Spatio-Temporal Analysis of Environment Quality of Ecotonal Zones in Iranian Central Plateau Using Landscape Ecological Metrics

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Extended Abstract

Introduction

Environmental changes can be monitored at many scales but the scale of landscape and region has more information in support of sustainable spatial planning. The availability of remote sensing imagery provides multi-scale observation with periodic repetitions over time. Landscape and regional scales are adequately covered by satellite images. Remote sensing images provide non-average and dis-aggregated data suitable for sustainable environmental planning. The spatial arrangement of elements influences horizontal flows and movements across land mosaics. Hence, modification of landscape affects directly the ecological processes, flows and movement. Coarse-scale monitoring focuses on the structural composition and spatial configuration at the scale of landscape or region.

Advances of environmental planning and management in the last decades can be described as two dimensions: 1. theoretical shift that has happened in the methodologies of the study of natural and cultural systems. Systems approach and nested hierarchical organization are the core concepts of this novel paradigm. Moving across scales is the most important strategy to cope with complexity, nonlinearity, and copious feedback loops of ecological systems. 2. The technological developments that have enhanced the efficiency of data collection, surveying, analysis and synthesis. Remote sensing and satellite imagery technology have granted synoptic and updated digital data and improved availability and accessibility of materials for spatial and temporal investigations. GIS and spatial information systems have promoted the application of techniques of analysis, simulation and modeling.

Spatial indices are quantitative tools for detection of structural pattern of land mosaics. The indices indicate three main aspects of landscape transformation, including loss, degradation and fragmentation. The temporal dynamics of land mosaics could be monitored by means of a comparative approach and variability of the landscape indices. The variability of the indices over space-time dimensions could serve as a bridge between spatial pattern and ecological functioning.

The spatial-temporal monitoring of landscape can act as a decision support system and is a prerequisite for diagnosis of adaptivity and resilience. Coarse scale monitoring of heterogeneous environment by measuring landscape ecological indices can help enhance the efficiency and the effectiveness of land use decisions.

Iranian landscapes

The high and arid plateau of Iran is composed of diverse and contrasting environments. Iran’s diversity in climatic conditions and its rich biodiversity and ecosystems are rooted in its unique geography. Iran is a typical high mountain country situated within the dry belt of Asia. Half of Iran is composed of high mountains. The Iranian high mountains are a rather continuous chain especially at the Elburz and Zagros which enclose Iran in northwest-northeast and northwest- southeast directions. The temperature in Iran is characterized by relatively large annual range about 22°C to 26°C. The rainy period in most of the country is from November to May
followed by dry period between May and October with rare precipitation. The average annual rainfall of the entire country is about 240 mm.

**Objectives**
The mountainous matrix in Iran has created specific conditions, constraints, opportunities and advantages. Sequence of different altitude zones in the upland to lowland (or mountain to desert) continuum can be regarded as an association of landscapes. Most human settlements and large metropolitan areas are placed on the mid-altitudes between mountain and desert. Current share of urbanization in Iran is more than 71.4 percent and the annual growth rate of urban population in the last decade was 4.69 %. Urbanization growth has caused the sprawl of urban areas upwardly into the ecotonal foothills (the zone between high- and mid-alt. lands) and has transformed the structure and function of this strategic zone. These Foothill zones connect mountains in the upland to the plains in the midlands. This ecotonal band serves as an interrelation joint between high and mid altitudes. The main goal of this study is to investigate the ways of connection, relations and changes in this ecotonal strip. However, Specific objectives of this study are: 1. applying landscape ecological concepts in evaluation of the ecotonal environment; 2. retrieval of land covers using Landsat images of 2000 and 2013; 3. calculation of spatial indices of landscape and analysis of spatial distribution of patches mosaic; and 4. monitoring and tracking the landscape changes over time by means of spatial indices.

**Materials and Methods**
**Study area**
Study area of this research is the ecotonal zone between up-land mountainous areas and mid-land plain in the southern slopes of the central Elburz region. Tehran-Karaj region placed on the southern slopes.

**Data**
Two satellite images of Landsat 8 OLI (2013) and two images of Landsat 7 ETM+ (2000) are used to capture land cover classes. Considering natural conditions and urbanization impacts, the ecotone strip is longitudinally divided into four zones: (1) north Tehran to Kan River; (2) Kan River to Karaj River; (3) Karaj River to Kordan River; and (4) Kordan River to Abyek. Analysis is performed zone-specifically using ArcMap (Version 9.3, ESRI) Zonal Statistics in Spatial Analyst Extension.

**Land cover classification**
We classified land covers into four main groups: vegetation covers, anthropogenic impervious surfaces, open spaces, and water bodies. The supervised method with maximum likelihood is applied to classify the satellite images.

**Calculation of landscape indices**
We used the eight landscape indices to quantify the spatial pattern of the ecotone zone in the southern slope of Elburz. This study considers each land cover as a patch. Landscape indices are as follows: NP (number of patches), CAP (class area proportion), MPS (mean patch size), AW-MPS (area-weighted mean patch size), TE (total edge), PARA (perimeter to area ratio) and MNND (mean nearest neighbor distance).

**Results and Discussion**
Our results indicate the measurement of indices for the years 2000 and 2013 in total landscape and sub-landscape as well as class levels. At the 13-years period from 2000 to 2013, land covers in the ecotonal belt have been changed as follows: vegetation changed from 12.8 to 8.53 percent; open class from 51.43 to 38.55 percent; and built class from 28.73 to 52.59 percent. Class area proportion of vegetation (\(CAP_{Veg}\)) in the entire area declined by 2000 to 2013. The same trend has also occurred in all other zones. Maximum and minimum changes of vegetation class have taken place, respectively, in zone 1 (North of Tehran) with 22.61 % and zone 4 (Suburb of Karaj-Qazvin) with 14.07%.

Total \(NP_{Bui}\) increased from 636 to 1155 during the period of 13 years. Interesting point was the reduction of \(NP_{Bui}\) in the zone 1 (from 202 in 2000 to 140 in 2013), contrary to the general trend of increase in other zones. This is due to the expansion of the built patches and then joining them together. This change is called a transformation of the contextual matrix. The highest value of \(NP_{Bui}\) was in zone 4 (212 for 2000 and 737 for 2013).

The mean patch size (MPS) is calculated as the division of the total area to the number of patches. Throughout the area, MPS descended from 36.97 in 2000 to 19.62 hectares in 2013, which are a result of the elevated numbers and the declined areas of patches. These are also signs of fragmentation process.

The arithmetic mean patch size (MPS) carries the same weight for all patches, but the area-weighted mean
patch size (AW_MPS) exerts the weight of each patch through the ratio of the patch area to the total area. When the variance of sizes is high, arithmetic mean cannot be a good description of the actual condition, but area-weighted mean can offer the better understanding of the landscape state. AW_MPS in the entire area was 8998.87 ha in 2000 and increased to 16685.13 ha in 2013. The extremes of AW_MPS in 2000, in order, were zone 4 (with a value of 13328.09 ha) and zone 2 (2915.71 ha), which changed to zone 1 (with a value of 11104 ha) and zone 2 (with 3476.89 ha) in 2013.

Conclusion
Generally, the landscape indices of NP, CAP_Bui, AW-MPS, TE, PARA and MNND had increasing trend during this period, but MPS, MNND, CAP_Veg and CAP_Opn declined from 2000 to 2013. MNND_Veg and MNND_Opn rose over time. This indicates the highest degree of fragmentation, but MNND_Bui is decreased showing that connectivity is increased. In the whole area NP_Veg, NP_Opn and NP_Bui had increased value between 2000 and 2013, which is a sign of fragmenting.

The results of this research show that 32.93 percent of the ecotonal zone has changed during 13 years (2000 to 2013). Vegetation covers and open spaces were the main source of land cover conversions and built area was the ultimate sink of conversions. The explosive trend of urbanization in the ecotonal zone signifies that regional inter-relations have been altered within upland-lowlands continuum. Local scale changes could only be perceived if the wider geographical context and its choric relations are taken into account. Broad scale monitoring with satellite images can be linked to a local scale monitoring to form a monitoring network of environment on many scales. Monitoring of landscape condition and its changes over time is a necessary tool for land use decision and spatial planning. Determining the state and trends of landscape elements are necessary for a better understanding of the ecological resources.

The ecotonal zone between two major landscapes (mountain and glacis) along highland-lowland continuum system acts as an intermediate connector. This has many ecological services at several scales. Ecotones are ecologically significant area for monitoring of environmental quality. Ecotonal belt formed at the foot of the mountain is more diverse than the surrounding context and have to be treated as a strategic location for monitoring of environmental quality.

Keywords: Geographical Information System (GIS), landscape ecology, remote sensing, urban region of Tehran-Karaj.