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Full Length Research Paper

Spatial and temporal dynamics of land use pattern response to urbanization in Kastamonu

Sanem Özen Turan[1]*, Ali İhsan Kadıoğulları[2] and Alkan Günlü[2]

[1]Research Assistant, Karadeniz Technical University, Faculty of Architecture, Department of City and Urban Planning 61080, Trabzon-Turkey.
[2]Research Assistant, Karadeniz Technical University, Faculty of Forestry, Department of Forest Engineering 61080, Trabzon-Turkey.

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This study analyses the spatial and temporal changes in land use and land cover patterns in a typical mountain forest area in Kastamonu regional directorate of forestry in the western part of Turkey. The area was investigated by evaluating the temporal changes of spatial structure of forest conditions through spatial analysis of forest cover type maps from 1984 - 2007 using GIS and FRAGSTATS™. Urban settlements account for only two percent of the Earth's land surface. However, over half of the world's population resides in cities (United Nations, 2001). The quantitative evidences presented here showed that there were drastic changes in the temporal and spatial dynamics of land use/land cover. As an overall change between 1987 and 2000, there was a net increase of 28.96% in total settlement areas. On one hand, forest areas increased to 111 466 ha and settlement areas increased to 1 440 ha, while on the other hand, open areas decreased to 112 888 ha. This is partially due to migration of rural population in Kastamonu regional directorate of forestry. In terms of spatial configuration, analysis of the metrics revealed that landscape structure in study area had changed substantially over the 13-year study period, resulting in fragmentation of the landscape as indicated by the small patch numbers and the large mean patch sizes due to immigration of rural population to urban population.

Key words: GIS, Land use/land cover change, remote sensing, landscape metrics, fragmentation, urbanization.

INTRODUCTION

Over the last few decades, the topic of land use/land cover change, especially forest cover change, has been very important in local and global scales. Land-cover (LC) composition and change are important factors that affect ecosystem condition and function. These data are frequently used to generate landscape-based metrics and to assess landscape condition and monitor status and trends over a specified time interval (Jones et al., 1997). The most important characteristics of recent century have been technological developments and elatedly rapid urbanization. This fact has led to many types of environmental and socioeconomic problems at various degrees in developing countries such as Turkey (Longley, 2002; Leao et al., 2004). Understanding the growth and change brought on by urbanization is critical to those who study urban dynamics and those who manage resources and provide services in these rapidly changing environments (Clark and Jantz, 1995; Wright, 1996; Aysan et al., 1997; Sancar, 2000; Chen, 2002; Yang, 2002; Sanchez, 2004). Urbanization is a result of a rapid population increase caused by mass immigration from rural areas to urban areas in Turkey. Together with this, unplanned and thus uncontrolled urbanization (development of urban and rural area) results in the destruction of green areas and water resources.

Land use change can play an important role in environmental changes and contributes to global change and biodiversity loss (Chen et al., 2001; Wang et al., 2006). Changes in urban (fringe) land-use has important

*Corresponding author. E-mail: sanem@ktu.edu.tr. Tel: +904623774072. Fax: +904623257499.

Abbreviations: LC, land cover; **PCA**, principle components analysis; **PL**, percent of landscape; **NP**, number of patch; **LPI**, largest patch index; **MPS**, mean patch size; **GIS**, Geographical information system.

consequences for natural resources, especially natural habitat ecosystems, through their impacts on soil and water quality and climatic systems (Chen et al., 2001) resulting in serious environmental problems from macro to micro scale. Understanding of land use changes is essential for sustainable management of natural resources and urban areas as it allows decision makers to take a broader view of urban system and its components (Doygun and Alphan, 2006). The local authorities are hardly able to manage the pace of urban and rural development and its impact on environment. Among many other factors, ecosystem degradation, habitat loss and fragmentation are the principal causes of biodiversity loss in the world (Whitcom et al., 1981; Terborgh, 1989; Chaves and Arango, 1998; Etter, 1998). The main problem is the dilemma between the protection of environment and urbanization. One of their spatial displays has been increased fragmentation and uniformity of ecosystem (landscapes) and cities. The rates, scales and causes of urban change has had large impacts on cities and generated strong reverse processes (Barber, 2000; Toledo et al., 2000; De Mattos, 2002; Borsdorf, 2003). Cities have become more vulnerable and globalization has reduced their security and independence (Troy, 2002).

Studying changes in land use pattern using remotely-sensed data is based on the comparison of time-sequential data. Change detection using satellite data and geographical information system (GIS) can allow for timely and consistent estimates of changes in land use trends over large urban areas (Prakash and Gupta, 1998; Güler et al., 2007). Additionally, some spatial statistic programs like FRAGSTATS offer a comprehensive choice of landscape metrics and have been used to quantify landscape structure. Spatial statistics facilitate the comparison of landscapes (land use) and the evaluation of processes. FRAGSTATS is a spatial pattern analysis program that was implemented by decision makers, urban planners and ecologists to analyse land use fragmentation describing the characteristics of land use, components (McGarigal and Marks, 1995). The advantage of FRAGSTATS is that the calculations are implemented in a fully integrated fashion in a GIS and consequently easy to apply to digitals map (McGarigal and Marks, 1995; Raines, 2002; Başkent and Kadıoğulları, 2007; Kadıoğulları et al., 2008; Kadıoğulları and Başkent, 2008; Günlü et al., 2009).

This study analyses the spatiotemporal changes in land use and land cover at a particular time in Kastamonu regional directorate of forestry. The study covers a large scale analysis of landscape structure and cover change using spatial database of GIS based on supervised classified images focusing particularly on the Kastamonu regional directorate of forestry. The objectives of this research were to:

(1) Map the distribution of land cover in a large area of Kastamonu city between 1987 and 2000.
(2) Describe spatial landscape patterns in regional directory unit with special focus on landscape fragmentation.

The study used GIS and remote sensing with substantial input from the field to achieve the stated objectives and a spatial statistics program-FRAGSTATS.

Study area

Kastamonu is located in a typical mountain watershed covering an area of 1 321 192 ha along the northeastern part of Turkey (477630–634200 E, 4519330-4652690 N, UTM ED50 datum Zone 36N) (Figure 1). The altitude varies between 0 and 2700 m above sea level with an approximately average slope of 35%. The vegetation is composed of tree species of *Fagus orientalis, Pinus sylvestris, Pinus nigra, Abies nordmandiana,* Acer species and Oak species. Kastamonu has Ilgaz Mountain National Park and Kure Mountain National Park. The study area covers legally Kastamonu province. Furthermore, Kastamonu province covers legally Kastamonu Forest Regional Directory which has fifteen forest industries as shown in blue line in (Figure 1). Demographic dynamics of Kastamonu is mostly dominated by migration of rural population to urban centers both within and outside the district between 1970-2000 (Table 1) (Republic of Turkey, State Institute of Statistics). For example, the rural population of Kastamonu province has decreased almost two times while the urban population increased more than two times during the study period. Urban population of Kastamonu city increased from 29 338 to 80 946 and the rural population decreased from 49 941 to 34 925 with the total population almost increasing from 79 279 to 115 871. Total urban population of Kastamonu city increased from 82 101 to 184 228 and the rural population decreased from 364 500 to 176 196 with the total population almost decreasing from 446 601 to 360 424. Urbanization of Kastamonu city changed parallel to Turkey.

MATERIALS AND METHODS

The data used in this research were forest cover type maps of 1/25 000 scale for the years 1987, 1999, 2000 and 2008, a landsat TM satellite image of 02.07.1987 and a landsat ETM image of 13.07.2000. The forest cover types, used as ground truthing, were originally generated from both the stereo interpretation of black and white aerial photos with an average of 1/25 000 scale and ground measurements of 300 × 300 sampling points. The landsat images were interpreted with ERDAS image analysis program.

Geometric correction of landsat images and digitizing stand type maps

Subsets of satellite images were rectified using 1/25 000 scale topographical maps with UTM projection (ED 50 datum) using first

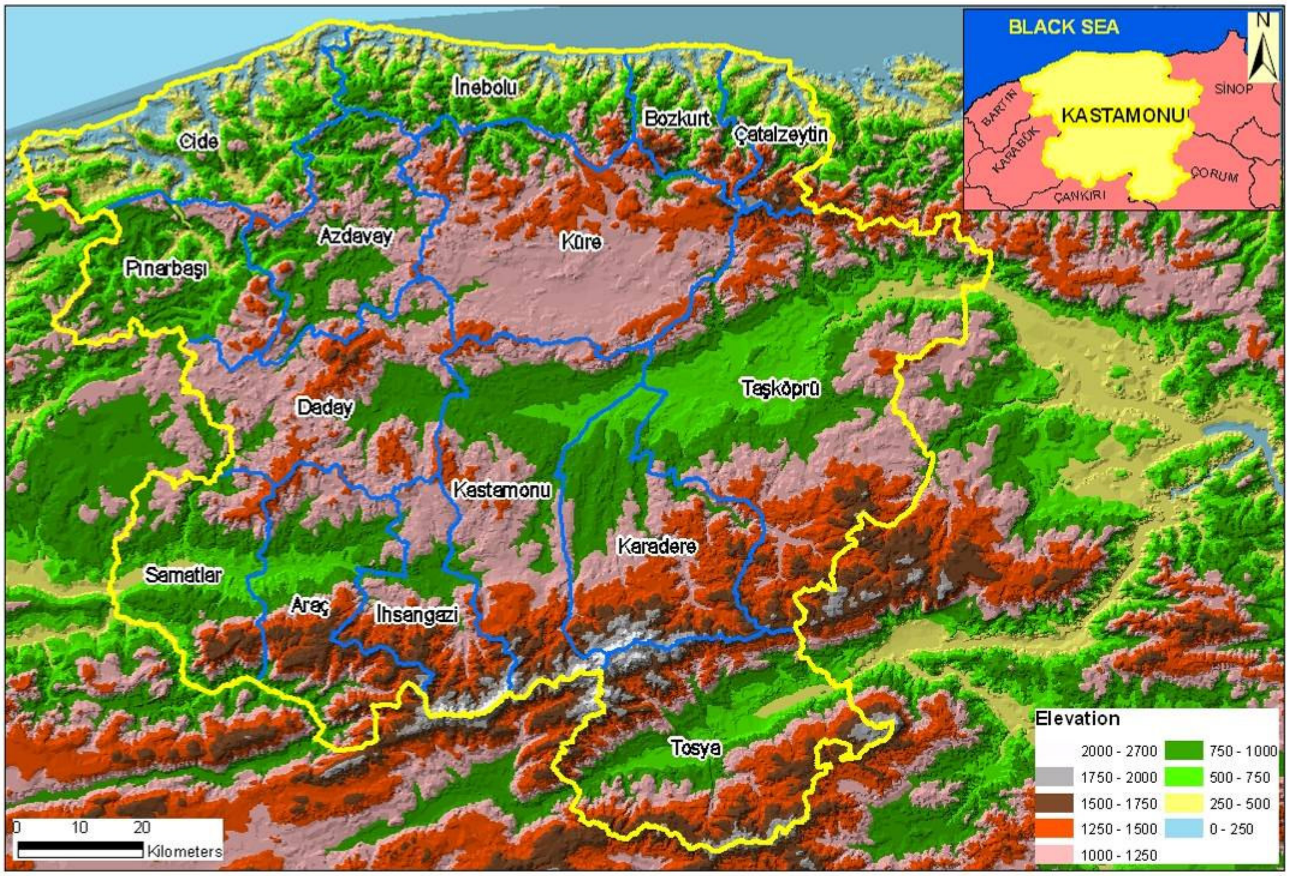

Figure 1. The geographic location of the Kastamonu surrounded with solid yellow lines, forest industry showed with blue lines.

Table 1. Demographic change in Kastamonu city, province and Turkey.

Location	Years	1970	1980	1990	2000	2008
Kastamonu city	Urban	29 338	35 464	51 560	64 606	80 946
	Rural	49 941	52 857	42 719	37 453	34 925
	Total	79 279	88 321	94 279	102 059	115 871
Kastamonu province	Urban	82 101	99 680	148 710	174 020	184 228
	Rural	364 500	351 266	274 901	201 456	176 196
	Total	446 601	450 946	423 611	375 476	360 424
Turkey	Urban	13 691 101	19 645 007	33 326 351	44 006 184	53 611 723
	Rural	21 914 075	25 091 950	23 146 682	23 797 743	17 905 377
	Total	35 605 176	44 736 957	56 473 035	67 803 927	71 517 100

order nearest neighbor rules. A total of 24 ground points were used to register the ETM image with the rectification error of less than 1 pixel. The TM images, however, were registered to the already registered ETM images through image-to-image registration technique with rectification error of less than 0.5 pixels.

The forest stand type maps used in this research were first scanned, saved in tiff format and then registered to the digital topographic maps in the same manner as with the landsat ETM image. Rectified forest stand type maps were digitized with a 1/3 000 to 1/5 000 screen view scale with Arc/Info 9.3^{TM} GIS by a number of qualified GIS experts. This allowed the direct comparison of the features between the images and aerial photographs during the selection of sample plots to be used in image classification and accuracy assessment of classified images.

Image classification of the 1987 landsat TM and 2001 landsat ETM Images

Ground reference data was obtained from more than 60 ground data points as signatures for each satellite image. The training points were equally distributed to each cover type with at least 10

Table 2. Land Use/Land Cover Classes descriptions.

Land Use/Land Cover Classes	Description
Open areas	Agriculture, range land, residence areas, shrub lands and grasslands
Water	River, Lake
Hardwood	Forest areas with pure hardwood trees
Softwood	Forest areas with pure softwood trees
Mix wood	Mixed forest areas
Settlement	Settlement, residential areas

Table 3. Confusion matrix for the 1987 Landsat TM image supervised classification.

Classes	Reference total	Classified total	Number correct	Producers accuracy (%)	Users accuracy (%)	Kappa
Open Areas	41	30	30	73.17	100.00	1.0000
Water/Lake	29	30	29	100.00	96.67	0.9603
Hardwood	30	30	27	90.00	90.00	0.8800
Softwood	26	30	25	96.15	83.33	0.8052
Mixed	29	30	28	96.55	93.33	0.9205
Settlement	25	30	25	100.00	83.33	0.8065

Overall Kappa statistics = 0.8933; overall classification accuracy = 91.11%.

Table 4. Confusion matrix for the 2000 Landsat ETM image supervised classification.

Classes	Reference total	Classified total	Number correct	Producers accuracy (%)	Users accuracy (%)	Kappa
Open Areas	35	30	30	85.71	100.00	1.0000
Water/Lake	29	30	29	100.00	96.67	0.9603
Hardwood	30	30	27	90.00	90.00	0.8800
Softwood	28	30	28	100.00	93.33	0.9211
Mixed	30	30	26	86.67	86.67	1.0000
Settlement	28	30	28	100.00	93.33	0.9211

Overall Kappa statistics = 0.9200; overall classification accuracy = 93.33%.

points per cover type. For the supervised classification of the 1987 image, the stand type maps of 1987 were obtained to create ground signatures. Likewise, the stand type maps of 1999, 2000 and 2008 were combined to create ground signatures for the supervised classification of the 2000 image. In order to classify cover types from the images, signatures were taken from the ground corrected stand type maps and adjusted based on the transformed vegetation index, principle components analysis (PCA) and unsupervised classification image. Supervised maximum likelihood classification methods were employed in the analyses. Then the 1987 and 2000 images were checked for accuracy using ground data points that were not used in the original classification process together with other points of known condition, such as forest areas visually surveyed with binoculars, stand maps, urban areas and rock outcrops identified in the image. Equal control point methods were used in Erdas Imagine 9.0™ program with at least 30 points for each class (Erdas, 2002). The accuracy assessment of image was checked for each image and accepted if the accuracy was higher than 80%. After the accuracy assessment, all images were clumped, eliminated 3x3 pixels and vectorized in Erdas Imagine 9.0™ program. These coverages were pre-processed to eliminate areas less than 0.81 ha for spatial landscape analysis with FRAGSTATS™.

Landsat TM image (1987) was classified for 6 land cover types successfully (Table 2). But hardwood and settlement cover types were classified with a lower accuracy (83%) than other classes (Table 3). However, this is generally acceptable as the overall classification accuracy is much higher (89%) with the Kappa statistics (Conditional Kappa for each Class) value of 0.91.

Landsat ETM image (2000) was classified into 6 land cover types successfully. But mixed cover types was classified with a lower accuracy (86%) than other classes (Table 4). Notwithstanding this, landsat ETM classification is generally acceptable due to a higher overall classification accuracy of 92% and Kappa statistics (Conditional Kappa for each Class) value of 0.93.

Temporal and spatial analysis of land cover/land use types

Temporal transitions among the cover types were documented and evaluated to see the temporal dynamics among various parameters indicative of both composition and configuration of cover types.

Table 5. Change of Landscape Pattern in Kastamonu (1987-2000 Land Use Change Maps).

Land Cover/Land Use Type	Class Area (ha)		Number of Patches (#)		Mean Patch Size (ha)		Percent of Landscape (%)		Largest Patch Index (%)		Patch density (no. of patches per 100 ha)		Patch size coefficient of variation (%)		Area-weighted Mean Shape Index	
Settlement	3533.3	4974.0	1503	1970	2.351	2.525	0.27	0.38	0.01	0.02	0.114	0.149	279.91	368.88	2.371	2.692
Water	192.9	268.8	10	15	19.286	17.920	0.01	0.02	0.01	0.01	0.001	0.001	172.74	238.69	3.345	2.757
Hardwood	166750.8	247086.8	19940	13091	8.363	18.875	12.61	18.69	0.38	2.98	1.508	0.990	812.10	2854.43	5.236	25.438
Softwood	195017.1	182701.8	14145	10114	13.787	18.064	14.75	13.82	0.97	1.17	1.070	0.765	1075.12	1421.31	6.827	11.153
Mixed	62542.7	105988.3	12708	11479	4.922	9.233	4.73	8.02	0.04	0.24	0.961	0.868	303.12	591.54	3.040	5.851
Open areas	894006.9	781118.8	9213	11407	97.038	68.477	67.62	59.08	63.56	47.11	0.697	0.863	9021.39	8536.74	125.106	85.270
Landscape	1322043.8	1322043.8	57519	48076	22.984	27.501	100.00	100.00	63.56	47.11	4.351	3.636	15247.4	10413.6	86.418	57.152

The transitions were evaluated using periodic results of classified images. The land use/ land cover polygon theme for 1987 - 2000 were overlaid and the area, converted from each of the classes to any of the other classes, was computed. The spatial configuration of landscape structure is important as it has important implications to the design and management of the resources (Baskent et al., 2000). The spatial dynamics of the landscape refers to the temporal change in the size, number, shape, adjacency and the proximity of patches in a landscape. A few metrics or measurements as proxy were used to quantify and spatially analyse the change in spatial structure as demonstrated by Başkent and Jordan (1995a, b) and McGarigal and Marks (1995).

Specifically, the FRAGSTATS (McGarigal and Marks, 1995) was used to quantify landscape structure of Kastamonu city for each of the land use classes. FRAGSTATS calculates a number of spatial metrics for each patch, for each cover class as well as for the entire landscape. Some class-level metrics were computed for the cover type maps of 1987 and 2000 years. The metrics were: class Percent of Landscape (PL), Number of Patch (NP), Largest Patch Index (LPI), Mean Patch Size (MPS), Patch Density (PD) and Area Weighted Mean Shape Index (AWMSI).

RESULTS

Temporal changes in landscape structure

According to classified images between 1987 and 2000, there was a net increase of 111 466 ha in forest areas, while open areas decreased to 112 888 ha (Figure 2). As an overall change between 1987 and 2000, the percen-tage of forest cover in Kastamonu increased from 32.09 in 1987 to 40.52 in 2000 based on classified images (Table 5, Figure 2). Settlement areas increased from 0.27% in 1987 to 0.38% in 2000 based on classified images. Cumulative urbanization accounted for 0.11% of Kastamonu as a whole (1 440 ha) and 28.96% of the settlement areas of Kastamonu from 1987 to 2000. This translates to an average 2.63% annual rate of urbanization.

Spatial analysis of the change in spatial landscape structure

The spatial analysis of the landscape pattern indicated that the total number of patches decreased from 57 519 to 48 076 between 1987 and 2000, as all patch types were taken into account. Mean patch size (MPS) increased from 22.98 to 27.50 ha. The MPS of hardwood areas changed significantly from 8.36 to 18.87 ha bet-ween 1987 and 2000. Similarly, the MPS of mixed areas changed from 4.90 to 9.20 ha. Reasons for these changes in hardwood areas probably relates to the net increase of 81 316 ha in patch size and a net decrease of 6 849 patches (Table 5). Also, area weighted shape index value of hardwood areas increased from 5.20 to 25.40. However, patch density value of hardwood decreased from 1.50 to 0.99 between 1987 and 2000 years. Area weighted shape index value of landscape decreased from 86.41 to 57.15. All these changes showed that landscape fragmen-tation decreased and the forest has become more substantial to harsh disturbances. Furthermore, the MPS of settlement areas increased from 2.35 to 2.52, but number of patch value of settlement increased from 1503.00 to 1970.00. These changes showed that, while the settlement areas increased, fragmentation of settlement areas decreased.

In addition to measuring spatial disturbance with a number of parameters, it is also important to understand landscape change over time. Annual forestation and urbanization rates were calculated using the compound-interest-rate formula due to its explicit biological meaning (Puyravaud, 2003). This is:

$$P = \frac{100}{t_2 - t_1} \ln \frac{A_2}{A_1}$$

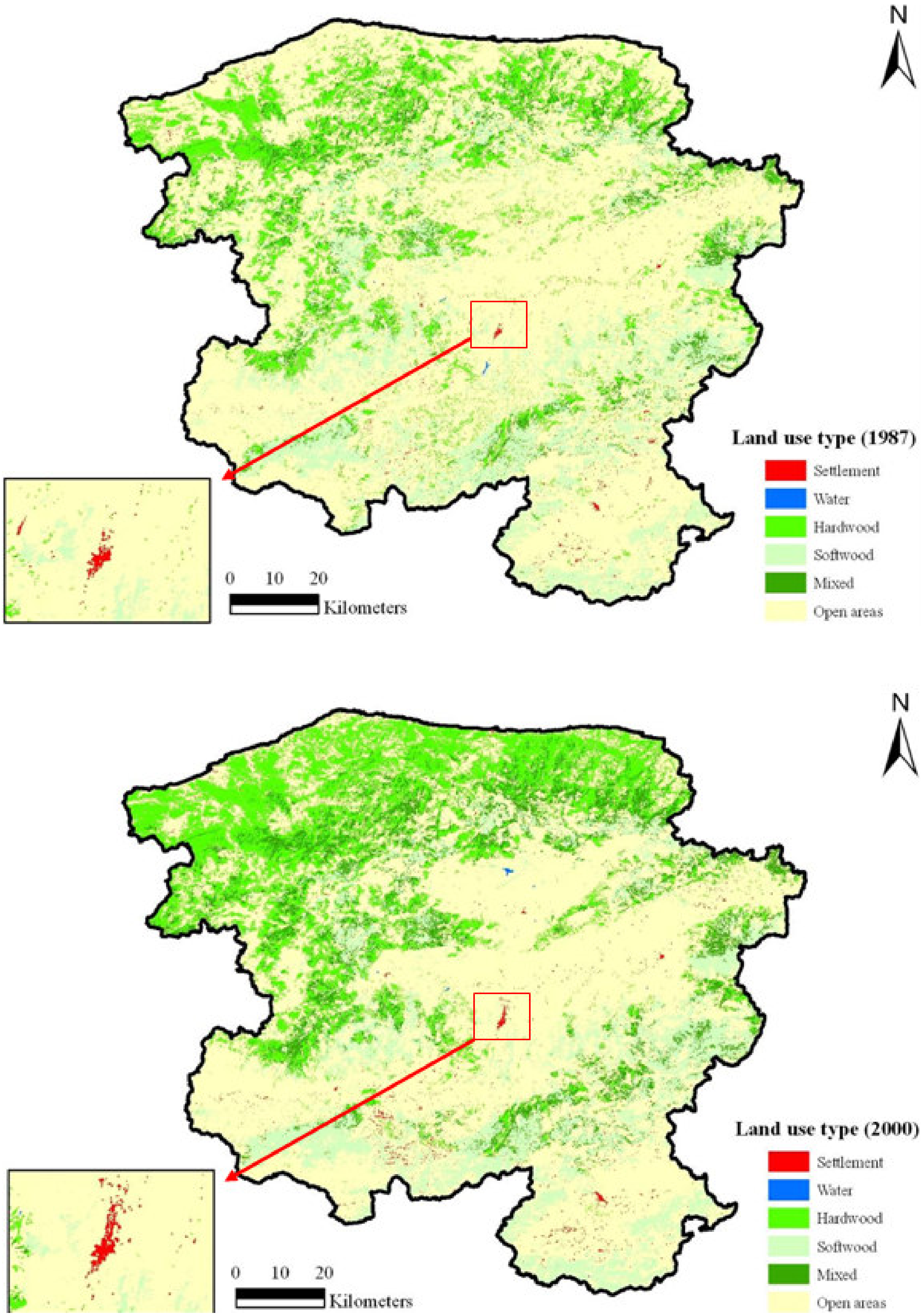

Figure 2. The spatial distribution of cover types of Kastamonu over two periods 1987 and 2000.

Where P = percentage of forest loss per year; A_1 and A_2 = the amount of forest cover at time t_1 and t_2, respectively.

As an overall change between 1987 and 2000, the percentage of forest cover in the Kastamonu increased from 32.09 in 1987 to 40.52 in 2000 based on image classification. Cumulative forest improvement accounted for 8.43% of Kastamonu as a whole (111 476 ha) and 20.81% of the forested area of Kastamonu from 1987 to 2000. This translates to an average of 1.79% annual rate of forest disturbance.

DISCUSSION

Turkey is one of the most important and the richest countries from natural resources viewpoint, especially biodiversity and forest resources in the world. Urbanization in the last 50 years has increased because of population increase as a result of immigrants from rural areas to urban areas. Increased population and urbanization has caused irregular land use/land cover changes in recent times. Thus, population increase and urbanization has been an important issue of land use/land cover changes in Turkey.

This study analyzed the spatial and temporal pattern of land use/land cover change of Kastamonu province in the western part of Turkey. The classified images periodically renewed from 1987 to 2000 with GIS and FRAGSTATS were used to analyze land use/land cover and the spatial configuration of landscape. The quantitative evidences of land use/land cover dynamics presented here showed that there were drastic changes in the temporal and spatial patterns of land use/land cover classes, especially on forest resources and settlement in the study area of Kastamonu.

The percentage of urbanization in Kastamonu province increased from 0.27 in 1987 to 0.38 in 2000 based on supervised classification of images. Cumulative urbanization accounted for 0.11% of the whole area of Kastamonu (1 440 ha) and 28.96% of the settlement area of the Kastamonu from 1987 to 2000. This translates to an annual rate of urbanization of 2.63% between 1987 and 2000. Similar results from some important studies in Turkey are also shown. Trabzon province as studied by Keles et al. (2008) is an indication of an annual rate of deforestations of 0.41% between 1987 and 2000 years. Another similar study about urbanization of Trabzon province showed an annual rate of urbanization of 3.13% from 1960 to 2000 years (Reis et al., 2003). Also, a research conducted by Günlü et al. (2009) showed that an annual rate of urbanization of 1.98% in Rize province. Besides, the same researchers in another study area in Turkey showed that annual rate of urbanization is 4.19% in İnegol district (Başkent and Kadıogulları, 2007).

Besides the land use/land cover change, the spatial structure of landscape was also investigated. In the study area, the total number of patches decreased from 57 519 in 1987 to 48 076 in 2000. Decreased in number of patches and increase in mean patch size (MPS) demonstrated that the landscape has gone into a more defragmented structure that positively affected biodiversity and the resilience of the ecosystem. On the other hand, it is possible to say that the population growth or urbanization has affected the dynamics of forest structure because the urban population in the study area always increased during the study area. The decrease in rural population who were generally responsible for forest improvement in many regions is also an indication of that result.

In conclusion, monitoring and understanding of the dynamics of land use/land cover changes and the factors affecting them is increasingly important for the sustainable management of natural resources, especially forest resources.

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