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MONITORING LONG-TERM CORK OAK FOREST SPATIO-TEMPORAL DYNAMICS BASED ON AERIAL PHOTOGRAPHS: A CASE STUDY OF KIADI CORKS OAK FOREST IN AKFADOU MOUNTAIN (ALGERIA)

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Abstract: This paper highlights the importance of remote sensing and GIS techniques applied on aerial photographs for forests spatio-temporal dynamics analysis. An assessment of the changes in the distribution and extension of Kiadi cork oak forest was carried out using historical imagery, covering a period of 35 years. The results indicate that, roadways and building surfaces in Kiadi forest have increased by 9.71 and 3.86% respectively, while the surface initially covered by vegetation decreased by 13.57%, as a result of anthropogenic disturbance. Digital processing of historical aerial photographs proved to be a powerful tool for quantitative analysis of forest dynamics.

Key words: Forest dynamics, Aerial photography, GIS, Remote Sensing, Kiadi forest, Akfadou, Algeria.

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INTRODUCTION

Understanding temporal dynamics of forests is crucial for conservation strategies at regional and local levels. For thousands of years, landscapes have been transformed in order to supply humankind with food, freshwater, fuel, and other essentials. However, the ongoing extents, rates, and magnitudes of land-use and land-cover changes are unprecedented (Ellis & Pontius, 2007; Mertens & Lambin, 2000; Grecchi, Gwyn, Bénié, & Formaggio, 2013; Kweyu, Thenya,

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Kiemo, &Emborg, 2020). During the last decades, the forest dynamics has been in continuous changes in the Mediterranean region due to a growing population and a changing economy (Hassan & Nazem, 2016). The land cover regressive changes such as deforestation and surface losses have often been related to community instability and anthropogenic pressure (Kweyu, Thenya, Kiemo, & Emborg, 2020; Akobi, Amoussou, Yabi, & Boko, 2018; Kafy, et al., 2021). This has caused important adverse effects on physical and ecological processes, on soil and water resources, on local and global climate systems and on the diversity and abundance of terrestrial species (Giri, Pengra, Zhu, Singh, & Tieszen, 2007).

Previous studies on forest dynamics have focused mainly on ecological aspects and their utilization as drivers of land cover change (Geist & Lambin, 2002; Vu, Le, & Vlek, 2014). Thus, there is a little focus on building extensions and human pressure as underlying drivers to forest changes. Human influence on vegetation cover is measured by the activities he carries out developing his environment (Anthelme, Mato, Boissieu, & Giazzi, 2006; Millogo, Nikiema, Koulibaly, & Zombre, 2017). Whether it is habitat, fields, roads or grazing areas; each of these elements influences vegetation cover in one way or another. In recent decades, accelerated population growth in developing countries, accompanied by unprecedented rates of building extensions, has placed tremendous pressure on the forested lands and their biotic and abiotic resources (Grecchi, Gwyn, Bénié, & Formaggio, 2013). In Algeria it is no less worrying, as the vegetation cover in all the region is in constant regression due to anthropogenic factors: agro-pastoral activities, timber harvesting, human settlements, forest fires, etc. (Meddour-Sahar, Meddour, & Derridj, 2008).

Despite the accuracy and spatial detail achieved by conventional forest field based surveys over large areas, they are still considered mono-temporally difficult (Hernández-Stefanoni, et al., 2012; Khare, Latifi, & Rossi, 2021)or multi-temporally infeasible, due to the vast time, logistic and manpower required (Hernández-Stefanoni, et al., 2012; Khare, Latifi, & Rossi, 2021). This problem can be overcome using aerial photographs (Brünig, 1973; Sanford Jr., Braker, & Hartshorn, 1986; Nakashizuka, Katsuki, & Tanaka, 1995; Miller, Quine, & Hadley, 2000; Morgan, Gergel, & Coops, 2010). Aerial photographs and remote sensing images are largely used to collect quickly accurate information on forests (Küchler & Zonneveld, 1998; Fensham & Fairfax, 2002). Due to an easier accessibility of aerial photographs and a significant decrease of their price as well as of the image analysis on GIS softwares (Paine & Kiser, 2012); these techniques are becoming increasingly popular. Moreover, the combination of RS and GIS technologies saves time and provides accurate information that enables land change evaluation and monitoring (Trolle, et al., 2015; Lillesand, Kiefer, & Chipman, 2015; Fu & Weng, 2018; Niyogi, 2019; Kafy, et al., 2021).

Nowadays, due to the development of high resolution and multispectral images and the increased flexibility of statistical algorithms with remotely sensed data, the spatio-temporal and historical data analyses of land cover dynamics have resulted in significant possibilities in solving the problems associated with forest dynamics (Rahman, 2016). In addition, historical aerial photographs provide crucial data for efficient long term environmental monitoring and change detection (Morgan, Gergel, & Coops, 2010); they offer unique background information at a very high spatial resolution (Forster, 1985). However, reproducible works based on these data can be challenging due to their inherent and heterogeneous properties, such as their spatial and radiometric resolutions (Aber, Aber, & Penner II, 2016; Pain, Pillans, Roach, Worrall, & Wilford, 2012). Furthermore, digital mapping cameras (DMC) are recently introduced to aerial photography; they have much higher radiometric resolution than traditional film cameras. Thus, despite a similarity in the level of spatial resolution, a digital aerial camera can capture much clearer images of the earth surface than a film camera (Yamazaki, Suzuki, & Maruyama, 2008a).Additionally, DMC data are available at a low cost, providing 3D data as well as spectral data of the vegetation (Bohlin, Wallerman, & Fransson, 2012).

Several studies highlighted the use of remote sensing and GIS in forest researches, particularly in forest dynamics studies (Nakashizuka, Takahashi, & Kawaguchi, 1997; Koch, Heyder, & Weinacker, 2006; Yu, Guo, & Wu, 2014; White, et al., 2016; Tanaka, Kajita, Natsume, Saeki, &

Ohno, 2020). There are few examples of topics which have benefited from advances in the generation and handling of digital geospatial data (Avery & Berlin, 1992; Véga & St-Onge, 2009); while, there are studies having developed methods for using digital data (aerial photographs, satellite images, historical maps, and digital elevation models) (Gougeon, 1995; Hyyppa, Kelle, Lehikoinen, & Inkinen, 2001; Khare, Latifi, & Ghosh, 2018; Khare, Latifi, & Rossi, 2021). In Algeria there are relatively few studies which rigorously addressed the spatio-temporal dynamics of forests and its driving factors. And in the case of Kiadi cork oak forest (Akfadou Mountain), to our knowledge, hitherto, there is no published work on this topic and no research having used the historical digital aerial photographs and supervised classification. When the objective is the preservation of natural resources, it is important to understand not only the historical distribution of the forest but also the driving factors of the changes (Da Ponte, Roch, Leinenkugel, Dech, & Kuenzer, 2017). Based on this consideration, this paper aims to investigate decadal forest changes i.e. from 1981 to 2016, in Kiadi cork oak forest which is part of Akfadou forest; using multi-temporal aerial photographs with an attempt to identify the significant driving forces of the forest area changes.

MATERIAL AND METHODS

Study site

The study site (Figure 1) is the so-called Kiadi cork oak forest (36°41’14.49’’N to 36°39’54.89’’ N latitude to 4°30’31.95’’ E and 4°30’49.31’’ E longitude), located in the western part of Akfadou forest Mountain, in Tizi-Ouzou province, Northern Algeria. The study site extends over 277.53 ha. Altitude varies between 700 and 960 m above sea level. The climate is Mediterranean, with annual rainfall varying between 900 and 1200 mm (Messaoudene, 1989). The soils are based on simple units consisting of Numidian sandstone. Such forest area is under the authority of Azazga forest district service, which is part of the regional directorate of Tizi-Ouzou forest service. The study site consists in a pure cork oak (*Quercus suber*) cover with various species: *Arbutus unedo, Erica arborea, Phillyrea angustifolia, Cistus salviifolius, Cytisus triflorus, Crataegus monogyna, Rubus ulmifolius, Phillyrea latifolia, Myrtus communis* and herbaceous such as *Ampelodesmos mauritanica* and *Asparagus acutifolius*. Kiadi forest is surrounded by three villages belonging to Idjeur municipality: Bouaouane from the North, Aguarsafen from the South and Tifrit nait oumalek from the Western side. The study area is characterized by both healthy and important forest cover and by relatively large spaces characterized by forest cover loss likely due to the activities of the surrounding populations who cleared the land to extend their houses, install poultry sheds and beekeeping equipments. The study area is also surrounded by 9 uncontrolled landfills

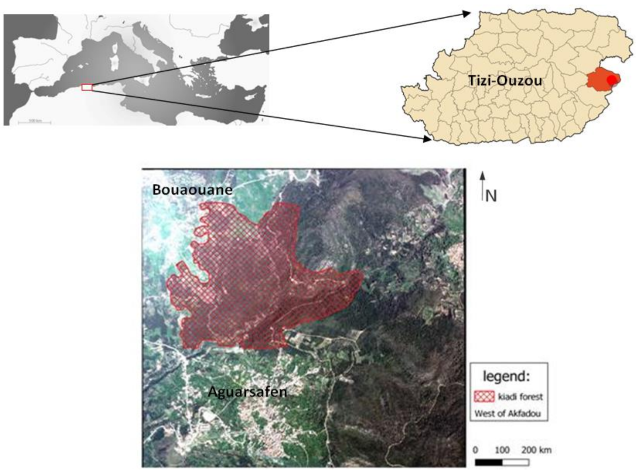

Figure 1. Location of the study area (Kiadi cork oak forest, Akfadou Mountain, Algeria)
(Source: (DIB Tassadit))

Data acquisition and pre-processing

Data acquisition

Datasets were available for 4 time periods (Table 1), the old cover was derived from colour balanced aerial photographs captured from an aircraft in 1981 and 1995 at a scale of 1/20000, whereas the more recent cover was based on colour digital aerial photographs, taken in 2011 and 2016 at a scale of 1/20,000, with a spatial resolutions of 24 cm and 50 cm respectively. Digital aerial photos are becoming common tools for aerial photography. They have better radiometric and spectral resolution than film cameras. Besides, their ground resolution and geometric accuracy are good enough for most applications. The digital aerial photographs presently used were acquired by "l'Institut national de cartographie et de télédetection (INCT, Algeria), i.e. the national Institute of cartography and remote sensing. They were captured with DMC Z/I Intergraph digital aerial camera, with 60% stereo overlap between adjacent images along-track and 30% across track. As pointed out in the literature, both flight altitude and degree of image overlap influence the accuracy of the 3D data produced. Here, DMC images were acquired at the standard altitude while, the aerial photographs, acquired from the same institute, were taken from an altitude of 4100 m, which resulted in a ground sample distance of approximately 1.5 m. The images have three bands (red, blue and green). 5 images were used for year 1981 and 1995 to obtain stereo images and a single digital image was used for year 2011 and 2016 (Table 1).

Table 1. Overview of photographs available in the database of the work
(Source: (DIB Tassadit))

Year	Spectral content	Spatial resolution (cm) GSD	Number of photos	Area covered (ha)	Sources
1981	RGB	150	5	277.53	INCT
1995	RGB	150	5	277.53	INCT
2011	RGB	24	1	277.53	INCT
2016	RGB	50	1	277.53	INCT

Data pre-processing

After the manual photo interpretation, each photo stereo-pair was imported in a GIS environment. The purpose of this computerization was the quantitative analysis of land use data base. This procedure requires scanned photogrammetric aerial photographs on which at least 2 fiducial marks can be distinguished. The photos received on paper version (i.e. those of 1981 and 1995) were scanned at a resolution of 600 dots per inch (DPI) and saved as a JPEG file. Although TIFF format is best for complete data preservation, the JPEG file format generates much smaller file sizes without compromising the ability to precisely locate GCPs at normal compression ratios.

We used PhotoScan professional which is a type of commercial computer vision software to generate a 3D point cloud from the sets of aerial photographs. The software uses the SFM approach for 3D reconstruction from overlapping collection of photographs. The workflow starts with the "Align Photos" step, which is the process used to find the camera position and orientation for each aerial photograph and build a sparse point cloud model [Agisoft LLC. Agisoft PhotoScan User Manual Professional Edition, Version 1.1. available online at: http://www.Agisoft.Com/Pdf/Photoscan-pro_1_1_en.Pdf. We selected "High accuracy" and "Ground control pre-selection" as settings. This step was conducted in the real-world coordinate system, which was Universal Transverse Mercator projection (Zone 31N, WGS 84) based on the camera positions provided by Airborne GPS. We also manually identified ground control points (GCPs) within the aerial photographs to improve the accuracy of the align photos step.

There are various methods for collecting ground control points. Here, GCP's were collected using two different procedures, so that their effect on the accuracy of the georeferencing could be assessed. A first set was collected by measuring the geographic position of some reference points by GPS in the field; a second set was obtained by collecting geographical co-ordinates of recognizable points on Google earth's image. Each dataset consists of at least 20 points, which were sampled systematically regarding both their geographical position and their elevation. On QGIS 3.4.4. software, each scene was reprojected using 20 ground control points (GCP) distributed evenly throughout the study area. Reprojection was performed using nearest neighbor resampling technique which provides an important spatial accuracy. At the end of the pre-processing, a clip by mask was applied to all the aerial photographs in order to delineate the borders of the study area.

Photo-interpretation

The success of aerial photo-interpretation varies with the nature of the objects, the quality of the photographs or images and the training and experience of the interpreter. In the present study, stand delineation and assessment of historical forest occupation were performed through a manual interpretation of the aerial photographs with three spectral bands (red, blue and green) acquired, on different intervals, using a stereo instrument. The stereoscopic view indicated that the ground occupation is visible in the photographs. As mentioned, the aerial photographs were interpreted for Kiadi cork oak forest land-cover and the vegetated spaces by using the standard photo-interpretation key developed on the basis of the target area recognition with aerial photographs. This step relies on the delineation of homogeneous entities on the photos in terms of land cover. The percentage of area covered by the identified units is then visually estimated. The characters of the vegetation cover on aerial photographs reflect, to a large extent, some global ecological aspects. Indeed, the forests appear on the aerial photographs in dark colors and the shades of this color, from dark to light, indicate changes in forest density and in land occupation through the 35 years period.

Supervised classification

The purpose of the supervised classification applied on aerial photography is to extract as much as possible interesting information and to remove all that is unnecessary. At each point of the image, a label from a collection defined previously is assigned. This collection of labels is called classes. In this study, in order to analyze the long-term changes of forest dynamics of Kiadi cork oak forest, a long term analysis of change was conducted using a supervised classification based on series of aerial photographs. We used forest cover layers for four time slices (1991, 1995, 2011 and 2016) to assign progression/regression historical dynamics. Training samples were collected from these mosaics. Around 30 samples were selected for each class in order to produce land cover maps. Selecting training samples from these photos was allowed by the very distinctive signature of the forest. Same samples with slight modifications in each mosaic (addition and removal of few training samples) were used for the classification of all the photo dataset. The aerial photographs pre-processed were classified into four major and well delineated classes such us: a) tree vegetation, b) herbaceous vegetation, c) build-up surfaces and, d) roadways (Table 2) for years 1981, 1995, 2011 and 2016 using the maximum likelihood algorithm in QGIS software. The process was repeated several times in order to refine them and validate the results.

Table 2. Definition of the supervised classification classes

Classes	Supervised classification class definition
Tree vegetation	Area covered by cork oak trees
Herbaceous vegetation	Area covered by a herbaceous stratum
Build-up surfaces	Area occupied by habitation
Roadways	Roads crossing the study area

RESULTS

Land cover status

Data registered in figure 2 and table 3 reveal that both positive and negative changes occurred in the land cover patterns of Kiadi forest. During the last 35 years, the data displays losses and gains in each class, highlighting a clear unprecedented increase in built areas and roadways with a noticeable decline in both the tree cover and the herbaceous vegetation cover.

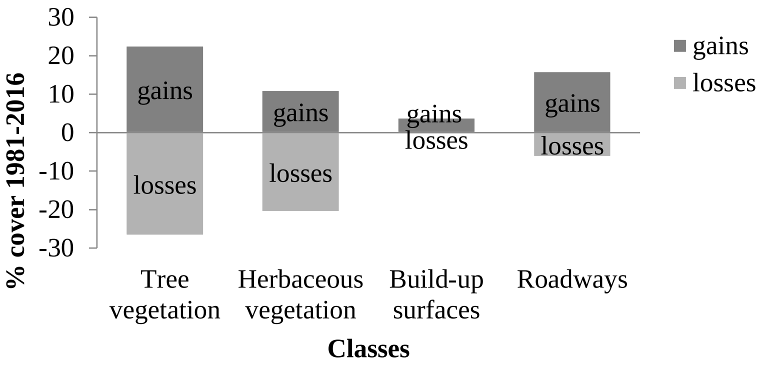

Figure 2. Dynamics of the Kiadi forest over 35 years period based on the percentages of land occupation classes (Source: (DIB Tassadit))

Table 3. Area estimates of major land cover classes in Kiadi cork oak forest at different periods (Source: (DIB Tassadit))

Class/Area	1981s		1995s		2011s		2016s	
	ha	%	ha	%	ha	%	ha	%
Tree vegetation	155.61	56.07	101.16	36.45	163.71	58.99	144.18	51.95
Herbaceous vegetation	103.94	37.45	134.57	48.49	81.31	29.3	77.71	28
Build-up surfaces	0	0	2	0.72	10.02	3.61	10.71	3.86
Roadways	17.98	6.48	39.8	14.34	22.48	8.1	44.93	16.19
Total	277.53	100	277.53	100	277.53	100	277.53	100

Over the last 35 years period, the herbaceous vegetation surfaces and tree cover surfaces were reduced by 9.45 and 4.12 % respectively (Table 4). Indeed, the study area experienced varying changes in land cover between 1981 and 2016 (figure 3). Overall, the tree vegetation cover decreased from 155.61 ha in 1981 to 144.18 ha in 2016. During this period, the major losses were in 2016; whereas, build up surfaces increased progressively reaching a peak in 2016. Apart from forested area, the herbaceous vegetation decreased from 103.94 ha in 1981 to 77.71 ha in 2016. Roadways, for their part, represented a relatively important surface (i.e. 44.92 ha) in 2016 within the studied area as a consequence of a relatively high demand for access to the forest.

Table 4. Amount of changes in different land cover categories in Kiadi cork oak forest (Source: (DIB Tassadit))

Class/change	1981s-1995s		1995s-2011s		2011s-2016s		1981s-2016s	
	ha	%	ha	%	ha	%	ha	%
Tree vegetation	-54.45	-19.62	62.55	22.54	-19.53	-7.04	-11.43	-4.12
Herbaceous vegetation	30.63	11.04	-53.25	-19.19	-3.61	-1.3	-26.23	-9.45
Build-up surfaces	2	0.72	8.02	2.89	0.69	0.25	10.71	3.86
Roadways	21.82	7.86	-17.32	-6.24	22.45	8.09	26.95	9.71
Total	0	0	0	0	0	0	0	0

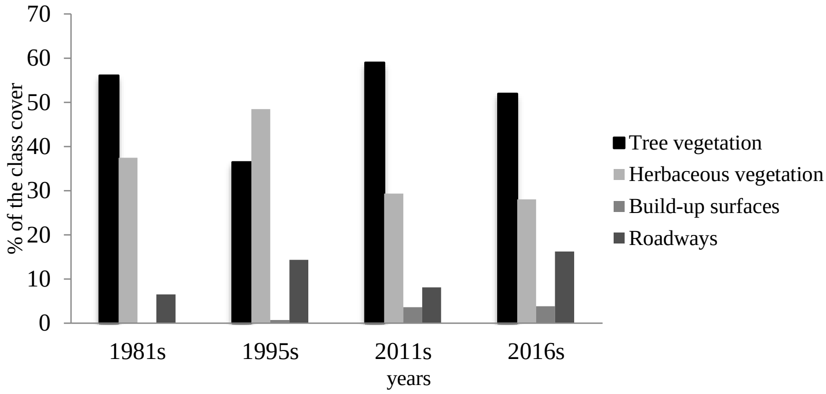

Figure 3. Land cover changes in Kiadi cork oak forest between 1981 and 2016
(Source: (DIB Tassadit))

Intra-decades land cover dynamics

We produced a dataset of annual forest dynamics maps between 1981 and 2016 for the Kiadi cork oak forest based on aerial photographs (Figure 4) then, we analyzed the changes decade by decade in order to evaluate the intra-decades dynamics (Figure 5). Non forested areas are found in the outer periphery of the Southern-West and Northern-West parts of this forest. The major changes were concentrated in the Southern side of the area, and are caused by anthropogenic pressure.

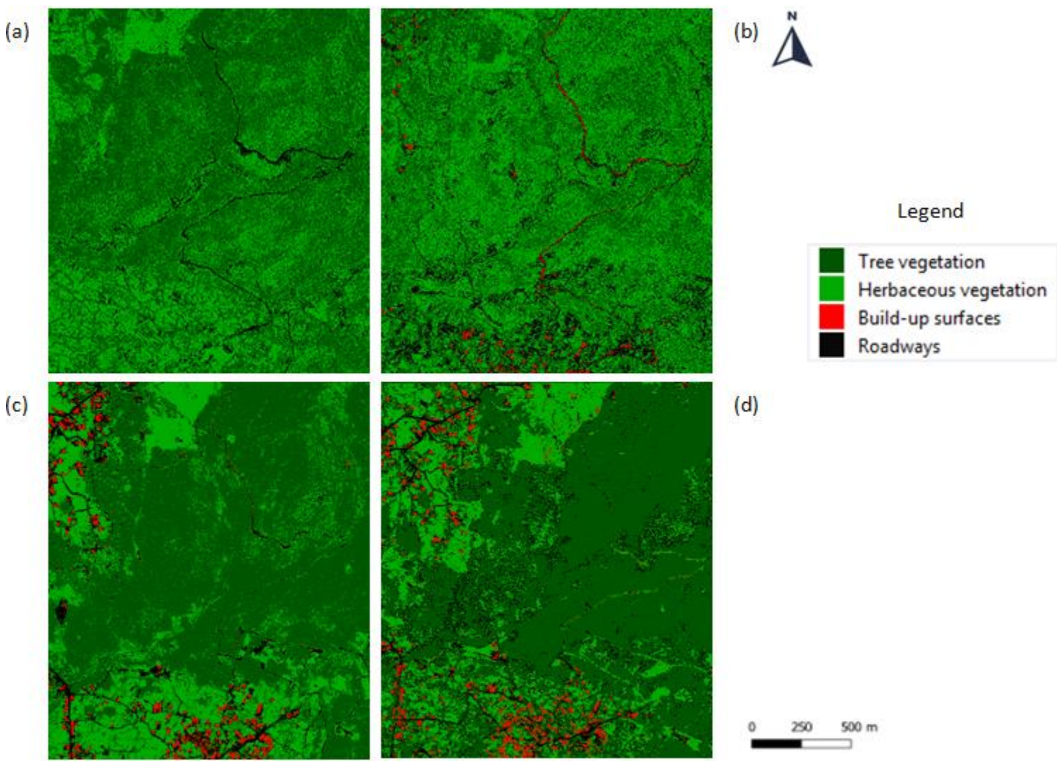

Figure 4. Land cover classification outputs at different years: (a) 1981, (b) 1995, (c) 2011 and (d) 2016
(Source: (DIB Tassadit))

Land cover for 1981-1995 period

During this period, the most significant change was in the green area category corresponding to tree and herbaceous vegetation covers. Tree cover decreased by 19.62% (54.45 ha) between 1981 and 1995, while the herbaceous vegetation area increased by 11.04%. This period coincided with large and moderate forest fires, particularly the fire of 1994, which was devastating. In 1981, no built surfaces were settled (figure 4), all the area was vegetated but in 1995 some houses were observed, which occupied 0.72% of the whole Kiadi surface. Roadways increased and occupied 7.86% of the whole area (Figure 5).

Land cover for 1995-2011 period

In comparison with the previous decade, the best tree cover was observed between 1995 and 2016; gaining about 22.54% (62.55 ha) of the total area. A loss of 19.19 % by the herbaceous vegetation surface was reported in that period; it was converted to forest and houses which started appearing and expanding in this forest, occupying new areas of 2.89% (8.02 ha) (Figure 5).

Land cover for 2011-2016 period

A reduction in forest cover was recorded for this period but at a lower rate compared to the previous period (1981-1995). Cork oak forest decreased by 7.04%, resulting in a loss of 19.53ha of the total forest cover; the same observation applies for the herbaceous vegetation which lost a surface of about 1.3%. In the period 2011- 2016 the built surfaces expanded by 0.25% (0.62 ha) and the roads by 8.09%, pointing out an increase in human activity in this area (Figure 5).

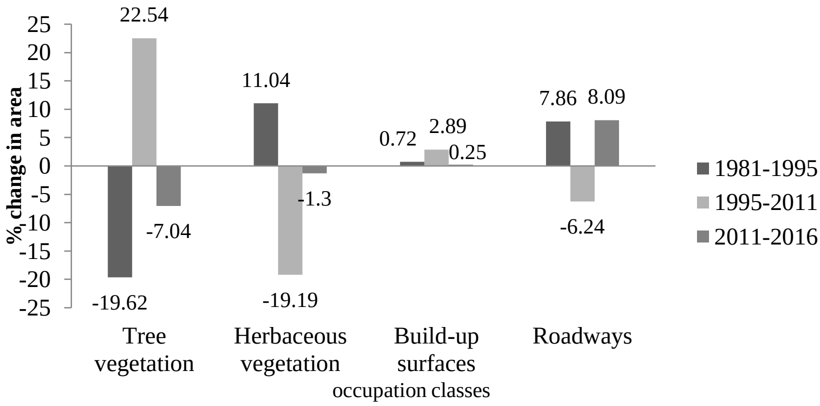

Figure 5. Intra-decade changes in Kiadi cork oak forest area according to land occupation classes (Source: (DIB Tassadit))

DISCUSSION

The study of forest dynamics is concerned by the changes in forest structure and composition over time, including its behavior in response to anthropogenic and natural disturbances (White & Jentsch, 2001). Here, we analyzed the spatio-temporal dynamics of a cork oak forest extending across 277.53 ha for a period of 35 years. Such analysis was based on photo-interpretation and supervised classification. Forest surfaces decreased gradually and were replaced by built areas, herbaceous vegetation surfaces and roadways following population demography which generated additional demand for space and for forest resources.

During the last decades, land use and land cover have changed drastically in Algeria, due to a growing population and a changing economy (Saadi et al., 2021).The present study revealed noticeable changes in Kiadi cork oak forest over the 35 years period with rates of forest cover loss being more important than the gains. Data analyses by decade indicate rates and patterns of change which differed for the three assessed periods. From 1981 to 1995, the overall changes were less accentuated in comparison with the second interval (1995-2011) characterized by new private houses spreading outside the ancient settlements of the village towards the forest area. However, the surface of tree cover was more important than the second interval pointing out a better situation of the forest during that period. The changes continued during the third interval (2011-2016) with a similar trend but at a higher rate (loss of Tree and herbaceous cover and gains in build-up surfaces and roadways). The quantification of surface loss and gain, during the last decades, indicates that the study area lost 37.66 ha of its green area of which 10.71 ha devoted to building and 26.95 ha devoted to roadways.

The present work indicates that the Northwestern and the Southern sides of Kiadi were the parts of the forest subject to forest cover losses. The displayed forest regressive dynamics is significant due to the surrounding villages of such forest sides and to an easy access for some agricultural activities. Anthropogenic pressure on Kiadi cork oak vegetation cover including logging, overgrazing, fire and clearing, revealed the regressive evolution of cork oak trees in favor of anthropogenic landscapes since such factors are a high candidates for forest regressive dynamics (Kadmon & Harari-Kremer, 1999; Akobi, Amoussou, Yabi, & Boko, 2018). Anthropogenic actions are major factors in forest changes and they affect the structure, composition and dynamics of forests at various spatio-temporal scales (Oloukoi, 2013; Kafy, et al., 2021).

Indeed, the history of Kiadi cork oak forest during the decade of 1981 to 1995 is intimately linked to the political and security context of Algeria. Algerian forests including Akfadou underwent very hard political and unsecured period (Meddour-Sahar, Meddour, & Derridj, 2008). There was an exodus of people from the mountain towards the centers of regions. Consequently during this period, the building class was almost absent and started to appear only after the stability of the country's security situation, in the beginning of the 2000s, coinciding with an exponential increase of the buildings and houses at the expense of the forest area. On another hand, during many years of that period, authorities were sitting up fires for security reasons, causing also forest cover loss. Indeed, Algeria lost 221 367 ha and 271 598 ha of its forested areas in 1983 and 1994 respectively (Meddour-Sahar, Meddour, & Derridj, 2008). Concordantly, Ramade (1997) and Kweyu, Thenya, Kiemo and Emborg (2020) pointed out the role of political disorders in forest cover losses.

Obviously, in Algeria, during the recent decades, urbanization and building of infrastructures and houses became an integral part of the socio-economic system giving rise to building expansion at the expense of forested areas in northern Algerian mountains; hence the importance of spatio-temporal evaluation of the phenomenon (Saadi, Bouder, Benkaci, & Abbes, 2021). Over the 35 years period, the natural Kiadi forest underwent a clearing in relation to the socio-economic changes. Two trends of change were evidently observed, a gradual increase in built areas and roadways from one hand and a loss of tree cover and herbaceous vegetation surfaces from another hand with the buildings taking place over the vegetation cover. According to the data mentioned in the master plan for development and urbanism (PDAU, 2012) (the three villages of Idjeur municipality surrounding the Kiadi forest had a high impact on such forest through both population growth and its sprawl at the expense of forested areas and several agricultural practices. The number of inhabitants rose from 8,222 in 1987 to 10,301 nowadays. This trend is not an exception for the target forest but is of concern also in other parts of the world, which, could be explained by the demographic growth and the unplanned building programs (Weng & Yang, 2004; Carr, Suter, & Barbieri, 2005; Hassan & Nazem, 2016; Akobi, Amoussou, Yabi, & Boko, 2018; Kafy, Rahman, Hasan, & Islam, 2020). Indeed, this phenomenon opens up the forest for encroachments through grazing, timber logging activities, apiculture, aviculture and others(Da Ponte, Roch, Leinenkugel, Dech, & Kuenzer, 2017; Rawat & Kumar, 2015). The PDAU (2012) mentioned the presence of over 18 poultry sheds at the level of the villages surrounding Kiadi forest, of which 14 and 4 at Iguersafene and Tifrit nait oumalek respectively. The same source identified 459 hives, in the same area, of which 159 at Iguersafene, 200 at Tifrit nait oumalek and 10 at Bouaouane.

Forest fires also played a crucial role in the dynamics of Algerian cork oak forests, including the study area where they constitute a scourge that threatens forest sustainability. Although cork oak is a fire resilient species (Pausas, Alessio, Moreira, & Segarra-Moragues, 2016), numerous studies suggest its variable responses to fire (Catry, Moreira, Duarte, & Acácio, 2009; Moreira F. , Catry, Duarte, Acácio, & Silva, 2009; Catry, Rego, Moreira, Fernandez, & Pausas, 2010; Moreira F. , Catry, Rego, & Bacao, 2010). Fire severity plays a significant role in cork oak trees dynamics (González, Trasobares, Palahi, & Pukkala, 2007) and the regressive dynamics of Kiadi forest between 1981 and 1995 can be explained by intensive and recurrent fires sets for security reasons, and some peaks of fire severity such as that of year 1994 may be linked to the xericity of such year (Meddour-Sahar, Meddour, & Derridj, 2008).This phenomenon applies also for other Mediterranean regions, such as Spain (Vélez, 1997) or France (Ningre, 1996). The fires of year 1994 concerned almost the whole Kiadi cork oak forest, decreasing its tree cover surface, one year after, from 155.61 to 101.16 ha. Similarly, during the last studied decade (2011-2016), Kiadi forest lost 19.53 ha of its tree cover surface due to four consecutive fires of 2014 which covered 40ha of the entire area. Indeed, it is worth mention the issue of the uncontrolled landfills in forest areas which is a real cause of forest fires. Kiadi forest is surrounded by 9 landfills, of which, 7 belonging to Iguersafene village, 1 to Bouaouane and another one to Tifrit nait oumalek (PDAU, 2012).

This study proved that the new digital aerial photos are very accurate for studying a small scale forests, however the use of Aerial photographs as data for supervised classification and analysis of the forest dynamics has been generally a success. The photo-interpretation and the digital aerial photos classification coupled with GIS have demonstrated its ability to provide comprehensive information on the nature; type and location of the land cover changes as a result of rapid building expansion and forest fires. However, a certain uncertainty in image classification still remains which may constitute a drawback of such method for two reasons: firstly, the roadways class and the building class have been confused in some results due to their similar spectral signature and this confusion hindered the obtainment of very accurate results; secondly, the image classification method used in this study was not spatially implicit. The method thus, has limitation in improving image classification accuracy of individual classes (Weng, 2002).

CONCLUSION

In conclusion, the study conducted in the cork oak forest of Akfadou Mountain (Algeria) indicates that multi-temporal aerial photographs may help quantifying and analyzing spatial and temporal phenomena which are otherwise not achievable through conventional methods. Forest spatio-temporal dynamics analysis is made possible by these cost effective technologies through time and cost saving and better accuracy.

The results of this study provided data on dynamics of Kiadi cork oak forest between 1981 and 2016. The analysis and the field survey concerning the land occupations revealed the main causes of the forest losses. Based on the major findings the main conclusions are as following:

- Results of the forest change analysis based on aerial photographs revealed a total forest cover loss of almost 11.43 ha (i.e. 7.35%) between 1981 and 2016.
- The outcomes of the time series analysis (by photo interpretation and supervised classification) revealed an important increase of forest losses and changes through the 3 recent decades. According to the history of the region, the present change is due to forest fires (a devastating fire occurred in 1994 and in 2014) and also to the population growth in the surrounding villages which led to deforestation for urbanization.

Further studies could rely on satellite images and high resolution imagery to increase the accuracy of the results, in particular when considering an assessment of forest cover change at a small scale. In addition, with the use of satellite imagery, a change matrix of land use during the given period could be addressed to quantify the land changes. Moreover, it would be interesting to consider additional dynamic information on the state of the forest (such as yearly forest degradation and regeneration rates) which would add more information with regards to the pressure exerted on forest resources by surrounding populations. The use of multi-temporal information along with ground data are key components for designing and supporting conservation strategies and policies. It is crucial to consider not only the outlook of rural populations but also their influence on the fate of natural resources over time.

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