Diyala Journal of Engineering Sciences

ISSN 1999-8716
Printed in Iraq

Vol. 09, No. 03, pp. 12-23, September 2016

CELLULAR AUTOMATA -DYNAMIC MODEL FOR URBAN GROWTH BAQUBAH CITY

Zainab Ahmed Al-kaissi [1], Ali Hussein Hameed [2]
[1] Assistant Professor, [2] Lecturer
[1] Department of Roads & Transportation Engineering-Engineering College- Al-mustansiryah University
[2] Department of Civil-Engineering college –Diyala University
E-mail: alkaisi77@gmail.com [1]
(Received: 11/1/2015; Accepted: 3/2/2015)

ABSTRACT: - This paper analyzes land use change in Baqubah city the capital of Iraq's Diyala Governorate, in the period from 2004 to 2010, using a cellular automata model. No previous research about this study in Iraq. The simulation experiment was carried out in the Dinamica EGO platform to 2030 year and the results revealed a constrained urban sprawl. The simulation outputs were validated using a multi-resolution procedure based on a fuzzy similarity index 81.5%, and showed a satisfactory fitness in relation to the historical reference data. The simulation scenario for the year 2030 showed an increase in the medium residential, high residential and road by (23%, 73%, and 11% respectively). As well as a significant decrease the orchard, vegetation, water, open area and mix by (41%, 36%, 20%, 23%, and 12% respectively)
Keywords: cellular automata, dynamic, model, urban, growth, the Dinamica

INTRODUCTION

Cellular automata (CA) were introduced by Ulan and Neumann in 1940 and since 1980 numerous models have been developed for simulating urban growth [1]. CA are defined as discrete dynamics systems, represented by a grid of cells, in which local interconnected relationships exhibit global changes [2]. Generally, the state of each cell depends on the value of the cell on its previous state as well as the values of its neighbors according to some transition rules. These rules affect the urban growth, indicating environmental and socioeconomic support or limitations. Therefore, the bottom up approach implemented in CA relies on the simulation of local actions that progressively create the global emergent structure [3]. CA deals with non-linearity of urban structures and the iterative process leads to produce fractal patterns, which are common characteristics in an urban environment [4].

The applications of CA in urban growth can be classified into: 1) theoretical model developments and 2) applied Urban Growth Prediction Models (UGPMs) in real data. The first category, which developed in early years of CA, includes theoretical developments of CA models in urban simulation [5].

Subsequently, these theoretical approaches found real world implementations. A large number of applications have incorporated CA for Urban Growth Prediction Models UGPM development using real data [6]. A combination of CA with Markov models has also appeared in multiple studies [7]. A Markov model can not only explain the conversion among land uses, but also calculate the transfer rates among different types. Multi-criteria evaluation techniques and weight of evidence [8,9] have been used for estimating the importance of qualitative and quantitative drivers within the CA modelling framework, as shown in Figure (1)[10] .The dynamic transitions from one form of land use to another occur over a period.

Therefore, a modeling framework that captures and simulates this complex behavior is essential for generating urban growth scenarios. Cellular Automata (CA)-based models have the potential to model such discrete dynamic systems. In this study, a constraint-based binary CA model was used to predict the future urban growth scenario of the city of Roorkee (India) [11] .An increasing number of models for predicting land use change in rapidly urbanizing regions are being proposed and built using ideas from cellular automata (CA). These land use change probabilities drive a CA model based on eight cell Moore neighborhoods implemented through empirical land use allocation algorithms. The model framework has been applied to a medium-sized town, Bauru, in the west of São Paulo State, Brazil. We show how various socio-economic and infrastructural factors can be combined using the weights of evidence approach which enables us to predict the probability of changes between land use types in different cells of the system. Different predictions for the town during the period 1979–1988 were generated, and statistical validation was then conducted using a multiple resolution fitting procedure [12].

Dynamic models were developed in these years, among which Dinamica EGO is a practical one and has been widely used in the world. In this study, we aim to use Dinamica EGO to simulate the land-use of China in 2005 with data extracted from SPOT VGT NDVI. The real land-use map was compared with the simulation result so as, to verify the feasibility of Dinamica EGO. Then we supposed three sceneries under which we could analyze the land-use change of China in 2020. Results indicated that: on the basis of no extreme natural disasters or exceptional policy fluctuation, the grassland area would reduce by 22.21 million hectares averagely. However, forest would increase by 19.81 billion hectares on average. Water and unused land would probably remain stable, as there was little change in three sceneries. Farmland areas showed a good agreement under these sceneries whereas the greatest difference in land-use area estimations lies in built-up with an uncertainty accounting for 1.67% [13].

The employed modeling platform – Dinamica EGO – consists in a cellular automata environment that embodies neighborhood-based transition algorithms and spatial feedback approaches in a stochastic multi-step simulation framework. Biophysical variables and legal restrictions drove this simulation model, and statistical validation tests were then conducted for the generated past simulations (from 2000 to 2005), by means of multiple resolution fitting methods. Based on optimal calibration of past simulations, future scenarios were conceived, so as to figure out trends and spatial patterns of forest conversion in the study area for the year 2015[14].

The model evaluates the consequences of road paving, within two alternative scenarios. A "business as usual" scenario and the Governance scenario. In which road paving occurs associated to a strong participation of the civil society and the State towards the planning and regulation of natural resource utilization. In this manner, the model projects the trends, and subsequently, analyzes the effects of a series of variables on the land use and land cover changes in light of alternative scenarios. The "alternative scenario model" is coupled to DINAMICA - a landscape dynamics simulator by the exchange of dynamic transition rates and the distribution of land use and land cover classes. As output, the "alternative scenario model" diverts the historical transition matrices a as a function of integrated effects of variables, such as rural and urban population growth; social capital, including social movements. DINAMICA comprises two modules: A cellular automata model and a road constructor. The road constructor aims to create and expand a road network throughout the region, taking into consideration a combination of agents, i.e. rancher, farmers, and colonists, to form various road network architecture. The spatially explicit simulations use Skole 1996 map as the initial landscape map. The model was set to run for a time span of 30 years, divided into annual time steps. DINAMICA spatially allocates the transitions, transitions by using a GIS database comprising information on topography, soil, vegetation, population, infrastructure, and protected areas [15].

Urban Growth Prediction Models (UGPMs) are tasked to capture intrinsic and complex relationships in space and time. The spatial complexity reflects the impact of numerous biophysical and socioeconomic factors and as a result heterogeneous patterns appear across location and scale thus making urban development a dynamic and non-linear process [16]. Temporal complexity presents itself through the prediction difficulty for extended temporal intervals. The urban evolution often implies irreversibility [17,18] therefore, in a changing urban environment, only short term predictions can be securely applied [10].

2-STUDY REGION

The study region is Baqubah city. Baqubah is located at the east of Iraq with geographic coordinates [latitude (37° 25 50) to (37° 40 52) N, longitude (45° 16 39) to (47° 55 32) E] on both sides of river Diyala. Baqubah is the capital of Iraq's Diyala Governorate. The city is located some 50 km to the northeast of Baghdad, on the Diyala River. Baqubah served as a way station between Baghdad and Khorasan on the medieval Silk Road. The city of Baqubah growing cities evolution result of the improved economic and living conditions, which caused an increase in the ownership of vehicles, but the city, suffers from the old poor planning and lack of necessary studies and the crisis for modeling the movement of transport within the city. Figure (2) Shows location of the study region Baqubah in Iraq.

3- METHODOLOGICAL DYNAMIC MODEL

The characteristics of the urban dynamic model land use are showed in Table (1) and the variables input data layers are shown in Table (2), also the procedures of model followed the steps:

1. The data input,(image 2004 and 2010) remote sensing, urban cartographic and census data are gathered and duly processed to integrate a digital geographic database.an exploratory analysis of the input data is carried out, aiming at the variables selection, as shown in Table (2). The aim of this stage is to extract the minimum and at the same time, the best set of variables to explain the phenomena under study: the land use transitions. After defining the final variables set for each type of transition, the modeling stage itself is approached.
2. Firstly, transition rates are calculated through cross-tabulation or via the Markov chain. Cells transition probabilities are obtained the weights of evidence method. With the transition rates and cells transition probabilities estimated, the simulations can be carried out at last.
3. Simulations outputs are continuously calibrated until the obtainment of satisfactory results, which will then be validated afterwards.
4. By getting familiar with trends of land use change throughout a sufficiently long time series, the modeler is finally able to conceive scenarios for future transitions.
5. Forecasts of urban land use change are generated for time horizons in the short- and medium-terms.

4-RESULTS AND DISCUSSION

The model can be integrated with GIS in order to take full advantage of the existing technologies related to urban studies. The role of GIS and remote sensing in cellular automata based urban modelling is essential, particularly for input data preparation, model calibration and verification, emergent urban spatial pattern analysis, and growth impact assessment. Furthermore, consistent, regional datasets derived from satellite imagery and other sources can be readily integrated into the CA modeling environment [30].To forecast land use change is important for land use management, with the development. And improvement of the society, to use the land resource reasonably and effectively has become more and more important Data collection and integrate analysis are important to forecast land use change, so, model of land use change be built by using mathematics, which can be joined GIS. By this way, it cans quantificational research the land use change and predict the developing in the future [85]. The results of dynamic model and the implementation of GIS and remote sensing techniques for interpretation of results for the study area are illustrated in different aspects as images, thematic maps, Figures, Tables and curves with discussion.

4-1 Validating simulation

Since the fuzzy similarity index (FSI) is a flexible method for CA model validation, in the sense that it does not operate on a pixel basis but rather on multiple levels of resolution, the values of this index in the cases. Where the constant decay is adopted, tend to be slightly larger, when compared to indices based on strict agreement, which are those derived from a direct pixel-by-pixel comparison between the real and the simulated scene [79]. Costanza (1989) introduced the multiple resolution fitting procedure that compares a map fit within increasing window sizes. In relation to the model validation, can be observed, taking into account the fuzzy method using exponential decay function, the generated model for 2010, subsequently designed to 2030, presented a similarity average around 78.5% for the minimum similarity and 81.5% for maximum similarity (window size 11x11) between the actual map 2010 and its simulation, whereas changes between 2004 and 2010.

The resulting simulations of the dynamic modeling of land use and land cover made in the application Dinamica EGO for the years 2004 and 2010 showed high fuzzy similarity in function exponential decay and function decay constant satisfactory ,as shown in Table (3). According to Novaes, et al. (2011) indexes close to 0.4 indicate a good level of compatibility between the real and the simulated scenario". Other studies make reference the values between 0.4 and 0.9, as Adams (2008) found that similarity values fuzzy between 0.83 and 0.85 in a simulation study in urban areas. Ferrari (2008) who is obtained 0.84 for the dynamic simulation models for land use and land cover. Table (3) presents the similarity indexes fuzzy, whereas constant decay function for the simulation produced by model for 2010, being the result of such analysis may be adjustment satisfactory with effectiveness. The first and second similarity maps are shown in Figure (4).

4-2 Simulation of Future Scenario

The simulation of future scenarios is an important tool to aid in regional planning and environmental, because it provides important data on the dynamics of the landscape. The process of scenario modeling conducted in this study simulated the landscape of the Baqubah city for the year 2030. The input is the old/new land use maps and the new weights of evidence coefficients and the transition matrix. The outcome of the model is the simulated map of year 2010. Land cover maps of the years 2004 and 2010are used as the initial and final land cover maps; Dinamica-EGO simulation is implemented from 2010 to 2030 at time steps of 5 years. This model is using so far the Functor patcher, which can create new seeds and start new clusters of land uses in new areas in accordance with the probability map. The model will be extended to use the functor expander than can continue the growth of existing clusters of land use. The scenarios simulation until the year 2030 was performed using the parameters of "Expander" and "Patcher" validated in simulation the year 2010.The process resulted in twenty (20) annual statements for the period 2011 to 2030.Since DINAMICA transition functions employ a stochastic cell selection mechanism, 10 repeats were produced for each model tested. The simulation model to 2030 can be seen in Figure (5), the values for each class area (hectare) of use are shown in Table (4). The urban growth of the city and the future land-use up to 2030 was projected by deploying the land-use simulation model (Dinamica-EGO), as shown in Figure (5).The trajectory of simulation results reveals the difference of urban expansion from West. Traditional western urban growth takes place from highly urbanized city cores to pair-urban areas or suburbs that contain low density of urbanized, residential areas. The suburbanization process drives urban sprawl in Western cities and creates huge residential areas with low urban density. Table (4) are shown the percent of area for each class during the simulation period (2010-2030).Urbanizing areas are expanding not only from urban centers, but also from rural areas that have a certain proportion of impervious areas, with a mixed land use type of industrial and residential functions, under the growth of population. To carry out an analysis with larger specificity, the quantification of each change forecasts use class and coverage of earth 2010-2030, noting that for all the classes are shown in Table (4) and Figure (6). These results from the scenario(2030) indicate that the orchard, vegetation, water, the medium residential, high residential open area , road and mix classes will be occupancy from the total city area by approximately (3.8%, 8.3%, 2.1%, 14.7%, 27.1%, 14.3%,10.7% and 18.9% respectively) in 2030. The simulation scenario for the year 2030 showed an increase in the medium residential, high residential and road by (23%, 73%, and 11% respectively). As well as a significant decrease the orchard, vegetation, water, open area and mix by (41%, 36%, 20%, 23%, and 12% respectively). Therefore, the cellular automata modelling has been found to be the most suitable for use in simulating growth of urban areas.

5-CONCLUSION

1. Land cover maps of the years 2004 and 2010 were used as the initial and final land cover maps ;Dinamica-EGO simulation was implemented from 2010 to 2050 at time steps of 5 years, it will become a densely populated city by 2030. A unique feature of the urban growth of Baqubah is the high growth and densification along road.
2. Baqubah rapid change in spatial structure and pattern during the past 50 years, also dynamic modelling was rapidly gaining popularity among geographers and urban planners as a tool for urban and landscape simulation.
3. The model can be integrated with GIS in order to take full advantage of the existing technologies related to urban studies. The role of GIS and remote sensing in cellular automata-based urban modelling is essential, particularly for input data preparation, model calibration and verification.
4. Spatial dynamic models, of which CA is one of the best representatives, are still the most promising means for rendering land cover change simulations communicable and transparent to politicians, and planners. The cellular automata modelling has been found to be the most suitable for use in simulating growth of urban areas.
5. Dynamic models for simulating land use and land cover, consists in very important tools for studies dedicated to the exploration of future scenarios. The simulations for the years 2004 and 2010 reached similarity indices 81.5%.
6. Land development in Baqubah city has resulted in a heavy loss of natural vegetation, open spaces and the medium, high residential, roads are increased during the period of simulation of model (2010 to 2030).
7. The simulation scenario for the year 2030 is showed an increase in the medium residential, high residential and road by (23%, 73%, and 11% respectively). As well as decrease the orchard, vegetation, water, open area and mix by (41%, 36%, 20%, 23%, and 12% respectively).

6-REFERENCE

1. I. Sante, A. M. Garcia, D. Miranda and R. Crecente, "Cellular Automata Models for the Simulation of Real- World Urban Processes: A Review and Analysis," *Land- scape Urban Planning*, Vol. 96, No. 2, 2010, pp. 108-122. doi:10.1016/j.landurbplan.2010.03.001
2. F. Wu, "Calibration of Stochastic Cellular Automata: The Application to Rural-Urban Land Conversions," *Interna- tional Journal of Geographical Information Science,* Vol. 16, No. 8, 2002, pp. 795-818. doi:10.1080/13658810210157769
3. M. Batty, "Agents, Cells and Cities: New Representa- tional Models for Simulating Multi-Scale Urban Dynam- ics," *Environment and Planning A*, Vol. 37, No. 8, 2005, pp. 1373-1394.
4. M. Batty and P. A. Longley, "Fractal Cities: A Geometry of Form and Function," Academic Press, London, 1994.

5. H. Couclelis, “Cellular Worlds: A Framework for Mod- eling Micro-Macro Dynamics,” *Environment and Plan- ning A*, Vol. 17, No. 5, 1985, pp. 585-596. doi:10.1068/a170585
6. J. Vliet, R. White and S. Dragicevic, “Modeling Urban Growth Using a Variable Grid Cellular Automaton,” *Computers, Environment and Urban Systems*, Vol. 33, No. 1, 2009, pp. 35-43. doi:10.1016/j.compenvurbsys.2008.06.006
7. D. Mitsova, W. Shuster and X. Wang, “A Cellular Auto- mata Model of Land Cover Change to Integrate Urban Growth with Open Space Conservation,” *Landscape and Urban Planning*, Vol. 99, No. 2, 2011, pp. 141-153. doi:10.1016/j.landurbplan.2010.10.001
8. R. B. Thapa and Y. Murayama, “Urban Growth Modeling of Kathmandu Metropolitan Region, Nepal,” *Computers, Environment and Urban Systems*, Vol. 35, No. 1, 2011, pp. 25-34. doi:10.1016/j.compenvurbsys.2010.07.005
9. C. M. de Almeida, M. Batty, A. M. V. Monteiro, G. Camara and B. S. Soares-Filho, “Stochastic Cellular Automata Modeling of Urban Land Use Dynamics: Em- pirical Development and Estimation,” *Computers, Envi- ronment and Urban Systems*, Vol. 27, No. 5, 2003, pp. 481-509. doi:10.1016/S0198-9715(02)00042-X
10. D. Triantakonstantis, and G.Mountrakis" Urban Growth Prediction: A Review of Computational Models and Human Perceptions" Journal of Geographic Information System, 2012, 4, 555-587,http://dx.doi.org/10.4236/jgis.
11. (D. Sathish Kumara, et al,(2013). Modeling of urban growth dynamics and its impact on surface runoff characteristics), 2013 Elsevier Ltd
12. Cláudia Maria de Almeidaa, et al." Stochastic cellular automata modeling of urban land use dynamics: empirical development and estimation", Computers, Environment and Urban Systems, Vol. 27, No. 5, 2013, pp. 481-509. doi:10.1016/S0198-9715(02)
13. Wei Yi ; et al.(Land-use and land-cover sceneries in China: an application of Dinamica EGO model) Remote Sensing and Modeling of Ecosystems for Sustainability, an Diego, California, USA , Conference Vol. 8513, (2012).
14. Eduardo E. Maedaa, et al. "Dynamic modeling of forest conversion: Simulation of past and future scenarios of rural activities expansion in the fringes of the Xingu National Park, Brazilian Amazon", 2010 .
15. Britaldo Soares-Filho,etal "Simulating the Response of Land use and Land cover Changes to Governance Along a Major Amazon High way :The Case of the Santar ,M-cuiab ,Corridor", Centro deSensoriamento Remoto/ Universidade Federal de Minas Gerais, Brazil,2013.
16. J. Cheng, “Modelling Spatial & Temporal Urban Growth,” International Institute for Geo-Information Sciences and Earth Observation, Enschede, 2003.
17. 17-G. Engelen, “The Theory of Self-Organization and Mod-elling Complex Urban Systems,” *European Journal of Operational Research,* Vol. 37, No. 1, 1988, pp. 42-57. doi:10.1016/0377-2217(88)90279-2
18. A. G. Yeh and X. Li, “A Constrained CA Model for the Simulation and Planning of Sustainable Urban Forms by Using GIS,” *Environment and Planning B*: *Planning and Design*, Vol. 28, No. 5, 2001, pp. 733-753.

Table (1): Characteristics of the Urban Dynamic Model

Characteristics	Description
Spatial Resolution	30 m
Cellular Automata Engine	Dinamica
Set of States (cells)	Road, Residential, Vegetation ,Open area
Neighborhood	Moore or
Transition Rules	Probability function
Temporal Resolution	Year
Initial Conditions	Derived from maps at a giving year
Case studies	Baqubah ,Iraq

Table (2): Variables Input Data Layers

Input Data	Number of class	Class
Layer		Slope
		DEM
		Garage place
		Bridge
		Intersection
Static land use class	1	Unclassified
	4	Water
	9	Industrial &commercial
Dynamic land use class	2	orchard
	3	vegetation
	5	medium residential
	6	high residential
	7	Open area
	8	road

Table (3): The Validation Result for Different Window Sizes

Model	Window Sizes	*Parameters of the spots (HA)*	Minimum Similarities Exponential	Maximum Similarities *Similarity index Fuzzy (ISF)*Constant
Simulation 2004-2010	1 x1	M=9 V=18 I=1.5	0.166	0.237
	3 x3		0.346	0.402
	5 x5		0.510	0.551
	7 x7		0.632	0.668
	9 x9		0.722	0.755
	11 x11		0.785	0.815

Table (4): Result Model for Area Classification and percent of Baqubah City

Class Type	Area 2010	Area 2010 %	Area 2015	Area 2015 %	Area 2020	Area 2020 %	Area 2025	Area 2025 %	Area 2030	Area 2030 %
orchard	335.4	6.5	325.78	6.3	244.75	4.7	216.46	4.2	196.72	3.8
vegetation	674.9	13.2	675.67	13.1	520.19	10.0	467.89	9.0	426.59	8.3
Water	136.2	2.7	141.93	2.8	127.89	2.5	117.27	2.3	108.09	2.1
medium residential	616.1	12.0	538.83	10.5	666.9	12.8	717.75	13.8	758.07	14.7
high residential	807.4	15.7	856.63	16.6	1151.64	22.1	1293.48	24.9	1399.95	27.1
Open area	960.0	18.7	996.89	19.3	1019.07	19.5	874.34	16.8	739.89	14.3
road	495.1	9.6	503.43	9.8	520.67	10.0	526.89	10.1	550.52	10.7
Mix	1106.	21.6	1116.7	21.7	968.46	18.6	987.56	19.0	976.87	18.9
City area (ha.)	5131.	100.	5155.9	100.	5219.5	100.	5201.6	100.	5156.7	100.

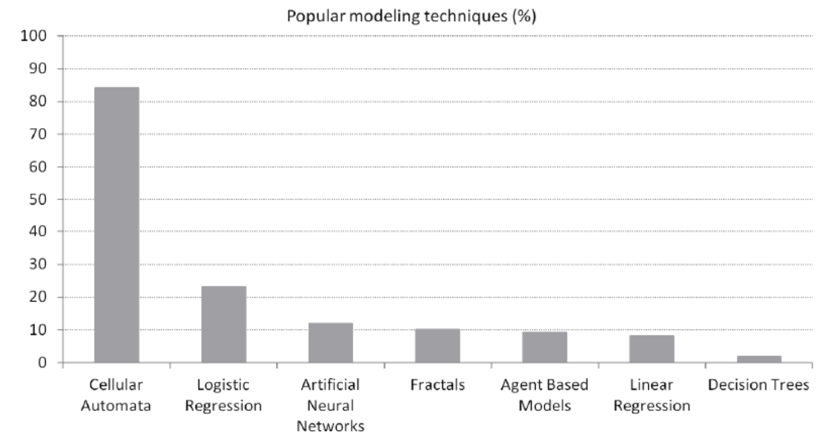


Figure (1) :Underlying UGPMs algorithms sorted by Popularity [10]

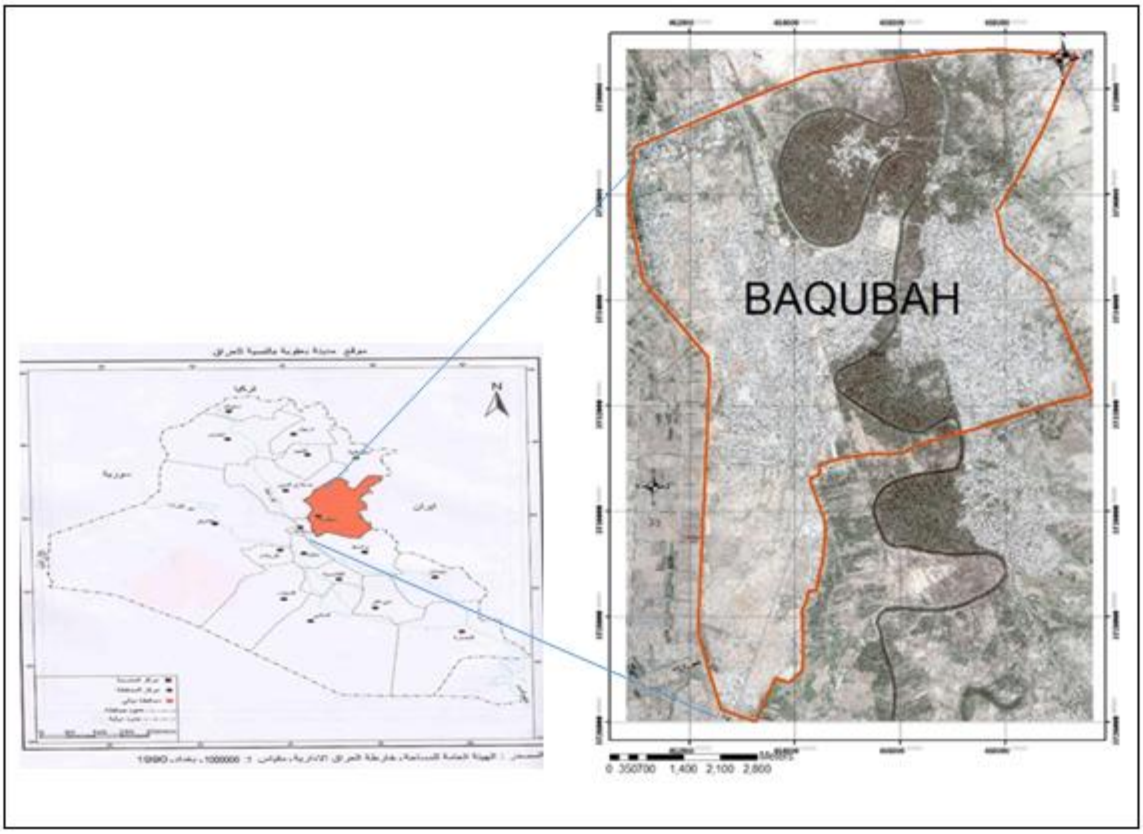
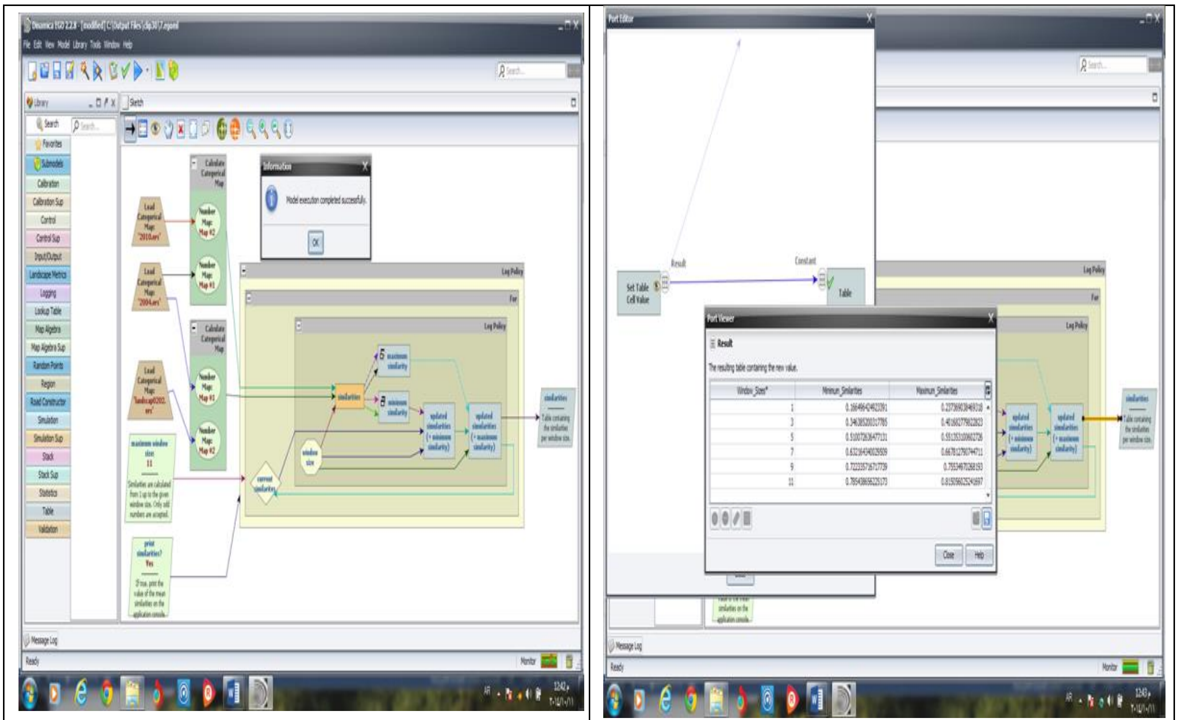
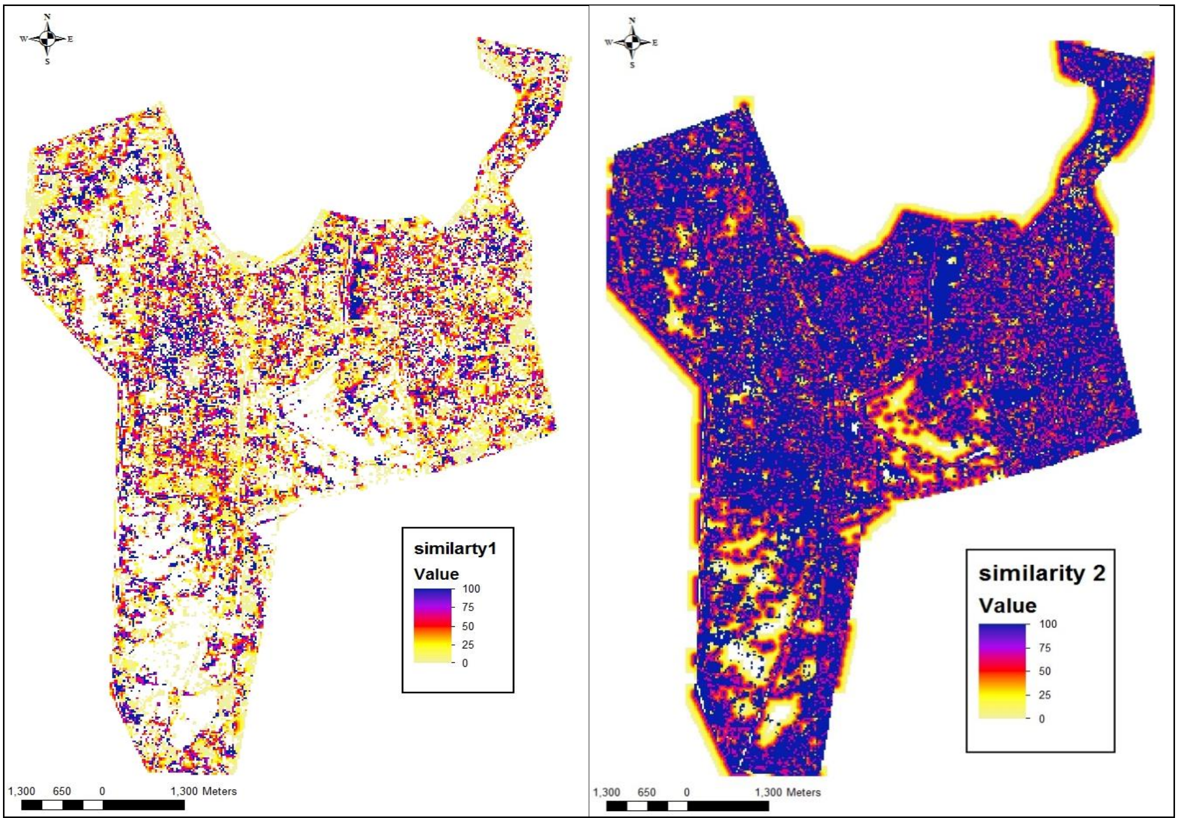


Figure (2): Location Study Area (Baqubah) from Iraq



a-validation similarity model	b-view result table

Figure (3): Similarity Model a- model and b-view result



a-First similarity	b-Seconded similarity

Figure (4): Validation Similarity a-first similarity, b-second similarity.

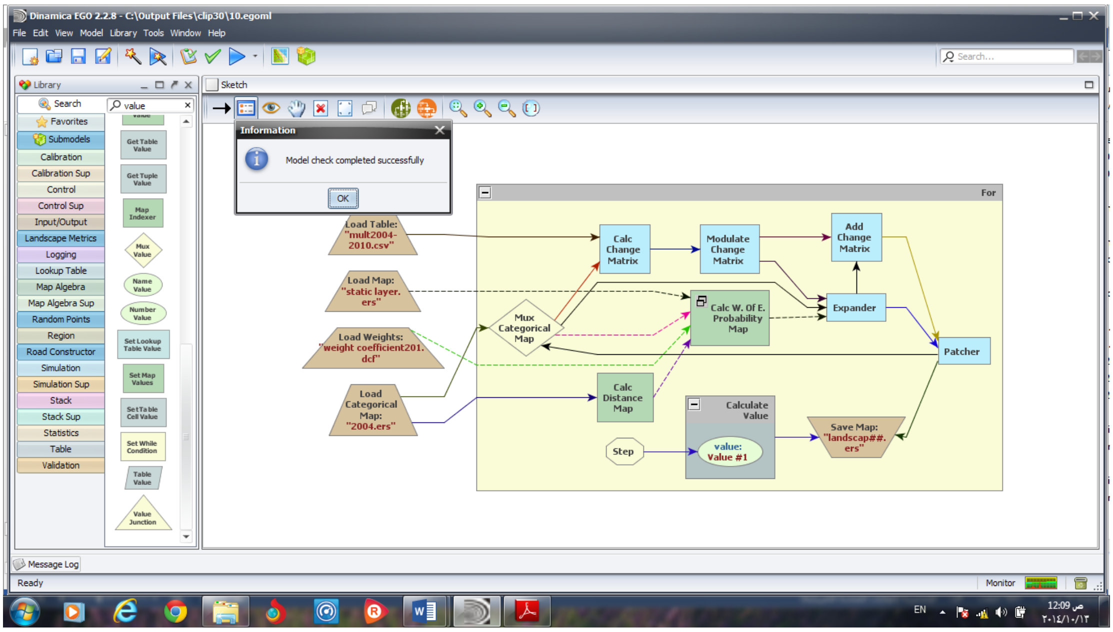
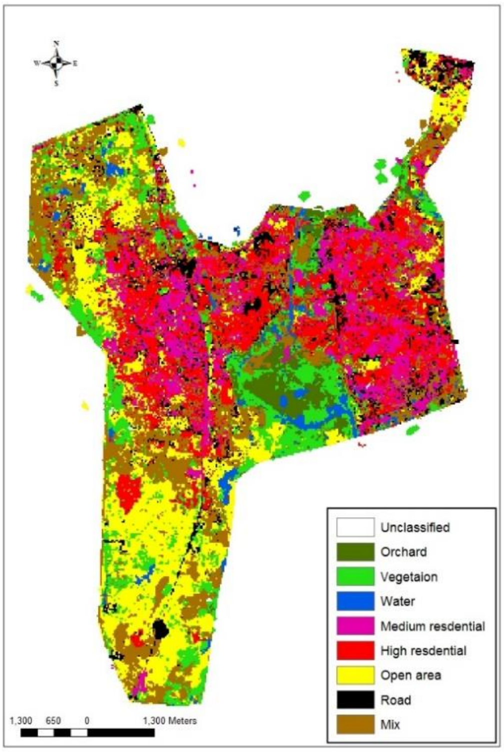
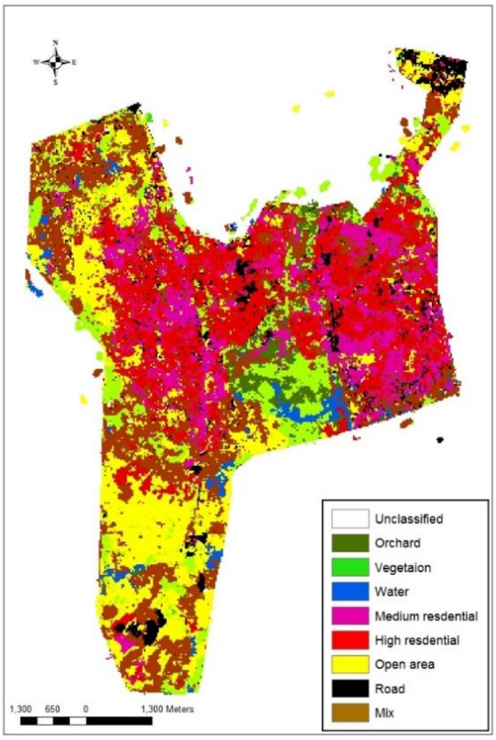


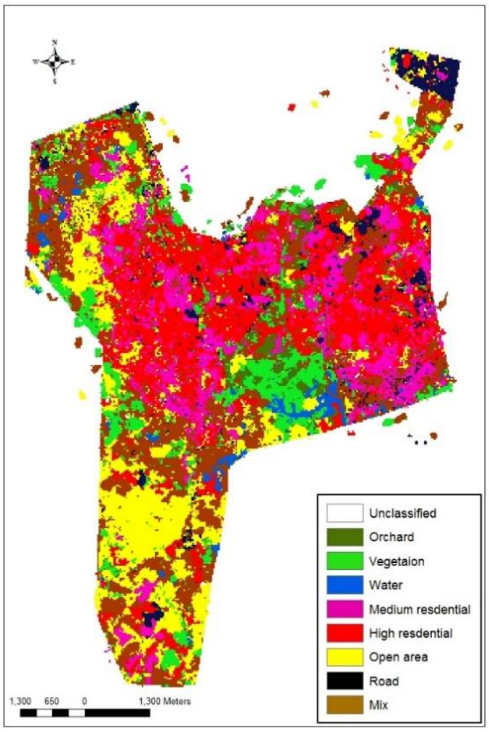
Figure (5): Simulation of Future Model Scenario



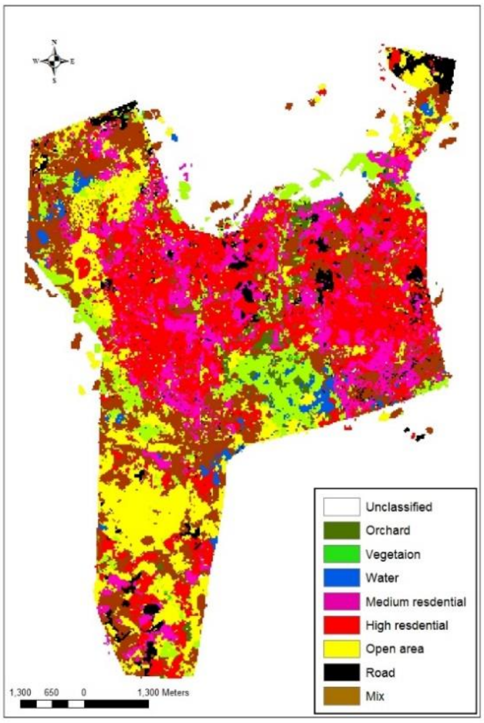
Expect image classification at 2015



Expect image classification at 2020



Expect image classification at 2025



Expect image classification at 2030

Figure (6): Sequence Simulation Future Model at 5 Years for Baqubah City from 2015 to 2030

Cellular automata -dynamic model for urban growth Baqubah City

أ.م.د زينب احمد عبد الستار
قسم الطرق –كلية الهندسة –الجامعة المستنصريه

م.علي حسين حميد
قسم المدني –كلية الهندسة –جامعة ديالى

الخلاصه

هذا البحث يحلل تغيرات استعمال الأرض ويتنبأ لموديل مستقبلي لمدينة بعقوبه وهي اكبر المدن لمحافظة ديالى في العراق ,في الفتره من 2004 الى 2010 باستعمال الموديل الخلوي الاوتماتيكي ولاتوجد بحوث سابقه لهذه الدراسه في العراق .النمذجه تم تنفيذها ببرنامج داينمكا لسنة 2030 والنتائج كشفت تقيد النمو التمددي .تم إعطاء شرعية النمذجة باستعمال طريقة متعدد الإيضاحات اعتمادا على عدد ثابت التشابه 81.5% وبينت تحقيق التطابق مع معلومات المصدر(2010) . نمذجة الحاله لسنة 2030 بينت زياده في السكن المتوسط ,السكن العالي والطرق بمقدار (23%,73%,و11% بالتتابع).اضافتا الى أهمية التناقص ب البساتين ,المزروعات ,الماء ,المساحات المفتوحة والمختلط ب(41%,36%,20%,23%,و12% بالتتابع).

مفتاح الكليمات: الخلوي الاوتماتيكي , الموديل المتحرك , النمو الحضري, برنامج ديناميكا