THE MODELING AND FORECASTING OF URBAN SPRAWL USING MULTI-TEMPORAL SATELLITES IMAGERY AND GIS (A CASE STUDY TABRIZ 1972-2010)

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Abstract: The City is phenomenon in the evolving situation is changing with regard to time and place constantly. In this changing, quickly process and unplanned growth especially in developing countries leads to abnormal growth. Physical growth and development of cities are dynamic and continuous process and now has become one of the problems of urban spaces that during which urban area and physical space in vertical and horizontal directions caused widespread cities to outside of urban area and lands around the cities conquered by converting to new habitats. Urban sprawl has desirable and undesirable effects in urban management, undoubtedly with urban sprawl economic and social problems such as change in urban systems, turbulence in land use, rapid land use change in urban around, destroying towns and villages around cities, agricultural land conversion to residential and industrial, reducing green space, environmental pollution, destruction of ranges, lack of infrastructure services, and more arise. Tabriz as the biggest urban area in northwestern Iran with 1,444,000 populations has rapid urban sprawl in recent years, like other cities in Iran. This urban sprawl is causes loss agricultural lands surrounding the city and environmental problems. For urban sprawl modeling in this paper using multi-temporal Landsat satellite imagery and GIS analysis Tabriz expansion has been measured in the period 1972 to 2010. First, geometric correction and contrast stretch were applied. In order to urban sprawl detection, image differencing, principal component analyses and Fuzzy ARTMAP classification method were applied. Finally, the results of land use classification for 4 different times are compared to reveal urban sprawl. Then, combined Cellular Automata with Markov Chain analysis is employed to forecast urban sprawl until 2020 in Tabriz area. The result shows that Tabriz city area in 1972 was 1731 hectares that has been reached to 11854 hectares in 2010. Most of this sprawl has been occurred in range and agricultural land. Also according to cellular automata and Markov chain forecasting model, Tabriz urban area will reach to 14312 hectares in 2020.

1. Introduction:

Urban growth is a management problem all over the world. In most big cities planning or policies are unable to control growth. This leads to uncontrolled, low density expansion, characteristic for sprawl (Torrens, 2006). Although some positive impacts can be seen from sprawl (e.g. dispersal of pollution) the negative impacts are dominating. This is noticed internally as well as externally.

Internally, it can be seen as more congestion, longer transports, economic segregation, and social disconnection, poor health, cost of infrastructure, and lately even as economic decline (Agency and Centre, 2006, Deal and Schunk, 2004, Sheehan et al., 2001).

Externally, it can be seen in loss of farmland, open land, carbon sinks, biodiversity, pollution of ground water (e.g. due to infiltration through asphalt) and increased risk of flooding (lati, 2008).

Urban sprawl, also known as suburban sprawl, is a multifaceted concept, which includes the spreading outwards of a city and its suburbs to its outskirts to low-density and auto-dependent development on rural land, high segregation of uses (e.g. stores and residential), and various design features that encourage car dependency (Frumkin,2002).

Discussions and debates about sprawl are often obfuscated by the ambiguity associated with the phrase. "The aim of creating sustainable and compact cities is inhibited by urban sprawl as development is uncontrolled." For example, some commentators measure sprawl only with the average number of residential units per acre in a given area. But others associate it with decentralization (spread of population without a well-defined center), discontinuity (leapfrog development, as defined below), segregation of uses, etc.

Urban economists have entered the debate relatively recently. They tend to examine urban sprawl as the aggregate extent of urban land use or as the average urban land use density. It has been shown that urban sprawl can increase the aggregate urban land use and lower the average land use density while at the same time lowering average commuting travel times and increasing discretionary mobility.

The term urban sprawl generally has negative connotations due to the health, environmental and cultural issues associated with the phrase (Frumkin, 2002).

Residents of sprawling neighborhoods tend to emit more pollution per person and suffer more traffic fatalities (Norman, 2006). Sprawl is controversial, with supporters claiming that consumers prefer lower density neighborhoods and that sprawl does not necessarily increase traffic (Moore, 1998).

2. Material and Methods

The first urban land use and transportation models were developed in the 1960s. They were based on the assumption that urban patterns are the result of changes in equilibrium within the city system, which could be understood from the macro level. These models are denoted “traditional” (Torrens, 2001) or “equation-based” (Parker et al., 2003) models. An example of equilibrium change, is the simple relationship which can be found between urban density and distance to the central business district (CBD). It is true that densities are often higher as one comes closer to the city center (Yeh and Li, 2002). However, for prediction purpose, these types of relationships are only valid as long as the city is in equilibrium. Cities are from equilibrium (Batty, 2005a).

In recently years Cellular automata have been used as a simulation technique in the study of an impressively wide range of urban phenomena, including regional growth, urban sprawl, gentrification, residential growth, population dynamics, economic activity and employment, historical urbanization, land use evolution, and polycentricity to name but a few. A spatial model consists of a collection of processes performed on spatial data that will produce information, usually in the form of a map. These models can often be represented as process flow diagrams, like showing how the output from one process can be the input to a subsequent process. CA are ideal for simulating static entities in spatial models and processes that operate by diffusion. They are ideal for encoding spatial structures into simulation models (MuraliKrishna, 2007).

In the present research, supervised classification based on Fuzzy Artmap is employed to detect land use changes. For modeling and predicting of urban sprawl in Tabriz city in this paper two methods were applied. The first method is Markov chain method analyses a pair of land cover images and outputs a transition probability matrix, a transition area matrix, and a set of conditional probability images. The transition probability matrix shows the probability that one land-use class will change to the others .The transition area matrix tells the number of pixels that are expected to change from one class to the others over the specified period (Eastman, 2006).

The conditional probability images illustrate the probability that each land cover type would be found after a specific time passes .These images are calculated as projections from the two input land cover images. The output conditional probability images can be used as direct input for specification of the prior probabilities in Maximum Likelihood Classification of remotely sensed imagery)such as with the Maxlike and Bayclass modules.(A raster group file is also created listing all the conditional probability images (Pontius, 2008).

The second method is Combination of Cellular Automata and Markov Chain. To know the changes that have occurred in the past may help to predict future changes .Combination of Cellular Automata and Markov Chain is often employed to predict land cover change estimation. Fig1 shows the flowchart of this study.

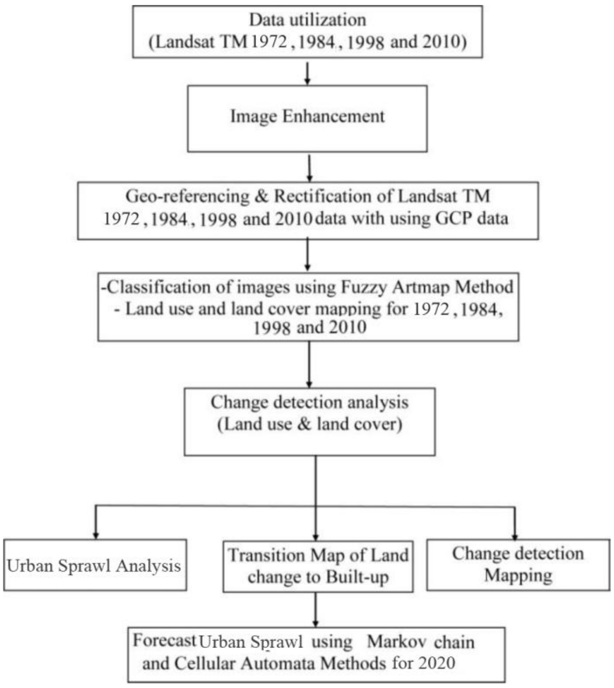

Fig1. Flow chart showing the major steps research

In this paper, Landsat TM images captured in 1972, 1984, 1998 and 2010 are employed for digital image processing. Fig2 shows Landsat TM image were used in this study.

Various methods have been employed for classification of satellite imagery .Recently, artificial fuzzy methods are used widely because they show very high accuracy in comparison with the conventional ones like Maximum Likelihood Classification (MLC), Minimum Distance Classification, and Parallelepiped Classification.

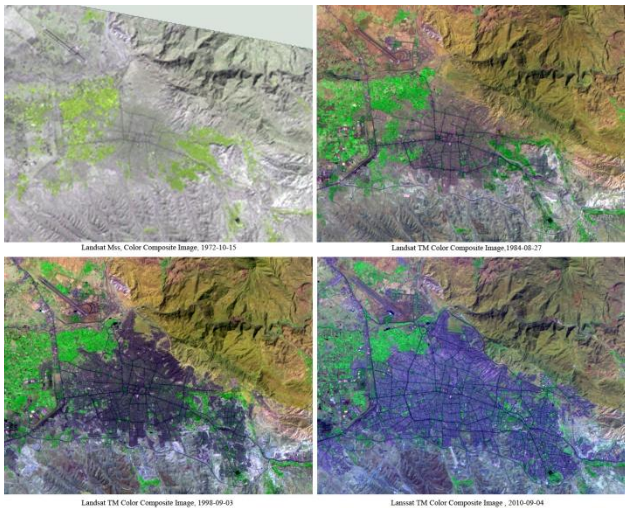

Fig2. Landsat TM and MSS colour composite images

In this paper, the fuzzy adaptive resonance theory (Fuzzy Artmap) is employed for image classification. First, 741 RGB color composites of Landsat images were prepared .Then, training areas were selected for 5 land use and Land cover classes, which are Built-up area, Orchards, Agriculture land, water, Bayer and waste land .These training areas were determined, referring to aerial photographs and GIS thematic maps. To assess the accuracy of classification, topographic maps and aerial photos were employed .Overall accuracy was estimated to be around 90% .Figures 3 to 6 shows the results of land use classification and Table 1 shows the summary of the classification.

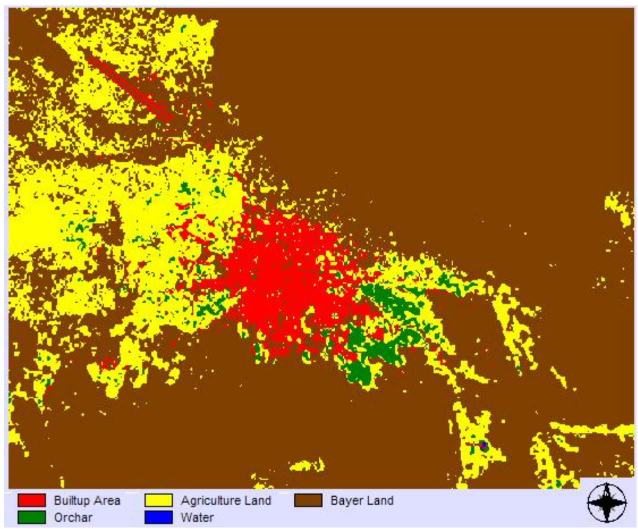

Fig3.Result of land use classification for Tabriz, Iran using Landsat MSS image captured in 1972

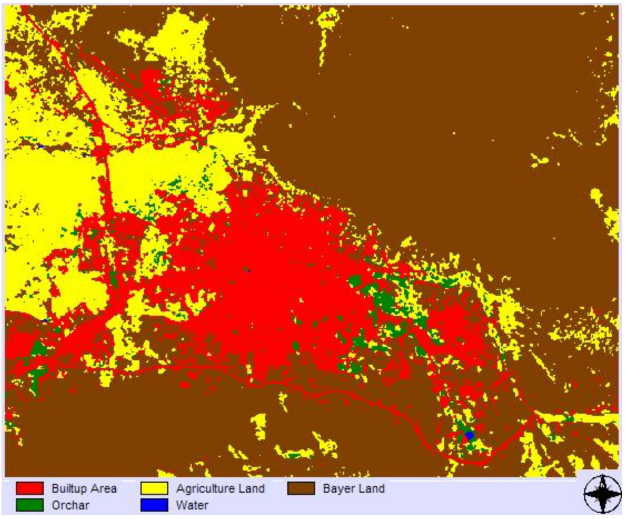

Fig4 :Result of land use classification for Tabriz, Iran using Landsat TM image captured in 1984

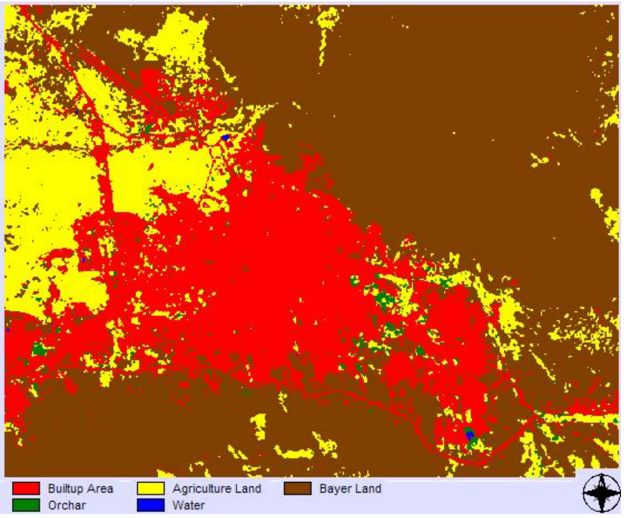

Fig5 :Result of land use classification for Tabriz, Iran using Landsat TM image captured in 1998

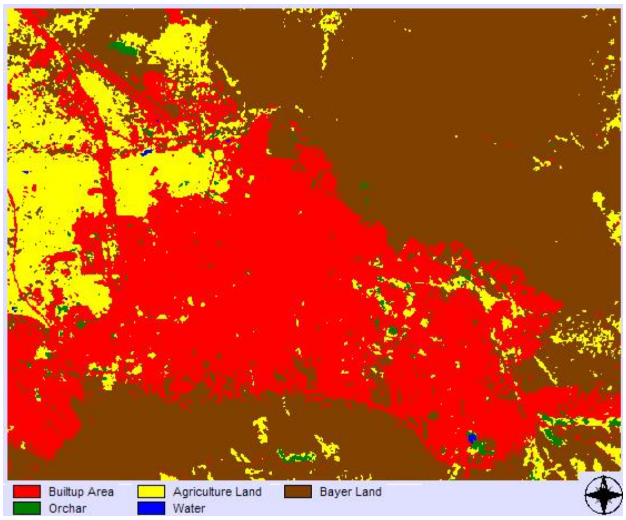

Fig6 :Result of land use classification for Tabriz, Iran using Landsat TM image captured in 2010

Table1. Summary of land use change to urban area in study area (Hectares)

Total	*1998 2010*	*1984 1998*	*1972 1984*	*Land use Type*	*Class*
1726	*8396*	*5768*	*1726*	Built-up Area	*1*
545	118	212	215	Orchards	**2**
2836	851	709	1276	Agriculture Land	**3**
8	6	2	0	Water	**4**
6740	2482	1706	2552	Bayer Land	**5**
11854	**3457**	**2629**	**4043**	**Total(H)**	

3. Results

The classification results for the four different times revealed that Built-up area has changed about 36% during the period of 1972-2011. According to table1 built-up area had 1726 hectares area in 1972 that reached to 11856 hectares in 2010. In other words, in during 1972-2010 built-up area had more than 10129 hectares growth that in between land use Bayer land with 6741 hectares has highest change to built-up area and agriculture land has 2837 hectares changes to built-up area. Also water land with 8 hectares has lowest changes to built-up area. Fig7 shows built-up area growth in during 1972-2010.

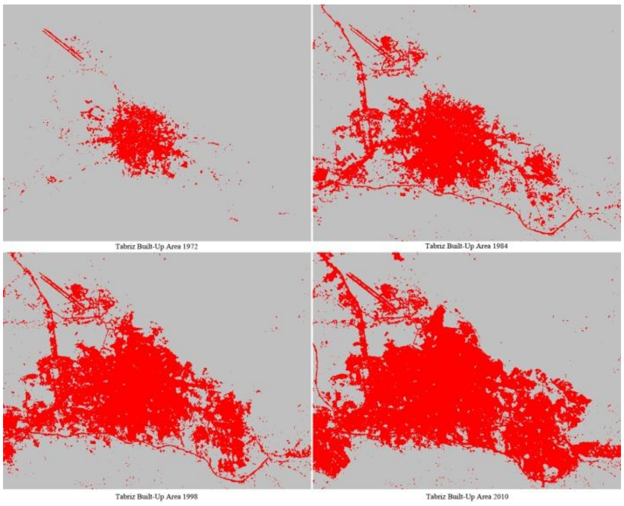

Fig7. Built-up area growth at during 1972-2010 in case study area

For detailed assessment of land use changes to urban area in during 1972-2010, in four times series 1972-1984, 1984-1998, 1998-2010 and 1972-2010 were evaluated. Fig 8,9,10 and shows land use changes to urban region in case study area.

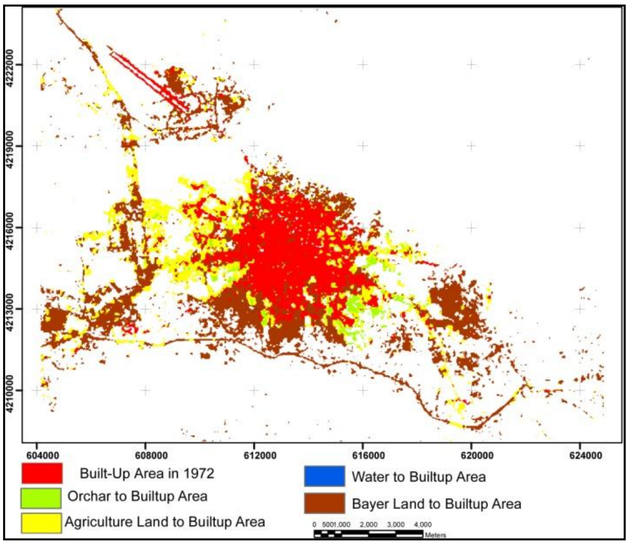

Fig8. Land use changes to urban area in during of 1972–1984

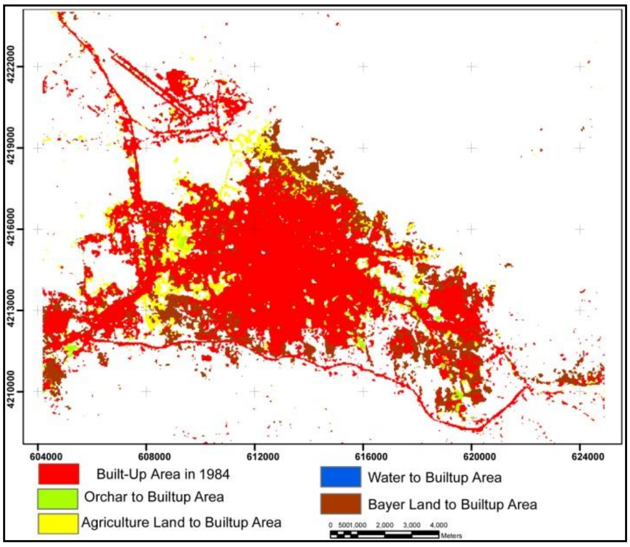

Fig9. Land use changes to urban area in during of 1984-1998

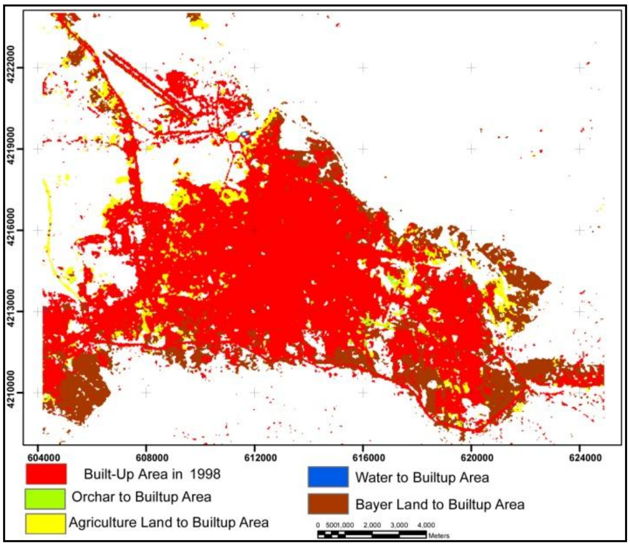

Fig10. Land use changes to urban area in during of 1998-2010

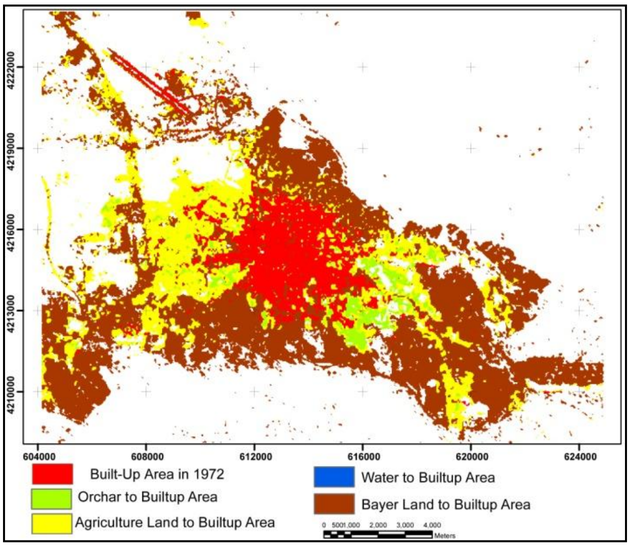

Fig11. Land use changes to urban area in during of 1972–2010

The comparing of result and figures shows that highest change has been occurred in 1972-1984 during. More than 4043 hectares has changed to urban area in this period also lowest change is related to 1984-1998 that 2629 hectares has changed to urban area (table1).

4. Discussion

There are many methods for Urban sprawl predicting as previously mentioned. One of these models is CA models that understood as a "cell-based" approach for modeling dynamic gravity processes at the micro level (Batty, 2005a). It has also been described as a diffusion approach (Almeida, 2003). Besides land use modeling, CA has been used for modeling deforestation (Menard and Marceau, 2007), forest fire (Karafyllidis and Thanailakis, 1997) and social phenomena (Smith and Stevens, 1996) to mention a few applications.

The main attraction of the method is that it shows complex behaviours from simple rules. This fits well with how complex systems work, where emergence (complexity from simplicity) is one of the characteristics (Torrens, 2001). The CA approach is also in line with bottom-up thinking and a decentralised understanding of processes (Torrens and O'Sullivan, 2001). It can simulate any physical system (Silva, 2005). At least as long as it is allows to be reduced to the components of a CA.

In this paper predicting of urban sprawl has been doing based on land use map in four series. After land use map preparing with use of

Markov chain the probability of changes to urban area till 2010 has been predicted that result shows in table2 and fig12.

Table2. The probability of land use changes based on Markov Chain in the period of 2010-2020

Class	1	2	3	4	5
Built-up(1)	1.000	0.000	0.000	0.000	0.000
Orchard(2)	0.553	0.131	0.308	0.001	0.008
Agriculture(3)	0.227	0.042	0.643	0.000	0.088
Water(4)	0.000	0.018	0.000	0.982	0.000
Bayer land(5)	0.079	0.003	0.056	0.000	0.862

(Row related to 2010 and Column related to 2020)

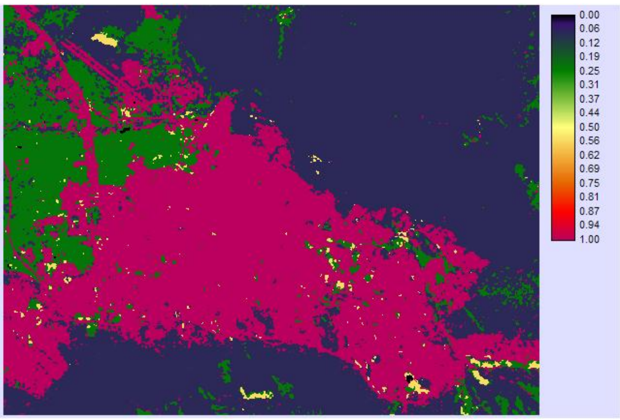

Figure12.The probability to remain/change to built-up areas by 2020 obtained by Markov Chain

According to table2 orchards has highest probability to changes to urban area with 55% and water has lowest probability with 0% change to urban area.

Then, combined method of Cellular Automata and Markov Chain was used for forecasting of land use change in 2020. Fig13 and table2 shows result of predicting.

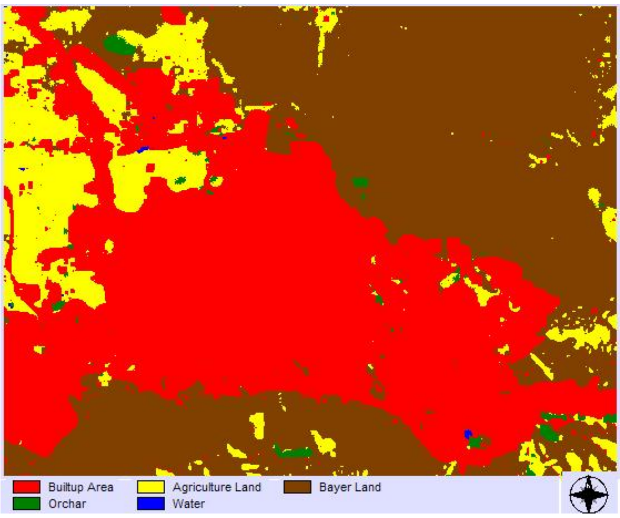

Figure13. Predicted result of land-use change in 2020 by the combination of CA and Markov Chain

Land use	***1***	***2***	***3***	***4***	***5***	***Total***
1	11854	0	0	0	0	11854
2	175	143	5	0	0	322
3	977	86	3220	0	0	4284
4	0	0	0	17	0	17
5	1307	47	559	0	14633	16546
Total	14312	275	3784	18	14633	33023

Table3. The result of prediction of land use in 2020 by the combination of CA and Markov Chain

According to the results, built-up areas increase from 11854 hectare in 2011 to 14312 hectares in 2020 and the probability change Bayer land and agriculture land to built-up area is highest in comparing with other land use and land cover types.

5. Conclusions

In this paper, using Landsat Satellite images in 1972 and 2010, land use changes in Tabriz city area, Iran were evaluated .For classification of the images, Fuzzy Artmap classification method was applied, which has very high confidence comparing with other classification methods .In addition, combined Cellular Automata with Markov Chain method was employed to forecast human impacts on land use change until 2020 for the study area.

According to Cellular Automata and Markov Chain Forecasting model, built-up areas will increase from 11854 hectares in 2011 to 14312 hectares in 2020 .The continuation of such a trend may endanger the surrounding land as well as the agricultural lands and Bayer land in the area .Hence, it is recommended to protect these critical areas.

The results of this study also revealed that agriculture land around major towns and settlements are recognized as critical regions in terms of land use changes, and special protection measures are needed to be taken .In case of improper planning, these regions will be changed to settlements in a very short time, which is totally in contradiction to sustainable development.

References

Agency, E.E. and Centre, E.C.J.R., 2006. Urban sprawl in Europe: the ignored challenge (Copenhagen, Denmark, European Environment Agency; Office for Official Publications of the European Communities).

Almeida, C.M.d.B., M., Antonio Miguel Vieira, Monteiro, Gilberto, Camara, Britaldo Silveira, Soares-Filho, Gustavo Coutinho, Cerqueira, Cassio Lopes, Pennachin.,2003. Stochastic cellular automata modeling of urban land use dynamics: empirical development and estimation, Computers, Environment and Urban Systems, In Press, Corrected Proof.

Batty, M., 2005. Cities and complexity understanding cities with cellular automata, agent-based models, and fractals (Cambridge, Mass., MIT Press).

Eastman, J .Ronald,. 2006. IDRISI Andes Tutorial .Clark Labs . Clark University

Frumkin, Howard., 2002. Urban Sprawl and Public Health. Centers for Disease Control and Prevention.

Karafyllidis, I. andThanailakis, A., 1997. A model for predicting forest fire spreading using cellular automata, Ecological Modeling, 99, pp. 87- 97.

Lahti, Johan., 2008. Modeling Urban Growth Using Cellular Automata: A case study of Sydney, Australia, M.Sc. thesis in International Institute for Geo-Information Science and Earth Observation (ITC) , Netherlands.

Menard, A. andMarceau, D.J., 2007. Simulating the impact of forest management scenarios in an agricultural landscape of southern Quebec, Canada, using a geographic cellular automata, Landscape and Urban Planning, 79(3-4), pp. 253-265.

Moore, Adrian; Rick Henderson,. 1998. Plan Obsolescence, Reason Magazine.

Norman, Jonathan; Heather L. MacLean and Christopher A. Kennedy, .2006. Comparing High and Low Residential Density: Life-Cycle Analysis of Energy Use and Greenhouse Gas Emissions. Journal of Urban Planning and Development (Reston, Virginia: American Society of Civil Engineers) 32 (1): 10–21.

MuraliKrishna,I. et al,. 2007. Integration of cellular automata and GIS for simulation land use changes, 5th International Symposium for Spatial Data Quality, ITC, Netherland.

Parker, D.C. et al,. 2003. Multi-Agent Systems for the Simulation of Land Use and Land-Cover Change: A Review, Annals of the Association of American Geographers, 93, pp. 314-337.

Pontius, Jr, Robert Gilmore, Olufunmilayo Thontteh and Hao Chen,.2008. Land Change Modeling with GEOMOD, Clark University.

Silva, E.A.a.K.C., 2005. Complexity, Emergence and Cellular Urban Models: Lessons Learned from Appling SLEUTH to two Portuguese Cities., European Planning Studies, 13(1), pp. 23.

Smith, T.S. andStevens, G.T., 1996. Emergence, Self-Organization, and Social Interaction: Arousal-Dependent Structure in Social Systems, Sociological Theory, 14(2), pp. 131-153.

Torrens, P.M. andO'Sullivan, D., 2001. Editorial: Cellular automata and urban simulation: where do we go from here?, Environment and Planning B, 28, pp. 163-168.

Torrens, P.M., 2001. Can geocomputation save urban simulation? Throw some agents into the mixture, simmer and wait ... Working papers series (London, Centre for Advanced Spatial Analysis).

Yeh, A.G.O. andLi, X., 2002. A cellular automata model to simulate development density for urban planning, Environment and Planning B, 29, pp. 431-450.