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## Preface

Although the total amount of urban areas covers insignificant percentage of the Earth's land surface, but still the growth of these areas is the main reason of various natural environmental related problems. Currently the influence of urban areas on Earth's resources consumption, environmental pollutions and climate changes is clearly observable. The continuous growth of manmade developments has increased these problems and produced several other negative effects on natural environments. Rapid growth of population and rural-urban migration due to higher quality of life especially in developing countries contribute to the horizontal and sprawl developments. Urban sprawl due to low density, large rural development, spatially segregated land uses and widespread commercial strip development does not provide a good quality of urban neighborhood. In addition, urban sprawl and unorganized horizontal city expansion because of high carbon emission, traffic congestion, agricultural and forest destruction, higher infrastructural provision costs, various public health problems and several other environmental, economic and social issues are not characterized as an acceptable and sustainable urban form. Hence, in recent decades there is a growing awareness about urban sprawl development and its negative consequences.

Due to these negative impacts, attaining urban sustainability is one of the most primary goals for planners and decision makers in urban-related applications. In general, sustainable development concerns about the consumption of natural resources in such a way that does not jeopardize the ability of future generations to use the same resources. With respect to urban perspectives, sustainable urban development concerns about the minimum inputs of energy and resources and minimum outputs of air pollution, water pollution, and wastes from an urban system. Hence, urban sustainability can also be defined as improving quality of life of human being within the availability of Earth's limited resources. Urban sustainability takes into account of three main aspects, namely; social, economic and environmental issues. Each of these aspects deals with separate issues of an urban system such as: security, livability and social equity; improve productivity, personal and public finances; pollution levels, the amount of reserve habitat and resource consumption respectively. Sustainable urban development can be achieved through an efficient land use growth and management by implementing proper planning and urban design. These tasks can be done by adopting various strategies and planning to minimize the energy consumption, protect biological diversity, reduce pollution, improve social interaction and develop more green landscapes. Therefore, the contribution of shape and form of the cities has become one of the main focal points to conduct these tasks.

Among various aspects of sustainable urban development, environmental protection especially agricultural and forest conservations are dominated in tropical regions. Particularly, small cities and towns with high potential of growth due to proximity to big metropolitan cities need to be controlled to avoid large horizontal urban expansion. Thus, it is important to propose various alternative development scenarios based on objectives of urban sustainability to avoid negative consequences of these urban sprawl developments. Compact city, transit oriented development (TOD) and smart growth are some examples of such development scenarios. Among these examples, compact city is widely accepted as one of the most promising solution for urban development pattern to achieve ultimate goals of urban

sustainability. Compact urban development with high built-up density, land use diversity and intensified neighborhood aims to protect natural environment, reduce land consumption, decrease car dependency, support public transportation facilities, increase walking and cycling behavior and etc. These characteristics are seen to have contributed to the sustainable urban development in the form of social, economic and environmental aspects. In addition to environmental perspectives, compact city has several aspects to improve quality of life as social advantages.

Compact land use pattern is a relatively new terminology in the field of *Urban Planning* which, assumes that the new development should be built around the existing built-up areas in higher density, intensity and land use diversity and therefore promoting city compactness characteristics. The revitalization and redevelopment of existing brownfields and abandoned lands within the city borders is one of the most feasible and cost effective strategies in increasing city compactness. Evaluation of existing compactness and simulation of compact urban forms are the main step towards the implementation of compact development initiative to achieve ultimate goals of urban sustainability. Land use change modeling based on city compactness, or in a proper terminology, compact land use pattern modeling not only should consider various complexities of a conventional land use change processing, but also full fill different perspective of compact urban development concept and eventually sustainable urban development. In compact land use development human scale factors and quality of life has higher priority rather than other aspects, which made these kinds of development modeling more sophisticated.

Generally speaking, compact urban development is a complex and long-term project that requires a flexible law system and supportive government. Unfortunately, improper understanding and agreement about the definitions comprising several concepts and indicators make urban sustainability and compact city is an extremely difficult achievable task. Consequently, these complexities have influenced on each phase of sustainable and compact development processes such as modeling, implementation and measurement. For instance, to develop a compact city, the initial step is to assess and evaluate the various aspects of existing compactness in order to realize the current situation before any decision-making takes place. In this regard, there is no standard and consistent evaluation methodology exists in the literature. Moreover, city compactness has been assessed mainly based on data availability, local zoning manner and objective of the research itself. For instance, measuring urban density and land use diversity are usually based on census tracts, which vary in size and resolution. Therefore, the assessments are not comprehensive and reliable enough because the results can be different by various zoning manner, cell size, and type of input data. In addition, in large-scale regions such as country basis, urban compactness is generally measured based on the cellular concept and the concentration of the built-up cells in a specific area. Whereas city compactness apart from the urban built-up density (which is an implication of physical compactness) consists of various other aspects related to functional compactness which reveals valuable and useful information about the existing condition of cities. Moreover, evaluation of city compactness can be done through applying common statistical techniques to measure various entities such as mixed land use development indicating the land use richness of a local neighborhood. However, the distribution pattern which depends on the adjacency and relationship among various land use categories can only be evaluated using spatial and mapping based approaches.

In addition to form and shape of the cities, an understanding of spatial distribution of land use changes and the resulting impacts of this process on urban environment is one of the most important tasks. The lack of a clear understanding of this process leads to a level of uncertainty due to inclusive of several unknown and complicated parameters. Land use change phenomenon is a result of complex interaction of various environmental, physical, political, cultural, and other factors. Monitoring of these changes could reveal the flow of conversion from natural environment (forest lands) to agricultural fields and finally to built-up areas. Thus, the simulation and prediction of these changes provide insightful information and allow

for more systematic analysis of the relationship between forms and process in several environmental and urban planning applications.

In this regard, evaluation of previous growth and extraction of development trend as historical components of land use change modeling is an essential task. This process is fundamental in order to simulate and predict the future growth and changes of various land use categories. However, the lack of proper understanding about urban systems, its related issues and several involved factors and stakeholders make modeling and prediction process a difficult task. Specifically, land use change arises from complex interaction of various factors and mainly dependent on spatial location, scale, and current state of land use. The existing modeling and prediction techniques cannot be solely applied for this complex phenomenon. A reliable and comprehensive modeling approach which can be created from integration of several modeling techniques should be proposed in order to tackle related issues and variables. In addition, the proposed hybrid models should be developed based on the core principles of land use change modeling. Similarly, the processing scale of the modeling is an important issue. In a large processing scale (low spatial resolution), the models can evaluate land use changes at a regional scale, thereby facilitating the definition of appropriate environmental policies. However, land use modeling at these resolutions is incapable of identifying subtle land use changes which is observable and effective in local neighborhood bases. Therefore, it is very important to propose a hybrid model at fine spatial resolution to deal with complexity of land use modeling and prediction.

First this book describes about the fundamental concept about urban growth and expansion, historical growth models, forms of urban growth, and its negative consequences on natural and green environments. Furthermore, the concept of sustainable development with an emphasis on urban sustainability and its relationship with two common urban forms (sprawl and compact development) will be discussed in detail. Generally, assessment and evaluation of various aspects of current pattern of urban areas is important. Hence, the current book has gone through a comprehensive urban form assessment in two physical and functional aspects. Especially, compactness assessment is discussed regarding urban density, land use diversity, and urban intensity evaluations. In this phase, two new terminologies, i.e., Degree of Compactness (DoC) and Trend of Compactness (ToC) which reveal the compactness growth pattern, will be proposed and explained. In addition to urban form and pattern evaluation, it is important to analyze the historical trend; and to model and predict the future trend of urban growth in a finer scale land use changes. This phase is presented with description about the effective factors through various applied techniques related to urban growth and land use changes, mainly based on two scenarios: “business as usual” and “compact land use pattern.”

This book is organized into 14 chapters. The first three chapters and Chap. 8 present a theoretical information and introduction to urban growth and expansion, sustainable urban development, forms of urban growth, and common techniques applicable in land use change modeling. Rest of the chapters present the application of these theoretical concepts on specific case studies with detail explanation about input data, study areas, methodological processes, and results and discussion.

Chapter 1 provides introduction to urban growth and expansions with retrospective view on urbanization process and driving factors of urban expansion. Additionally, more descriptions are given on the forms of urban growth and expansion, historical modeling theories of urban growth such as Von Thünen theory, concentric zone theory, and central place theory, and urban growth and natural environment deterioration.

Chapter 2 provides general information about sustainable development with an emphasis on urban sustainability with respect to three main aspects i.e. environmental, economic and social sustainability. Next, as a case study, Malaysian perspectives of urban growth and sustainability is discussed, specifically related to Kuala Lumpur as capital city and Putrajaya as a newly developed city based on sustainable development paradigms.

Chapter 3 presents two main forms of urban growth: sprawl and compact development. First, the origin and various positive and negative aspects of sprawl development are

explained, and then compact development is discussed in detail as an alternative solution to avoid the negative social, environmental, and economic consequences. Next, compact development is evaluated with respect to various aspects of sustainable urban development. Finally, a brief discussion is presented about Malaysian perspectives of compact urban development.

Chapter 4 presents an assessment and analysis approach of the spatiotemporal patterns of urban expansions in the Tripoli metropolitan area (Libya) based on the urban sprawl assessment concept. Urban expansion and sprawl are assessed and investigated as a pattern and process using Urban Expansion Intensity Index (UEII), population and urban expansion proportions, landscape metrics, entropy model, and degree of freedom model. Tripoli metropolis, which has not been studied before, was chosen as the area to discover its urban sprawl patterns, and assess well-established urban modeling techniques in a North African city. Next, the results of urban sprawl assessment are presented and discussed in detail with respect to the study area.

In contrast to Chap. 4, Chap. 5 presents the methodological process of city compactness assessment of Kajang city (Malaysia) based on main compact city paradigms (urban density, intensity, and land use diversity) for four temporal land use maps of this city (2004, 2008, 2012, and 2015). Kajang is a city located in the eastern part of Selangor province in the southwestern region of Peninsular Malaysia. City compactness assessment is performed as an initial step of compact city modeling based on physical and functional assessment by proposing two new terminologies; degree of compactness (DoC) which illustrates the level of compactness of the smallest pixels or cells of the study area, and trend of compactness (ToC) which shows the trend of the growth and loss of compactness of the study area. These two measurements are implemented and evaluated to reveal the growth pattern of compactness of the Kajang city. This assessment provides baseline information and guidelines for analysis of compact land use pattern.

Chapter 6 presents the methodological approaches dealing with the relationship between city compactness and residential land use growth. Residential land use is selected due to more significant growth of this land use type than other urban land use categories. This growth causes the destruction of large amount of green and natural environment, especially in sprawl urban expansion. Thus, a proper analysis of the reciprocal relationship between residential growth and compact development is necessary to predict and propose different future alternative scenarios. In this process, first, the city compactness of the study area is assessed with respect to residential land use changes. Second, the growth of residential areas is predicted by using two common land use change modeling approaches and the future residential maps are evaluated with respect to city compactness maps. In this manner, the performances of the selected models are also evaluated for land use change modeling applications in terms of model accuracy, complexity, and functional relationships between dependent and independent variables.

Chapter 7 presents a change detection process to discover the spatiotemporal analysis of urban land use change patterns and highlight the trend of historical development of Kajang city (Malaysia) during 2004–2015. Land use change assessments provide a clear understanding of the built-up growth through various land uses and land cover categories. These assessments reveal the rates, amount, and directions of the growth. Thus, significant growth and/or loss of a specific land use type can be highlighted precisely. Cross-tabulation analysis is applied to each pair of available land use maps of the study area (2004, 2008, 2012, and 2015) to implement this analysis for Kajang City.

Chapter 8 identifies and explains several common land use change modeling techniques in order to provide baseline knowledge for the methodological approaches applied in Chaps. 9–11. Various statistical-based approaches, agent-based models, rule-based models, artificial neural networks, cellular automata model, and decision tree models are explained and discussed in detail. In addition, validation of urban modeling techniques is also explained. Urban growth and land use changes are the main reasons for environmental, social, and economic issues, such as

hydrological problems, destruction of forests and agricultural fields, natural and wildlife disturbance, and global warming. Thus, a proper understanding of the reason, degree, direction, and consequences of urban growth and expansion is essential for most urban application projects which are discussed with examples.

Chapter 9 presents a methodological process for land use change modeling for the Tripoli metropolis as case study. In this chapter, the simulation process of urban growth in the Tripoli metropolis is presented and explained to understand its pattern and the role of each urban driving force behind the urbanization process. In the simulation process, the frequency ratio (FR) model is first applied based on the real urban expansion rather than entire urbanized area to present the role of classes within each urban factor and reflect actual urban expansion tendency. Second, the evidential belief functions (Dempster–Shafer) model (EBF) is applied to provide further information by generating four maps representing belief, disbelief, uncertainty, and plausibility of predicted future urban growth. Third, the logistic regression (LR) model is applied to assess the overall effect of each urban driving factor, and subsequently combined with a simple growth ratio equation to present probable future scenarios. Fourth, the classic CA–Markov chain (MC) model was used to predict explicit future urban land use in Tripoli in 2020 and 2025. Finally, a novel hybrid model of CHAID–CA–Markov is proposed based on the advantages and shortcomings of the aforementioned models, and employed to model, explain, and predict explicit urban growth in 2020 and 2025. Several multi-temporal space-borne remote sensing data are used to conduct spatial analysis, modeling, and predictions for urban expansion such as Landsat image 1984, Landsat image 1996, Spot 5 image 2002, Spot 5 image 2010, road networks, population data, digital contour map, and topographic map.

Chapter 10 presents a methodological process of compact land use change modeling to simulate and predict future spatiotemporal urban growth in compact form. These processes are conducted to identify and assess the various aspects of land use change modeling, especially regarding statistical (factor analysis) and cellular-based concepts. A hybrid land use modeling approach based on applied modeling techniques is also developed to create a comprehensive projection of the future development pattern in two scenarios. The first scenario (business-as-usual scenario) is based on several urban-related factors and interaction among various land use categories through a historical trend of land use change and growth. Next, the results are integrated into the CA model to facilitate the application of contiguity filters and project future land use maps based on the neighborhood concept. In the second scenario (compact land use scenario), the proposed land use modeling approach and evaluation of degree of compactness (DoC) and trend of compactness (ToC) are considered in proposing and implementing a compact land use scenario using the city intensification process. The proposed model considers the advantages and disadvantages of the existing models and analyzes the interactions of urban factors as well as their interaction among various land use categories. The analyses and modeling approaches used in this study can be employed to guide the identification and measurements of the changes and growth likely to happen in urban areas. The output maps and results can likewise be helpful for town planning in order to design compact and eventually sustainable urban areas.

Chapter 11 proposes a brownfields land use change modeling process according to a compact city paradigm in a larger scale perspectives rather than local aspects. The proposed model is a statistical-based weights-of-evidence (WoE) approach in the GIS environment. The growth of three main land use types in Kajang, Malaysia was predicted using several compact development parameters and other urban and physical site characteristics. This process are aggregated with an existing brownfields map in order to project future land use types according to planning strategies, as well as compact development characteristics. It is concluded that the combination of land use change modeling techniques and compact urban development theory in GIS environment can provide a strong tool for brownfields redevelopment planning and strategies.

Chapter 12 presents a methodological process for extracting the land use/land cover of Karbala City in Iraq using high-resolution satellite images based on rule-based algorithm of the object-oriented classification method. Change detection analysis is implemented on the growth of built-up areas to evaluate the previous trends of land use change pattern. Furthermore, future urban growth and expansion of the study area are projected using the integrated cellular automata and Markov chain technique. Finally, a novel approach for building extraction and counting was presented using the eCognition rule-based method. The methodological process is validated using ground truth points and standard confusion matrix. These analyses indicate the logical and accepted performance of the methods. The projected and produced maps can help identify the spatial growth pattern of urban settlement. Such identification can be used to create adequate future planning for the proper provision of social and infrastructural facilities for the local residences.

Chapter 13 discusses the applications of geographical information system (GIS) and remote sensing (RS) in urban-related fields, especially urban development and planning perspectives. This chapter explains the fundamental concept about GIS and RS and their necessities and relationship with urban-related issues. The basic concept of GIS is explained regarding its main components, input data, capabilities, basic analysis tools, mapping, and visualization abilities. Remote sensing also is explained regarding its advantages with respect to in situ data collection, resolutions, various sensors, and its capabilities for urban problems. Specifically, application of radar imagery in building extraction is presented and explained with proper examples and references. Next, site suitability process as one of the main application of GIS in urban planning and design is discussed and presented in detail with a special focus on multicriteria decision-making (MCDM) and analytical hierarchical process (AHP) techniques in this field. Finally, brief information about GIS application in urban planning and development regarding Malaysian perspective from past to present is explained.

Chapter 14 presents a methodological process attempted to describe and quantify the spatial pattern of urban expansion of the selected study area using several landscape metrics. Four satellite images of the study area from the years 1984, 1996, 2002, and 2010 are used to conduct the analysis of urban sprawl patterns in the Tripoli metropolitan area. The applied spatial landscape metrics provided good insight into urban sprawl from different perspectives and presented a reliable urban sprawl investigation tool. The findings of this study are useful in directing prospective urban plans and urbanization policies in Tripoli.

Chapter 15 presents an interesting application on relationship between urbanization and urban heat island (UHI) effect. The UHI phenomenon affects the environment, regional climate, and socioeconomic development. In this study, Enhanced Thematic Mapper Plus (ETM+) and Landsat Thematic Mapper (TM) images acquired in 2002 and 2009, respectively, are used to evaluate changes in land surface temperature (LST) over different land cover (LC) types during those years in Putrajaya, a planned city in the south of Kuala Lumpur, Malaysia. Urban thermal characteristics were further analyzed by investigating the relationships between LST and two indices, namely, normalized difference vegetation index (NDVI) and normalized difference built-up index (NDBI). Results suggest an inverse relationship between NDVI and LST and a strong direct correlation between NDBI and LST in Putrajaya city. Therefore, detecting the amount of changes in the significant areas, such as vegetated and urban areas, is essential for future urban strategies related to decreasing LST.

In general, this book discusses about the application of geospatial data, geographic information system (GIS) and remote sensing (RS) technologies in analysis and modeling of urban growth process and its pattern, with a specific focus on sprawl and compact development. This book confirms that the proposed advanced modeling approaches, geospatial data and GIS are very practical for identifying urban growth, land use change patterns and their general trends in future. The analyses and modeling approaches presented in this book can be employed to guide in identifying and measuring the changes and growth likely to happen in urban areas. This book also can serve as a guiding text book for postgraduate students and researchers who are interested in urban growth modeling. Though a lot of work on urban growth and

assessment has been published as individual papers in various scientific journals; however, there is also a disconnection between the urban growth modeling and compact city assessment using remote sensing data. This book can provide an easy path from theory to practical algorithms with many case studies. In addition, this book can be helpful for town planning and local development agencies in order to design urban areas in a compact form and eventually sustainable manner.

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Biswajeet Pradhan

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