ISSN 1848-0071
719(55)+517=111
Recieved: 2013-09-30
Accepted: 2013-10-14
Original scientific paper

APPLICATION OF LANDUSE CHANGE MODELING FOR PROTECTED AREA MONITORING

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Globally, land use change impacts biodiversity, water and radiation budgets, emission of green house gases, carbon cycling, and livelihoods. The study of LUCC and its dynamics is crucial for environmental management, especially with regard to sustainable agriculture and forestry. Different models, in terms of structure and application, have been used to understand LUCC dynamics. The present study aims to simulate the spatial pattern of land use change in Varjin protected area, Iran. Land cover maps for 2000 and 2010 were prepared using TM images. Images were classified using supervised classification. CA Markov model was used to predict land cover map for 2020 as a top-down approach in investigating land use change. A comparison was made between the predicted and older land use map. The findings of the study suggest that the region will experience a degradation in poor range and increase rate in urban from 2010 to 2020. Moreover, if the trend of land exploitation and current management policy of the region continue as before, the region will experience with urban development and degradation in the Varjin protected area.
Key words: Land use and land cover changes; Land use and land cover modeling; Cellular automata; Ecological modeling.

Primjena modeliranja promjene uporabe zemljišta za nadzor zaštićenog područja. Globalno, promjena uporabe zemljišta utječe na biološku raznolikost, vodu i zračenje, emisiju stakleničnih plinova, ciklus ugljika i egzistenciju. Proučavanje LUCC i njezine dinamike je presudno za upravljanje okolišem, posebno s obzirom na održivu poljoprivredu i šumarstvo. Različiti modeli, u smislu strukture i primjene, korišteni su za razumijevanje LUCC dinamike. Ovo istraživanje ima za cilj simulirati prostorni raspored promjene uporabe zemljišta u zaštićenom području Varjin, u Iranu. Karte zemljišnog pokrova za 2000 i 2010 su pripremljene uz pomoć TM slika. Slike su klasificirane pomoću nadzirane klasifikacije. CA Markov model je korišten za predviđanje karte zemljišnog pokrova za 2020 kao najpovoljniji pristup u istraživanju promjene uporabe zemljišta. Napravljena je usporedba predviđene i stare zemljišne karte uporabe. Rezultati studije upućuju na to da će regija doživjeti degradaciju i povećati stopu urbanizacije u periodu 2010-2020. Štoviše, ako se trend eksploatacije zemljišta i trenutne politike upravljanja u regiji nastavi kao i prije, regija će doživjeti razvoj urbanizacije i degradaciju zaštićenog područja Varjin.
Ključne riječi: promjene uporabe zemljišta i pokrova, modeliranje uporabe zemljišta i zemljišnog pokrova, stanični automati, ekološko modeliranje.

INTRODUCTION

Protected areas are deemed pivotal in the conservation of biodiversity, and they play a central role in sustainable development strategies [1, 2]. Governed by a number of stakeholders, protected areas have a wide range of management aims [3]. The 4th category of IUCN gives a hint to protected areas principally managed for conservation through management interference [4]. With the multiple objectives of protected areas [5, 6], to concentrate on the social preferences, institutional structures and conflicting opinions of what is important becomes crucial. Preparing management plans for protected areas is essential for the well-being of the natural and cultural resources which are managed [3]. However, it can be challenging since all these concerns have to be taken into consideration. Land use/cover change which comes in the wake of mostly unintentional development is a major cause of wildlife habitat loss and leads to the destruction and degradation of natural habitats [7, 8, 9]. Degradation is the result of a complex interaction of biophysical factors and has various economic and social causes, which must be taken into account altogether when developing new management approaches [7, 10, 11]. Therefore, linking social survey information from local stakeholders to land cover change is becoming a focused subject in different researches [12, 13, 14, 15]. Managers will be able to come up with more appropriate solutions for conserving natural resources if they understand the social and economic factors that cause degradation and land use change [16, 17]. To detect and analyze land use and land cover change, satellite remote sensing and GIS have been widely utilized [18, 19].

Analyzing the trend of changes in the past and predicting changes in the future have a central role in decision making and long term planning [20]. A key instrument for investigating and studying land use and land cover change is modeling [18, 20, 21]. A model can help to explore the functioning of a system by developing “what – if” scenarios and to visualize land use configuration that stems from the changes in a society [8, 22, 23]. So far, numerous models have been developed and utilized to predict land use change [16]. They have been classified as: mathematical equation based, system dynamic, statistical, expert system, evolutionary, cellular, hybrid models and so on [24, 25, 26, 27]. Stochastic models have been used to simulate and explore the entire gamut of dynamic systems including that of land-use change [28]. Markov chains have been used to describe and predict land use changes inside a city, while [29] investigated land-use change patterns over the larger area of San Juan Island, Washington. In this study Markovian analysis is used as a descriptive and interrogative tool to understand and quantify the land-use changes that occurred over a human dominated landscape. In this study, an integrated approach incorporating GIS, RS and modeling is applied to identify and analyze patterns of urban changes within the Varjin protected area between the years 2010 and 2020. The study also aims to determine the probable future developed areas so as to enable the anticipation of planning policies that aim to conserve the unique natural characteristics of the Varjin protected area.

MATERIALS AND METHODS

Varjin protected area

Located on southern of central Alborz Mountains adjacent to Tehran. The altitude range of 1700-3900 m, and mean annual perception and temperature of 700 mm and 5° C, respectively have resulted in warm Mediterranean and temperate sub-humid climate (figure 1). The exceptionally high animal and plant biodiversity of the area is a characteristic feature of the area. 577 plant and 162 animal species have been identified in Varjin. Some of the main plant species are: Juniper, Willow, Ash tree, Almond, Oxytropis, Thyme, Rhubarb, Mullein, Borage, Prickly thrift, and different species of Gramineae. The main animal species of the region include Alborz red sheep, wild goat, leopard, wild boar, hyena, chukar partridge, Caspian snowcock , tawny eagle, transcaucasian meadow viper, Latifi's viper, brook trout, and lenkoran. The region plays an important role as a corridor for the animals, especially wild sheep between central Alborz and Lar national park [30].

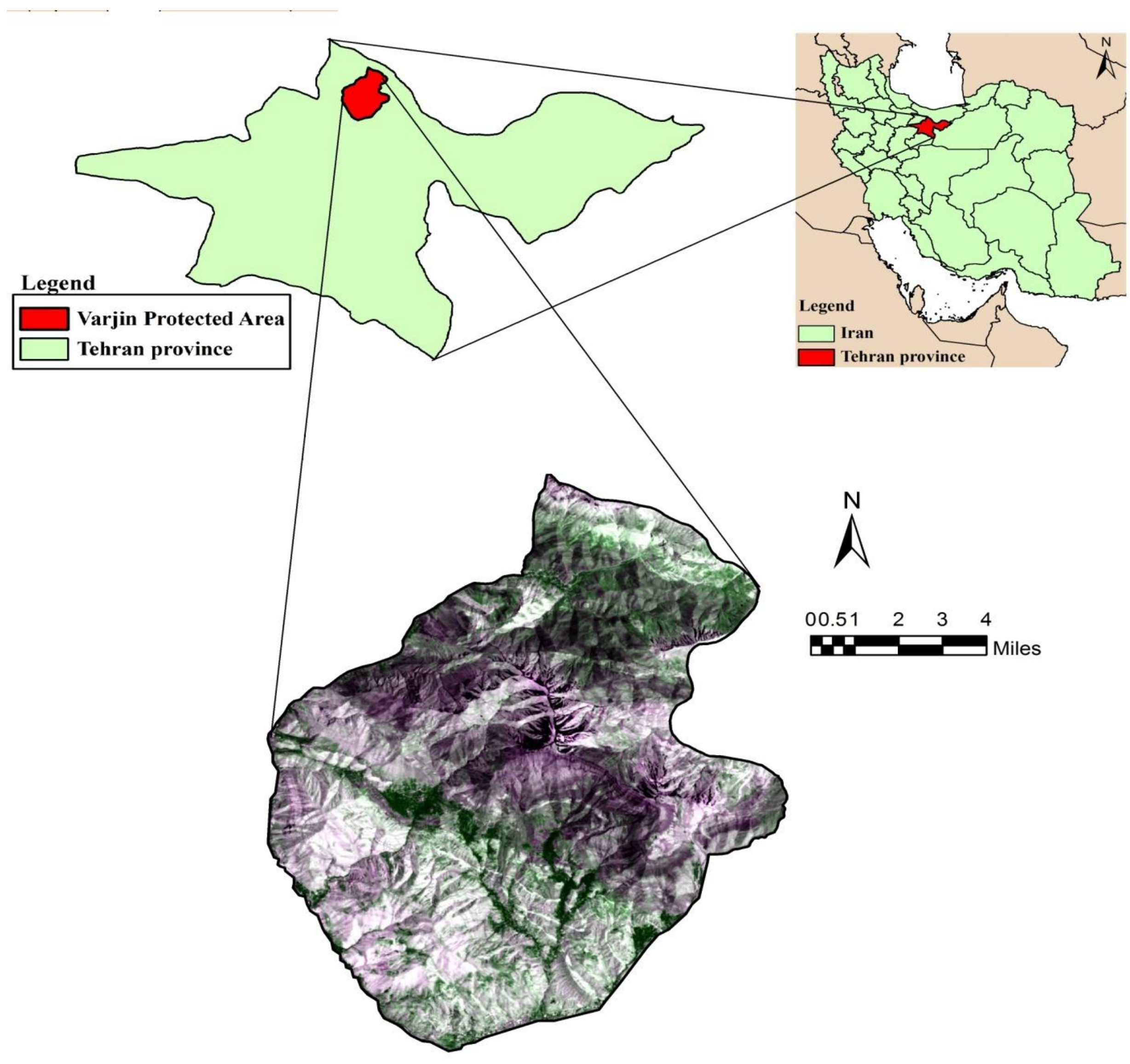

Figure 1. Study area
Slika 1. Istraživano područje

Methods

In this study, we acquired two Landsat TM images of the Varjin protected area (WRS2 path 165, row 35). Two images were georeferenced with a UTM map projection provided by the USGS. To correct for changes in atmospheric conditions, illumination angles, and seasonal variation across the images, a relative radiometric normalization technique was used [31]. Based on fieldwork and visual interpretation of the images, we have identified four classes including: poor range, good range, Orchard and urban for Varjin protected area. Supervised classification and maximum likelihood algorithm was used for land use identification.

LUCC models are important for environmental evaluation. Factors that cause land cover change, such as land tenure policies, human activities or vegetation succession, can be analyzed in terms of their contribution to observed changes, and then employed in projecting possible future LUCC scenarios [32, 33, 34] We used a Markov Chain and Cellular Automata model (M-CA) to project future LUCC scenarios based on several factors identified as important causes of observed land use changes: (1) tendencies of local inhabitants to perform both traditional and new economic activities; (2) management policies; and (3) local land use patterns over the next 10 years.

M-CA models are a useful and simple method for projecting future land cover based on changes observed in the past [35, 36, 37]. Here we used a hybrid M-CA model, available as a routine in the IDRISI Selva software [38], which analyzes images of observed land use and land cover from at least two different dates (in this case 2000 and 2010), producing a transition probability matrix, a transition area matrix, and a set of conditional probability images. The transition probability matrix expresses the probability that a cell or pixel could change from one land-use category in 1999 to any other category over the projected period. This matrix is the result of cross tabulation between the images from the two dates, adjusted by proportional error and translated into a set of probability images, one for each land cover category. The transition area matrix expresses the number of cells or pixels that could change from one category of land use in 2000 to any other land use map category over the projected period. It is produced by multiplying each column in the transition probability matrix by the number of cells of the corresponding land use in the later image. The conditional probability images-set shows the probability that each land cover category could be found at each cell or pixel in a future number of specified time units. These images have been calculated as projections based on the later of the two land cover images. M-CA models combine global transition probabilities between land cover categories with local transition rules to predict future land cover. This method uses an iterative process that establishes the number of time steps used in the simulation. For Varjin protected area, we determined the number of years to project into the future based on the difference between 2000 and 2010 (10 years), and then used the same time interval (10 years) in projecting future land cover (2020).

RESULTS AND DISCUSSION

Figures 2 and 3 indicate that good range and poor range areas were the dominant land use/cover classes in the study area. From 2000 to 2010, good range areas increased from 9726.85 ha to 9880.92 ha, while in 2010 to 2020 they slightly increased to 9893.52 ha. However, Orchard decreased significantly from 859.86 ha to 529.65 ha between 2000 and 2020. During the 2000 to 2020 period, poor range areas decreased from 16145.9 ha to 15836.49 ha. During the 2000 to 2020 period, urban areas increased from 192.06 ha to 631.98 ha. The major land use/cover changes were mainly from poor range and Orchard areas to urban areas. The land use/cover transition probabilities and transition area matrix for the 2000–2010 and 2010–2020 periods, urban areas on the basis of the frequency distribution of the observations, are shown in Table 1.

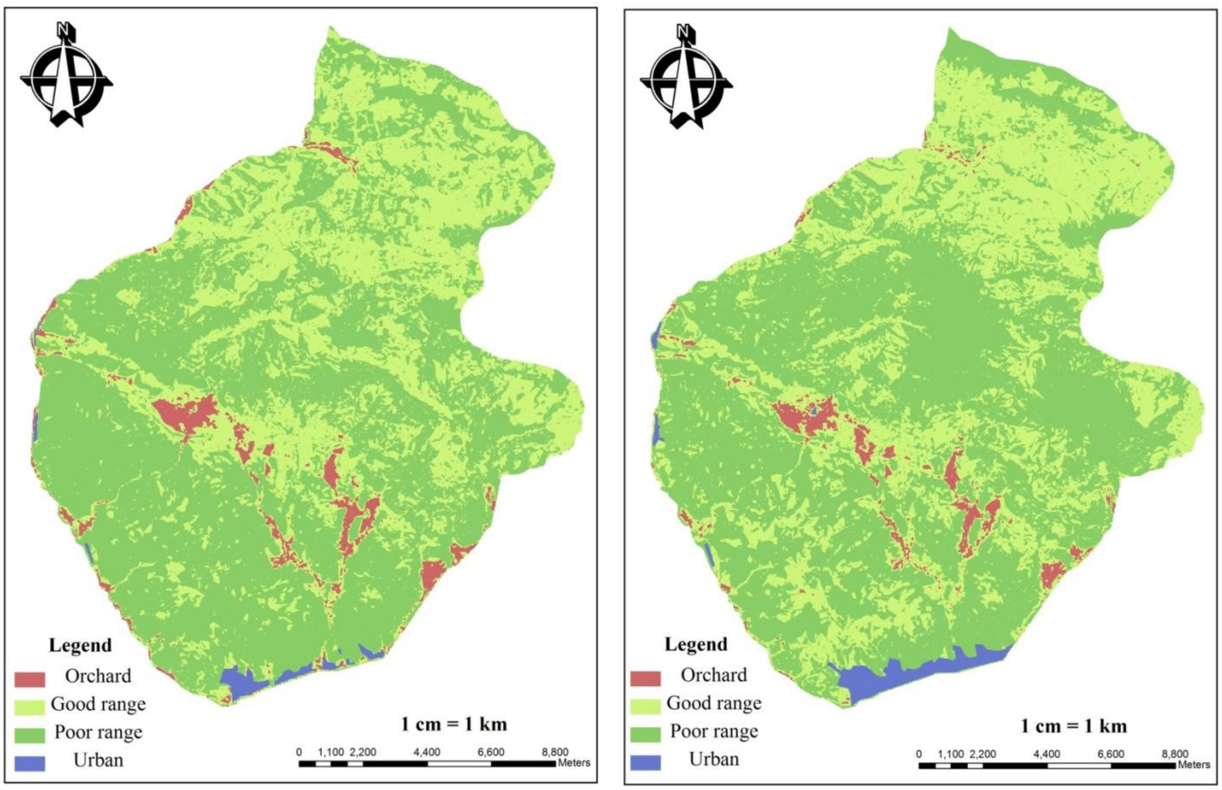

Figure 2. Land use map of Varjin protected area for 2000. and 2010.
Slika 2. Karta uporabe zemljišta zaštićenog područja Vajin za 2000. i 2010.

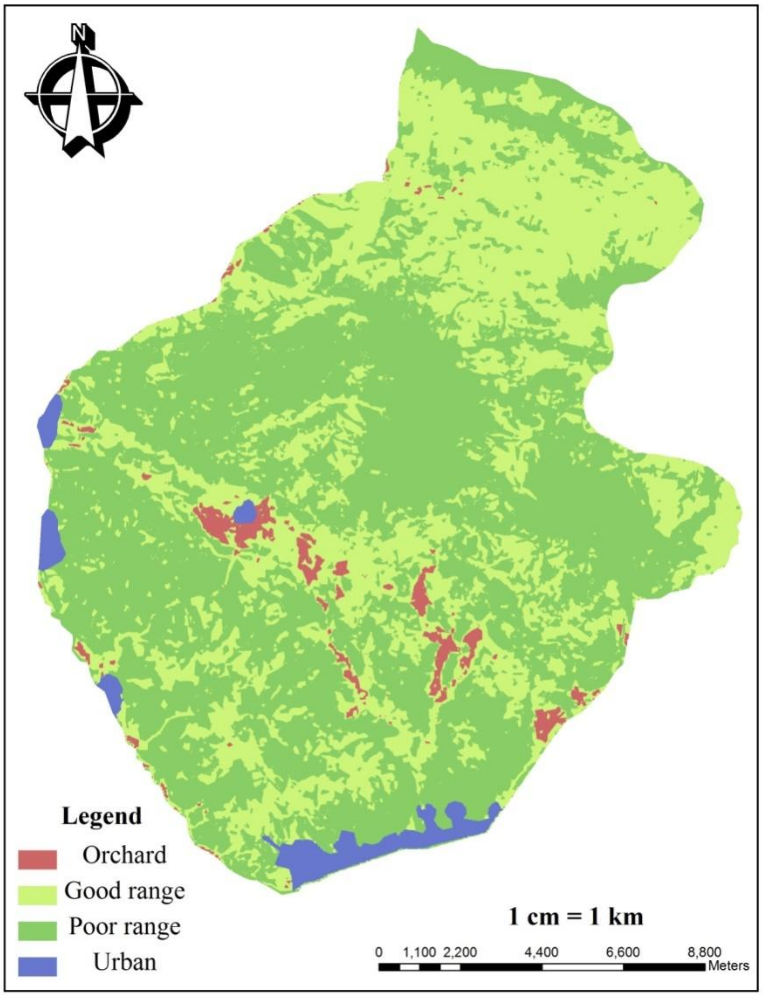

Figure 3. Predicted land use map of Varjin protected area for 2020.
Slika 3. Predviđena karta uporabe zemljišta zaštićenog područja Vajin za 2020.

Table 1. The amount of different classes for 2000.-2020. (per hectare)
Tablica 1. Količina različitih klasa za 2000.-2020. (po hektaru)

Class / Year	Good range	Poor range	Orchard	Urban
2000.	9726.85	16145.90	859.86	192.06
2010.	9880.92	15958.08	660.60	415.08
2020.	9893.52	15836.49	529.65	631.98

Table 2. Abbreviations used in the paper and them explanation
Tablica 2. Kratice korištene u radu i njihovo objašnjenje

Abbreviations	Explanation
LUCC	Land Use and Cover Change
TM	Thematic Mapper
UTM	Universal Transverse Mercator
CA Markov	Cellular Automata Markov
GIS	Geographic Information System
RS	Remote Sensing
M-CA	Markov Cellular Automata

CONCLUSION

The simulated future land use/cover changes have significant environmental and socioeconomic implications for sustainable rural land use planning in the study area. Taking into consideration the high population density and overcrowding in the urban area, the simulated future land use/cover changes indicates increasing pressure on poor range and Orchard area in Varjin protected area. For instance, the continuing decline in Orchard area on one study area and the increase in urban areas on the other hand imply severe land degradation in the future. The Markov-cellular automata model employed in this study area was able to advance previous research [39] by incorporating additional socioeconomic factors such as „land value“, distance travelled to Orchard and urban area.

Considering the amounts in Table 1, Orchard and urban area had a more significant effect on the transition 2020 map (Figure 3), which determined the quantity and location of the simulated future land use/cover changes, particularly the increase in urban areas. Because the simulated future land use/cover change maps takes into account significant socioeconomic factors, areas such as Orchards are identified, which can thus be prioritized for immediate policy interventions.

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