BOSQUE 43(3): 321-328, 2022 DOI: 10.4067/S0717-92002022000300321

Exploring the nexus of land use changes with afforestation and urbanization: A case study of Elmalar Forest Planning Unit in Turkey

Explorando el nexo de forestación, urbanización y cambio de uso de la tierra: el caso del bosque de Elmalar en Turquía

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SUMMARY

Monitoring and understanding of ecosystem dynamics is essential for sustainable management of forest ecosystems. This study investigates the effects of afforestation activities and population factors on spatio-temporal changes of forest ecosystems. Geographic Information System was used to assess temporal and spatial changes between 2002 and 2014 in the Elmalar forest planning unit, located around the eastern Mediterranean city of Kahramanmaraş, Turkey. The results indicated that total forest area increased by 2,279 hectares during the 12-year period with a 20 % cumulative improvement of the forested area. The increase in the productive and total forest areas can be attributed to the afforestation activities carried out in the study area. Notably, with the Green Belt Afforestation Project of GDF carried out in the Elmalar forest planning unit, 1,574 hectares of non-forest areas were afforested which contributed to an increase in total forest areas. Forest areas converted to non-forest area were less compared to forest increased. Increased population growth, internal migrations and resettlements within the study area are the primary reasons for expansion of residential areas, which lead to increased pressure on forest resources.

Keywords: land use change, afforestation, urbanization, GIS.

RESUMEN

El seguimiento y la comprensión de la dinámica de los ecosistemas son fundamentales para la ordenación sostenible de los ecosistemas forestales. Este estudio se centró en investigar los efectos de las actividades de forestación y los factores poblacionales sobre los cambios espacio-temporales de los ecosistemas forestales a lo largo del tiempo. Se utilizó un sistema de información geográfica (SIG) para evaluar los cambios temporales y espaciales entre 2002 y 2014 en la unidad de planificación forestal de Elmalar, ubicada alrededor de la ciudad mediterránea oriental de Kahramanmaraş, Turquía. Los resultados indicaron que las áreas forestales totales aumentaron 2.279 ha durante el período de 12 años, con una mejora acumulada del 20 % del área boscosa en el mismo período. El aumento en las áreas productivas y forestales totales, definitivamente, se pudo atribuir a las actividades de forestación realizadas en el área de estudio. En particular, con el Proyecto de Forestación del Cinturón Verde de la Dirección General de Silvicultura (GDF) que se llevó a cabo en el bosque Elmalar, donde se forestaron 1.574 hectáreas de áreas no forestales, contribuyendo a un aumento de las áreas forestales totales. En cambio, las áreas forestales convertidas en áreas no forestales y áreas de asentamientos fueron menores: 734 ha y 28 ha, respectivamente. El aumento del crecimiento de la población, las migraciones internas y los reasentamientos en el área de estudio son las principales causas de la expansión de las áreas residenciales que conducen a una mayor presión sobre los recursos forestales.

Palabras clave: cambio de uso del suelo, forestación, urbanización, SIG.

INTRODUCTION

Forest ecosystems are the second most important system for sequestering atmospheric carbon dioxide (CO_2), and play a crucial role in the mitigation of climate change affecting ecological systems (Lossou *et al*. 2019). Forest ecosystems provide fuel and bioproducts, water and air purification, wildlife habitat, nutrient cycling and areas for recreation. In addition to planning and application, essential components of sustainable forest management planning include the study and monitoring of the dynamics of forest development as impacted by the implementation of management activities and natural disturbances (Başkent *et al*. 2020). Land use changes impact not only water quality (Camara *et al*. 2019), but also species loss (Falcucci *et al*. 2007), ecosystem fragmentation (Sivrikaya *et al*. 2007), deforestation, soil loss (Çakır *et al*. 2008b) and overall reduction of ecosystem functionality (Duncan *et al*. 2020). Thus, it is important to identify the causes of land use changes and analyze their effects on forest ecosystem development.

The global human population continues to increase exponentially and is projected to reach 8.3 and 8.9 billion

in 2020 and 2030, respectively (UNDESAPD 2017). As a result of population growth, demands such as food and fiber production also grow (Balatsky *et al*. 2015). Forest ecosystems continue to face serious human influence and pressure that often results in their degradation and conversion (Buytaert *et al*. 2014). Human development, especially in or around forests, has negative impacts on forest ecosystems and plays important roles in land use changes at global, local, and regional scales (Song *et al*. 2018). The expansion of urban areas is generally the predominant source of ecological problems (Rimal *et al*. 2019a) as it alters ecological processes and functions due to over-extraction of fuel wood, charcoal and other forest products (Fu *et al*. 2017).

Afforestation has gained prominence in recent years and is primarily carried out to restore degraded areas and provide environmental benefits such as increasing carbon sequestration, reducing erosion, controlling salinization and protecting watersheds. Some of the most important objectives of forestry incentives are economic development, minimizing loss of forest cover, recovery of degraded or deforested land, afforestation, restoration, and reforestation (UN 2019). Indeed, the total area of afforestation activities increased globally from 262 million to 294 million hectares from 2010 to 2020 (FAO 2020). Turkey, in particular, has increased forest areas from nearly 20.2 million hectares to 22.7 million hectares over 40 years due mainly to intensive afforestation activities, sustainable forest management and economic development in general. The country has rich natural resources with various forest ecosystems covering nearly 27 % of the land base (TSI 2019). The population is about 83 million with a growth rate of 13.9 % (as of 2019). It is expected that the population may reach 93 and 120 million by 2050 and 2075, respectively, according to the Turkish Statistical Institute (TSI 2019). There are nearly 18,000 villages with 11 million residents living in and around forest areas, who depend heavily on forest management activities.

Afforestation has been implemented by seeding or planting saplings in order to protect the water supply, meet the demand for raw material and ensure the provision of ecosystem services. In Turkey, planting was carried out on 3,120,000 hectares by the end of 2015 and 2,800,000 hectares for rehabilitation (Bilir 2017). The General Directorate of Forestry (GDF) implemented the Green Belt Afforestation Project mostly around settlement areas to prevent soil loss and landslides, reduce air pollution, support regular development of cities and provide local people with new recreational areas, as well as to balance negative effects of land use changes and climate change.

Several studies related to spatio-temporal dynamics of forest ecosystems have been conducted to analyze land use changes (Çakır *et al*. 2007a, Bozali *et al*. 2015, Lossou *et al*. 2019), spatial forest dynamics (Günlü *et al*. 2009), fragmentation (Sivrikaya *et al*. 2007, Çakır *et al*. 2008a), urbanization (Çakır *et al*. 2008b), stand succession (Çakır *et al*. 2007b) and driving factors of land use change (Sivrikaya *et al*. 2011). Socio-demographic structure (*i.e.*, population) impacts forest ecosystems and land use changes. There are a limited number of studies that investigate human-environment relationship and the effects of socio-demographic structure on forest ecosystems (Call *et al*. 2017). However, no studies have evaluated the influence of both socio-economic dynamics and afforestation activities on land use changes. The hypothesis of this work postulates that afforestation is a crucial intervention to enhance the capacity of land to provide multiple ecosystem services. Land encroachment, particularly urbanization, impacts landscape dynamics, threatening the ability of forest ecosystems to sustain ecosystem services for a given society. The objective of this study is to explore the nexus of afforestation, urbanization and land use change by investigating the spatial and temporal changes in land use between 2002 and 2014 in the Elmalar forest planning unit in the Kahramanmaraş province of Turkey. This study will provide decision makers with an opportunity to analyze how socio-economic dynamics and afforestation activities affect forest ecosystems over time.

METHODS

Study area. The Elmalar forest planning unit, located in the Kahramanmaraş province in the Eastern Mediterranean Region of Turkey, was selected as the case study area. The location of the study area is 668,970 - 716,792 E and 4,103,218 - 4,151,137 N under UTM European 50 datum at zone 37 (figure 1). The planning unit covers an area of 32,958.8 ha, 32.7 % of which is forested as of 2014. The forested areas are characterized by steep terrain with an average slope of 50 %. The vegetation of the Elmalar forest planning unit is primarily composed of cedar, red pine, crimean pine, fir, oak, hornbeam and Mediterranean maquis (*Arbutus unedo* L., *Quercus ilex* L., *Myrtus communis* L., etc.) (FMP 2014). Mediterranean and continental climate types are dominant in the study area. Mean annual temperature and precipitation is 16.7 ºC and 737 mm, respectively. The driest month in the study area is July and the wettest month is January. Soil depth is 30 - 50 cm and physiological depth is 60 - 120 cm (FMP 2014).

The population of Kahramanmaraş was recorded as 1,063,174 in 2002 and 1,154,102 in 2019. Local communities engage in traditional agriculture, animal husbandry and forestry on a small scale in the area's villages (TSI 2019). The Eastern Mediterranean region, where Kahramanmaraş province is located, is at high risk for land degradation and desertification due mainly to high erosion risk, erroneous land uses, deforestation and climate change (Bozali *et al*. 2015). Therefore, in 2004-2005, afforestation was implemented extensively in Kahramanmaraş using local and introduced tree species over an area of 675 hectares. Fast growing and drought resistant trees such as brutia pine (*Pinus brutia* var. *eldarica* (Medw.) Silba), sto-

ne pine (*Pinus pinea* L.), Mediterranean cypress (*Cupressus sempervirens* L.), mahaleb cherry (*Prunus mahalep* L.), European pear *Pyrus communis* L.), oleaster-leafed pear (*Pyrus elaeagrifolia* Pall.) and [*Amygdalus* sp.] were planted during this time.

Spatial data acquisition. This study focused on monitoring and assessing trends in land use change using time series of ancillary data. The two most recent forest management plans (1992, 2014) along with maps of forest cover type (2002 and 2014), taken from the Kahramanmaraş Regional Directorate of Forestry in digital format, were used to carry out the spatio-temporal analysis. Forest inventory in Turkey has been carried out on a ten-year cycle with field survey and remote sensing data (aerial photograph, digital aerial photograph and satellite image) in accordance with state management guidelines. Circular sample plots with 300 x 300 meter intervals were established and the neces-

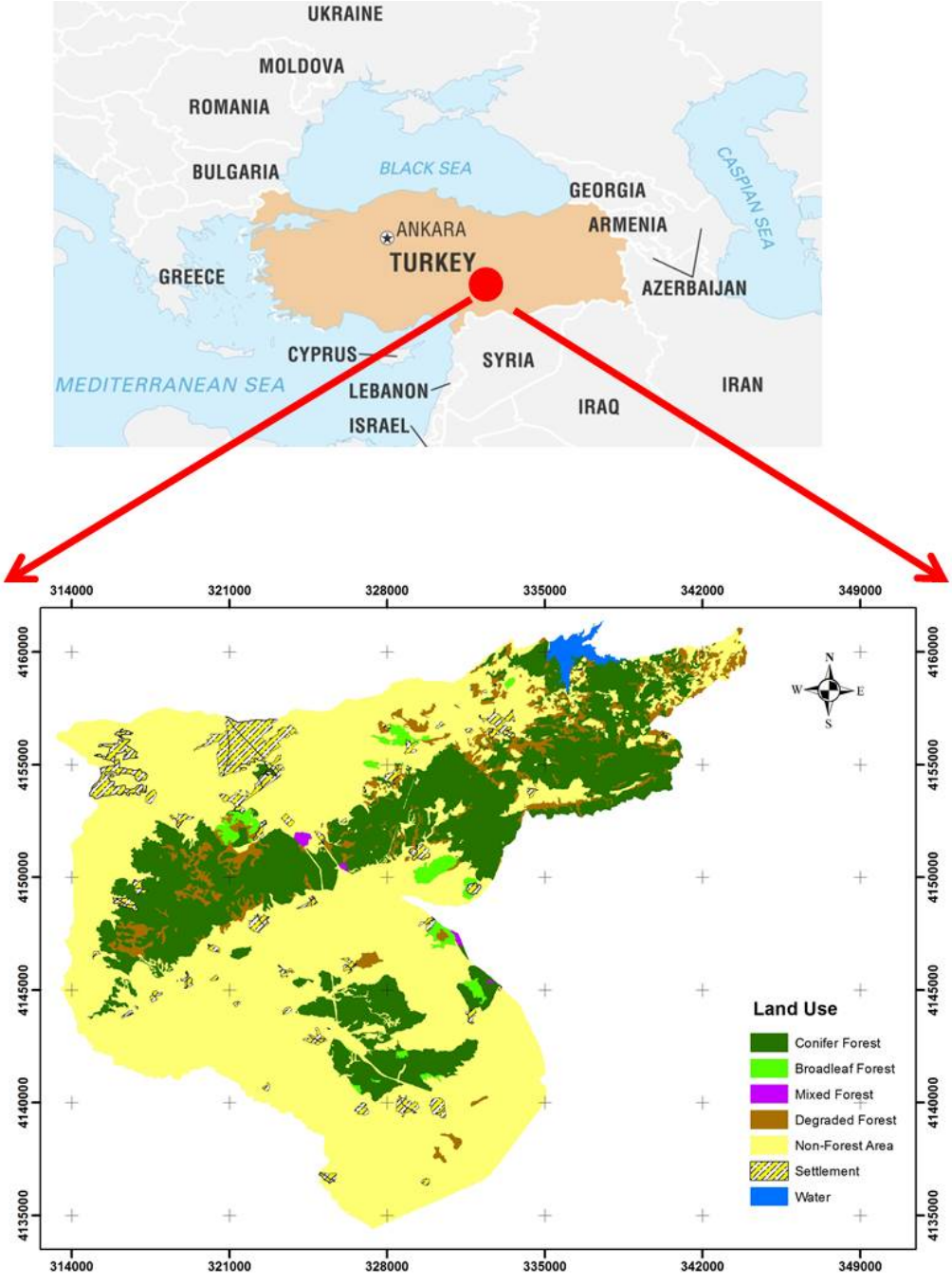

Figure 1. Location of the study area and distribution of major land use types.

Ubicación del área de estudio y distribuciones de los principales tipos de uso del suelo.

sary ground measurements were conducted in each sample plot. The sizes of a circular sample plot were 400, 600 and 800 m^2 depending on crown closures of > 71 %, 41–70 % and 11–40 %, respectively. Diameters at breast height (dbh) were measured for all trees with a dbh of >7.9 cm in each sample plot. A map of forest cover type was produced by interpreting digital aerial photographs with 1 / 25000 scale, and combining them with field survey data using ArcGIS 10.1™. A spatial database was then established for monitoring spatial and temporal dynamics of the forest ecosystem within the case study area. The attribute data of forest ecosystems such as species composition, topographic data and management activities were also taken from the related forest management plans to finalize the spatial database.

The land use / land cover types considered in this study can be described as Conifer forest (CF), Broadleaf forest (BF), Mixed forest (MF), Degraded forest (DF), Non-Forest Area (NFA), Settlement (S), and Water bodies (W) (table 1).

A comparison of the change in each land use class from 2002 to 2014 was performed using the transition matrix from one land use category to another. The transitions in land cover for the period were determined according to maps of forest cover type. The land use polygon themes for years 2002 and 2014 were overlaid and the area that changed from one land use class to any other was estimated.

Annual deforestation/forestation rates were estimated using the following formula (Puyravaud 2003):

$$P = \frac{100}{t2-t1} \ln \frac{A2}{A1} \quad [1]$$

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

Table 1. Definitions of land use/land cover classes.

Definición de clases de uso del suelo / cobertura del suelo.

Land use classes	Description
Conifer forest (CF)	Forest areas with pure conifers, crown closure more than 10 %
Broadleaf forest (BF)	Forest areas with pure broadleaf, crown closure more than 10 %
Mixed forest (MF)	Mixed (BF-CF, CF-BF) forest areas, crown closure more than 10 %
Degraded forest (DF)	Forest areas with crown closure less than 10 %
Non-forest area (NFA)	Pasture and agricultural lands
Settlement (S)	Settlements areas
Water (W)	River and lake

RESULTS

The temporal variation of land use classes based on the digitized maps of forest cover type obtained from forest management plans between 2002 and 2014 is shown in table 2. The analysis showed that total forest areas, which include CF, BF, MF, and DF, increased 2,279.2 ha over a 12-year period and forest improvement was 20 % in the same period. Dramatic changes were observed in both productive and degraded forest. Productive forest areas increased by about 5,198.2 ha (79 %) while DF areas declined by approximately 2,919 ha (58 %). The results showed that forest areas within the study area increased in both quality and quantity, which enhances the capacity of forests to provide ecosystem services such as biodiversity, and carbon sequestration. Major changes were encountered in CF, as its land area increased from 4,874.1 ha (14.7 % of the study area in 2002) to 11,115.7 ha (26.2 % of the study area in in 2014). An important change also occurred in the areal distribution of BF (93.7 ha in 2002 and 577.1 ha in 2014). Moreover, settlement areas increased from 1,200.6 ha in 2002 to 1,747.7 ha in 2014 (table 2). On the other hand, water covered areas (W) were reduced from 369.2 ha in 2002 to 298.4 ha in 2014. The reduction in W may be related to the intensity of climate change and annual precipitation. Due to the increasing total forest area (degraded and productive), the average annual total forest improvement rate and annual productive forest improvement rate were 1.49 % (190 ha $year^{-1}$) and 4.86 % (433 ha $year^{-1}$), respectively.

The transitions among land use classes were estimated based on forest management plans of 2002 and 2014 (table 3 and figure 2). The comprehensive analysis indicated that about 763 ha (1.8 % of the study area) of forested areas was converted to NFA including S and W areas while 3,042 ha (7.2 % of the study area) of NFA including S and W was transformed to forested areas, with a net forested area of

Table 2. Changes in land use classes in Elmalar forest planning unit.

Clases de uso del suelo en la unidad de planificación de Elmalar.

Year	2002		2014	
Total area	ha	%	ha	%
CF	6,241.6	14.7	11,115.7	26.2
BF	93.7	0.2	577.1	1.4
MF	220.0	0.5	60.7	0.1
DF	5,059.7	11.9	2,140.7	5.0
NFA	29,216.5	68.9	26,461.3	62.4
S	1,200.6	2.8	1,747.7	4.1
W	369.2	0.9	298.4	0.7
Total	42,401.5	100.0	42,401.5	100.0

Table 3. The transition matrix of land use classes in Elmalar forest planning unit (2002, 2014).
Matriz de transición de las clases de uso de la tierra en Elmalar (2002, 2014).

Land use class		Total (ha)	2014 Land use						
			CF	BF	MF	DF	NFA	S	W
2002 Land use	CF	6,241.6	5,800.1	5.6	3.0	196.2	235.2	1.5	0
	BF	93.7	0.1	83.5	0	1.1	6.4	2.6	0
	MF	220.0	68.8	0	0	105.5	45.7	0	0
	DF	5,059.7	2,630.3	402.7	14.5	1,540.8	446.8	24.2	0.4
	NFA	29,216.5	2,578.6	84.9	43.2	282.1	25,422.3	805.2	0.3
	S	1,200.6	5.3	0.4	0	10.2	271.6	913.2	0
	W	369.2	32.4	0	0	4.8	33.3	1.0	297.7
Total (ha)			11,115.7	577.1	60.7	2,140.7	26,461.3	1,747.7	298.4

2,279 ha (5.4 % of the study area). The results showed that 84 ha of BF, 5,800 ha of CF, 1,541 ha of DF, 25,422 ha of NFA, 913 ha of S areas and 298 ha of W areas remained unchanged between 2002 and 2014. About 3,047 ha of DF area was transformed to productive forest areas, while 303 ha of productive forest area was converted to DF areas. Another interesting result was the conversion of 2,579 ha of NFA to CF.

DISCUSSION

According to analysis, total forest area and productive forest area increased moderately between 2002 and 2014, with a net increase of 2,279.2 ha and 5,198.2 ha, respectively. The apparent changes in total and productive forest area in terms of both quality and quantity can be attributed primarily to the afforestation activities carried out in the region between 2002 and 2014. Indeed, massive afforestation activities were carried out around large cities in Turkey within the scope of the Green Belt Afforestation Project **(**GDF 1992**).** The project was carried out in 2002, over an area of 1,574 ha where *P. brutia*, the dominant native fast-growing tree species, *P. pinea, C. sempervirens*, *P. mahalep*, *P. communis,* and *P. elaeagrifolia* were planted. According to GDF statistics, reforestation efforts in Turkey have accelerated and expanded since 1984 (GDF 2015).

In addition to the afforestation of 1,574 ha, the forest area increased by a further 2,279.2 ha within the study area. The main reason for this phenomenon is the internal migration of local people from their villages far from the cities to urbanized areas over a 13-year period. Such an increase in forest areas may be explained by land abandonment and population reduction in rural areas due to many people leaving their villages in search of better living conditions, higher salary and more job opportunities in metropolitan cities. However, these internal migrations also caused a population increase in urban areas, as reflected in the 734 ha and 28 ha of forested area that was converted to NFA and S, respectively (table 3). The population in the study area was 19,178 ha in 2000, and 22,142 ha in 2013 (TSI 2019). The increasing human population, internal migration and resettlement within the study area caused expansion of S and excessive pressure on forest ecosystems.

The primary reasons for the increase in forest area in Turkey vary according to the region. Bozali *et al*. (2015) showed that there are three major reasons for the expansion of forested areas in the study area; recent afforestation activity, effective protection and forest management plans by GDF, and migration from rural areas to urban areas. Sivrikaya *et al*. (2007) stated that main reasons for increasing forest areas are effective protection measurements, light silvicultural prescriptions and sustainable management activities instead of intensive harvest. Similarly, Çakır *et al*. (2008a) confirmed that factors leading to an increase in forest areas include light silvicultural prescriptions, planting in forest clearings, migration from rural to urban areas and development of new forest management policies towards ecosystem-based multiple use planning.

Moreover, in terms of forest area increase, there are several related studies to support our results. A study by Rimal *et al*. (2019b) in Nepal showed a 36.6 % change in forest areas in 2006, 36.8 % in 1996 and 39.6 % in 2016. A recent study (Fonge *et al*. 2019) found that open forest area increased by 31.48 ha / yr in Barombi Forest reserve. Gautam *et al*. (2003) reported a 5.2 % increase in forest areas between 1976 and 2000 in Nepal. In Canada, Lier *et al*. (2011) reported that forest areas increased 0.16 % annually from 2001 to 2007. Similar research conducted by Bozali *et al*. (2015) in the Başkonuş forest planning unit in Kahramanmaraş city, within the same region as the present study, revealed that total forest area increased from 11,446 ha to 11,827 ha, covering 2 % of the case study area from 1992 to 2012. This study also recorded a considerable increase (9.7 %) in productive forests. Sivrikaya *et al*. (2007) examined the spatio-temporal land use changes during a 33-year period

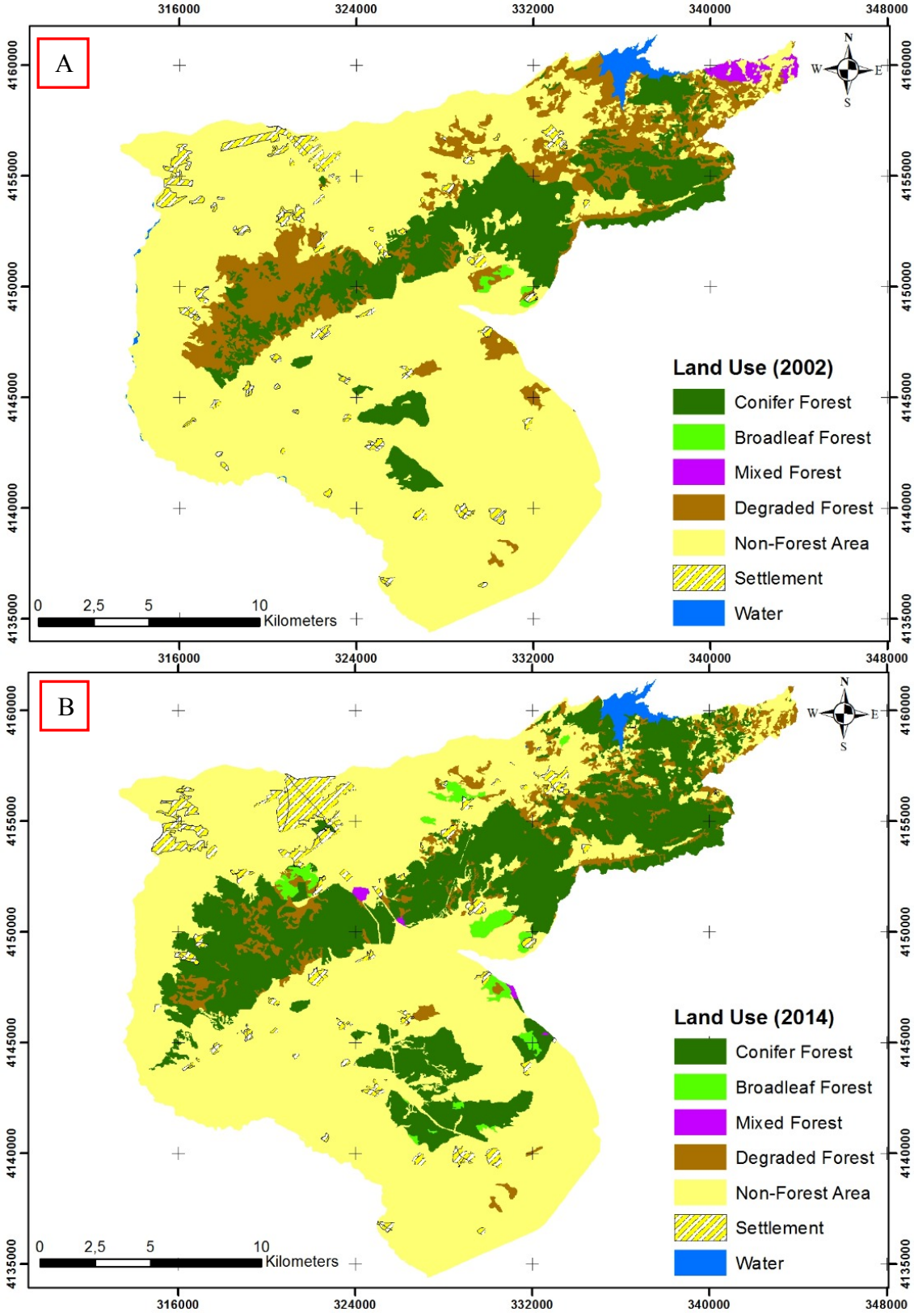

Figure 2. Spatial distribution of land use classes in 2002 (A) and 2014 (B).

Distribución espacial de las clases de uso de la tierra en el área de estudio para 2002 (A) y 2014 (B).

in Camili, including the Camili Biosphere Reserve Area in Turkey. Their results showed that the total forested areas increased from 19,946.5 ha in 1972 to 20,797.3 ha in 2005, with a net increase of 851 ha. Another study was carried out in Maçka planning unit located in Trabzon, part of the East Black Sea Region of Turkey during 1975, 1987, and 2000. Results revealed that the forest area increased from 56,903 ha in 1975 to 60,865 ha in 2000 (Çakır *et al*. 2008a). A similar study was conducted by Çakır *et al*. (2008b) regarding land use change in the city of Istanbul between 1971 and 2002. They determined that total forested areas increased from 277,337 ha to 282,724 ha during the 31-year period, with a net increase of 5,387.3 ha. There was a 1.9 % increase of forested areas with an average 0.06 % annual rate of forest improvement due mainly to reforestation activities.

While the main cause of land use change is the afforestation initiative, creation of awareness, development of a scientific basis for sustainable forest management planning, and implementation with the involvement of stakeholders have helped significantly to further the improvement of forest areas. Local people's perception of forest management activities has become more positive due to active participatory planning of ecosystem-based forest management in Turkey (Başkent *et al*. 2008). Total forest area was 20.2 million ha according to the first national forest inventory conducted across the country between 1963 and 1972 by GDF (GDF 2015). In the latest forest inventory carried out at the end of 2019, total forest area in Turkey was 22.7 million ha. The difference between the first and the most recent forest inventories clearly indicated net forest improvement (2.5 million hectares with 12 % increase over 46 years, 0.27 % yearly changes) in Turkish forest ecosystems (FI 2019). However, the net forest improvement in the case study area is 1.49 % per year. The main reasons for this difference are the intensive afforestation activities (1,547 ha) and high migration rate. The average area of afforestation activities in Turkey between 2008- 2019 covers 48,000 ha, and Kahramanmaraş is the region with the 13th highest afforestation rates among 81 provinces in Turkey.

CONCLUSIONS

The apparent changes in total and productive forest areas in terms of both quality and quantity can mainly be attributed to afforestation activities carried out in the region between 2002 and 2014. In addition to the afforestation of 1,574 hectares, forest area increased by a further 2,279.2 hectares in the study area, due primarily to the internal migrations of local people from their villages to urban areas. This suggests a strong link between land use changes, population movement and afforestation activities.

In this study, driving factors affecting land use change both positively (afforestation activities) and negatively (population) are evaluated together. According to the data, the positive effect of afforestation activity has more impact than the negative effect of population movement, and therefore an increase in forest area has occurred. Population has some of the most important negative impacts on forest ecosystems and land use change. Generally, forest area experienced a decrease in parts of the study area where population increased. However, what matters is not the total population growth, but how the population changes in rural areas versus cities. Although the total population increased in the study area, the decrease of the population in rural areas caused an increase in forest area. These results revealed the driving factors affecting land use change in forest ecosystems and how they affect change. The specifics of how certain factors affect land use change in different geographical regions should be further investigated.

ACKNOWLEDGMENTS

We thank the Head of Forest Management and Planning Department, General Directorate of Forestry, Republic of Turkey, for their support.

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Recibido: 14.03.22
Acceptado: 16.10.22