Research Article

# Spatio-temporal analysis and simulation pattern of land use/cover changes, case study: Naghadeh, Iran☆

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ABSTRACT

As a result of the growing impacts on global environments, it has become important for land use planners to extract, detect, monitor and predict land use/cover changes (LUCCs). The monitoring of LUCCs within a certain time period and predicting future trends of temporal and spatial changes are absolutely necessary. The aim of this research was to analyze and monitor LUCCs in Naghadeh County, Iran over a time span of 27 years and predict the future trend of changes during the period of 2014–2041. Land use/cover (LULC) maps were extracted (as built-up regions, water body, agricultural and bare lands) for 1987, 2000 and 2014 via RS images obtained from Landsat TM, ETM+ and OLI, respectively. The overall classification and Kappa index for all the classified maps were over 85% and 0.8, respectively. The C-A Markov model was used to predict future trend of LULC for the next 27-years. The obtained Kappa agreement statistics results from comparing actual and simulated maps of 2014 suggested the high capability of the model in LUCCs simulation in the study area. The results indicated the growth of built-up regions (urban area) from 1989 to 2014, while there was decrease in bare land. The projected land use for 2041 revealed more urbanization with potential expansion in agricultural and bare lands. Therefore, if the current management trends continue without any attention to sustainability measures, remnant water body and bare lands decline will ensue. This research provides useful and up-to-date information to local land use planners, managers and policy-makers to step up towards sustainable development in the study area.

## 1. Introduction

LUCC has become one of the major issues in sustainable development and global environmental changes (Guan et al., 2011; Halmy, Gessler, Hicke, & Salem, 2015; Wei, Qiping, Wang, & Hong, 2015). Economic development and rapid population growth have resulted in urban growth and urbanization, and in turn the development of human-built regions an inevitable process (Deep & Saklani, 2014; Gong, Yuan, Fan, & Stott, 2015; Shalaby & Tateishi, 2007; Wu et al., 2006). Land use in human-built regions, especially urban area is a complex process affected by many factors which include human and physical factors (Huang et al., 2008; Lambin, 1997). It should be noted that accelerated urban growth and expansion are usually associated with or driven by socioeconomic factors. On the other hand, the urban growth and urbanization process itself has significant impacts on the economy of the societies (He, Okada, Zhang, Shi, & Li, 2008; Huang et al., 2008). Urbanization and urban growth is a major issue throughout the many regions of the world (Samat, Hasni, & Elhadary, 2011; Zanganeh Shahraki et al., 2011), usually accompanied by poor planning (Deep & Saklani, 2014; Weber & Puissant, 2003) and this lack of planning results in numerous consequences and

problems including deforestation, intrusion into and destruction fertile agricultural lands, conversion of bare and range lands into human built environments (Quan et al., 2015; Shalaby & Tateishi, 2007; Yu, Zang, Wu, Liu, & Na, 2011). Up-to-date, adequate and reliable LUCCs information from the past to present together with the future plausible changes is vital to understand and evaluate several social, economic and environmental consequences of these changes (Foley et al., 2005; Giri, Zhu, & Reed, 2005; Williams & Schirmer, 2012; Wilson & Chakraborty, 2013). Therefore, for substantial and sustainable development, the regional, local and municipal authorities, land use managers, planners and policymakers require tools to monitor how the land is used and understand the development and directions of various kinds of land uses,in particular, urban land use in the past, present and future. So, analysis of land use from the past to the present and simulating the future changes is absolutely essential for regional and local planners and policymakers.

Unfortunately, traditional methods and techniques for LUCCs mapping especially in the developing countries (such as Iran) are very time consuming and costly; therefore, in recent years, the attention of researchers has been directed towards Geographical Information Systems (GIS) and remote sensing (RS) techniques for monitoring land use changes. The RS data and GIS techniques have been increasingly applied in the land use map extraction, LUCC analysis and urban development investigation due to their cost-effectiveness and high efficiency (i.e. Zubair 2006; Wang and Zhang 2001; Abd El-Kawy, Rød, Ismail & Suliman, 2011; Reveshty 2011). Considering lack of available data and the impossibility of experiencing all natural events, researchers employed modeling to study the land use change trends and also simulate the future land use system condition and pattern. The land-use simulation models describe or predict land-use change in time and space. Recent review of land-use simulation models shows a large number of models and applications (see Koomen and Beurden 2011; Heistermann, Müller, and Ronneberger 2006; Montesino Pouzols et al. 2014). Various models have been developed to predict and simulate land uses change dynamics including cellular automata, statistical analysis, Markov chain and artificial neural network (Koomen & Beurden, 2011; Subedi, Subedi, & Thapa, 2013). A series of studies applied CA-Markov using both GIS and RS data and techniques in LULC modelling and simulation (i.e. Kityuttachai, Tripathi, Tipdecho & Shrestha, 2013; Subedi *et al.*2013; Nurmiaty, Baja, and Arif 2014; Sayemuzzaman and Jha 2014; Nejadi, Jafari, Makhdoum & Mahmoudi, 2012; Gong et al., 2015).

One of the major problems in Iran with regard to sustainable land use planning and management, especially in urban area is lacking or shortage of valid and up-to-date information on the type and intensity of land use changes, and more importantly future patterns. So various perspectives, methodologies and techniques examined partially to overcome this problem which divided into: 1- monitoring only a past trend (i.e. Mazaheri, Esfandiari, Masih Abadi, & Kamali, 2013; Mohmmad.Esmaily, 2010; Mosayebi & Maleki, 2014; Sanjari & Boroomand, 2013; Soffianian, 2009; Zanganeh Shahraki et al., 2011), and 2- monitoring past, current and future trend which can be classified as (a) application of single model (i.e. Markov model (Alimohammadi, Mousiovand, & Shayan, 2010), Cellular Automata (Ziaeian Firouzabadi, Shakiba, Matakan, & Sadeghi, 2009), CLUE_S (Zamani, Maleki, & Movahhed, 2010) and (b) Combination of models (i.e.: Markov chain and Logistic regression (Shooshtari, Esmaili-Sari, Hosseini, & Gholamalifard, 2014), CA-Markov (Parsa, Salehi, Adeli, & Azizi, 2015).

Rapid population growth and the traditional land management, inappropriate land use planning during recent decades resulted in unrestrained human settlement area and also uncontrollable agricultural land expansion which pose critical challenges for managing the various aspects of environment especially in Naghadeh County within Urmia Lake's basin with an agrarian economy.

One of the main crisis threatened viability of Naghadeh County is the problem of ecological degradation and regressive trend of *Lake Urmia*. Massive study under the umbrella of "Urmia Lake Restoration program" from 17th of October, 2013 indicated that due to several factors, including drought and increased demands for agricultural water, human settlement expansion (*as consequences of inappropriate land use planning*) and multiple dam construction in the lake's basin, the water level of the lake decreased incredibly (Marden, Micklin, & Wurtsbaugh, 2014). Therefore, there is an immediate need for proper planning (land use as core principle) within the lake's basin, including all the surrounding counties specially Naghadeh County to overcome the current condition and move to environmental sustainability and viability of the basin particularly cities and human built environment.

This may require more advanced spatial techniques supported by the land use planners and policy makers involving shifting of emphasis from basic geographic data handling into manipulation modeling and analysis to solve the real problem (Ramachandran, 2010). So the applied methodology and the obtained information can serve these requirements and enable regional and local planners and policy makers to recognize and manage land use changes specially urban expansion and agricultural land growth.

The main aims of the present study are to provide multi-temporal land use information using RS techniques integrated with geographic information systems (GIS) for better analyzing and monitoring LUCC, predict the future distribution and configuration of the land use types using CA–Markov model and explore the process of the changes. Understanding such changes can play a critical role in formulating effective environmental policies and management strategies in the study area and the surrounding region. So, the regional and local managers, planners and policy makers can step up towards sustainable development with adequate and up-to-date information.

## 2. Materials and methods

### 2.1. Study area

Naghadeh County is located in the southern part of West Azerbaijan Province, Iran whose capital is Naghadeh City. This region lies on the fertile plain of Naghadeh with an area of about 1133.3 km2, extending northwards up to Urmia Lake (Fig. 1). The population of the study area was 121,602 persons (Iranian Census, 2011). This area has experienced dramatic LUCCs due to the considerable population growth over the past few decades. Rapid population growth and, in turn, the constructions in the cities and
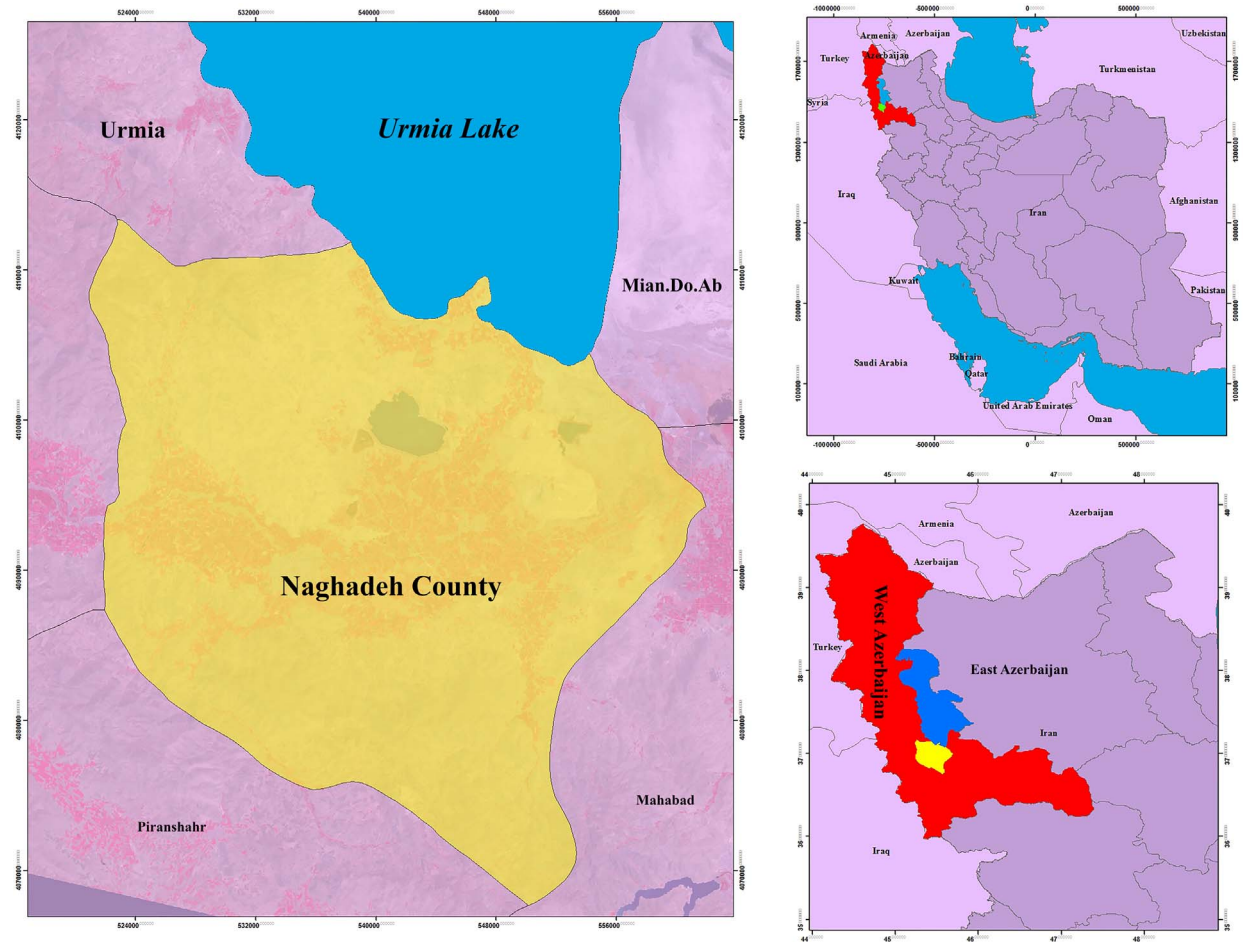
**Fig. 1.** Location of study area.

villages, have resulted in the destruction of the adjacent agricultural lands and expansion of human built areas, underlying significant changes and transformations in the land use and cover of the studied area.

### 2.2. Methods

In order to use satellite images of different periods, considering the suitability of cloud-free spatial coverage, relatively high spatial and spectral resolution and same image date-acquired for the year (especially the same plant growing seasons) are essential. Based on these criteria, relevant literature review and the wide range application of Landsat images for land use studies, RS images of Landsat satellites were used to investigate the long term land use changes in the study area (Table 1).

According to the exiting limitations and constraints in acquisition and selection of proper images, the time period of 27 years was considered potentially possible for monitoring and evaluating land use dynamic. The analysis of land-use changes dynamics from the past to the future was undertaken through the algorithm shown in Fig. 2.

In order to geo-reference the satellite images, ground control points including the intersection of roads, rivers, etc. were utilized in the pre-processing stage,. So, the following stages were followed for images classification and LULC maps extraction:

a) At the first stage, unsupervised classification was done in the Erdas Imagine 2014 software. The aim of this classification was to

**Table 1**
Landsat data sources.

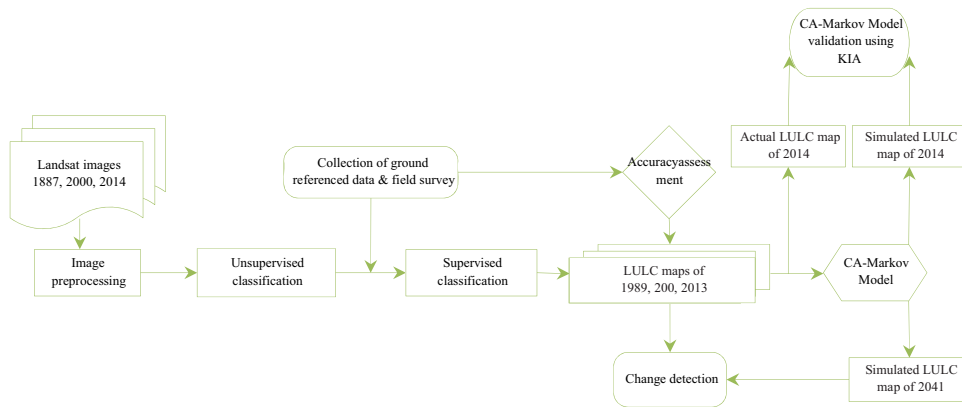| Satellite | Sensor | Acquisition | Band combination |
| --- | --- | --- | --- |
| Landsat 4–5 | TM | 19 July 1987 | 1,2,3,4,5,7 |
| Landsat 7 | ETM+ | 14 July 2000 | 1,2,3,4,5,7 |
| Landsat 8 | OLI | 29 July 2014 | 1,2,3,4,5,6,7 |

**Fig. 2.** Schematic presentation of the methodology used in this study

achieve an overall understanding of land-use types available in the region (Enderle & Jr, 2005; Giri, 2012). The outputs of this stage were used as tools in training samples.

b) The training samples (the ground referenced data) were gathered by combining Google Earth data and GPS points during the field survey. So, the resulting samples were imported to the Erdas Imagine 2014 environment and the signature files were generated.

c) The supervised classification was carried out using maximum likelihood method (MLC) for each image separately. The output of this stage was the preliminary LULC map of each image. This was followed by modification and correction on the maps. Eventually, the LULC maps were extracted from TM, ETM+ and OLI images. When the image classification stages were completed, accuracy assessment was done for each image based on 260 points selected by stratified random method.

In order to predict the future LULC pattern of the study area, integration of Markov chain and cellular automata model (CA-Markov) was used. Markov chain gives no information on the spatial distribution of each land use category (Araya & Cabral, 2010; Koomen & Beurden, 2011). In other words, there is no spatially referred output. Accordingly, cellular automata adds spatial contiguity and also probable spatial transitions occurring in a particular area over a period of time into Markov chain (Arsanjani, Helbich, Kainz, & Booloorani, 2012; Subedi et al., 2013).This combination develops an advancement in spatial-temporal dynamic modeling. The algorithms in the IDRISI Andes package was used to simulate the future LULC of the study area based on CA-Markov model.

To investigate similarities between actual map and the simulated map, it is required that the output data compared with actual ones. To assess the accuracy level of the model output, simulated or predicted LULC map of 2014 was compared with the actual one based on Kappa Index of Agreement (KIA) approach, a method widely used to validate LULC model outputs (see Jiang, Chen, Lei, Jia & Wu, 2015; Pontius, Cornell, and Hall 2001; Vliet 2009). The VALIDATE module in the IDRISI Andes was applied.

Cross tabulation in Idrisi Andes software package was used to determine conversions' amounts occurring with regards to each particular LULC classes, to other types during 1987–2000, 2000–2014, 1987–2014 and 2014–2041.

## 3. Results and discussion

In order to investigate the trend of land-use changes, 27 years period was considered according to the limitations in selection of satellite images and LULC maps were extracted for 1987, 2000 and 2014 (Fig. 1). Coverage of land use changes from 1987 to 2041 is shown in Table 2.

The accuracy of RS data was analyzed for robust classification results. The overall classification accuracy (the percentage of correctly classified pixela (Liu & Zhou, 2004)) of each classified map for 1987, 2000 and 2014 was estimated to be 85.4%, 86.03% and 88.9%, respectively. The overall statistical Kappa values were also 0.8233, 0.8445 and 86.765, respectively. The accuracy indexes

**Table 2**
Partitioning (ha) of Naghadeh Conuty into LULC types in each of the studied years.

| LULC type | Year | | | |
|---|---|---|---|---|
| | **1987** | **2000** | **2014** | **2041** |
| **A** | 27694.37 | 25471.04 | 29293.54 | 30322.22 |
| **BR** | 82104.62 | 84411.28 | 80252.60 | 77970.27 |
| **B** | 971.75 | 1482.14 | 2522.49 | 4073.43 |
| **W** | 2756.34 | 2162.61 | 1458.45 | 954.64 |

*A: Agricultural land, **BR**=Bare land, **B**=**Built-up area (**also expresses as human built emvironment or urban area in this paper**), W**: Water body
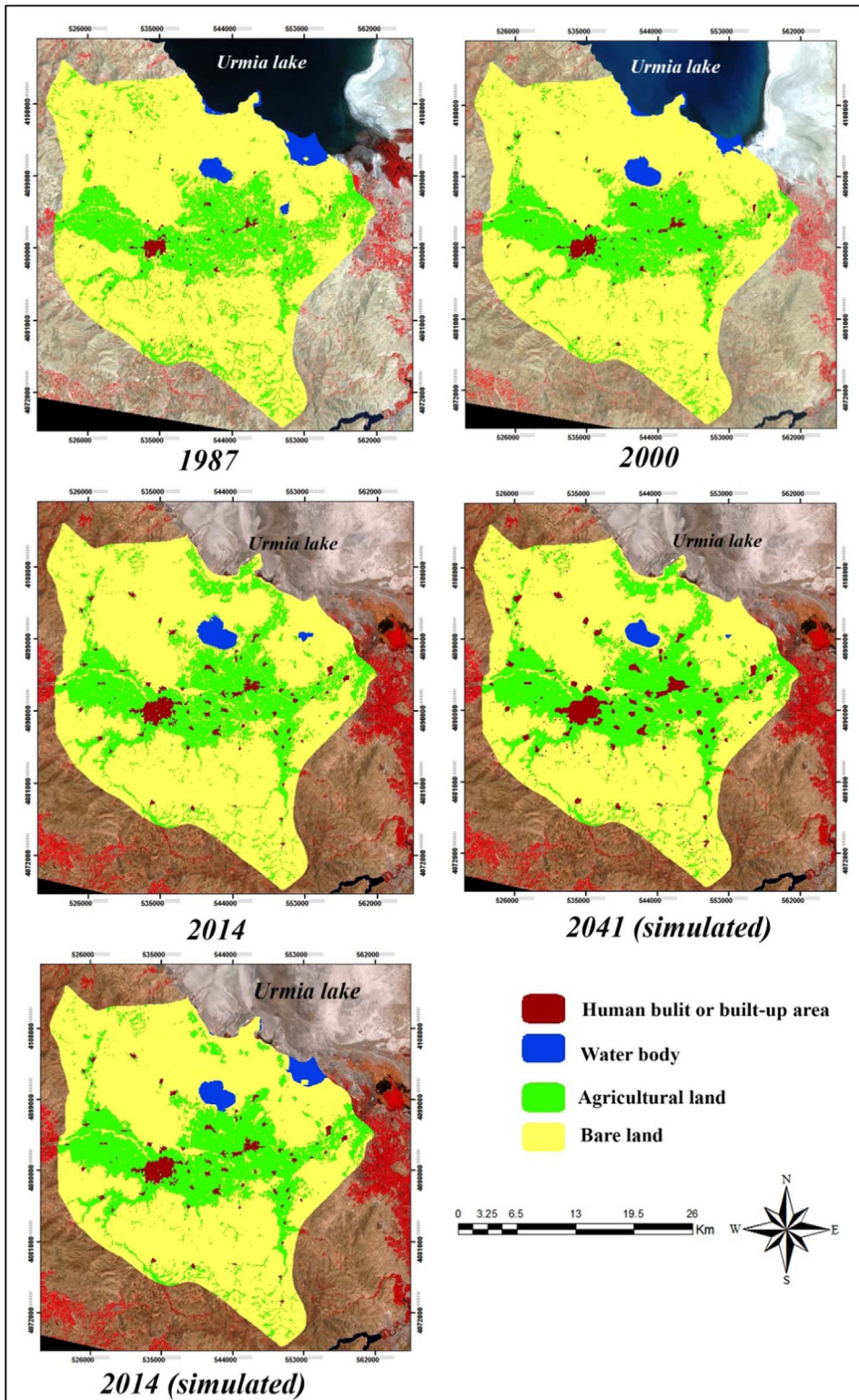
**Fig. 3.** LULC distribution maps; actual (1987, 2000, to 2014) and simulated (2014 and 2041)

(Kappa value) were also 0.79, 0.81 and 0.86, respectively. The obtained Kappa values indicate high classification accuracy for each map (Viera & Garrett, 2005).

Table 2 and Fig. 4 show that within the time period of 1987–2000, the agricultural land coverage reduced from 24.43 to 22.47%,
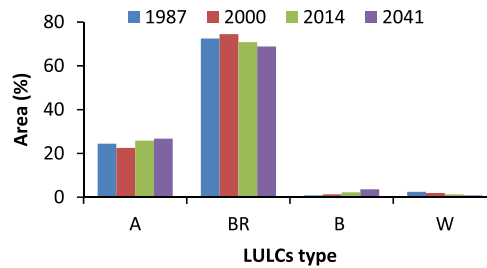
**Fig. 4.** Area (%) change of LULC from 1987–2041

while during 2000 to 2014, it increased by 25.84%. The share of urban area increased from 0.857% in 1987 to 1.3% in 2000. Similarly, in 2014, it had a 2.22% share of the study area, suggesting an ascending trend in the development of urban areas. It should be noted that the water body located in the study area is related to part of the Urmia Lake. Unfortunately, over the past few years, depletion of the lake has been observed; the results obtained from the LUCCs tend for the water body in the study area also support the fact that the lake was drying up (the water body share of the study area was reduced to about half).

Then, LULC map was predicted for 2014 using CA-Markov, assuming the continuation of the current management trend in the study area. To simulate plausible future land use changes, the Markov chain model was carried out to estimate Markovian probability transition matrix using land use map of 1987 and 2014 and then the output was used to predict future land use for the year 2041 using CA-Markov model (Fig. 3). The results indicated that from 2014 to 2041, agricultural land will reach about 26.75%, indicating an incremental trend. The coverage of human built area will reach 3.59% by the next 27 years, which show an increase in comparison with its value in 2014 (Table 2 and Fig. 4).

Validation of the land-use prediction model was done to assess the performance of the model. For model validation, similarity between the simulated 2014 map and actual 2014 map were compared. The results indicate that in the simulated map, the area of agricultural land and water body was a little underestimated but the value of the predicted human-built area was a little overestimated (Table 3 and Fig. 5).

This type of percentage and eye comparison is not adequate to assess model accuracy. Hence, more detailed statistical analysis (based on the Kappa statistics) is needed. Kappa statistics measure the level of agreement between the predicted and observed data (Arsanjani et al., 2012; Congalton, 1991). Kappa statistics was calculated from the observed and actual land use maps of 2014 using VALIDATE module in Idrisi Selva. Since all Kappa statistics value were above 0.9, the CA-Markov model is suitable to predict future land use changes in the study area (Viera & Garrett, 2005).

Table 4 illustrates the changes and conversions of each LULC during different periods. The results indicate that from 1987 to 2000, 5226.3 and 261.18 ha of the bare lands changed to agricultural land and human built area (urban areas), respectively. The results revealed that if the land exploitation continues with the current management, 1047.87 ha of agricultural land will degrade to urban area, 2097.99 and 502.47 ha of bare lands will change to agriculture and urban areas, respectively.

Overall, it can be stated that with the human settlement expansion (resulting from various factors, especially rapid growth of population), the agricultural land has also had an incremental trend, which is quite natural. Because, as residential areas expand and increase, the urban need for resources (that is, ecological footprint) grows, which require further fertile lands to meet these needs. This growth of urban areas and in turn increase in agricultural lands has resulted to the decrease in bare lands; since agricultural and urban land uses are devouring the bare and range lands around them.

## 4. Conclusions

An updated LULC map is one of the important information sources for sustainable planning and management. Land use changes modelling provides accurate prediction regarding the amount, state, composition and configuration of the changes which can be used as an early warning system for proper planning, on time policy and decision making. These information aid urban planners to step up towards sustainable development, especially in the area faced with rapid, unregulated and unrestrained urban expansion.

**Table 3**
Comparison of actual and projected LULC type in 2014.

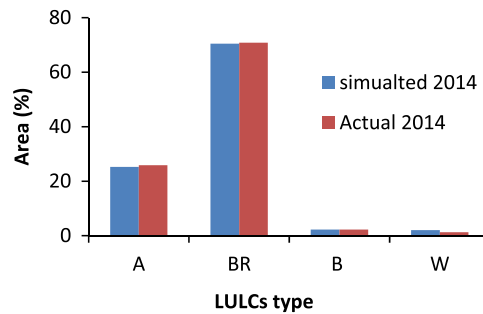| LULC type | Area | | | |
| --- | --- | --- | --- | --- |
| | **Actual map** | | **Simulated map** | |
| | (ha) | (%) | (ha) | (%) |
| **A** | 29,293.54 | 25.85 | 28,614.48 | 25.25 |
| **BR** | 80,252.60 | 70.81 | 79,841.69 | 70.45 |
| **B** | 2522.49 | 2.23 | 2523.06 | 2.23 |
| **W** | 1458.45 | 1.29 | 2341.23 | 2.07 |

Fig. 5. : Comparison of simulated and actual spatial pattern of LULC in 2014

Considering the rapid growth of the human built environment, especially urban area and in turn the resulting land use change in the surroundings, RS data (satellite images) is a suitable tool for revising, renovating the land use maps and then manage land use changes based on these up to date information.

This research highlights the significance of LUCC monitoring using RS data, technology and CA-Markov model. According to the ascending trend of built up area and the rising environmental, social and economic impacts on Naghadeh County, the predicted LULC maps can play an important role as an early warning system to understand the future effects of these changes. Furthermore, the results of this research can be used as strategic guide for land use planning. Results of accuracy assessment of the image classification model indicate that unsupervised classification and visual interpretation with supervised classification of RS images could provide a powerful tool for extracting appropriate LULC maps. The ability of prediction and simulation of CA-Markov model shows that such kind of prediction can help to manage urban growth and land use system in the study area.

As the results indicate the area has undergone the significant land use changes over the studied time span and if no proper intervention undertake it will continue in an unsuitable way.

Unless the political and legal land use mechanism, especially "the rule of maintaining agricultural and horticultural land" which forbids and limits the changing them to built-up area have been undertaking since 1995, but the expansion trend of urban area at the expense of decreasing agricultural land is visible (about 11,272.23 ha converted from agricultural land to built-up area during 1987–2014). The prediction results show if any appropriate intervention would not carry out the urban expands by 2041 (reach 4073.43 ha of the area). The common land use strategies based on the above-mentioned rule should be revised to counteract the deteriorating situation of LUCCs.

The present trend of land use changes within the study area (as a part of the Lake Urmia basin) has visible environmental impacts on the surrounding natural resources and the ecosystems, especially on the viability of the lake and in complicated feed backs on the viability of human settlement (Anvari & Valaie, 2015). As "Urmia Lake Restoration program" indicated agricultural sector is one of the main drivers of drying up of the lake (Tourian et al., 2015). So any expansion of agricultural land, including converting bare land to agricultural land was forbidden by the directive which launched in 2015.

Also the second main objectives of "The Integrated Management Plan for Lake Urmia Basin" proposed by cooperation between the Iranian Department of Environment, UNEP and gef within" conservation of Iranian Wetland Project" was "Sustainable management of water resources and land use" (Faramarzi, 2012). In this regard previous land use change within the whole basin was analyzed (Kamali & Yunes zadeh, 2015) but without any look at the future plausible changes.

According to the above mentioned problems, necessity of land use change analyze and prediction and also regarding the fact that planning is done for the future and based on the simple definition of planning which is achieving a desired situation from the current situation, the local and regional land use planners and policy makers require the information of the past, current and future situation in order to establish the necessary decisions and policies to overcome the consequences; and the approach adopted in this research can fulfill this necessity. Prediction of future land use changes of the study area provides this possibility that the consequent damage and changes are prevented with the involvement of local officials and managers through proper and on time policies.

In another words the obtained information in this study will be useful to help the decision and policy makers to make proper

**Table 4**
Area (ha) of LULC conversions in during the studied period.

| LULC conversions | Times pan | | |
|---|---|---|---|
| | 1987–2000 | 2000–2014 | 2014–2041 |
| **A to B** | 301.95 | 774.27 | 1047.87 |
| **A to BR** | 7110.63 | 4161.6 | 2.7 |
| **BR to B** | 261.81 | 316.8 | 502.47 |
| **BR to W** | 344.88 | 274.5 | 0.09 |
| **BR to A** | 5226.3 | 8720.28 | 2097.99 |
| **W to BR** | 1024.56 | 980.37 | 503.91 |
| **Total changes** | 14270.13 | 15227.82 | 4155.03 |

decision and policies to control incremental tend of urbanization and decrease the possible negative consequences of urbanization in the near future as well as help develop complex adaptive measures.

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