

A SPATIOTEMPORAL SURVEY OF TIKJDA FOREST DYNAMICS OVER A 34-YEAR PERIOD BY AERIAL PHOTOGRAPHS

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Abstract

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Obtaining accurate forest cover information and dynamics of land occupation, through time, such as the spatial extent and pattern of disturbance and recovery is essential knowledge and assistance for forest managers and a crucial basis for the protection and conservation of current forest resources. Because most recent researches have focused on forest field survey and monitoring, a land classification containing information on forest cover dynamics is critically needed. Over the last decades, advances in remote sensing technology have enabled an accurate classification of different land covers from several sensors and remotely sensed data. We presently retained Tikjda forest (Djurdjura southerner, Algeria) as a case study to investigate the possibility of aerial photos classification and to analyze the historical dynamics of the area using a change detection analysis of multi-temporal data. To classify the study area's main cover types, we used photographs collected over a period of 34 years (i.e., from 1983 to 2017). The results revealed that in 2017, Tikjda forest was composed of forest areas (24.1%), degraded areas (49.7%), and barren areas (26.2%). Throughout the investigated period, the analysis revealed a notable increase in barren areas (+9.8%), and degraded areas (+14.4%). While forest areas experienced a significant decrease (–24.2%). Moreover, the results confirm the potential of aerial photographs for an accurate classification of forests.

Key words: remote sensing, supervised classification, Djurdjura, Algeria.

Introduction

Spatiotemporal dynamics of forest areas over large extents is relevant for an improved understanding of forest ecology, for example, concerning species dynamics, and their role in ecosystem functions and services (Van Ewijk et al., 2014; Fassnacht et al., 2016; Mboga et al., 2020). Forest cover dynamics is largely evaluated around the world due to the increasing socioeconomic needs following the exponential increase of human population (Hassan et al., 2016; Zhu et al., 2021). Furthermore, understanding the dynamics of land cover and its impact on forest landscape functioning is critical for biodiversity conservation (García-Vega, Newbold, 2020), as it is necessary to understand the extent of the forest covers to identify the drivers and their effects on the ecological and anthropogenic processes (Adhikari et al., 2022). Nowadays, thanks to the combination of ecological history and remote sensing data, novel solutions are readily developed (Mboga et al., 2020; Solano et al., 2021).

Ecological, physical, and anthropogenic variables all together have an impact on the landscape spatial heterogeneity (Zhu et al., 2021). Numerous studies have demonstrated that anthropogenic activities remain the primary cause of terrestrial ecosystems' disturbance (García-Vega, Newbold, 2020; Solano et

al., 2021). Thus, many forest landscapes reflect the ecological and socio-economical history (Caetano-Andrade et al., 2020). Forests in the Mediterranean region have been exploited by humans for thousands of years, and as a result, their species composition, structure, and spatial patterns have changed (Munteanu et al., 2015), transforming their natural regimes and functionality compared to the natural ecosystems (Sommerfeld et al., 2018; Mertens et al., 2000). Forest changes are thought to be mostly caused by human activity (Roper, 2001). With the growing population, the demand for resources like food, water, housing, timber, and fuel is a source of stress on the landscape. In recent decades, the Mediterranean forests have experienced increasing extended damages, high degradation, drought, forest fires, species losses, and deforestation activities (Mensing et al., 2018; Asenova et al., 2021), Algerian forest ecosystems also suffer from loss of 100ha each year mainly due to forest fires (Meddour-Sahar, 2015).

Remote sensing technology has proved to be a useful tool for surveying, analyzing, and better managing natural resources (land, soil, water, forests, and mountains), as well as monitoring desertification, floods, droughts, forest fires, and landform change (Cho et al., 2010). Remote sensing is used in forest studies to provide data about resource inventories (Van Aardt,

Wynne, 2007), biodiversity assessment and monitoring (Shang, Chisholm, 2013), hazards, forest fires and stress management (Fassnacht et al., 2014), invasive species monitoring (Boschetti et al., 2007), and wildlife habitat mapping (Jansson, Angelstam, 1999). Remote sensing data are an alternative tool for assessing forest cover and its change over time, as well as monitoring forest dynamics (Lillesand et al., 2015; Taylor et al., 2020). Remote sensing helps avoiding gaps caused by administrative and national borders (Fagua, Ramsey, 2019; Potapov et al., 2015) and allows spatiotemporal examination of forest cover trends over several decades through long-term data collection (Vogeler et al., 2018; Hermosilla et al., 2019).

As remotely sensed data, aerial photographs are important elements used to assess and map landscape changes. In earlier studies (Bakker et al. 1996; Condit, 1998), large-scale and long-term analysis of forest dynamics had been well identified using aerial photographs, despite the high spatial heterogeneity within a forest and the consequences of uncommon or episodic occurrences. They have been used as a key data to solve a variety of environmental problems, including disturbance studies (Martha et al., 2012; Shu et al., 2019), land cover mapping (Robertson, 2012; Pinto et al., 2019), and vegetation dynamics monitoring (Carter et al., 2011; Jeter Jr, Carter, 2016). Because of their high spatial and radiometric resolutions, aerial photographs are useful for mapping tiny ecosystems and fine-scale landscape features such as individual trees (Tuominen, Pekkarinen, 2005). Aerial photographs are also the most comprehensive, temporally continuous, and geographically full record of landscape change, dating from the early 1930s in some cases (Morgan et al., 2010).

Despite the numerous benefits of aerial photographs, there are specific challenges associated with their use, particularly in terms of manual aerial photograph interpretation. Although manual interpretation by highly trained personnel remains one of the most effective and widely used ways for classifying aerial photographs (Wulder, 1998), this methodology is heavily dependent on the interpreter's own experience, knowledge, and expectations for a given place. Human interpretations are, therefore, subjective and prone to inconsistency and mistakes. As a result, there is a need for new approaches to reduce or eliminate the inconvenience associated with traditional aerial photograph analysis to help nurture their sustained and increasing usage, such as the digital processing of the aerial photographs based on remote sensing technology. The Djurdjura National Park (Algeria) has been classified as such a protected area by the Algerian legislation in 1983. Despite its protected status, such an area continued to undergo various anthropogenic disturbances, mainly fires. Between the years 1991 and 2010, fires burned 406.8, 1711, and 132.9 ha of pure cedar forest, pure holm oak forest, and Atlas cedar–holm oak mixed forest, respectively. The areas correspond to 7.57, 31.84, and 2.47% of the total (i.e., 5375.08 ha) burned area over this period (PND, 2010). However, there is a lack of published works on land cover dynamics through time despite the usefulness of such kind of data as the management tool. Our present contribution aims at providing a diachronic analysis of land cover changes over a 34-year period in Tikjda forest area (Djurdjura southerner) based on an integrated approach which combines historical forest cover and remote sensing techniques to help supporting policies aimed at reinforcing protection of this area.

Material and methods

Study area

Tikjda forest is part of the Djurdjura Mountain classified as a protected area, that is, the Djurdjura National Park (herein after abbreviated as DNP) in 1983 with five administrative sectors (Fig. 1). Forest cover on this mountain is not continuous but fragmented and the main forest patches, from west to east, are Tala-Guilef, Tikjda, Tala-Rana, and Ait-Ouabane. The forest cover is mainly constituted by Atlas cedar and holm oak, a native species to Algeria and the main forest trees in the Djurdjura Mountain. The forest physiognomy is dominated by *Quercus rotundifolia* at medium elevations and by *Cedrus atlantica* at higher ones. The mixed forest organized by these two major species is more densely covered by *Quercus rotundifolia* on thermophilous slopes and by *Cedrus atlantica* on mesic ones. From a floristic point of view, the Atlas cedar forest of the Djurdjura Mountain is a part of the *Senecio perralderiani-cedretum atlanticae* (Yahi, Djellouli, 2010). Regarding its patrimonial value, the Djurdjura Mountain constitutes one of the Mediterranean biodiversity hot-spots (Véla, Benhouhou, 2007).

Besides forest covers, there are degraded areas and barren ones including cliffs and limestone rocks. The degraded areas comprise maquis in the vegetation belt originally covered by holm oak, while in the vegetation belt originally covered by Atlas cedar forest, degraded areas of high elevations comprise meadows on mesic sites as well as the covers dominated by sparse shrubs such as *Juniperus communis*, *Crataegus laciniata*, *Berberis hispanica*, and prickly xerophytes such as *Bupleurum spinosum* and *Astragalus armatus*. Degradation of mixed stands on thermophilous slopes may lead to open spaces dominated by *Ampelodesmos mauritanicus*, *Genista tricuspidata*, and *Asphodelus* sp.

The mountain comprises touristic infrastructures at Tikjda and Tala-Guilef forests. Two villages, that are, Ait-Ouabane and Ait-Allaoua (Djurdjura north-easterner) were settled within the DNP before its classification as a protected area. This mountain is crossed by two main roads: the RN 30 and the RN 33, in addition to secondary roads and treks. It is also surrounded by a high density of population at its periphery and is still used as a rangeland by the local populations, a legacy of the ancient land use. This area is also open to touristic activities, as expected for this category of protected areas.

Tikjda sector covers an area of 3810 ha (Chaib, Kherbouche-Abrous, 2021); its substrate is essentially sandstone and limestone (Flandrin, 1952). As for its bioclimate, the study area is characterized by a Mediterranean climate type. Based on extrapolations from Seltzer data over a relatively long period, Deridj (1990) found a humid bioclimate with a fresh variant for an elevation of 1500 m and an annual precipitation of 1257.7 mm with snow cover duration of more than 4 months. The land cover of Tikjda site comprises relatively pure stands dominated by Atlas cedar or holm oak, depending on the slope aspect, and mixed stands of both species, as well as their corresponding degraded areas in addition to barren areas.

Within the administrative sector of Tikjda, we retained an area which encompasses the main forest cover delineated by the following geographic extent: 4°04'E–4°09'E, 36°27'N–36°25'N. Such choice is motivated by two main reasons: firstly, because this area has undergone frequent fires during the recent decades

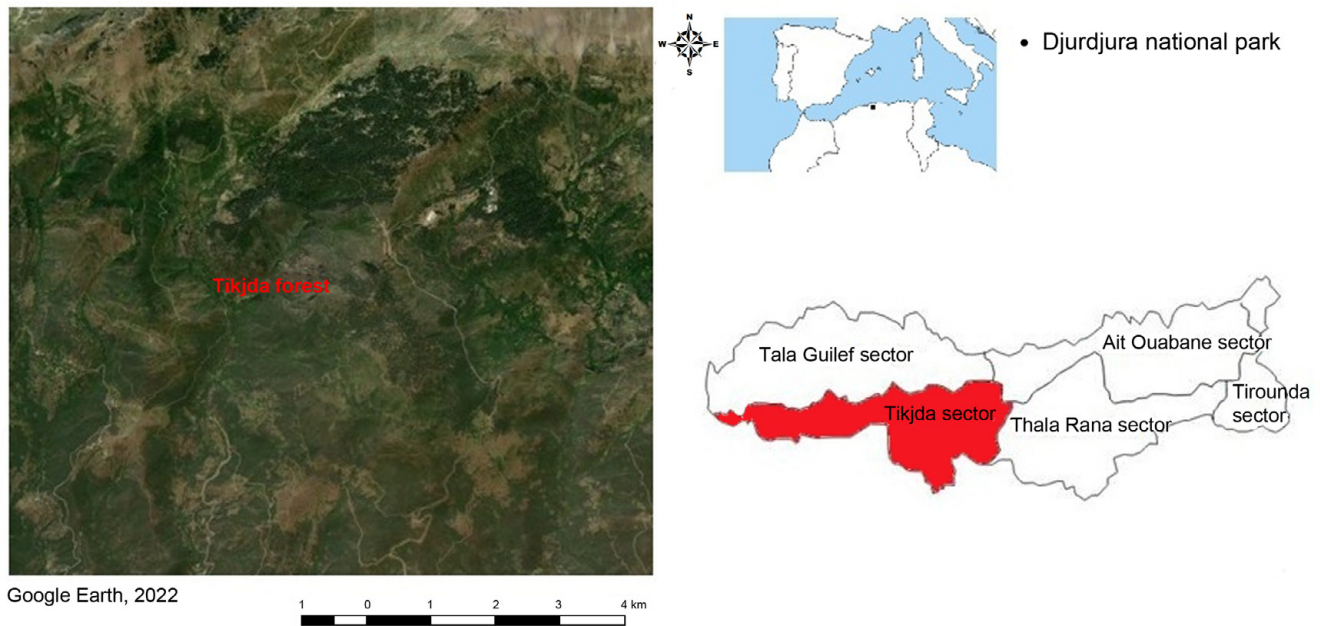


Fig. 1. The geographic location of Tikjda administrative sector (south of the Djurdjura National Park).

(the DNP administration recorded 120 fires in Tikjda between 1991 and 2014 with a maximum of 18 fires in 2014) which destroyed a large part of its forest cover while data on the cumulative loss of such forest cover are lacking, and secondly, because it is subjected to the highest touristic flow according to DNP administration.

Methodology

This study evaluates forest cover changes between 1983 and 2017 using aerial photographs. Our approach was based on photointerpretation and spatial image analysis, processed on QGIS 3.0 software. It was realized through a preprocessing step, mainly, mosaic formation and georeferencing and a supervised classification of land cover types.

Data acquisition and preprocessing

In the present study, the aerial photographs were acquired from the Algerian National Institute of Cartography and Remote Sensing (INCT). The photographs were available for 4 years, 1983, 1999, 2012, and 2017, as RGB (Red-Green-Blue) images and cover a total period of 34 years. Depending on the land coverage, the photos were divided into ten, five, eight, and four images for the years 1983, 1999, 2012, and 2017, respectively.

The film-based photographs (1983 and 1999) were first converted into a digital format through scanning at a resolution of 600 dpi, which is visually and geometrically accurate and sufficient to create a representation of the original aerial photograph (Morgan et al., 2010), while those obtained as digital images at 30-cm scale (Digital mapping camera images of 2012 and 2017) were directly processed. Then, each digital image was checked using metadata and was georeferenced to the WGS-84 datum and Universal Transverse Mercator (UTM), zone 31 north co-

ordinate system. A mosaic of the images for each period of time was constructed on the QGIS 3.00 software using fusion tool.

Image-supervised classification

Supervised classification is a procedure which uses known specific sites through a combination of field knowledge, analysis of aerial photographs, maps, and personal experience in the remotely sensed data, which represent homogenous examples of land cover types to identify areas of specific features of interest to the analysis. These areas are commonly referred to as training sites (Jensen, 2000). More than 30 training samples were chosen for each class in each scene for a better and accurate classification. The supervised classification was performed using one of the most popular methods of classification in remote sensing, namely, neighbor classifier. This algorithm is considered as less sensitive to the overlap between classes than the maximum likelihood classifier and is considered by Carmel, Kadmon (1998) as useful for aerial photographs, where there is a large spectral overlap between classes. The signature classes or training sets were prepared from Google earth map for each year of interest and were used to prepare signature classes for the supervised classification.

The consistency of land cover classes at national, regional, and international levels is always different (Wang et al., 2020; Adhikari et al., 2022). In this study, we classified the land cover of Tikjda forest into three major classes (Table 1) based on the dominant soil present. The dominant plant composition in the area is of mixed type from Atlas cedar and holm oak species and is difficult to separate into subcategories. Hence, we classified such forest under a class named “Forest area.” The second class named as “Degraded area” included the herbaceous vegetation, the cushion vegetation, and the young trees and regenerations, and the third class named as “Barren

Table 1. Recorded land cover classes in Tikjda.

Classes from historical aerial photographs	Recorded land cover classes
Dense evergreen forest with <i>Cedrus atlantica</i> and <i>Quercus ilex</i> as the dominant species	Forest area
Disturbed forest dominated by young trees and herbaceous vegetation	Degraded area
Areas without any kind of vegetation	Barren area

Table 2. Changes in the extent of the land cover types in Tikjda forest area between 1983 and 2017.

Land cover type	1983		1999		2012		2017	
	Covered area		Covered area		Covered area		Covered area	
	(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)	(%)
Forest area	1840.23	48.3	1303.02	34.2	979.17	25.7	918.21	24.1
Degraded area	1344.93	35.3	1695.45	44.5	1642.11	43.1	1893.57	49.7
Barren area	624.84	16.4	811.53	21.3	1188.72	31.2	998.22	26.2
Total	3810	100	3810	100	3810	100	3810	100

Table 3. Forest cover changes in Tikjda forest area between 1983 and 2017.

Land cover change	1983–1999		1999–2012		2012–2017	
	(ha)	(%)	(ha)	(%)	(ha)	(%)
Forest area	-537.21	-14.1	-323.85	-8.5	-60.96	-1.6
Degraded area	+350.52	+9.2	-53.34	-1.4	+251.46	+6.6
Barren area	+186.69	+4.9	+377.19	+9.9	-190.5	-5

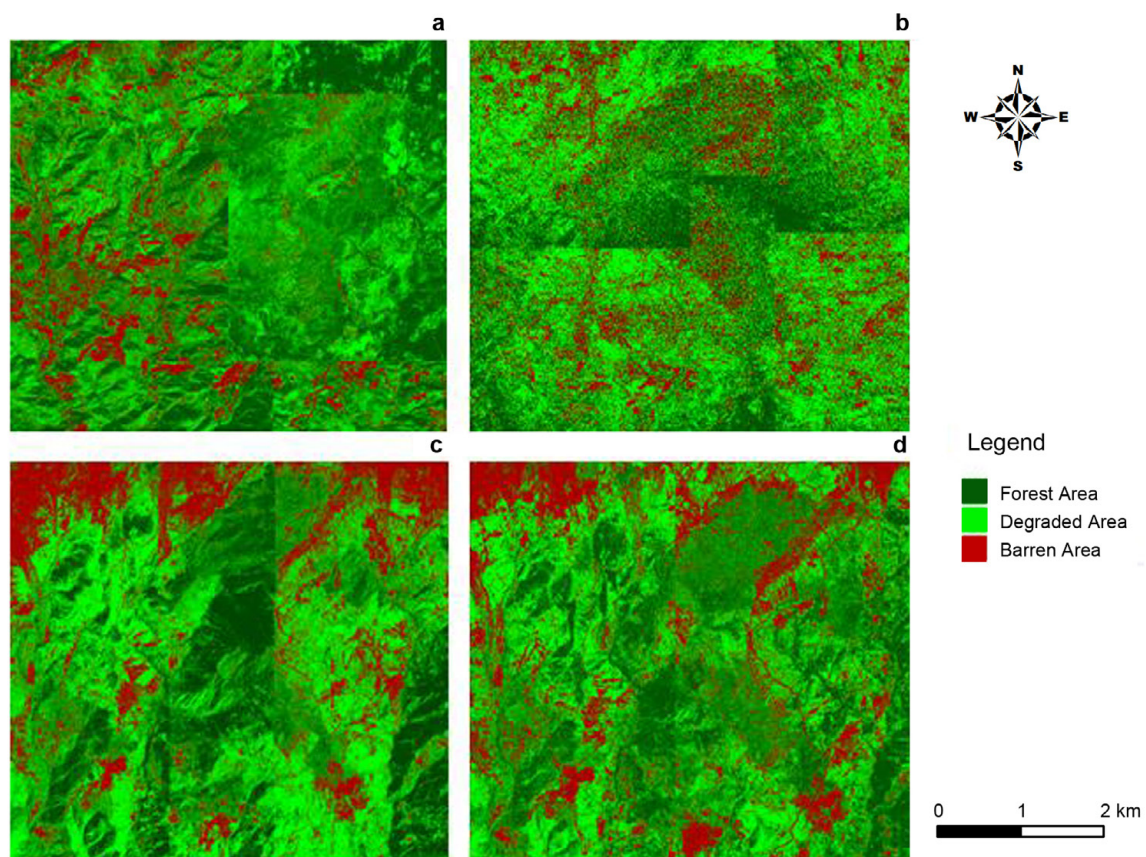


Fig. 2. Land cover maps between 1983 and 2017 (a - 1983; b - 1999; c - 2012; d - 2017).

area” included the nonvegetated areas, snow feed areas, landslides, dry beds, roads, and buildings. Furthermore, for every time period, the built area was measured by digitalization to evaluate the importance of built areas in Tikjda forest between 1983 and 2017.

Results

Forest cover patterns between 1983 and 2017

Land cover patterns in the study area (Table 2, Fig. 2) revealed that in 1983, out of the total investigated area, the forest cover occupied 1840.23 ha (48.3%), the degraded area 344.84 ha (16.4%), and the barren area 624.84 ha (16.4%). In 1999, the forest area decreased to 1303.02 ha (34.2%), the degraded area increased to 1695.45 ha (44.5%), and the barren area increased to 811.53 ha (21.3%). In 2012, the analysis revealed that the forest area decreased to 979.17 ha (25.7%), while the degraded area increased notably to 1642.11 ha (43.1%). Similarly, the barren area increased to 1188.72 ha (31.2%). Finally, in 2017, the forest area represented 918.21 ha (24.1% of the investigated area), while the degraded and barren areas occupied 1893.57 ha (49.7%) and 998.22 ha (26.2%), respectively. Obviously, half of the forest area has been lost within three decades (i.e., during 34 years).

Forest cover changes between 1983 and 2017

To find the land cover changes in Tikjda forest area over the 34-year period (i.e., 1983–2017), the differences between the classes of land occupation were calculated (Table 3). Results (Figs 3, 4) indicated a gradual loss of the forest area between 1983 and 2017, with a total loss of 922.02 ha (corresponding to -24.2% of the initial area occupied by this category). Indeed, the lost forest cover was converted into degraded and/or barren areas, which gained 14.4% (i.e., +548.64 ha) and 9.8% (i.e., + 373.38 ha) of their initial area, respectively.

The diachronic analysis of forest cover changes over three periods of time pass (Table 3 and Fig. 5) revealed for the period 1983–1999, a loss of 14.1% of the forest area and an increase in degraded and barren areas by 9.2 and 4.9%, respectively. Between 1999 and 2012, the forest area and the degraded areas decreased by 8.5 and 1.4%, respectively, while the barren area gained 9.9% of its initial cover. Between 2012 and 2017, the forest area and the barren one decreased by 1.6 and 5%, respectively, while the degraded area increased by 6.6%.

The importance of built surfaces in Tikjda by year is depicted in Figure 6. The calculated surfaces were derived from our interpretation of the photos, a research in the history of the area, and from a surface calculation of the buildings represented in the aerial photograph, which showed their gradual rise through time totalizing 3.04 ha in 2017.

Discussion

The integrated methodology presently used provided a landscape overview of land cover dynamics over 34 years in Tikjda forest. It categorized three land cover classes including forest area, degraded area, and barren area. Each time interval showed significant differences in the proportion of such categories of land cov-

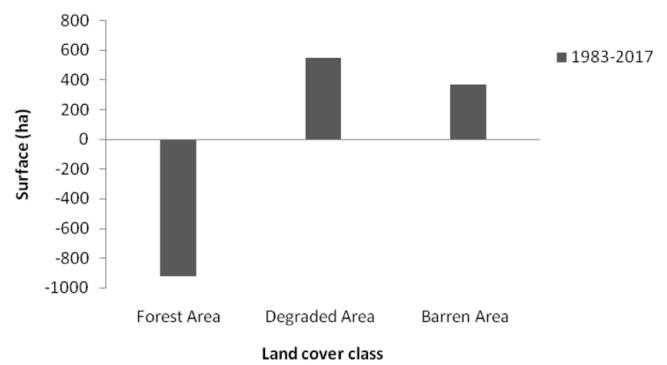


Fig. 3. Global land cover changes between 1983 and 2017 in Tikjda forest area.

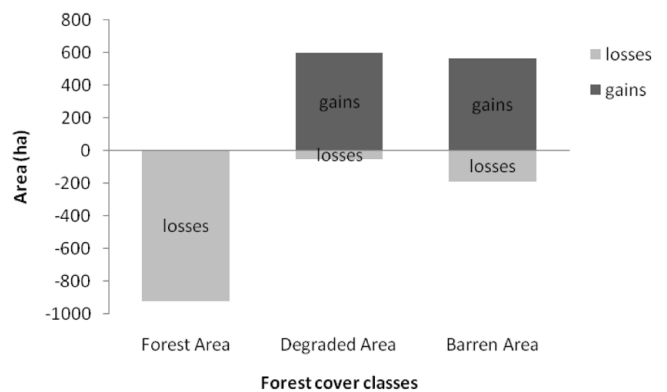


Fig. 4. Overall losses and gains of land cover types in Tikjda forest area between 1983 and 2017.

er. However, one of the drawbacks in the supervised classification presently used was the misclassification of the nonvegetated areas since all the areas other than the green ones, including the roads, buildings, and the barren areas themselves, were saved as barren areas. Indeed, despite the high resolution of the image, the performance of this technique is challenging, according to Mboga et al. (2020), due to the large overlaps between class signatures and the poor radiometric quality of the scenes. Although, nowadays, there are novel technologies, which are more accurate for image classification, such as Unmanned Aerial Vehicles (UAVs), Synthetic Aperture Radar (SAR), and Light Detection And Ranging (LIDAR) (Amani et al., 2020; Lechner et al., 2020), they are with short time series and high costs. Therefore, the presented methodology seemed to be the most adequate for our research.

The classified photos revealed a decrease in forest areas and a sharp rise in both degraded and barren ones. The change in forest cover is a consequence of either regional or global changes over a period of time and also various other reasons, mainly, the frequent forest fires and human activities, as reported by Keenan et al. (2015) and Li, Hong (2022). In the present study, the forest area decreased by 922.02 ha (i.e., -24.2%), an observation in concordance with that of Yahi (2007), who demonstrated, based

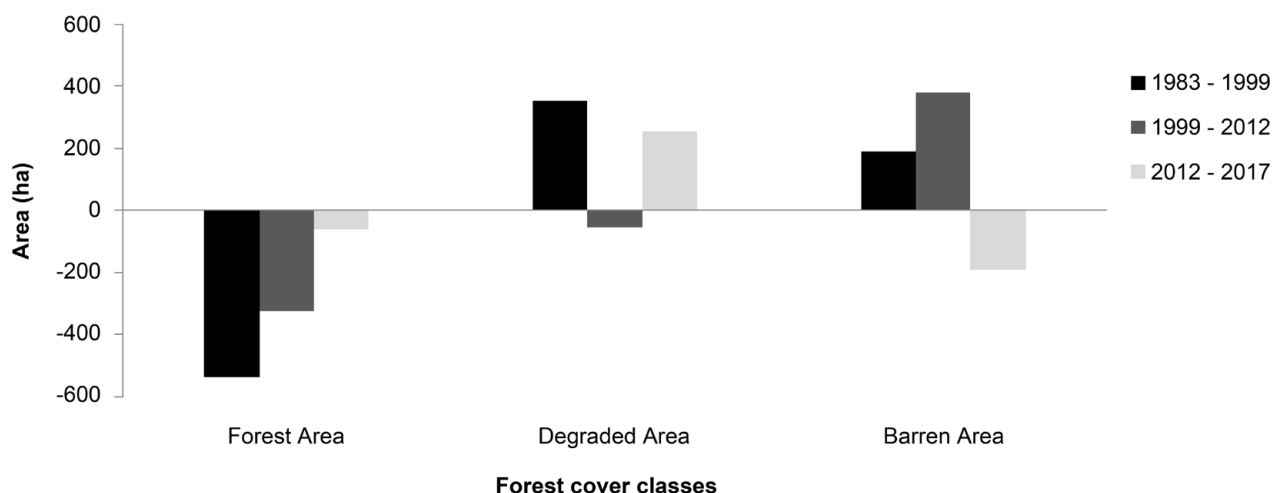


Fig. 5. Land cover changes during three periods of time pass within a total period of 34 years.

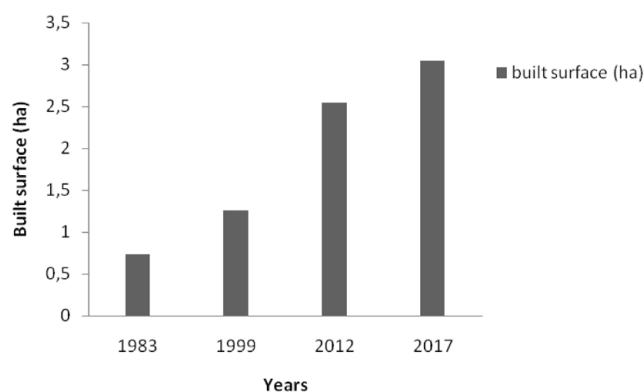


Fig. 6. Importance of built areas in Tikjda forest between 1983 and 2017.

on a floristic study, the regressive dynamics of Tikjda forest and noted the dominance of degraded areas. Overall, the diachronic analysis carried out showed that the forest cover of Tikjda is under intense pressure which led to its regression. Regarding the causes of such changes, besides the legacy of ancient human land uses (logging, fires, grazing, prescribed burning, etc.), actually, the main sources of disturbance are fires, overgrazing, and touristic pressure.

Frequent forest fires are the main driving force of regressive dynamics in the Mediterranean forests, with more than 50,000 fires burning 1.5% of its total area annually (Meddour-Sahar, 2015). Algerian forests also were subject to a similar trend with a loss of more than 910, 640 ha of their total area during the few past decades, with three particularly disastrous years: 1983, 1994, and 2012 (Meddour et al., 2013). Archive data indicate that the DNP and, mainly, the Tikjda forest experienced repeated and numerous fires between 1990 and 2017. Among such fires, those of 1994, 1999, 2000, 2004, and 2012 remained in memories (DNP report, 2014) as they respectively caused consistent losses,

that is, 208,166,1461,136, and 257 ha of the overall surface. For example, the fire of year 2000 burned a notable portion of an old Atlas cedar stand on the eastern slope of djebel Taouialt and that of 2012 burned a great portion of its northern slope including two dozens of *Pinus nigra* individuals, reducing the number of stands occupied by this taxon in Tikjda from three to two.

In addition to loss of forest areas in Tikjda between 1983 and 2017 due to fires, there are other sources of disturbances such as touristic pressure. Visitors and tourism activities are recognized by many authors (Mann et al., 2002; Cunha, 2010; Adhikari et al., 2022, among others) as having negative impacts on ecosystems and species dynamics. Mountain recreation areas around the entire world frequently experience issues with erosion, mud formation, waste management, and water contamination (Cunha, 2010). Tikjda forest site and surroundings are visited annually by thousands of tourists. In the year 2020, for example, Tikjda received the main visitor flow (i.e., 850,000 out of the 1,298,548 who visited DNP). Such huge numbers of tourists are out of control of the DNP administration because of travel agencies and other visitors scheduling their visits by their own initiative without seeking coordination by the DNP administrators. One of the most obvious consequences of this over-visiting is illustrated by the great quantities of solid waste left by visitors on the site, in addition to other potential detrimental effects on the ecosystem, such as accidental fire starts, trampling of new regenerations, soil compaction, acoustic disturbance, and so on.

Our data analysis indicated a noticeable increase of built-up surfaces from 0.73 to 3.04 ha between 1983 and 2017 in the studied area despite its protected status since 1983. This outcome indicates that forest areas of Tikjda have been partially converted into various infrastructures including hotels, cafeterias, fire station, youth hostels, and a mosque. One may note that the infrastructures of 1983 were built before the protected area classification. Such infrastructures occupy a relatively small area compared to the overall area of Tikjda. However, they are located within the protected area instead of its periphery and at the expense of a mixed forest of Atlas cedar and holm oak. Such buildings and related activities may generate other forms of dis-

turbance by bringing tourists and their negative impacts to the parks, as pointed out by some authors (Buczowski, Richmond 2012; Agyapong et al., 2018).

Uncontrolled grazing within DNP as a whole, including the Tikjda site, is also a source of disturbance. The DNP administration faces a big issue regarding the persistence of grazing as a legacy of ancient land use to the benefit of the populations inhabiting the periphery of DNP, despite its protected status. Indeed, in addition to seasonal grazing by goat and sheep, there is permanent grazing by cows beyond the site's carrying capacities. The way grazing is practiced (e.g., the exact number of cattle per owner is not disclosed by owners and the restricted access to some sites is transgressed) is not in compliance with the conservation goals of this category of protected area. Indeed, grazing is recognized to have pervasive impacts on native ecosystems through changes in primary production, fire regimes, nutrient cycling, soil characteristics, vegetation structure, and species distribution (Molvar et al. 1993; Mutze et al., 2016; Prowse et al., 2019). Uncontrolled grazing causes excessive grazing of vegetation and young seedlings, prevents regeneration, exhausts the supply of resources, and damages and erodes rangelands (Eldridge et al., 2017).

Regarding the possibilities of regeneration of Atlas cedar and holm oak, the main tree species in this forest area, the former is an obligate seeder while the latter is a resprouter and a seeder. Natural regeneration of Atlas cedar is plentiful in environments with receptive soil and high availability of cones containing viable seeds (Messiaoudene et al., 2013). In Djurdjura, Atlas cedar seeds germinate successfully at the forest edge following manual soil digging (Derridj, 1990). Natural regeneration of the species also takes place in forest gaps (Alileche et al., 2021), and there are trees of the species which may ensure a regular cone production even in years of low production due to masting (Krouchi et al., 2004). The presence of very big and very aged Atlas cedar trees (i.e., several hundred years) in Tikjda, and elsewhere in the Djurdjura mountain, is an indicator of its longevity, but it takes a long time for the species to recover, following disturbances, as pointed out by Messiaoudene et al. (2013). Holm oak, on its part, relies on resprouting in the face of disturbances such as fire and logging, what causes a shift in the landscape physiognomy and structure. An additional shift in tree species composition may result from the extension of Aleppo pine, a fire-prone species, in the contact zones with Atlas cedar since there are scattered individuals of this pine already settled on the thermophilous sides of the forest below 1500 m of elevation. Indeed, despite the intrinsic natural regeneration capacities of these main tree species, the diverse constraints exerted on the forest site including Tikjda (i.e., frequent fires, overgrazing, soil compaction and degradation, drought, and other anthropogenic activities) may hinder their natural regeneration process.

The Djurdjura Mountain is recognized as a priority corridor for biodiversity protection since it is the habitat of various species that are protected and it is classified as a National Park since 1983. Algerian forest policy prescribes a regulatory framework for the management of national parks. However, the implementation of this policy faces a complex socioeconomic situation due to the persistence of some ancient land uses by the populations on one hand and the touristic pressure on the other hand, particularly, the recent years are characterized by an increase in the demand for hikes beyond the carrying capacities of DNP and the supervision capacities of its administrative staff.

Conclusion

The present study showed a gradual decrease of Tikjda forest cover over 34 years (from 1983 to 2017). It serves as a warning case to the authorities, highlighting the need for the reinforcement of protection measures to preserve the remnant forest patches, particularly the cedar heritage. Hence, the protected status of this area in particular and of the Djurdjura Mountain as a whole did not prevent their degradation by anthropogenic pressure including frequent fires, permanent cow grazing, overtourism, and related consequences. Therefore, we strongly recommend a strict application of the legislation governing this protected area and implementation of policies and strategies aimed at protecting the remnant forests patches, to prevent them from regressing and to promote future regeneration of species. Tourism in this protected area should be restricted, and it is important to design and implement effective forest fire prevention strategies. Moreover, for an adequate management of grazing, the carrying capacity of grazing sites and the allowed number of cattle per owner should be determined and the fenced areas should not be transgressed. Regarding the presently used tools, we proved their usefulness in forest cover delineation and diachronic survey. Therefore, we may apply the same methodology to the rest of forest covers in Djurdjura.

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