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Scenario-based land cover change modeling and its implications for landscape pattern analysis in the Neka Watershed, Iran

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A B S T R A C T

Land cover changes and urbanization cause destruction of natural habitats and threaten biodiversity. Land cover modeling is one of the most important procedures for evaluating this trend. This study was performed with the objective of comparing multi-layer perceptron (MLP) artificial neural network with logistic regression (LR) in predicting land cover change and quantifying future landscape change using landscape metrics in the Neka River Basin, a small part of the eastern Hyrcanian forest, in northern Iran. For this purpose, first, change analysis was carried out using satellite imagery, from 1987 to 2011. Then, transition potential modeling was conducted using MLP and LR in 5 different scenarios. A Relative Operating Characteristic (ROC) analysis was carried out to detect the degree of correlation between variables and transitions in LR. In addition, the accuracy rate for assessing the transition potential modeling using MLP was employed. Land cover change prediction was conducted using prediction for 2011 and 2017. The accuracy assessment model was determined by comparing the actual land cover map of 2011 with the predicted land cover map of 2011. Landscape indices for 1987, 2001, 2006, 2011, and 2017 were calculated and analyzed using Fragstats to determine the impact of land cover change on landscape fragmentation. The result showed that during 1987–2001, agriculture was the main contributor to the increased built-up area. The most important transition was the conversion of agriculture to orchard and residential, between 2001 and 2006. Forest regenerated from orchard and agricultural lands, between 2006 and 2011. The maximum and minimum amounts of Cramer's V were obtained for the empirical likelihood to change variable and distance from the river. Overall kappa obtained in the best scenario based on LR was 88%. Furthermore, the prediction results showed that major deforestation will occur in surrounding forest areas and most residential development is in the outskirts of the town of Neka. Increased fragmentation in the landscape will continue in 2017, more shape complexity will be observed, and habitats of the Neka Basin will become more diverse and abundant. The results of this study provide useful information for Reducing Emission from Deforestation and Forest Degradation (REDD) project.

1. Introduction

Perusal of the procedures of evaluating land cover change is one of the research subjects within coupled human and natural systems (Pérez-Vega et al., 2012). On a

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global scale, population growth can be discussed as one of the major reasons for land cover change (Muñoz-Rojas et al., 2011). Land transition, habitat loss, degradation and fragmentation are typical processes of landscape change (Paudel and Yuan, 2012). Patterns, rate, and trend scenarios of land cover change are essential for understanding forest dynamics, sustainability conservation, and management assessment approaches (Gómez et al., 2011). Landscape metrics are commonly used to quantify composition and spatial configuration of landscapes and to assess the area, shape, contagion, aggregation, and diversity of patches of a landscape (McGarigal and Marks, 1995). There has been an increasing interest in employment of the landscape indices to assess landscape pattern change (Seto and Fragkias, 2005; Deng et al., 2009; Hassett et al., 2012). These metrics consist of area, patch density and size, edge, shape, nearest neighbor, diversity and interspersion. Landscape structure could be explained by configuration and composition of landscape. Landscape composition describes features associated with the presence and value of each patch within the scenery, without considering the spatial character, placement, or location of patches. Landscape configuration interprets the spatial structure of landscape (Apan et al., 2002). Rafiee et al. (2009) surveyed application of a set of landscape metrics in change detection in urban green space of the city of Mashhad. These indices provide tools for assessing life quality and functions and services of the green areas. Effects of protection on habitat structure are indicated by landscape structure metrics and patch-size distribution models at two spatial scales in the Bozin and Marakhil protected area in the province of Kermanshah, Iran (Khalyani et al., 2013). In addition to landscape metrics, spatial–temporal models can be applied in predictions of landscape dynamics, aiding in comprehensive landscape change assessments (Paudel and Yuan, 2012). Land surface represents by itself a complex system, and land cover change modeling is a complex process that depends upon a variety of driving factors.

Models of land cover change are tools aimed at helping the analysis of the causes and outcome of landscape patterns, better understanding the functioning of the land use system, and supporting land cover management. These models' applications are harnessed to the release of a complex set of economic-social and biophysical forces that are useful in understanding rates and spatial patterns of change and in estimating the effects of changes in land cover (Verburg et al., 2004). Modeling is one of the procedures in the portfolio of tools and techniques available to discover the dynamics of the land cover system. Model-based analysis can assist in capturing the major mechanisms of conversion in a certain area (Verburg, 2006). One of the leading problems in land cover change prediction, especially on regional and global scales, is the wide variety of both drivers and constraints of LULC on a local scale (Park et al., 2005). Recently, special attention has been given to land cover change modeling (Joshi et al., 2011; Yu et al., 2011; Munsi et al., 2012; Mas et al., 2014). Usually, thematic maps are acquired for modeling with remote sensing methods, image processing, and mapping software. Satellite remote sensing with GIS has been widely identified as a pragmatic, useful, and efficient tool in detecting and modeling land cover (Weng, 2002; Wilson and Weng, 2011; Thapa and Murayama, 2011; Carmona and Nahuelhual, 2012).

In general, land cover change models have three major components: 1) change demand submodel, 2) transition potential submodel, and 3) change allocation submodel (Eastman et al., 2005). The critical stage in the land change prediction procedure is transition potential modeling. The generic logic of transition potential modeling is to establish a set of variables that can be discussed as predictive of the location of change, and then to assign the relationship through empirical testing. There are many methods for the generation of transition potentials (Eastman et al., 2005), such as logistic regression (LR) used in CLUE-S (Verburg et al., 1999) and Land Change Modeler (LCM) (Eastman, 2006); empirical probabilities used in GEOMOD (Pontius et al., 2001); Weights of Evidence used in DINAMICA (Soares-Filho et al., 2002); and Multi-Layer Perceptron used in LCM (Eastman, 2006). Eastman et al. (2005) showed among these methods, two procedures—MLP and LR—are viable techniques, and their experience has been that the MLP is the most robust. For these reasons, they have been used in several other studies. For example, MLP and LR were compared in generation of land cover scenarios for hydrological modeling in the Catamayo-Chira Binational Basin in South America. The best result of the land cover change was obtained based on applying LR (Oñate-Valdivieso and Bosque Sendra, 2010) too. GEOMOD's empirical frequency, LCM's logistic regression, and LCM's multilayer perceptron were compared to simulate business-as-usual deforestations in Chiquitanía, Bolivia (Kim, 2010). MLP in LCM was used to predicted areas vulnerable to forest changes in Vietnam's Tam Dao National Park (Khoi and Murayama, 2010). LCM's multilayer perceptron was applied to show the impact of land cover change on erosion risk in the West Fork White River Watershed in Northwest Arkansas (Leh et al., 2011). Thapa and Murayama (2011) demonstrated how urban growth in Nepal caused fragmentation in the landscape.

Carbon dioxide emissions of developing countries (such as Iran) are mainly due to land cover change, e.g., deforestation (Baumert et al., 2005), because much of human population depends on natural resources especially natural vegetation for their livelihoods (Ahmadi and Nusrath, 2010). Amongst different statistics of the area of the Hyrcanian forest in Iran are the initial 3.6 million ha in 1942 (Saei, 1942), 3.4 million ha in 1964 (Marvi Mohadjer, 2005), and 1.92 million ha in 1990 (Moshtagh Kahnamuii and Rasaneh, 1990). The forests are increasingly fragmented, degraded and transitioning to other forms (such as agricultural land, grass land, barren land, orchard, residential) of land cover (Mohammadi and Shataee, 2010). Industrial development, road construction without detailed environmental consideration, increasing land transformation, mismanagement of natural resources, and shortage of human/financial resources for monitoring of the forest are drivers of deforestation in Iran (Poorzady and Bakhtiari, 2009). Hyrcanian forests have a long history (arising in the Jurassic Period) and are among the world's most valuable forests; the decline in the Hyrcanian forests