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Effects of Climate Change and Anthropization on Dynamics of Vegetation Cover in the Taounate Region of Morocco

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ABSTRACT

The forest area of the region of Taounate has experienced significant pressure from the combined effects of climate change and anthropization, leading to a strong regression of the cover plant. This study was aimed at evaluating the changes in the Taounate forest region landscape between 1975 and 2019 to create awareness in the public about the impact human activities have on the environment and to engage them in its preservation through the integration of residents' knowledge with that of the provincial office in charge of water and forests. The study was conducted in the province of Taounate, which is located in the pre-Rifa and Rifa regions in the north of the Kingdom. The forest estate covers an area of 40,690.96 ha (7%) of the provincial area. Information related to vegetation cover was obtained from the Provincial Directorate of Water and Forests and the Fight against Desertification. Data on climate change were acquired through a questionnaire. The quantification of the degradation of the forest surface under the combined effects of climate change and anthropization was evaluated with remote sensing, coupled with Geographic Information System (GIS) techniques. The results obtained show that the forest landscape has experienced a strong regression, mainly due to invasive species (cannabis) and environmental changes. The largest successive area of cut vegetation cover is that of 2015, 2014, 2013, 2017, 2018, and finally 2016. The findings of this study indicate that urgent intervention of all social actors is required to save the local ecosystems of this region.

Keywords: Anthropization, Climate change, Morocco, Taounate, Vegetation cover.

Introduction

Forests have played an essential role in the lives of human beings from ancient times untill the present. They are one of the primary natural resources that need to be protected for future generations.[1] Forest cover 31% of the planet's surface.[2] Currently, due to the population explosion that is still growing,[3] and the industrial revolution, humans choose to rely on natural resources to meet their demands rather than managing them rationally to protect them.[4] This will result in the overexploitation of natural resources and an imbalance among the various ecosystems.[5] Grazing, wood cutting, serious mutilation, debarking, dismantling, destruction of markers (fence), plowing, extraction of byproducts, fires, the fire inside or at a prohibited distance from the forests, forgery of the hammer or use of a fraudulent hammer, and clearing of the forest estate have all combined to cause a strong regression of the cover vegetation to meet the socio-economic needs of the population.[7]Morocco is characterized by a Mediterranean climate,[8] or there is an overlap of multiple bioclimatic stages, which are reflected in the country's extensive vegetative cover. Accordingly, the Moroccan forest surface ranges from 180,000 to 200,000 ha.[9] Taounate is distinguished for a sizeable forest cover area of 40,690.96 ha.

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It is located in the northern part of the province, which includes mainly 12,740 ha (31%) of holm oak; 5,120 ha (13%) of cork oak; 1,285 ha (3%) of Tauzin oak and Zeen oak; and 9,700 ha (24%) of other formations (Thuja and secondary species). Artificial plantations cover 11,500 ha (29%) of the total area. The industrial revolution, the rapid growth in population, and the cultivation of cannabis (lkif) are all contributing to the anthropogenic pressure, as well as climate change, which is destroying plant biodiversity. Making maps of vegetation cover using remote sensing and geographic information system (GIS) techniques from 1975 to 2019 and comparing them to one another will help to better understand the spatiotemporal evolution of plant cover in this area.The aim of this study was to quantify the degradation of the forest area in the Taounate region to draw people's attention and make them aware of the impact of their activities on the environment.

Materials and Methods

Study area
The province of Taounate is located in the pre-Rifa and Rifa regions in the north of the Kingdom and covers an area of 5616 km^2 in the Fez-Meknes region, Morocco(Figure 1). The rural population represents 78% of the total population and is dispersed throughout more than 1,600 km^2. The forest estate covers an area of 40,690.96 ha (7%) of the provincial area. The forest cover is located entirely in the northern part of the province and is scattered and dispersed. It is made up of 118 cantons ranging from a few hectares to 2,600 ha, shaped by the human pressure exerted for a long time on the forest space, notably through clearing and cultivation of lands originally covered by the forest.

Methodology

To understand this subject on all levels, three approaches were used. The Provincial Directorate of Water and Forests and the Fight against Desertification provided information on the types of anthropogenization, the types of vegetation that were most frequently cut, as well as the cut forest area. Data on climate change was obtained through a questionnaire sent to the riparian population. To gather as much information as possible and to make interviews with illiterates, both questionnaires were made in a language that the public is familiar with.

The quantification of the degradation of the forest surface under the combined effects of climate change and anthropization was carried out by mapping vegetation cover from 1975 to 2019 using remote sensing coupled with geographic information system (GIS) techniques. This was done to compare them with each other to have a better understanding of the spatio-temporal evolution of vegetation cover in this region and to calculate the normalized difference vegetation index (NDVI), which is constructed from the red and near-infrared channels and is sensitive to the amount of vegetation. NDVI uses the reflectance of solar radiation to measure the density and intensity of vegetation growth.
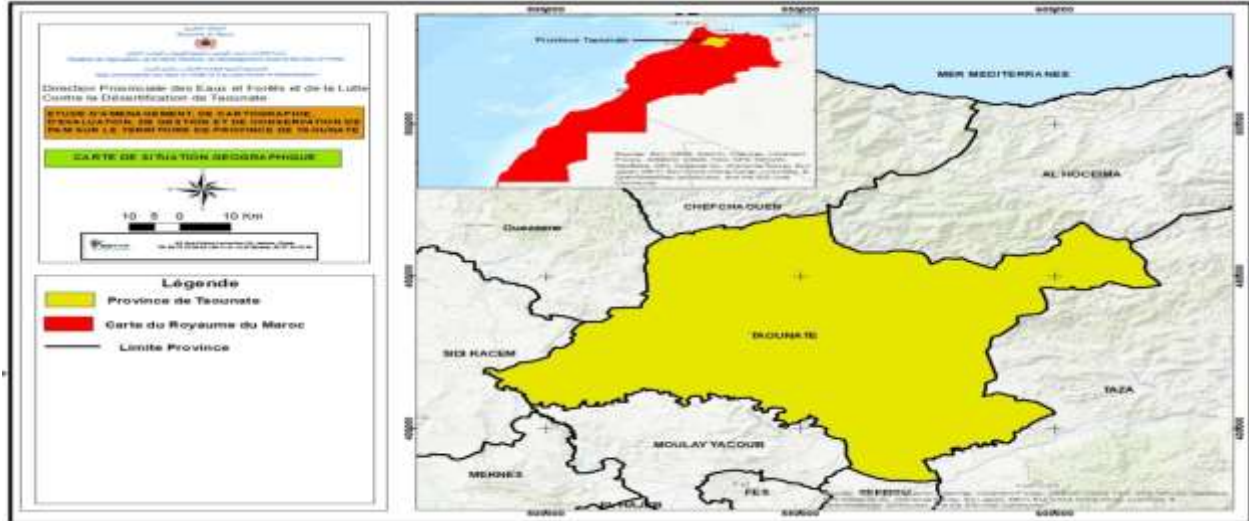

Figure 1: Map of the study area.

Table 1: Characteristics of the images used

Image	Sensor	Pixel size (m)	Spectral bands and wavelength (µm)	Date taken
(Situation 1975)	Landsat 1 MSS	70	1 (B) 2 (V) 3 (R) 4 (IR) pan	August
(Situation 1985)	Landsat 4 MSS	30	1 (B) 2 (V) 3 (R) 4 (IR) pan	August
(Situation 1995)	Landsat 5 MSS ET TM	30	1 (B) 2 (V) 3 (R) 4 (IR) pan	August
(Situation 2005)	Landsat 5 MSS ET TM	30	1 (B) 2 (V) 3 (R) 4 (IR) pan	August
(Situation 2019)	Landsat 8 OLI ET TIRS	30	1 (A) 2 (B) 3 (V) 4 (R) 5 (IR) 6 (IRM) 7 (IRT) 8 (Pan) 9 (Cirrus)	August

Using the reflectance of solar radiation (Red and IR), NDVI enables control over the density and intensity of vegetation growth. NDVI is calculated as (PIR (Photochemical Reflection Index)-R) / (PIR+R), where PIR and R are the pixel values for the infrared and red channels, respectively. The range of the NDVI value is from -1 to 1, where -1 denotes the absence of vegetation (such as water, clouds, or snow), 0 denotes bare soil, 0.1 to 0.3 denotes shrubs and grasses, and 0.6 to 0.8 denotes tropical or temperate rainforest.

Data presentation
The Landsat 1 MSS, Landsat 4 MSS, Landsat 5 MSS and TM, Landsat 8 OLI, and TIRS satellite images were used to evaluate the forest cover and avoid other types of agriculture. All the satellite images used belong to the Earth Explorer database. The software used for the processing of the images includes ArcGis 10. 4. 1, ERDAS and Excel. Table 1 displays the characteristics of the images used.

Results and Discussion

Survey dedicated to the Provincial Directorate of Water and Forests and the Fight against Desertification.
The travel document received by type of anthropization from 2010 to 2019.
Figure 2 demonstrates that plowing forest land, followed by clearing and cutting wood, are the most common travel documents recorded by the Provincial Directorate of Water and Forests and the Fight against Desertification.

Vegetative cover removed from 2013 to 2018 in Ha
The results presented in Figure 3 show that the largest successive area of cut vegetation cover is that of 2015, 2014, 2013, 2017, 2018, and finally 2016. Therefore, the total area of vegetative cover removed between 2013 and 2018 is approximately 347.28886 ha.

Types of the most cut vegetation from 2013 to 2019 in Ha:
As shown in Figure 4, the vegetation types that were most frequently cut down in ranking order include aromatic and medicinal plants, followed by holm oak, cork oak, and finally pine.

Land clearing by rural communities from 2009 to 2015
As shown in Figure 5, the municipalities with a high level of land clearing are Khlalfa, Fennassa Bab El Hait, Bouhoda, Timezgana, Retba, Tamdite, Beni Ouanjel, Galaz, Beni Oulid and Kissane.
The results represented above show that the scenic biodiversity of the Taounate region has significantly degraded, as evidenced by the results of the questionnaire for the Provincial Directorate of Water and Forests and the Fight against Desertification. Accordingly, it was observed that the degraded vegetation covers between 2013 and 2018 are estimated to be 347 ha due to anthropogenic activity. This observation is in agreement with the findings of Hervé,[10] who discovered that anthropogenization and climate change severely degrade the vegetation cover and woody resources. Also, the results are in agreement with the findings of Éric,[11] who discovered that the population depends on the vegetation cover to meet their socioeconomic needs. As a result, in Africa, the vegetation cover decreased from 749 million hectares in 1990 to 674 hectares in 2010.
The primary plant species that have been removed during this time are aromatic and medicinal plants, followed by holm oak, cork oak, and then pine. These results are similar to those of Grevin's research, which found that the JbelOutka forest has experienced a regression of about 37.67% of its total area, with this regression affecting the cork oak, zean oak, and pine mainly due to the cultivation of cannabis. Between 2010 and 2019, the administrative staff of the Directorate received 3,990 reports, of which the reports of the plowing came in first with 2,128.[13] It was discovered that the rural population uses forest lands for the cultivation of cannabis and Trésor.[14] Also, the studied landscape has experienced a strong anthropogenic pressure that causes regression of the vegetation cover, to use the forest land for agriculture. The following communities are identified by a strong clearing: Khlalfa, Fennassa Bab El Hait, Bouhoda, Timezgana, Retba, Tamdite, Beni Ouanjel, Galaz, Beni Oulid, and Kissane. The reason

for the strong clearing in these rural communes is the use of the forest surface for cannabis cultivation, construction, and other agricultural activities.
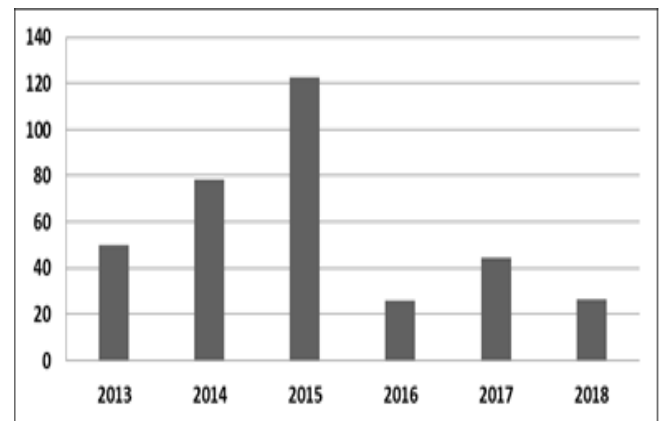
Survey dedicated to the riparian on climate change
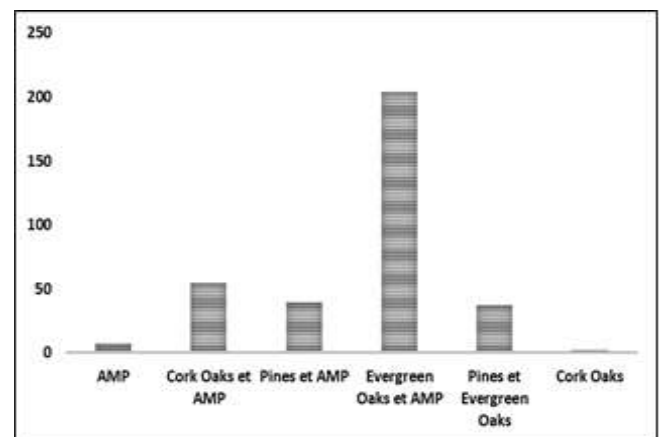*Effects of temperature and precipitation*
The whole sampled population feels that the average temperature has been rising and the average precipitation has been declining during the past few decades.
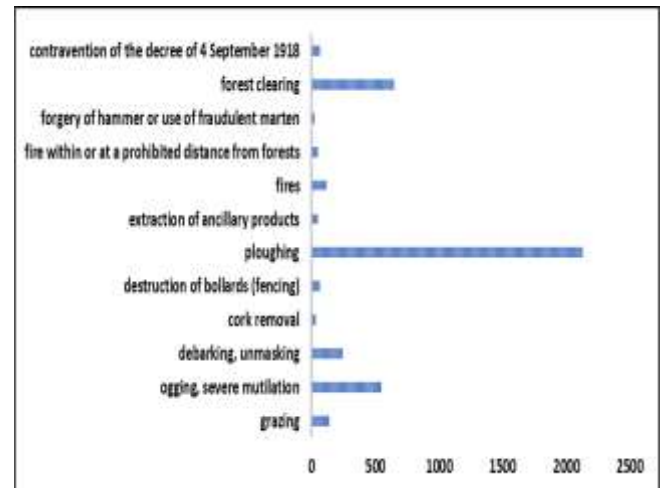
Figure 2: Travel document received by anthropization type from 2010 to 2019.

Figure 3: Cut surface of **v**egetative cover from 2013 to 2018 in ha.

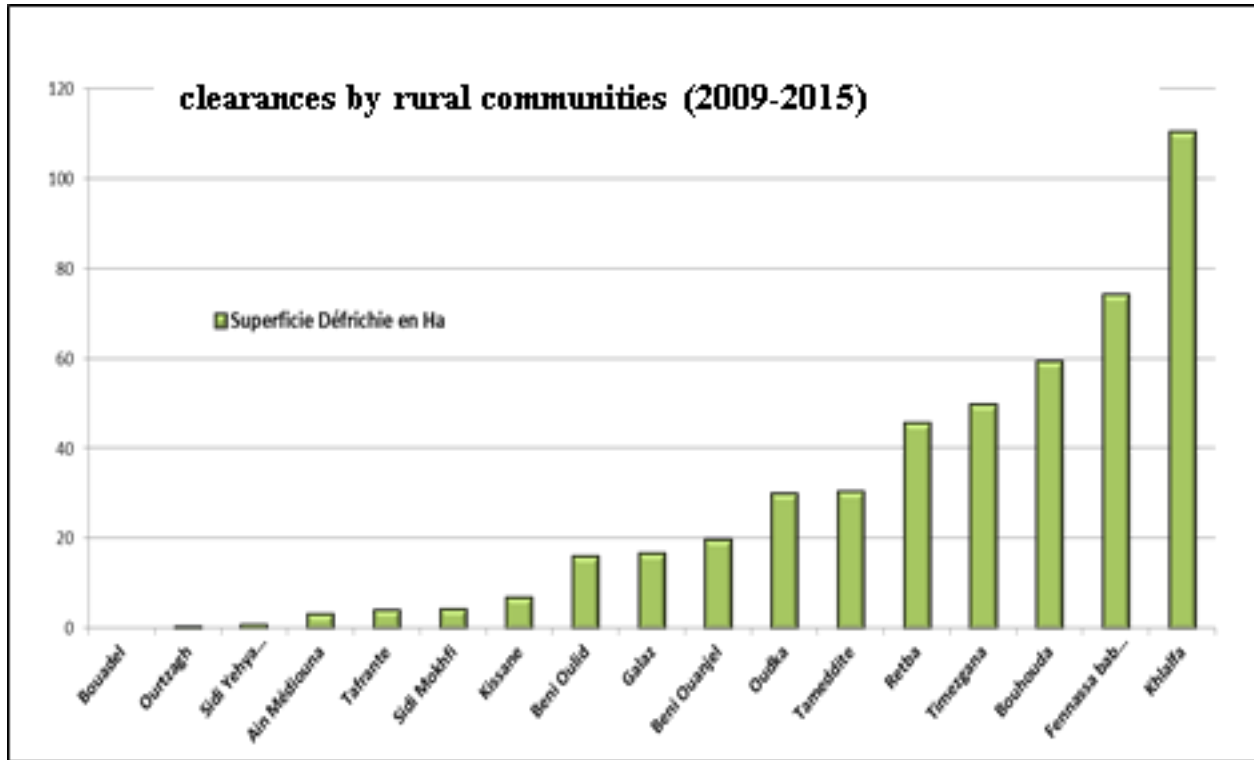**Figure 4:** Types of the most cut vegetation from 2013 to 2019 in ha.

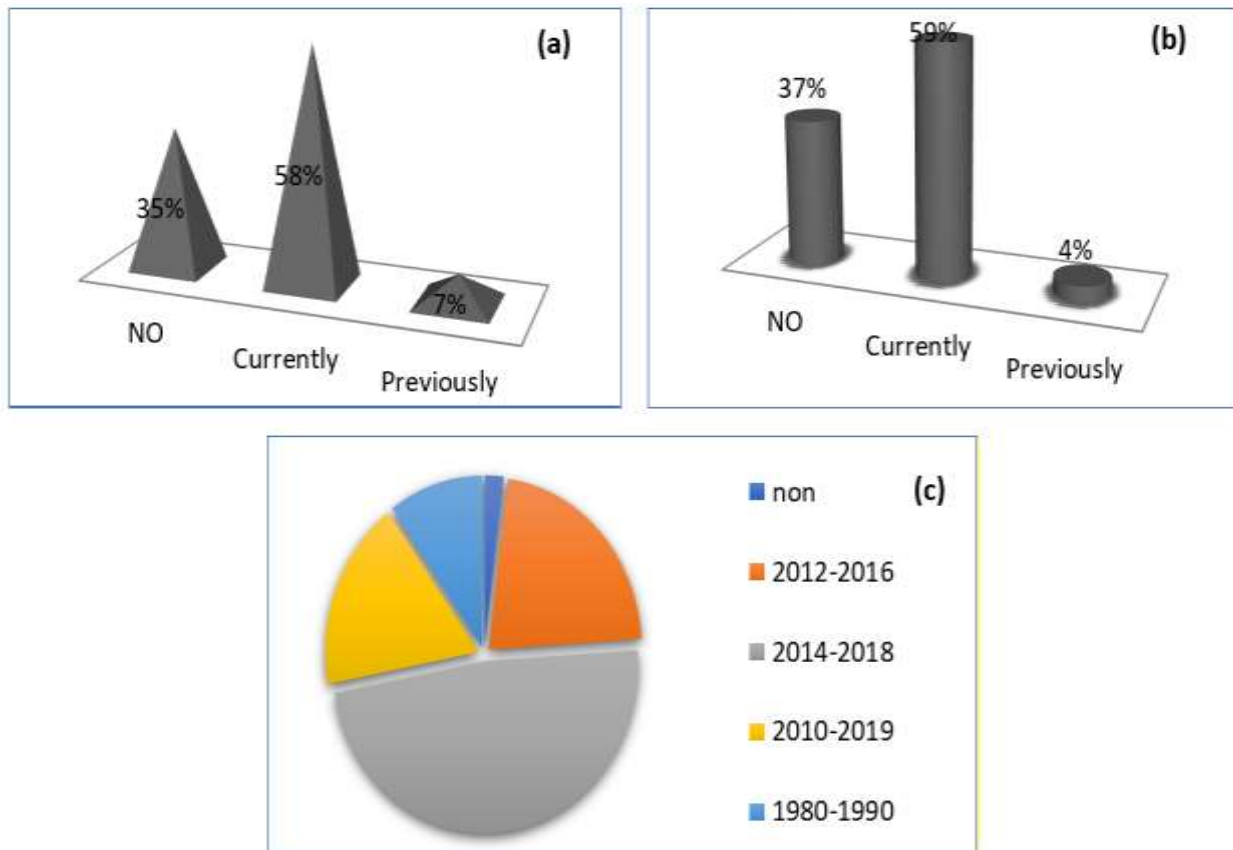**Figure 5:** Clearances by rural communities (2009-2015).

Figure 6: Frequency of storms (a), Frequency of floods (b) and Frequency of droughts (c)

Effects of natural disasters (storms, droughts, and floods)
Figures 6 indicates that the majority of the people questioned opined that natural catastrophes are becoming more severe, particularly droughts and flooding.

Effects of water resources
The results of the survey conducted among the residents show that the entire population experienced a deficit in surface water resources and a regression of the water table, which were both indicated by a decline in the water level in various wells and an increase in drilling depth that caused the water to rise.

Effects of vegetation cover
 The disappearance of certain forests and grazing is evidence of a regression in the degree of vegetation cover, as shown by the entire sample investigated.

Effects of climate change on plant biodiversity
Concerning the vegetative species that have appeared and disappeared in the region, nobody from the surveyed population mentioned any change in vegetative species that has taken place in the study area. In terms of the vegetative species on the verge of extinction in the region, the results show that the hygrophilous plants; walnut, willow, *Juncus acutus*, Marrube commune, and Vitus are implicated (Figure 7). The data obtained from the survey indicate that the results of the survey on climate change conducted among the riparian population of the Taounate region reveal that the respondents were aware of it and have observed changes in the climatic parameters, such as a decline in precipitation and a temperature rise. These results were confirmed by Kabé,[15]Konte,[16] and Arsène,[17] who observed that there has been an increase in temperature and a decrease in the rainy season over the past few decades. The increase in the intensity of natural disasters, particularly droughts and floods, is similar to the findings of Thibaut,[18] and Etene,[19] who found that climate change has worsened the intensity of droughts and floods.

They observed a decline in surface water resources and a regression of the water table. Hamidou,[20,] and Hachad,[21] reported that both surface water and subsurface water are being affected by the decrease in rainfall. The decrease in the vegetation cover was discovered in research conducted by Bouazza,[22] that the plant cover of the Atlas of Beni-Mellal declined by an estimated 19% between 1978 and 2014, or 121,8 km^2. The absence of riparian plants was noticed.

Vegetation cover dynamics between 1975 and 2019 by remote sensing
The territory of Taounte is separated into two distinct parts. The southern part with the hilly ground is where most agriculture is performed. This division is evident from the maps of the normalized difference vegetation index (NDVI) displayed on the maps (Figure 8) from the years 1975, 1985, and 2019. It is a part of the pre-field and covers around 60% of the area of the province. The altitudes range from 150 m (Oued Inaouen) to 1000 m (JbelZaidour), which is a comparatively low altitude.
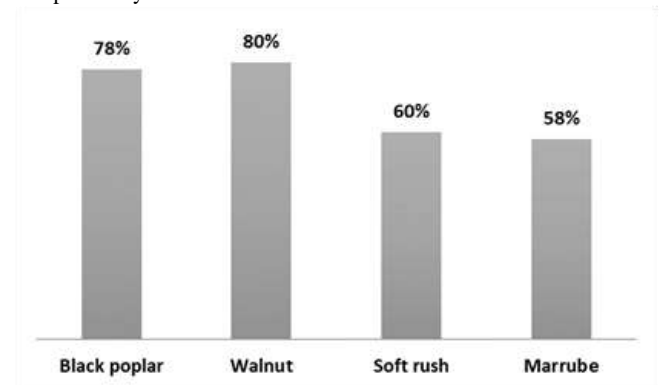

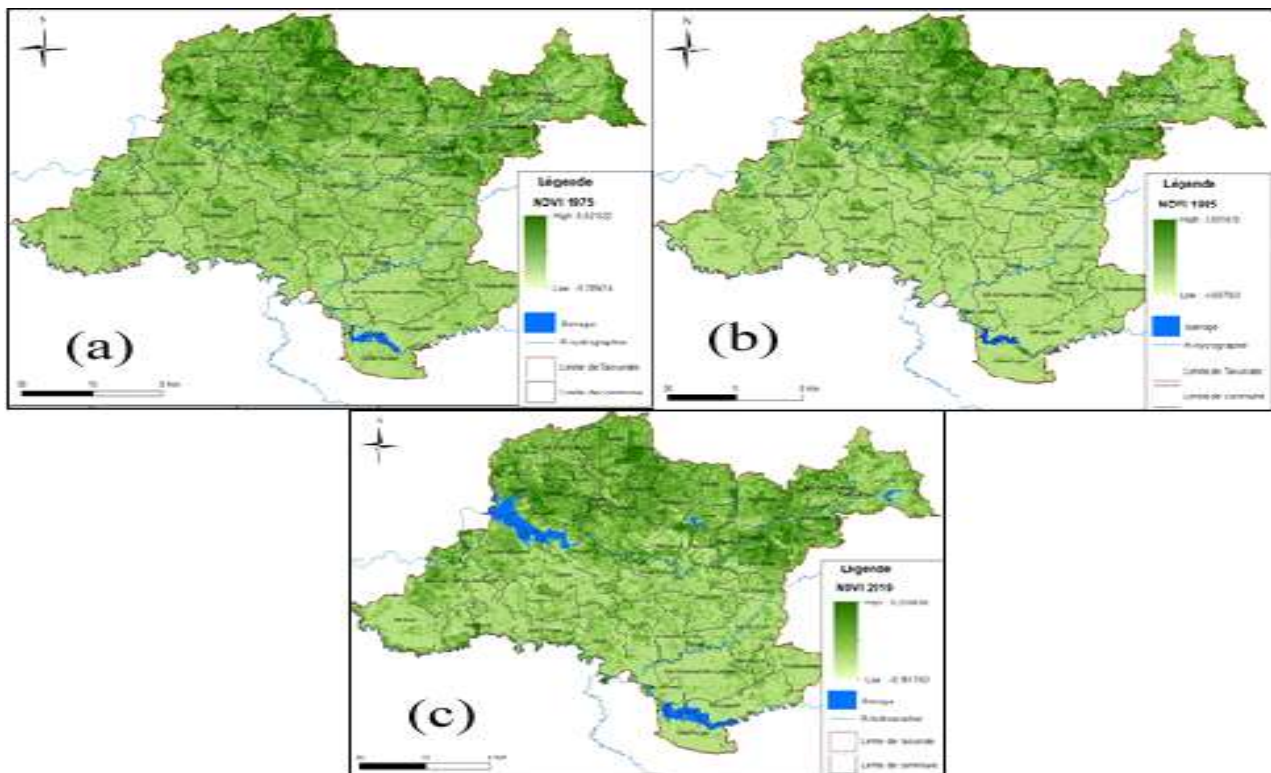**Figure 7:** Endangered plant species.

Figure 8: Maps of the normalized difference vegetation index: Maps of the normalized difference vegetation index 1975 (a); Maps of the normalized difference vegetation index 1985 (b); Maps of the normalized difference vegetation index 2019 (c).

The second region is the more mountainous northern part, which is connected to the Rifian domain and contains most of the forest area. It constitutes about 40% of the area of the province. The altitudes vary from 80 m (bed of Ouergha) to 1730 m at JbelTajerfat. From the maps of 1975 and 1985, the density of vegetation is about the same in the different communes of the province of Taounate, except in the commune of Tamdite, which has experienced a strong regression of vegetation cover. Between 1985 and 2019, an increase in vegetation cover was observed in Ghouazi, Moulay Abdelkrim, Moulay Bouchta, Kissane, and Tabouda. Also, a strong regression was recorded in the following communes: Oudka, Sidi Mokhfi, Timezgana, Khlalfa, BniOulid, Fennasa Bab El Hait, Tamdit, Bouhoda, and Galaz.

Therefore,the obtained results have been confirmed by Barmo,[23] and Tahiri,[24] discovered that the vegetation cover decreased by several hectares every year under the combined influence of climate change and anthropization. This indicates that the forest area has been under significant pressure in recent decades. According to Guessan,[25] and Atsu,[26] who discovered that there is a regression in forest land and a progression of agricultural land. The rural population of the Taounate region depends primarily on agriculture for their income. To meet their growing needs, the population has been forced to search for new land for cultivation and construction. As a result, since the province legalized cannabis production, the degree of incursion has increased. The imbalance among the various local ecosystems will be caused by the ongoing incursion into the forest realm. As it was discovered, the exploitation of forest lands for cannabis cultivation is a ticking time bomb that endangers the sustainability of the province's natural resources.[6] Land erosion is increasing, agricultural lands are losing their fertility and productivity, and climate change and human activity are degrading the soil and shrinking the forest cover. Therefore, the intensity of encroachment has been accentuated since the introduction of cannabis cultivation in the province. The continued encroachment into the forest domain will create problems, causing an imbalance in different local ecosystems. The exploitation of forest lands for cannabis cultivation is a time bomb that threatens the sustainability of the provincial natural resources as they were discovered.[6] Land erosion is increasing, agricultural lands are losing their fertility and productivity, and climate change and human activity are degrading the soil and shrinking the forest cover.[27]All rural communes of the province of Taounate are affected by encroachment, but the most affected communes are the rural communes at the border of the provinces of Chefchaouen and Al Hoceima where cannabis is widely grown. These include the rural communes of Oudka, Sidi Mokhfi, Timezgana, Khlalfa, BniOulid, Fennasa Bab El Hait, Tamdit, Bouhoda, and Galaz. In the other communes where Kif is not yet cultivated on a large scale, the clearances are not significant.

Conclusion

The regression observed in the different ecosystems under the combined effect of climate change and anthropization has been effectively highlighted by the assembly between the information obtained from residents, the Provincial Directorate of Water and Forests, and the Fight against Desertification, and the use of satellite images through the exploitation of remote sensing coupled with techniques of geographic information systems. This study demonstrates that every member of the sampled community is aware of the effects of climate change and that, between 1975 and 2019, the forest surface underwent a significant regression estimated at 347,288.86 ha due to the combined effects of climate change and anthropogenization. Therefore, invasive species, primarily represented by cannabis cultivation, grazing, construction, and encroachment, are the primary sources of biodiversity destruction in the Taounate region. Aromatic and medicinal plants, such as cork oak, zea oak, holm oak, and pine, are the main plant species affected. Finally, the conservation of ecosystems requires social awareness and the participation of different social actors to guarantee the sustainability of natural resources for future generations within the framework of sustainable development.

Conflict of Interest

The authors declare no conflict of interest.

Authors' Declaration

The authors hereby declare that the work presented in this article is original and that any liability for claims relating to the content of this article will be borne by them.

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