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CASE STUDY

Analyzing and modeling urban sprawl and land use changes in a developing city using a CA-Markovian approach

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ABSTRACT: Mashhad City, according to the latest official statistics of the country is the second populated city after Tehran and is the biggest metropolis in the east of Iran. Considering the rapid growth of the population over the last three decades, the city's development area has been extended, significantly. This significant expansion has impacted natural lands on suburb and even some parts e.g. rangelands and agricultural area have been transited to urban land uses. The study was aimed at analyzing and simulating land use changes in Mashhad, Iran. The work needs a model to simulate land use changes among multiple categories and combine spatial and temporal changes during the projection period. Thus, Cellular Automata-Markov model was chosen to meet this target. In this work, the projected time period corresponded to the final 20-year vision period of all-round development of Iran for the target point of 2025 based on a long-term plan. Multi criteria evaluation approach integrated along with analytic hierarchy process were employed for preparing suitability maps for the five land uses, i.e. urban continuous patches, urban discontinuous patches, rural patches, agricultural lands, and range lands. Having applied the matrices utilized in model calibration, the best kappa coefficient proved to be associated with the land use maps dated 1996 and 2002. The Kappa index of quantity and allocation agreement was determined to be 0.9189 and 0.9529, respectively, which established an almost perfect agreement between simulated and observed land uses according to the year 2015. Change detection results showed that with the physical expansion of urban continuous patches, range lands and agricultural lands mostly transited to urban discontinuous patches and eventually were promoted to urban continuous texture. These developments or gains in urbanized patches will lead to some loses in agricultural lands and rangelands of the suburb in 2025. In addition, the analysis of projected land use map indicated that over the upcoming years, the development of the city in northern front, especially in northwestern region will be more intense with a higher speed in comparison with the other regions.

KEYWORDS: *Analytic hierarchy process (AHP); Cellular Automata-Markov (CA-Markov); Fuzzy theory; Land use/ cover change (LUCC); Multi criteria evaluation (MCE); Urban sprawl*

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INTRODUCTION

Urbanization is one of the major contemporary phenomena, which is also called urban revolution (Darvishi and Masoumi, 2013). As the urban populace exceed the provincial populace in 2009, the globe has turned out to be more urban than country (Li *et al*., 2014). Today 50% of the world's populace lives in urban regions and the prospect is that 60 % of the world's populace will be townie by 2030. Amid most recent 50 years, creating nations have encountered quick and uncommon urban development because of exceptionally industrialization and changes in the worldwide economy (Cohen, 2006). Iran, as a

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developing country, is no exception to this rule. This phenomenon has been accelerating since 1979, after Islamic Revolution, under the influence of some policies. According to a census in 2012, 71.4% of Iran's population is dwelling in cities, where this ascending trend is continuously growing (Iran's Statistics Center, 2012). However, the supportive policies and laws in the country's development plans have always emphasized the development of rural life and preservation of their generating population. The overtaking of urban population over the rural population has been the result of many factors such that despite similarities between them, they do not have a similar structure across all regions of the country. The intensity of urbanization indeed represents the growth of urban texture within specific time ranges and has been underlying the physical development of urban texture across various regions of the country. The most direct consequence of fast urbanization is the intense change of land use/cover (Li *et al*., 2014).

Understanding the urban patterns, dynamic processes, and their connections is an essential target in the urban research motivation with a wide accord among researchers, asset administrators, and organizers. Future improvement and administration of urban territory require point by point data about continuous procedures and patterns (Bhatta, 2010). Remote sensing has created analysis of the spatial heterogeneity of urban environment (Jensen and Lolla, 1987; Herold *et al*., 2004) and always has been a source of reliable data for urban studies (Donnay *et al*., 2001). Nowadays, various models are employed to simulate and predict the physical development of cities based on the identification and prioritization of effective factors of the urban development. Modeling is becoming an important tool in the context of conflicts between urbanization and landscape sustainability. They can provide valuable insights into the development trends caused by different policy scenarios, even if the prediction power of models is sometime limited (Westhoek *et al*., 2006). To see how urbanization has changed the desert scene in the focal Arizona, Jenerette and Wu, (2001) utilized a progression of spatial investigations of the land use design in a time of 1912–1995 by the utilization of Cellular Automata-Markov (CA-Markov) model. Results demonstrated that the degree of urban area has expanded exponentially for as far back as 83 years. The urban development was corresponded with the expansion in populace size for the period 1912-1995 (Jenerette and Wu, 2001). Wang and Li (2011) projected various classes of urban land use/cover changes (LUCC) by CA-RFBN (CA-radial basis function) model, in Shenzhen City, China. To reenact changes of the complex urban land use framework, two high resolution remote sensing data sets, i.e. 2000 and 2005 Landsat thematic mapper (TM) images were used. Results uncovered that the changes of land use sorts were impacted by a progression of spatial variables as far as availability or vicinity e.g. vicinity to urban focuses, and transportation lines. In general, this exploration showed the helpfulness of the CA-RFBN model for reenacting different classes of land use/cover changes and for anticipating future patterns of land use/cover changes. In another study, Samat, (2009) applied CA-Markov to evaluate urban spatial growth in Seberang Perai, Malaysia. Validation analysis was performed using the Kappa index of agreement (KIA). In this work, the poor execution of CA-Markov in the displaying of commercial/public facilities development and industrial exercises basically came about because of the model advancement in light of physical components, model presumption in view of the uniform spatio-fleeting development of urbanized area, and failure of the model in perceiving new developments. Samat *et al*., (2011) demonstrated that the forecast exactness of CA-Markov diminished when the model attempted to foresee for a more drawn out timeframe, conceivably because of the way that a uniform move guideline was utilized by the model all through the projection time period. As indicated by Arsanjani *et al*. (2011), the basic issue in utilizing CA-Markov is to consolidate the social, human and economic elements in the simulation, which can be acknowledged in agent-based modeling systems. Be that as it may, they attempted to take care of this issue by utilizing the coordination of logistic regression and CA-Markov. Araya and Cabral, (2010) modeled and examined urban land use change utilizing CA-Markov and landscape metrics in Portugal. They reported that CA-Markov was approved effectively, with Klocation and Kquantity of 87% and 83%, separately. However, they didn't break down the model capacity for change reproduction utilizing a three-dimensional methodology. Wang *et al*. (2010) examined land use change taking into account vector information source using CA-Markov as a part of China. Results established that vector information enhanced simulation exactness by taking into account Kappa

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values. Memarian *et al*. (2012) in an exploration entitled, validation of CA-Markov for simulation of land use and cover change in the Langat Basin, Malaysia, revealed that CA-Markov did not precisely project land use change elements around there which brought about the high estimations of quantity and allocation disagreements and low estimation of figure of merit processed utilizing a three-dimensional methodology. The CA-Markov forced spatial reliance by the contiguity principle, which brought on erroneous simulation of land use change for bare land and grassland. In addition, CA-Markov projection included noises which were overwhelming in agriculture and urban area classes. However, the simulation power of CA-Markov was higher in circumstances where significant signals overwhelmed noises. Crisscrossing among land use polygons because of various elucidations of land use definitions added to errors in the simulation of land use change. Information shortage and absence of flexibility in information choice brought on some transition irregularities between calibration and validation interims. Moreover, CA-Markov displayed trouble in change projection because of minimal changes around there after some time.

Mashhad, according to the latest official statistics of the country (Iran's Statistics Center, 2012) is the second populated city after Tehran and is the biggest metropolis in the east of Iran. Considering the rapid growth of population over the last three decades, the city's development area has extended considerably. This significant expansion has impacted natural lands on suburb and even some parts e.g. rangelands and agricultural area have been transited to urban land uses.

This study was aimed at analyzing and stimulating land use changes in Mashhad using CA-Markov model. In this work, the projected time period corresponds to the final 20-year vision period of all-round development of Iran (2025) based on a long-term plan.

MATERIALS AND METHODS

Study Area

Fig. 1 illustrates the geographic location of study area. Based on the aim of this work, available sources of information and also according to the comprehensive studies of urban planning conducted by the Ministry of House and Urban Planning of Iran, the final limit of Mashhad development for a 25-year

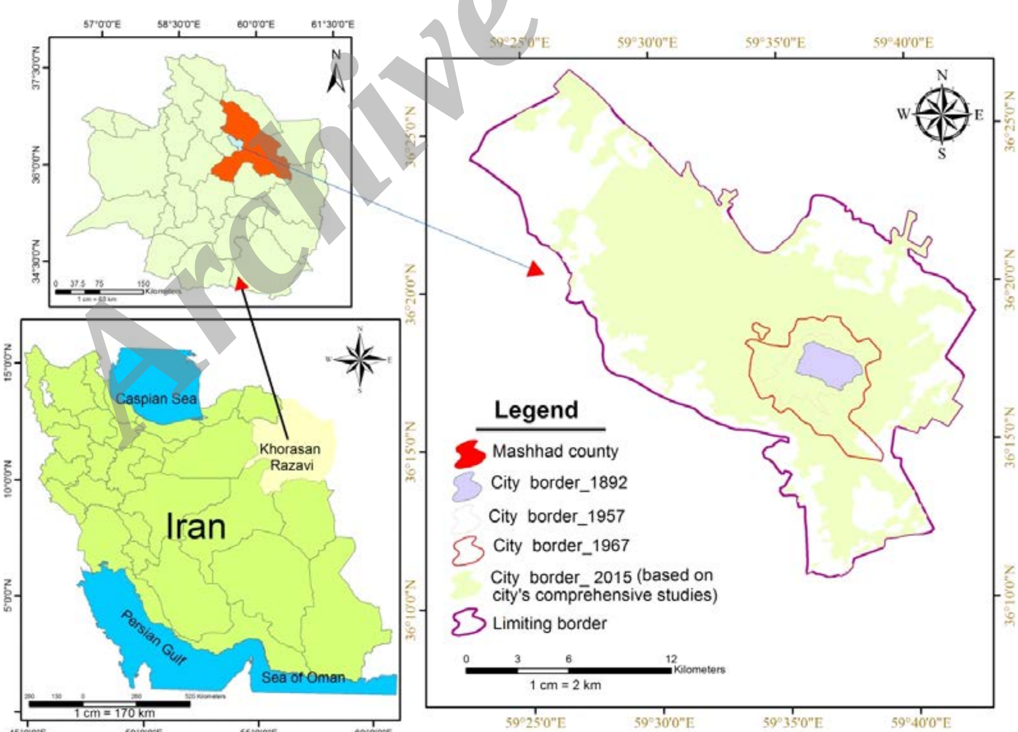

Fig. 1: Geographic area of study territory

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period (1977-2022) has been considered as the projecting border whose area has been as much as 368 km^2. This range is indeed the largest limit for the city's development, where an area beyond that is not adequately justifiable. At the time of this research in 2015, the urban area has been 253 km^2, where in terms of the various types of use, the lands surrounding the urban patch have mostly non-urban uses with an area of around 115 km^2.

Since the growth of urban population is highly associated with the development of its physical area and always regarded as a key variable in the changing trend of urban area, the changes of urban area was plotted against the level of the population dwelling in it as presented in Fig. 2.

Previous experience indeed implies the continuation of the city's population growth rate by the target point, i.e. the year 2025, yet with a rate slower than the past. Accordingly, if policies remain stable, the possibility of urban sprawl in a continuous fashion is not far from the mind.

Data set

The preliminary data used in this work included a set of aerial photos as well as their relevant maps together with the satellite imagery. These data were utilized for preparation of land use maps. The investigated data have dealt with the early 1970s (1962-1972) until 2015. Since the land use maps prepared for comparing the land use changes should correspond with each other, thus some standards were considered for all land use maps based on the existing circumstances. These standards were: Using a similar boundary for the study area within the periods of interest, using a consistent classification scheme for land use categorization and using an identical principle related to the identification process of land uses. Based on the above considerations, five categories were defined and delineated for land use maps as exposed in Table 1.

To prepare the land use map, related to the year 1967, aerial photos with a scale of 1:20000 were utilized. To this end, 60 aerial photos of the city's area were scanned, georeferenced and formed into a photomosaic. Topographic maps and aerial photos with a scale of 1:50000 were utilized to map the land uses dated 1984. The third time corresponded to 1996 for which topographic maps with a scale of 1:25000 were employed. For the fourth time corresponding to 2002, satellite images of the Landsat-7 (Enhanced Thematic Mapper sensor) were utilized. Satellite images presented by the Google Earth technology were employed to map the land uses dated 2015 (Fig. 3).

Table 1: Delineated land use categories

Land use type	Code #
Urban continuous patches	1
Urban discontinuous patches	2
Rural patches	3
Agricultural lands	4
Range lands	5

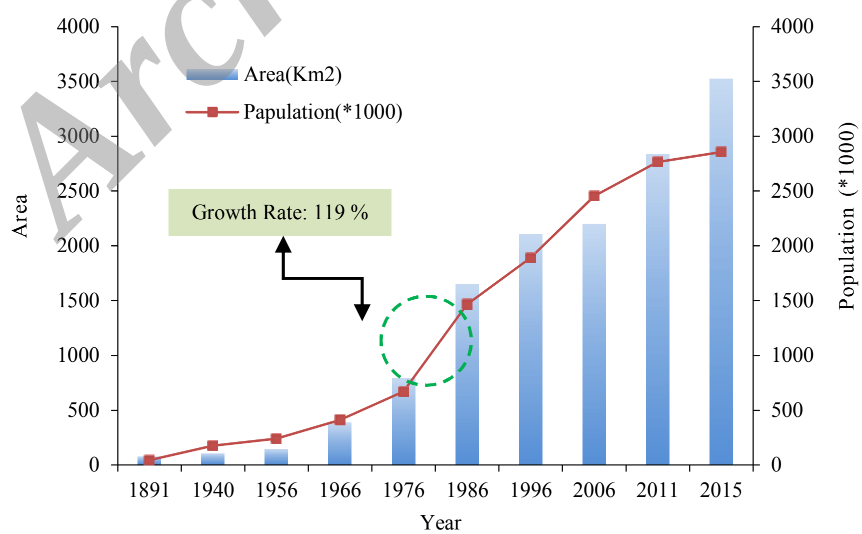

Fig. 2: Population versus city area during the different years of urban expansion of Mashhad

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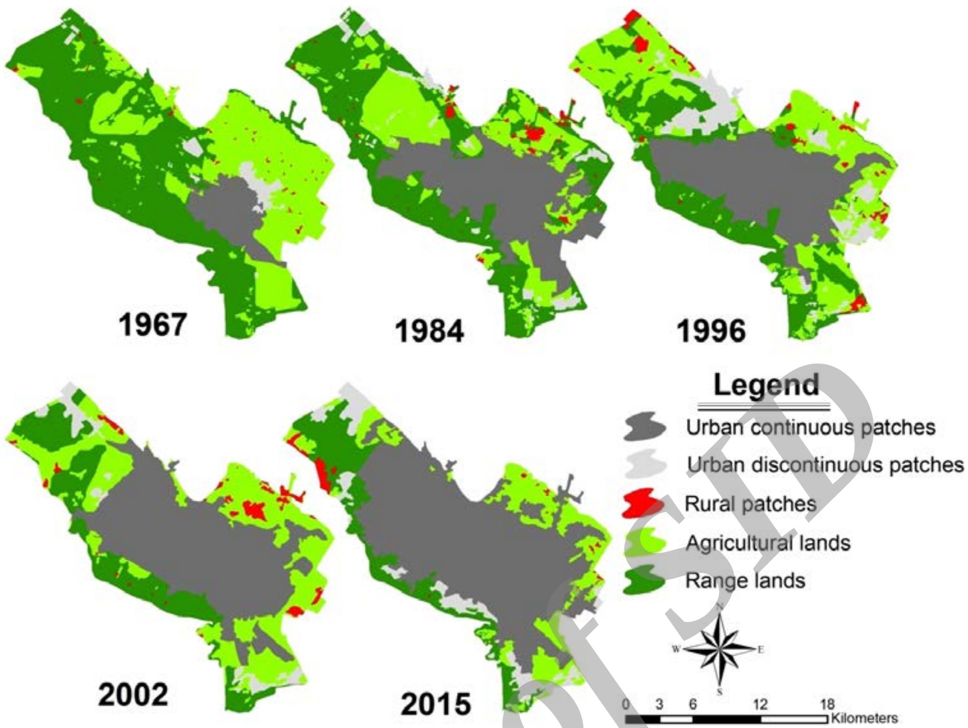

Fig. 3: Land use maps in different time periods

CA Markov model

Late advances in geographic information systems and remote sensing apparatuses and techniques empower specialists to show urban sprawl viably (Alkheder and shan, 2008). Up to this point, diverse experimental estimations and dynamic reproduction models have been utilized to simulate land use and cover changes. Different sorts of rule based modeling, for example CA, are fitting for joining spatial cooperation impacts and the treatment. The capacity of CA to represent complex frameworks with spatio-temporal conduct, from a little arrangement of straightforward standards and states, makes it appropriate for demonstrating and examining urban situations (Alkheder and shan, 2008). A CA-Markov coordinates two systems: Markov chain investigation and CA. The Markov Chain investigation portrays the likelihood of land use change starting with one period then onto the next by building up a transition likelihood matrix between t1 and t2. The transition probability matrix's elements represent the probability of transition from one category to another (Markov, 1971). The probabilities might be precise on category premise, yet there is no learning of the spatial dissemination of events inside every land use class. With a specific end goal to add the spatial character to the model, CA is coordinated into a Markovian methodology (Memarian *et al*., 2012). The CA part of the CA-Markov model permits the transition probabilities of one pixel to be a component of the neighboring pixels. CA-Markov models the change of several classes of cells by utilizing a Markov move framework; a suitability map and a neighborhood kernel (Eastman, 2006).

Modeling

Maybe the most innovative assignment in settling on a choice is picking the components that are imperative for that choice (Saaty, 1990). In this work, 12 factors were identified for suitability mapping that were not equally influential in each land use (Fig. 4). These factors are as follows:

1. Proximity to highways, as the most influential infrastructure on urban sprawl in the study region.
2. Proximity to continuous urban patch or the core of the city: The most important part of Mashhad, i.e. its center is occupied by the holy shrine of the eighth

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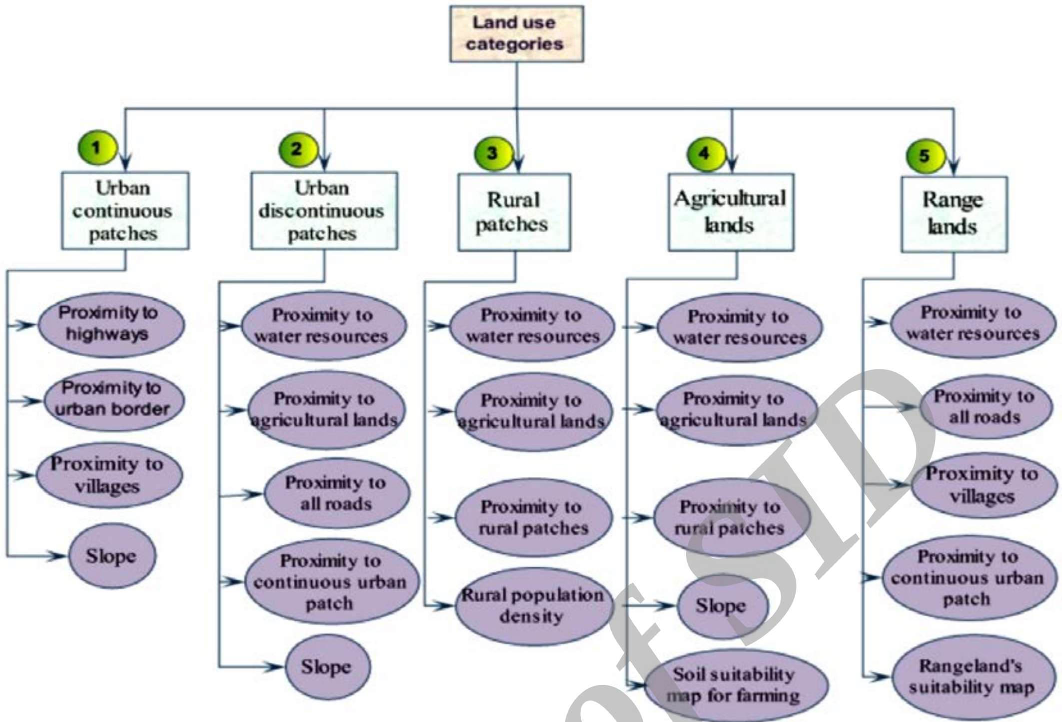

Fig. 4: Different land uses within the territory of Mashhad, affected by multiple driving factors

Imam of the Shias. This part is the center and the start point of development in the city of Mashhad.

3. Proximity to urban border which includes continuous or discontinuous patches
4. Proximity to villages, where are the center of agricultural activities.
5. Proximity to water resources. In three recent decades, Mashhad plain has encountered with water scarcity due to mostly unmanaged agricultural activities and unsustainable urban development. In arid and semi-arid regions, water crisis is the most important constraint for urban and agriculture development.
6. Proximity to rural patches
7. Proximity to agricultural lands
8. Proximity to all roads
9. Slope, which is significantly related with agriculture and urban expansion in the study area.
10. Soil suitability for farming
11. Rangeland's suitability map based on rangeland's condition
12. Rural population density: The greater the density, the higher the tendency to development is.

Multi criteria evaluation (MCE) strategies give straightforward and instinctive tools to settling on choices on issues that include uncertain and subjective data. These techniques have the favorable position that they can evaluate an assortment of choices as per an assortment of criteria that have distinctive units. This is an essential point of interest over conventional choice helping strategies where all criteria should be changed over to the same unit. Another noteworthy point of preference of most MCE techniques is that they have the ability to examine both quantitative and subjective assessment criteria together. In spite of the fact that the MCE techniques are for the most part used to take care of discrete issues, some of them can likewise be utilized inside the connection of continuous decision problems. To determine this trouble, fuzzy set theory is adopted herein (Cheng, 2000; Li *et al*., 2010).

Fuzzy theory as a supplement to the classical Boolean theory was presented by Zadeh in 2008 (Zadeh, 2008). Fuzzy multiple attribute decision-making strategies have been created inferable from the imprecision in evaluating the relative significance of characteristics and the execution appraisals of options regarding properties. Imprecision may emerge from an assortment of reasons: unquantifiable data, fragmented data, unobtainable data and partial ignorance. Ordinary

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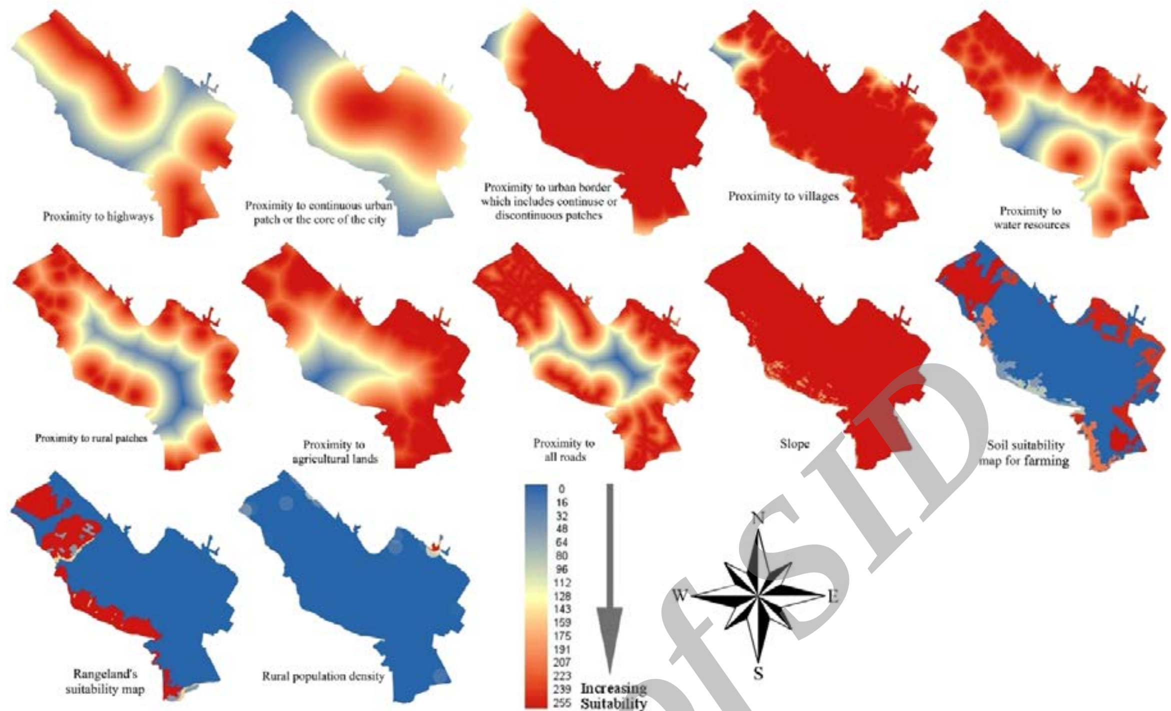

Fig. 5: Driving factors, standardized using the Fuzzy technique

multiple attribute decision making techniques cannot viably handle issues with such imprecise information (Oguztimur, 2011; Bozbura *et al.*, 2007; Mendoza and Martins, 2006; Chang, 1996).

In view of the fuzzy rationale, the parameter maps were standardized into a suitability continuous scale from 0 (the least reasonableness) to 255 (the most extreme reasonableness) (Fig. 5). Three sorts of fuzzy membership functions, i.e. sigmoidal, symmetrical, and user characterized were utilized to rescale parameter maps into the reach 0-255. Analytic hierarchy process (AHP) was utilized to compute the weights of driving elements. AHP examines complex problems based on their interactions at various levels, providing the possibility of solving them easily. Fundamentally AHP is a technique for separating an intricate, unstructured circumstance into its segments parts; orchestrating these parts, or variables, into a hierarchic request; blend the judgments to figure out which variables have the most noteworthy need and ought to be followed up on to impact the result of the circumstance. It utilizes a various leveled structure to digest, decay, arrange and control the many-sided quality of choice including numerous properties, and it utilizes educated judgment

Table 2: Rating scale used in AHP (adopted from Saaty, 1980)

Power of significance on a flat out scale	Description	Details
1	Equal significance	Two exercises contribute similarly to the target
3	Moderate significance of one over another	Experience and judgment unequivocally favor one activity over another
5	Vital or solid significance	Experience and judgment emphatically favor one activity over another
7	Extremely solid significance	An activity is unequivocally favored and its strength showed practically speaking
9	Amazing significance	The proof favoring one activity over another is of the most elevated conceivable request of assertion
2-4-6-8	Transitional qualities between the two adjoining judgments	At the point when compromise is needed

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Table 3: Guideline to determine the capability of agreement indicated with Kappa values (Adopted from Kundel *et al*., 2003)

Kappa value	Range quality
<0	Poor
0 - 0. 20	Slight
0.21- 0.40	Reasonable
0.41- 0.60	Moderate
0.61- 0.80	Generous
0.81- 1.00	Verging on great

or master sentiment to gauge the relative worth or commitment of these traits and incorporate an answer (Saaty, 2000). The basis of this model is a paired comparison between the influential and homogenous factors and investigation of their dichotic relative importance such that it can provide the possibility of examining different scenarios to present decision for an individual (Table 2) (Memarian *et al*., 2012; Memarian *et al*., 2014). In AHP, if the consistency ratio (CR) surpasses 0.1, arrangement of judgments might be too conflicting to possibly be dependable and the CR of zero implies that the judgments are superbly steady (Saaty, 1980; Memarian *et al*., 2012). In this work, all pairwise comparisons of the hierarchy process were controlled and conducted by academic members of the Faculties of "Natural Resources and Environment" and "Geography" in the University of Birjand.

Weighted Linear Combination (WLC) is the most common technique in Multi Criteria Evaluation (MCE). This approach is based on the principle of weighted average (Eq. 1):

$$A_i = \sum_{j=1}^{n} W_j * X_i \quad (1)$$

Where, W_j is the j criterion weight; X_{ij} is a value in the place i in relation to the criterion j, n is total number of criteria and A_i is a suitability value which finally will attach to the location *i* (Alizadeh *et al*., 2013).

Calibration and Validation of the Model

Since the aim of this research is projection of the urban sprawl, the land use maps dated 1996 and 2002 were employed to obtain the most suited transition probability matrix. After model calibration, the land use map dated 2002 was used to analyze the validity of model simulation results. The Cohen's Kappa Agreement Index was used in validation analysis. The Cohen's Kappa coefficient is a statistic which measures inter-raster agreement for two maps that assesses the same classes used. It ranges between 0 and 1; the index values closer to 1 indicate more agreement between two thematic maps (Cohen, 1960).

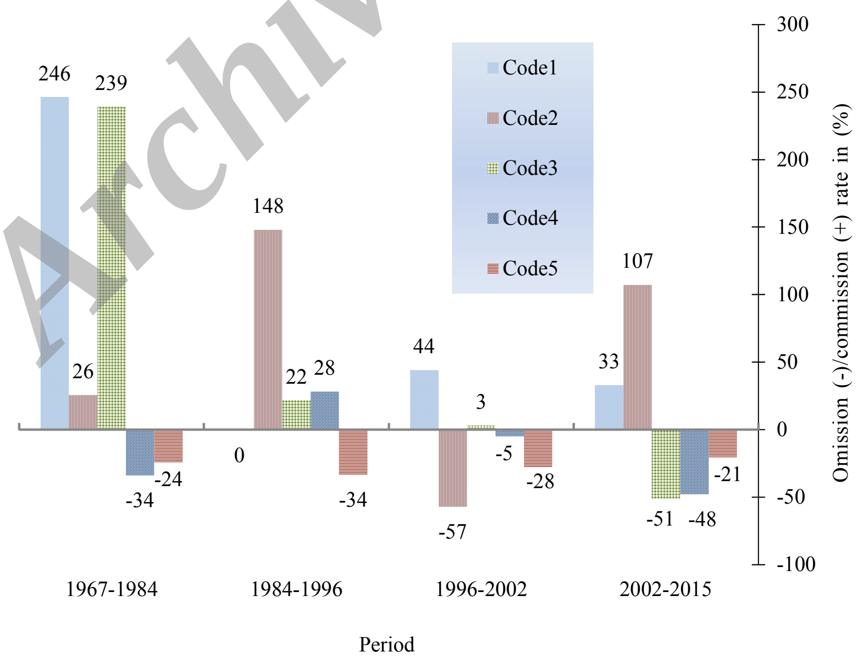

Fig. 6: The rate of omission or commission of land uses during different time periods

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Table 4: AHP results for urban continuous patches including pairwise comparisons, weights of factors and consistency ratios

Factors	Proximity to highways	Proximity to urban border	Proximity to villages	Slope	Final weight of factor
Proximity to highways	1				0.0436
Proximity to urban border	9	1			0.6045
Proximity to villages	7	0.25	1		0.2463
Slope	3	0.2	0.33	1	0.1056
Consistency ratio					0.06

Table 5: AHP results for urban discontinuous patches including pairwise comparisons, weights of factors and consistency ratios

Factors	Proximity to water resources	Proximity to agricultural lands	Proximity to all roads	Proximity to continuous urban patch	Slope	Final weight of factor
Proximity to water resources	1					0.1113
Proximity to agricultural lands	3	1				0.1414
Proximity to all roads	3	5	1			0.4597
Proximity to continuous urban patch	2	2	0.33	1		0.1938
Slope	0.5	1	0.25	0.5	1	0.0938
Consistency ratio						0.08

Table 6: AHP results for rural patches including pairwise comparisons, weights of factors and consistency ratios

Factors	Proximity to water resources	Proximity to agricultural lands	Proximity to rural patches	Rural population density	Final weight of factor
Proximity to water resources	1				0.0664
Proximity to agricultural lands	3	1			0.1598
Proximity to rural patches	5	3	1		0.5120
Rural population density	5	2	0.33	1	0.2618
Consistency ratio					0.05

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The Kappa agreement index can be computed as Eq. 2:

$$k = \frac{P_o - P_e}{1 - P_e} = 1 - \frac{1 - P_o}{1 - P_e} \quad (2)$$

Where P_o is the relative observed agreement between two rasters, and P_e is the hypothetical probability of chance agreement (Kundel *et al*., 2003). Table 3 provides a guideline to decide whether the model performance is good enough or not.

RESULTS AND DISCUSSION

Investigation of land use alterations during the study period revealed that the trend of urban population growth had not been proportional with the urban physical expansion rate. Moreover, the trend of changes in different land uses has not followed a uniform rate due to different driving forces, imposed on various land uses. Results showed that with the physical expansion of urban continuous patches (code #1), range lands (code #5) and agricultural lands (code #4) mostly transited to urban discontinuous patches (code #2). Due to governmental policy, this type of transition has been accelerated especially in two recent decades. The change trend of rural patches (code #3) was more regular during the study period, as compared with other land uses. Urban discontinuous patches and rural patches were mostly transited to urban

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Table 7: AHP results for agricultural lands including pairwise comparisons, weights of factors and consistency ratios

Factors	Proximity to water resources	Proximity to agricultural lands	Proximity to rural patches	Slope	Soil suitability map for rangeland	Final weight of factor
Proximity to water resources	1					0.0735
Proximity to agricultural lands	2	1				0.0813
Proximity to rural patches	2	3	1			0.1397
Slope	2	3	2	1		0.1982
Soil suitability map for rangeland	5	6	5	3	1	0.5073
Consistency ratio						0.05

Table 8: AHP results for range lands including pairwise comparisons, weights of factors and consistency ratios

Factors	Proximity to water resources	Proximity to all roads	Proximity to rural patches	Proximity to continuous urban patch	Rangeland's suitability map	Final weight of factor
Proximity to water resources	1					0.0495
Proximity to all roads	2	1				0.0594
Proximity to rural patches	7	5	1			0.3140
Proximity to continuous urban patch	3	5	0.33	1		0.1612
Rangeland's suitability map	5	7	2	3	1	0.4159
Consistency ratio						0.06

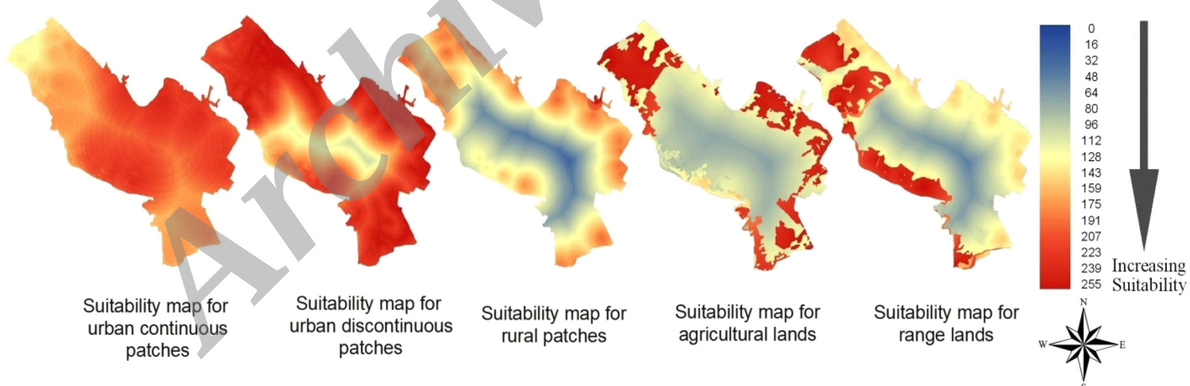

Fig. 7: Suitability maps obtained through WLC approach for different land uses

continuous patches and agricultural lands, respectively. Fig. 6 illustrates the rate of omission or commission of land uses during different time periods. The level of significance of each of driving factors in changing the land uses has been identified using the AHP model. The paired scores of the influential factors in every land uses, were represented individually in Tables 4-8.

Urban development always occurs under the influence of an array of factors. These factors enjoy different relative levels of importance, where each affects the land use alteration in a different way. Indeed,

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Table 9: Transition probability matrix obtained through the Markov analysis of land use alterations during the period 1996-2002

Land use categories	Urban continuous patches	Urban discontinuous patches	Rural patches	Agricultural lands	Range lands
Urban continuous patches	0.9631	0.0002	0.0004	0.0280	0.0083
Urban discontinuous patches	0.6873	0.0774	0.0416	0.1654	0.0283
Rural patches	0.2671	0.1783	0.1335	0.3702	0.0509
Agricultural lands	0.1251	0.0499	0.0319	0.5605	0.2326
Range lands	0.2735	0.0436	0.0176	0.3181	0.3472

by identifying the factors affecting the development also their prioritization in each land use, the MCE approach was employed for preparing suitability maps. The results were represented in Fig. 7. Having applied the matrices utilized in model calibration, the best kappa coefficient proved to be associated with the land use maps dated 1996 and 2002. Thus, the matrix related to this period has been utilized for preparation of the projection map for the city's future, i.e. 2025. The relevant matrix was summarized in Table 9. The Kappa index of quantity and allocation agreement was determined to be 0.9189 and 0.9529, respectively, which established an almost perfect agreement between simulated and observed land uses according to the year 2015 (Nouri *et al*., 2014; Kundel *et al*., 2003; Carletta, 1996).

Having compared the transition probability matrix's elements, it was observed that the probability of transition of rangeland and agriculture to other categories was relatively higher than the other transitions. The highest probability of transition (i.e. 0.9631) was related to the transition of urban continuous patches to the same land use, which demonstrated a fully planned urbanization in the study area. The transition probability of urban discontinuous patches to continuous patches, i.e. 0.6873 was quantitatively placed in the second order. Urban discontinuous patches have mostly some infrastructures related to urban regions. Therefore, this type of transition is very probable in urbanizing regions which is also affected by the urban management policies. Table 9 shows that by a probability of 56.05%, agricultural lands were persisted in agricultural uses which it was mainly caused by the occupation of people of suburb villages in agriculture section. The transition probability of agricultural lands to rural patches was estimated to be

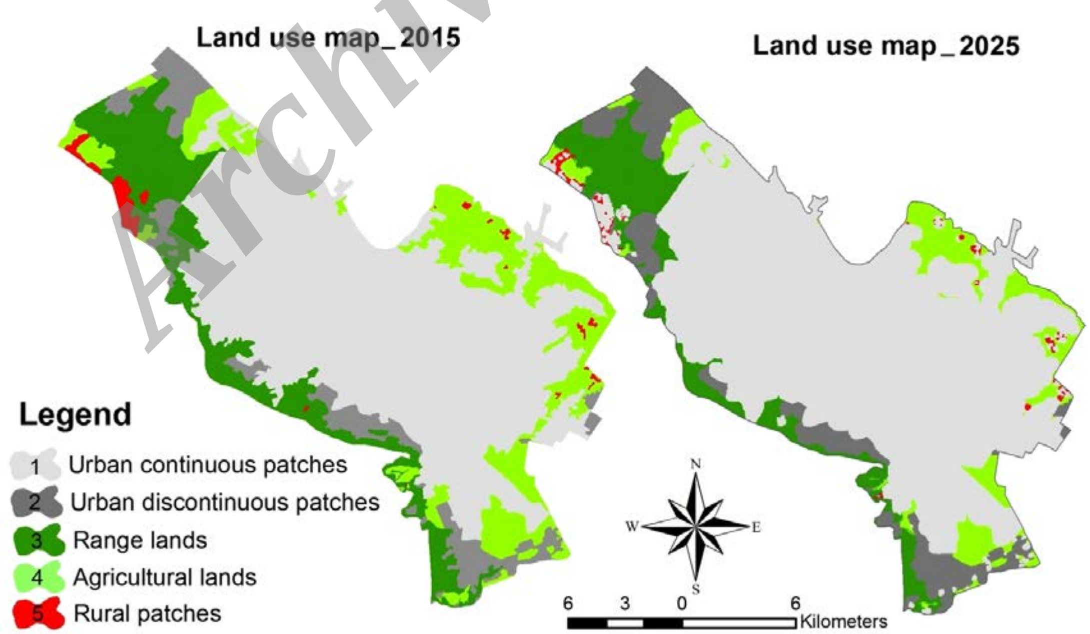

Fig. 8: The land use map dated 2015 versus projected land use map dated 2025

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37.02%. This type of transition was mainly originated from the marginalization. The transition of rangelands to agricultural uses with a probability of 0.3181 is of a great importance in the study area. This tendency of transition can be termed as speculation, which unfortunately is a serious problem for developing cities in Iran. In the study area, the land use category of rural patches always acted as an intermediary. It means that with the growth of rural patches, the conditions were changed so that rural patches were finally transited to the urban texture. Typically, with the development of rural area, agricultural patches and rangelands were gradually connected to the village territories. With the development of urban patches, the villages around the city gradually transited into urban discontinuous patches, and eventually were promoted to urban continuous texture. Comparatively, it was revealed that urban patches with the main priority of development have always been of attraction for the change of other uses toward their own. Based on this concept, the projection of Mashhad land use map for the target point 2025 was executed as shown in Fig. 8.

Analysis of projected land use map for the target point 2025 indicated that urban continuous texture will grow by 4251 ha, as compared with its latest state in 2015. Moreover, urban discontinuous texture, which is somehow influenced by urban continuous patches, will be developed by 585 ha in 2025. Totally, urban continuous and discontinuous patches will be developed by around 38% until the target point as compared with 2015. These developments or gains in urbanized patches will lead to some loses in agricultural lands and rangelands of the suburb in 2025, which results in a reduction of soil permeability of upper catchments and ground water recharge and increase of flood occurrence. Totally, the mesoclimate will be impacted by the lessening of carbon sequestration. These findings are in conformity with the results of other research works carried out by Nouri *et al*. (2014), Memarian *et al*. (2014), Memarian *et al*. (2013) and Cai *et al*. (2012). In addition, the analysis of projected land use map indicated that over upcoming years, the development of the city in northern front, especially in northwestern region will be more intense with a higher speed in comparison with other regions.

CONCLUSION

The results predicted by the CA-Markov model imply that over the upcoming years, the rapid development of the city in northern front, especially in northwestern region will be more intense with a higher speed in comparison with the other regions. With the physical expansion of urban continuous patches, range lands and agricultural lands mostly will transit to urban discontinuous patches and eventually will promote to urban continuous texture. These developments or gains in urbanized patches will result in some loses in agricultural lands and rangelands of the suburb in 2025, which causes a reduction of soil permeability of upper catchments and ground water recharge and increase of flood occurrence. Furthermore, undue emigration from rural areas and smaller cities to metropolis, with the aim of finding the better life conditions, accessing to more facilities, and enhancing economic power, creates a number of challenges in urban areas. Currently, marginalization and gradual development of the physical texture of Mashhad city, being the result of inconsiderate migrations, have changed into one of the major plights in metropolis of Mashhad. Therefore, according to the sustainable development basics, reinforcement of the environmental protection plans at the northwestern border should be given the highest priority by planners and decision makers.

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CONFLICT OF INTEREST

The authors announce that there are no irreconcilable circumstances with respect to the distribution of this original copy.

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