UNIVERSITI PUTRA MALAYSIA

DEVELOPMENT OF HYBRID LAND USE CHANGE MODEL FOR COMPACT CITY ASSESSMENT

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By

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ABSTRACT

In recent decades, attaining urban sustainability is one of the most primary goals for planners and decision makers in urban related applications. Rapid population growth and rural to urban migration increase the conversion of valuable natural environments to build up areas, and produce several environmental, economic and social issues. Among various aspects of urban sustainability, environmental protection especially agricultural and forest conservations are dominated in tropical countries like Malaysia. Hence, it is important to propose various alternative development scenarios based on objectives of urban sustainability to avoid negative consequences of urban sprawl developments. Compact city is widely accepted as one of the most promising solution for urban development pattern. Compact urban development aims to protect natural environment, reduce land consumption, decrease car dependency, support public transportation facilities, and so on. This study as the first objective discovered the spatiotemporal of urban land use change patterns to highlight the trend of historical development of Kajang City (Malaysia) during years 2004 to 2015. In the second objective, as an initial step of compact city modeling, comprehensive compactness assessment were proposed and implemented based on urban density, intensity and land use diversity. Next, by considering the degree of compactness (DoC) of temporal land use maps, trend of compactness (ToC) of the study area were extracted and evaluated which reveal the growth pattern of compactness. Third objective deals with projection of future development pattern (business as usual scenario) based on several urban related factors and interaction among various land use categories through a novel hybrid cellular and statistical-based integration approach. In this hybrid model, statistical methods such as Weights-of-Evidence (WoE) and Markov Chain were used to evaluate the probability of growth of Kajang City land use types. Next, the results were integrated to Cellular automata (CA) model to facilitate the application of contiguity filters and project the future land use maps based on neighbourhood concept. Finally, by considering the proposed land use modeling approach and evaluation of DoC and ToC, a compact land use scenario were proposed and implemented using city intensification process. Kajang City is selected as case study, because this city in recent years has faced rapid urbanization and large sprawl developments due to its proximity to three main cities of Malaysia. In addition, availability of large proportion of natural environments in this region caused an adequate observation of the effects of urban growth. Although there are many abandoned plots and brownfield sites exist within the municipality, most of the current growth and developments are occurring at the outskirts and through rural environments. Therefore, this study attempts to analyse and

model compact development to provide an alternative solution instead of current development patterns of this city. In general, this study utilized geospatial data within GIS environment to analyse the urban growth process and its pattern with respect to compact city paradigm. According to evaluation of historical land use growth pattern of the study area, it was observed that this city had significant growth and changes during years 2004 to 2012, but few changes have occurred in last three years. Residential, commercial and industrial land use categories had the main growth, and agricultural and open spaces had the main loss during the selected period of time. However, compactness assessment process indicated a gradual growth of DoC of Kajang City which in fact should be enhanced to achieve sustainable environment. This aim was achieved, by evaluating city compactness of both proposed land use scenarios for year 2026, in which the DoC of compact land use scenario was higher than business as usual scenario. Results confirmed that the proposed modeling approaches, geospatial data, statistical techniques and GIS are very practical for identifying urban growth and land use change patterns and their general trends in future. 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.

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

Pembangunan Model Perubahan Guna Tanah Hibrid Untuk Penilaian Kepadatan Bandar

Oleh

SALEH ABDULLAHI

Mac 2016

Pengerusi: Profesor Madya Dr. Biswajeet Pradhan, PhD
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ABSTRAK

Kebelakangan ini, pencapaian dalam kemampanan pebandaran adalah salah satu matlamat yang paling utama bagi perancang dan pembuat keputusan dalam aplikasi yang berkaitan pebandaran. Pertumbuhan penduduk yang pesat dan penghijrahan dari luar bandar ke kawasan bandar menyumbang kepada perkembangan yang berselerak dan mendatar. Corak pembangunan yang kebanyakannya telah menukar persekitaran semulajadi yang berharga kepada kawasan pembangunan telah menghasilkan beberapa isu alam sekitar, ekonomi dan isu sosial yang bertentangan dengan kemampanan bandar. Antara beberapa aspek di dalam pembangunan bandar yang mampan adalah, perlindungan alam sekitar khususnya konservasi hutan dan pertanian didominasi oleh negara-negara tropika seperti Malaysia. Oleh itu, adalah penting untuk membincangkan pelbagai alternatif untuk senario pembangunan berdasarkan objektif kemampanan bandar untuk mengelakkan kesan negatif daripada pembangunan bandar berselerak. Kepadatan bandar diterima dengan meluas sebagai salah satu penyelesaian yang paling menjanjikan untuk corak pembangunan bandar untuk mencapai matlamat utama bagi pemampanan bandar. Pembangunan bandar yang padat dengan kawasan pembangunan berkepadatan tinggi, kepelbagaian penggunaan tanah dan peningkatan kejiranan yang bertujuan untuk melindungi alam semulajadi, mengurangkan penggunaan tanah, mengurangkan pergantungan kepada kereta, menyokong kemudahan pengangkutan awam , menggalakan berjalan kaki dan berbasikan dan banyak lagi. Objektif pertama kajian ini adalah untuk mengenalpasti corak perubahan ruang-masa guna tanah untuk mengetengahkan trend perkembangan sejarah pembangunan Bandar Kajang bermula dari tahun 2004 hingga 2015. Dalam objektif kedua pula, sebagai langkah awal dalam memodelkan bandar padat, penilaian fizikal dan fungsi komprehensif telah dicadangkan dan dilaksanakan berdasarkan kepada kepadatan bandar, intensiti dan kepelbagaian penggunaan tanah. Seterusnya, dengan mengambil kira tahap kepadatan (DoC) peta guna tanah beberapa tahun, trend kepadatan (ToC) di kawasan kajian telah diekstrak dan dinilai dimana telah mendedahkan corak pertumbuhan kepadatan. Objektif ketiga pula mengambilkira unjuran corak pembangunan masa hadapan (perniagaan sebagai senario biasa) berdasarkan kepada beberapa faktor dan interaksi antara pelbagai kategori penggunaan tanah melalui pendekatan novel hybrid selular dan integrasi berasaskan statistik. Dalam model hybrid ini, kaedah statistik seperti Weigth-of-Evidence (WoE) dan rantaian Markov telah digunakan untuk menilai kebarangkalian pertumbuhan jenis guna tanah Bandar Kajang. Selepas pengesahan peta kebarangkalian dengan peta guna tanah sebenar, keputusan elah diintegrasikan dengan model Cellular automata (CA) untuk

memudahkan permohonan penapis persentuhan dan menonjolkan peta guna tanah masa hadapan berdasarkan konsep selular. Akhir sekali, dengan mengambil kira penggunaan pendekatan guna tanah yang dicadangkan dan penilaian DoC dan ToC, senario kepadatan gunatanah dicadangkan dan dilaksanakan menggunakan proses penumpuan perbandaran. Bandar Kajang telah dipilih sebagai kes kajian tesis ini, kerana kebelakangan ini, bandar ini menghadapi perbandaran yang pesat dan perkembangan berselerak yang besar kerana kedudukannya yang berhampiran dengan tiga bandar utama di Malaysia. Tambahan pula, dengan adanya sebahagian besar persekitaran semula jadi di rantau ini menyebabkan cukupnya pemerhatian keatas kesan pertumbuhan bandar. Walaupun banyak plot yang ditinggalkan dan kawasan brownfield wujud didalam kawasan perbandaran tersebut, namun sebahagian besar daripada pertumbuhan semasa dan pembangunan yang berlaku di kawasan pinggir dan luar bandar telah memusnahkan kawasan yang semulajadi dan produktif. Oleh itu, kajian ini cuba untuk menganalisis dan memodelkan pembangunan yang padat untuk menyediakan alternatif baharu berbanding corak perkembangan semasa bandar ini. Secara umumnya, kajian ini menggunakan data geospatial dalam persekitaran GIS untuk menganalisis proses pertumbuhan bandar dan corak berkenaan dengan paradigm kepadatan bandar. Menurut penilaian corak sejarah pertumbuhan guna tanah kawasan kajian, dapat diperhatikan bahawa Bandar ini mempunyai perubahan dan pertumbuhan yang ketara semenjak tahun 2004 hingga 2012, tetapi beberapa perubahan telah berlaku dalam tempoh tiga tahun ini. Kawasan guna tanah untuk kediaman, komersial dan industry mempunyai pertumbuhan utama dan kawasan terbuka dan pertanian mengalami pengurangan semasa jangka masa yang telah dipilih. Walaubagaimanpun, proses penilaian kepadatan menunjukkan pertumbuhan DoC secara beransur-ansur (tahap kepadatan) Bandar Kajang sebenarnya perlu dipertingkatkan untuk mencapai persekitaran yang mampan. Matlamat telah tercapai, dengan menilai kepadatan kedua-dua senario penggunaan tanah yang dicadangkan untuk tun 2026, dimana DoC untuk senario kepadatan guna tanah lebih tinggi dari biasa sebagai senario yang biasa. Keputusan mengesahkan bahawa pendekatan model yang dicadangkan, data geospatial, teknik statistic dan GIS adalah praktikal untuk mengenalpasti kepadatan pertumbuhan bandar dan corak perubahan guna tanah dan corak umumnya pada masa hadapan. Analisis dan pendekatan yang digunakan dalam kajian ini boleh digunakan untuk membantu dalam mengenalpasti dan mengukur perubahan dan perubahan yang mungkin berlaku di kawasan bandar. Disamping itu, peta hasil dan keputusan ini boleh menjadi berguna untuk perancang bandar bagi merangka kawasan bandar dalam bentuk yang padat dan mampan.

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I certify that a Thesis Examination Committee has met on …2015 to conduct the final examination of Saleh Abdullahi on his thesis entitled "Development of hybrid land use change model for compact city assessment" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1988. The committee recommends that the candidate be awarded the Doctor of Philosophy.
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LIST OF ABBREVIATIONS

ABM	Agent Based Model
AI	Aggregation Index
ANN	Artificial Neural Network
AUC	Area Under The Curve
CA	Cellular Automate
CBD	Central Business District
CLPI	Compact Landscape Shape Index
DOC	Degree of compactness
ED	Edge Density
ENN	Euclidean Nearest-Neighbor Distance
FR	Frequency Ratio
GIS	Geographic Information System
GYRATE	Radius Of Gyration
LPI	Landscape Patch Index
LR	Logistic Regression
LSI	Landscape Shape Index
NP	Number Of Patches
ROC	Relative Operating Characteristics
RS	Remote Sensing
PD	Patch Density
PLADJ	Proportion Of Like Adjacencies
SHAPE	Shape Index
SHDI	Shannon's Diversity Index
SHEI	Shannon's Evenness Index
SIDI	Simpson's Diversity Index
SIEI	Simpson's Evenness Index
TOD	Transit Oriented Development
TOC	Trend of compactness
WoE	Weights-of-Evidence

CHAPTER 1

INTRODUCTION

1.1. General

Although the total amount of urban areas covers a very insignificant percentage of the Earth's land surface, but still the growth of these areas is the main reason of various natural environmental problems. Currently the influence of urban areas on Earth's resources consumption, environmental pollutions, climate changes and etc. is clearly observable. The continuous growth of these manmade developments has strengthened these problems and produced several other negative effects on natural environments. Rapid growth of population and migration of people from villages to cities due to higher quality of life especially in developing countries expand the urban environments. Hence, in recent decades there is a growing awareness about urban sprawl development and its negative consequences (Hennig et al. 2015; Sisodia et al. 2016).

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 (Burchell et al. 2000). 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 etc. (Burchell et al. 2000; Carruthers 2002; Gu et al. 2013; Litman 2015; Post et al. 2015) are not characterized as an acceptable and sustainable urban form.

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 (CEC 1992). Regarding 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 capacity 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 (Lin and Yang 2006).

Generally, 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 landscape planning (Kropp and Lein 2013). Therefore, the contribution of shape and form of the cities has become one of the main focus points to conduct these tasks. In this regard, compact urban development due to various sustainable urban characteristics such as less car dependency, public transportation promotion, rural development containment, natural environment preservation and etc. is recognized as one of the most sustainable urban forms (Livingstone and Authority

2003; Wolsink 2016). These characteristics are seen to have contributed the objectives of sustainable urban development in the sense of social, economic and environmental concerns.

Compact land use pattern is a relatively new terminology in this field 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 (Kocabas and Dragicevic 2007). 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. Simulation of compact urban forms is the first step towards the implementation of compact development initiative (Li et al. 2008) to achieve ultimate goals of urban sustainability.

In addition to form and shape of urban areas, 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 (Pijanowski et al. 2002; Tayyebi et al. 2014; Schmidt et al. 2015). 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 result of complex interaction of various environmental, physical, political, cultural, and other factors (Houghton 1994; Medley et al. 1995; Chen and Han 2015). Monitoring of these changes showed that, the flow of conversion is mainly from natural environment (forest lands) to agricultural fields and finally to built-up areas (Tayyebi et al. 2014). Thus, the simulation and prediction of these changes provide insightful information and allow for more systematic analysis of the relationship between forms and process for various environmental and urban planning applications.

1.2. Problem Statement

Rapid urban expansion and massive conversion of natural environment to urban areas has created a major concern regarding urban sustainability (Li and Yeh 2000; Pribadi and Pauleit 2015). Compact urban development as one of the most sustainable urban forms is a complex and long-term project that requires a flexible law system and supportive government (Chinyio et al. 1998). Unfortunately, improper understanding and agreement about the definitions and comprising several concepts and indicators make urban sustainability and compact city difficult achievable tasks (Li and Yeh 2000). Consequently, these complexities have influenced on each phase of sustainable and compact developments processes such as modeling, implementing 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 (Burton 2002; Turskis et al. 2006). 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 (Burton 2002; Li and Yeh 2004; Turskis et al. 2006). For instance, measuring urban density and land use diversity are usually based on census tracts, which vary in size and resolution (Adolphson 2010). 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 (Openshaw 1984). 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 (Thinh et al. 2002). Whereas, city

compactness besides of 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 (Burton 2002; Turskis et al. 2006; Zagorskas et al. 2007). Moreover, evaluation of city compactness by applying common statistical techniques to measure for example mixed land use development, can only indicates the land use richness of a local neighborhood (Bhat and Gossen 2004; Van Eck and Koomen 2008; Manaugh and Kreider 2013). 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 (Adolphson 2010; Schädler et al. 2013).

With respect to urban growth analysis, evaluation of previous growth and extraction of development trend as historical components of land use change modeling is an essential task (Lantman et al. 2011; Betts et al. 2015; Tayyebi et al. 2015). 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 stockholders make modeling and prediction process a difficult task (Lantman et al. 2011). Specifically, land use change is arises from complex interaction of various environmental, physical, political, cultural, and other factors and mainly dependent on spatial location, scale, and current state of land use (Pijanowski et al. 2002; Liu and Phinn 2003; Wang et al. 2011; Chen and Han 2015). The existing modeling and prediction techniques cannot be solely applied for this complex phenomenon (Li et al. 2008). A reliable and comprehensive modeling approach which can be created from integration of several modeling techniques should be proposed in order to take into account the related issues and variables (de Almeida et al. 2003). In addition, the proposed hybrid model should be consists of and based on the main core principles of land use change modeling (Lantman et al. 2011). 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 (Wang 2012). Therefore, it is very important to propose a hybrid model at fine spatial resolution to deal with complexity of land use modeling and prediction.

On the other hand, land use change modeling based on city compactness, or in a proper terminology, compact land use pattern modeling not only should considers 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 (Li et al. 2008; Mubareka et al. 2011; Jang and Kang 2015). In compact land use development which is relatively new topic human scale factors and quality of life perspective has higher priority rather than other aspects, hence this issue made these kinds of development modeling more sophisticated (Doi 2005). Therefore, in these modeling process, a calibrated and hybrid approaches are required to achieve all objectives of planning and development strategies (Mubareka et al. 2011).

Kajang City which is located 21 km from Kuala Lumpur (capital city of Malaysia) due to proximity to three main cities of Malaysia in recent years has encountered sprawl developments and horizontal expansions. Particularly, as of 2004 a few townships have been developed in and around this city, such as Taman Prima Saujana, Sungai Chua,

and Taman Kajang Perdana (Hassan et al. 2013). An increasing proportion of brownfields and conversion of the agricultural fields to built-up areas are results of such sprawl developments. This city consists of urban developed area and a large proportion of green environment and agricultural fields. Therefore, the effects of growth and changes of various land use types can be adequately observed, particularly on the natural environment. Thus, this study is conducted on Kajang City to evaluate and analyze the urban growth patterns especially from the year 2004 onwards and to model and propose compact city as an alternative instead of current development pattern.

1.3. Research Motivation

The lack of proper understanding and definition of compact city in general and its various aspects such as assessment, modeling and prediction, were the main motivations of this research. In addition, by considering urban growth and expansion in tropical regions with huge amount of green environments, it is very essential to propose some kinds of development patterns with minimum land consumption strategies. Geographic Information System (GIS) and remote sensing which have been produced huge prospects and supported significant achievements in monitoring and analyzing urban growth, considered as a best platform to implement this research objectives. However, it is obviously clear that, to deal with these complex concepts and processes at the micro and macro levels, several decision analysis tools and multidisciplinary approaches should be simultaneously applied. Hence, this thesis proposed a hybrid modeling approach consists of various aspects of assessments and prediction phases using geospatial data within the GIS environment.

1.4. Research Objectives

The main objective of this study is to integrate land use change modeling process with compact city paradigms to model and predict compact land use pattern. The research focused on the growth and changes of urban land use types of Kajang City to be useful in terms of city compactness assessment of urban plans and urbanization processes of this region.

The specific objectives are as follow;

1) To evaluate the spatiotemporal land use change patterns in Kajang City at high spatial resolution to identify, assess and quantify urban growth behaviour as a process and pattern during the period of 2004 to 2015 from different perspectives.
2) To implement effective and comprehensive sustainable city compactness assessments based on the compact urban development indicators.
3) To develop a new hybrid land use change modeling approach based on cellular and factor-based statistical analysis to project future land use growth.
4) To calibrate the proposed hybrid land use change model with brownfield redevelopment as a city intensification process to project compact land use pattern.

1.5. Scope of the Study

This study aims to investigate, assess and analyze the urban growth, land use changes and city compactness of land use maps from year 2004 to 2015, and then to model and

predict the future urban growth and land use changes based on current pattern and compact urban development. Several urban land use categories are considered for analysis and assessment, such as residential, commercial, industrial, facilities, agriculture, and etc. For city compactness assessment three main compactness indicators; urban density, land use diversity and urban intensity were utilized. In case of land use modeling stage, several urban related and physical parameters (such as proximity to road networks, proximity to public transportation facilities, population, soil and geological characteristic and etc.) and local neighborhood effects are applied and evaluated using statistical and cellular-based analysis to project future development patterns as business as usual scenario. In addition, compact land use modeling was proposed using city intensification process to produce compact land use pattern scenario. All the output maps produced from various stages of modeling process were validated using relative operating characteristics (ROC) and Kappa index of agreement.

1.6. Thesis Organization

This thesis is organized into five chapters. The first chapter includes the introduction which gives a brief background about the urban growth and land use change process, their impact on natural environment and the solution through compact urban development. This chapter also, discuss the challenges regarding these issues, research gaps, objectives and scope of the current study. The second chapter covers the literature review related to definitions and concepts of urban growth, land use change processes and compact city and in-depth discussion about the related studies and researches about the analysis and modeling of the above mentioned terms. The third chapter presents and discuss about the study area, data and proposed models employed in this study. The fourth chapter deals with results and discussions of the implemented analysis. And finally, the fifth chapter concludes this research with a summary of the work and suggestion for future researches.

REFERENCES

Adolphson, M. 2010. "Kernel densities and mixed functionality in a multicentred urban region." *Environment and planning. B, Planning & design*, *37*(3), 550.

Al-shalabi, M., Billa, L., Pradhan, B., Mansor, S., & Al-Sharif, A. A. 2013. "Modelling urban growth evolution and land-use changes using GIS based cellular automata and SLEUTH models: the case of Sana'a metropolitan city, Yemen." *Environmental earth sciences*, *70*(1), 425-437.

Al-sharif, A. A., & Pradhan, B. 2014. "Monitoring and predicting land use change in Tripoli Metropolitan City using an integrated Markov chain and cellular automata models in GIS." *Arabian Journal of Geosciences*, *7*(10), 4291-4301.

Al-sharif, A. A., & Pradhan, B. 2015. "A novel approach for predicting the spatial patterns of urban expansion by combining the chi-squared automatic integration detection decision tree, Markov chain and cellular automata models in GIS." *Geocarto International*(ahead-of-print), 1-24.

Almeida, C., Gleriani, J., Castejon, E. F., & Soares-Filho, B. 2008. "Using neural networks and cellular automata for modelling intra-urban land-use dynamics." *International journal of geographical information science*, *22*(9), 943-963.

Almeida, C., Monteiro, A., Câmara, G., Soares-Filho, B., Cerqueira, G., & Pennachin, C. Modeling urban land use dynamics through Bayesian probabilistic methods in a cellular automaton environment. In *Proceedings of the 29thInternational Symposium on Remote Sensing of the Environment, 2002*

Almeida, C., Monteiro, A. M. V., Câmara, G., Soares-Filho, B. S., Cerqueira, G. C., Pennachin, C. L., et al. 2005. "GIS and remote sensing as tools for the simulation of urban land-use change." *International Journal of Remote Sensing*, *26*(4), 759-774.

Alphan, H. 2003. "Land-use change and urbanization of Adana, Turkey." *Land degradation & development*, *14*(6), 575-586.

Alpkokin, P., Cheung, C., Black, J., & Hayashi, Y. 2008. "Dynamics of clustered employment growth and its impacts on commuting patterns in rapidly developing cities." *Transportation Research Part A: Policy and Practice*, *42*(3), 427-444.

Althuwaynee, O. F., Pradhan, B., & Lee, S. 2012. "Application of an evidential belief function model in landslide susceptibility mapping." *Computers & Geosciences*, *44*, 120-135.

Angel, S., Parent, J., & Civco, D. Urban sprawl metrics: an analysis of global urban expansion using GIS. In *Proceedings of ASPRS 2007 Annual Conference, Tampa, Florida May, 2007* (Vol. 7)

Arbury, J. (2005). *From urban sprawl to compact city: an analysis of urban growth management in Auckland*. Geography and Environmental Science)--University of Auckland,

Arifwidodo, S. D. 2012. "Exploring the effect of compact development policy to urban quality of life in Bandung, Indonesia." *City, Culture and Society*, *3*(4), 303-311.

Arsanjani, J. J., Kainz, W., & Mousivand, A. J. 2011. "Tracking dynamic land-use change using spatially explicit Markov Chain based on cellular automata: the case of Tehran." *International Journal of Image and Data Fusion*, *2*(4), 329-345.

Banister, D. 2012. "Assessing the reality—Transport and land use planning to achieve sustainability." *Journal of Transport and Land Use*, *5*(3), 1-14.

Barbier, E. B. 1987. "The concept of sustainable economic development." *Environmental conservation, 14*(02), 101-110.

Barnes, K. B., Morgan III, J. M., Roberge, M. C., & Lowe, S. 2001. "Sprawl development: its patterns, consequences, and measurement." *Towson University, Towson, Available online at: http://chesapeake.towson.edu/landscape/urbansprawl/download/Sprawl_white_paper.pdf (last accessed 13 February 2008).* 1-24.

Barnsley, M. J., & Barr, S. L. 1996. "Inferring urban land use from satellite sensor images using kernel-based spatial reclassification." *Photogrammetric engineering and remote sensing, 62*(8), 949-958.

Barredo, J. I., Kasanko, M., McCormick, N., & Lavalle, C. 2003. "Modelling dynamic spatial processes: simulation of urban future scenarios through cellular automata." *Landscape and Urban Planning, 64*(3), 145-160.

Basse, R. M., Charif, O., & Bódis, K. 2016. "Spatial and temporal dimensions of land use change in cross border region of Luxembourg. Development of a hybrid approach integrating GIS, cellular automata and decision learning tree models." *Applied geography, 67*, 94-108.

Batty, M. 2008. "The size, scale, and shape of cities." *science, 319*(5864), 769-771.

Batty, M., & Longley, P. A. 1994. *Fractal cities: a geometry of form and function*: Academic Press.

Batty, M., & Xie, Y. 1994. "From cells to cities." *Environment and Planning B, 21*, s31-s31.

Batty, M., Xie, Y., & Sun, Z. 1999. "Modeling urban dynamics through GIS-based cellular automata." *Computers, environment and urban systems, 23*(3), 205-233.

Bengston, D. N., Potts, R. S., Fan, D. P., & Goetz, E. G. 2005. "An analysis of the public discourse about urban sprawl in the United States: monitoring concern about a major threat to forests." *Forest Policy and Economics, 7*(5), 745-756.

Benz, U. C., Hofmann, P., Willhauck, G., Lingenfelder, I., & Heynen, M. 2004. "Multi-resolution, object-oriented fuzzy analysis of remote sensing data for GIS-ready information." *ISPRS Journal of photogrammetry and remote sensing, 58*(3), 239-258.

Betts, R., Golding, N., Gonzalez, P., Gornall, J., Kahana, R., Kay, G., et al. 2015. "Climate and land use change impacts on global terrestrial ecosystems and river flows in the HadGEM2-ES Earth system model using the representative concentration pathways." *Biogeosciences, 12*(5), 1317-1338.

Beurden, J., Bakema, A., & Tijbosch, H. 2007. "A land-use modelling system for environmental impact assessment; Recent applications of the LUMOS toolbox." *Modelling Land-Use Change*(Progress and Applications, Springer, Dordrecht), 281-296.

Bhat, C. R., & Gossen, R. 2004. "A mixed multinomial logit model analysis of weekend recreational episode type choice." *Transportation Research Part B: Methodological, 38*(9), 767-787.

Bhatta, B. 2009. "Modelling of urban growth boundary using geoinformatics." *International Journal of Digital Earth, 2*(4), 359-381.

Bhatta, B. 2010. *Analysis of urban growth and sprawl from remote sensing data*: Springer Science & Business Media.

Bhatta, B., Saraswati, S., & Bandyopadhyay, D. 2010. "Urban sprawl measurement from remote sensing data." *Applied geography, 30*(4), 731-740.

Bhattacharya, A., Oppenheim, J., & Stern, N. 2015. "Driving sustainable development through better infrastructure: Key elements of a transformation program." *Global Economy & Development Working Paper, 91*.

Bingham, G., Bishop, R., Brody, M., Bromley, D., Clark, E. T., Cooper, W., et al. 1995. "Issues in ecosystem valuation: improving information for decision making." *Ecological Economics, 14*(2), 73-90.

Blaikie, P., & Brookfield, H. 2015. *Land degradation and society*: Routledge.

Bleicher, A., & Gross, M. 2010. "Sustainability assessment and the revitalization of contaminated sites: operationalizing sustainable development for local problems." *International Journal of Sustainable Development & World Ecology, 17*(1), 57-66.

Bohman-Carter, G. (1994). Geographic information systems for geoscientists. Pergamon, Oxford.

Breheny, M. J., Town, & Association, C. P. 1999. *The People: Where Will They Work?: Report of TCPA Research Into the Changing Geography of Employment*: Town and Country Planning Association.

Briassoulis, H. 2001. "Policy-oriented integrated analysis of land-use change: an analysis of data needs." *Environmental management, 27*(1), 1-11.

Bui, D. T., Pradhan, B., Lofman, O., Revhaug, I., & Dick, O. B. 2012. "Spatial prediction of landslide hazards in Hoa Binh province (Vietnam): a comparative assessment of the efficacy of evidential belief functions and fuzzy logic models." *Catena, 96*, 28-40.

Burchell, R. W. Economic and fiscal impacts of alternative land-use patterns. In *Center for Urban Policy Research, Rutgers University. Prepared for Michigan State Land Use Forum Conference, 1996*

Burchell, R. W., Listokin, D., & Galley, C. C. 2000. "Smart growth: More than a ghost of urban policy past, less than a bold new horizon." *Housing policy debate, 11*(4), 821-879.

Burnham, B. O. 1973. "Markov intertemporal land use simulation model." *Southern Journal of Agricultural Economics, 5*(01), 253-258.

Burton, E. 2000. "The compact city: just or just compact? A preliminary analysis." *Urban Studies, 37*(11), 1969-2006.

Burton, E. 2002. "Measuring urban compactness in UK towns and cities." *Environment and Planning B, 29*(2), 219-250.

Burton, E., Jenks, M., & Williams, K. 2003. *The compact city: a sustainable urban form?* : Routledge.

Calthorpe, P. 1993. *The next American metropolis: Ecology, community, and the American dream*: Princeton Architectural Press.

Candau, J. T. (2002). *Temporal calibration sensitivity of the SLEUTH urban growth model*. University of California, Santa Barbara, CA.

Carruthers, J. I. 2002. "The impacts of state growth management programmes: a comparative analysis." *Urban Studies, 39*(11), 1959-1982.

Carruthers, J. I., & Ulfarsson, G. F. 2008. "Does smart growth'matter to public finance?". *Urban Studies, 45*(9), 1791-1823.

CEC, C. o. t. E. C. 1992. *Sustainable Mobility: Impact of Transport on the Environment* (Vol. COM 9246.). Brussels: Commission of the European Communities.

CEC, C. o. t. E. C. 2004. *Towards a thematic strategy on the urban environment* (Vol. 60): Commission of the European Communities.

CEC, C. o. t. E. C. 2005. *Green paper on energy efficiency or doing more with less*: Commission of the European Communities.

Chen, C., He, B., & Zeng, Z. 2014. "A method for mineral prospectivity mapping integrating C4. 5 decision tree, weights-of-evidence and m-branch smoothing techniques: a case study in the eastern Kunlun Mountains, China." *Earth Science Informatics, 7*(1), 13-24.

Chen, G., & Han, M. 2015. "Virtual land use change in China 2002–2010: internal transition and trade imbalance." *Land Use Policy, 47*, 55-65.

Chen, J., Chang, K.-t., Karacsonyi, D., & Zhang, X. 2014. "Comparing urban land expansion and its driving factors in Shenzhen and Dongguan, China." *Habitat International, 43*, 61-71.

Cheng, J., & Masser, I. 2003. "Modelling urban growth patterns: a multiscale perspective." *Environment and Planning A, 35*(4), 679-704.

Chinyio, E. A., Olomolaiye, P. O., Kometa, S. T., & Harris, F. C. 1998. "A needs-based methodology for classifying construction clients and selecting contractors." *Construction Management & Economics, 16*(1), 91-98.

Chiu, R. L. 2008. "Shanghai's Rapid Urbanization: How Sustainable?". *Built Environment, 34*(4), 532-546.

Chiu, R. L. 2012. "Urban sustainability and the urban forms of China's leading mega cities: Beijing, Shanghai and Guangzhou." *Urban Policy and Research, 30*(4), 359-383.

Chung, H. 2010. "Building an image of Villages-in-the-City: A Clarification of China's Distinct Urban Spaces." *International Journal of Urban and Regional Research, 34*(2), 421-437.

Clark, T. A. 2013. "Metropolitan density, energy efficiency and carbon emissions: Multi-attribute tradeoffs and their policy implications." *Energy Policy, 53*, 413-428.

Clarke, K. C., & Gaydos, L. J. 1998. "Loose-coupling a cellular automaton model and GIS: long-term urban growth prediction for San Francisco and Washington/Baltimore." *International journal of geographical information science, 12*(7), 699-714.

Collins, F. P. 2002. "Small Business Liability Relief and Brownfields Revitalization Act: A Critique, The." *Duke Envtl. L. & Pol'y F., 13*, 303.

Commission, W. (1987). Our common future. The world commission on environment and development. Oxford: Oxford University Press.

Corr, G., Walker, A., Benz, U., Lingenfelder, I., & Rodrigues, A. Classification of urban SAR imagery using object oriented techniques. In *Geoscience and Remote Sensing Symposium, 2003. IGARSS'03. Proceedings. 2003 IEEE International, 2003* (Vol. 1, pp. 188-190): IEEE

Costanza, R., & Ruth, M. 1998. "Using dynamic modeling to scope environmental problems and build consensus." *Environmental management, 22*(2), 183-195.

Couclelis, H. 1985. "Cellular worlds: a framework for modeling micro-macro dynamics." *Environment and Planning A, 17*(5), 585-596.

Dadhich, P. N., & Hanaoka, S. 2011. "Spatio-temporal urban growth modeling of Jaipur, India." *Journal of Urban Technology, 18*(3), 45-65.

Dadi, D., Azadi, H., Senbeta, F., Abebe, K., Taheri, F., & Stellmacher, T. 2016. "Urban sprawl and its impacts on land use change in Central Ethiopia." *Urban Forestry & Urban Greening, 16*, 132-141.

Dale, V. H., O'NEILL, R. V., Pedlowski, M., & Soutworth, F. 1993. "Causes and effects of land-use change in central Rondônia, Brazil." *Photogrammetric engineering and remote sensing, 59*(6), 997-1005.

de Almeida, C. M., Batty, M., Monteiro, A. M. V., Câmara, G., Soares-Filho, B. S., Cerqueira, G. C., et al. 2003. "Stochastic cellular automata modeling of urban

land use dynamics: empirical development and estimation." *Computers, environment and urban systems, 27*(5), 481-509.
De Chiara, J. 1990. *Time-saver standards for building types* (McGraw-Hill). New York: McGraw-Hill.
de Koning, G. H., Verburg, P. H., Veldkamp, A., & Fresco, L. 1999. "Multi-scale modelling of land use change dynamics in Ecuador." *Agricultural systems, 61*(2), 77-93.
Deal, B., & Schunk, D. 2004. "Spatial dynamic modeling and urban land use transformation: a simulation approach to assessing the costs of urban sprawl." *Ecological Economics, 51*(1), 79-95.
DeMaris, A. 1992. *Logit modeling: Practical applications* (Vol. 86): Sage.
Dempster, A. P. 1967. "Upper and lower probabilities induced by a multivalued mapping." *The annals of mathematical statistics*, 325-339.
DETR, D. o. t. E., Transport and the Regions. 1998. *The Use of Density in Urban Planning* (London SW1E 5DU). The Stationery Office, London: Department of the Environment,Transport and the Regions.
Dieleman, F., & Wegener, M. 2004. "Compact city and urban sprawl." *Built Environment, 30*(4), 308-323.
Dietzel, C., & Clarke, K. 2006. "The effect of disaggregating land use categories in cellular automata during model calibration and forecasting." *Computers, environment and urban systems, 30*(1), 78-101.
Ding, C. 2004. "Urban spatial development in the land policy reform era: evidence from Beijing." *Urban Studies, 41*(10), 1889-1907.
Doi, K. 2005. "Multiagent land-use and transport model for the policy evaluation of a compact city." *Environment and Planning B: Planning and Design, 32*, 485-504.
Domencich, T. A., & McFadden, D. (1975). Urban Travel Demand-A Behavioral Analysis.
Donnay, J.-P., Barnsley, M. J., & Longley, P. A. 2003. *Remote Sensing and Urban Analysis: GISDATA 9*: CRC Press.
Economic, U. N. D. o. 2005. *World Population Prospects: Sex and age distribution of the world population* (Vol. 2): United Nations Publications.
EPU (2006). Ninth Malaysian plan 2006-2010. Putrajaya: Economic Planning Unit.
Esch, T., & Roth, A. Semi-automated classification of urban areas by means of high resolution radar data. In *ISPRS 2004 Congress, 2004* (pp. 478-482)
Esch, T., Thiel, M., Schenk, A., Roth, A., Muller, A., & Dech, S. 2010. "Delineation of urban footprints from TerraSAR-X data by analyzing speckle characteristics and intensity information." *Geoscience and Remote Sensing, IEEE Transactions on, 48*(2), 905-916.
Ewing, R., Pendall, R., & Chen, D. 2003. "Measuring sprawl and its transportation impacts." *Transportation Research Record: Journal of the Transportation Research Board*(1831), 175-183.
Eyoh, A., Olayinka, D. N., Nwilo, P., Okwuashi, O., Isong, M., & Udoudo, D. 2012. "Modelling and predicting future urban expansion of lagos, nigeria from remote sensing data using logistic regression and GIS." *International Journal of Applied Science and Technology, 2*(5), 116-124.
Fatone, L., Maponi, P., & Zirilli, F. Fusion of SAR/optical images to detect urban areas. In *Remote Sensing and Data Fusion over Urban Areas, IEEE/ISPRS Joint Workshop 2001, 2001* (pp. 217-221): IEEE
Figueira, J., Greco, S., & Ehrgott, M. 2005. *Multiple criteria decision analysis: state of the art surveys* (Vol. 78): Springer Science & Business Media.

Force, U. T., & Rogers, R. G. 1999. *Towards an urban renaissance*: Spon London.
Forster, B. 1984. "Remote Sensing and its application to urban studies." *Urban Policy and Research, 2*(4), 25-32.
Frumkin, H., Frank, L., & Jackson, R. J. 2004. *Urban sprawl and public health: Designing, planning, and building for healthy communities*: Island Press.
Gainza, X., & Livert, F. 2013. "Urban form and the environmental impact of commuting in a segregated city, Santiago de Chile." *Environment and Planning B: Planning and Design, 40*(3), 507-522.
Gettings, M. E., Bultman, M. W., & Fisher, F. S. 2004. "A complex systems model approach to quantified mineral resource appraisal." *Environmental management, 33*(1), 87-98.
Gillham, O. 2002. *The limitless city: a primer on the urban sprawl debate*: Island Press.
Gong, W., Yuan, L., Fan, W., & Stott, P. 2015. "Analysis and simulation of land use spatial pattern in Harbin prefecture based on trajectories and cellular automata—Markov modelling." *International Journal of Applied Earth Observation and Geoinformation, 34*, 207-216.
Grant, J. 2006. *Planning the good community: New urbanism in theory and practice* (Vol. 9): Taylor & Francis.
Grimm, V., Berger, U., Bastiansen, F., Eliassen, S., Ginot, V., Giske, J., et al. 2006. "A standard protocol for describing individual-based and agent-based models." *Ecological modelling, 198*(1), 115-126.
Gross, M. 2010. "Ignorance, research and decisions about abandoned opencast coal mines." *Science and public policy, 37*(2), 125-134.
Gu, Z., Sun, Q., & Wennersten, R. 2013. "Impact of urban residences on energy consumption and carbon emissions: An investigation in Nanjing, China." *Sustainable Cities and Society, 7*, 52-61.
Hagoort, M. J., & te Utrecht, R. 2006. *The neighbourhood rules: land-use interactions, urban dynamics and cellular automata modelling*: Koninklijk Nederlands Aardrijkskundig Genootschap.
Harrell, F. 2015. *Regression modeling strategies: with applications to linear models, logistic and ordinal regression, and survival analysis*: Springer.
Hassan, A., Sarah, H., & Algadi, M. (2013). Kajang sustainable urban design. Malaysia: University Kebangsaan Malaysia.
Hayek, U. W., Jaeger, J. A., Schwick, C., Jarne, A., & Schuler, M. 2011. "Measuring and assessing urban sprawl: What are the remaining options for future settlement development in Switzerland for 2030?". *Applied Spatial Analysis and Policy, 4*(4), 249-279.
He, B., Chen, C., & Liu, Y. 2010. "Mineral potential mapping for Cu-Pb-Zn deposits in the East Kunlun Region, Qinghai Province, China, integrating multi-source geology spatial data sets and extended weights-of-evidence modeling." *GIScience & Remote Sensing, 47*(4), 514-540.
Heistermann, M., Müller, C., & Ronneberger, K. 2006. "Land in sight?: Achievements, deficits and potentials of continental to global scale land-use modeling." *Agriculture, Ecosystems & Environment, 114*(2), 141-158.
Henderson, F. M., & Xia, Z.-G. 1997. "SAR applications in human settlement detection, population estimation and urban land use pattern analysis: A status report." *Geoscience and Remote Sensing, IEEE Transactions on, 35*(1), 79-85.
Hennig, E. I., Schwick, C., Soukup, T., Orlitová, E., Kienast, F., & Jaeger, J. A. 2015. "Multi-scale analysis of urban sprawl in Europe: Towards a European de-sprawling strategy." *Land Use Policy, 49*, 483-498.

Henninger, H. B., Reese, S. P., Anderson, A. E., & Weiss, J. A. 2010. "Validation of computational models in biomechanics." *Proceedings of the Institution of Mechanical Engineers, Part H: Journal of Engineering in Medicine*, *224*(7), 801-812.

Herold, M., Goldstein, N. C., & Clarke, K. C. 2003. "The spatiotemporal form of urban growth: measurement, analysis and modeling." *Remote sensing of Environment*, *86*(3), 286-302.

Herold, M., Roberts, D. A., Gardner, M. E., & Dennison, P. E. 2004. "Spectrometry for urban area remote sensing—Development and analysis of a spectral library from 350 to 2400 nm." *Remote sensing of Environment*, *91*(3), 304-319.

Hilferink, M., & Rietveld, P. 1999. "Land Use Scanner: An integrated GIS based model for long term projections of land use in urban and rural areas." *Journal of Geographical Systems*, *1*(2), 155-177.

Ho, C. S., Matsuoka, Y., Simson, J., & Gomi, K. 2013. "Low carbon urban development strategy in Malaysia–The case of Iskandar Malaysia development corridor." *Habitat International*, *37*, 43-51.

Holtzclaw, J., Clear, R., Dittmar, H., Goldstein, D., & Haas, P. 2002. "Location efficiency: Neighborhood and socio-economic characteristics determine auto ownership and use-studies in Chicago, Los Angeles and San Francisco." *Transportation Planning and Technology*, *25*(1), 1-27.

Hoppenbrouwer, E., & Louw, E. 2005. "Mixed-use development: Theory and practice in Amsterdam's Eastern Docklands." *European Planning Studies*, *13*(7), 967-983.

Houghton, R. 1994. "The worldwide extent of land-use change." *BioScience*, 305-313.

Hu, Z., & Lo, C. 2007. "Modeling urban growth in Atlanta using logistic regression." *Computers, environment and urban systems*, *31*(6), 667-688.

Huang, J., Lu, X., & Sellers, J. M. 2007. "A global comparative analysis of urban form: Applying spatial metrics and remote sensing." *Landscape and Urban Planning*, *82*(4), 184-197.

Irwin, E. G., & Bockstael, N. E. 2007. "The evolution of urban sprawl: evidence of spatial heterogeneity and increasing land fragmentation." *Proceedings of the National Academy of Sciences*, *104*(52), 20672-20677.

Jaeger, J. A., Bertiller, R., Schwick, C., Cavens, D., & Kienast, F. 2010. "Urban permeation of landscapes and sprawl per capita: New measures of urban sprawl." *Ecological Indicators*, *10*(2), 427-441.

Jang, M., & Kang, C.-D. 2015. "Urban greenway and compact land use development: A multilevel assessment in Seoul, South Korea." *Landscape and Urban Planning*, *143*, 160-172.

Jantz, C. A., Goetz, S. J., & Shelley, M. K. 2004. "Using the SLEUTH urban growth model to simulate the impacts of future policy scenarios on urban land use in the Baltimore-Washington metropolitan area." *Environment and Planning B*, *31*(2), 251-272.

Jenerette, G. D., Harlan, S. L., Brazel, A., Jones, N., Larsen, L., & Stefanov, W. L. 2007. "Regional relationships between surface temperature, vegetation, and human settlement in a rapidly urbanizing ecosystem." *Landscape Ecology*, *22*(3), 353-365.

Jensen, J. R. 2009. *Remote sensing of the environment: An earth resource perspective 2/e*: Pearson Education India.

Jensen, J. R., & Im, J. (2007). Remote sensing change detection in urban environments. In *Geo-Spatial Technologies in Urban Environments* (pp. 7-31): Springer.

Jiang, F., Liu, S., Yuan, H., & Zhang, Q. 2007. "Measuring urban sprawl in Beijing with geo-spatial indices." *Journal of Geographical Sciences, 17*(4), 469-478.

JPBD (2006). National urbanization plan. Kuala Lumpur: Federal Dept. of Town & Country Planning (JPBD).

JPBD (2010). National urbanization plan. Kuala Lumpur: Federal Dept. of Town & Country Planning (JPBD).

Kahn, M. E. 2009. "Urban growth and climate change." *Annu. Rev. Resour. Econ., 1*(1), 333-350.

Kamusoko, C., Aniya, M., Adi, B., & Manjoro, M. 2009. "Rural sustainability under threat in Zimbabwe–simulation of future land use/cover changes in the Bindura district based on the Markov-cellular automata model." *Applied geography, 29*(3), 435-447.

Kang, J. (2012). *A Study on the Future Sustainability of Sejong, South Korea's Multifunctional Administrative City, Focusing on Implementation of Transit Oriented Development*. Uppsala University, Sejong city, South Korea.

Karteris, M., Theodoridou, I., Mallinis, G., Tsiros, E., & Karteris, A. 2016. "Towards a green sustainable strategy for Mediterranean cities: Assessing the benefits of large-scale green roofs implementation in Thessaloniki, Northern Greece, using environmental modelling, GIS and very high spatial resolution remote sensing data." *Renewable and Sustainable Energy Reviews, 58*, 510-525.

King, L. J. (1985). Central place theory. In *Regional Research Institute, West Virginia University Book Chapters*.

Kocabas, V., & Dragicevic, S. 2007. "Enhancing a GIS cellular automata model of land use change: Bayesian networks, influence diagrams and causality." *Transactions in GIS, 11*(5), 681-702.

Koomen, E., & Borsboom-van Beurden, J. 2011. *Land-use modelling in planning practice* (Vol. 101): Springer Science & Business Media.

Koomen, E., Rietveld, P., & de Nijs, T. 2008. "Modelling land-use change for spatial planning support." *The Annals of Regional Science, 42*(1), 1-10.

Koomen, E., & Stillwell, J. 2007. "Modelling land-use change, Theories and methods." *Modelling land-use change: progress and applications. Springer Verlag*, 1-24.

Kopfmüller, J., Brandl, V., Jörissen, J., Paetau, M., Banse, G., Coenen, R., et al. 2001. *Nachhaltige Entwicklung integrativ betrachtet: Konstitutive Elemente, Regeln, Indikatoren*: Ed. Sigma Berlin.

Kropp, W. W., & Lein, J. K. 2013. "Scenario analysis for urban sustainability assessment: A spatial multicriteria decision-analysis approach." *Environmental Practice, 15*(02), 133-146.

Kuijpers, M. A. J., Bouwman, A., & Natuurplanbureau, M.-e. 2007. *Nederland later: tweede duurzaamheidsverkenning: deel fysieke leefomgeving Nederland*: Milieu en Natuur Planbureau Bilthoven.

Kumar, J. A. V., Pathan, S., & Bhanderi, R. 2007. "Spatio-temporal analysis for monitoring urban growth–a case study of Indore city." *Journal of the Indian Society of Remote Sensing, 35*(1), 11-20.

Kuzera, K., & Pontius, R. G. 2008. "Importance of matrix construction for multiple-resolution categorical map comparison." *GIScience & Remote Sensing, 45*(3), 249-274.

Lambin, E. F., Turner, B. L., Geist, H. J., Agbola, S. B., Angelsen, A., Bruce, J. W., et al. 2001. "The causes of land-use and land-cover change: moving beyond the myths." *Global environmental change, 11*(4), 261-269.

Lantman, J. v. S., Verburg, P. H., Bregt, A., & Geertman, S. (2011). Core principles and concepts in land-use modelling: a literature review. In *Land-Use Modelling in Planning Practice* (pp. 35-57): Springer.

Leao, S., Bishop, I., & Evans, D. 2004. "Spatial–temporal model for demand and allocation of waste landfills in growing urban regions." *Computers, environment and urban systems, 28*(4), 353-385.

Lee, S., & Pradhan, B. 2006. "Probabilistic landslide hazards and risk mapping on Penang Island, Malaysia." *Journal of Earth System Science, 115*(6), 661-672.

Lee, S., & Pradhan, B. 2007. "Landslide hazard mapping at Selangor, Malaysia using frequency ratio and logistic regression models." *Landslides, 4*(1), 33-41.

Lemonsu, A., Viguié, V., Daniel, M., & Masson, V. 2015. "Vulnerability to heat waves: Impact of urban expansion scenarios on urban heat island and heat stress in Paris (France)." *Urban Climate, 14*, 586-605.

Lesschen, J. P., Verburg, P. H., & Staal, S. J. 2005. *Statistical methods for analysing the spatial dimension of changes in land use and farming systems*: Citeseer.

Li, X., Yang, Q., & Liu, X. 2008. "Discovering and evaluating urban signatures for simulating compact development using cellular automata." *Landscape and Urban Planning, 86*(2), 177-186.

Li, X., & Yeh, A. G.-O. 2000. "Modelling sustainable urban development by the integration of constrained cellular automata and GIS." *International journal of geographical information science, 14*(2), 131-152.

Li, X., & Yeh, A. G.-O. 2002. "Neural-network-based cellular automata for simulating multiple land use changes using GIS." *International journal of geographical information science, 16*(4), 323-343.

Li, X., & Yeh, A. G.-O. 2004. "Analyzing spatial restructuring of land use patterns in a fast growing region using remote sensing and GIS." *Landscape and Urban Planning, 69*(4), 335-354.

Liao, J., Tang, L., Shao, G., Su, X., Chen, D., & Xu, T. 2016. "Incorporation of extended neighborhood mechanisms and its impact on urban land-use cellular automata simulations." *Environmental Modelling & Software, 75*, 163-175.

Liao, T. F. 1994. *Interpreting probability models: Logit, probit, and other generalized linear models* (Vol. 101): Sage.

Lin, J., & Yang, A. 2006. "Does the compact-city paradigm foster sustainability? An empirical study in Taiwan." *Environment and planning B planning and design, 33*(3), 365.

Litman, T. 2015. "Analysis of public policies that unintentionally encourage and subsidize urban sprawl."

Liu, Y. 2008. *Modelling urban development with geographical information systems and cellular automata*: CRC Press.

Liu, Y., & Phinn, S. R. 2003. "Modelling urban development with cellular automata incorporating fuzzy-set approaches." *Computers, environment and urban systems, 27*(6), 637-658.

Livingstone, K., & Authority, G. L. 2003. *Housing for a compact city*: Greater London authority.

Lobo, J. M., Jiménez-Valverde, A., & Real, R. 2008. "AUC: a misleading measure of the performance of predictive distribution models." *Global ecology and Biogeography, 17*(2), 145-151.

Longley, P. A., Barnsley, M. J., & Donnay, J.-P. (2003). Remote sensing and urban analysis: a research agenda. In M. J. B. J.P. Donnay, P.A. Longley (Ed.), *Remote Sensing and Urban Analysis: GISDATA 9* (pp. 245-258). London: Taylor and Francis.

López, E., Bocco, G., Mendoza, M., & Duhau, E. 2001. "Predicting land-cover and land-use change in the urban fringe: a case in Morelia city, Mexico." *Landscape and Urban Planning, 55*(4), 271-285.

Macfarlane, G. S., Garrow, L. A., & Mokhtarian, P. L. 2015. "The influences of past and present residential locations on vehicle ownership decisions." *Transportation Research Part A: Policy and Practice, 74*, 186-200.

Maktav, D., Erbek, F., & Jürgens, C. 2005. "Remote sensing of urban areas." *International Journal of Remote Sensing, 26*(4), 655-659.

Malaitham, S., Vichiensan, V., Fukuda, A., & Wasuntarasook, V. Determinants of Land Use Change Using Geographically Weighted Logistic Regression. In *Transportation Research Board 94th Annual Meeting, 2015*

Manaugh, K., & Kreider, T. 2013. "What is mixed use? Presenting an interaction method for measuring land use mix." *Journal of Transport and Land Use, 6*(1), 63-72.

Marceau, D., & Moreno, N. (2008). An object-based cellular automata model to mitigate scale dependency. In *Object-based image analysis* (pp. 43-73): Springer.

Mas, J.-F., Puig, H., Palacio, J. L., & Sosa-López, A. 2004. "Modelling deforestation using GIS and artificial neural networks." *Environmental Modelling & Software, 19*(5), 461-471.

Matthews, R. B., Gilbert, N. G., Roach, A., Polhill, J. G., & Gotts, N. M. 2007. "Agent-based land-use models: a review of applications." *Landscape Ecology, 22*(10), 1447-1459.

McGarigal, K., & Marks, B. J. (1995a). Spatial pattern analysis program for quantifying landscape structure. *Gen. Tech. Rep. PNW-GTR-351. US Department of Agriculture, Forest Service, Pacific Northwest Research Station*.

McGarigal, K., & Marks, B. J. 1995b. "Spatial pattern analysis program for quantifying landscape structure." *Gen. Tech. Rep. PNW-GTR-351. US Department of Agriculture, Forest Service, Pacific Northwest Research Station*.

Medley, K. E., Okey, B. W., Barrett, G. W., Lucas, M. F., & Renwick, W. H. 1995. "Landscape change with agricultural intensification in a rural watershed, southwestern Ohio, USA." *Landscape Ecology, 10*(3), 161-176.

Mellino, S., & Ulgiati, S. (2015). Monitoring Regional Land Use and Land Cover Changes in Support of an Environmentally Sound Resource Management. In *Sustainable Development, Knowledge Society and Smart Future Manufacturing Technologies* (pp. 309-321): Springer.

MEM (2011). Smart Cities. Kuala Lumpur: Malaysian Economic Monitor.

Mertens, B., & Lambin, E. F. 2000. "Land-cover-change trajectories in southern Cameroon." *Annals of the Association of American Geographers, 90*(3), 467-494.

MGTC (2010). National energy balance table 2009 Putrajaya: Ministry of Energy, Green Technology & Water, Malaysia (KeTTHA).

Milan, B. F., & Creutzig, F. 2016. "Municipal policies accelerated urban sprawl and public debts in Spain." *Land Use Policy, 54*, 103-115.

Mindali, O., Raveh, A., & Salomon, I. 2004. "Urban density and energy consumption: a new look at old statistics." *Transportation Research Part A: Policy and Practice, 38*(2), 143-162.

Mubareka, S., Koomen, E., Estreguil, C., & Lavalle, C. 2011. "Development of a composite index of urban compactness for land use modelling applications." *Landscape and Urban Planning, 103*(3), 303-317.

Musakwa, W., & Van Niekerk, A. 2013. "Implications of land use change for the sustainability of urban areas: A case study of Stellenbosch, South Africa." *Cities, 32*, 143-156.

Naghibi, S. A., Pourghasemi, H. R., Pourtaghi, Z. S., & Rezaei, A. 2015. "Groundwater qanat potential mapping using frequency ratio and Shannon's entropy models in the Moghan watershed, Iran." *Earth Science Informatics, 8*(1), 171-186.

Nauman, E., VanLandingham, M., Anglewicz, P., Patthavanit, U., & Punpuing, S. 2015. "Rural-to-urban migration and changes in health among young adults in Thailand." *Demography, 52*(1), 233-257.

Neuman, M. 2005. "The compact city fallacy." *Journal of planning education and research, 25*(1), 11-26.

Newman, P. 1992. "The compact city: an Australian perspective." *Built Environment, 18*(4), 285-300.

Newman, P., & Kenworthy, J. 1999. *Sustainability and cities: overcoming automobile dependence*: Island Press.

Newton, P. (1997). Re-shaping cities for a more sustainable future. *Research Monograph* (Vol. 6). Canberra: Australian Academy of Technological Sciences and Engineering.

Newton, P., Tucker, S., & Ambrose, M. (2000). Housing form, energy use and greenhouse gas emissions. In *Achieving sustainable urban form* (pp. 74-83).

Norman, J., MacLean, H. L., & Kennedy, C. A. 2006. "Comparing high and low residential density: life-cycle analysis of energy use and greenhouse gas emissions." *Journal of urban planning and development, 132*(1), 10-21.

Norte Pinto, N., & Pais Antunes, A. 2007. "Cellular automata and urban studies: a literature survey." *ACE: Arquitectura, Ciudad y Entorno, núm. 3, Febrero 2007*.

Nykänen, V., Lahti, I., Niiranen, T., & Korhonen, K. 2015. "Receiver operating characteristics (ROC) as validation tool for prospectivity models—A magmatic Ni–Cu case study from the Central Lapland Greenstone Belt, Northern Finland." *Ore Geology Reviews, 71*, 853-860.

O'Sullivan, D., & Torrens, P. M. (2001). Cellular models of urban systems. In *Theory and Practical Issues on Cellular Automata* (pp. 108-116): Springer.

Oliver, L., Ferber, U., Grimski, D., Millar, K., & Nathanail, P. The scale and nature of European brownfields. In *CABERNET 2005-International Conference on Managing Urban Land LQM Ltd, Nottingham, UK, Belfast, Northern Ireland, UK, 2005*

Openshaw, S. The modifiable areal unit problem. In, *1984*: Geo Abstracts University of East Anglia

Openshaw, S., & Clarke, G. (1996). Developing spatial analysis functions relevant to GIS environments. In *Spatial analytical perspectives on GIS* (pp. 21-37).

Ozdemir, A., & Altural, T. 2013. "A comparative study of frequency ratio, weights of evidence and logistic regression methods for landslide susceptibility mapping: Sultan Mountains, SW Turkey." *Journal of Asian Earth Sciences, 64*, 180-197.

Paez, A., Uchida, T., & Miyamoto, K. 2001. "Spatial association and heterogeneity issues in land price models." *Urban Studies, 38*(9), 1493-1508.

Parker, D. C., Manson, S. M., Janssen, M. A., Hoffmann, M. J., & Deadman, P. 2003. "Multi-agent systems for the simulation of land-use and land-cover change: a review." *Annals of the Association of American Geographers, 93*(2), 314-337.

Parker, S. 2015. *Urban theory and the urban experience: Encountering the city*: Routledge.

Pijanowski, B. C., Brown, D. G., Shellito, B. A., & Manik, G. A. 2002. "Using neural networks and GIS to forecast land use changes: a land transformation model." *Computers, environment and urban systems, 26*(6), 553-575.

Pijanowski, B. C., Pithadia, S., Shellito, B. A., & Alexandridis, K. 2005. "Calibrating a neural network-based urban change model for two metropolitan areas of the Upper Midwest of the United States." *International journal of geographical information science, 19*(2), 197-215.

PNMB (2010). New economic model for Malaysia. Putrajaya: National Economic Advisory Council, Pencetak Nasional Malaysia Bhd. (PNMB).

Pontius Jr, R., & Chen, H. 2006. *GEOMOD modeling. Idrisi 15: The Andes Edition* (Clark University, Worcester, MA).

Pontius Jr, R. G., & Millones, M. 2011. "Death to Kappa: birth of quantity disagreement and allocation disagreement for accuracy assessment." *International Journal of Remote Sensing, 32*(15), 4407-4429.

Pontius Jr, R. G., & Parmentier, B. 2014. "Recommendations for using the relative operating characteristic (ROC)." *Landscape Ecology, 29*(3), 367-382.

Pontius, R. G., Cornell, J. D., & Hall, C. A. 2001. "Modeling the spatial pattern of land-use change with GEOMOD2: application and validation for Costa Rica." *Agriculture, Ecosystems & Environment, 85*(1), 191-203.

Pontius, R. G., & Schneider, L. C. 2001. "Land-cover change model validation by an ROC method for the Ipswich watershed, Massachusetts, USA." *Agriculture, Ecosystems & Environment, 85*(1), 239-248.

Post, C., Ritter, B., Akturk, E., Breedlove, A., Buchanan, R., Che, C., et al. 2015. "Analysis of factors contributing to abandoned residential developments using remote sensing and geographic information systems (GIS)." *Urban Ecosystems, 18*(3), 701-713.

Pourghasemi, H., Pradhan, B., Gokceoglu, C., & Moezzi, K. D. 2013. "A comparative assessment of prediction capabilities of Dempster–Shafer and weights-of-evidence models in landslide susceptibility mapping using GIS." *Geomatics, Natural Hazards and Risk, 4*(2), 93-118.

Pradhan, B., & Lee, S. 2010a. "Delineation of landslide hazard areas on Penang Island, Malaysia, by using frequency ratio, logistic regression, and artificial neural network models." *Environmental earth sciences, 60*(5), 1037-1054.

Pradhan, B., & Lee, S. 2010b. "Landslide susceptibility assessment and factor effect analysis: backpropagation artificial neural networks and their comparison with frequency ratio and bivariate logistic regression modelling." *Environmental Modelling & Software, 25*(6), 747-759.

Pradhan, B., Oh, H.-J., & Buchroithner, M. 2010a. "Weights-of-evidence model applied to landslide susceptibility mapping in a tropical hilly area." *Geomatics, Natural Hazards and Risk, 1*(3), 199-223.

Pradhan, B., Sezer, E. A., Gokceoglu, C., & Buchroithner, M. F. 2010b. "Landslide susceptibility mapping by neuro-fuzzy approach in a landslide-prone area (Cameron Highlands, Malaysia)." *Geoscience and Remote Sensing, IEEE Transactions on, 48*(12), 4164-4177.

Pribadi, D. O., & Pauleit, S. 2015. "The dynamics of peri-urban agriculture during rapid urbanization of Jabodetabek Metropolitan Area." *Land Use Policy, 48*, 13-24.

Qiang, Y., & Lam, N. S. 2015. "Modeling land use and land cover changes in a vulnerable coastal region using artificial neural networks and cellular automata." *Environmental monitoring and assessment, 187*(3), 1-16.

Ramachandra, T., Bharath, H., & Sowmyashree, M. 2013. "Analysis of spatial patterns of urbanisation using geoinformatics and spatial metrics." *Theoretical and Empirical Researches in Urban Management, 8*(4), 5-24.

Rosenqvist, A., Shimada, M., Watanabe, M., Tadono, T., & Yamauchi, K. Implementation of systematic data observation strategies for ALOS PALSAR, PRISM and AVNIR-2. In *Geoscience and Remote Sensing Symposium, 2004. IGARSS'04. Proceedings. 2004 IEEE International, 2004* (Vol. 7, pp. 4527-4530): IEEE

Saaty, T. L. 1980. *The analytic hierarchy process: planning, priority setting, resources allocation* (New York: McGraw).

Salas, J. F. 2009. "La ciudad lineal del centenario: Los cien años de la utopía lineal." *Revista de Urbanismo*(20).

Sandhya Kiran, G., & Joshi, U. B. 2013. "Estimation of variables explaining urbanization concomitant with land-use change: a spatial approach." *International Journal of Remote Sensing, 34*(3), 824-847.

Schädler, S., Finkel, M., Bleicher, A., Morio, M., & Gross, M. 2013. "Spatially explicit computation of sustainability indicator values for the automated assessment of land-use options." *Landscape and Urban Planning, 111*, 34-45.

Schädler, S., Morio, M., Bartke, S., Rohr-Zaenker, R., & Finkel, M. 2011. "Designing sustainable and economically attractive brownfield revitalization options using an integrated assessment model." *Journal of Environmental Management, 92*(3), 827-837.

Schmidt, J. H., Weidema, B. P., & Brandão, M. 2015. "A framework for modelling indirect land use changes in life cycle assessment." *Journal of Cleaner Production, 99*, 230-238.

Schneider, A., & Woodcock, C. E. 2008. "Compact, dispersed, fragmented, extensive? A comparison of urban growth in twenty-five global cities using remotely sensed data, pattern metrics and census information." *Urban Studies, 45*(3), 659-692.

Schwarz, N. 2010. "Urban form revisited—Selecting indicators for characterising European cities." *Landscape and Urban Planning, 96*(1), 29-47.

Serneels, S., & Lambin, E. F. 2001. "Proximate causes of land-use change in Narok District, Kenya: a spatial statistical model." *Agriculture, Ecosystems & Environment, 85*(1), 65-81.

Shafer, G. 1976. *A mathematical theory of evidence* (Vol. 1): Princeton university press Princeton.

Shannon, C. E. 2001. "A mathematical theory of communication." *ACM SIGMOBILE Mobile Computing and Communications Review, 5*(1), 3-55.

Sharma, L., Pandey, P. C., & Nathawat, M. 2012. "Assessment of land consumption rate with urban dynamics change using geospatial techniques." *Journal of Land Use Science, 7*(2), 135-148.

Sisodia, P. S., Tiwari, V., & Dahiya, A. K. (2016). Prediction of Urban Sprawl Using Remote Sensing, GIS and Multilayer Perceptron for the City Jaipur. In *Intelligent Systems Technologies and Applications* (pp. 403-410): Springer.

Skapura, D. M. 1996. *Building neural networks*: Addison-Wesley Professional.

Soffianian, A., Nadoushan, M. A., Yaghmaei, L., & Falahatkar, S. 2010. "Mapping and analyzing urban expansion using remotely sensed imagery in Isfahan, Iran." *World applied sciences journal, 9*(12), 1370-1378.

Song, Y., & Knaap, G.-J. 2004. "Measuring the effects of mixed land uses on housing values." *Regional Science and Urban Economics, 34*(6), 663-680.

Song, Y., Merlin, L., & Rodriguez, D. 2013. "Comparing measures of urban land use mix." *Computers, environment and urban systems, 42*, 1-13.

Song, Y., & Rodríguez, D. A. 2005. "The measurement of the level of mixed land uses: a synthetic approach." *Environment and Planning B*.

Squires, G. D. 2002. "Urban sprawl and the uneven development of metropolitan America." *Urban sprawl: Causes, consequences, and policy responses*, 1-22.

Stasolla, M., & Gamba, P. 2008. "Spatial indexes for the extraction of formal and informal human settlements from high-resolution SAR images." *Selected Topics in Applied Earth Observations and Remote Sensing, IEEE Journal of, 1*(2), 98-106.

Stone Jr, B., Mednick, A. C., Holloway, T., & Spak, S. N. 2007. "Is compact growth good for air quality?". *Journal of the American Planning Association, 73*(4), 404-418.

Stone Jr, B., & Rodgers, M. O. 2001. "Urban form and thermal efficiency: how the design of cities influences the urban heat island effect." *Journal of the American Planning Association, 67*(2), 186-198.

Sui, D. Z. 2004. "Tobler's first law of geography: A big idea for a small world?". *Annals of the Association of American Geographers, 94*(2), 269-277.

Tayyebi, A., & Pijanowski, B. C. 2014. "Modeling multiple land use changes using ANN, CART and MARS: Comparing tradeoffs in goodness of fit and explanatory power of data mining tools." *International Journal of Applied Earth Observation and Geoinformation, 28*, 102-116.

Tayyebi, A., Pijanowski, B. C., Linderman, M., & Gratton, C. 2014. "Comparing three global parametric and local non-parametric models to simulate land use change in diverse areas of the world." *Environmental Modelling & Software, 59*, 202-221.

Tayyebi, A., Pijanowski, B. C., & Pekin, B. K. 2015. "Land use legacies of the Ohio River Basin: Using a spatially explicit land use change model to assess past and future impacts on aquatic resources." *Applied geography, 57*, 100-111.

Teixeira, A. M. G., Soares-Filho, B. S., Freitas, S. R., & Metzger, J. P. 2009. "Modeling landscape dynamics in an Atlantic Rainforest region: implications for conservation." *Forest Ecology and Management, 257*(4), 1219-1230.

Thapa, R. B., & Murayama, Y. 2011. "Urban growth modeling of Kathmandu metropolitan region, Nepal." *Computers, environment and urban systems, 35*(1), 25-34.

Thinh, N. X., Arlt, G., Heber, B., Hennersdorf, J., & Lehmann, I. 2002. "Evaluation of urban land-use structures with a view to sustainable development." *Environmental Impact Assessment Review, 22*(5), 475-492.

Thomas, M. R. 2002. "A GIS-based decision support system for brownfield redevelopment." *Landscape and Urban Planning, 58*(1), 7-23.

Tian, G., Ewing, R., White, A., Hamidi, S., Walters, J., Goates, J., et al. 2015. "Traffic Generated by Mixed-Use Developments: Thirteen-Region Study Using Consistent Measures of Built Environment." *Transportation Research Record: Journal of the Transportation Research Board*(2500), 116-124.

Tobler, W. (1979). Cellular geography. In *Philosophy in geography* (pp. 379-386): Springer.

Torrens, P. M. 2000. "How cellular models of urban systems work (1. Theory)."

Torrens, P. M., & Alberti, M. 2000. "Measuring sprawl."

TRB (2005). Does built environment influence physical activity? Examining the evidence. In 282 (Ed.), *Special Report*. Washington, DC: Transportation Research Board.

Turner, M. G., O'Neill, R. V., Gardner, R. H., & Milne, B. T. 1989. "Effects of changing spatial scale on the analysis of landscape pattern." *Landscape Ecology, 3*(3-4), 153-162.

Turskis, Z., Zavadskas, E. K., & Zagorskas, J. 2006. "Sustainable city compactness evaluation on the basis of GIS and Bayes rule." *International Journal of Strategic Property Management, 10*(3), 185-207.

Van Eck, J. R., & Koomen, E. 2008. "Characterising urban concentration and land-use diversity in simulations of future land use." *The Annals of Regional Science, 42*(1), 123-140.

van Wee, B., & Handy, S. 2016. "Key research themes on urban space, scale, and sustainable urban mobility." *International Journal of Sustainable Transportation, 10*(1), 18-24.

Veldkamp, A., & Fresco, L. 1996. "CLUE: a conceptual model to study the conversion of land use and its effects." *Ecological modelling, 85*(2), 253-270.

Veneri, P. 2009. "Urban polycentricity and the social costs of commuting."

Verburg, P. H., Kok, K., Pontius Jr, R. G., & Veldkamp, A. (2006). Modeling land-use and land-cover change. In *Land-use and Land-cover Change* (pp. 117-135): Springer.

Verburg, P. H., Schot, P. P., Dijst, M. J., & Veldkamp, A. 2004a. "Land use change modelling: current practice and research priorities." *GeoJournal, 61*(4), 309-324.

Verburg, P. H., Van Eck, J. R., de Nijs, T. C., Dijst, M. J., & Schot, P. 2004b. "Determinants of land-use change patterns in the Netherlands." *Environment and Planning B, 31*(1), 125-150.

Vörösmarty, C. J., Green, P., Salisbury, J., & Lammers, R. B. 2000. "Global water resources: vulnerability from climate change and population growth." *science, 289*(5477), 284-288.

Wakode, H. B., Baier, K., Jha, R., & Azzam, R. 2014. "Analysis of urban growth using Landsat TM/ETM data and GIS—a case study of Hyderabad, India." *Arabian Journal of Geosciences, 7*(1), 109-121.

Walsh, S., Soranno, P., & Rutledge, D. 2003. "Lakes, wetlands, and streams as predictors of land use/cover distribution." *Environmental management, 31*(2), 0198-0214.

Wang, F. (2012). *A Cellular Automata Model to Simulate Land-use Changes at Fine Spatial Resolution*. University of Calgary, Calgary

Wang, F., Hasbani, J.-G., Wang, X., & Marceau, D. J. 2011. "Identifying dominant factors for the calibration of a land-use cellular automata model using Rough Set Theory." *Computers, environment and urban systems, 35*(2), 116-125.

Wang, J., & Mountrakis, G. 2011. "Developing a multi-network urbanization model: a case study of urban growth in Denver, Colorado." *International journal of geographical information science, 25*(2), 229-253.

Ward, D. P., Murray, A. T., & Phinn, S. R. 2000. "A stochastically constrained cellular model of urban growth." *Computers, environment and urban systems, 24*(6), 539-558.

Wegener, M., & Fürst, F. 2004. "Land-use transport interaction: state of the art." *Available at SSRN 1434678*.

Wei, Y., Huang, C., Lam, P. T., & Yuan, Z. 2015. "Sustainable urban development: A review on urban carrying capacity assessment." *Habitat International, 46*, 64-71.

Weng, Q. 2001. "A remote sensing? GIS evaluation of urban expansion and its impact on surface temperature in the Zhujiang Delta, China." *International Journal of Remote Sensing, 22*(10), 1999-2014.

Weng, Q., Lu, D., & Schubring, J. 2004. "Estimation of land surface temperature–vegetation abundance relationship for urban heat island studies." *Remote sensing of Environment, 89*(4), 467-483.

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.

Williams, K., Jenks, M., & Burton, E. 2000. *Achieving sustainable urban form*: Taylor & Francis.

Wilson, E. H., Hurd, J. D., Civco, D. L., Prisloe, M. P., & Arnold, C. 2003. "Development of a geospatial model to quantify, describe and map urban growth." *Remote sensing of Environment, 86*(3), 275-285.

Wolsink, M. 2015. "Environmental education excursions and proximity to urban green space–densification in a 'compact city'." *Environmental Education Research*, 1-23.

Wolsink, M. 2016. "'Sustainable City'requires 'recognition'—The example of environmental education under pressure from the compact city." *Land Use Policy, 52*, 174-180.

Wright, F. L. 1935. "Broadacre City: A new community plan." *Architectural Record, 77*(4), 243-254.

Wrigley, N., & Bennett, R. J. 1981. *Quantitative geography: a British view*: Routledge.

Wu, F. 1998. "SimLand: a prototype to simulate land conversion through the integrated GIS and CA with AHP-derived transition rules." *International journal of geographical information science, 12*(1), 63-82.

Wu, F. 2002. "Calibration of stochastic cellular automata: the application to rural-urban land conversions." *International journal of geographical information science, 16*(8), 795-818.

Wu, F., & Yeh, A. G.-O. 1997. "Changing spatial distribution and determinants of land development in Chinese cities in the transition from a centrally planned economy to a socialist market economy: a case study of Guangzhou." *Urban Studies, 34*(11), 1851-1879.

Xie, C., Huang, B., Claramunt, C., & Chandramouli, C. Spatial logistic regression and GIS to model rural-urban land conversion. In *Proceedings of PROCESSUS Second International Colloquium on the Behavioural Foundations of Integrated Land-use and Transportation Models: Frameworks, Models and Applications, 2005* (pp. 12-15)

Yamu, C., & Frankhauser, P. 2015. "Spatial accessibility to amenities, natural areas and urban green spaces: using a multiscale, multifractal simulation model for managing urban sprawl." *Environment and Planning B: Planning and Design*, b130171p.

Yang, J., Shen, Q., Shen, J., & He, C. 2012. "Transport impacts of clustered development in Beijing: Compact development versus overconcentration." *Urban Studies, 49*(6), 1315-1331.

Yang, X., & Lo, C. 2003. "Modelling urban growth and landscape changes in the Atlanta metropolitan area." *International journal of geographical information science, 17*(5), 463-488.

Yeh, A., & Li, X. 1998. "Sustainable land development model for rapid growth areas using GIS." *International journal of geographical information science, 12*(2), 169-189.

Yeh, A., & Li, X. 2001. "A constrained CA model for the simulation and planning of sustainable urban forms by using GIS." *Environment and Planning B: Planning and Design, 28*(5), 733-753.

Yeh, A., & Xia, L. 2001. "Measurement and monitoring of urban sprawl in a rapidly growing region using entropy." *Photogrammetric engineering and remote sensing, 67*(1), 83-90.

Yeh, C.-T., & Huang, S.-L. 2009. "Investigating spatiotemporal patterns of landscape diversity in response to urbanization." *Landscape and Urban Planning, 93*(3), 151-162.

Yuan, F. 2008. "Land-cover change and environmental impact analysis in the Greater Mankato area of Minnesota using remote sensing and GIS modelling." *International Journal of Remote Sensing, 29*(4), 1169-1184.

Yuan, F. 2010. "Urban growth monitoring and projection using remote sensing and geographic information systems: a case study in the twin cities metropolitan area, Minnesota." *Geocarto International, 25*(3), 213-230.

Zagorskas, J., Burinskienė, M., Zavadskas, E., & Turskis, Z. 2007. "Urbanistic assessment of city compactness on the basis of GIS applying the COPRAS method." *Ekologija, 53*(2), 55-63.

Zeug, G., Eckert, S., Steiner, U., Kukuk, T., & Ehrlich, D. 2006. "Monitoring urban growth and its impact on the environment: the case of Sana'a, Yemen." *Proceedings digital earth summit on geoinformatics, 2008*, 206-211.

Zhou, W., & Troy, A. 2008. "An object-oriented approach for analysing and characterizing urban landscape at the parcel level." *International Journal of Remote Sensing, 29*(11), 3119-3135.