Predicting the future growth depending on GIS and IDRISI program, city of Najaf-Iraq

Amna Hussain Sabree Ali1*, Amany A. Kh1, Mustafa.Abdul.jalil1
1Center Of Urban& Regional Planning for post graduate, University of Baghdad
*Email: amna20052005@yahoo.com

Abstract. This study aims to employ modern spatial simulation models to predict the future growth of Al-Najaf city for the year 2036 by studying the change in land use for the time period (1986-2016) because of its importance in shaping future policy for the planning process and decision-making process and ensuring a sustainable urban future, using Geographical information software programs and remote sensing (GIS, IDRISI Selva) as they are appropriate tools for exploring spatial temporal changes from the local level to the global scale. The application of the Markov chain model, which is a popular model that calculates the probability of future change based on the past, and the Cellular Automata (CA) model determines the spatial location of the change. CA-Markov is known as a more effective way to model simulation of temporal and spatial change. Space images have been relied upon by applying models for the information they provide on the reality of the state of land uses, which can help in understanding the engines and dynamics of land transformation and forecasting future economic and environmental impacts.

1. Introduction:
In general, Cellular Automata CA is a model of spatial dynamics that is widely used in studying changes of land use. It is a popular simulation model where time and place are separate and interactions are local. Cellular automation shows a natural landscape as a grid in which each cell at each time stage T + 1 is updated using the law of transition based on the state of the neighboring cells at time t and according to the predefined transport laws. Cellular automation, can be occurred a method for spatial dynamics, so it is can simulate changes in two-dimensional axis. This method is widely used in many geographical areas, especially for predicting urban development and land use change. Decision laws can be expert opinions or the result of statistical analyzes.

The approach that is adopted in using the cellular automation model may be defined as the bottom-up approach, and the simplicity is one of the most important features of this model. By using this model we can define the dynamics of complex systems and suggest them in the form of simple laws. Then, using these laws, we can model the future of the system [1].

1.1 The Problem:
Most of the attractive cities suffer from the urban sprawl that represents a low-density settlement pattern with a slight general planning that is not economically, socially, environmentally, or aesthetic, and most of these areas are deprived of infrastructure services, and basic facilities such as health and education, Urban expansion is considered as a major problem in many cities all over the world, especially important cities.
1.2 Hypotheses
The CA-Markov integrated model is an effective way to model simulation of temporal and spatial change, meaning that model outputs will generate information on an appropriate dimension for urban policy making, help decision makers, and relevant authorities to determine the extension directions of urban growth.

2. Cellular automation consists of five main components:
- The cell: which is the primary spatial unit in cellular space. The two-dimensional cell network is the greater known cellular cell, especially in using modeling with urban growth and change detection of land use.
- Organism: are group of cells in which the concerned cell works with.
- The base of transition, which explains how the state of a single cell changes in response to its current state and of its neighboring cells.
- These rules represent the process of the system, in which, they are designed, and are therefore essential to the success of good modeling application.
- Time dimension determination is a cellular person as present. According to the classification of cellular automation, the states of all cells are updated simultaneously at all occurrences over time ((Verburg, Schot, Dijst, p316.

3. Markov Chain Model
The Markov model is widely used in environmental modeling, the Markov chain is a random model where the state of one future system (t2) can be predicted according to its previous state (t1) and the potential for transmission. The application of the Markov model in land-use change modeling is due to its ability to determine not only the different states between different land uses, but also the rate of transition among different land uses. Markov model in homogenous mode is displayed to compute landuse changes such as Eq. 1

\[ L_{t+1} = P \times L_t \]

\[ 0 \leq P_{ij} \leq 1 \quad \text{and} \quad \sum_{j=1}^{m} P_{ij} = 1 \quad i, j = (1, 2 \ldots m) \]

T + 1, respectively, and Pij are matrix of probable transition in one case. In other words, the Markov chain is like Eq. 2 It is created from the land use distribution at the beginning (Mt) and the end of a separated period of time Mt + 1) as well as from a transition matrix (MLc) that illustrates the changes that occurred in the intended time period. Given this presumption, the change in use in a plot of land is estimated based on the estimated probabilities and the transition matrix[1]

\[ M_{t+1} = M_t \times M_{t+1} \]

4. CA_MARKOV
This model is considered as an interesting "integrative approach" to model the changes in space and time for two reasons:
1- The Markov model controls the dynamics of time between different lands, covering through the transition probability; the dynamics of space are controlled by local principles using the CA mechanism and according to the condition of the neighborhood and the probability of transition for each land use.
2- The Ability to connect to GIS and remote sensing technologies.

This model is the result of the combination of the Markov chain model and the cellular automation model CA. Both are separate models in time and space. The Markov chain does not add any information about the random spatial distribution within each landuse category. There is no spatial component in the output of modeling, moreover, its failure to provide information about
spatial distribution in the Probability Markov model, another issue arise which is the study of the homogeneous transition probability for the categories use in this model, whereas the probability of transition is not constant in each class. Therefore, cellular automation can be used as a supplement to this model, especially when different processes are analyzed at different spatial and temporal scales and this model is characterized by high flexibility and simulation potential [2].

5. Study area:
Al-Najaf city is one of the important historical cities, and many variables have contributed to its origin and development, and the effects of these variables have varied according to its importance, starting with the religious and political changes in addition to the natural variables and other variables.

The holy city off al- Najaf is located on the western side of the Euphrates River, between latitude (31-32) and longitude (44-45), and away from the southwest of the capital, Baghdad, by a distance of (160 km), and from the sea level by about (230 feet). It is bounded on the southwest (Bahr al-Najaf), on the north and northeast (the Valley of Peace cemetery), and on the west the western desert, and on the eastern side it is linked to the Kufa district, which is about 10 km from the city center [3].

Figure 1. The location of the Najaf Governorate according to Iraq
Figure 2. The location of the Governorate center according to the Governorate

Land use / land cover (LULC): Changes in the use of different lands are determined in order to identify the changes of the limits of the city during the years 1986 - 2016. Land use maps are extracted from the Land sat TM satellite imagery and during two 10-year time periods in 1986, 1996 and 2006 And 2016. The coordinate system for images is designated as Universal Mercator.

Figure 3. Satellite image for 1996
Figure 4. Satellite image of the of the city of Najaf city of Al-Najaf for 1986
Source: US Geological Survey
After pre-processing the satellite images and truncating the part shown in the above figures with an area (80,463 hectares) that includes the center of Najaf Governorate and its adjacent areas for the purpose of determining the direction of future growth, it is classified by the GIS program through the work of a (database) and then (shapefile) for each satellite image. Accordingly, the study area is classified into six categories of land use, which are:

1. Residential areas
2. Agricultural lands
3. Water sources
4. Religious areas
5. And open lands (pastures and empty lands).
6. Industrial areas

Table 1 below includes the areas of the varieties for the years 1986 and 2016. We note that the increase in the area of residential areas increased by 22% and the decrease in the area of empty lands by 15%, while the rest of the varieties change in very few percentages.

| Land use area | 1986   | 2016   |
|---------------|--------|--------|
| Agricultural lands | 20933  | 20840  |
| Industry      | 600    | 603    |
| Religious     | 546    | 643    |
| Residential   | 1972   | 8772   |
| river         | 8673   | 8673   |
| vacant land   | 46886  | 39713  |

Figure 5. Satellite image of the City of Al-Najaf for 2016

Figure 6. Satellite image of Al-Najaf for 2016

Source: US Geological Survey [4]

Figure 7. Land Use Map for the year 1986, Researcher using the GIS program
Figure 8. Land Use Map for the year 1996, Researcher using the GIS program

Figure 9. Land Use Map for the year 2006, Researcher using the GIS program

Figure 10. Land Use Map for the year 2016, Researcher using the GIS program

6. Import data in IDRISI Selva and download the results:

Landuse maps are imported to the IDRISI Selva program, it will be inserted as txt format, simulating spatial temporal changes in future extension through Markov Chain model, depending on classification maps of landuse for previous years. A specific set of states is produced as separate values. This value defined in the system is in the form of a transition matrix, meaning that the transition matrix records the probability of moving from one state (land use category) to another (land use category) In this study, the probability of changing each landuse category to another form through transition probability matrix for Markov for the time periods between 1986 and 2016. In order to verify the CA-Markov model for the target year 2036, by assuming that the first target year is 2016; accordingly, based on the transition probability matrix in the period 1986-2006, the land use map is simulated for 2016. Below are the shapes of landuses for the years chosen for the study area, and 30-meter cell size was determined based on the spatial resolution of the spatial satellite imagery.
Application of the Markov model for the years 1986-1996

The conditional probability images and the matrix of the transition probability and the expected areas of transition for each type of land use to simulate the distribution for the year 2006 and the frequency of the process for the years 1996-2006 and 2006-2016 were obtained to predict the changes for the year 2036, the process was repeated for a map Forecasting for the years 2006 and 2016 for use in ensuring the accuracy of the model and the possibility of adopting the results to predict the direction of future growth.

Application steps:

1. Enter the names of the land use maps for the years to be compared (1986-1996), taking into consideration the following:
   a) Land use categories should be numbered from 1, i.e. the land use numbers for the six categories should be 1,2,3,4,5,6.
   b) The class values in both images must exactly match, meaning that the forest with the value 1 in the first image, the forest must contain the value 1 in the second image.

2. Enter the number of time periods between the first and second map of land use and the number of time periods that will be displayed in the future to output the images, the time period of both maps must match the assumption of a fixed transmission rate of 10 years.

3. Background areas (off-label areas) were processed by giving them a zero value so 0.0 to the background areas in the output probability images were chosen to maintain those areas as background.

4. The relative error associated with the input maps, is about 0.15 (15%) as the default for the program. The figure below shows the model application window.
Table 2. Expected transportation areas

| Cells in | Expected to transition to: |
|----------|---------------------------|
| Cl. 1    | Cl. 2 | Cl. 3 | Cl. 4 |
| Cl. 5    | 5911  | 1338  | 61   | 309  |
| Class 1  | 3598  | 40871 | 84   | 4955 | 0   |
| Class 2  | 135   | 624   | 5248 | 287  |
| Class 3  | 119   | 14729 | 4396 | 33993|
| Class 4  | 0     | 160   | 0    | 2503 |
| Class 5  | 0     | 2485  | 0    | 42303|
| Class 6  | 77054 | 50642 | 0    | 7586 |

Table 3. Probability Matrix of Markov model

| Given: Cl. 6 | Probability of changing to: |
|--------------|-----------------------------|
| Class 1      | 0.7759 | 0.1756 | 0.0080 | 0.0406 | 0.0000 | 0.0000 |
| Class 2      | 0.0727 | 0.8253 | 0.0017 | 0.1001 | 0.0000 | 0.0003 |
| Class 3      | 0.0215 | 0.0992 | 0.8337 | 0.0456 | 0.0000 | 0.0000 |
| Class 4      | 0.0002 | 0.0302 | 0.0090 | 0.6982 | 0.1582 | 0.1040 |
| Class 5      | 0.0000 | 0.0019 | 0.0000 | 0.0295 | 0.8346 | 0.1340 |
| Class 6      | 0.0000 | 0.0099 | 0.0000 | 0.1677 | 0.0301 | 0.7923 |

The rows represent the uses of the previous private lands and the columns represent the new uses, meaning that the probability of changing the first category, which is agricultural use to the same use is 0.775, and from agricultural to industrial use is .0175 and to religious use 0.0080, ... etc., below are pictures of conditional possibilities:
The value 0 indicates the lowest probability and increases when approaching the value 1, and from the above form we note that the fourth class class 4, which represents residential use, increases the likelihood of expansion towards vacant land and that the probability of changing empty land to residential is 0.7 in pink.

7. The CA-Markov model application

CA_MARKOV is a land cover forecasting procedure that adds an element of geographic communication as well as knowledge of the potential spatial distribution of transfers to the Markov chain analysis.

Application steps:
1. Enter the name of the basic land use map, which is the 1996 land use map
2. Enter the name of the transition area file (created by MARKOV).
3. Enter a file name containing transition suitability images created by MARKOV.
4. Enter the name of the resulting prediction map.
5. The number of iterations (time periods) for prediction.

- The last iteration is the date of the future prediction.

Upon completion of the steps of the model, the resulting 2006 forecast map appears as follows:

We repeat the previous steps to obtain the prediction map for 2016 and then for the target year 2036, the validity of the model is achieved by testing the Kappa IDRISI Selva program by comparing the simulated map of landuse for 2006 with the actual map of landuse derived from the satellite image for 2006 as well as for 2016.
From figures (18 and 19) above, VALIDATE provides in addition to calculating the K Kappa Index, three additional statistics for Kappa:

1. **Kno**, lack of information.
2. **Location K** to measure the cell network plane location.
3. **Kappa for stratum (Klocation Strata)** for measuring site level, Klocation indicates how network cells are in the scene. Klocation Strata indicates the extent to which network cells are inside the layers.

(KAPPA) K standard test obtained from the years 2006 and 2016 indicates that, it is 0.79 and 0.86, respectively, a good score between the actual maps and the simulated maps. This indicates the accuracy of the simulation. After confirming the accuracy of the model and applying the CA-MARKOV model, we get the prediction map for the year 2036 as follows:
Table 4. Probability Transition Areas for 2036

| Cells in | Expected to transition to |
|---------|---------------------------|
| Cl. 1   | Cl. 2 | Cl. 3 | Cl. 4 | Cl. 5 | Cl. 6 |
| Class 1 : | 6291 | 1181 | 51 | 224 | 0 | 0 |
| Class 2 : | 9616 | 88356 | 798 | 6422 | 0 | 69 |
| Class 3 : | 599 | 381 | 10061 | 925 | 0 | 0 |
| Class 4 : | 68 | 63664 | 9184 | 269306 | 66159 | 30588 |
| Class 5 : | 0 | 155 | 14396 | 76544 | 4639 |
| Class 6 : | 0 | 11711 | 38207 | 10809 | 169851 |

Table 5. Probability Matrix for 2036

| probability of changing to |
|---------------------------|
| Cl. 1 | Cl. 2 | Cl. 3 | Cl. 4 | Cl. 5 | Cl. 6 |
| Class 1 : | 0.8121 | 0.1525 | 0.0065 | 0.0289 | 0.0000 | 0.0000 |
| Class 2 : | 0.0914 | 0.8394 | 0.0076 | 0.0610 | 0.0000 | 0.0007 |
| Class 3 : | 0.0500 | 0.0318 | 0.8408 | 0.0773 | 0.0000 | 0.0000 |
| Class 4 : | 0.0002 | 0.1450 | 0.0209 | 0.6135 | 0.1507 | 0.0697 |
| Class 5 : | 0.0000 | 0.0016 | 0.0000 | 0.1504 | 0.7995 | 0.0485 |
| Class 6 : | 0.0000 | 0.0508 | 0.0000 | 0.1657 | 0.0469 | 0.7366 |

8. Discussion and Conclusion:
Understanding the dynamics of urbanization would help urban managers and planners make rational decisions when controlling urban sprawl and its consequences for the future are worrying. Simulating and anticipating urbanization is a must for urban planners and land conservatives in formulating sustainable development strategies. Possible land changes were presented in quantitative terms. We note the increase in the area of industrial areas from 603 hectares to 620 hectares and from 8772 hectares of residential areas to 8806 hectares, and the decrease of empty lands by a ratio of 39713 hectares to 39390 hectares with a ratio of 0.096, and based on the results of the changes, it is possible to determine the direction of urban and urban expansion rate of the city to be a rationale base upon which the growth alternatives are built on.

In the baseline chart to create a better and clearer vision "to make more informed planning decisions when preparing the baseline plan for the city."

The success of the model is directly related to the analysis of the data and methods used. Land sat images have moderate accuracy and classification errors have negative effects on the results; however, the recent ability to easily access Land sat archives data online increases the use of these images in a wide range of fields. This study demonstrates that the CA-Markov series approach integrated with remote sensing and GIS can be used effectively in studying potential future changes and in analyzing...
the direction and rate of future growth of cities, simulation accuracy can be increased using high-resolution satellite imagery.

The CA-markov model has proven to be a flexible and applicable model, when it using available data, also it proven to be efficient in dealing with urban landuse through monitoring, forecasting and growth trend. The values of 0.79 and 0.86 for the Kappa index indicated a high degree of similarity between the actual maps and the maps resulting from simulations for the years 2006 and 2016, which supports the accuracy of the model and the possibility of dependence in predicting the direction of the city's growth for future years, as the result showed that the city will extend to the northern and northwestern parts in 2036 toward the empty lands. The newly increased land use is likely to increase in that direction as the Probability Matrix of the Markov model shows that the probability of land use change within the city is reduced by a small percentage.

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