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Monitoring of cork oak *(Quercus suber)* post-fire recovery using Sentinel 2A data: a case study in Taksebt forest, Zekri, Algeria

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Abstract

In the mediterranean region a significant decline in the vitality of vegetation has been observed in the last decades, resulting in high forest losses for several species. In Algeria, the increase in species mortality has been attributed to several factors, mainly forest fires resulting from an increase in human activities, temperature and long periods of drought. To monitor the impact of fire events on tree recovery, a rapid and efficient method is required. In this paper, an approach based on the change detection is proposed to evaluate a post-fire cork oak forest recovery using sentinel 2A images. A highly burned area was selected and its recovery rates were monitored throughout three different post-fire periods. Three months after the fire event, several patterns were recognized and differentiated in the area with an important forest recovery rate of 11.41%.

Key Words: *Quercus suber,* Forest fire, Post-fire recovery, Sentinel 2A, Taksebt, Tizi-Ouzou, Algeria.

Suivi du recouvrement du chêne liège *(Quercus suber)* après incendie à l'aide des données Sentinel 2A : Cas de la suberaie de Taksebt (Zekri, Tizi-Ouzou, Algérie)

Résumé

Dans la région méditerranéenne, un déclin significatif de la vitalité de la végétation a été observé au cours des dernières décennies, entraînant une forte perte de forêt pour plusieurs espèces. En Algérie, l'augmentation de la mortalité des espèces a été attribuée à plusieurs facteurs, principalement les feux de forêt résultant d'une augmentation des activités humaines, de la température et de longues périodes de sécheresse. Pour surveiller l'impact des incendies sur le recouvrement forestier, une méthode rapide et efficace est nécessaire. Dans cet article, une approche basée sur la détection des changements est proposée pour évaluer l'état d'une forêt de chêne-liège après un incendie à l'aide d'images sentinel 2A. Une zone fortement brûlée a été sélectionnée et ses taux de recouvrement ont été suivis pendant trois périodes post-incendie. Trois mois après l'incendie, plusieurs changements ont été reconnus et différenciés dans la zone avec un taux de recouvrement important du couvert végétal de l'ordre de 11,41%.

Mots clés : Quercus suber, Feu de forêt, Recouvrement post incendie, Sentinel 2A, Taksebt, Tizi-Ouzou, Algérie

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INTRODUCTION

Cork oak ecosystem is one of the most representative ecosystems in the western mediterranean basin (Catry et al. 2012), both in Europe and in North Africa, covering more than 2.3 million hectares (Cowling et al., 2005). *Quercus suber* plays an important ecological, economic and social role in several mediterranean countries (Pereira and Fonseca, 2003; Bulgalho et al. 2011). Due to their uniqueness these ecosystems are recognized as habitats of conservation value, supporting a large variety of animal, plant and fungi species, including many endemics (Bernal, 1999). Cork is a renewable natural resource constituting a valuable and versatile raw material for industry since it is used for an important variety of products (Pereira, 2011). It is the second most important marketable non-wood forest products in the mediterranean regions (Silva and Catry, 2006).

Forests are a valuable and natural resource, however, despite of their value, several factors, ranging from diseases, drought, human activities, and air pollution to forest fires influence the vegetation condition and health (Costa et al., 2010). Pausas (1997) and Silva and Catry (2006) considered wildfires as one of the major causes of *Quercus suber* forests decline in mediterranean regions with nearly half a million hectare burned every year (FAO, 2011), and more than 50 000 fires sweep through a million hectares of the forests (Dimitrakopoulos and Mitsopoulos, 2006). Further more fire risk is likely to increase in the future due to climate change (Pinol et al., 1998; Pausas et al., 2004). Most of the mediterranean broadleaved species have the capacity of resprouting after disturbances. Indeed, after severe fires, cork oak is considered the only species with stem and crown resprouting ability through epicormic buds (Pausas et al. 2009; Moreira et al. 2009). In previous researches, the study of the post-fire cork oak state was based on field survey and measurements, but, nowadays, the introduction of remote sensing technology offers an alternative approach to detect and quantify forest vegetation, composition, regeneration and association structure (Wolter and Townsend, 2011; Wolter et al., 2012). Remote sensing has great potential for monitoring disturbances; it can provide valuable information at different spatiotemporal scales, due to its inherently spatial nature, repeatability and ability to observe large extents at fine scales (Frolking et al., 2009; Lasaponara et al., 2022). Several platforms such as Landsat have been proved to be effective in vegetation monitoring studies (Souza et al., 2005; Asner, 2009). Recently, Sentinel 2A data, launched in 2015, has been widely used in post-fire recovery studies. One of the most common techniques of spatiotemporal monitoring is the supervised classification. This methodology allows highlighting land cover changes and temporal trends.

In this paper, we aim to monitor a cork oak post-fire vegetation recovery, from 15 days to one year after the fire, in Taksebt *Quercus suber* forest located in Zekri, northern Algeria. For this purpose, a supervised classification was used based on the sentinel 2A imagery. Therefore, the main objectives of this proposed research are: (1) to monitor the post-fire recovery in the study area, (2) to highlight the potential of using Sentinel 2A imagery for the post-fire monitoring studies, (3) and to provide information to forest services, about the forest states for future actions.

MATERIAL AND METHODS

Study area

The study was undertaken in one of the northern Algerian cork oak forests, namely Taksebt (36° 45' 19.28"N and 4° 38' 9.49E"), which is situated in the western side of Zekri area, belonging administratively to Tizi-Ouzou forest service. The area is surrounded by several forests; Sidi Aissa from the north, Yakourene from the west and the Akfadou Mountain from both the east and the south (Figure 1). Taksebt lies over an area of 1127ha (BNEF, 1989), with an altitude varying from 850 to 900m and a considerable slopes ranging from 20 to 70%. It has a rocky topography and a brown, humid forest soil with an important layer of humus (Lapie, 1909). The bioclimate is considered temperate, humid, situated in the thermo-mediterranean stage with a mean annual temperature of 18°C. *Quercus suber* is the dominant species in Taksebt (more than 80 % of the total area), while the remaining area is composed of a mix between cork oak and zeen oak. The understory is mainly represented by *Cytisus triflorus, Daphne gnidium, Arbutus unedo, Crataegus monogyna, Ampelodesmos mauritanicus* and *Erica arborea* .

Most of the northern Algerian forests were subjected to an important forest fires during the summer of 2021. Taksebt underwent a very important fire in August 10th, 2021, which caused severe damages to the trees and a reduction of the understory biomass.

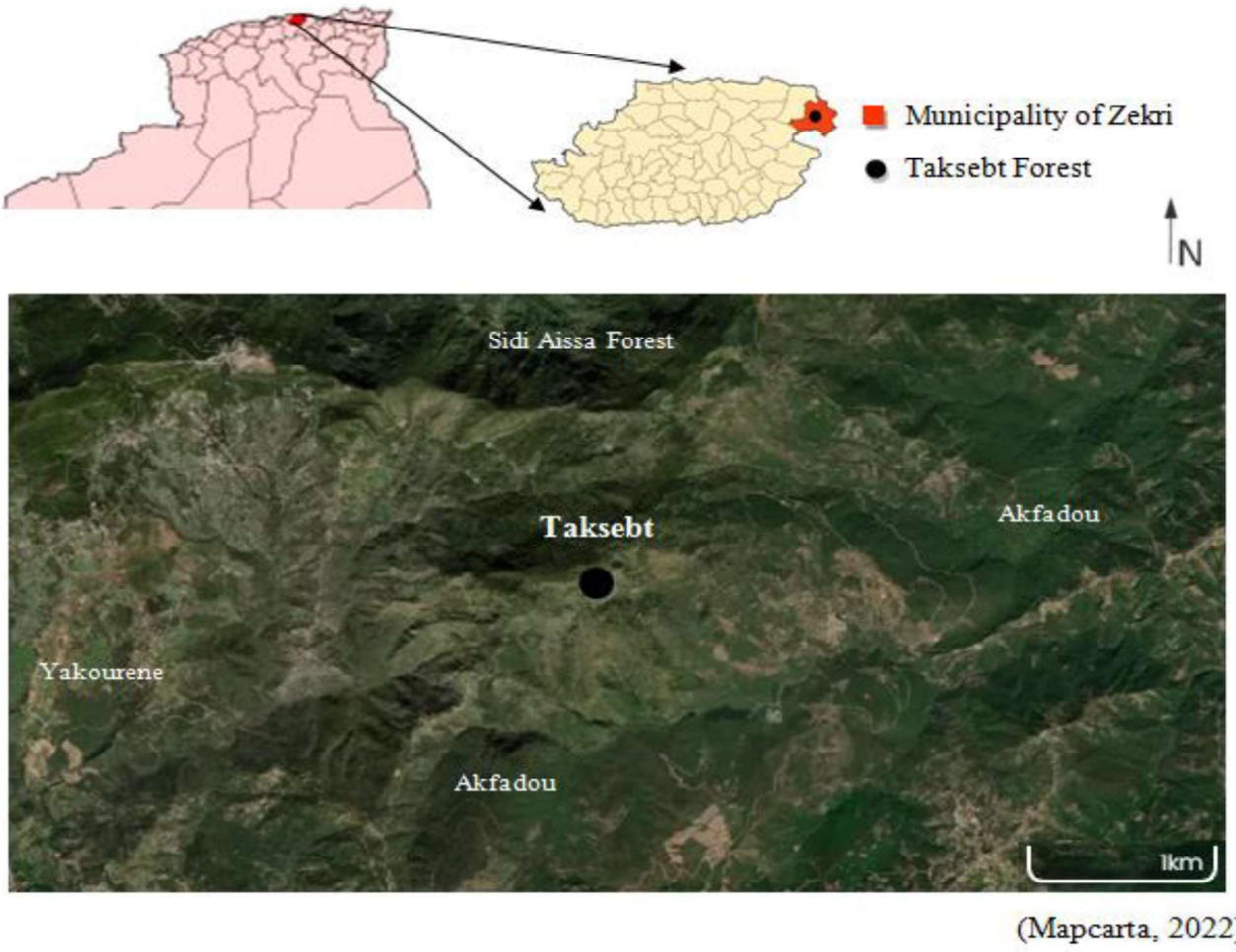

Figure 1: location of the study area (Taksebt forest, Zekri, Tizi-Ouzou, Algeria)

Data processing

Sentinel-2A satellite is a Copernicus mission, one of the various missions of the European Union's earth observation program It was launched on June 2015, offering coverage with a high spatiotemporal resolution (temporal resolution of 5 days and a spatial resolution of up to 10m) (Navarro et al., 2007) and a swath width of 270 km. Sentinel images have 13 spectral bands, from the visible and the near infrared to the short waves infrared (Table 1).

Table 1: Wavelengths and spatial resolution of Sentinel 2A bands (Liorens et al., 2021).

Band	Name	Central wavelength (nm)	Spatial Resolution (m)
1	Coastal aerosol	443	60
2	Blue	490	10
3	Green	560	10
4	Red	665	10
5	Red-edge 1	705	20
6	Red-edge 2	740	20
7	Red-edge 3	783	20
8	Near Infrared	842	10
8a	NIR narrow	865	20
9	Water vapor	945	60
10	Cirrus	1375	60
11	SWIR 1	1610	20
12	SWIR 2	2190	20

For the present study, three Sentinel 2A images, corrected atmospherically, radiometrically and geometrically, with less than 5% of clouds coverage, were downloaded (https://sentinels.copernicus.eu/web/sentinel/missions/sentinel-2), for 3 different dates, from some days to a year after the forest fires of Taksebt area (Table 2).

Table 2: Acquisition dates of the sentinel 2A images.

Image	Date of acquisition
1	27th August, 2021
2	16th October, 2022
3	11th September, 2022

On a Geographical Information System software, the free open access software QGIS, a supervised classification was performed using images of the spatial resolution of 10m. The methodology was applied on a subset of images, clipped using the geographical coordinates of the study area under a coordinate system WGS84/UTM zone 31N. The three images were classified into 3 classes according to their spectral signatures and the land occupations (Table 3).

Table 3: Description of the post-fire land cover classes in Taksebt cork oak forest.

Name of the class	Description
Forest area	Represents the green areas: cork oak forest and all Taksebt's vegetation
Bare soil	Represents non vegetation areas: burned areas and rocky ones.
Others	Gathers all the other land covers: roads, settlements, poultry sheds and others.

RESULTS

Immediately after the fire, the results (Table 4) show a forested area of 204.55 ha; a bare soil covering 851.11 ha and the other land occupations covering an area of 71.34 ha. Three months after the fire, the forest area increased by 124.53ha, similarly for the other occupations (paths, roads and urban) which increased to 300 ha, while the bare soil decreased to almost half of its surface (353.19ha). On September 2022, the forested area and the bare soil continued increasing by 4.06 ha and 11.94 ha, respectively, while the other land covers decreased from 300 to 284 ha.

Table 4: Post-fire land cover classes and their respective areas.

Dates	August 2021		October 2021		September 2022	
Land cover	Area (%)	Area (ha)	Area (%)	Area (ha)	Area (%)	Area (ha)
Forest Area	18,15	204,55	29,2	329,08	29,56	333,14
Bare soil	75,52	851,11	44,18	497,92	45,24	509,86
Others	6,33	71,34	26,62	300	25,2	284
total	100	1127	100	1127	100	1127

According to the classification results, the overall post-fire land cover changes from August 2021 to September 2022, the forested area in Taksebt forest recovered over an area of 12.59ha. The change in the bare soil class is regressive, it lost an important area of 341.25ha, while the other land occupations, represented mainly by the roads and settlements, have increased by 212.666ha (Figure 2).

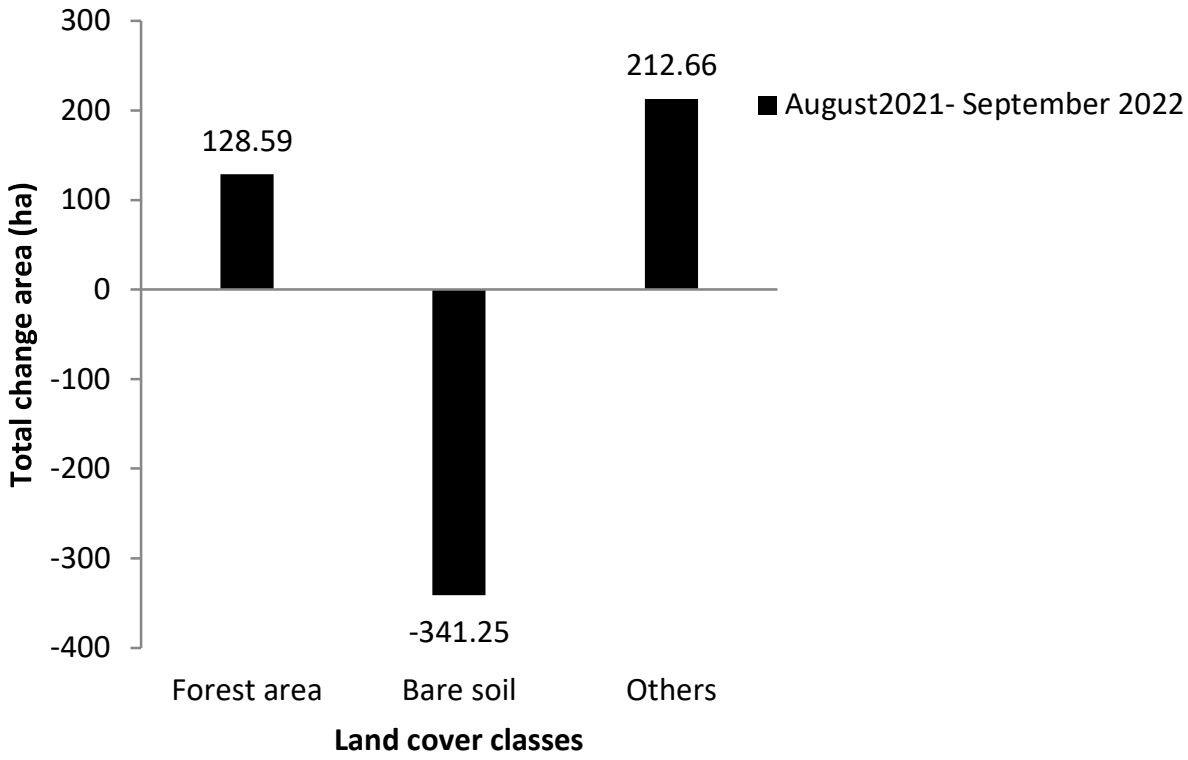

Figure 2: The overall post-fire Land cover changes in Taksebt forest.

Three months after the fire, the land cover changes in Taksebt were positive for the forest area and the other class with surfaces of 124.53 ha and 22.66, respectively; the bare soil, in its side, decreased highly with an area of 353.19 ha. From October 2021 to September 2022, the rates of changes in the study area were very low, as, the forest area and the bare soil increased with 4.06 ha and 11.94 ha, while the other occupations of the forest area decreased with 16 ha (Figure 3).

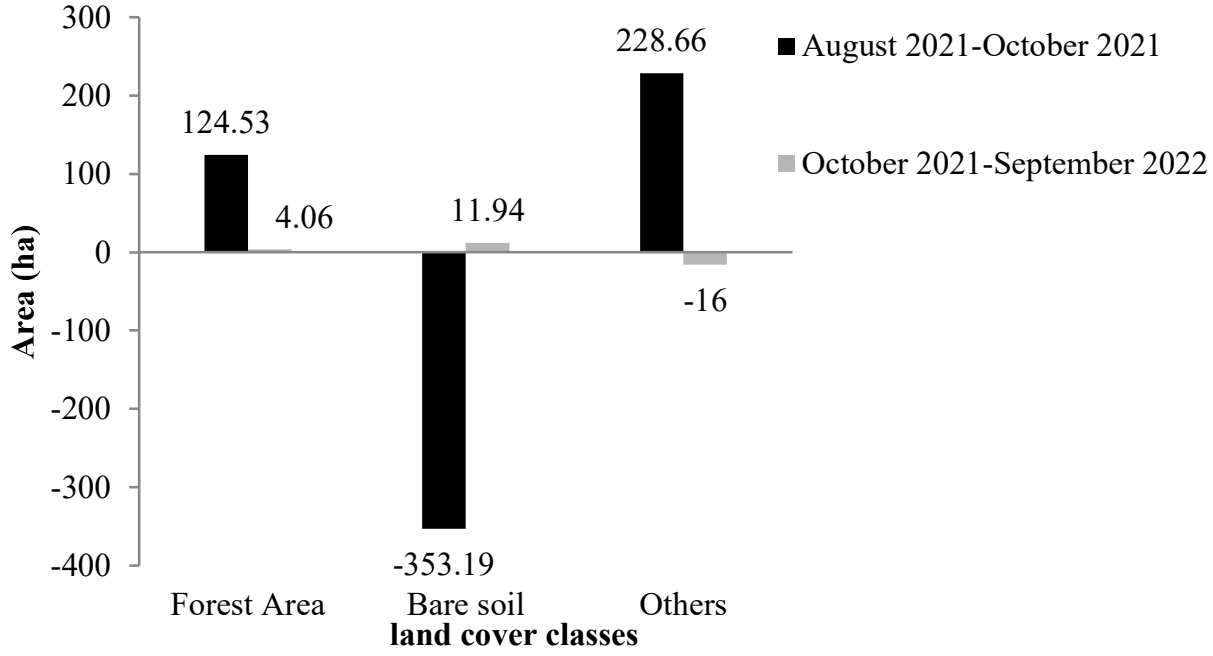

Figure 3: Periodic post-fire land cover changes in Taksebt forest.

Overall, the histogram of the losses and gains in the post-fire land cover occupations of Taksebt (Figure 4) shows important gains in vegetation area and the other classes with surfaces of 128.59 and 22.66 ha, respectively, while, the bare soil lost over 353.19 ha of its area

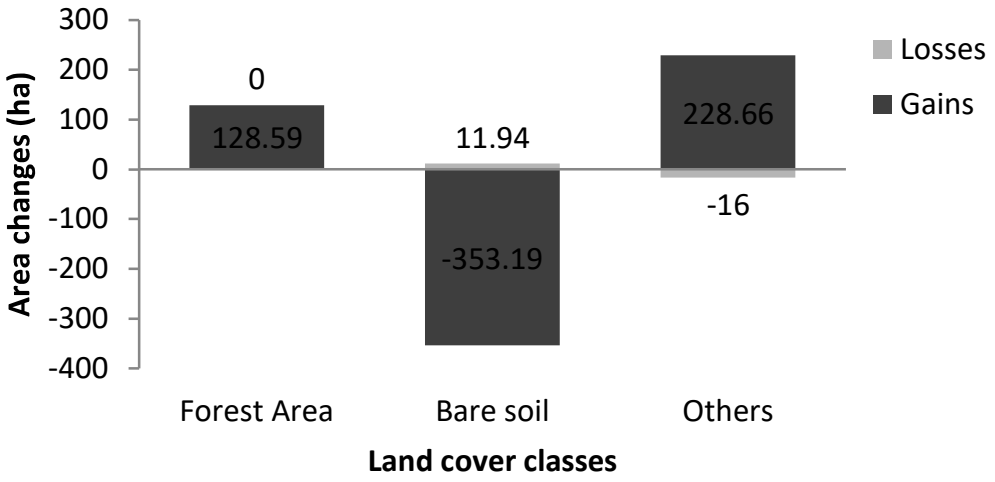

Figure 4: The overall post-fire losses and gains of areas in Taksebt.

The results displayed by the obtained maps from the post-fire supervised classification (Figure 5) follow the above mentioned results. Few days after the fire, the bare soil, which is represented by burned areas, was the dominant cover class, while the forested area was on a restricted surface. Three months after the fire, a clear spread of the green area was noticeable on the map B and the bare soil lost a part of its from which was converted into forest and other land occupations. A year after the forest disturbance, the forest expanse seemed to be the same, while some unknown land covers changed into bare soils.

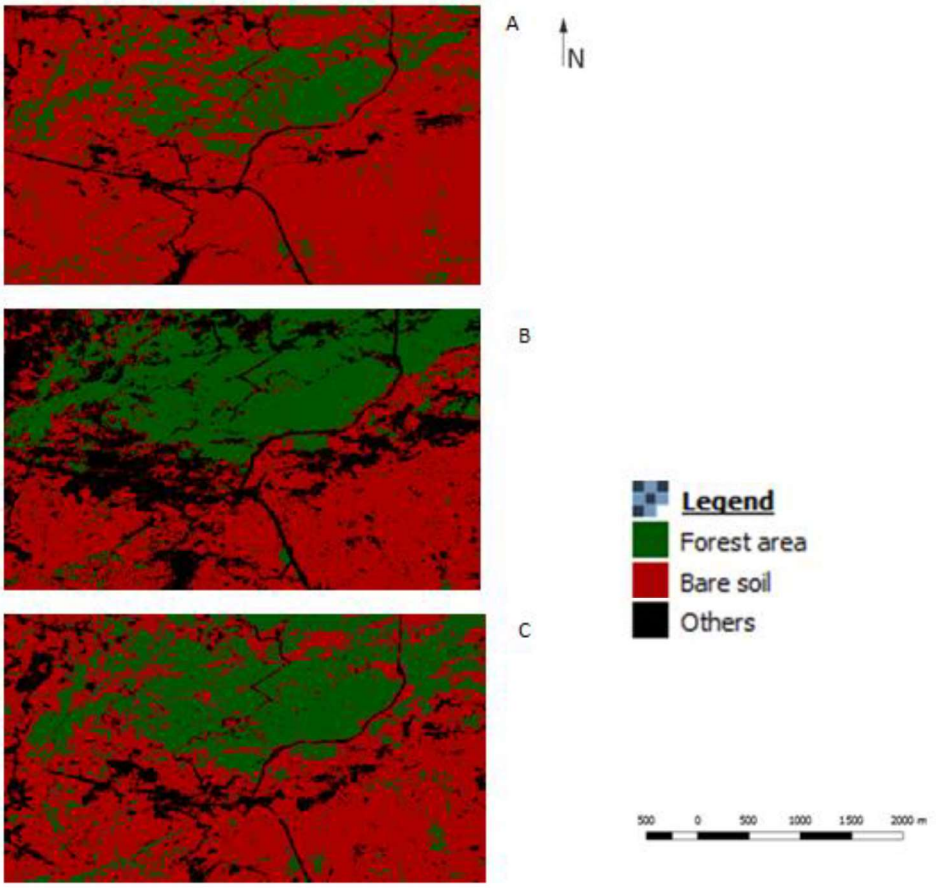

Figure 5: Post-fire supervised classification maps (A: August 2021; B: October 2022; C: September 2022).

DISCUSSION

The use of supervised classification as an explanatory method applied on Sentinel 2A imagery (10m) provided interesting results for all the analyzed images. Furthermore, the methodology was efficient for monitoring of post-fire forest recovery and suitable for identification of the changes. It highlighted every land cover change both visually, through the obtained maps and quantitatively, through the numerical results. Thus, the classification provided excellent and accurate results with well defined groups of pixels.

The identification of the areas where land cover has changed over time in the post-fire chosen periods was significantly distinguishable. In fact, the overall change was characterized by an important increase in the post-fire cork oak recovery along with a decrease in the bare soil area. Three months after the fire, the forested area recovered over 124.53ha, which were as a bare soil just after the fire. The bare soil, represented mainly, by burned surfaces just after the fire, decreased by 353.19ha, an area converted into both vegetation and others, such as roads and paths opened after the fire. A year after the event, in comparison with the previous period, only very small and non noticeable changes occurred in Taksebt forest. Those results may be directly related to the behavior of cork oak after fires, which request a period of three months to recover (Moreira et al., 2009; Dib et al., 2022). In most cases, the foresters allow the forest to recover by itself before any management actions. In this study, it is proved that for cork oak ecosystems a period of three months is requested.

Quercus suber recovery has been the most conspicuous landscape change in this study area, despite the significant disturbances caused by fires on the forests, it has been highlighted that the natural vegetation of this study area has a high resilience capacity. Previously (Pereira, 2011; Bardadi et al., 2021), cork oak proved to be a well adapted species to the mediterranean climate with its dry and hot summers and its environmental hazards. According to Catry et al. (2011), cork oa is the only mediterranean species recovering vegetatively. However, in Algeria, *Quercus suber* is the unique tree with the ability to resprout from epicormic buds, a characteristic which allows its survival after severe damages (Pausas et al., 1997). Moreover, thanks to their insulating bark, cork oak trees have a remarkable resistance to fires (Catry et al., 2011). It has been noticed that, when the bark is sufficiently thick, it protects the epicormic buds, allowing trees to resprout quickly from stem and crown buds after fires (Silva and Catry, 2006).

Forest fires are a problematic and recurrent issue in several countries (Sobrino et al., 2019; Liorens et al., 2021). In Algerian forests, they are the most challenging hazard (Meddour et al., 2013). They are major disturbance factors playing a critical role, modifying ecosystem structure and function, on short and long terms (Garcia-Liamas et al., 2019). However, post-fire forest recovery largely depends on the fire event and characteristics which are known as the fire regime (Bond and Van Wilgen, 1996). In the present study, the fact that cork oak of Taksebt forest seemed to have recovered three months after the fire event, suggests that the fire was moderate and swiped over the area only once during the summer of 2021, exactly on the 10th of August.

Although a Sentinel 2 is a medium resolution sensor, it has allowed improving mapping of fires and their consequences at finer scales compared to other sensors (Drusch et al., 2012; Mpakairi et al., 2020). The investigation conducted in the present research contributed to the assessment of Sentinel 2A free images usefulness in forest spatiotemporal dynamics analysis. They allow an extraction of useful information and therefore, highlight several land cover parameters. It was previously evidenced by Huang et al. (2016) that sentinel 2A images can provide spectral differentiation between unburned and burned areas. And in the present study such images allowed differentiation between classes of land occupancy mainly between the burned areas and the vegetation cover.

CONCLUSION

In conclusion, in the burned area investigated, the post-fire spatiotemporal dynamics seems to lead towards an important cork oak forest. The presented results prove that only three months are necessary for cork oak ecosystems to recover after large and important fires. Sentinel 2A imagery provides a great opportunity for global vegetation monitoring due to its enhanced spatial, spectral and temporal characteristics compared to other free access satellites. However, this data and the applied methodology have proven to be of great use in forest dynamics studies, especially when it is necessary to operate, as in this case, in a spatiotemporal analysis. The present study will be as a support for the concerned forest services for any future management of Taksebt cork oak forest, which is an important area, with high ecological, economic and social values.

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