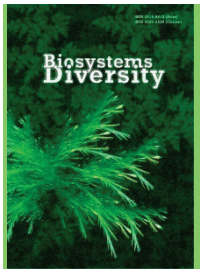

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The degradation of forest areas in Morocco: Case of Benslimane province

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This article aims to shed light on the process of known degradation of the forest area of Benslimane province during the period 1990–2020 and to specify the most important human causes which contributed to it (quarries, extension of the built-up area, the impact of agricultural activities, grazing and collection of firewood), by using remote sensing techniques (spatial images for the years 1990–2000–2010–2020) to produce Land Cover maps. The following satellite images were used, Landsat 5 TM, Landsat 7 ETM+ and Landsat 8 OLI, with a spatial precision of 30 m, the Semi-Automatic Classification Plugin (SCP) in QGIS was used for atmospheric correction, and the Spectral Angle Mapping algorithm for the images' classification. The rating evaluation of the Kappa coefficient shows the following ratios for the years 1990–2000–2010–2020 respectively ; 0.89–0.90–0.90–0.93. The results showed that the forest area of Benslimane province has declined by 11.4% or about 6,027.7 ha between 1990–2020 at the rate of 200 ha/year, which has been turned into matorral land or bare land. This forest also lost 35.2% of its vegetative density and has become much sparser, while the original grazing areas surrounding it have been reduced by 50.4%. Moreover, the area of quarries increased by 1,097.4%, the percentage of built-up area increased by 328.2%, and the agricultural area expanded by 32.7%. These results can be used as preliminary data for future studies and can help policymakers focus on the real drivers of forest degradation, in order to develop interventions to ensure the sustainability of natural resources.

Keywords: Benslimane; Morocco; land cover; remote sensing; mapping; forest degradation; grazing; quarries; human causes.

Introduction

Morocco's high ground conditions and exposed location on two seacoasts allow Morocco to embrace the greatest botanical diversity in North Africa (Benabid, 1985; Benabid & Fennane, 1994). Moroccan forests cover an area of approximately 9 million hectares, i.e. 12.7% of the territory (Chebli et al., 2018), including more than 50 urban forests, and 100 peri-urban forests, encompassing some of the richest and most threatened forest ecosystems in the Mediterranean area (Lamhamedi et al., 2021). A significant part of this wealth is distributed within the province of Benslimane. This geographical space has a significant forest cover estimated at 57,000 ha, it has a southeast-northwest extension, composed of cork oak formations (26%), wild juniper (23%), holm oak (11%), reforestation (20%), matorral (20%). The western part of it is considered a national heritage represented in the largest cork oak forest plain at its southernmost border globally (Machouri, 2010). The Benslimane forest is also an important biological habitat for one endangered species endemic to Morocco, double-spurred francolin *Francolinus bicalcaratus ayesha* (Hanane & Magri, 2016). Likewise, the forest contains many temporary ponds (Rachdi et al., 2011), it provides an environment of great and exceptional importance for the plants and animals that live in the ponds (Rhazi et al., 2007; Acil, 2015; Ichen, 2020).

Increased human pressure has led to the loss of the original extension of this wealth (Laouina et al., 2010), most studies in this region agree that there is a continuing process of forest cover degradation due to inappropriate human intervention (Saber et al., 2008; Machouri, 2009; Acil, 2015; Rachdi et al., 2016; Khalile et al., 2018; Mohamed et al., 2020). In this situation, it becomes necessary to assess the deterioration of forest cover, considering that insufficient knowledge of the fundamental value of forests and ineffective monitoring of their condition are among the causes of biological crises (Zafar et al., 2021). In particular, the challenges posed by climate change in different Moroccan territories (Tramblay et al., 2012; Aoubouazza et al., 2019) and their impact on the national forest system (Navarro-Cerrillo et al., 2020; Camarero et al., 2021) such as water scarcity (El Abidine, 2003) and wildfires (Serbouti et al., 2022) require building a good knowledge of the general contexts that guide the elements of the territory, which is essential for good and sustainable management of natural resources. These negative natural effects are amplified by inappropriate models and systems of exploitation of available natural resources, which lead to deforestation and loss of biological resources (Benbrahim et al., 2004), good and sustainable management of natural resources (Gomes et al., 2019).

The concept of Land Cover refers to the biophysical properties that can be detected directly from aerial or satellite images taken of the earth's surface, and this expression implies the human or natural dimension of this surface (Lambin et al., 2001), this technique helps produce spatial change maps, and historically it was invented in order to realize the effect of increased agricultural and urban space on deforestation (Zhou et al., 2021). Land cover/land use is one of the variables associated with indicators of climate change (DeFries & Townshend, 1994) and global environmental degradation caused by human behaviour (Turner et al., 1994; Hu et al., 2021), it is also linked to Sustainable Development Goals such as change in the proper functioning of water-related ecosystems and percentage of degraded land (Tsendbazar et al., 2021).

Through this article, we aim to make to a more complete diagnosis of the state of the forest cover in the province of Benslimane, in parallel with the mutations of the elements of the land surrounding the forest area, through the use of satellite images in the application of a diachronic study over the last three decades 1990–2020.

Material and methods

Definition of the studied area. The province of Benslimane is located in the North-West of Morocco (33°61' N, –7°14' E) (Acil, 2015), within

the territorial limits of the Casablanca-Settat region (Faroukh et al., 2017), its center (Benslimane City) is located 50 km to east of the city of Casablanca and 50 km south of Rabat (Yasmina et al., 2000). The province belonging to the Mohammedia-Benslimane-ElGara-Berrechid basin is located in the northwest of the Moroccan coastal Meseta (Afenzar & Essamoud, 2020). This area is geologically characterized by Paleozoic layers consisting mainly of quartzite, sandstone, shale and limestone (Rhazi et al., 2001). Benslimane province is characterized by a Mediterranean climate of the semiarid type with a tendency to sub-humidity especially towards the coast (Rachdi et al., 2011), where the average annual rainfall reaches 450 mm (Rhazi et al., 2009), the rainfall regime of the region is also characterized by significant heterogeneity represented in the succession of rainy and dry years (Bellichi, 2016), while the minimum and maximum annual thermal rates oscillate between 10.3 °C and 23.7 °C (Zaakour & Saber, 2014).

Methodology and data analysis. Mapping of land cover change and production of the change matrix was based on comparing the distribution of the classes of land cover maps between 1990–2020.

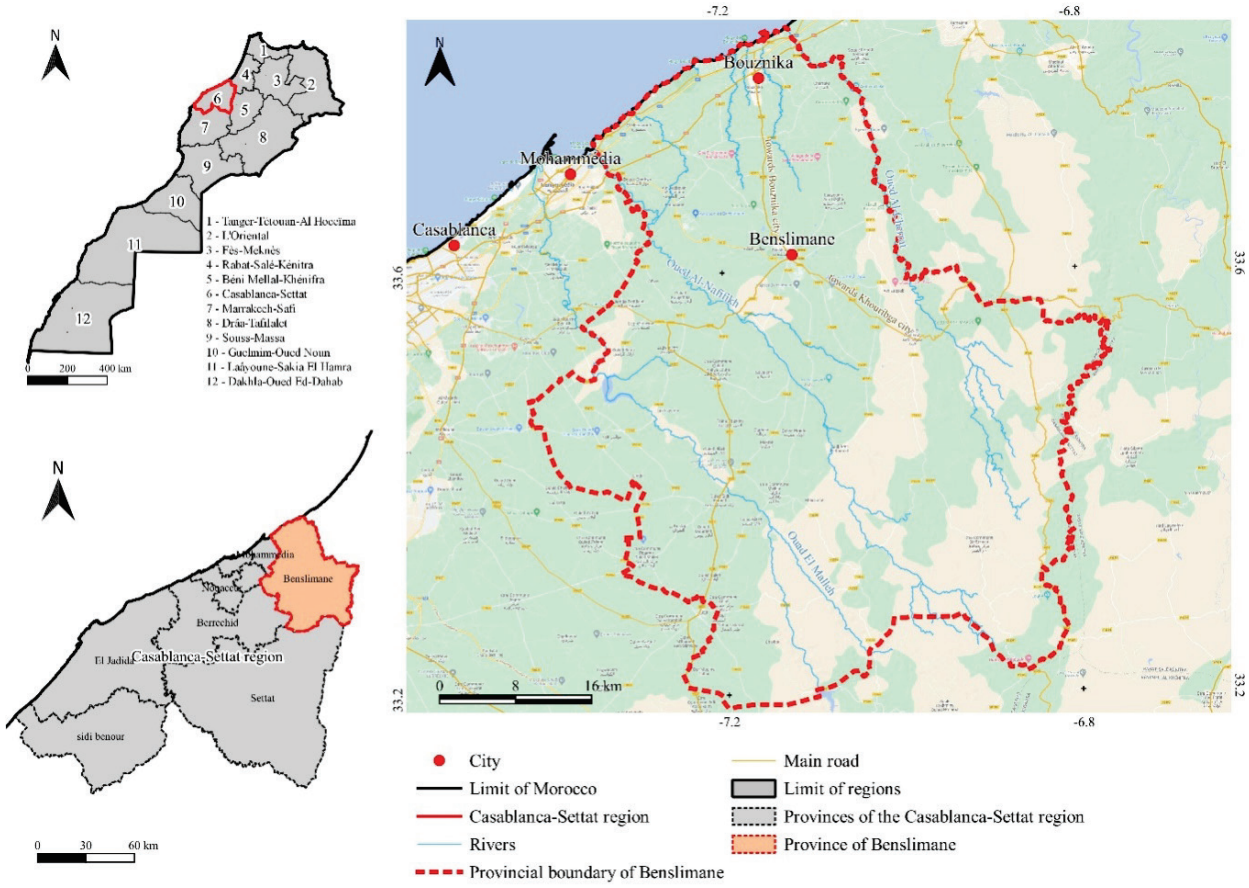

Fig. 1. Location of Benslimane province

The land cover mapping was done by the following phases. Collection of sources and data; downloading satellite images from earthexplorer.usgs.gov of the US government (Izadi & Sohrabi, 2021; Seenipandi et al., 2021) for the satellite Landsat 5 TM, 7 ETM+ and 8 OLI for the years 1990–2000–2010–2020 according to the following table (Table 1). The summer period was chosen for the downloading of satellite images in order to determine more precisely the forest area.

Table 1
Characteristics of satellite images

Satellite	Spatial resolution, m	Bands	Date
Landsat 5 TM	30	7	10/08/1990
Landsat 7 ETM+	30	8	13/08/2000
Landsat 7 ETM+	30	8	25/08/2010
Landsat 8 OLI	30	11	29/09/2020

The features of the land's surface were classified into 8 classes, from the largest to the smallest, according to the cartographic statistics of 1990, which are: agriculture, pasture land, bare land, dense forest, sparse forest, built-up, water, quarries. FAO criteria were used to distinguish forest cover (FAO, 2020) (Table 2).

Production of land cover maps was made for the years 1990–2000–2010–2020. The images were processed and classified using the Spectral Angle Mapping algorithm applied to the Semi-Automatic Classification Plugin (SCP) in Qgis Geographic Information System software (Obodai et al., 2019) a free and open source program (Ellsäßer et al., 2020).

Table 2
Classification of forest density between mapping criteria land coverage and national forest classification

Criteria for mapping	National classification (FAO)	Density rate,%
Dense forest	dense	> 66
	medium density	33–66
Sparse forest	clear	10–33
	scattered	5–10

The Kappa coefficient is the de facto standard to evaluate the agreement between raters, which factors out expected agreement due to chance (Mao & Wang, 2012). The Kappa coefficient indicates the extent of agreement between frequencies of two sets of data collected on two different occasions (Yu, 2005). This process aims to assess precision by calculating the Kappa index, which varies from 0 to 1, and expresses the decrease in error each time the result is close to 1 (Congalton, 1991) (Table 3).

Table 3
Global precision and Kappa coefficients for each map separately

Indicator	1990	2000	2010	2020
Global precision	91.97	92.99	92.98	95.62
Kappa coefficient	0.89	0.91	0.90	0.94

Production of the change map; the land cover maps were used to deduce the change map and therefore the change matrix. The aim is to determine the direction of change of each type of land use during the study period, and then to measure these changes in terms of surface area in order to be able to deduce the direction and extent of land use changes (Elmalki et al., 2021).

Results

The satellite image processing process produced the following maps (Fig. 2–5). Land cover maps produced the following results (Table 4).

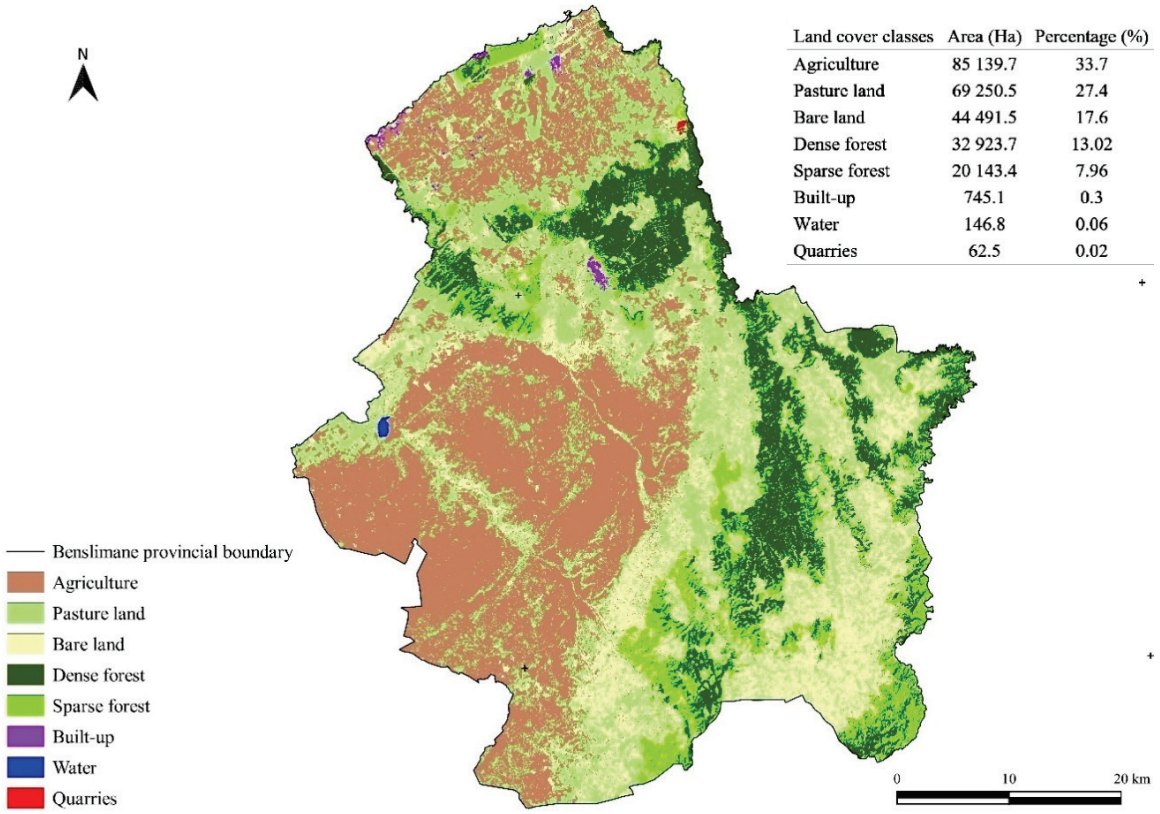

Fig. 2. Land cover map of Benslimane province in 1990

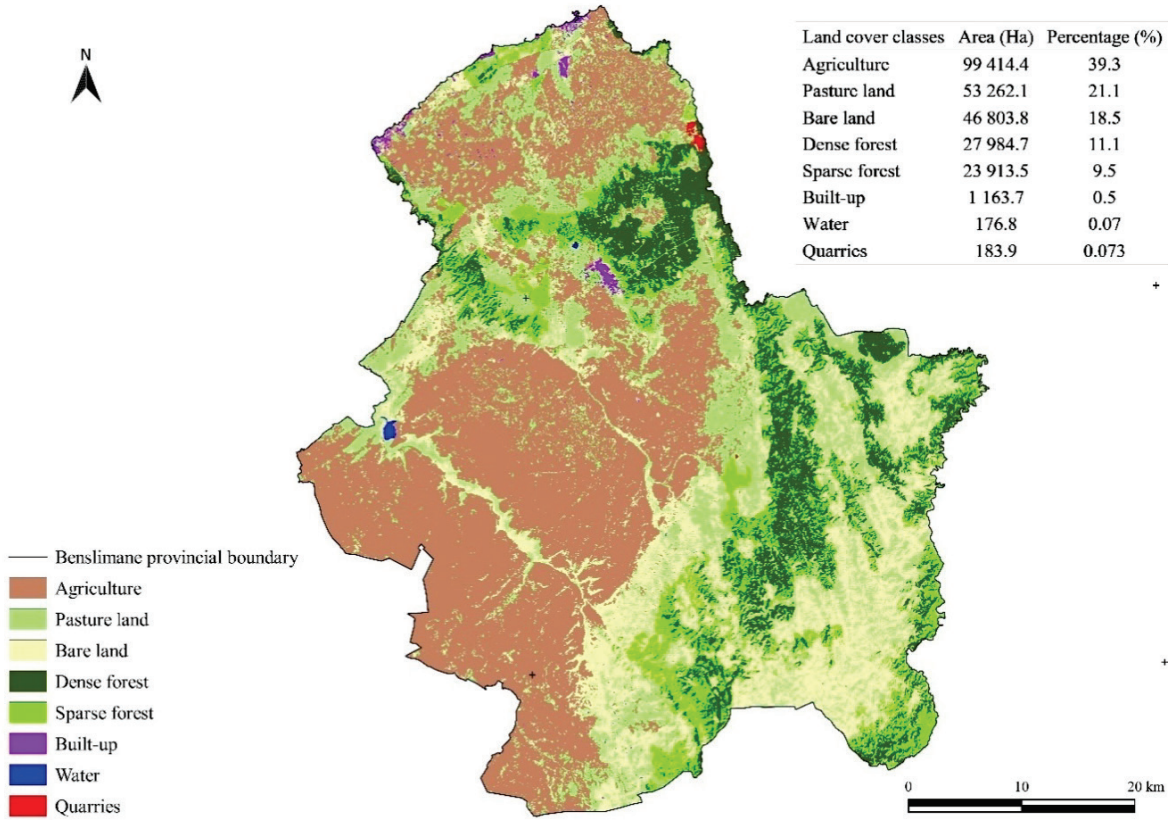

Fig. 3. Land cover map of Benslimane province in 2000

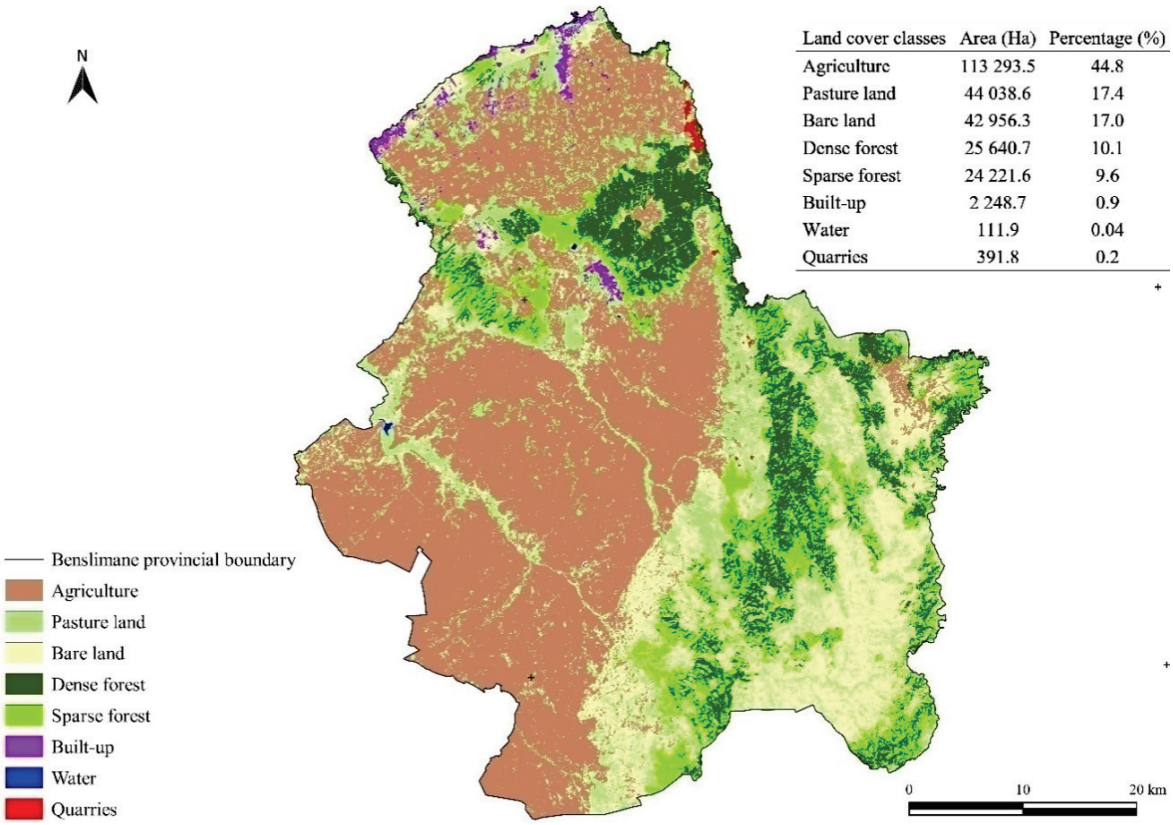

Fig. 4. Land cover map of Benslimane province in 2010

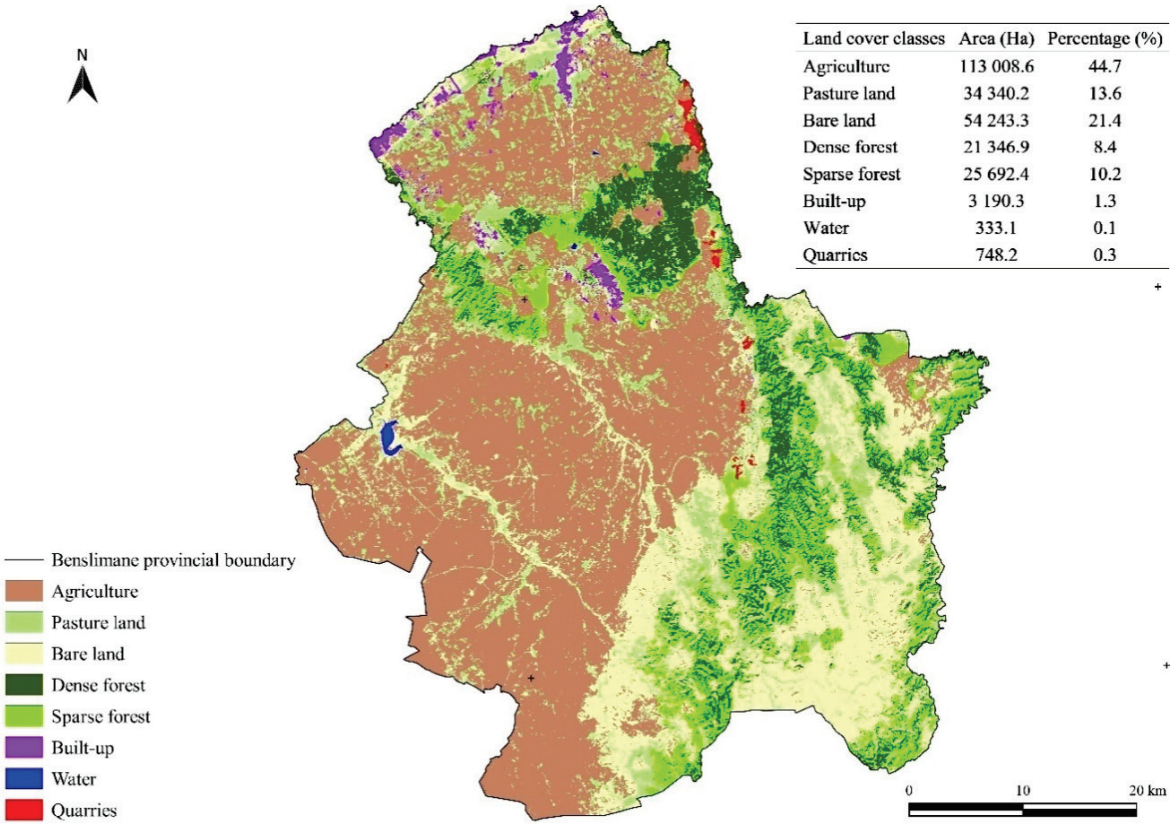

Fig. 5. Land cover map of Benslimane province in 2020

The province of Benslimane is a mixture of a group of elements that have seen many changes over 30 years from 1990 to 2020, which can be seen as follows; The agricultural area increased by 32.7%, as it increased from 85,139.7 ha in 1990 to 113,008.6 ha in 2020, especially in the area extending south of the town of Benslimane, while a progressive decline was recorded near the coast. The pasture area decreased by 50.4% from 69,250.5 ha in 1990 to 34,340.2 ha in 2020, especially in the area surrounding the forests and the southern part of the province. The area of bare land increased by 21.9%, from 44,491.5 ha in 1990 to 54,243.3 ha in 2020, including in particular the southern zone, the slopes of the valleys,

and the surroundings of urban centers, in addition to plots in the middle of the forest. The area of dense forest has decreased by 35.2%, since its area decreased from 32,923.7 ha in 1990 to 21,346.9 ha in 2020. This dynamic has included all forest area, especially in the southern and western parts. The sparse forest area increased by 27.5% from 20,143.4 ha in 1990 to 25,692.4 ha in 2020, especially in the southern zone and the edges of the forest. The built-up area increased at a significant rate of 328.2%, from 745.1 ha in 1990 to 3,190.3 ha in 2020, which is clearly seen in the littoral zone and in the city of Benslimane. The water area increased by 126.9%, from 146.8 ha in 1990 to 333.1 ha in 2020, an area confined to the western part represented by the Oued El-Maleh dam. The area of quarries increased at a significant rate of 1,097.4% from 62.5 ha in 1990 to 748.2 ha in 2020, most of which is distributed longitudinally near the forest zone.

Table 4

Land cover maps statistics and area change rates for each class

Rate of spatial change	Agriculture	Pasture Land	Bare land	Dense forest	Sparse forest	Built-up	Water	Quarries
Land cover map 1990 (ha)	85 139.7	69 250.5	44 491.5	32 923.7	20 143.4	745.1	146.8	62.5
Land cover map 2000 (ha)	99 414.4	53 262.1	46 803.8	27 984.7	23 913.5	1 163.7	176.8	183.9
Global rate of spatial change (%)	16.8	–23.1	5.2	–15.0	18.7	56.2	20.5	194.3
Annual rate of spatial change (%)	1.7	–2.3	0.5	–1.5	1.9	5.6	2.05	19.4
Land cover map 2000 (ha)	99 414.4	53 262.1	46 803.8	27 984.7	23 913.5	1 163.7	176.8	183.93
Land cover map 2010 (ha)	113 293.5	44 038.6	42 956.3	25 640.7	24 221.6	2 248.7	111.9	391.8
Global rate of spatial change (%)	14.0	–17.3	–8.2	–8.4	1.3	93.2	–36.7	113.01
Annual rate of spatial change (%)	1.4	–1.7	–0.8	–0.8	0.1	9.3	–3.7	11.3
Land cover map 2010 (ha)	113 293.5	44 038.6	42 956.3	25 640.7	24 221.6	2 248.7	111.9	391.8
Land cover map 2020 (ha)	113 008.6	34 340.2	54 243.3	21 346.9	25 692.4	3 190.3	333.1	748.2
Global rate of spatial change (%)	–0.3	–22.0	26.3	–16.7	6.1	41.9	197.7	91.0
Annual rate of spatial change (%)	–0.03	–2.2	2.6	–1.7	0.6	4.2	19.8	9.1
Land cover map 1990 (ha)	85 139.7	69 250.5	44 491.5	32 923.7	20 143.4	745.1	146.8	62.5
Land cover map 2020 (ha)	113 008.6	34 340.2	54 243.3	21 346.9	25 692.4	3 190.3	333.1	748.2
Global rate of spatial change (%)	32.7	–50.4	21.9	–35.2	27.5	328.2	126.99	1 097.4
Annual rate of spatial change (%)	3.3	–5.04	2.2	–3.5	2.8	32.8	12.7	109.7

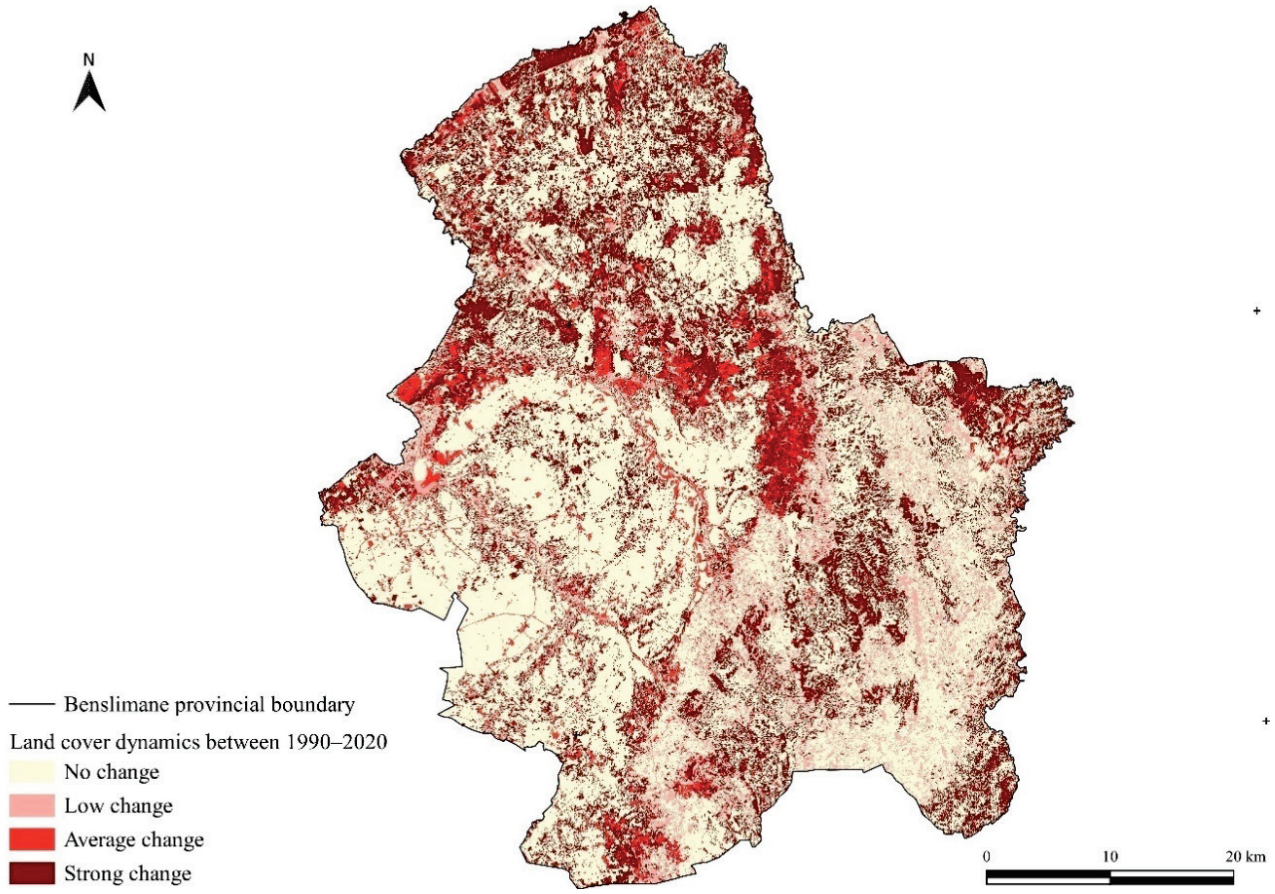

Fig. 6. Benslimane province change map between 1990–2020

The forest area of Benslimane province experienced a range of changes during the period 1990–2020, which can be classified into three dimensions. The first dimension concerns the decline of the forest area in general, whatever its density (dense forest + sparse forest), since its area decreased by 11.4%, or nearly 6,027.7 ha between 1990–2020, at a rate of 200 ha/year, by a deterioration pattern that was constantly increasing over time, rising from 2.2% in the first decade to 4.9% in the second decade, and finally 5.7% in the last decade (Table 5 and 6). The second dimension is the shrinking of the density of this land cover itself, since the density rate decreased by about 35.2% between 1990–2020, interspersed with variable periods of deterioration, including 15% in the first decade, 8.4% in the second decade and 16.7% in the third decade, while the proportion of sparse forest area increased (Table 7). The third dimension is the trend towards degradation, where most of the forest area (dense forest + sparse forest) affected has turned into pasture land (55.8%), bare land (33.5%), agriculture (7.03%), quarries (2.5%), built-up (1.1%) and water (0.01). The direct damage to the forest is estimated at 6 027.7 ha (Table 8).

Table 5
Forest area statistics (dense forest + sparse forest) in the province of Benslimane for the year 1990–2000–2010–2020

Forest cover area of Benslimane province	1990	2000	2010	2020
Forest area, ha	53 067.01	51 898.2	49 862.3	470393

Discussion

Statistics (Table 5 and 6) indicate continued deterioration of forest cover in Benslimane province, faced with the growth in the pace of urbanization (Table 4). This expansion can be clearly seen on the land cover maps for the years 1990 and 2020, in particular for the city of Benslimane in depth or the city of Bouznika on the coast.

Table 6
Statistics of the forest area evolution (dense forest + sparse forest) in Benslimane province between 1990–2020 by periods

The spatial evolution of the forest area	1990–2000	2000–2010	2010–2020	1990–2020
Overall rate of spatial evolution, %	–2.2	–4.9	–5.7	–11.4
Evolution of the area, ha	1 168.8	2 035.9	2 823.01	6 027.7

Table 7
Statistics of the density evolution of the forest area in Benslimane province between 1990–2020 (According to the degree of density)

Density degree	Spatial evolution	1990–2000	2000–2010	2010–2020	1990–2020
Dense forest	overall rate of spatial evolution, %	–15.0	–8.4	–16.7	–35.2
	evolution of the area, ha	4 939	2 344	4 293.8	11 576.8
Sparse forest	overall rate of spatial evolution, %	18.7	1.3	6.1	27.5
	evolution of the area, ha	3 770.1	308.1	1 470.8	5 549

Table 8
Statistics of change in the Benslimane province forest area (dense forest + sparse forest) to other classes between 1990–2020

Change in forest area	Pasture land	Bare land	Agriculture	Quarries	Built-up	Water	Total
Area, ha	3 365.3	2 021.5	423.56	147.78	68.93	0.64	6 027.7
Percentage, %	55.8	33.5	7.0	2.5	1.1	0.01	100

Generally, the Moroccan coast experienced a slow expansion of construction that lasted several centuries, while this phenomenon crystallized more quickly during the colonial and post-independence era (Nakhli, 2010; Karibi, 2019) The coast is currently home to around a 60–66% of the country's population (Snoussi et al., 2009; Bahi et al., 2019). Like the other sections of the Moroccan coastline, the area extending between the lower valley of Oued Al-Nafifikh and Oued Al-Cherrat (Benslimane province coast) has experienced rapid and steady development in recent years, at the expense of agricultural land and neighbouring forests. It is an extension of its original core, the city of Bouznika, which until recently was considered a simple bus station. This urbanization is mainly composed of tourist complexes and luxurious real estate structures that have been built in the coastal areas (Troin, 1979; Troin & Berriane, 2002; El-Idrissi, 2022), taking advantage of real estate speculation. This process has led to a deterioration of the situation of agricultural activity and the deterioration of the quality of water resources (Sehlaoui et al., 2020). In fact, the typical Bouznika sequence reveals, in several coastal sections, negative indicators in the management of local affairs and the temporary exploitation of the public domain in favour of personal interests (El-Idrissi, 2022). This resulted in the loss of approximately 1,208.4 ha of coastal forest cover and its conversion to developed areas between 1990 and 2020 (the current study) (Fig. 7).

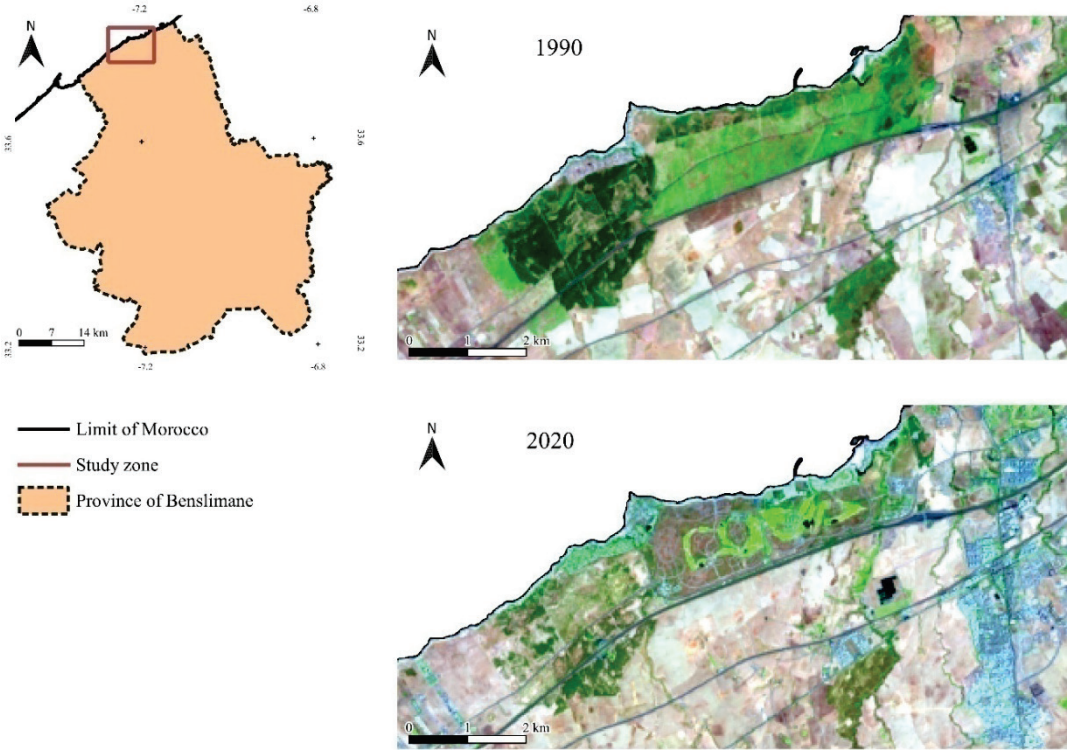

Fig. 7. Coastal forest degradation

Internally, the built-up area of the city of Benslimane in the south and southwest direction has doubled from 1.2 to 5.0 km² between the years 1989–2019 with expectations that urban expansion will continue to reach 6.8 km² in 2039, which puts about 0.34 km² (34 ha) of the vegetation area in danger of disappearing (Mohamed et al., 2020). In addition, one of the most important transformations that the Benslimane Forest has undergone in recent years is the departure of rural families and the arrival of new urban occupants along the roads. This change deeply affects the spatial management system as well as orienting the local economic activity towards recreation and tourism (Faroukh et al., 2017), such as the cultural tourism, educational and sports activities, which cause damage to vegetation cover, deterioration of water ponds and pollution (Machouri, 2010).

On the other hand, by analyzing the spatial change map (Fig. 6) and the land cover maps for the year 1990–2020 (Fig. 2 and 5) and the statistics on the agricultural area (Table 4), the province of Benslimane has experienced a change in land use and its transformation into an agricultural zone, in particular to the south of Benslimane (towards Khouribga city) and to its north (towards Bouznika city), on the edge of the forest zone and sometimes inside it in degraded areas (field notes). This has led to a decrease in the density of temporary ponds in the region, where about 201 ponds disappeared from the surroundings of the Benslimane Forest during the last decades of the 20th century and have been turned to agriculture (Rhazi et al., 2012). While the rate of plant richness decreases in the forest area near the city of Benslimane and in the rural area, with a greater negative impact from the urban area, the deep areas of the forest remain relatively diversified, particularly those associated with hunting reserves (Acil, 2015). All these elements contributed to the formation of an urban/agricultural front that exerts constant pressure on the forest, creating a field of friction between nature and human beings.

This study shows many data related to quarries, first, it gives a spatial description of the spread of these quarries, which are spread at or near the forest area (Fig. 2–5) second, it gives increasing statistics for the area covered by the quarries (Table 4). The province of Benslimane has approximately 42 quarries producing a total of 2.8 million m³/year of materials intended for construction (76% gravette, 21.4% random rock, 1.9% clay, 0.08% marble), most of these quarries are distributed linearly on the left bank of Oued Al-Cherrat, parallel to the forest zone, where the expansion of the area of mining activity has led to the erosion of the forest zone, quarries produce huge waves of dust. This dust is very dangerous for living beings (reduced air quality). In some cases it can cause permanent respiratory diseases such as silicosis for quarry workers and surrounding populations. In addition, the presence of this dust on the leaves influences photosynthesis and can even stop it (Farki et al., 2016). The quarries contribute to the high potential for soil erosion in the extraction areas and surrounding areas (Taoufik et al., 2020). Quarrying can cause significant disturbances to the natural environment. It inevitably leads to the depletion of natural resources and environmental problems such as the destruction of fauna and flora, groundwater pollution, visual impacts and so on (Abidi et al., 2018; Dellero & El Kharim, 2017). The quarrying industry is a significant business sector; it presents a job opportunity also, a significant source of income through taxes that contributes to local economic development; but it generates negative effects on the environment. The awareness of the protection of the environment requires the reconciliation between the imperatives of preserving the environment and those of sustainable socio-economic development (Hattabi et al., 2020).

The decline in the forest area can also be explained by the activities of local individuals and groups, such as overgrazing and the unsustainable collection of firewood. Pastoralism is an economic base in many regions and the sole source of income for many families (Benabid, 1985), a large proportion of the Moroccan herd grazes and reproduces traditionally between the steppes and the mountains and open areas close to the forests, contributing to the aggravation of the environmental situation (Laouina, 2006). The percentage of the herd that grazes inside the Moroccan forests is estimated at about 35% in normal climatic years and 53% in dry years, its feed requirement in normal years (35%) being 4 billion FU (fodder unit)/year), while the sustainable production capacity of the forest is only about 1.6 billion FU/year (Ellatifi, 2012).This issue constitutes a major obstacle to preparation of forestry plans because of its negative impact on the processes of natural succession or reforestation (Hetier & Lilin, 1989). In Benslimane province, livestock raising is one of the activities necessary for the subsistence of the local population (Saber et al., 2008), the actual weak situation of the forest is mainly due to the increase in animal grazing, especially by goats (Ongaro & Ramat, 2003), which are known for their multiple abilities to adapt, climb and consume rough elements (Von Maydell, 1980; Lovreglio et al., 2014). This trend is also linked to the decline of pastures in the region (Saber et al., 2008). Because of these factors, the valuable natural resource the Benslimane Forest is placed under excessive pressure from herders, varying between 3 to 6 times the productive capacity of the forest, with an average length of stay in the forest between 245 to 276 days/year (Machouri, 2009) 228 days/year (Faroukh et al., 2017). There is a close association between the practice of grazing and the deterioration of vegetation cover in Benslimane province. An unsustainably high biomass is found in the protected range where grazing is forbidden (123.15 ± 25.81 g/m² against 42.26 ± 23.28 g/m²) (Bouahim et al., 2010).

As for collection of firewood, it is considered to be one of the most harmful phenomena for the forest domain in developing countries (Osei, 1993; Chettri et al., 2002), figures indicate that approximately 2.8 billion people worldwide rely on wood as a source of energy (Reyes et al., 2018), intended primarily for domestic use due to its ease of access (Bhatt & Sachan, 2004). At the national level, the quantity of wood extracted from the Moroccan forest reaches 10 million m^3/year, while the productive capacity of the forest estate is 3 million m^3/year at its highest production levels, three times the natural capacity (Benzyane, 2007). Up to 69% of firewood is collected illegally in Morocco (Croitoru, 2007), which causes damage to 111,200 ha/year of forest area (Ellatifi, 2012). The state through the National Agency for Water and Forests (NAWF) tries to reduce the tension between the state and the local population through the promulgation of a legal instrument instituting the granting of compensation for forest conservation. This mechanism depends on a financial incentive based on the temporary purchase of the right to use pasture in return for compensation of the areas removed from grazing (Naggar, 2013), by granting a financial subsidy of 1,000 dirhams (100$) ha/year of set-aside. This instrument has allowed the emergence of an associative dynamic of rural user communities in favour of a concerted management of forest resources. By the end of 2017, 165 pastoral associations had been created across the national territory and these ensure the joint management of nearly 92,000 ha of protected silvopastoral areas (Naggar, 2018).

Conclusion

The Benslimane province forest resource has experienced a significant decline in recent decades due to the direct and indirect impact of human activities, which have exerted additional pressure in addition to climate change and land degradation. This situation requires the cooperation of a group of actors in order to find a lasting solution to this degradation, in particular identifying the ecological roles the forest plays and the economic benefits it provides to individuals. Efforts should be concentrated on improving the socio-economic situation of the local population and on providing sustainable opportunities outside the forest zone, whether for large investors or the local population. Social differences must be taken into account, more efforts should be made in reforestation of degraded areas and development of abandoned quarries. In addition the legal basis of forest conservation should be strengthened by placing more effective restrictions on irresponsible interventions and taking into account the ecological component in urban planning.

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