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Analyzing riparian forest cover changes along the Firniz River in the Mediterranean City of Kahramanmaras in Turkey

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Abstract Riparian forests adjacent to surface water are important transitional zones which maintain and enrich biodiversity and ensure the sustainability in a forest ecosystem. Also, riparian forests maintain water quality, reduce sediment delivery, enhance habitat areas for aquatic life and wildlife, and provide ecological corridors between the upland and the downstream. However, the riparian ecosystems have been degraded mainly due to human development, forest operations, and agricultural activities. In order to evaluate the impacts of these factors on riparian forests, it is necessary to estimate trends in forest cover changes. This study aims to analyze riparian forest cover changes along the Firniz River located in Mediterranean city of Kahramanmaras in Turkey. Changes in riparian forest cover from 1989 to 2010 have been determined by implementing supervised classification method on a series of Landsat TM imagery of the study area. The results indicated that the classification process applied on 1989 and 2010 images provided overall accuracy of 80.08 and 75 %, respectively. It was found that the most common land use class within the riparian zone was productive forest, followed by degraded forest, agricultural areas, and other land use classes. The results also indicated that the areas of degraded forest and forest openings increased, while productive forest and agricultural areas decreased between the years of 1989 and 2010. The amount of agricultural areas decreased due to the reduction in the population of rural people. According to these results, it can be concluded that special forest management and operation techniques should be implemented to restore the forest ecosystem in riparian areas.

Keywords Riparian forests · Forest cover changes · GIS · Remote sensing · Mediterranean forest

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Introduction

Riparian forests adjacent to water bodies (i.e., streams, lakes, and wetlands) are considered as vital ecological corridors that enhance biodiversity in forest ecosystem and protect water quality (Naiman and Decémps 1997; Akay et al. 2012). Besides that, riparian forests reduce the amount of sediment delivered to streams and provide better habitat for aquatic life and wildlife (Newton et al. 1996; Poulin and Simmons 1999). The areas along the surface water are favorable for residential areas, road networks, and agricultural activities due to their suitable terrain structures; such human-made interventions in and around riparian forests cause habitat fragmentation, alterations, and losses, which may result in long-term impacts on the riparian ecosystem (Forman and Alexander 1998). Also, degradation of riparian forest reduces genetic diversity by fragmenting flora communities and fauna populations.

In order to maintain the important features of riparian forests, a riparian buffer zone should be determined along the surface water and human developments, agricultural activities, and forestry operations should be restricted in this zone. The riparian zone widths usually vary with its classes of surface water and beneficial uses (OAR 2007). Besides, climatic features and existence of aquatic life are considered in determining riparian zone widths (Akay 2010).

Special strategies should be developed for the riparian forests and then integrated into forest management plans. Ecosystem-based multipurpose management plans should be implemented to minimize human interventions along riparian buffer zones (Sivrikaya et al. 2008). Besides, changes in these areas should be systematically monitored to update the strategies (Naiman et al. 1993).

In environmentally sensitive areas such as riparian forests, monitoring activities should not be performed

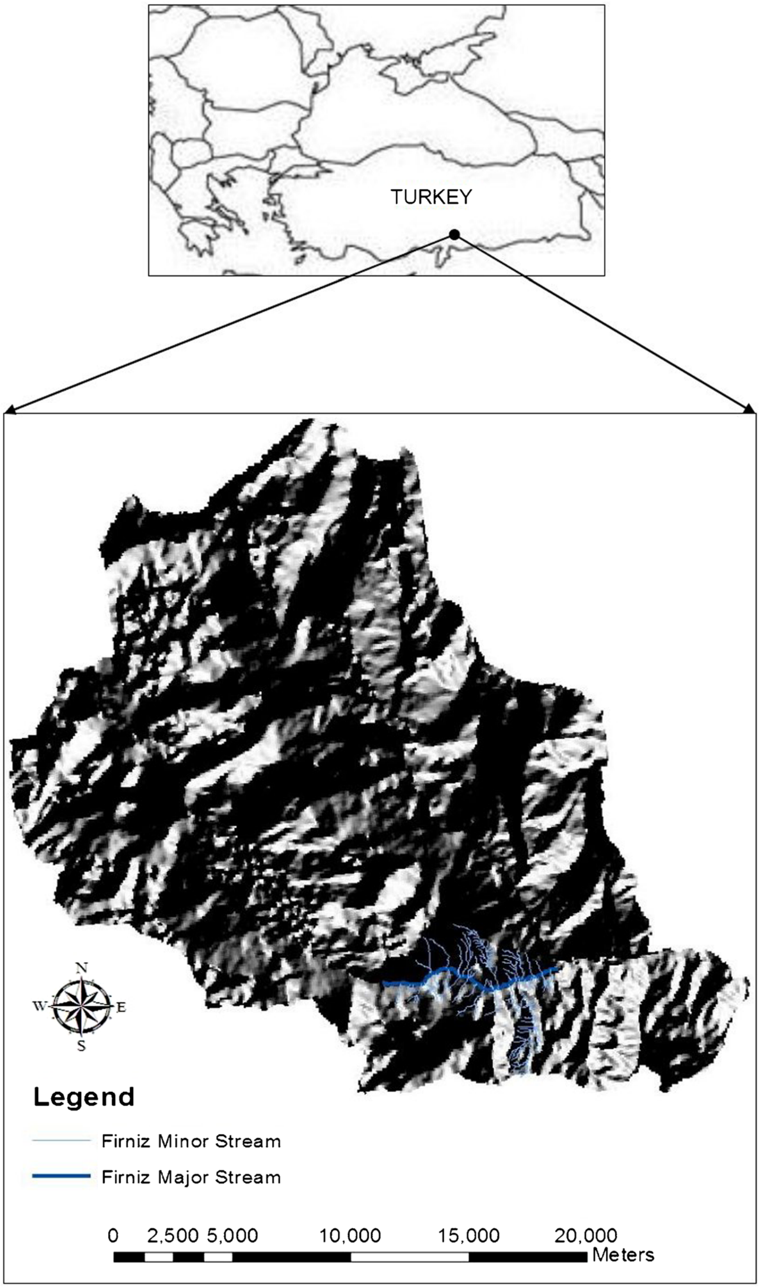

Fig. 1 The location of study area and map of the Firniz River basin

Table 1 Description of Landsat 4/5 TM images

Acquisition date	Type of imagery	Path/row	Nominal spatial resolution (m)
July 26, 1989	TM 4	174/34	28.5
July 12, 2010	TM 5	174/34	28.5

for a short term but for a long period of time. By using advanced features of Geographical Information System (GIS) and Remote Sensing technologies, it has been possible to assess and monitor land use changes (Congolton et al. 2002; Desai et al. 2009; Akay et al. 2012). Especially remotely sensed data have been commonly used to monitor land use changes for large-scale areas at low cost and in a short time.

In this study, riparian forest cover changes along a sample river located in the Mediterranean city of Kahramanmaras in Turkey were analyzed based on a series of satellite imagery (1989 and 2010). Riparian buffer zone was determined by using GIS tool (ArcGIS 10) and supervised classification method was applied by using ERDAS Imagine software. The accuracy of the classification process was evaluated based on the forest stand type maps of the study area.

Material and methods

Study area and digital database

The study area was located along the Firniz River which is about 45-km northwest of Kahramanmaras province in the Mediterranean region of Turkey (Fig. 1). Firniz River provides water to the Sucati Dam used for electricity power and irrigation purposes. Along the river, there are hydroelectric power plant, private fish hatchery, and recreational areas. The river network consisted of major streams with year-round water flow and minor streams with seasonal water flow in certain months. The elevation within the basin ranges from 625 to 1,992 m with an average elevation of 1,112 m. The main land use classes in the basin area include forest, agricultural lands, and settlement areas. The major tree species are *Pinus buritia*, *Pinus nigra*, *Cedrus libani*, Juniper sp., and Oak sp. in general.

In order to analyze riparian forest cover change, a digital database was generated for the study area. The database included 1/25,000 scaled topographic maps, 1/25,000 scaled forest management maps, and Landsat 4/5 Thematic Mapper (TM) images. The forest management maps have been usually generated every 10 years in Turkey since forest management activities have been also planned for every 10 years. The forest management maps used in this study have been generated in 1992 and 2012, while available Landsat 4/5 TM images with appropriate resolution were from the years of 1989 and 2010. In addition, field reconnaissance were performed to collected coordinate information using hand GPS (Magellan SporTrack), to take pictures of the riparian forest zone using a digital camera (Fujifilm FinePix S2980 14 MP 18×), and to observe land use types and tree species in the study area.

Mapping riparian zones

In this study, riparian zone widths suggested by GDF (2006) for various stream sizes were used for mapping riparian zones. The average widths of riparian zones from both sides of major and minor stream sizes are suggested as 100 and 50 m, respectively. The major streams are defined as streams with continuous water

Table 2 The classes used in classification process

Classes	Description
Productive forest (PF)	Conifer, boreal and mixed-forest types with newly planted areas that provide timber for commercial works
Degraded forest (DF)	Due to human activities or natural incidents, extinct forest areas to change or be converted to other uses
Forest openings (FO)	Non-vegetated areas including clear-cuts, cultivated land without crops
Agriculture (A)	Cultivated places, high percentages of grasses, and other herbaceous vegetation including lands that are regularly mowed for hay and/or grazed by livestock
Others (O)	Settlement, water bodies, and rocky areas

flow throughout the year. The minor streams are defined as streams that contain periodic water flow only during rainy seasons while there is no water flow during dry periods. In order to map the riparian zone of the Firniz River, firstly, stream network was digitized based on topographic maps and forest management maps using ArcGIS 10. Then, riparian zone map was generated by considering the riparian zone widths as described above. Buffer analysis in ArcGIS 10 was performed to map riparian zones along the Firniz River.

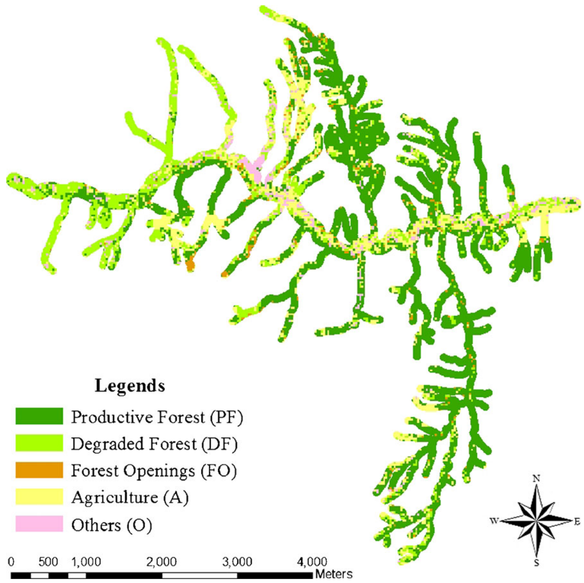

Fig. 3 The land use map of riparian zone based on classification of 1989 image

Analyzing forest cover changes

In this study, land use maps were generated to analyze forest cover changes along Firniz River based on a series of satellite images acquired in July 1989 and July 2010. Digital image processing is an essential task for analyzing land use changes. The methods used in digital image processing procedure in this study include (1) pre-processing, (2) land use classification, and (3) accuracy assessment. These applications were carried out by using ERDAS 9.1.

Riparian zone map was used to subset image of riparian zones from Landsat 4-5 TM images (Table 1). The images were acquired as a geometrically rectified product with a reported maximum root mean square error of 20 m. Geometric correction of satellite images were performed by the references of topographic maps and ground control points obtained by hand GPS. The nearest neighbor re-sampling method was used for images.

Supervised classification method in ERDAS 9.1 was used to generate land use maps based on a set of user-defined classes, by creating the appropriate spectral signatures. In classification process, "User-Defined

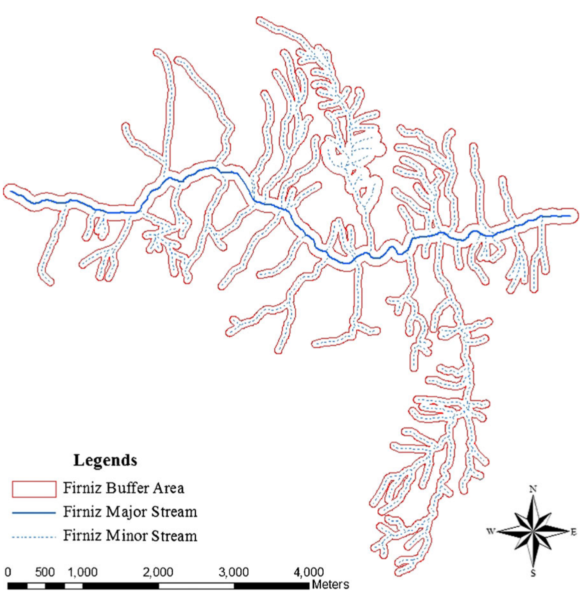

Fig. 2 The riparian buffer zone along the Firniz River

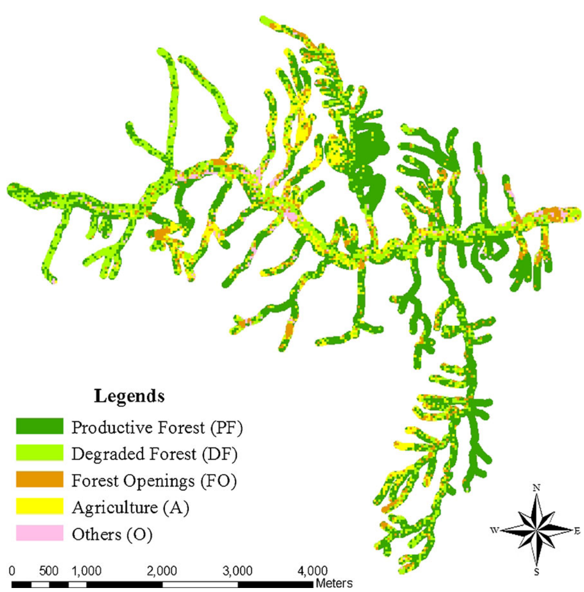

Fig. 4 The land use map of riparian zone based on classification of 2010 image

Table 3 The area of land use classes based on classification of 1989 and 2010 images

Land use classes	1989 Image		2010 Image		Change (%)
	Area (ha)	Area (%)	Area (ha)	Area (%)	
Productive forest (PF)	485	54.25	474	53.02	−1.23
Degraded forest (DF)	176	19.69	195	21.81	2.13
Forest openings (FO)	24	2.68	79	8.84	6.15
Agriculture (A)	167	18.68	119	13.31	−5.37
Others (O)	42	4.70	27	3.02	−1.68
Total	894	100	894	100	0.00

Polygon" function involves a high degree of user control which reduces the chance of underestimating class variance (Moller-Jensen 1997). The training points were selected by drawing a polygon around training sites of interests based on general knowledge obtained from topographic maps and forest management maps (1992 and 2012). Then, supervised classification was performed using the parallelepiped non-parametric rule provided by ERDAS 9.1. After the classification process, "Recode" function in ERDAS 9.1 was applied to combine the classes into five main classes including Productive Forest (PF), Degraded Forest (DF), Forest Openings (FO), Agriculture (A), and Others (O) (Table 2).

The "Accuracy Assessment" tool was used to evaluate the accuracy of the classified image, based on 256 control points automatically selected in ERDAS 9.1 (Yuksel et al. 2008). A random sampling approach was employed to assess the accuracy of land use classification. The referenced values were recorded on the "Accuracy Assessment Table" based on forest management maps and field reconnaissance. The forest management maps of 1992 and 2012 were used as references for the accuracy assessment of satellite images of 1989 and 2010, respectively. The overall accuracy and kappa values were computed by using user's accuracy (a measure of commission error) and producer's accuracy (a measure of omission error) for land use classes. Kappa analysis is a discrete multivariate technique used in accuracy assessments (Moller-Jensen 1997).

Results and discussion

The digital database of the study area indicated that the basin of the river was about 3,327 ha with 9 km of major streams (year-round water flow in the stream) and with 75 km of minor streams (seasonal water flow in certain months of the year). The stream network was buffered according to the riparian buffer zone widths to generate a riparian area dataset. The results indicated that the total area of the resulting riparian zone was approximately 894 ha (Fig. 2).

Based on the field studies, productive forests were mainly located on the side of major streams while degraded forests were mostly seen on the west part of the Firniz River basin. The forest openings were mainly located on the southwestern part of minor streams. The agricultural areas were mostly located along the major stream sides.

Land use maps of the riparian zone were used to evaluate temporal changes of land use for a 21-year period. Supervised classification method was used to classify land use classes based on a series of Landsat TM images retrieved in 1989 and 2010 (Figs. 3 and 4).

The results of supervised classification procedures implemented on both image obtained in 1989 and 2010 indicated that the most common land use class

Table 4 The results of accuracy assessment based on classification of 1989 and 2010 images

Land use classes	1989 Image			2010 Image		
	Reference points	Producer's accuracy (%)	User's accuracy (%)	Reference points	Producer's accuracy (%)	User's accuracy (%)
Productive forest (PF)	140	85.14	90.00	117	83.76	85.96
Degraded forest (DF)	50	67.86	76.00	49	65.31	60.38
Forest openings (FO)	7	100.00	57.14	36	55.56	66.67
Agriculture (A)	48	77.50	64.58	40	72.50	74.36
Others (O)	11	75.00	54.55	14	92.86	65.00

within the riparian zone was productive forest, followed by degraded forest and agricultural areas (Table 3). It was found that the areas of degraded forest and forest openings increased, while there was a reduction in the rest of the land use classes between the years of 1989 and 2010.

The areas of productive forest cover decreased because of recently constructed road networks, hydroelectric plant, and human activities in the region. Besides, the areas of agricultural land significantly decreased because of the reduction in population of rural people who economically depend on agricultural activities. In another study conducted in the Mediterranean city of Antalya in Turkey, it was also found that urban land use and its area dramatically increased while agricultural lands decreased from 1987 to 2006 (Sönmez and Onur 2012).

The accuracy of the classified image was assessed by using randomly selected 256 points based on referenced forest management maps. The results indicated that the classification process applied on 1989 and 2010 images provided overall accuracy of 80.08 and 75 %, respectively (Table 4). Supervised classification of 1989 image provided satisfactory results in terms of distinguishing productive forest, degraded forest, and agricultural areas; however, accuracy of other land use classes were relatively low due to large variation of spectral signatures. The highest producers and users accuracy was reached in classification of forest openings (100.00 %) and productive forest (90.00 %), respectively. The lowest producers and users accuracy was for degraded forest (67.86 %) and others (54.55 %), respectively.

Supervised classification of 2010 image provided satisfactory results in terms of distinguishing productive forest, agricultural areas, and others; however, accuracy of other land use classes were relatively low. The highest producers and users accuracy was for others (92.86 %) and productive forest (85.96 %), respectively. The lowest producers and users accuracy was for forest openings (55.56 %) and degraded forest (60.38 %), respectively.

Conclusions

In this study, riparian forest cover changes from 1989 to 2010 along Firniz River located in Mediterranean city of Kahramanmaras in Turkey were analyzed by implementing supervised classification method on a series of Landsat TM images. The results suggested that the land use classes in the study area have changed over time in response to social and economic factors for two decades. It was found that the agricultural lands decreased by 5.37 %, while forest opening increased by 6.15 %. The riparian areas are one of the most important natural resources which maintain and enrich biodiversity and ensure the sustainability in forest ecosystems. Therefore, understanding the nature of forest cover changes is essential knowledge to facilitate proper planning techniques in the riparian buffer zones. Besides, specific strategies for these areas should be developed and properly integrated into the management plans. Especially ecosystem-based multiple use planning approach should be considered for riparian areas.

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