sciendo

Ekológia (Bratislava) - Journal of the Institute of Landscape Ecology, Slovak Academy of Sciences Vol. 40, No. 3, p. 212–221, 2021

doi:10.2478/eko-2021-0023

STUDY OF THE DYNAMICS OF VEGETATION COVER BY SATELLITE IMAGES: CASE OF EL KALA NATIONAL PARK (ALGERIA)

BOUBAKER KHALLEF ✉, KHALED BRAHAMIA, ABDELRAZZEK OULARBI

Research Laboratory Natural Resources and Development, Faculty of Earth Sciences, Planning Department, Badji Mokhtar University, Annaba, Algeria; e-mail: bokhallef@yahoo.fr, Khaledbrahamia@gmail.com, ouelarbi@yahoo.fr

✉ Corresponding author

Received: 3 November 2019 / **Accepted:** 5 March 2020

Abstract

Khallef B., Brahamia K., Oularbi A.: Study of the dynamics of vegetation cover by satellite images: Case of El Kala National Park. Ekológia (Bratislava), Vol. 40, No. 3, p. 212–221, 2021.

In recent years, wetlands in Algeria have experienced a significant deterioration in the natural quality of the landscapes that compose them. This is the case of the El Kala National Park in the far northeast of Algeria. The state of degradation of the open plant of this park is urgently to look at the state of the art in the face of multiple threats that affect these spaces. The exploitation of the Landsat satellite images, coupled with GIS and supplemented by field surveys and climate and documentary data, made it possible to analyze the vegetation cover and its evolution between 1987 and 2016. The results of our study show that the vegetation cover during the period (1987–2016) lost 7.49% (6038 ha) of its natural vegetation. Also this work allowed us to set up a cartographic base which can constitute a precious tool of management of this protected area. This method is simple and adaptable to other protected areas of Algeria.

Key words: remote sensing, wetlands, vegetated cover, degradation, El Kala National Park, Algeria.

Introduction

In Algeria, the influence of natural and anthropogenic factors on fragile environments, particularly natural parks and wetlands, leads to the degradation of resources that are difficult to renew in these environments, vegetation cover, water, and soils. El Kala National Park is the subject of this study, with these wetlands inscribed on the Ramsar List, and its endemic fauna constitutes a mosaic of particular ecosystems and unique in the Mediterranean basin. The El Kala National Park is an inhabited entity; the high population growth (199 inhabitants/km^2 in 2016) is reflected in a pressure on the biological spaces (Brahmia, Samouk, 2010). The changes in land use throughout the park's territory are multiple and varied; housing and other services have exacerbated the need for urbanized land and building materials, and urbanization from 1998 to 2004 has affected all the communes of the park with rates ranging from 39% in Bougous to 56% in El kala and El Taref (Bouazouni, 2004). In addition, the stretch of the East-West Highway, 17.8 km long and 120 m wide, is a plague in the forest landscape. Other pressures on the park space are the crops which now extend over a useful agricultural area of 13,149 ha (DSA, 2016), combined with extensive livestock farming with a herd estimated in 2004 at 10,410 head of cattle, 16,225 goat heads, and 40,807 sheep heads and at the end the delinquent clearing (411delits are 520 ha for the period 1992–2012).Fires of anthropogenic or natural origin are another devastating factor that weakens the vegetation cover of El Kala National Park (3000 ha in 2000 and 225.38 ha in 2016). Irregular rainfall and repeated periods of drought combined with severe anthropogenic impacts have led to serious ecological and social disturbances (Raach, 2007). Today, we are witnessing an insidious but continuous degradation of this natural heritage; water erosion varies from 0 to> 75 t/ha/year spread over the whole of the study area, with an average of about 13.48 t/ha/year leads to siltation of lakes and dams (Khallef et al., 2018), water pollution, and plant diseases. Given this paradoxical situation for a park that is supposed to be protected by national and international regulations, it is of utmost importance to reactivate or even upgrade the observation and management systems for this type of space. The main question that arises of itself is how to reduce the vulnerability of the main factor which is moreover the essence of this space namely the vegetal cover in the face of the multiplication of the natural and anthropic attacks? To answer this question, a diachronic study is the most appropriate for the case of this site. Based on satellite images from the Landsat program, the aim is to characterize and map the different types of land use, to evaluate the dynamics of vegetation cover between 1987 and 2016, and to remove problematic areas (degraded areas).This upgrading of information by GIS and remote sensing tools will modernize decision support planning techniques essential for managers to implement an appropriate natural resources management policy. Today more than ever, the management of the territory of El Kala National Park requires an integrated system of decision support to preserve the park character of this space.

© The Author(s) 2021. This is an open access article distributed under the terms of the CC BY-NC-ND license.
https://content.sciendo.com/view/journals/eko/eko-overview.xml

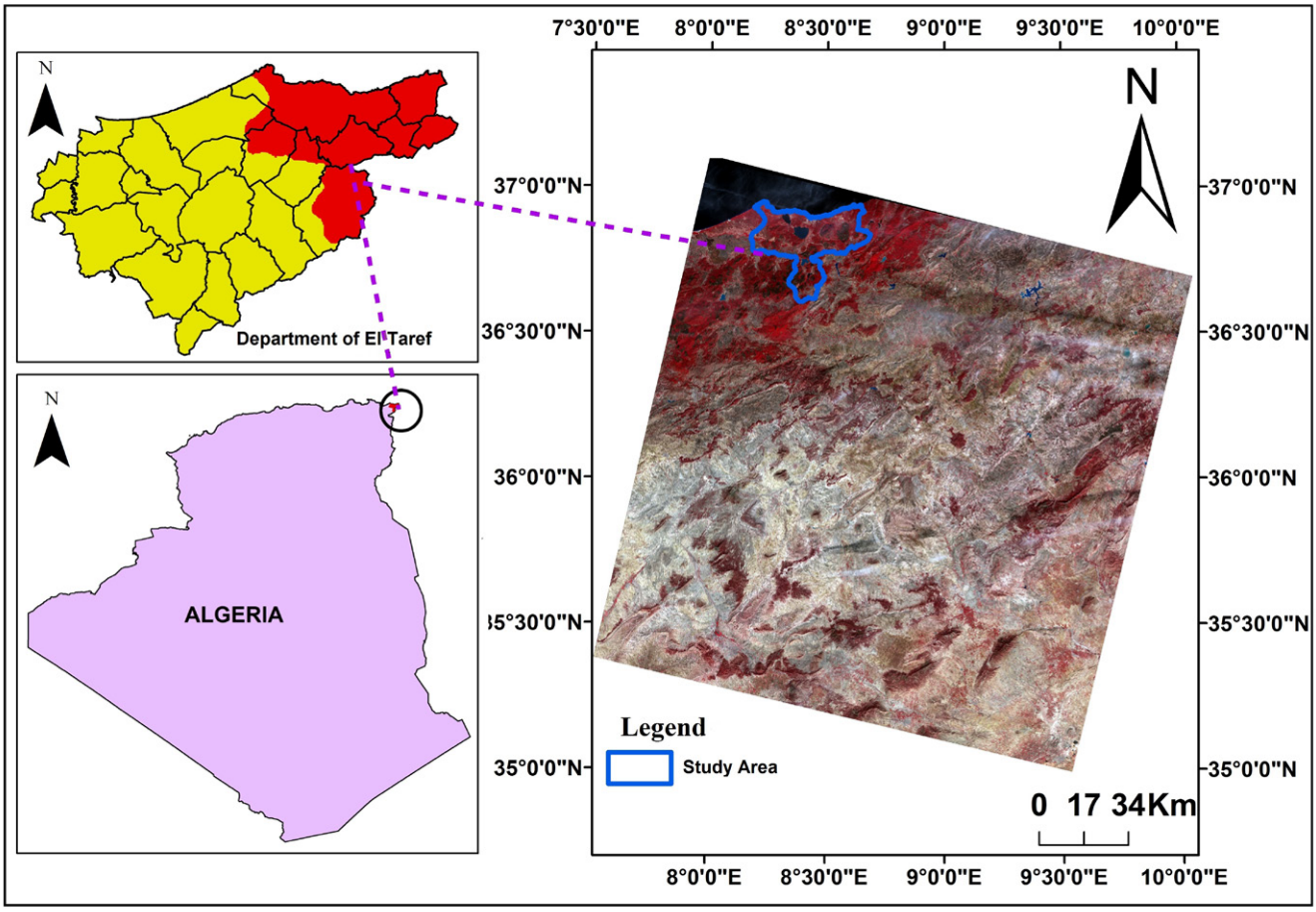


Fig. 1. Location of study area.

Material and methods

Presentation of the study area

The El Kala National Park, one of the first parks created in Algeria, with an area of 80,510 ha, is located in the extreme northeast Algerian, bounded by the following geographical coordinates: latitude between 36°56'N and 36°34'N and longitude between 8°12'E and 8°41›E as shown in Fig.1.

It is bounded on the east by the Algerian-Tunisian border, on the north by the Mediterranean Sea, on the west by the end of the alluvial plain of Annaba, and on the south by the mountains of the Medjerda. Administratively, the El Kala National Park is composed of the municipalities of Ain El Assel, Barrihane, Bougous, Bouteldja, El Aioun, El Kala, El Taref, Ramel El Souk, Souarekh, all the municipalities of the wilaya of ‹El-Tarf, five municipalities are completely included in the national park (Fig. 2). Seen by the satellite images, the park emits a mosaic of topographical and color forms.The first topographic form that is obvious in the eyes is that it is occupied by water, it is the low-lying areas where the altitude is sometimes negative, it is the domain of the lakes: Tonga, Obeira, and Mellah, and geographically they are an intermediate space between the coastal hills that overlook the sea by modest altitudes not exceeding 200 m and the mountain environment which in reality is only the eastern end of the Tellian range. It is in the form of mounds of modest altitudes 400 and 500 m. Nevertheless this physical unit can reach 1073 m of altitude inside the chain. The climate is subhumid Mediterranean with a rainy period from October to April and a dry period from May to September, with rainfall amounts ranging from 710 to 910 mm/year. The average annual temperature is around 18 °C. The hottest months are July and August, when the average temperature hovers around 25 °C. The coldest months are December and January with average temperatures of around 12 °C. The vegetation cover includes cork oak forests, zeen oak, maritime pine stands, and Eucalyptus reforestation. There are also dense scrub oak kermes on the coastal dunes and Mediterranean maquis with heather, myrtle, arbutus, worms, and other species (Khallef et al., 2018).

Methodology

It is necessary in such a study as the case of the El Kala National Park to be able to study the dynamics of the vegetation cover in order to identify the problematic areas to use geographic information systems (GIS) and remote sensing. This study is based on

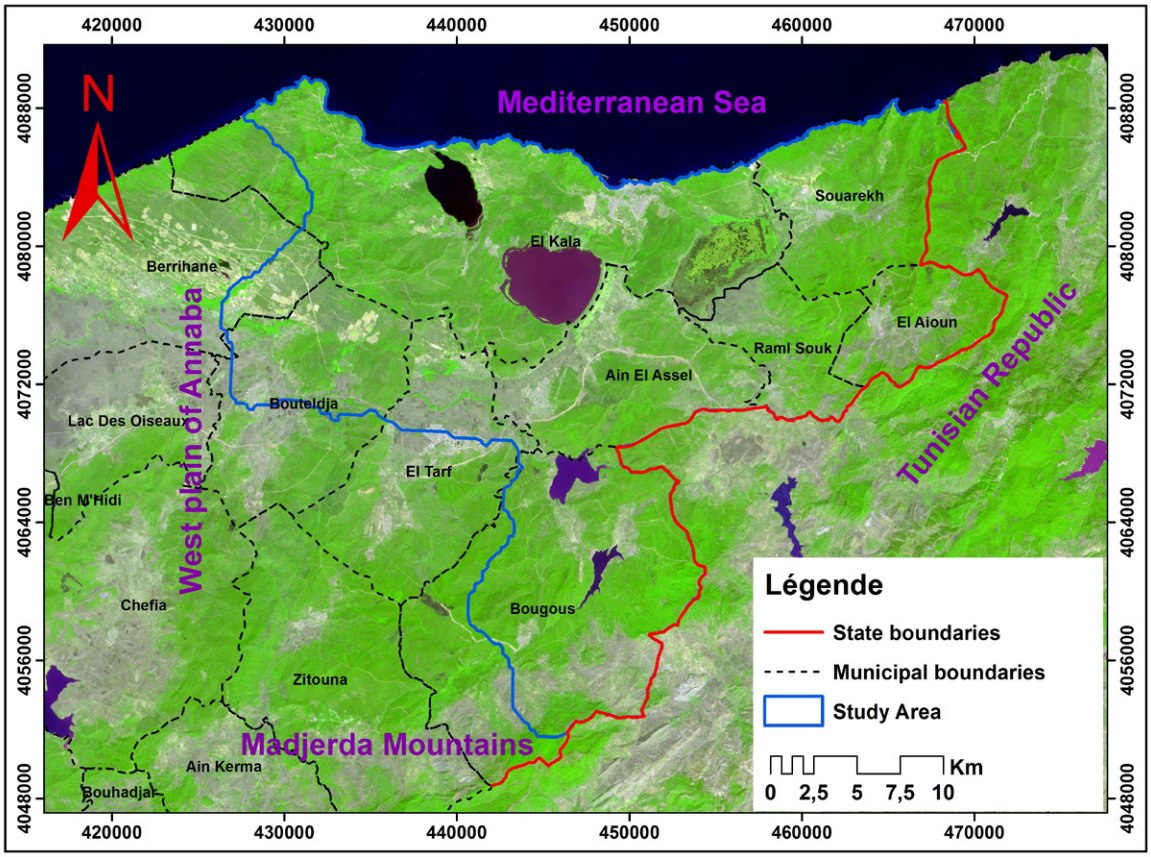


Fig. 2. Administrative situation of the study area.

the processing and analysis of a time series of medium-resolution (30 m) satellite images using ENVI 5.1 and Arc Gis 10.2.2 software over the period1987–2016 (Landsat 5 TM1987, Landsat 7 ETM + 2002, and Landsat 8 OLI/TIRS 2016), as well as field surveysand socioeconomic and climatic data. The basic satellite images of this work are all acquired during the dry season, the period of maximum differentiation of the land-use elements. The three reference dates chosen cover two periods with singular situations for the region and Algeria. The first situation from 1987 to 2002 (15 years) is marked by extreme drought in 1992 (412.70 mm), 1998 (463.60 mm), and 2002 (399 mm) and coupled with an acute security crisis (black decade 1991-2001) when the forest was totally abandoned. The second period from 2002 to 2016 (14 years) is marked by the return to social peace, a favorable situation for investments in various fields and socioeconomic transformations which accelerated the attacks on the forest areas, by various modes (construction of housing and light industries, etc.), despite the return to normal of a substantial rainfall, the resumption of reforestation and the reintegration of foresters into their natural element, the park remains in a precarious situation, the threat to biological balance is present and deserves attention at all times. The coverage of the study area is produced from three images, from 1987, 2002, and 2016 (the images of 1987 and 2002 are produced after a mosaic of two scenes), subject to a geometric and radiometric correction followed by a geometric mask urban areas and the water body to avoid any confusion with other land-use units. Our satellite images are all geometrically cut to limit the study area and reduce the data processing time, thanks to a vector file format EVF, which corresponds to the delineation of the study area of El Kala National Park. To obtain a good information-rich color composition, we used the calculation of the optimum index factor (OIF) using the ILWIS software. The good color composition rich in information for the images acquired in 1987 and 2002 is the one that composes the bands B6, B4, and B1, whereas the image acquired in 2016 shows a good three-color process from the spectral bands B6, B5, and B1.The coupling of remote sensing, the GIS, and the reality of the field allow to integrate a quantity of sufficient data to analyze the change of the vegetation cover in the El Kala National Park for 29 years (1987-2016). The "Maximum Likelihood" supervised classification used as an approach is based on the identification of homogeneous samples in representative images of both types of surfaces (vegetation and off vegetation) (Congalton, 1991).These samples then form a set of test data (Soudani, 2006). The choice of test data is based not only on the types of surface identified in the images but also on the field knowledge. The intensive visual analysis of our images, the use of Google Earth support, and some features of the ENVI 5.1 software (principal component analysis and unsupervised classification) provided a general idea of the components of the study area. In addition, the information acquired during field surveys on one hand and the results obtained from the visual interpretation of the satellite image on other hand made it possible to determine eight classes: Forest, Reforestation, Maquis, Rangelands, Summer Crops, Bare soil, Urban, and Body of water.

Results

The supervised classification (maximum likelihood) of the ground units of the El Kala National Park allowed us to obtain good-quality maps (Figs 3, 4, and 5).This is due, on one hand, to the shooting date of the satellite images in the dry season (excluding vegetation) and, on other hand, to the good knowledge of the terrain. However, it was preferred the use of color images for the years 1987, 2002, and 2016 to show the reality of the field on one hand and visually distinguish the various classes on other hand.

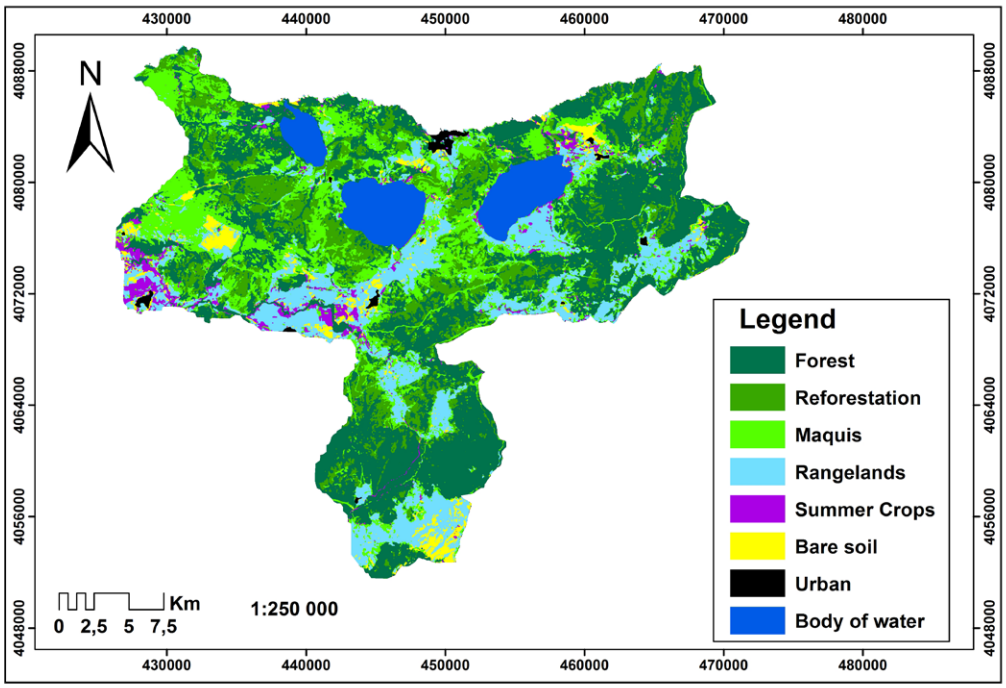


Fig. 3. Land use of El Kala National Park: Landsat 5 TM classified image selected for the year 1987 (resolution 30 m).

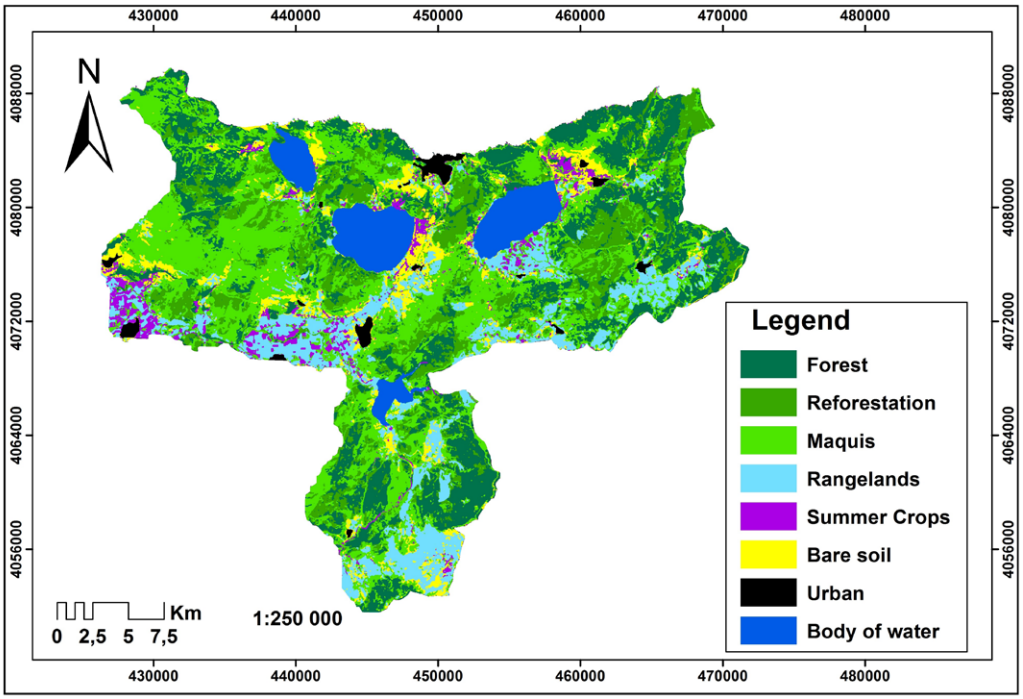


Fig. 4. Land use of El Kala National Park: Landsat 7 ETM+ classified image selected for the year 2002 (resolution 30 m).

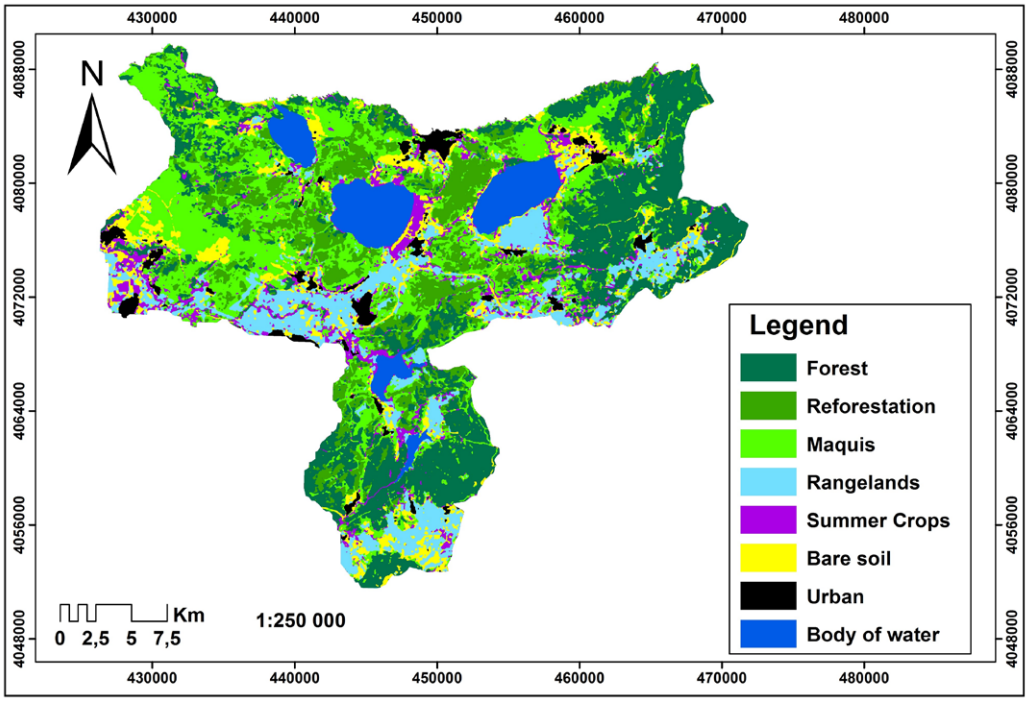


Fig. 5. Land use of El Kala National Park: Landsat 8 OLI/TIRS classified image selected for the year 2016 (resolution 30 m).

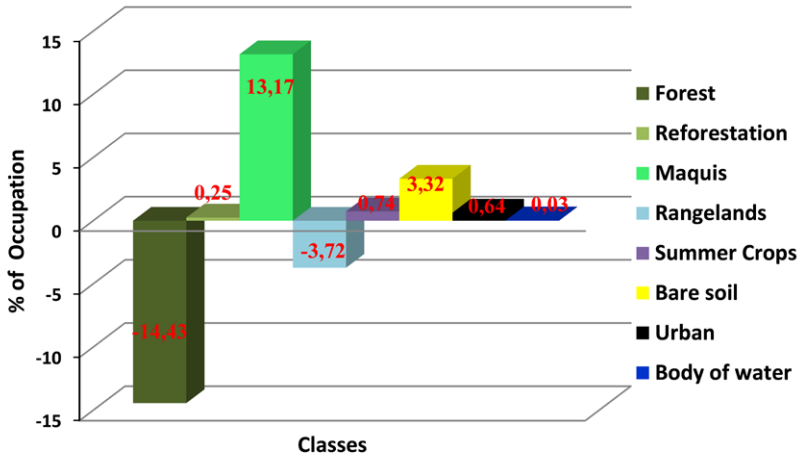


Fig. 6. Land cover dynamic rate between 1897 and 2002 (El Kala National Park).

Consecutive states of vegetation cover

The result of the classification of the images of 1987, 2002, and 2016 realized thanks to the software "ENVI 5.1" allows us to estimate quantitatively the vegetation cover of the national park of El Kala and to highlight the various changes which occurred during 29 years.

The dynamics of vegetation cover between 1987 and 2002

The map of land use resulting from the classification of the image of 1987 reveals only the vegetal cover (forests, reforestation, and maquis), which occupy 71.38%, that is, 57,467 ha of the total surface of the study area. With an area of 28,622 ha, forests are the most dominant type of vegetation cover. The dynamics of these eight classes (Fig. 6) show that the forests experienced a considerable regression during thisperiod (–14, 43%), they went from 35.55 to 21.12%. Rangelands have also lost –3.72% of the total area, unlike the maquis which has increased by 13.17%, as the bare soil has increased from 3.02% in 1987 to 6.34% in 2002, in 3.32% more during this period. The remaining classes (reforestation, summer crops, urban, and water) all experienced a slight increase, which did not exceed 1%.

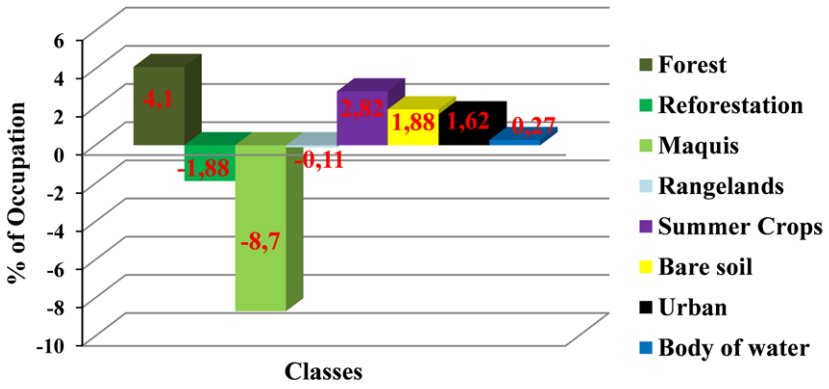


Fig. 7. Land cover dynamic rate between 2002 and 2016 (El Kala National Park).

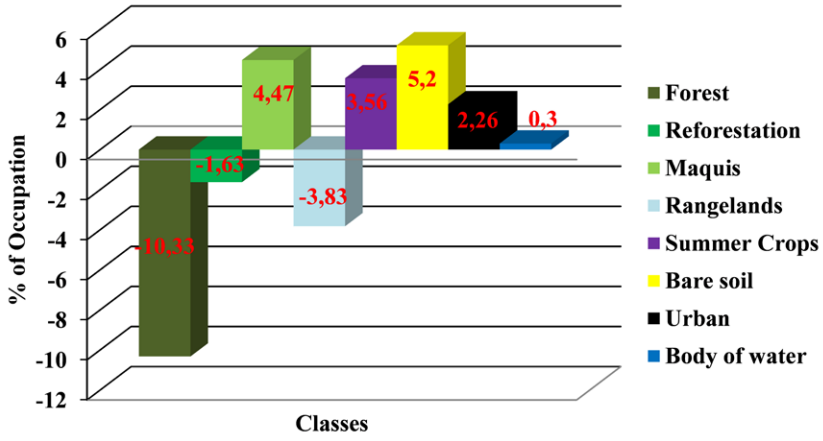


Fig. 8. Land cover dynamic rate between 1987 and 2016 (El Kala National Park).

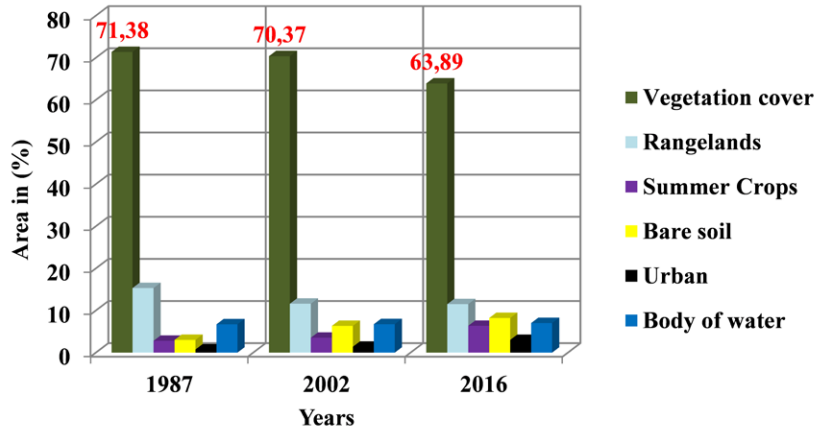


Fig. 9. Dynamics of vegetation covers 1987-2016 (El Kala National Park).

The dynamics of vegetation cover between 2002 and 2016

From the year 2002, forests have recovered more or less importantly and they recordan increase of 3304 ha or 4.10% for 14 years (Fig. 7). On other hand, there is an alarming deterioration of the maquis of –8.7% of its surface area (clearings, fires, urbanizations). Indeed, during this period, Algeria has just emerged from a security crisis which has encouraged people to return to urban or rural areas, as evidenced by data on construction activities where the built space to grow by 1.62%, bare soil to grow by

1.88%, and the recovery of agricultural activity rose from 3.54% in 2002 to 6.36% in 2016.Reforestation and rangelands decreased by −1.88 and −0.11%, respectively. During this period, the only class that did not exceed the 1% from 1987 to 2016 is the water bodies, increasing by 0.27% for the period (2002-2016).

Syntheses of vegetation cover dynamics between 1987 and 2016

During this period (29 years), human pressure is maintained on the Park, summer crops, bare soil, and urbanization continue to take more and more space, and only water bodies manage to maintain certain stability (Fig. 8). There is also a spectacular growth of the maquis with an area of 16,204 ha in 1987; it climbs to 19,791 ha in 2016 or 4.47%. In contrast, the area of forest and reforestation is subject to a surprising deterioration with a rate of −11.96%, the routes also lost (−3.83%) of their initial area.

Discussion

An overview shows that the greatest changes or mutations are marked by the regression of the areas of woody vegetation (forests and reforestation). Figure 9 shows a clear regression of vegetation cover. This regression reaches −1.01% for the first 15 years (1987-2002), i.e., an area of 814 ha lost. For the last 14 years from 2002 to 2016, we observed a loss of vegetation cover estimated at 5224 ha, i.e., a rate of −6.48%.

In 29 years of observation, the plant cover of the El Kala National Park has lost −7.49% of its surface area or 6038 ha, which have changed land-use class. The pace of evolution of spaces: 208,20 ha per year led to a very high increase of bare soil and urban +8.76% between 1987 and 2016 followed by summer crops with 3.56% and water bodies more 0.3%. These results attest to the profound changes in the time and space of the plant cover. This upheaval can be explained by anthropogenic actions (fires, overgrazing, illegal logging, clearing) and natural (drought). The monitoring of the evolution of overall vegetation cover recovery for the observation periods (1987, 2002, and 2016) is referred to in Table 1.

In general, the diachronic study carried out shows that the vegetation cover of the El Kala National Park is subjected to a strong pressure which led to its regression. We note that the rate of regeneration of vegetation is always dependent on the health status of the vegetation cover of the regression factors and climatic conditions of the region. Exposure of soils through clearing, overgrazing, urbanization, and fires encourages the onset of erosion and makes regeneration of the vegetation cover more and more problematic.

Climate impact

The dynamic variability of climatic parameters can also have significant implications on the richness, diversity, and productivity of plant species (Gamoun, 2013). The El Kala National Park is characterized by significant interannual variations in rainfall, with alternating deficit years and surplus years. These variations result in the occurrence of drought periods, the most memorable of which are those of the years 1992, 1998, 2001, and 2002 favoring the outbreak of fires leading to the disappearance of several perennial species (Fig. 10).

Forest fires

In the Middle East and North Africa (MENA) region, Algeria is the country most affected by forest fires in percentage of traveled surface (Belgherbi et al., 2018).

Repeated forest fires are major obstacles to the regeneration of vegetation and contribute to the emergence of water erosion. Fires are, therefore, an important factor in the degradation of vegetation, which is difficult to control (Benabdeli, 1998). The annual average area burned for the period 2001-2016 is 155,67 ha (Fig. 11) with 38 fires per year. Maxima on the order of 1062,94 ha in 2008 and 245,86 ha in 2011 were recorded. However, the figures reported each year from 2001 to 2016 do not express the actual area burned, and this is mainly due to lack of resources and modern techniques in the park administration for the accurate calculation of areas burned.

Clearing

Clearing has always been a factor of regressive evolution of the initial forest (Amandier, 2002). In the municipality of El Kala, there are 344 offenses for the period 1985-1995 with an average of between 25 acres and 10 ha (Ouelmouhoub, 2005). In fiscal year 2011, the forest conservation of the El Taref wilaya recorded the clearing of 84 ha of the dune cordon of Berrihane in addition

Table 1. Evolution of the areas of the units of occupation of the soil during the three dates 1987, 2002 and 2016 (El Kala national Park).

Classes	Years						Evolution	
	1987		2002		2016			
	(%)	(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)
Forest	35.55	28 622	21.12	17 004	25.22	20 308	-10.33	-8314
Reforestation	15.7	12 641	15.95	12 845	14.07	11 330	-1.63	-1311
Maquis	20.13	16 204	33.3	26 804	24.6	19 791	4.47	3587
Rangelands	15.33	12 343	11.61	9351	11.5	9261	-3.83	-3082
Summer Crops	2.8	2252	3.54	2853	6.36	5122	3.56	2870
Bare soil	3.02	2428	6.34	5107	8.22	6622	5.2	4194
Urban	0.75	606	1.39	1113	3.01	2427	2.26	1821
Body of water	6.72	5414	6.75	5433	7.02	5649	0.3	235
Total	100	80 510	100	80 510	100	80 510	0	0

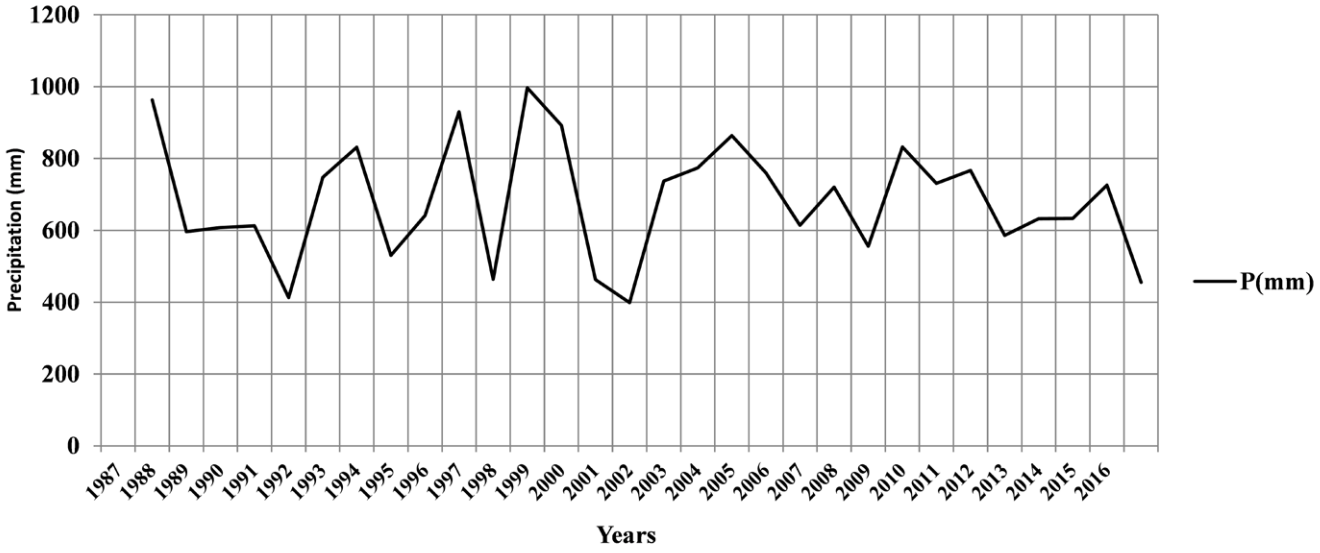


Fig. 10. Evolution of rainfall in the El Kala National Park (1987-2016).

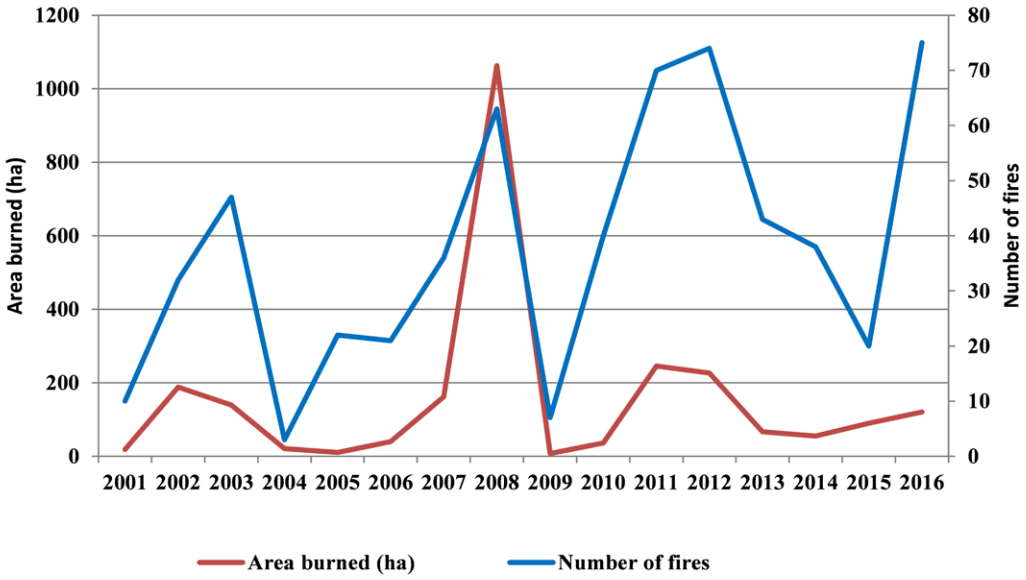


Fig. 11. Fire report period 2001-2016 (El Kala National Park).

to illicit tillage carried out on 33 ha inside the forest (Fig. 12). In 2012, the forest guards arrested 20 people for the illegal clearing of 34 ha followed by 54 ha in 2013 at the same place (dune ridges) (PNEK, 2016). This clearing consists of cutting or removing trees in order to clear a space for the cultivation of watermelon.

Overgrazing

Overgrazing causes excessive grazing of vegetation and small seedlings, prevents regeneration, depletes available resources, and degrades and erodes rangelands (Ouelmouhoub, 2005). Plant formations in the park are subject to extensive uncontrolled grazing. The cattle (bovine, sheep, andgoat) stay in the forest (Fig. 13) for several months without supervision, which prevents the growth of young plant shoots to develop. The number of livestock has increased from 67,442 head in 2004 (10,410 cattle, 40,807 sheep, and 16,225 goats) to 80,582 head in 2016 (19,616 cattle, 40,220 sheep, and 18,730 goats), an evolution of 1095 head per year for a period of 12 years (direction of agricultural services of El Taref). This significant increase in livestock accelerates the degradation of vegetation cover, especially in sensitive areas.

Urbanization and illicit construction

Urbanization around urban centers (Fig. 14), illicit constructions in rural areas, and the implementation of investment projects or



Fig. 12. Clearing around Lake EL Mellah (Source: Author, 2017).



Fig. 13. Cattle within the park (Source: Author, 2017).



Fig. 14. Urban extension of El Kala city (Source: Author, 2017).

public interests are today a real threat to the vegetation of the park. In El Watan in 2013, on the dune cord (zone being classified as a protected area), the wilaya officials authorized the clearing of 10 ha of forest formations to install an aquaculture farm. And a concession for 15 years on 43 ha of dunes for the extraction of sand from a coastal dune massif located in the region of Oum Teboul has just been attributed to a private company specialized in mining (El Watan, 2017). In addition, the East-West Highway project that passes through the park damages about 213.6 ha of vegetation.

Conclusion

The land-use maps produced from a supervised classification of Landsat 5 TM, 7 ETM +, and 8 OLI/TIRS images showed that El Kala National Park has been marked overthe past 29 years by remarkable evolution and change in its landscape, obviously due to several factors. For several years, forest areas have been under heavy anthropic and natural pressure, causing various forms of degradation of natural vegetation. This degradation is mainly related to the extension of agricultural areas, urbanization, overgrazing, fires, and clearing under different pretexts for all forest areas. The main changes of the natural park space are as follows:

A) Regression of the area of vegetal cover with 6038 halost a degradation rate of −7.49%.
B) Decrease in rangelands area with a rate of −3.83% or 3082 ha affected.
C) Extension of the area of the summer crops with 2780 ha more, a rate of increase reached +3.56%.
D) Extension of the bare soil with an increase of +4194 ha, i.e., an evolution rate of +5.20%.
E) Enlargement of the urban area, i.e., 1821 habuilt a growth rate of +2.26%.
F) Strengthening the surface of the water body with an additional surface area of 235 ha, an increase rate of +0.30%.

Indeed, the anthropogenic and natural degradation factors to which the El Kala National Park is subject seems worrying: the park has lost 6038 ha for 29 years, a rate of degradation reached 208.20 ha lost per year. The remote sensing data used in this study provide only limited information in time and space because of their spatial resolution (mean resolution), they cannot provide the detail to have a map of vegetation species by species. In the El Kala National Park, the vegetation cover is quite complex, and to map this vegetation cover species by species, it is necessary to have satellite images of high resolution (0.5 m of maximum resolution). However, we are interested in this study and have shown the state of degradation in an environment classified as a Ramsar site and have focused on the factors responsible for this degradation and especially that of fire.

References

Amandier, L. (2002). *La subéraie : biodiversité et paysageen ligne*. www.vivexpo.org/

Belgherbi, B., Benabdeli, K. & Mostefai K. (2018). Mapping the risk forest fires in Algeria: Application of the forest of Guetarnia in Western Algeria. *Ekológia (Bratislava),* 37(3), 289–300. DOI: 10.2478/eko-2018-0022.

Benabdeli, K. (1998). *Protection de l'environnement, quelques bases fondamentales, appliquées, et réglementaire présentation d'une expérience réussie*. Algérie: Graphi Publishing.

Bouazouni, O. (2004). *Projet Régional pour le Développement d'Aires marines et côtières Protégées dans la région de la Méditerranée (MedMPA*): *Etude socio-économique du PNEK*. Rapport. http://medmpa.rac-spa.org/pdf/Rapports/Algerie/etude%20socio-economique_El%20Kala%20ALG.pdf.

Brahamia, K. & Samouk A. (2010).Activité touristique dans un espace fragile-cas du parc national d'El Kala. *El-Tawassol*, 26, 34–57. http://www.univ-annaba.org/attachments/120_Article3.pdf.

Congalton, R.G. (1991). A review of assessing the accuracy of classifications of remotely sensed data. *Remote Sens. Environ.,* 37(1), 35–46. DOI: 10.1016/0034-4257(91)90048-B.

DSA (2016). *Direction des services agricoles de la Wilayad'El Taref, Algérie*. Consultation des documents et entretien avec les personnels administratifs au siège de l'administration.

El Watan (2013). *El Tarf : encore des défrichements dans une zone écologique*. *Quotidien généraliste algérien en langue française*. https://www.elwatan.com/archives/actualites/el-tarf-encore-des-defrichements-dans-une-zone-ecologique-28-06-2013.

El Watan (2017). *Le Parc national d'El Kala en voie de disparition*. *Quotidien généraliste algérien en langue française*. https://www.elwatan.com/regions/est/actu-est/le-parc-national-del-kala-en-voie-de-disparition-09-10-2017.

Gamoun, M. (2013). Vegetation change in variable rangeland environments: the relative contribution of drought and soil type in arid rangelands. *Ekológia (Bratislava)*, 32(1), 148–157. DOI: 10.2478/eko-2013-0013.

Khallef, B., Brahmia, K. & Ouerbi A. (2018). Study of the vulnerability of soil to water by remote sensing and GIS: Case of the El Kala National Park (Algeria). *Journal of Biodiversity and Environmental Sciences (JBES)*, 13(6), 52–65. http://www.innspub.net/wp-content/uploads/2019/01/JBES-Vol-13-No-6-p-52-65.pdf

Ouelmouhoub, S. (2005). *Gestion multi-usage et conservation du patrimoine forestier: Cas des subéraies du P.N.E.K*. Mémoire de Master: Centre International de Hautes Études Agronomiques Méditerranéenne. https://www.iamm.ciheam.org/ress_doc/opac_css/doc_num.php?explnum_id=4403.

PNEK (2016). *Direction du parc national d'El Kala Wilaya d'El Taref, Algérie*.

Raach, M.L. (2007). *Étude préalable pour une gestion intégrée des ressources du bassin versant du lac Tonga au nord-est algérien*. Mémoire de Maitrise en Géographie.Montréal: Université du Québec. https://archipel.uqam.ca/736/1/M10067.pdf.

Soudani, K. (2006). *Corrections atmosphériques, géométriques et classification des images de télédétection sous ENVI*. Travaux Dirigés en Télédétection, version PDF. http://www.ese.u-psud.fr/wp-content/uploads/2017/08/td2_teledec.pdf.