Greenspace of HCMC

(Source: <http://khudothimoi.com/tintuc/dau-tu-quy-hoach/3005-du-an-bai-do-xe-cong-vien-le-van-tam-duoc-khoi-cong.html>, 10 August 2010; <http://www.saigonnews.vn/doi-song/37113-go-vap-co-khu-vui-choi-moi-cho-thieu-nhi.html>)

Table 8.3 described the spatial distribution of greenspace density in urban districts and peri-districts of HCMC. In comparison to flooded areas in these districts, it showed the remarkable relationship between greenspace density and flooding increase in HCMC. The urban districts with very low greenspace had tended to be flooded by rain, such as District 11, Go Vap, Phu Nhuan, Tan Binh and Tan Phu. The urban districts which have large networks of canals (such as District 6, 8, and Binh Thanh), beside of low greenspace, they had many filled-up lakes and ponds. Therefore, they had the larger flooded areas. The average greenspace per capita in urban districts was 0.48 square meter.

In peri-districts, the average greenspace per capita was about 2.51 square meters, five times higher than in urban districts. However, there was different distribution of greenspace density among them. The lowest greenspace density was in Thu Duc District with 0.27 square meter. And the highest was in District 9, where they were concentrated with many green parks and amusement parks in this area. Most of peri-districts locate in lowland areas, therefore, the flooded areas here were mostly by tide.

Table 8.3: The Potential Areas of Urban Greenspaces for Flooding Adaptation of HCMC

Urban districts	Parks and green spaces (ha)	Population 2010	Green spaces area/Pers (m <sup>2</sup> )	Flood areas (ha)
1	58.03	187,435	3.10	7.22
3	4.23	188,945	0.22	14.32
4	7.83	183,261	0.43	45.96
5	6.12	174,154	0.35	69.25
6	10.67	253,474	0.42	308.75
8	5.68	418,961	0.14	397.81
10	3.74	232,450	0.16	133.39
11	1.32	232,536	0.06	323.70
Binh Thanh	31.98	470,054	0.68	422.34
Go Vap	52.00	548,145	0.95	93.27
Phu Nhuan	0.89	175,175	0.05	91.66
Tan Binh	2.17	430,436	0.05	210.61
Tan Phu	3.33	407,924	0.08	202.19
<b>Total</b>	<b>187.99</b>	<b>3,902,950</b>	<b>0.48</b>	<b>2,320.47</b>
Peri-districts	Parks and green spaces (ha)	Population 2010	Green spaces area/Pers. (m <sup>2</sup> )	Flood areas (ha)
2	51.71	140,621	3.68	214.14
7	14.49	274,828	0.53	171.38
9	409.91	263,486	15.56	242.22
12	41.45	427,083	0.97	115.97
Binh Tan	12.47	595,335	0.21	322.92
Thu Duc	12.50	455,899	0.27	175.28
<b>Total</b>	<b>542.53</b>	<b>2,157,252</b>	<b>2.51</b>	<b>1,241.91</b>

(Source: Data statistics from MCA analysis)

By these results, the adaptive solutions to these districts and peri-districts are to protect the current green spaces and restore the permeable surface by reducing the constructed areas and planting more trees in current parks and open spaces (Jha et al., 2011). The green space also offers some potential for flood storage through sustainable urban drainage systems such as swales, infiltration, detention and retention ponds in parks (Mansell, 2003; CIRIA, 2000).

To the peri-districts, it is necessary to increase the permeable surface in current parks and green spaces. The new parks and green spaces should be developed in the low-land areas. These parks and green spaces will improve the micro climate and specially, they have function to store the water when tidal flows and heavy rains come (WB, 2011b). These solutions will help to decrease from 5 to 10% or flooded areas in urban districts. And the peri-districts would not be flooded in the near future.

#### **8.4.2 Flooding Adaptation to Water-Infiltration Areas for Agriculture in Peri-Districts**

Map 8.2 and Table 8.4 also showed the remaining agricultural areas were only 64.76 hectares near the rivers and low-land areas in Binh Thanh District (in Ward 13 and 28), Go Vap District (Ward 5 and 12), and Tan Phu District (Tay Thanh Ward). These areas have a positive role to reduce the flood by tide and rain in surrounded areas. One of example is the agricultural area in Ward 13 and 28 of Binh Thanh District, near the Saigon River. When tidal floods come, the flooded level is lower and the shorter time, because flood water run into this area. However, the agricultural area in urban area is decreasing for new urban areas (Nguyen & Duong, 2007). Therefore, it is necessary to have the timely planning for these areas to be the water storage areas, or the permeable surface for receive water when tidal flows and heavy rains.

The agricultural areas in peri-urban districts are 3,384.25 hectares in districts of 2, 7, 9, 12, Binh Tan and Thu Duc. They are below 1.5 meter AMSL and along the Sai Gon and Dong Nai Rivers. They are the natural permeable surfaces to adjust flood water from the higher-land when heavy rains come and tide flood from the Rivers.

Therefore, to adapt the flooding and climate change in HCMC, the necessary solutions are to conserve the current agricultural areas; increase green-tree areas; and restrict constructing in these areas. Furthermore, the complete drainage system would help to reduce better flood for these areas (Tucci, 2007).

If these adaptive solutions would be applied in city planning, there would be 7% to 12% of flooded areas in the city come down. The solutions also support to adaptive strategy to flooding by sea level rise in the future.

Table 8.4: The Analysis Results of Agriculture Areas and the Permeable Surface for Flooding Adaptation of HCMC

Urban districts	Areas (ha) (1)	Peri-districts	Areas (ha) (2)
8	4.61	2	449.09
Binh Thanh	42.75	7	184.27
Go Vap	12.17	9	2,110.05
Tan Phu	5.25	12	312.88
		Thu Duc	203.07
		Binh Tan	124.89
Total (1)	64.78	Total (2)	3,384.25
Total (1+2)		3,449.03	

(Source: Data statistics from MCA analysis)







## 8.5 Flooding Adaptation to Water-Storage Areas – Lakes and Ponds

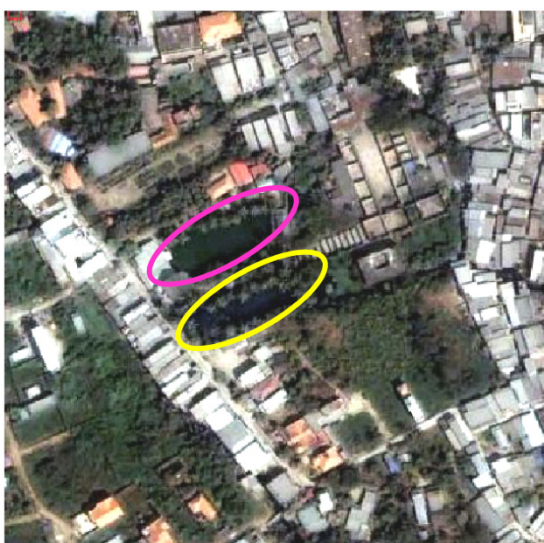
This research also showed another outcome from urbanization result in HCMC was the filling-up of rivers and canals, lakes and ponds in the low-land areas of districts and peri-districts for the new-urban residential areas. From the watercourse data in 1995 to 2009 combined to the GeoEye image 2010, this research had identified the filled-up areas of lakes and ponds in this period.

Map 8.3 and Table 8.5 finalized the total filled-up areas of lakes and ponds in urban Districts were 496.9 hectares (about 84.5%). The largest filled-up areas were in District 6, 8, 11, and Binh Thanh District (Figure 8.3). These areas also were the highest flooding areas in urban center.

In peri-districts, the areas of lakes and ponds filled-up were about 932.1 hectares (about 63.78%). They mostly are below 1.5 meter AMSL. The new-urban residential areas here are totally flooded by tide. In the future, when the tide level increases, these areas would be affected stronger.

Therefore, the suggestion to adaptive solutions in this part is to conserve the current ponds and lakes and restore the filled-up ponds and lakes in the low-land areas, where could be the water storage areas in flooding time (Tucci, 2001).

When these solutions would be applied, HCMC would reduce more 5 to 10% of flooded areas. And to the peri-districts, this solution would help to reduce 15 to 20% of flooded areas.



2 Ponds in Ikonos image 1999



2 filled-up ponds in Ikonos image 2010

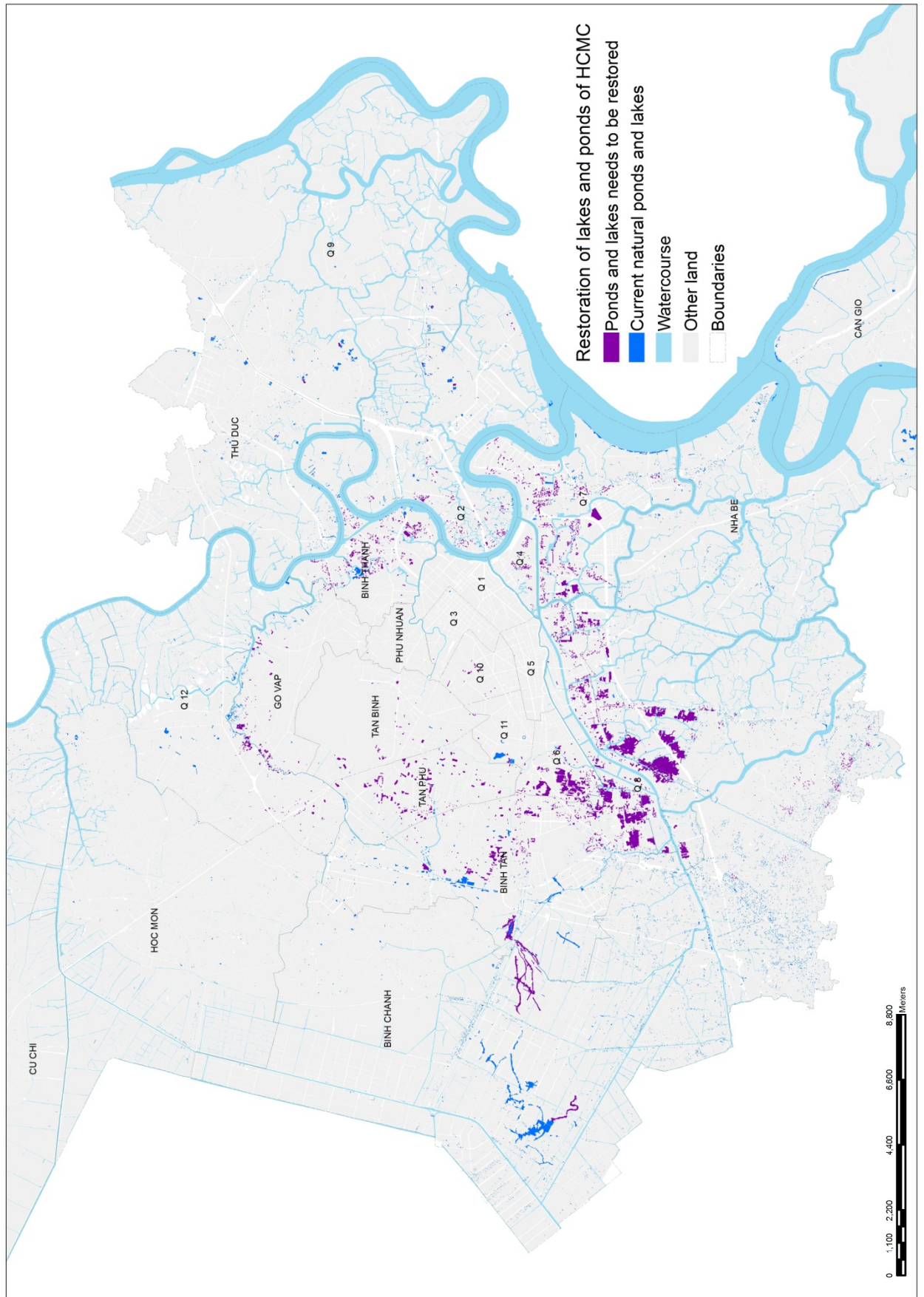
Figure 8.3: Illustration of Filled-up Pond in District 7 for Apartment Building

(Source: From Ikonos images 1999-2010)

Table 8.5: The Potential Areas of Lakes and Ponds as the Water Storage for Flooding Adaptation of HCMC

Urban districts	Lakes and ponds (ha)		Peri-districts	Lakes and ponds (ha)	
	Area protection	Area restoration		Area protection	Area restoration
4	0.8	6.5	2	46.3	147.5
6	11.2	85.8	7	84.24	242,8
8	39.5	137.4	9	166.6	367.5
10	0.8	0.3	12	92.8	144.9
11	14.8	45.5	Thu Duc	86.5	86.6
Binh Thanh	9.8	127.2	Binh Tan	50.7	185.6
Go Vap	10.6	48.6			
Tan Binh	0.5	1.3			
Tan Phu	2.7	44.3			
Total (a)	90.7	496.9	Total (b)	527.14	932.1

(Source: The result statistics of MCA on urban function map)



Map 8.3: Restoration of Lakes and Ponds to Flooding Adaptation of HCMC

(Source: Analysis from watercourse maps 2005-2009)

## **8.6 Restoration of Rivers and Canals System to Flooding Mitigation**

From mapping analysis in this research, there were 23.96 kilometers of tributaries filled-up. In which, the urban districts had 7.81 kilometers and the peri-districts had 16.15 kilometers of filled-up tributaries (see Figure 8.4). Most of these areas are residential areas.

According to Tucci (2001), to reduce flood to an adaptive solution, the restoration of these filled-up tributaries is truly necessary, as the results presented in Map 8.4 and Table 8.6. To the urban districts, the filled-up ditches in the strongly flood areas should be prioritized to restore (such as in District 6, 8, 11, and Binh Thanh District), as well as the filled-up ditches for new-urban development areas. It was difficult to give these areas back to the original ditches, however; these filled-up areas should be upgraded to improve the drainage capacity for storm-water run-off management and to lessen the flood risk for 10-20% of residential areas. To the filled-up areas with the current temporarily houses and works. They must be stopped developing and must be permanent dredged to enhance the water-carrying capacity.

In another aspect, all the main rivers and canals have not regularly been dredged during the years. It has resulted in the large agglomeration of pollute substances from waste water and solid waste of the city. This has narrowed the beds of rivers and canals and caused the big problems to the drainage capacity in the city. It should be systematically dredged to increase their water storage capacity and minimize the flood risk for 20-30% of residential areas

Therefore, the suggestions to adaptive solution in this part are to dredge totally the river and canal system of the city (Tucci, 2001), and enhance the capacity of the city's drainage system. With these solutions, city would able to reduce about 25 to 30% of current flood areas. And in comparison between these solutions to the city's current development projects of drainage system, these projects' outcomes have not brought a good result to flooding control in HCMC.



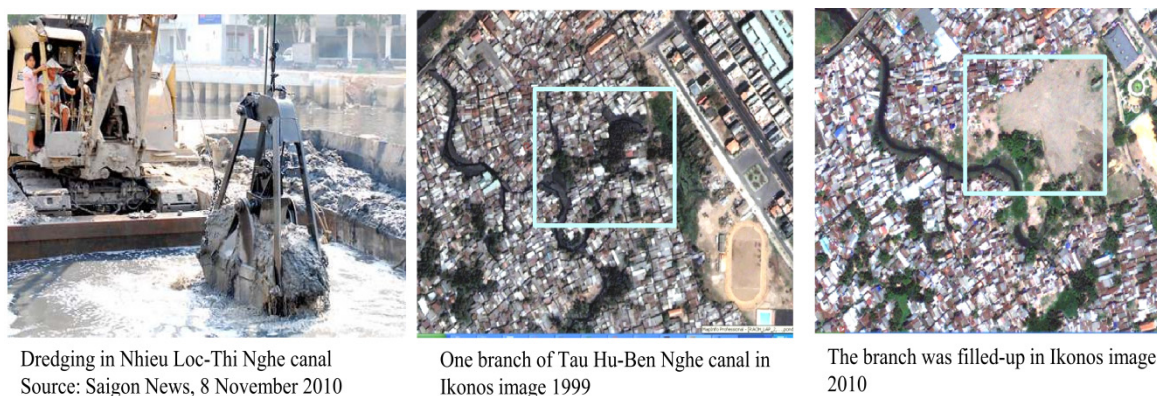


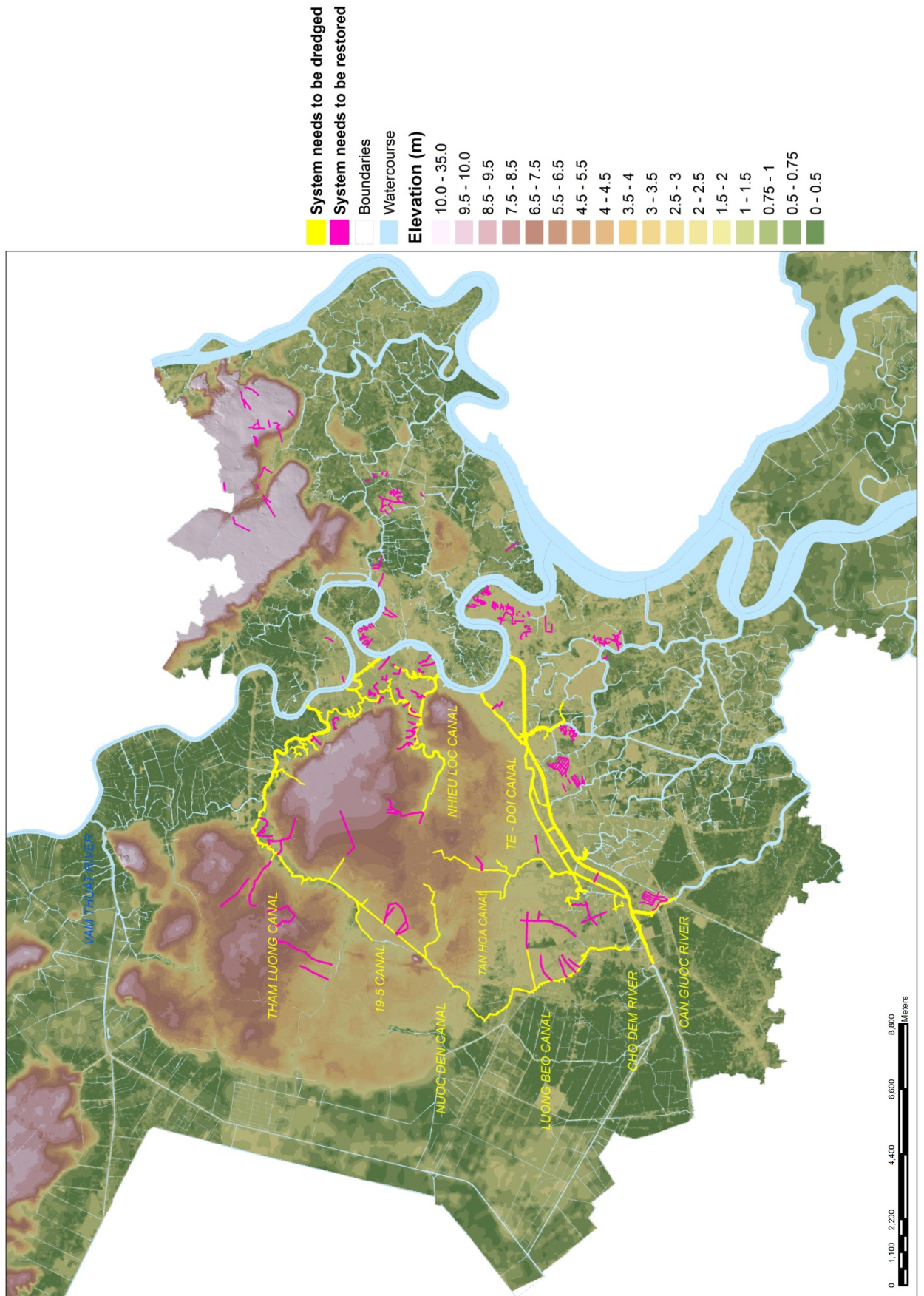
Figure 8.4: Illustration of One Filled-up Branch of Tau Hu-Ben Nghe Canal for Residential Area

(Source: From Ikonos images 1999-2010)

Table 8.6: The Restoration of Canals and Ditches as the Water Storage for Flooding Adaptation of HCMC

Urban districts	Length (km) (1)	Area (ha) (2)	Peri-districts	Length (km) (3)	Area (ha) (4)
4	0.34	1.09	2	3.09	7.62
6	1.82	4.86	7	5.21	15.21
8	1.71	3.72	9	2.05	8.25
11	0.95	1.24	12	2.11	7.82
Binh Thanh	1.98	4.35	Thu Duc	2.17	14.07
Tan Phu	1.01	2.23	Binh Tan	1.52	4.66
Total	7.81	17.49	Total	16.15	57.63
Total (1+3)	23.96		Total (2+4)	75.12	

(Source: The result statistics from watercourse maps 2005-2009)



Map 8.4: Restoration of Drainage Canals System to Flooding Mitigation of HCMC

(Source: Watercourse maps 1995-2009)

## **8.7 Summary for Chapter Eight**

Urban morphology analysis showed the uneven development of population and residential density between the urban areas: too much in the urban districts. This requires more land for built-up area and demand of filling up rivers and canals. It made the imbalance between the permeability of land surface and the run-off water flows; then leads to the inundation increasing. Flooding in the rainy season due to high tides, heavy rains or both the reasons is urgent and is insolvable problems of HCMC.

The results also showed the importance of rivers and canals, ponds and lakes filled-up during the urbanization. It is the main reason to reduce the water-storage capacity during flooding and in rain season. Flooding in urban residential area was more impacted than in rural residential area, higher flood level and longer flooding time.

## 9 CONCLUSION

This chapter presents a summary of the research based on objectives set at the beginning of research. The purpose is to verify the hypothesis of the research. And the suggestions are also provided based on the findings in the final analysis of the study.

### 9.1 Conclusion

Flooding has many impacts in many areas in HCMC. City government has implemented many adaptive projects (Ho, 2008; Trinh, 2008; To, 2008; SCFC, 2010), though, the flooding control and flooding adaption on the city are not totally effective. And the flooding points are still happening, and even increasing. One of the necessary solutions to flooding adaptation should be considered is the comprehensive approach in combination of many factors impacted by flood in flooding areas of HCMC (To, 2008; Ho, 2008).

This study applied the urban morphology analysis to finalize the solutions to flooding adaptation to HCMC. And the results of the study, in step by step (in three work packages) have proved that the hypothesis of measuring the urban morphology to flooding adaptation in HCMC could help to solve the flooding problems.

Based on the hypothesis, the research objectives, research scope and methodology were developed. The main method of the research is to apply fractal geometry, GIS and Remote Sensing for measuring the urban morphology. The combination of high resolution images and large scale maps has intensified the accuracy of research (Chapter Five). The results of urban morphology were used to analyze flooding impacts on urban residential areas in HCMC. The aim of this research is to better understand the flooding problems through the relationship between high density of residential areas, high density of built-up and urban function areas. Especially, the study had developed the links of the spatial analysis and population census data, land-use, building types at the large scale level.

This research found that fractal geometry helped to identify the urban morphology map based on land-use, building typologies and population at commune level. It also helped to identify the urban built-up density, population density, urban residential density, and urban functions in the city (Chapter Six). Chapter Six analyzed the urban morphology based on the fractal geometry of a GIS to generate graphical output such as thematic maps. Especially, large scale data and population census were used together for urban morphology detection. Overlay and variable analysis by using GIS technique help to identify the relationship between population, land-use blocks and building footprints



such as built-up density, floor-space ratio and population density on land-use blocks. Therefore, urban morphology in this research analyzed the urban function and urban residential densities at the detail levels for urban districts, peri-districts and rural based on land-use blocks and building types.

The outcome of the urban morphology map and flood data was analyzed to identify flooding impacts on HCMC (Chapter Seven). The flooding impact of differing factors of population, building footprints and residential areas have also estimated in many GIS operations such as the MCA, intersect and union.

As explained in Chapter Eight, by using the urban morphology map as tool for flooding adaptation it is very important in the context of urban growth in HCMC. Estimates of underlying surfaces of potential areas for flooding adaptation used the MCA method with six criteria. The preferred criteria to determine the urban flood adaptation are a sensible idea to proceed in focus of more contexts – based urban morphology and urban flood impact assessment. This result can show exactly where the potential areas adapt to the urban flooding situation in HCMC such as green space, new residential areas without flood impacted.

Although this needs to be researched, it is convinced that the association of flood impact statistic with urban morphology would lead to better informed solution-making for flooding adaptation. With the above hypothesis, objective and methodology, this study had shown the comprehensive urban structure of HCMC and the reasons driven flooding in the city as follows:

The interpreted results on land-use and building footprint 2005-2010 showed the urbanization had been expanding onto peri-districts and rural areas, especially on the low-land below 1.5 meter AMSL. In the results, the agricultural land in rural area reduced 23% in five years (2005-2010) instead for 18% of urban area increased. The urban building footprints area in urban area increased 64.52% with 30.94% of building footprints numbers increased. The terraced and detached were the widespread housing typologies in urban areas with 89.36% of total. These are the single houses (normally one house for one family) with three to five floors occupied in large urban areas. They were the main reason of increasing the built-up ratio, cutting down the public areas and reducing the permeable surface. And they were the indirect reasons which caused flooding in HCMC.

*This part of the results had solved partly the first strategic objective and answered the questions a of the study.*

From fractal geometry analysis, there were the big differences between the areas of building footprints density in HCMC. In this analysis, the urban area was divided into three zones. Zone A: old urban district in the inner center; zone B: the developed Dis-

tricts between zone A and C; and zone C: the new-developing urban and peri-districts in sub-urban areas.

- Zone A was the old urban districts with high density of building footprints three times higher than in zone B and eight times higher than in zone C. Inversely, the area of zone A was three times less than zone B and eight times less than zone C. Its population density was more than 500 persons per blocks in average; and the built-up ratio was 0.7 to 0.9 building footprint area per land-use area. With this built-up ratio, people live in zone A has less open space and green space.
- Zone B had built-up ratios from 0.5 to 0.7; and this ratio in zone C was less than 0.5. However, the urban border between B and C was unclear in planning. Therefore, there was the occupation of land from B to C.

*This part of results had solved the last part of the first strategic objective and answered the question **b** of the study.*

Other results from fractal geometry were the urban functions identified in HCMC. In which, the distribution of urban residential areas was the very important result. It included four categories: (1) Urban-high-density residential areas, (2) Urban-medium-density residential areas, (3) Urban-low-density residential areas, and (4) New-urban-development residential areas. The results showed the high-density residential areas were mixed with the concentrated commercial areas and most of the new-urban-development areas were in the low-land area below 1.5 meter AMSL.

In combination to flooding impact data, the result showed the high concentration of population in high-density residential areas of urban districts was the main reason of flooding increase.

Chapter Seven had presented the heavy flooded areas concentrated mostly in the high density residential areas in urban districts. It was caused by the high built-up density, less permeable surface and less green space. Some deep-flooded areas in inner center were by the filled-up of lakes and ponds, and small tributaries.

*This part of results had solved the second and third strategic objectives and answered the question **c** of the study.*

In connection with Chapter 8, the suggestions of this research were based on the following measures:

- Reducing terraced type of urban residential areas impacted by flooded. It will re-plan the built-up areas to reduce the soil-ceiling surface, and increase the green space for water infiltration.
- Restoring the filled-up rivers and canals, ponds and lakes will increase the water-storing capacity in the flooding time.

- Dredging the sediments from rivers and canals to improve the carry capacity of water and storm-water of the river system.
- Drainage system should be upgraded in the old urban areas and completed in the new-development areas.
- The current river system, ponds and lakes should be protected and developed to control flooding.
- Controlling the agriculture areas in peri-urban districts and development in urban districts by land-use regulations and building codes. It will protect the green space and decrease the build-up density.

These suggestions are based on the results of the research because of the complication of the impacts of urban flooding; there is a strong demand to cooperate between different administrative levels and organizations (city government, DoNRE, DoT, etc.) as well as further participations of local people. Although this needs to be researched, it is convinced that the association of flood impact statements with urban morphology would lead to better informed solution-making for flooding adaptation in HCMC.

*This part of results had solved the fourth strategic objectives and answered the question d of the study.*

The final result of this study said that, flooding in HCMC was not mainly by climate change, but mostly by the urbanization process with losing urban management and non-comprehensive planning between government, department, and institution at levels. These reasons led to the increase of unplanned residential areas in urban area and caused the imbalance between urban functions areas of the city, such as the imbalance ratio between high-density built-up areas to green space and public areas.

One more important conclusion on urban development in HCMC was urban development aimed to economic development rather than to sustainable development. This resulted in the development of many residential areas in low-land areas, where should be the city's water storage areas (such as the areas in Districts 2, 7 and 8).

*All the results have proved that, **urban morphology and fractal geometry could be used to measure the distributions and densities of population, built-up coverage, and floor-space in residential areas (and other urban functions areas) to control flood-impact in residential areas.** It would be the important results to support for urban planning to flooding adaptation for HCMC.*

## **9.2 Limitation of Study**

During the research, some limitations were met with difficulties about data capacity, software applying and time of processing data. The limitations of this research could be concluded as follows:

Study was hampered by the big data capacity of layers. Therefore, processing data of the study needed long computation time and longer verification duration of GIS software. On the other hand, use of the AVENUE program of Arcview GIS was only set up in 32 bit operating system. This led to very slow processing and updated data for analysis of fractal geometry.

## 10 REFERENCES

- ADB (Asian Development Bank). (2010). Ho Chi Minh City Adaptation to Climate Change. Summary Report (publication No. RPT101580). Philippine: ADB.
- Adolphe, L. (2001a). A Simplified Model of Urban Morphology: Application to an Analysis of the Environmental Performance of Cities. *Environment and Planning B: Planning and Design*, 28 (2), 183-200. Doi:10.1068/b2631.
- Adolphe, L. (2001b). Modelling the Link Between Built Environment and Urban Climate: Towards Simplified Indicators of the City Environment. In IBPSA (Eds.) The Seventh International IBPSA Conference. Rio de Janeiro (pp. 679-684). Brazil: IBPSA.
- Alexander, E. (1993). Density Measures: A Review and Analysis. *Journal of Architectural and Planning Research*, 10 (3), 181-202.
- Anselin, L. (1995). Local Indicators of Spatial Association - LISA. *Geographical Analysis*, 27 (2), 93-115.
- Banik-Schweitzer, R. (2010). Vienna: Transformation of the Cityscape by Different Urban Typologies. In ISUF (Eds.) The 17th Conference in International Seminar on Urban Form "Formation and Persistence of Townscape" (17 pp.). Hamburg and Luebeck.
- Batistae-Silva, E. & Sá Marques, T. (2010). The Study of Urban Growth through Multi-Temporal Cartography and Spatial Indicators: The Case of Porto Region, Portugal. In ISUF (Eds.) The 17th Conference in International Seminar on Urban Form "Formation and Persistence of Townscape" (24 pp.). Hamburg and Luebeck.
- Baltsavias, E., Pateraki, M. & Zhang, L. (2001a). Radiometric and Geometric Evaluation of Ikonos GEO Images and Their Use for 3D Building Modeling. In ISPRS (Eds.) Proceedings of the Joint ISPRS Workshop "High Resolution Mapping from Space 2001". Hannover. Germany: ISPRS.
- Barnsley, M. J. & Barr, S. L. (1996). Inferring Urban Landuse from Satellite Sensor Images Using Kernel-Based Spatial Reclassification. *Photogram-metric Engineering and Remote Sensing*, 62 (8), 949-958.
- Batty, M. & Kim, K. (1992). Form Follows Function: Reformulation Urban Population Density Function. *Urban Studies*, 29, 1043-1069. Doi: 10.1080/00420989220081041
- Batty, M. & Longley, P. A. (1994). *Fractal Cities: a Geometry of Form and Function*. San Diego: Academic Press.

- Batty, M. & Longley, P. A. (1986). The Fractal Simulation of Urban Structure. *Environment and Planning A*, 18 (9), 1143-1179. Doi: 10.1068/a181143.
- Batty, M. (2001). Exploring Isovist Fields: Space and Shape in Architectural and Urban Morphology. *Environment and Planning B: Planning and Design*, 28 (1), 123-150. Doi:10.1068/b2725.
- Bérubé, D. & Jébrak, M. (1999). High Precision Boundary Fractal Analysis for Shape Characterization. *International Journal of Computers and Geosciences*, 25, 1059-1071.
- Bengui, L. & Daoud, M. (1991). Is the Suburban Railway System a Fractal? *Geographical Analysis*, 23 (4), 362-368. Doi:10.1111/j.1538-4632.1991.tb00245.x
- Bengui, L. (2001). The Dynamics of Urban Morphology: The Case of Petah Tikvah. *Environment and Planning B: Planning and Design*, 28, 447-460. Doi:10.1068/b2703.
- Biswas, A. K. & Agarwala, S. B. C. (1992). *Environmental Impact Assessment for Developing Countries*. United Kingdom: Butterworth-Heinemann, Oxford.
- Burrough, P. A. (1986). *Principles of Geographical Information Systems for Land Resources Assessment*. Clarendon Press, Oxford.
- Buttstädt, M., Sachsen, T., Ketzler, G. & Schneider, C. (2010). Urban Temperature Distribution and Detection of Influencing Factors in Urban Structure. The 17th Conference in International Seminar on Urban Form – ISUF. “Formation and Persistence of Townscape”. 20-23 August 2010. Hamburg and Luebeck.
- Cardew, R. (1996). Residential Densities in Sydney. Defining and Measuring Residential Densities, *Australian Planner*, 33 (2), 105-113. Doi: 10.1080/07293682.1996.9657724.
- Carter, T. (2007). *Assessing the Adaptive Capacity of the Finnish Environment and Society under a Changing Climate: FINADAPT*. Summary for Policy Makers.
- Cavan, G. (2012). Spatial Modelling and Web-GIS Tools for Climate Change Adaptation Planning in Urban Areas. In Earth Systems Engineering Symposium. Newcastle University.
- Caliskan, O. (2010). Design Control for Planned Residential Districts: A Morphologically Comparative Inquiry in the Cases of the Netherlands, the U.K., and Turkey. In ISUF (Eds.) The 17th Conference in International Seminar on Urban Form “Formation and Persistence of Townscape” (15 pp.). Hamburg and Luebeck.
- CIRIA. (2000). *Sustainable Drainage Systems: Design Manual for England and Wales*. London: Construction Industry Research and Information Association.

- Choi, H. S. (SUNNY). (2010). *Place Identity in 21<sup>st</sup> Century Contemporary New Town Development in South Korea*. In ISUF (Eds.) *The 17th Conference in International Seminar on Urban Form "Formation and Persistence of Townscape"* (18 pp.). Hamburg and Luebeck.
- Cohen, J. A. (1960). *A Coefficient of Agreement for Nominal Scales*. *Educational and Psychological Measurement*, 20 (1), 37-46. Doi: 10.1177/001316446002000104.
- Conzen, M. (1968). *The Use of Town Plans in the Study of Urban History, in Dyos*. In *the Study of Urban History*. H.J. (Ed.) (pp. 113-30). London: Edward Arnold.
- Conzen, M. (2001). *The Study of Urban Form in the U.S. Urban Morphology V*, 5 (1), 3-4. Henry Ling Ltd, Dorest Press, Drochester, Dorest, England.
- Curdes, G. (2010). *Urban Morphology and Climate Change: Which Morphology Can Survive?* In ISUF (Eds.) *The 17th Conference in International Seminar on Urban Form "Formation and Persistence of Townscape"* (17 pp.). Hamburg and Luebeck.
- Daneke, C. & Oßenbrügge, J. (2010). *Computer Based Predictions of Urban Land Use Patterns: A Possibility to Test Mitigation and Adaptation Policies*. *The 17th Conference in International Seminar on Urban Form "Formation and Persistence of Townscape"* (15 pp.). Hamburg and Luebeck.
- Davoudi, S., Crawford, J. & Mehmood, A. (2009). *Climate Change and Spatial Planning Responses*. In Davoudi, S., Crawford, J. & Mehmood, A. (Eds): *Planning for Climate Change: Strategies for Mitigation and Adaptation for Spatial Planners*. London: Earthscan, 7-19.
- Department of Cadastry and Housing Land. (2001a). *Ho Chi Minh City Housing Development Program 1991-2000 and Orientation to 2010*. HCMC: Department of Cadastry and Housing Land.
- Department of Cadastry and Housing Land. (2001b). *Program of Removing and Evacuating 10,000 Slums on HCMC Canals 2001-2005*. HCMC: Department of Cadastry and Housing Land.
- Department of Cadastry and Housing Land. (2001c). *Housing Development in HCMC during Ten Years (1991-2000) and Strategies for Housing Development in Ho Chi Minh City to 2010*. HCMC: Department of Cadastry and Housing Land.
- Dias-Coelho, C. (2010). *A Morphological Inventory: Urban Fabric in the Portuguese City*. In ISUF (Eds.) *The 17th Conference in International Seminar on Urban Form "Formation and Persistence of Townscape"* (16 pp.). Hamburg and Luebeck.
- Dickinson, R. E. (1968). *The Town Plans of East Anglia: A Study in Urban Morphology*. *Geography*, 19, 37-50.



- DoC (HCMC Department of Construction). (2005). *Housing Development Programs in Hochiminh City in 2006-2010*. HCMC: DoC.
- DoC (HCMC Department of Construction). (2010). *The Four Housing Development Programs in Hochiminh City in 2011-2015*. HCMC: DoC.
- Donnay, J. P., Barnsley, M. J. and Longley, P. A. (2001). *Remote Sensing and Urban Analysis*. London and New York: Taylor & Francis.
- DoNRE (HCMC Department of Natural Resources and Environment). (2013). *Land-use Planning to 2020. The Five-Years Land-use Strategic in 2011 – 2015. Ho Chi Minh City*. The Full Draft. April 2013. HCMC: DoNRE.
- DoPA (HCMC Department of Planning and Architecture). (2010). *Construction Planning, Urban Management in Ho Chi Minh City to Sustainable Urban Development*. In HIDS (Eds.) *The 17th Conference on Urban Sustainable Development* (7 pp.). HCMC Institute for Development Studies. HCMC: HIDS.
- DoT (HCMC Department of Transportation). (2010). *Development of Green Parks, Flower Gardens for Ho Chi Minh City – Current Problems and Solutions*. In (HIDS) (Eds.) *The 17th Conference on Urban Sustainable Development*. HCMC Institute for Development Studies (8 pp.). HCMC: HIDS
- Eastman, J. R. (1999). *Multi-Criteria Evaluation and GIS, in Geographical Information Systems. Volume 1: Principles and Technical Issues*. Longley P.A et al.(Eds.) New York: John Wiley & Sons Inc. 493-502.
- Filicaia, I. G. D. (2007). *The Housing Forms and Urban Morphology of Poverty Areas in the London Borough of Islington*. Master of Science Built Environment: Housing Futures. University of London.
- Fraser, C., Baltsavias, E. & Grun, A. (2002). *Processing of Ikonos Imagery for Submetre 3D Positioning and Building Extraction*. ISPRS Journal of Photogrammetry and Remote Sensing, 56 (3), 177–194
- Friesecke, F., Schetke, S. & Kötter, T. (2012). *Urban Planning for Climate Change. (Position paper of FIG Working Group 8.1. TS07G) - Planning, Environment and Water Management*, (602 pp). FIG Working Week 2012 Knowing to manage the territory, protect the environment, evaluate the cultural heritage Rome, Italy: FIG.
- Forsyth, A. (2003). *Measuring Density: Working Definition for Residential Density and Building Density*, *Design Center for American Urban Landscape*. Design Brief. University of Minnesota. 2-6. Retrieved from [http://www.corridordevelopment.org/pdfs/from\\_MDC\\_Website/db9.pdf](http://www.corridordevelopment.org/pdfs/from_MDC_Website/db9.pdf)

- Frankhauser, P. (2000). *GIS and the Fractal Formalisation of Urban Patterns: Towards a New Paradigm for Spatial Analysis.* "Spatial Models and GIS. A. S. Fotheringham and M. Wegener (Eds.) (pp. 121-143). London: Taylor & Francis.
- Gerosa, P. G. (1999). The Philosophical Foundations of Urban Morphology. *Urban Morphology*, 3, 44-45.
- Genovese, E. (2006). *A Methodological Approach to Land-use-Based Flood Damage Assessment in Urban Areas: Prague Case Study.* European Commission. Directorate General. Joint Research Center. EUR 22497 EN.
- Gill, S. E. (2006). *Climate Change and Urban Greenspace.* PhD Thesis. Faculty of Humanities. School of Environment and Development. University of Manchester. Retrieved from [http://www.greeninfrastructurenw.co.uk/resources/Susannah\\_PhD\\_Thesis\\_full\\_final.pdf](http://www.greeninfrastructurenw.co.uk/resources/Susannah_PhD_Thesis_full_final.pdf).
- Gill, S. E., Handley, J.F., Ennos, A. R. & Pauleit, S. (2007). Adapting Cities for Climate Change: The Role of the Green Infrastructure. *Built Environment*, 33 (1), 115-133. Doi: 10.2148/benv.33.1.115.
- Gill, T. E. & Collins, T. W. (2010). Differential Impacts of Flash Flooding Across the Paso del Norte. *Urban Watershed Management: Southwest Hydrology*, January/February 2010, 20-33.
- Griffith, D. A. (1988). *Advanced Spatial Statistics: Special Topics in the Exploration of Quantitative Spatial Data Series.* Kluwer, Dordrecht: Springer-Verlag New York.
- Goodchild, M. F. & Longley, P.A. (1999). The Future of GIS and Spatial Analysis. In Longley, P. A., Goodchild, M. F., Mcguire, D. J., & Rhind, D. W. (Eds.) *Geographical Information Systems: Principles, Techniques, Management and Applications*, (pp. 567–580). New York: John Wiley.
- Gu, K. (2001). Urban Morphology of China in the Post Socialist Age: Towards a Framework for Analysis. *Urban Design International*. 6 (3-4), 125-142.
- Haghani, T. & Larkham, P. (2010). Fractal Mapping: A New Tool for Analysing Urban Morphological Complexity. In ISUF (Eds.) *The 17th Conference in International Seminar on Urban Form. "Formation and Persistence of Townscape"*. Hamburg and Luebeck.
- Hainc, J. (2010). Inner Periphery of the City: Integration of Recently Built-up Areas into the Pattern of the City. In ISUF (Eds.) *The 17th Conference in International Seminar on Urban Form. "Formation and Persistence of Townscape"*. Hamburg and Luebeck.
- Handley, J. & Carter, J. (2006). *Adaptation Strategies for Climate Change in the Urban Environment.* Draft Final Report to the National Steering Group. Center for Urban

- and Regional Ecology. Manchester: School of Environment and Development. University of Manchester.
- Handley, J. (2007). Adaptation Strategies for Climate Change in the Urban Environment (ASCCUE). Narrative report for GR/S19233/01 (6 pp.). Retrieved from [http://www.sed.manchester.ac.uk/research/cure/downloads/asccue\\_epsrc\\_report.pdf](http://www.sed.manchester.ac.uk/research/cure/downloads/asccue_epsrc_report.pdf).
- Hee, L., Boontharm, D., Viray, E. & Ladouce, N. (2010). Urban Space Morphology for High Density Environments. In ISUF (Eds.) The 17th Conference in International Seminar on Urban Form "Formation and Persistence of Townscape". Hamburg and Luebeck.
- Hess, P., Sorensen, A. & Parizeau, K. (2007). Urban Density in the Greater Golden Horseshoe. Research paper 209. Retrieved from the University of Toronto, Centre for Urban and Community Studies Web site: [http://www.urbancentre.utoronto.ca/pdfs/publications/RP209\\_Hess\\_et%20al\\_May2007.pdf](http://www.urbancentre.utoronto.ca/pdfs/publications/RP209_Hess_et%20al_May2007.pdf)
- Hern, W. M. (2008). Urban Malignancy: Similarity in the Fractal Dimensions of Urban Morphology and Malignant Neoplasms. *Anthropology*, 23 (1-2), 1-19.
- Hillier, B. (2002). A Theory of the City as Object: or, How Spatial Laws Mediate the Social Construction of Urban Space, *Urban Design International*, 7 (3-4). 153–179.
- Ho, L. P. (2007). Climate Changes and Urban Flooding in Ho Chi Minh City. In Finnish Environment Institute Syke (Eds.) The Third international conference on climate and water. Helsinki, Finland: Finnish Environment Institute Syke.
- Ho, L. P. (2008). Inundation and Storm-Water Drainage in Ho Chi Minh City. In HCMC University of Technology (Eds.) Conference Proceedings of Technical Sciences, (pp. 476-482). HCMC: University of Technology.
- Ho, L. P. (2010). The Local Climate Changes and Urban Inundation in Ho Chi Minh City. In HIDS (Eds.) Proceedings on Urban Sustainable Development (11 pp.). HCMC: HIDS.
- Hsie, T. S. & Ward, I. C. (2006). A GIS-Based Method for Determining Natural Ventilation Potentials and Urban Morphology. In PLEA (Eds.) The 23<sup>rd</sup> Conference on Passive and Low Energy Architecture, (6 pp.). Geneva, Switzerland: PLEA.
- Hsie, T. S. (2008). Achieving Urban Sustainability through Urban Morphology Analyses and Optimum Ventilation. In PLEA (Eds.) The 25th Conference on Passive and Low Energy Architecture, (7 pp.). Dublin: PLEA.
- IIED (International Institute for Environment and Development). (2007). Adapting to Climate Change in Urban Areas: The Possibilities and Constraints in Low- and Middle-Income Nations, (pp. 50-87). Bellagio: IIED.

- IPCC. (2007a). *Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Core Writing Team, Pachauri, R.K and Reisinger, A. (eds.)]. IPCC, Geneva, Switzerland, 104 pp.
- IPCC. (2007b). *Summary for Policymakers. In: Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
- Janssen, R. (2000). *Multiobjective Decision Support for Environmental Management. Environment & Management, Volume 2*. Dordrecht: Kluwer Academic Publishers.
- Jensen, J. R. & Cowen, D. C. (1999). Remote Sensing of Urban/Suburban Infrastructure and Socio-Economic Attributes. *Photogrammetric Engineering and Remote Sensing*, 65 (5), 611–622.
- Jha, A. K., Bloch, R. & Lamond, J. (2011). *Cities and Flooding – A Guide to Integrated Urban Flood Risk Management for the 21st Century*. Washington DC: The World Bank.
- Jones, C. B. (1997). *Geographical Information Systems and Computer Cartography*. Essex, USA: Addison Wesley Longman Limited.
- Kazmierczak, Aleksandra & Kenny, Christopher. (2011). *EcoCity: The Brunwood for Initiative for Sustainable Cities at the University of Manchester. Risk of Flooding to Infrastructure in Greater Manchester*. February 2011.
- Kubin, C. (1992). *Basic Characteristics of Planned and Spontaneous Environments*. Unpublished Master thesis, METU, Turkey, Ankara p 10.
- Landcom. (2011). *Residential Density Guide*. The Landcom Project Teams: Author. Retrieved from [http://www.landcom.com.au/downloads/uploaded/Density%20Guide%20Book%20V9LR\\_0880.pdf](http://www.landcom.com.au/downloads/uploaded/Density%20Guide%20Book%20V9LR_0880.pdf)
- Lamond, J. E. & Batema, I. J. (2012). *Methods for Valuing Preferences for Environmental and Natural Resources: An overview*. In C. A. Booth, F. N. Hammond, J. E. Lamond and D. G. Proverbs (Eds.) *Climate Change Challenges for the Built Environment*. London: Blackwell.
- Landis, J. & Zhang, M. (1998a). The Second Generation of the California Urban Futures Model. Parts 1, 2 & 3. *Environment and Planning B*, 25 (5), 657–666.
- Landis, J. & Zhang, M. (1998b). The Second Generation of the California Urban Futures Model. Parts 1, 2 & 3. *Environment and Planning B*, 25 (6), 795–824.

- Langford, M. & Unwin, D. J. (1994). Generating and Mapping Population Density Surfaces Within a Geographical Information System, *The Cartographic Journal*, 31 (1), 21-26.
- Larkham, P. J. (1991). *A Glossary of Urban Form IBG, Historical Geography Research series 26*, GeoBooks, Norwich.
- Larkham, P. J. (2006). The study of urban form in Great Britain. *International Study of Urban Form. Urban Morphology*, 10 (2), 117-41.
- Langkamp, T., Bechtel, B. & Böhner, J. (2010). Alteration of Urban Climate by Urban Morphology Taking Wind and Temperature as Examples. In ISUF (Eds.) *The 17th Conference in International Seminar on Urban Form "Formation and Persistence of Townscape"* (14 pp.). Hamburg and Luebeck.
- Levina, E. & Tirpak, D. (2006). *Adaptation to Climate Change: Key Terms* (Report No. COM/ENV/EPOC/IEA/SLT) (25 pp.). Paris, Cedex, France: OECD & IEA (Organisation for Economic Co-Operation and Development & International Energy Agency). Retrieved from <http://www.oecd.org/environment/cc/36736773.pdf>.
- Le, V. Thanh. (2005). Urbanization, Environment, Development and Urban Policies in Ho Chi Minh City, Vietnam. In Iussp (Eds.) *The 25th IUSSP International Population Conference on July 18-23, 2005*. Retrieved from Princeton University, International Union for Scientific Study of Population (IUSSP) Web site: <http://iussp2005.princeton.edu/papers/50030>.
- Le, V. Trung. (2009). Outline of the Waterlog and Flood Prevention Solutions in Ho Chi Minh City. In FIG (Eds.) *The 7th FIG Regional Conference Spatial Data Serving people: Land Governance and the Environment – Building the Capacity*, (9 pp.). Hanoi, Vietnam: FIG (International Federation of Surveyors).
- Longley, P. A. & Mesev, T. V. (2000). On the Measurement and Generalization of Urban Morphology. *Environment and Planning A*, 32, 473–488. Doi:10.1068/a3224.
- Longley, P. A. & Mesev, T. V. (2001). *Measuring Urban Morphology Using remote Sensing Image. Remote Sensing and Urban Analysis. GIS data 9*. London and New York: Taylor and Francis Group.
- Longley, P. A., Goodchild, M., Maguire, D. & Rhind, D. (2001). *Geographic Information Systems and Science*. Wiley, Chichester: Taylor and Francis Group.
- Longley, P. A. & Mesev, T. V. (2002). Measurement of Density Gradients and Space-Filling in Urban Systems. *Regional Science Association*, 81 (1), 1-28.
- Lynch, K. & Rodwin, L. (1958). A Theory of Urban Form. *American Institute of Planners, Journal of American Institute of Planners*, 24 (4), 201-214.

- Luong, V. V. (2008). City Development and the Trend of Climate Change in Ho Chi Minh City. In IMHEN (Eds.) *The 10th Science Proceedings of IMHEN*, (pp. 369-375). Hanoi: IMHEN (Vietnam Institute of Meteorology Hydrology and Environment).
- Mather, M. P. (2004). *Computer Processing of Remote-Sensed Images: An Introduction* (3rd Eds.), (324 pp.). United Kingdom: J Wiley & Sons.
- Martin, L. R. G. (1989). An Evaluation of Landsat-Based Change Detection Methods Applied to the Rural-Urban Fringe. In C.R. Bryant, E.F. LeDrew, C. Marois & E. Cavayas (Eds.) *Remote Sensing and Methodologies of Land Use Change Analysis* (pp. 101–116). Waterloo, Canada: University of Waterloo.
- Mandelbrot, B. (1977). *The Fractal Geometry of Nature*. San Francisco: Freeman.
- Mansell, M. G. (2003). *Rural and Urban Hydrology*. London, UK: Thomas Telford.
- Meinshausen, M., Meinshausen, N., Hare, W., Raper, S. C. B., Frieler, K., Knutti, R., et al., (2009). Greenhouse-gas emission targets for limiting global warming to 20C. *Nature*, 458, 1158-1162. Doi:10.1038/nature08017.
- Meliefste, C. J., Ankersmit, G. J., Meere, M. & Verwer, E. A. (2008). *Building on Structures, Adaptation to Climate Change: Master atelier Landscape Architecture*. Wageningen: WUR.
- Mesev, V. (1998). The Use of Census Data in Urban Image Classification. *Photogrammetric Engineering and Remote Sensing*, 64, 431–438.
- Mesev, T. V., Longley, P. A. & Batty, M. (1995). Morphology from Imagery: Detecting and Measuring the Density of Urban Land-use. *Environment and Planning A*, 27 (5), 759 -780. Doi:10.1068/a270759.
- MoC (Minister of Construction). (2005). Vietnam Standards 353 (TCXDVN 353, 2005), Hanoi: MoC.
- Moudon, A. V. (1997). Urban Morphology as a Emerging Interdisciplinary Field. *Urban Morphology*, 1, 3-10.
- Muller, M. (2007). Adapting to Climate Change: Water Management for Urban Resilience. *Environment and Urbanization*, 19 (1), 99-113. Doi: 10.1177/0956247807076726.
- Mukheibir, P. & Ziervogel, G. (2007). Developing a Municipal Adaptation Plan (MAP) for Climate Change: the City of Cape Town. *Environment and Urbanisation*, 19 (1), 143-158. Doi: 10.1177/0956247807076912.
- Nguyen, D. T. & Duong, V. V. (2007). Some Solutions for Flooding Control to Ho Chi Minh City. Retrieved June 15, 2013 from [http://www.vncold.vn/Modules/CMS/Upload/10/KhoaHocCongNghe/60-Giai-Phap-Chong-Ngap-TPHCM\\_24\\_12\\_07/60-Giai-Phap-Chong-Ngap-TPHCM.pdf](http://www.vncold.vn/Modules/CMS/Upload/10/KhoaHocCongNghe/60-Giai-Phap-Chong-Ngap-TPHCM_24_12_07/60-Giai-Phap-Chong-Ngap-TPHCM.pdf).

- Nicholls, R. J., Hanson, S., Herweijer, C., Patmore, N., Hallegatte, S., Corfee-Morlot, J., et al. (2008). Ranking of the World's Cities most Exposed to Coastal Flooding Today and in the Future (Environment working paper No. 1 (ENV/WKP(2007)1). CA, USA: OECD.
- Orford, S. (1999). *Valuing the Built Environment: GIS and House Price Analysis*. Aldershot: Ashgate.
- Petrov, L. O., Barredo, J. I., Lavallo, C., Sagris, V., De Roo, A., Gierk, M., et al. (2005). Adaptation Strategies for Flood Mitigation in the Urban Environment: The Case Study Friulivenezia Giulia (FVG), Italy. In ACTIF (Eds.) The International Conference on Innovation Advances and Implementation of Flood Forecasting Technology (5 pp.). Tromso, Norway: ACTIF (Achieving Technological Innovation in Flood Forecasting).
- Peter, A. & Forest, E. (2007). Ensemble Climate Predictions Using Climate Models and Observational Constraints. *Philosophical Transactions. The Royal Society A.* (365), 2029-2052.
- Pesaresi, M. & Bianchin, A. (2001). Recognizing Settlement Structure Using Mathematical Morphology and Image Texture. In Donnay, J.P., Barnsley, M.J., Longley, P.A. (Eds.) *Remote Sensing and Urban Analysis*, 55–67. London and New York: Taylor and Francis.
- Pierce, D. W. and Barnett, T. P. (2009). IPCC Expert Meeting on Detection and Attribution Related to Anthropogenic Climate Change. Detection and Attribution of Anthropogenic Climate Change in the World's Oceans. Geneva, Switzerland.
- PSO – HCMC Statistic Office. HCMC's Yearly Statistics to 2012.
- Public Company of Urban Drainage System. (1995). *The Categories of Urban Drainage System for Hochiminh City*. HCMC: Public Company of Urban Drainage System.
- Raford, N. & Ragland, D. R. (2003). *Space Syntax: An Innovative Pedestrian Volume Modeling Tool for Pedestrian Safety*. USA: UC Berkeley Traffic Safety Center.
- Rashed, T., Weeks, J. R. & Roberts, S. (2003). Measuring the Physical Composition of Urban Morphology Using Multiple Endmember Spectral Mixture Models. *Photogrammetric Engineering & Remote Sensing*, 69 (9), 1011–1020.
- Rashed, T., Weeks, J. R. & Roberts, S. (2005). Measuring Temporal Compositions of Urban Morphology through Spectral Mixture Analysis: toward a soft approach to change analysis in crowded cities. Taylor and Francis Group. *International Journal of Remote Sensing*, 26 (4), 699–718.
- Richards, J.A. (1986). *Remote Sensing Digital Image Analysis*. New York: Springer.

- Ryan, B. D. (2006). Morphological Change through Residential Redevelopment: Detroit, 1951-2000. *Urban Morphology*, 10 (1), 5-22.
- Roggema, R. (2009). *Adaptation to Climate Change: a Spatial Challenge*. Washington DC, USA: Springer.
- Sadar, M. H. & Dirsch, H. J. (1996). Generic Environmental Impacts Identified from Water Impoundment Projects in the Western Canadian Plains Region. *Impact Assessment*, 14 (1), 41-57. Doi: 10.1080/07349165.1996.9725885.
- Samuels, I. & McGlynn, S. (2000). The Funnel, the Sieve and the Template: towards an operational urban morphology. *Urban Morphology*, 4 (2), 79-80.
- Satoh, S. (1997). The Morphological Transformation of Japanese Castle-Town Cities. Urban Morphology as an Emerging Interdisciplinary Field. *Urban Morphology*, 1, 11-18.
- SCES (HCMC Steering Committee for Environmental Sanitation). (2010). The Ho Chi Minh City's Environmental Sanitation Project: The Nhieu Loc – Thi Nghe Balley. In HIDS (Eds.) Proceedings on urban sustainable development on May 17, 2010 (7 pp.). HCMC: HIDS.
- Silander, J., Vehviläinen, B., Niemi, J., Arosilta, A., Dubrovin, T., Jormola, J., et al. (2006). Climate Change Adaptation for Hydrology and Water Resources. Finnish Environment Institute Mimeographs (FINADAPT Working Paper 6) (63 pp.). Helsinki, Finland: Finnish Environment Institute.
- Silander, J., Vehviläinen, B., Niemi, J., Arosilta, A., Dubrovin, T., Jormola, J., et al. (2007). Climate Change Impacts and Adaptation in the Hydrology of Urban Areas. Conference Proceeding. In FMI (Eds.) Proceeding of 3rd International Conference on Climate and Water (6 pp.). Finland: FMI (Finnish Meteorological Institute).
- Slater, T.R. (1990a). Starting again: Recollections of an Urban Morphologist. In Slater, T.R. (Eds.) *The Built Form of Western Cities* (pp. 23-36). Leicester: Leicester University Press.
- SCFC (Steering Center of Flooding Control Program). (2010). The Current Situation and Solution for Flooding Prevention in Ho Chi Minh City. In HIDS (Eds.) Proceedings on Urban Sustainable Development on May 17, 2010 (8 pp.). HCMC: HIDS.
- Sheltair Group. (2003). *Climate Change Impacts and Adaptation Strategies for Urban Systems in Greater Vancouver*. Volume 1: Preliminary Assessment. Vancouver, Canada: The Sheltair Group.
- Senga, R. (2009). *Natural or Unnatural Disasters: the Relative Vulnerabilities of Southeast Asian Megacities to Climate Change*. UK: WWF International.



- Shaw, R., Colley, M. & Connell, R. (2007). *Climate Change Adaptation by Design: A Guide for Sustainable Communities*. London, UK: TCPA.
- SIHYMETE (Sub-Institute of Hydrometeorology and Environment of South Vietnam). (2008). *Results of Hydrometeorology Characteristics for Flooding Control in Ho Chi Minh City*. HCMC: SIHYMETE.
- SIHYMETE (Sub-Institute of Hydrometeorology and Environment of South Vietnam). (2011). *Statistic Monitored Results on Meteorology and Hydrology in Ho Chi Minh City*. HCMC: SIHYMETE.
- Srivanit, M. & Kazunori, H. (2011). The Influence of Urban Morphology Indicators on Summer Diurnal Range of Urban Climate in Bangkok Metropolitan Area, Thailand. *International Journal of Civil and Environmental Engineering IJCEE-IJENS*, 11 (05), 34-46.
- Slater, T. R. (1990a). Starting Again: Recollections of an Urban Morphologist. In Slater, T. R. (Eds.). *The Built Form of Western Cities* (pp. 23-36). Leicester: Leicester University Press.
- Storch, H., Downes, N. & Le, T. H. (2012). The Urban Risk Dilemma: Urbanisation, Modernisation and Disaster Risks in Ho Chi Minh City. In: Schrenk, M.; Popovich, V.V., Zeile, P. & Elisei, P. (Eds.), *REAL CORP 2012: Remixing the City Towards Sustainability and Resilience*, 881-887, Schwechat: CORP. ISBN: 978-3-9503110-3-7. Retrieved from [http://www.corp.at/archive/CORP2012\\_83.pdf](http://www.corp.at/archive/CORP2012_83.pdf).
- Tannier, Cécile & Puman, Denise. (2011). *Fractals in Urban Geography : A Theoretical Outline and an Empirical Example*. Cybergeog: *European Journal of Geography*. Article 307, 22 pp.
- Timber. (2009). *Mende: A Study of Urban Morphology in a Key Settlement*. UK: Discover Ltd.
- Timm, L. C., Reichardt, K. & Bacchi, O. S. (2003). Dimensional Analysis, Scaling and Fractals. Lecture given at the College on Soil Physics Trieste (pp. 3-21). Retrieved from [http://users.ictp.it/~pub\\_off/lectures/lms018/36Timm&Reichardt.pdf](http://users.ictp.it/~pub_off/lectures/lms018/36Timm&Reichardt.pdf).
- To, V. T. (2008, October 17). *Drainages in Ho Chi Minh City*. Retrieved June 15, 2013 from <http://www.vncold.vn/Web/Content.aspx?distid=136>.
- Trinh, D. L. & Nguyen, Q. V. (2001), *Socio-Economic Impacts of 'Doi Moi' on Urban Housing in Vietnam*. National Center for Social Sciences and Humanities, University of British Columbia, Canada: Social Sciences Publishing House.
- Trinh, C. V. (2008). *The Irrigation Planning Against Flooding in Ho Chi Minh City*. Retrieved June 15, 2013 from

[http://www.wrd.gov.vn/Modules/CMS/Upload/10/PhatTrienNuoc/TCVanQHLLTPHCM\\_CM\\_03\\_08\\_08/TCVanQHLLTPHCM.pdf](http://www.wrd.gov.vn/Modules/CMS/Upload/10/PhatTrienNuoc/TCVanQHLLTPHCM_CM_03_08_08/TCVanQHLLTPHCM.pdf).

- Tucci, C. E. M. (2001). Urban Drainage Issue in Developing Countries. In E.M.C. Tucci (Ed.). *Urban Drainage in Humid Tropics*. UNESCO's International Hydrological Programme. Urban Drainage in Specific Climates (Chief Ed.: C. Maksimovic), Vol.1 (40), (pp. 23-41). Paris: UNESCO.
- Tucci, C. E. M. (2007). *Urban Flood Management* (WMO/TD No. 1372). WMO (World Meteorological Organization): Cap-Net.
- Tullis, J., A. & Jensen, J. R. (2003). Expert System House Detection in High Resolution Image Using Size, Shape, and Context. *Geocarto International*, 18, (1), 5-15.
- UNEP (United Nations Environment Programme). (1998). *Handbook on Methods for Climate Change Impact Assessment and Adaptation Strategies*. Institute for Environment Studies. USA: UNEP.
- UN-Habitat (United Nations Human Settlements Programme). (2004). *Urban Patterns for a Green Economy Leveraging Density*. UN-Habitat: Author. Retrieved from <http://www.unhabitat.org/categories.asp?catid=671&q=urban%20patterns%20for%20a%20green%20economy%20leveraging%20density>
- UN-VN (United Nation – Vietnam). (2009). *Climate Change Fact Sheet – The Effects of Climate Change and the UN's Response*. Hanoi, Vietnam: UN.
- Vincente, M., Celine, T.M., Villarin S. J., Jose, R. T., Galgana, G. A., Guzman, M., et al. (2006). *The Urban Poverty Morphology Project: RS-GIS Applications for Metro-Manila, Philippines*. In GSDI (Eds.) *The 9<sup>th</sup> Conference Proceedings*. Santiago, Chile: GSDI.
- VNPM (Vietnam Prime Minister). (2010). *Master Plan Adjustment for Ho Chi Minh City to 2025* (Decision No. 24/2010/QD-TTg). Hanoi: VNPM.
- VNPM (Vietnam Prime Minister). (2012). *Approval of Regional Planning on Social Economic Development of The South-East Area of Vietnam to 2020* (Decision No 943/QD-TTg). Hanoi: VNPM.
- Vo, L. P. (2009). Water Resource in Ho Chi Minh City, Viet Nam: An overview. *Journal of Sciences and Technology Development, University of Technology*. 12 (2), 51-63.
- Vu, D. Q. (2010). Experiences and Solutions in Compensation and Evacuation for Industrialization and Urbanization in Ho Chi Minh City. In HIDS (Eds.) *Proceedings on Urban Sustainable Development on May 17, 2010* (7 pp.). HCMC: HIDS.
- Watt, W. E., Waters. D. & McLean, R. (2003). *Climate Variability and Urban Storm water Infrastructure in Canada: Context and Case Studies*. Toronto Niagara Region

- Study Report and Working Paper Series. Waterloo, Ontario: Meteorological Service of Canada.
- Weber, C., Hirsch, J., Perron, G., Kleinpeter, J., Ranchin, T., Ung, A., and Wald, L. (2001). Urban Morphology, Remote Sensing and Pollutants Distribution: A Application to the City of Strasbourg, France. In IUAPPA (Eds.) 12th Symposium on World Clean Air and Environment (pp. 26-31). Séoul, Korea: IUAPPA (International Union of Air Pollution Prevention and Environmental Protection Associations).
- Western Australian Planning Commission. (2012). Residential Design Codes of Western Australia Explanatory Guidelines 2012. Department of Planning: Author. Retrieved from [http://www.planning.wa.gov.au/dop\\_pub\\_pdf/Residential\\_Design\\_Codes-Explanatory\\_Guidelines.pdf](http://www.planning.wa.gov.au/dop_pub_pdf/Residential_Design_Codes-Explanatory_Guidelines.pdf)
- Wilbanks, T.J., Romero Lankao, P., Bao, M., Berkhout, F., Cairncross, J. S., Ceron, P., Kapshe, M., Muir-Wood, R. and Zapata-Marti, R. (2007): Industry, Settlement and Society. Climate Change (2007). Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, (Eds.), Cambridge University Press, Cambridge, UK, 357-390.
- Whitehand, J. W. R. & Morton, N. J. (2003). Fringe Belts and the Recycling of Urban Land: An Academic Concept and Planning Practice. *Environment and Planning B: Planning and Design*, 30 (6), 819-839. Doi:10.1068/b12997.
- Whitehand, J. W. R. (2005). Urban Morphology, Urban Landscape Management and Fringe Belts. *Urban Design*, 93, 15-21.
- White, R. & Engelen, G. (1993). Cellular Automata and Fractal Urban Form: A Cellular Modelling Approach to the Evolution of Urban Land-use Patterns. *Environment and Planning A*, 25 (8), 1175-1199. Doi:10.1068/a251175.
- World Vision. (2009). Adapting to a More Threatening Climate in Disaster-Prone Areas- Reducing Flood and Storm Vulnerability, Vietnam. Climate Change Case Study. Vietnam: World Vision.
- WB (The World Bank). (2011b). Guide to Climate Change Adaptation in Cities. Washington DC: WB.

## **11 APPENDIX**

### **11.1 General Statistics Data of Flooded Locations 2010 of HCMC**

Table 11.1: Statistics of flooded locations 2010 of HCMC

*Source: Statistics data from HCMC Steering Center of Flooding Control Program - SCFC, 2010*

Table 11.1: Statistics of flooded location 2010 in HCMC (continue)

Total	Streets	Flooding areas	Flooding types	Rainfall (mm)	Flood level (m)											
					JUN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
<b>1. Nhieu Loc - Thi Nghe Valley (10 locations)</b>					1.45	1.24	1.26	1.46	1.0	0.92	0.82	1.35	1.25	1.48	1.55	1.49
1	Bay Hien (Truong Chinh)	from Bay Hien to Nguyen Thai Binh	rain	low						0.17	0.2	0.22	0.25	0.18	0.2	
2	Bach Dang - Hong Hao street	from Hong Ha to Muong Nhat Ban from Bach Dang to Nguyen Kiem	rain	medium						0.17	0.18	0.25	0.28	0.22	0.24	
3	Phan Dinh Giot street	Chien Thang park (Hoang Van Thu-Phan Dinh Giot)	rain	medium						0.2	0.22	0.28	0.3	0.28	0.22	
4	Ly Thuong Kiet street	from Ng. Thai Binh School to Tan Binh market	rain	medium						0.22	0.21	0.23	0.25	0.28	0.17	
5	Dinh Tien Hoang street	from 61 No to 131 No	rain + tide	deep	0.4			0.42		0.15	0.35	0.4	0.28	0.41	0.55	0.42
6	Phan Dinh Phung street	from 26C to Phu Nhuan market	rain + tide	deep	0.4			0.41		0.17	0.35	0.4	0.3	0.42	0.57	0.42
7	Phan Van Han street	Pham Van Han	rain + tide	medium	0.38			0.38		0.21	0.23	0.25	0.22	0.32	0.43	0.4
8	Vu Tung street	Vu Tung	rain + tide	medium	0.31			0.31		0.15	0.2	0.2	0.3	0.31	0.38	0.35
9	Xo Viet Nghe Tinh street	from Hang Xanh to Nguyen Cuu Van	rain + tide	medium	0.3			0.3		0.15	0.2	0.2	0.27	0.33	0.4	0.35
10	Nguyen Kiem street	Nguyen Thai Son to SN 51	rain	medium						0.1	0.1	0.15	0.18	0.16	0.12	

(Source: Statistics data from HCMC Steering Center of Flooding Control Program - SCFC, 2010)

Table 11.1: Statistics of flooded location 2010 in HCMC (continue)

Total	Streets	Flood areas	Flooding types		Flood level	JUN	MAY	APR	MAR	FEB	JUN	MAY	APR	MAR	FEB	JAN	DEC			
			Rainfall (mm)	Flood level (m)																
<b>2. Hang Bang valley (28 locations)</b>																				
11	3 thang 2 street	From Ton That Hiep to Minh Phuing	rain	deep	1.45	1.24	1.0	1.46	1.26	1.46	0.92	1.0	1.46	1.26	1.46	0.82	1.25	1.48	1.55	1.49
12	Cao Van Lau	From Le Quang Sung to Phan Van Khoe	rain + tide	medium	0.33			0.33			0.2		0.33			0.24	0.35	0.35	0.43	0.33
13	Chu Van An	From Trang Tu to Phan Van Khoe	rain + tide	medium	0.35			0.36			0.2		0.36			0.22	0.3	0.37	0.4	0.35
14	Hau Giang	From Thap Muoi to Binh Tien	rain + tide	medium	0.37			0.38			0.2		0.38			0.25	0.28	0.35	0.42	0.4
15	Han Hai Nguyen	From 3 Thang 2 to Minh Phuing	rain	medium							0.12					0.15	0.3	0.25	0.2	
16	Minh Phung	From Xom dat to Bung Binh Cay Go	rain	deep							0.2					0.25	0.4	0.3	0.2	
17	Le Quang Sung	From Trang Tu to Minh Phuing	rain + tide	deep	0.5			0.5			0.25					0.27	0.35	0.52	0.6	0.5
18	Nguyen Thi Nho	From 3 -2 to Le Quang Sung	rain + tide	deep	0.55			0.55			0.25					0.27	0.39	0.57	0.6	0.55
19	Pham Dinh Ho	From Hung Vuong to Hau Giang	rain + tide	medium	0.37			0.37			0.21					0.23	0.3	0.4	0.4	0.37
20	Binh Tay	Binh Tay	rain + tide	low	0.36			0.36			0.2					0.22	0.25	0.4	0.42	0.36
21	Duong Tu Giang	From Trang Tu to Pham Huu Chi	rain	medium							0.15					0.2	0.3	0.25	0.3	0.39

(Source: Reported Flood Data from HCMC Steering Center of Flooding Control Program - SCFC, 2010)

Table 11.1: Statistics of flooded location 2010 in HCMC (continue)

Total	Streets	Flood areas	Flooding types	Flood level	JUN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
<b>2. Hang Bang valley (28 locations)</b>					<b>1.45</b>	<b>1.24</b>	<b>1.26</b>	<b>1.46</b>	<b>1.0</b>	<b>0.92</b>	<b>0.82</b>	<b>1.35</b>	<b>1.25</b>	<b>1.48</b>	<b>1.55</b>	<b>1.49</b>
22	3 thang 2 street	From Ton That Hiep to Minh Phuing	rain	deep						0.13	0.25	0.32	0.4	0.3	0.2	
23	Cao Van Lau	From Le Quang Sung to Phan Van Khoe	rain + tide	medium	0.33			0.33		0.2	0.24	0.32	0.35	0.35	0.43	0.33
24	Chu Van An	From Trang Tu to Phan Van Khoe	rain + tide	medium	0.35			0.36		0.2	0.22	0.32	0.3	0.37	0.4	0.35
25	Hau Giang	From Thap Muoi to Binh Tien	rain + tide	medium	0.37			0.38		0.2	0.25	0.35	0.28	0.35	0.42	0.4
26	Han Hai Nguyen	From 3 Thang 2 to Minh Phuing	rain	medium						0.12	0.15	0.28	0.3	0.25	0.2	
27	Minh Phung	From Xom dat to Bung Binh Cay Go	rain	deep						0.2	0.25	0.32	0.4	0.3	0.2	
28	Le Quang Sung	From Trang Tu to Minh Phuing	rain + tide	deep	0.5			0.5		0.25	0.27	0.48	0.35	0.52	0.6	0.5
29	Nguyen Thi Nho	From 3 -2 to Le Quang Sung	rain + tide	deep	0.55			0.55		0.25	0.27	0.5	0.39	0.57	0.6	0.55
30	Pham Dinh Ho	From Hung Vuong to Hau Giang	rain + tide	medium	0.37			0.37		0.21	0.23	0.35	0.3	0.4	0.4	0.37
31	Binh Tay	Binh Tay	rain + tide	low	0.36			0.36		0.2	0.22	0.35	0.25	0.4	0.42	0.36
32	Duong Tu Giang	From Trang Tu to Pham Huu Chi	rain	medium						0.15	0.2	0.25	0.3	0.25	0.3	0.39

(Source: Reported Flood Data, from HCMC Steering Center of Flooding Control Program - SCFC, 2010)

Table 11.1: Statistics of flooded location 2010 in HCMC (continue)

Total	Streets	Flooding areas	Flooding types	Rainfall (mm)	JUN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
	<b>2. Hang Bang valley (28 locations)</b>			<b>Flood level (m)</b>	<b>1.45</b>	<b>1.24</b>	<b>1.26</b>	<b>1.46</b>	<b>1.0</b>	<b>0.92</b>	<b>0.82</b>	<b>1.35</b>	<b>1.25</b>	<b>1.48</b>	<b>1.55</b>	<b>1.49</b>
33	Phan Van KHoe	From Ngo Nhan Tinh to Mai Xuan Thuong	rain + tide	medium	0.32			0.32		0.1	0.15	0.25	0.32	0.32	0.35	0.32
34	Tan hung	From Do Ngoc Thach to Duong Tu Giang	rain + tide	medium	0.34			0.34				0.27	0.34	0.31	0.36	0.34
35	Tan Thanh	From Do Ngoc Thach to Ta Uyen	rain	low						0.15	0.21	0.25	0.38	0.22	0.25	
36	Thai Phien	From Hung Vuong to 3/2	rain + tide	medium	0.33			0.33				0.3	0.33	0.33	0.36	0.33
37	Ton That Hiep	From Tue Tinh to 3 thang 2	rain	medium						0.15	0.2	0.22	0.27	0.22	0.25	
38	Tran Hung Dao	From Phung Hung to Hoc Lac	rain	medium						0.15	0.16	0.24	0.27	0.24	0.25	
38	Vo Truong Toan	From Hung Vuong to Tan Thanh	rain + tide	medium	0.36			0.36		0.1	0.15	0.32	0.36	0.36	0.4	0.36

(Source: Reported Flood Data from HCMC Steering Center of Flooding Control Program - SCFC, 2010)



Table 11.1: Statistics of flooded location 2010 in HCMC (continue)

Total	Streets	Flooding areas	Flooding types	Rainfall (mm)	JUN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
<b>3. Tau Huu – Ben Nghe - Doi Te Valley (5 locations)</b>				<b>Flood level (m)</b>	<b>1.45</b>	<b>1.24</b>	<b>1.26</b>	<b>1.46</b>	<b>1.0</b>	<b>0.92</b>	<b>0.82</b>	<b>1.35</b>	<b>1.25</b>	<b>1.48</b>	<b>1.55</b>	<b>1.49</b>
39	Nancy	Nguyen Bieu – Tran Hung Dao	rain	medium						0.1	0.15	0.25	0.28	0.26	0.25	
40	Le Hong Phong	Nga 7 to 3 Thang 2	rain	deep						0.2	0.24	0.37	0.4	0.32	0.4	
41	Me Coc	Me Coc	rain + tide	deep				0.65				0.6	0.65	0.65	0.67	0.62
42	Tran Nhan Ton	From Hoa Hao to Hung Vuong	rain + tide	medium				0.38				0.35	0.38	0.37	0.4	0.38
43	3 Thang 2	From Cao Thang to Le Hong Phong	rain	medium						0.12	0.15	0.25	0.28	0.2	0.28	

(Source: Reported Flood data from HCMC Steering Center of Flooding Control Program - SCFC, 2010)

Table 11.1: Statistics of flooded location 2010 in HCMC (continue)

Total	Streets	Flooding areas	Flooding types	Rainfall (mm)	JUN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
<b>4. Tan Hoa – Lo Gom Valley (10 locations)</b>				<b>Flood level (m)</b>	<b>1.45</b>	<b>1.24</b>	<b>1.26</b>	<b>1.46</b>	<b>1.0</b>	<b>0.92</b>	<b>0.82</b>	<b>1.35</b>	<b>1.25</b>	<b>1.48</b>	<b>1.55</b>	<b>1.49</b>
44	Bau Cat residential	From Dong Den, Bau Cat, Truong Cong Dinh	rain	medium						0.1	0.15	0.23	0.28	0.22	0.25	
45	Ba Hom	From Hospital District 6 to Vong Xoay	rain + tide	medium	0.31			0.31		0.1	0.18	0.3	0.35	0.31	0.35	0.31
46	Tan Hoa – Lo Gom	From Hung Vuong to Dang Nguyen Can	rain + tide	deep	0.6			0.6		0.25	0.3	0.58	0.61	0.6	0.61	0.6
47	Tan Hoa Dong	From 151N to Vong Xoay	rain + tide	medium	0.38			0.38		0.2	0.25	0.36	0.4	0.38	0.4	0.38
48	Hung Vuong (Hong Bang)	From Minh Phung to Ong Buong bridge	rain + tide	deep	0.61			0.65		0.24	0.28	0.6	0.65	0.65	0.65	0.61
49	Phu Thi	From 70 Str to Hung Vuong	rain + tide	medium	0.34			0.34		0.1	0.15	0.34	0.34	0.34	0.4	0.34
50	An Duong Vuong	From Ly Chieu Hoang to My Thuan bridge and Tan Hoa Dong to Mui Tau	none drain	medium						0.1	0.12	0.22	0.27	0.23	0.27	
51	Au Co	From Truong Chinh to Thoai Ngoc Hau	rain, small drain	medium						0.1	0.14	0.22	0.3	0.3	0.3	
52	Luy Van Bich	From 323 N to Hoa Binh, and Tribico Co to Tan Hoa bridge	rain, small drain	medium						0.1	0.12	0.25	0.3	0.2	0.22	
53	Thach Lam	From Luy Van Bich to 44/13 No	rain, small drain	medium								0.26	0.31	0.22	0.2	

(Source: Reported Flood Data from HCMC Steering Center of Flooding Control Program - SCFC, 2010)

Table 11.1: Statistics of flooded location 2010 in HCMC (continue)

Total	Streets	Flood areas	Flooding types	Rainfall (mm)	JUN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
<b>5. Other (18 locations)</b>					<b>1.45</b>	<b>1.24</b>	<b>1.26</b>	<b>1.46</b>	<b>1.0</b>	<b>0.92</b>	<b>0.82</b>	<b>1.35</b>	<b>1.25</b>	<b>1.48</b>	<b>1.55</b>	<b>1.49</b>
54	Le Lai – Le Loi	Le Lai – Le Loi	rain	low						0.1	0.15	0.25	0.27	0.25	0.24	
55	Le Duc Tho (Go Vap District)	Lang Son parish to Tay Son school	rain	medium						0.1	0.15	0.25	0.3	0.25	0.2	
56	Le Duc Tho (Go Vap District)	Lam Son church to commune 8	rain	medium						0.1	0.15	0.2	0.28	0.27	0.25	
57	Phong Phu	from Tung Thien Vuong to Ben Nguyen Duy	rain + tide	medium	0.35			0.35				0.32	0.35	0.35	0.37	0.35
58	Nguyen Anh Thu	Nguyen Anh Thu	rain	medium						0.1	0.15	0.24	0.27	0.24	0.27	
59	Nguyen Xi	from Dinh Bo Linh to Do bridge	tide, rain, small drain	medium	0.35			0.35				0.3	0.35	0.35	0.38	0.35
60	Bui Dinh Tuy	From 388 N to 362 N	tide, rain, small drain	medium	0.35			0.35				0.32	0.35	0.35	0.35	0.35
61	Inner city streets 43 (Thu Duc)	Binh Chieu to Le Thi Hoa	rain, small drain	medium								0.24	0.27		0.27	
62	Nguyen Huu Canh	Ngo Tat To to Sai Gon bridge	rain + tide	deep	0.35			0.35				0.65	0.35	0.45	0.65	0.51

(Source: Reported Flood Data from HCMC Steering Center of Flooding Control Program - SCFC).

Table 11.1: Statistics of flooded location 2010 in HCMC (continue)

Total	Streets	Flood areas	Flooding types	Flood level	JUN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
					1.45	1.24	1.26	1.46	1.0	0.92	0.82	1.35	1.25	1.48	1.55	1.49
<b>5. Other (18 location)</b>					<b>1.45</b>	<b>1.24</b>	<b>1.26</b>	<b>1.46</b>	<b>1.0</b>	<b>0.92</b>	<b>0.82</b>	<b>1.35</b>	<b>1.25</b>	<b>1.48</b>	<b>1.55</b>	<b>1.49</b>
63	Kha Van Can	From Go Dua bridge to Ngang bridge	rain + tide	medium	0.35			0.35				0.35	0.35	0.35	0.4	0.35
64	Phan Huy Ich	Trung Chinh to Huynh Van Nghe	rain, small drain	deep								0.4	0.5	0.28	0.25	
65	Hoa Binh	Tan Hoa canal to Lac Long Quan	rain, small drain	deep								0.4	0.6	0.3	0.26	
66	To Hieu	Duong Khue to Hoa Binh	rain, small drain	medium								0.33	0.35	0.3	0.25	
67	Binh Quoi	Thanh Da to Hoang Ty Hotel	rain + tide	medium	0.37			0.37				0.37	0.37	0.37	0.4	0.37
68	Thanh Da	Thanh Da	rain + tide	medium	0.37			0.37				0.37	0.37	0.37	0.38	0.37
69	Nguyen Duy Trinh	Giong Ong To market to Xay Dung bridge	rain	medium								0.25	0.3	0.25	0.2	
70	Dang Thi Ranh	To Ngoc Van to Duong Van Cam	rain	medium								0.25	0.35	0.25	0.15	
71	QL 1A	Binh Dien bridge to Long An	small drain	deep	0.61			0.61				0.41	0.61	0.61	0.65	0.55

(Source: Reported Flood Data from HCMC Steering Center of Flooding Control Program - SCFC, 2010)

Table 11.1: Statistics of flooded location 2010 in HCMC (continue)

Total	Streets	Flood areas	Flooding types	Flood level	JUN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
6.	Update on new flooding location (29 locations)				1.45	1.24	1.26	1.46	1.0	0.92	0.82	1.35	1.25	1.48	1.55	1.49
72	Tran Khanh Du	11N to Nguyen Van Nguyen	rain + tide	low	0.37		0.37			0.12	0.2	0.35	0.35	0.37	0.4	0.37
73	Tran Nhat Duat	57C N to 10C N Tran Nhat Duat	rain + tide	medium	0.36		0.36			0.1	0.15	0.35	0.35	0.36	0.41	0.36
74	Tran Khac Chan	70 N to Hoang Sa	rain + tide	medium	0.35		0.35			0.1	0.2	0.34	0.34	0.35	0.38	0.35
75	Nguyen Van Nguyen	Nguyen Van Nguyen	rain + tide	medium	0.37		0.37			0.1	0.15	0.35	0.35	0.37	0.42	0.37
76	Ha Huy Giap	Ga 21. Intersections to Phu Long bridge	no drain	medium						0.14	0.17	0.35	0.35		0.35	
77	Cho Lon	Nguyen Van Luong to Binh Phu	rain + tide	medium	0.38		0.38			0.12	0.15	0.37	0.37	0.38	0.41	0.38
78	Nguyen Thai Binh	Pho Duc Chinh to NKKN	rain + tide	medium	0.35		0.35			0.15	0.2	0.32	0.32	0.35	0.32	0.35
79	Truong Vinh Ky	Tan son Nhi to Nguyen Xuan Khoat	rain	low							0.15	0.23	0.25	0.22	0.2	
80	Bui Huu Nghia	Bui Huu Nghia to Dong Da	tide	medium	0.32		0.32					0.3	0.3	0.32	0.4	0.35
81	Nguyen Van Luong	Ba Lai bridge to Ly Chieu Hoang	tide	medium	0.33		0.33					0.32	0.32	0.33	0.36	0.34

(Source: Reported Flood Data from HCMC Steering Center of Flooding Control Program - SCFC, 2010)

Table 11.1: Statistics of flooded location 2010 in HCMC (continue)

Total	Streets	Flood areas	Flooding types		Flood level	JUN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV
				Rainfall (mm)												
<b>6. Update on new flooding location (29 locations)</b>			<b>Flood level (m)</b>		<b>1.45</b>	<b>1.24</b>	<b>1.26</b>	<b>1.46</b>	<b>1.0</b>	<b>0.92</b>	<b>0.82</b>	<b>1.35</b>	<b>1.25</b>	<b>1.48</b>	<b>1.55</b>	<b>1.49</b>
82	Huynh Tan Phat	Huynh Tan Phat	tide	medium	0.32			0.32			0.3	0.3	0.3	0.32	0.35	0.32
83	Pham The Hien	Ba Tang bridge to Nhi Thien Duong bridge	tide	deep	0.47			0.47			0.45	0.45	0.45	0.47	0.55	0.52
84	Binh Phu	Ly Chieu Hoang to Cho Lon market	tide	medium	0.31			0.31			0.3	0.3	0.3	0.31	0.35	0.33
85	Hung Phu	302 N to Le Quang Kim	tide	medium	0.32			0.32			0.31	0.31	0.31	0.32	0.31	0.32
86	Kinh Duong Vuong	Mien Tay bus station to An Lac	tide	deep	0.55			0.55			0.55	0.55	0.52	0.55	0.62	0.55
87	Ho Hoc Lam	Kinh Duong Vuong to Phu Dinh	rain + tide	medium	0.32			0.32			0.15	0.31	0.3	0.32	0.35	0.33
88	Trinh Quang Nghi	Nguyen Van Linh to Pham The Hien	rain + tide	medium	0.33			0.33			0.15	0.32	0.3	0.33	0.35	0.34
89	Dang Van Ngu	Dang Van Ngu	rain	low						0.1	0.12	0.22	0.25	0.2	0.2	
90	Go Xoai	Go Xoai	rain + tide	low	0.27			0.27			0.25	0.25	0.25	0.27	0.35	0.27
91	Go Xoai temple	Go Xoai temple	rain + tide	medium	0.33			0.33			0.3	0.3	0.3	0.33	0.35	0.33

(Source: Reported Flood Data from HCMC Steering Center of Flooding Control Program - SCFC, 2010)

Table 11.1: Statistics of flooded location 2010 in HCMC (continue)

Total	Streets	flooding areas	Flooding types	Rainfall (mm)	JUN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
<b>6. Update on new flooding location (29 locations)</b>					<b>1.45</b>	<b>1.24</b>	<b>1.26</b>	<b>1.46</b>	<b>1.0</b>	<b>0.92</b>	<b>0.82</b>	<b>1.35</b>	<b>1.25</b>	<b>1.48</b>	<b>1.55</b>	<b>1.49</b>
92	Quoc Huong, Thao Dien Commune	Thao Dien	tide	deep	0.62			0.62				0.6	0.6	0.62	0.67	0.62
93	To Ky	To Ky	rain	medium	0.32			0.32		0.15	0.2	0.3	0.3	0.32	0.35	0.33
94	Center District 9	Center District 9	rain + tide	medium	0.32			0.32				0.32	0.32	0.32	0.32	0.33
95	Phan Van Hon	Phan Van Hon	rain	medium								0.3	0.3		0.3	
96	Le van Luong – Nguyen Thi Thap	Le van Luong to Nguyen Thi Thap	rain + tide	medium	0.35			0.35				0.34	0.34	0.35	0.4	0.35
93	Le van Luong	Dia bridge to Nguyen Huu Tho	tide	medium	0.35			0.35				0.34	0.34	0.35	0.4	0.35
98	Le van Luong	Kieng bridge to Nguyen Binh	tide	medium	0.32			0.32				0.3	0.3	0.32	0.35	0.34
99	Le van Luong	Bung bridge to Dia bridge	tide	medium	0.33			0.33				0.32	0.32	0.33	0.37	0.35
100	Tran Xuan Soan	Tan Thuan bridge to Tran Xuan Soan	tide	medium	0.35			0.35				0.33	0.33	0.35	0.33	0.36

(Source: Reported Flood Data from HCMC Steering Center of Flooding Control Program - SCFC, 2010)

## 11.2 Source Program

```
'([Name_building] <> "") or ( [Name_building] = "Detached" ) or ([Name_
building] = "Villas") or ([Name_building] = "Terraced") or ([Name_
building] = "Semi detached") or ([Name_building] = "Apartment") or
([Name_building] = "Temporarily-built and others") or ([Name_
building] = "Wood- farmed, thatch- roofed") or ( [Land_use] <>
"Population" )
```

```
_HM="UM_MAP"
```

```
pr=av.getproject
  'theView = av.GetActiveDoc
  theView=av.FindDoc (_HM)
  listthemes=theView.getthemes
    for each t in listthemes
      t.setActive(false)
      T.SetVisible (false)
    end
  thethemeURBANMORPHOLOGY = theview.findtheme("BUILDING.shp")
  thethemeURBANMORPHOLOGY.setActive(true)
  thethemeURBANMORPHOLOGY.SetVisible(true)
  vtab_UBMP=thethemeURBANMORPHOLOGY.GetFTab
  theBitmap = vtab_UBMP.GetSelection
  theBitmap.clearall

  'thethemeURBANMORPHOLOGY.ClearSelection
  'vtab_UBMP.UnjoinAll
  ' T = av.GetProject.FindDoc( "VALUE_D"+R+".dbf" )
  'THETABLE_ VALUE_D =
av.GetProject.FindDoc(_CODE+"_VALUE_D.dbf")
  ' thevtabVALUE_D=T.GetVTab
  vtab_UBMP.SetEditable(true)
  FName1=vtab_UBMP.FindField ("Name_building")
  FName2=vtab_UBMP.FindField ("Area_space")
  FName3=vtab_UBMP.FindField ("Land_use]")
  FName4=vtab_UBMP.FindField ("id_1")
  FName5=vtab_UBMP.FindField ("Area_m2")
  FName6=vtab_UBMP.FindField ("Resident")
  FName7=vtab_UBMP.FindField ("Range")
  FName8=vtab_UBMP.FindField ("Lu_name")
  FName9=vtab_UBMP.FindField ("Zone")

  ' vtab_UBMP.Calculate ("no", FName9)

  ' ff="["+FName9.asstring+]"
'25675 '825469
```



```

' ([Name_building] = "Hotels") or ([Name_building] =
"Terraced") and ([Lu_name] = "PRODUCTION AND BUSINESS")
' ( [Lu_name] = "PRODUCTION AND BUSINESS" )
' [Name_building] = "Hotels") or ([Name_building] =
"Markets")
' [Lu_name] = "PUBLIC OFFICES"
' ( [Name_building] = "Hotels" ) or ([Name_building] =
"Markets")
theQuery4 = "( [Name_building] = "+"Hotels" .QUOTE+) or ([Name_
building] = "+ "Markets".QUOTE+) and ([Lu_name] = "+"PRODUCTION AND
BUSINESS".QUOTE+) "
vtab_UBMP.Query(theQuery4, theBitmap, #VTAB_SELTYPE_NEW )

' for each d in 1983 .. 25675
' for each d in 1983.. 1985
'msgbox.info(Fname9.asstring,"ccc")

' D=10061' MEDIUM
' D=12928 '130088.872 - 107013.861
' D=7033 'LOW
' D=1
' d=966
' ' D=1010
' theQuery2 = "[ Land_use] <> "+"Population".QUOTE
' theQuery2 = "[ Land_use] <> "+" Population".QUOTE
' theQuery2 = "[ Land_use] <> "+" Population".QUOTE
'
'
'
' theQuery = "[id_1] = "+d.asstring
' theQuery2 = "[ Land_use] <> "+" Population".QUOTE
' msgbox.info(theQuery.asstring,"ccc")
' vtab_UBMP.Query(theQuery, theBitmap, #VTAB_SELTYPE_NEW)
' vtab_UBMP.Query(theQuery2, theBitmap, #VTAB_SELTYPE_AND)
' C=vtab_UBMP.GetSelection .COUNT
' ' T1 = vtab_UBMP.ReturnValue(C, D).'asstring
'
' msgbox.info(T1.asstring,"ccc")
' IF (C=0 ) THEN
' msgbox.info("SKIP","ccc")
' EXIT
' BREAK
' RETURN NIL
' continue
' ELSE
' msgbox.info("CONTINUE","ccc")

'theQuery3 = "( [Name_building] = "+"Detached" .QUOTE+) or
([Name_building] = "+ "Villas".QUOTE+) or ([Name_building] =

```

```

"+"Terraced".QUOTE+" ) or ([Name_building] ="+ "Semi detached".QUOTE+"
or ([Name_building] ="+ "Apartment".QUOTE+" ) or ([Name_building] =
"+"Temporarily-built and others".QUOTE+" ) or ([Name_building] =
"+"Wood- farmed, thatch- roofed".QUOTE+" ) "
'      vtab_UBMP.Query(theQuery3, theBitmap, #VTAB_SELTYPE_AND )
'      CC=vtab_UBMP.GetSelection .COUNT
'      IF (CC=0 )THEN
'      'msgbox.info("SKIP","NO VALUE")
'      'EXIT
'      'BREAK
'      'RETURN NIL
'continue
'vtab_UBMP.Query(theQuery, theBitmap, #VTAB_SELTYPE_NEW )
      for each B in vtab_UBMP.getselection
          vtab_UBMP.SetValue (Fname9, B, "BUSINESS")

          END

          '      ELSE

          ' T=0
          for each b in vtab_UBMP.getselection
          '      T1 = vtab_UBMP.ReturnValue(Fname5, b)'.asstring
          '      T2 = vtab_UBMP.ReturnValue(Fname2, b)'.asstring
          '      T=T+T2
          '      END
          '      msgbox.info(T1.ASSTRING,"ccc")
          '      P=(T*100)/T1
          '      msgbox.info(P.ASSTRING,"PERCENT")
          vtab_UBMP.Query(theQuery, theBitmap, #VTAB_SELTYPE_NEW )
          for each B in vtab_UBMP.getselection
          vtab_UBMP.SetValue (Fname6, B, P)
          IF (P<50) THEN
          vtab_UBMP.SetValue (Fname7, B, "LOW")
          ELSEIF ((P>=50)AND (P<=100)) THEN
          vtab_UBMP.SetValue (Fname7, B, "MEDIUM")
          ELSEIF (P>100) THEN
          vtab_UBMP.SetValue (Fname7, B, "HIGH")
          END
          end
          END
          END
          'end
          '([Name_building] = "Building") or ([Name_building] = "Office
building") and ([Lu_name] = "PUBLIC OFFICES")
          theQuery5 = "([Name_building] = "+"Building" .QUOTE+" ) or ([Name_
building] = "+ "Office building".QUOTE+" )and([Lu_name] = "+"PUBLIC
OFFICES".QUOTE+" ) "
          vtab_UBMP.Query(theQuery5, theBitmap, #VTAB_SELTYPE_NEW )

```

```

    for each B in vtab_UBMP.getselection
        vtab_UBMP.SetValue (Fname9, B, "OFFICE")

    END

theQuery9 = "( [Zone] = "+"OFFICE" .QUOTE+) or ([Zone] = "+"
"BUSINESS".QUOTE+) " '#VTAB_SELTYPE_OR
'theQuery6 = "( [Zone] <> "+"OFFICE".QUOTE+)"
'theQuery7 = " ([Zone] <> "+" BUSINESS".QUOTE+) "
'theQuery8 = " ([Zone] = "+" ".QUOTE+) "

vtab_UBMP.Query(theQuery9, theBitmap, #VTAB_SELTYPE_NEW )
'vtab_UBMP.Query(theQuery7, theBitmap, #VTAB_SELTYPE_OR )
'vtab_UBMP.Query(theQuery8, theBitmap, #VTAB_SELTYPE_NEW )
theBitmap.Not
    for each b in vtab_UBMP.getselection
        Tlu = vtab_UBMP.ReturnValue(Fname8, b).asString
        vtab_UBMP.SetValue (Fname9, B, Tlu)
'vtab_UBMP.Calculate (Tlu, ff)
    END

        vtab_UBMP.SetEditable(FALSE)

        AV.RUN("LOADLEG2", "")

        '            CODEID=thevtabVALUE_D.FindField ("CODE")
        '            vtab_UBMP.Join (UBMP ID, thevtabVALUE_D, CODEID)

'' pr=av.getproject
''         'theView = av.GetActiveDoc
''         theView=av.FindDoc (_HM)
''         thethemeURBANMORPHOLOGY =
theview.findtheme("BUIL_LU_UNION.shp")
''         vtab_UBMP=thethemeURBANMORPHOLOGYT.GetFTab
''         theBitmap = vtab_UBMP.GetSelection
''         ' theBitmap.clearall
''         ' thethemeURBANMORPHOLOGY.ClearSelection
''         ' vtab_UBMP.UnjoinAll
''         ' T =av.GetProject.FindDoc("VALUE_D"+R+".dbf" )
''         ' THETABLE_ VALUE_D =
av.GetProject.FindDoc(_CODE+"_VALUE_D.dbf")''
'         ' thevtabVALUE_D=T.GetVTab
''         ' vtab_UBMP.SetEditable(true)
''         Fname1=vtab_UBMP.FindField ("Name_house")
''         Fname2=vtab_UBMP.FindField ("Area_space")
''         Fname3=vtab_UBMP.FindField ("Zone_urban]")
''         Fname4=vtab_UBMP.FindField ("id_1")
''         Fname5=vtab_UBMP.FindField ("Area_m2")
''         Fname6=vtab_UBMP.FindField ("Resident")
''         Fname7=vtab_UBMP.FindField ("Range")

```

```

''      Fname8=vtab_UBMP.FindField ("Statistic")
''      Fname9=vtab_UBMP.FindField ("Area_HL")
''      Fname10=vtab_UBMP.FindField ("Sum_Area")
'T="100.235"
'vtab_UBMP.Calculate (T, Fname10)
'r=10918.311.ln
' MsgBox.Info( "NO SELECTION", r.asstring)
'
''      '_k=k
''      ''''ww=2.718281828.Log (0)
''      ''''k=81.Log (3)
''      '''' 3 mu k =81 --> k=log 3 (81)
''      'MsgBox.Info( "NO SELECTION", _k.asstring)
''      'A= 119209521.991
''      'lnr=A.ln
''      'lnr1=A.log(2.718281828)
''      R=4^0.5
''      MsgBox.Info( r.asstring, r.asstring)
''      'R=T2^0.5
''K = MsgBox.Input( "INPUT LANDUSE IDS", "INPUT DATA CALCULATE", _k )
''''h=k.AsEnum 1..25672
''''kk=k
''''kk.AsString
''''
'''' l=k.AsTokens( ".." )
'''' lmin= l.get(0).asnumber
'''' lmax= l.get(1).asnumber
'''' t=lmin..lmax
''''MsgBox.Info( t.asstring, t.asstring)
''''_k=k
''''''ww=2.718281828.Log (0)
''''''k=81.Log (3)
'''''' 3 mu k =81 --> k=log 3 (81)
''''MsgBox.Info( "NO SELECTION", _k.asstring)

'theVal= "D:\ANALYSIS_URBANMORPHOLOGY\DATA\GRAPH.XLS".AsFileName

        theVal="D:\ANALYSIS_URBANMORPHOLOGY\DATA\GRAPH.XLS"
        System.Execute("C:\Program Files\Microsoft
        Office\Office12\EXCEL.EXE"++theVal)
        'System.Execute("c:\windows\explorer.exe"++theVal)
        'end
'system.execute("C:\Program Files\Microsoft
Office\OFFICE12\EXCEL.exe")
'f = "D:\ANALYSIS_URBANMORPHOLOGY\DATA\GRAPH.XLS".AsFileName
'system.execute(f.ASFILENAME)
''''*****
*****

```