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Assessing of forest cover changes in Zaouit Ahansal (Central High Atlas, Morocco) using remote sensing and field data

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Abstract:

This research aimed to evaluate and analyze the forest cover changes in the Zaouit Ahensal region (Morocco), using high spatial resolution and free satellite images data. To achieve this, Landsat-7 ETM+ and Sentinel-2A MIS multispectral images acquired in 2000 and 2022, respectively, were classified and thresholded using the Support Vector Machine (SVM) classification and NDVI index. The overall accuracy of the classification was 85% and 84.3% for the 2000 and 2022 images, respectively. The results obtained showed that the forest of Zaouit Ahansal underwent a slight regression with a decrease in the areas of Phoenicean juniper, Thuya and Zeen oak, as well as an increase in the areas of bare soil and agricultural areas. The area of Holm oak and Aleppo pine increased by 0.89% and 0.23% respectively. Also, the statistical results of the analysis of NDVI showed the class of low density of forest cover was decreased about 10,49% of the total area of study area. This study provides data on the distribution and spatiotemporal dynamics of forest cover in the study area. Therefore, the results of this study can be useful in selecting sites for reforestation of degraded species and implementing conservation action.

1. Introduction

Morocco has important forest ecosystems in North Africa with an area estimated to be about 9 million hectares, or about 12.6% of the total area of the country (Lahlaoi *et al*., 2017). Moroccan forests are very diverse and include a high diversity of animal and plant species, some of which are endemic to the region (Fennane and Ibn Tattou, 2012; El Alami *et al*., 2022). Moreover, they are the providers of essential ecological and socio-economic services for the local population and the country in general. They can provide food and wood for construction and industry, protect the basins from erosion, regulate the hydrological cycle, preserve biodiversity (Nasi *et al*., 2002; White and Martin, 2002). The forest is also a place for recreation and tourism activities (Aafi, 2000). However, these ecosystem values have been considerably reduced due to natural processes and human activities such as overexploitation,

overgrazing, fire, soil degradation, population pressure and land clearing. In addition, the lack of natural regeneration and tree dieback in some localities is probably related to drought (Badri, 2003; Abouatallah *et al*., 2011; Laita *et al.*, 2024b). This is clearly observed in the Cedar Forest in the central Middle Atlas (Mohajane *et al*., 2018), and in the Maamoura forest (Aafi *et al.*, 2005b). All these factors are leading to a remarkable regression of the Moroccan forest cover (Moukrim *et al*., 2012).

In the high mountains of Zaouit Ahensal, the forest ecosystems have an important ecological and socio-economic role to the local mountain populations, namely, grazing, forage and the production of firewood and construction. But these activities are difficult to control and monitor which leads to unreasonable exploitation. As a result, a large majority of these forest stands are extensively deteriorated. Hence, it is necessary to realize in-depth studies on the ecosystem services provided by this forest ecosystem, as well as the interaction between human and natural phenomena, in order to identify the appropriate strategies to implement conservation actions. At present, with the development of remote sensing techniques and geographic information systems (GIS), it is possible to evaluate and quantify the dynamics of different plant species. This is through the availability of satellite data from several captures (SPOT, Landsat, ASTER, MODIS, Sentinel 2A) As well as the use of several techniques of remote sensing such as vegetation indices (NDVI, EVI) and the method of spectral analysis by using a classification oriented to a supervised or unsupervised algorithm. In this context, several authors have used different remote sensing data and different algorithms to map and detect changes in forest species in Morocco (Montès *et al*., 2002; Linares et al., 2013; Barakat *et al*., 2018; Laita *et al*., 2024). These studies show that the application of remote sensing methods coupled with field data for the mapping, estimation and evolution of different plant species gives successful results. In the study area, to this date, no study has analyzed changes in vegetation cover using satellite data. For this purpose, this work is aimed to map, monitor and analyze the changes of forest cover in Zaouit Ahansal region using Landsat-7 ETM+ and Sentinel-2a MIS images acquired in 2000 and 2022 respectively, and based on the calculation of NDVI and the SVM (Support Vector Machine) classification.

2. Data and Methodology

2.1 Study area and climate

The study area corresponds to Eastern Mountain area of Azilal (32°49′02″N and 6°06′18″W), with a total area of 24 882 ha (Figure 1). It covers villages and riparian agglomeration (Zaouit Ahensal, Tamga, Tifouina, Tisselmi) which are located principally in the proximity of forest resources. The total human population in 2014 was 140,000 (HCP, 2014). This population is generally based on agriculture, livestock, cereal farming and forestry activities. The climate of the study area is Mediterranean, characterized by a semi-arid to sub-humid climate, with a very cold winter and spring and a fairly hot summer. Due to its geographical position, topography, geology and climate, the study area is part of the center of biodiversity that has several sites recognized by its rich and diverse flora (Moulay Driss, 1998).

2.2 Field Work

Field trips were conducted around the study area to identify the major land cover classes. For this reason, areas where homogeneous forest stands were visited, and their spatial locations (altitude, latitude, longitude) were registered using the GPS instrument (60CSx-Garmin). The dominant higher plant species are stratified into four distinct stands: Phoenicean juniper (*Juniperus phoenicea*), Holm oak (*Quercus rotundifolia*), Thya (*Tetraclinis articulata*), Aleppo pine (*Pinus halepensis*), In total, 162

GPS points of these different forest stands were located, 100 are used for the extraction of spectral signatures of each forest species and 62 are used to validate the results. However, some information on the current state of the stands was determined from our field observations.

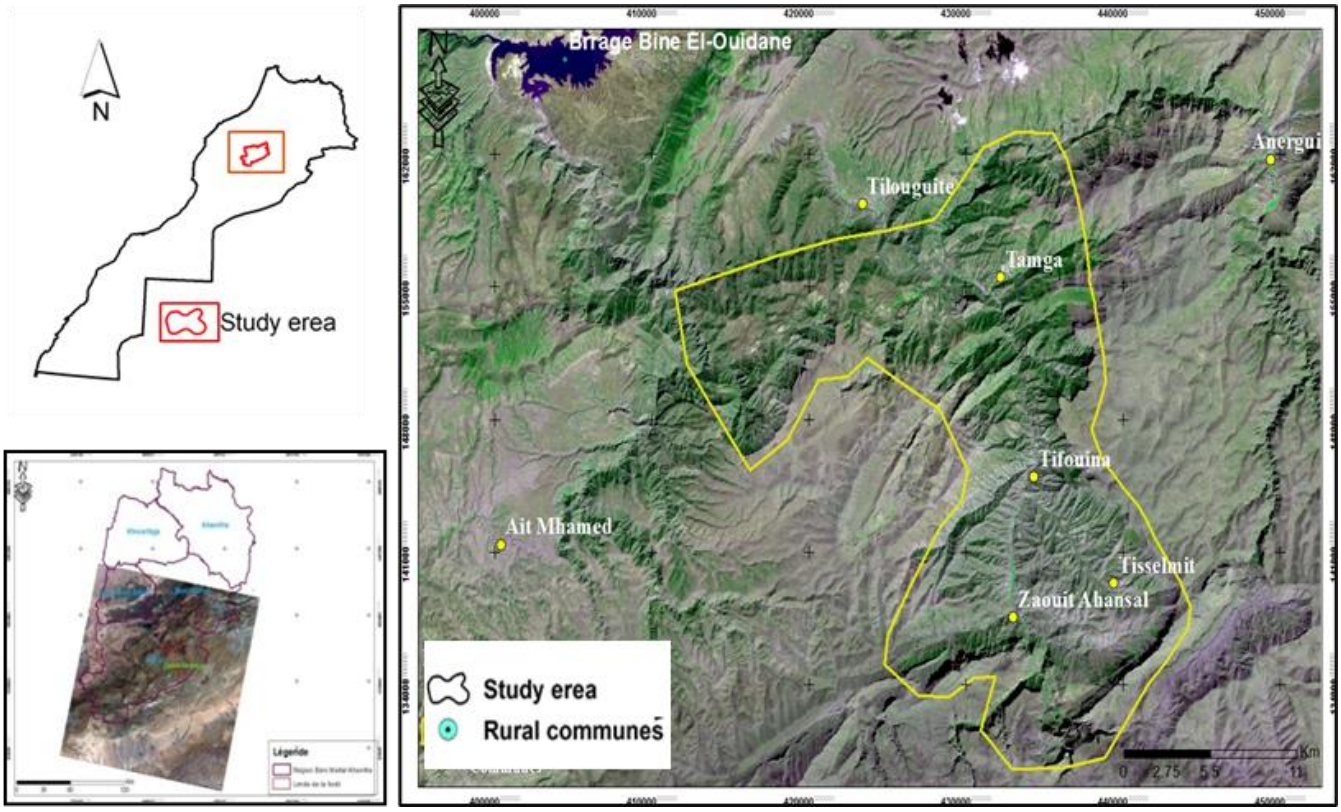

Figure 1. Location map of the study area

2.3 Data Used

To analyze and monitor the spatial and temporal dynamics of forest cover in the Zaouit Ahensal region, two series of satellite images, Landsat-7 ETM+ (Enhanced Thematic Mapper) and Sentinel-2A MIS, were used (Table 1). These images were downloaded for free from the USGS website (http://earthexplorer.usgs.gov/) and were acquired during the summer and without cloud cover. All visible and infrared bands were used in this study to identify and to discriminate vegetation cover (Guyot *et al.*, 1988).

Table 1. Satellite images and bands used in the analysis (NASA,2022).

Image	Date acquisition	Résolution (m)	Bands	Wavelength (µm)
Sentinel-2A	12 July 2022	10	Band 3: Green Band 4: Red Band 8: NIR	0.542–0.577 0.650–0.680 0.7845–0.8995
Landsat-7 ETM+	05 July 2000	30	Band 3: Green Band 4: Red Band 5: NIR	0.525–0.600 0.630–0.680 0.845–0.885

2.4 Satellite Data pre-processing

Before being able to use the raw data acquired, they must be pre-processed by going through the stages of radiometric calibration and atmospheric corrections (Lu et al. 2004). These steps are essential to eliminate the various sources of error, particularly errors due to sensor irregularities and atmospheric effects (absorption and scattering). Consequently, the atmospheric correction of Landsat-7 ETM+ and Sentinel-2A MIS images was performed by the Dark Object Subtraction (DOS) method (Congedo, 2016). Concerning, the color composition, the three bands (B2-B3-B5) were used for the Landsat-7 image and (B3-B4-B8) for the Sentinel-2A image.

2.5 Calculation of the vegetation index NDVI

The NDVI is developed by Rouse et al. (1974) and is a widely used vegetation index and provides information on the amount and vigor of vegetation considering the near infrared (NIR) and visible red bands of the electromagnetic spectrum (Red). It is calculated by the following formula:

$$\mathbf{NDVI = (NIR-Red) / (NIR+Red)}$$

This index varies between -1 and 1. Negative values correspond to non-vegetative cover, while positive values represent vegetation cover (Desclée *et al*., 2006). For this work, this NDVI was calculated from a module in ArcGis 10.8 software, and its values range from -0.25 to 0.63 for two images (Landsat-7 and Sentinel-2A). Then, it is classified by thresholding method into four levels: NDVI <0.1: Bare soil, 0.1<NDVI <0.3: Low density of forest, 0.3<NDVI <0.5: Moderate density of forest, 0.5<NDVI: High density of forest.

2.6 Image classification

The SVM is a supervised classification approach developed by Vapnik (1999). It considers each pixel of the image to one of the identified classes. The SVM was applied based on field data observation, Google Earth images and local forest maps. Five land cover classes were defined are Phoenicean juniper (*Juniperus phoenicea*), Holm oak (*Quercus rotundifolia*), Thya (*Tetraclinis articulata*), Aleppo pine (*Pinus halepensis*), Bare ground and Crops. The methodology adopted for this research is resumed in Figure 2.

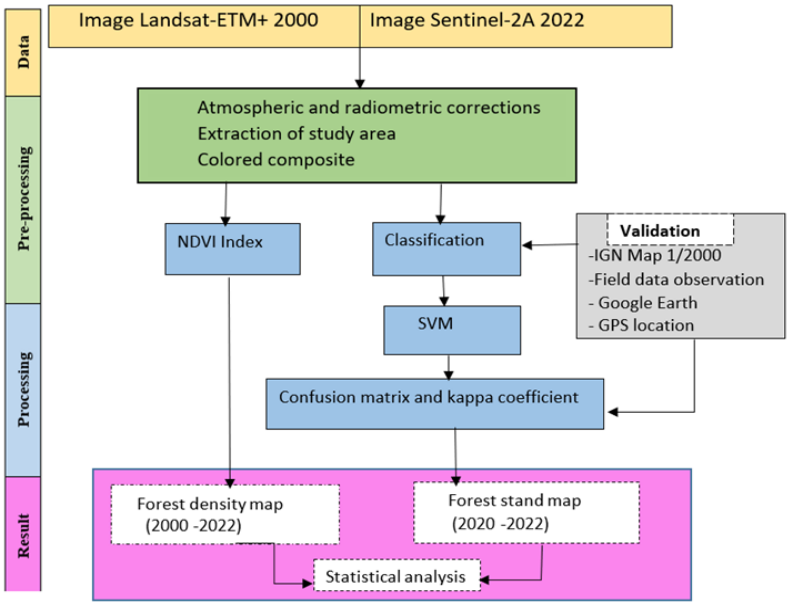

Figure 2. Flowchart for the methodology used

3. Results and Discussion

3.1 Validation of Classifications and Mapping Results

The values obtained are 85% and 84.3% respectively in the years 2000 and 2022, given that the critical value above 75% considers that the classification is acceptable (Girard *et al.*, 2010). This indicates a good accuracy between classification and observation.

3.2 Analysis of the Changes of NDVI

The NDVI derived from Landsat ETM 2000 and Sentinel 2A images is shown in Figure 3 and Table 2. The Low values of NDVI are recorded in the western and central part of the study area, with values ranging from -0.25 to 0.30. In these areas, forest stands are distributed on the high plateaus from 1800 to 2600 m of altitude in the form of dispersed population. In the northern part, at the level of Tamega, Adendoun, Taourart and Igherwizene, the NDVI had high values ranging from 0.4 to 0.68. In the terrain, these areas are composed of several sites characterized by very dense forests. This is the case of the forest of Tamga and gherwizene.

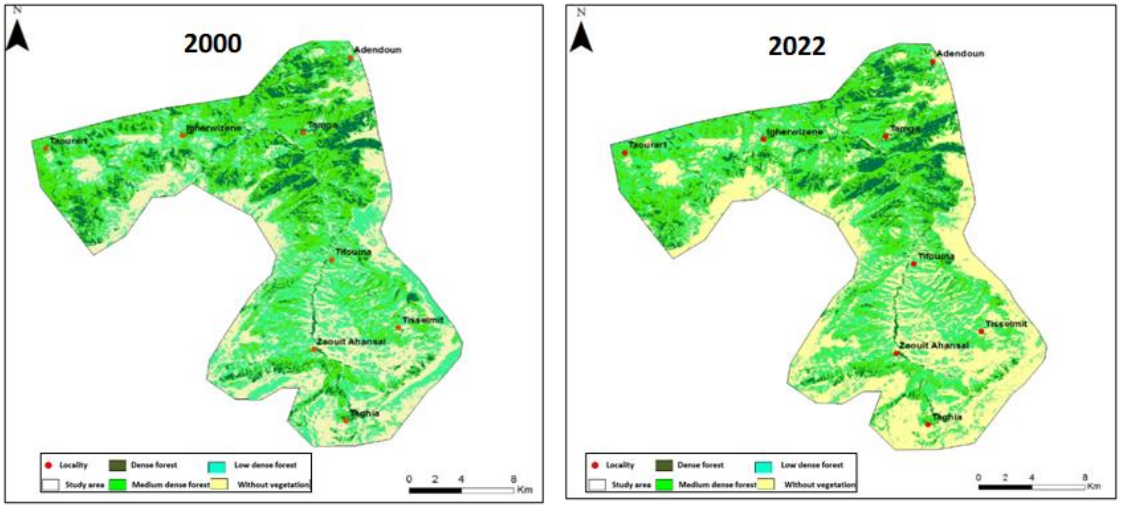

Figure 3. Maps of NDVI variation in Zaouit Ahansal forest in 2000 and 2022

According to the results presented in Table 2, the class of « Without vegetation " increased with a rate of 5.79% from 17317.53 ha in 2000 to 18320.67 ha in 2022, as well as the Moderate density of forest increased by 6.42% (11049.84 in 2000 to 11760.16 ha in 2022). In addition, the area of High density of forest increased from 4597.11 ha in 2000 to 4728.56 ha in 2022. On the other hand, the area of low dense forest decreased by 10.59%, with a loss of 1,844.91 ha. These results show that the vegetation cover fluctuates in space and time. Several factors can explain these fluctuations, whether they are regression or progression, particularly anthropic pressure (fires, overgrazing, wood cutting), as well as the effects of natural factors.

3.3 The spatial and temporal dynamic of forest stands

For the two images classified (2000 and 2022), the qualitative analysis of the results presented in Figure 5 shows that the Phoenicean juniper formations are dominant. They are very concentrated in the southern regions and very little in the northwest and extreme northeast of the study area (blue color). The Holm oak is also occupied a large area. It is found mainly in the north of the villages of Tamga, Ighrwizene and Adenoun. Concerning the Zeen oak, Thya and Aleppo pine, they are the lowest area compared to the other classes.

Table 2. Normalized difference vegetation index (NDVI) land cover change from 2000 to 2022.

Land cover classes	Area (ha)				Variation	
	2000		2022		ha	%
Without vegetation	17317,53	34,26	18320,67	36,25	+1003,14	+5,79
Low dense forest	17571,51	34,77	15726,6	31,12	-1844,91	-10,49%
Medium dense forest	11049,84	21,88	11760,16	23,27	+710,32	+6,42%
dense forest	4597,11	9,09	4728,56	9,36	+131,45	+2,85%
Total	50535,99	100	50535,99	100,00	-	-

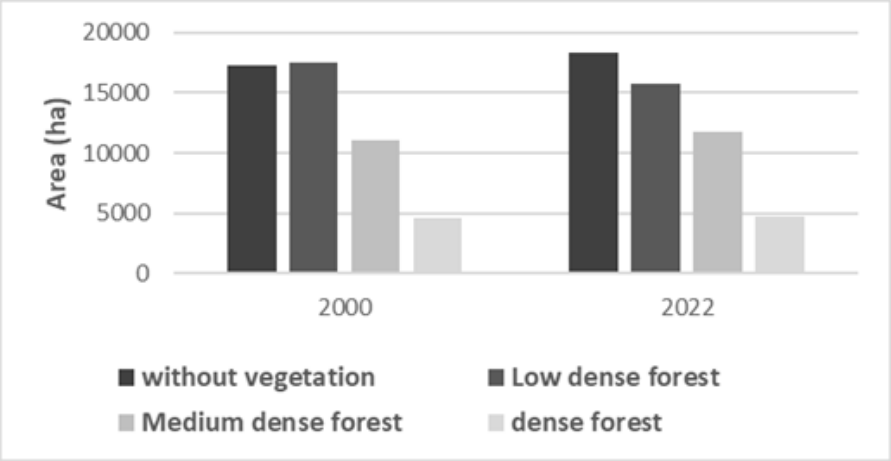

Figure 4. NDVI variations of different land cover classes (2000-2022)

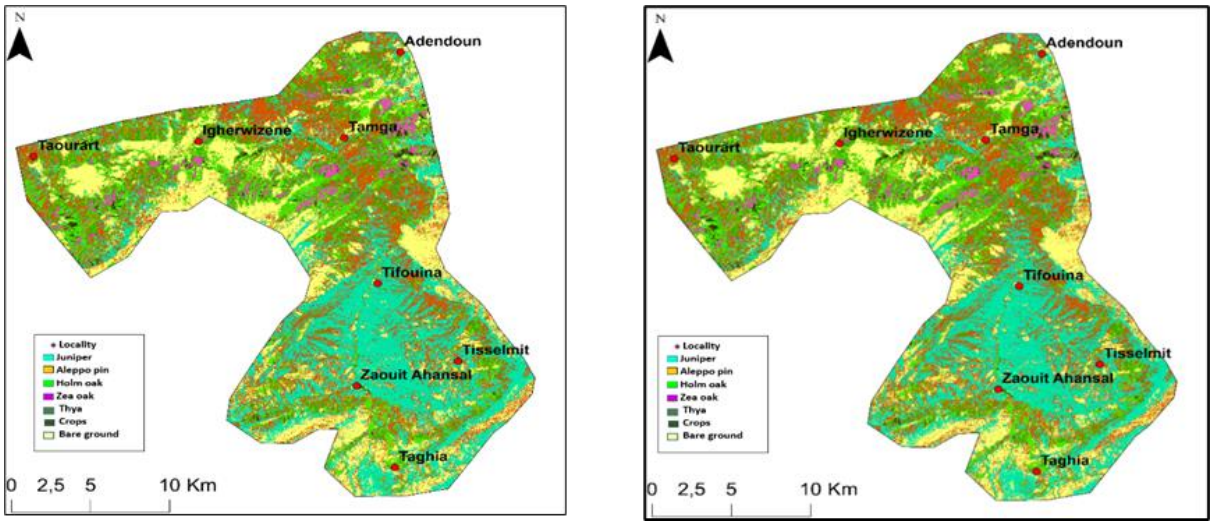

Figure 5. Forest stand map for 2000 and 2022.

The quantitative analysis of the changes in the area of the different land use classes of Zaouit Ahensal during the period 2000-2022, showed that the class of Phoenicean juniper has gone from 28.03% in 2000 to 26.98% in 2022 or a loss of about -530.27 ha. There are also decrease in the area of zea oak and Thya, which have lost 0.30% and 1.93% respectively. The area of crops increased by 1.13% from 551 ha in 2000 to 1080 ha in 2022, an expansion of 572.68 ha. In fact, the decrease in the

area of three species (Phoenician juniper, Thya and Zea oak) increased the area of bare soil from 10762.65 in 2000 to 11008.17 ha in 2022. This decrease in area can be explained by using wood of these species in the manufacture of houses and for heating, as well as the increase in the surface area of crops, mainly fruit trees and cereal crops around the forest areas **(**Figure 6**)**. However, the areas covered by Aleppo pine increased by +114.52 ha, a gain of +0.23. This increase could probably be related to reforestation programs launched by the Directorate of Forest Conservation in the region (Provincial Directorates of Agriculture d'Azilal, 2005). In addition, the Holm oak has also experienced an increase of 0.89% (8358.57 ha in 2000 to 8808.03 ha in 2022) probably due to the regeneration of leaves for trees that have been cut (Barakat *et al.,* 2018) and conservation by forestry officials at the level of the region (HCWFCD, 2002).

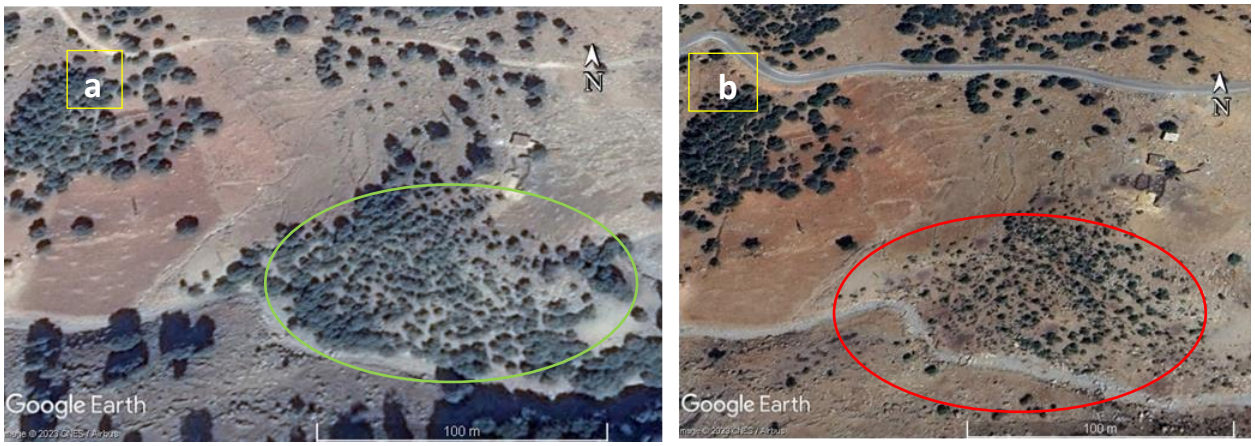

Figure 6. Google Earth image of the same area in 2000(a) and 2022(b)

Table 3. Temporal variation in density by forest stand (2000-2022)

Land cover classes	Area (ha)				Variation (2000-2022)	
	2000		2022			
	ha	%	ha	%	ha	%
Juniper	14166,63	28,03	13636,36	26,98	-530,27	-1,05
Aleppo pine	11434,95	22,62	11549,47	22,85	+114,52	+0,23
Holm oak	8358,57	16,54	8808,03	17,43	+449,46	+0,89
Zea oak	1341,18	2,65	1191,11	2,36	-150,07	-0,30
Thya	3960,99	7,84	3259,15	6,45	-701,84	-1,39
Bare ground	10762,65	21,30	11008,17	21,78	+245,52	+0,49
Crops	511,02	1,01	1083,7	2,14	+572,68	+1,13
Total	50535,99	100,00	50535,99	100,00		

Analysis of the overall change in forest cover showed a slight decrease in the area of forest cover between 2000 and 2022. Forest was the dominant land cover in 2000 with 76.5% of the total study area, followed by the bare soil class (21.30%) and the crop and other class (1.01%). This forest area has decreased by about 2.75% (1382.18 ha) of the total area in 2022 or an average annual loss of about 62.826 ha/year (Figure 7, Table 3).

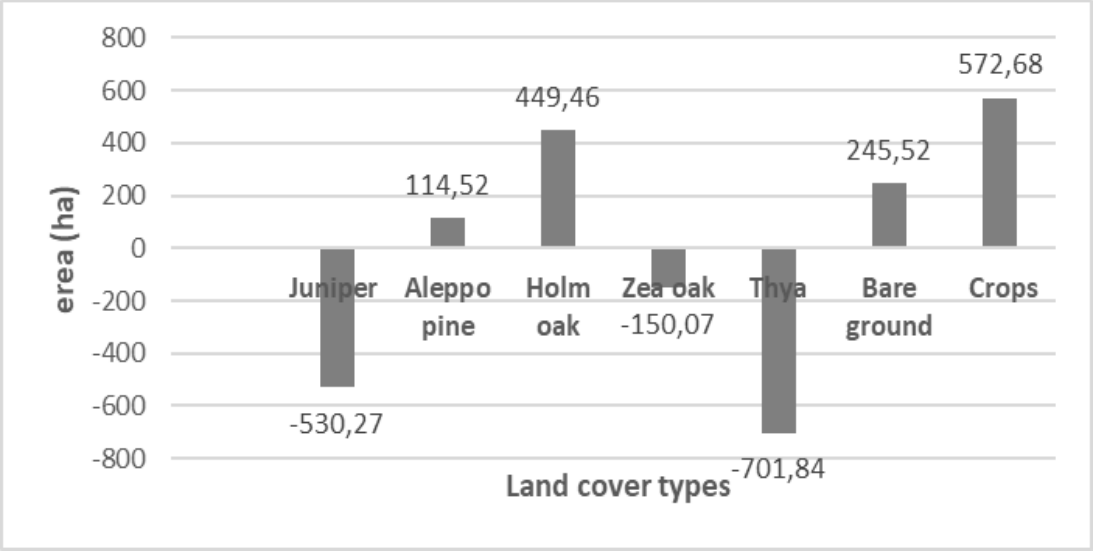

Figure 7. Evolution of the areas of the different elements of land use (2000-2022)

This change in area is mainly explained by the severity of climatic conditions in conjunction with the high anthropic pressure exerted on these ecosystems. Anthropic action is manifested on the terrain by traces of tree cutting, traces of fire, traces of grazing and the extension of agricultural land (cereal crops). In addition, other constraints are taken into consideration such as the aging of trees, parasitic diseases, the absence of natural regeneration and the effect of climate change. This is coherent with other previous studies that have reported that Moroccan forest ecosystems have been suffering since long periods, to severe and fluctuating natural and anthropogenic pressure and several species are threatened and at risk of extinction (El Alaoui El Fels, 1999; Fennane and Tattou,1998). In some places, the good state of forest stands, could be due mainly to favorable climatic conditions, and inaccessible these areas to human habitation or agricultural practices (Maimouni *et al.*, 2021a). In addition, the traditional management is also applied in some localities through defense by forest or pastoral Agdal. Examples of this type of management are installed and studied in Zaouit Ahensal and Ait Bougumaz (Hammi, 2010;). This result shows that spatiotemporal changes in forest cover are not only affected by human activities, but also by other factors such as parasitic diseases and climate change. This study also confirms that NDVI calculation and supervised SVM classification give good and reliable results on mapping and spatiotemporal dynamics of forest cover (Mohajane *et al.*, 2018; Mancino *et al.*, 2014). It could be used as a reference of the status and mapping of forest stands in the study area and can help forest authorities and managers to make decisions for conservation, monitoring, and sustainable management.

Conclusion

In the present study, field surveys and remote sensing were used to map and analyze the dynamics of forest cover in the Zaouit Ahensal region. The results obtained show that the forest stands have undergone a slight regression due to anthropogenic and natural factors, this is manifested by a decrease in the areas of Phoenicean juniper, Thya and Zeen oak, as well as the increase in the areas of bare soil and agricultural areas. The observed expansion of holm oak (+0.89 %) and Aleppo pine (+0.23%) may be due to the favorable climate of the period examined, protection, reforestation programs and regeneration by cutting trees. This first study of its kind in the study area provides information on the distribution of forest formations and their dynamics. Therefore, this study can be a useful starting point

to deepen and follow up research on the structure, dynamics, as well as specific knowledge of the characteristics of forest areas in which bioclimatic conditions are most favorable to identify conservation predictors to protect the remaining populations.

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