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Evolution of Mediterranean Forest Ecosystems and Impact of Natural and Anthropogenic Disturbances: Case of the Cork Oak Forest- Tlemcen- Algeria

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Abstract

Background: Forest cover change continues to be one of the most important topics in global environment discussions and negotiations. In North Africa, there is a broad consensus on forest decline but available information on the extent and rate of degradation has been far lower than needed. The present study uses the example of the cork oak forest of Tlemcen (Hafir-Zariffet forest), North West Algeria, to provide spatially explicit and up-to-date information on forest cover changes. The goal was to fill a knowledge gap in a poorly studied area by determining the extent of changes in forest cover.

Methods: Land use land cover maps of 1989, 1999, 2009 and 2019 were classified using Random Forest Algorithm in R software and change assessed via intensity analysis.

Results: The results revealed that sparse vegetation was the dominant land cover at the end of the study period, although it decreased from 71.25% in 1989 to 65.24% in 2019. The lowest coverage was water body from 0.47% in 1989 to 0.18% in 2019. Sparse vegetation and dense forest experienced a major decline of 6.01% and 3.22% respectively. On the other hand, open forest (+6.96%), bare areas (+0.37%), settlements (+1.99%) and agricultural (+0.21%) increased. In the LULC transitions analysis, dense forest recorded loss for two consecutive periods (1989-1999 and 1999-2009). The path of conversion was mainly from dense forest to open forest, an evidence of anthropogenic activities.

Conclusion: The findings show that the cork oak forest of Hafir-Zariffet suffered multiple pressures, which cause degradation of this natural heritage. These pressures continue to increase the fragility of forest ecosystem and can affect the rehabilitation or even its resilience. In order to conserve the dwindling cork oak forest, a sustainable and effective management which ensures ecological, economic and social balance should be adopted.

Background

Over the years, humans have depended on the forest for timber, construction materials, firewood, aromatic plants, fruits and nuts and other essential materials. Trends of forest utilization has progressed unceasingly with different cultures showing high or low preferences for different forest goods and services at different times and season (Matthews et al. 2000). The forest accounts for 45% carbon storage in the terrestrial biosphere and accumulates nearly half of terrestrial net primary production (Wu et al. 2017; Yang et al. 2014). Despite their relevance in providing ecosystem services, the forest is being threatened by human activities.

Globally, about 29 percent of the earth's land surface was originally under forest cover. However, it is only a fifth of this original cover that currently remains undisturbed (FAO 2001; Melese 2016). FAO (2010), reported that the 2.5 million ha forest cover in 1990 declined to 2.1 million ha in 2000, which further dwindled to 1.7 million ha in 2010 at a decreasing rate of 1.6% and 2.0% per annum respectively for the two decades. Anthropogenic activities appear to cause the highest transformation of the present state of the earth's surface (Islam et al. 2018). To meet human needs, the interaction between humans and their environment has altered the earth’s surface more than any other living species have ever done (Betru et al. 2019; Melese 2016).

The Mediterranean Basin has developed a resilient mechanism to its ancient anthropogenic activities such as grazing, fires, drought and clearing coupled with the annual dry summers and cool winter seasons (Davis et al. 1996). However, the increasing land exploitation (e.g. agriculture and grazing), frequent fire occurrence coupled with settlement expansion, has contributed to large areas of land experiencing reduced ecosystem recovery rate and low productivity after disturbance and land use abandonment (Le Houérou 2000; Zdruli 2014). According to Nunes et al. (2016), high demand for water and regular occurrence of disasters weakens the resilience of the ecosystem thereby initiating land degradation.

Forest degradation poses a great threat to the stability of global climate, because of its carbon sink capacity (Wu et al. 2017; Yang et al. 2014). One of the key agents of global warming and the changing climate is forest removal (Shah and Sharma 2015). Biodiversity loss and carbon emissions are linked to forest degradation, facilitating a decline in social and environmental function of the forests (Morales-Barquero et al. 2015). According to Ramachandra et al. (2016) forest structure changes will lead to sudden impacts, disrupting the ecosystem functions and services. Although the level of forest loss has lessened worldwide (FAO 2015), the issues of forest cover replacement still remains relevant at international meetings and conferences on global environment. Reliable and up-to-date information on the state of forest resources is necessary for land use planning and development (Sulieman 2018). A lot of researchers have emphasised the need for combining high resolution images, remote sensing data and aerial photography for understanding changes in land cover patterns (Brown et al. 2000; Sader et al. 2001; Sharma et al. 2017; Sulieman 2018). Land cover assessment has become an essential approach for environment and natural resources management towards effective land use and environmental policies (Forejt et al. 2017; Grecchi et al. 2014).

Hafır-Zariffet forest, which forms part of the Tlemcen National Park, covers an area of 10834 hectares (Letreuch-Belarouci et al. 2010). The forest is home to many species of plants and wild animals of the north-western region of Algeria. The forest resources are essentially represented by oak and other formations in the form of mixed stands (cork oak, holm oak and zeen oak) (Mesli et al. 2009). Other species such as wild olive and few stands of juniper also constitute the forest formation (Bouhraoua 2003). The forests provide varieties of ecosystem services. They supply wood, cork and other products, which are sources of income for many. They contribute to the conservation of biodiversity, capture and store carbon, protect soil and offer areas for recreation. The forest stands which forms an aesthetically pleasing green cover also protects hillsides against erosion (Mesli et al. 2009). Despite their importance in providing ecosystem services, Hafır-Zariffet forest is among the most threatened forest ecosystems in Algeria. The forests have suffered from pressures such as grazing, fires, and crop cultivation (Bouhraoua 2003).

Several studies have been conducted in Hafir-Zariffet cork oak forest investigating the health status of cork oak trees on annual growth and cork quality, fire occurrence, development strategy and conservation, floristic diversity, climate change impacts on forest species composition and assessment of the forest resources (Bencherif and Bellifa 2017; Benmostefa 2004; Bouhraoua 2003; Dehane 2012; Henaoui and Bouazza 2012; Letreuch-Belarouci et al. 2010). However, no study has specifically focused on forest cover change and the pattern of change. The need for evidenced-based information on the current forest cover is necessary for the development of policies and measures that will ensure sustainable use of the forest toward a more climate and biodiversity-friendly outcome (Hosonuma et al. 2012; Kissinger et al. 2012; Van Khuc et al. 2018).

The present study used the example of the Hafir-Zariffet cork oak forest of Tlemcen, North West Algeria, to provide spatially explicit and up-to-date information on forest cover changes, as well as to identify factors that contribute to forest cover change. Using a spatiotemporal analysis approach, the following questions were addressed: What are the changes in the forest cover? And how does it change over time? What are the determining factors of these changes?

Materials And Methods

Study area

The study area is located in the cork oak forest of Hafir-Zariffet (10834 ha) in the northern part of the mountains of Tlemcen in the meso Mediterranean (Dehane 2012) . The climate in the study area is of Mediterranean type, smoothed by the influence of the Mediterranean Sea (Ghalem et al. 2016).

The mean temperature of the coldest month (January) is 3.5°C and of the hottest month (July) is 30.7°C (Ghalem et al. 2016). The rainfall Emberger index is 51.1, which confirms a semi-arid climate than temperate variant (Letreuch-Belarouci et al. 2010). At Hafir-Zariffet, the elevation ranges from 1,000 to 1,220 m a.s.l. and the landscape is steeply undulated (with slopes ranging between 3 and 12%) (Dehane 2012). The area is composed mainly of high forest on mountain ranges on Jurassic lands and plains and valleys on tertiary and quaternary lands. The soils are characterized by more or less deep brown forest type, rich in herbaceous layer with the existence of a strong biological activity. The texture is sandy-loam with some concretions in the A1 horizon. The fersiallitic brown soils are highly established (Gaouar 1980).

Methodology

Image processing

Landsat images at 30 m spatial resolution were acquired from United States Geological Survey's (USGS) Global Visualisation Viewer (GLOVIS). The images for the years 1989 (24 June), 1999 (20 June), 2009 (09 July) and 2019 (11 June) with a cloud cover criterion of less than 10% from path 198 row 36. Reference data used to support classification were Google Earth historic images, the S2 2016 prototype land cover map at 20 m for Africa recently released by the European Space Agency (ESA), the Chinese global land cover map at spatial resolution 30 m (globeland30) for 2010 (Jun et al. 2014) and published maps of previous studies.

Atmospheric correction of all images for the purpose of temporal analysis was done in QGIS 2.18 using the pre-processing tool under Semi-Automatic Classification Plugin (SCP). Bands combination 543 and 654 were used to differentiate the various land use classes for Landsat 5 (1989, 1999) & 7 (2009) and Landsat 8 (2019) images respectively in QGIS (Ololade 2012). Based on the pixel grouping and unsupervised classification records, the unit classification were Dense forest (trees in the various storeys with undergrowth covering a high proportion that is, above 40% of the ground and do not have a continuous dense grass layer); Open forest (discontinuous tree layer with coverage between 10 and 40%); Sparse vegetation (Natural herbaceous vegetation, small shrubs and grassland); Water (water areas of natural or artificial origin); Agriculture (rainfed and irrigated agriculture, olive farms and fruits orchards); Bare areas (Land with no vegetation cover and of no land use); and Settlement (built-up areas) (FAO 1995).

Supervised classification was carried out in R software using the random forest algorithm following the procedure in Figure 2. Training site for classification was created in QGIS and accuracy assessment indicating the level of correspondence of classified maps to reality were assessed based on confusion matrix from the random forest algorithm which was set at a maximum of 100 samples for each class. The error matrix technique, which is one of the most widely used for accuracy assessment was adopted for this purpose (Braimoh and Vlek 2005; Forkuo and Frimpong 2012). Both pixel-based and area-based error matrix were done (Olofsson et al. 2013).

Change detection, *categorical* and transition intensity analysis

Change detection was carried out (e.g. 1999 – 1989) to estimate the overall changes in land classes. TerrSet analysis software developed by Clark University was used to examine the category and transition levels analyses, from the cross-tabulation matrix of three intervals 1989–1999, 1999-2009 and 2009–2019 with the Land Change Modeller (LCM). The transition analysis examined the net change and the variation of both gross gains and losses in size during transitions from one land class to another.

Results

Land use and land cover change dynamics

Forest (dense and open) covered the south-west and centre to the east (Fig. 3). Dense forest decreased spatially from 1989 to 2009 and showed an increase from 2009 to 2019, particularly at the central forest zone. Settlement showed a significant increase at the end of the study period with a lesser decline in 1999-2009 period (Fig. 3).

The results further revealed that sparse vegetation was the dominant land cover at the end of the study period, although it decreased from 71.25% in 1989 to 65.24% in 2019 out of the 313 km^2 total area analyzed in this study (Table 1). The land cover that recorded the lowest coverage at the end of the study period was water body from 0.47% to 0.18% (Table 1). The results also revealed that the land cover classes that experienced a major decline were sparse vegetation and dense forest (Table 1).

Table 1 Evolutions of the land cover classes and area percentage during the period 1989–2019

LULC	Area coverage (%)				Change detection (%)			
	1989	1999	2009	2019	1989-1999	1999-2009	2009-2019	1989-2019
Dense forest	6.14	4.98	1.28	2.92	(1.16)	(3.70)	1.64	(3.22)
Open forest	16.76	17.47	27.88	23.71	0.71	10.41	(4.17)	6.95
Sparse vegetation	71.25	70.90	64.46	65.24	(0.35)	(6.44)	0.78	(6.01)
Settlement	1.05	2.18	1.33	3.04	1.13	(0.85)	1.71	1.99
Water	0.47	0.28	0.51	0.18	(0.19)	0.23	(0.33)	(0.29)
Agriculture	0.92	0.85	1.32	1.14	(0.07)	0.47	(0.18)	0.22
Bare areas	3.40	3.34	3.23	3.77	(0.06)	(0.11)	0.54	0.37
Total	100	100	100	100				

*Bracket means negative/decrease

All land use classes (settlement, agriculture and bare areas) and one land cover class (open forest) recorded increase at the end of the study period. The cover of open forest in 1989 was 16.76% but increased to 23.71% at the end of the study period (2019). The share of settlements and agriculture increased by about 2% and 0.22% respectively (Table 1). For the entire 30-year study period, it is clear that the cork oak forest of Hafir-Zariffet has undergone changes in land use land cover as supported by the satellite images of 1989 and 2019 at decadal interval.

The result shows that in the first interval (1989-1999), dense forest and sparse vegetation declined by 1.16% (3.62 Km^2), and 0.35% (1.1 Km^2) respectively. Non-forest cover such as water, agriculture and bare areas also recorded a decreased of 0.19% (0.61Km^2), 0.07% (0.24 Km^2) and 0.06% (0.19 Km^2) respectively in the 1989-1999 same periods whereas Open forest and settlement on the other hand recorded an increase of 0.71% (2.22 Km^2) and 1.13% (3.53 Km^2) respectively (Table 1).

The second interval between 1999-2009 periods revealed an astonishing pattern. Dense forest reduced further by 3.70% (11.58 Km^2) more than twice the decrease in the first interval (Table 1). Sparse vegetation recorded a sharp decline by 6.44% (20.17 Km^2) making it the land cover class that recorded the highest loss during the 1999-2009 period. Surprisingly, settlement which recorded an increase in the first period (1989-1999) began to dwindle in 1999-2009 period (Table 1). Bare areas further decline by 0.12%. Open forest which increased during the first period further expanded, making it the land cover class which recorded the highest increase in the second interval. Agriculture land cover which had recorded a decrease in the 1989-1999 periods began to increase by 0.47% in the second interval (Table 1).

The third interval (2009 - 2019) also revealed remarkable trends. Land cover classes (dense forest, sparse vegetation and bare areas) that had recorded constant decrease for the first two periods (1989-1999 and 1999-2009) increased. Dense forest increased by 1.64% (5.13Km^2), sparse vegetation increased by 0.78% (2.45 Km^2) whereas bare areas expanded by 0.54% (1.7Km^2) whilst open forest declined for the first time in the study period by 4.17% (13.04 Km^2) (Table 1). Water and agriculture also decreased by 0.33% (1.03Km^2) and 0.18% (0.56 Km^2) respectively in the third interval. The overall change between 1989 and 2019 showed an increase in open forest (6.95%), settlement (1.99%), agriculture (0.22%) and bare areas (0.37%), whereas dense forest, sparse vegetation and water recorded a decrease of 3.22%, 6.01% and 0.29% respectively (Table 1).

Intensity land use land cover (LULC) change

Land use land cover categorical change and transitions

The highest net change in LULC in the first interval (1989-1999) took place in settlement (+3.75) and dense forest (-3.78). Open forest and sparse vegetation experienced the largest coverage of gains and losses above 30 km^2 in the first interval (Fig. 4). In the second interval (1999-2009), open forest and sparse vegetation recorded the highest net change of +33.71 km^2 and - 21.21 km2 respectively. Surprisingly, settlement which recorded the highest net change in the first interval (1989-1999) began to decline with net change of -2.79. In the third interval (2009-2019), land covers that recorded the highest net change were settlement (+5.83) and open forest (-13.98). Dense forest which experienced loss for first two intervals, recorded gain with a net change of +5.37 (Fig.4). Generally, sparse vegetation recorded the highest spatial change of both area gains and losses in the three intervals.

Transitional level of change

The land use land cover transitions were assessed to determine the land cover change directions and the magnitude of change for the entire study period. In the first interval (1989-1999), the major land cover conversions were sparse vegetation to settlement and dense forest to open forest which is majorly anthropogenic (Fig. 5). Moreover, Agriculture targeted open forest for transition than dense forest.

During the second interval (1999-2009), there were changes in the transitions as open forest gained more from sparse vegetation and dense forest (Fig. 5). Agriculture and water slightly gained from sparse vegetation. Remarkably, settlement which gained from sparse vegetation in the first interval was transformed to sparse vegetation and open forest. The transition in the second interval was a regeneration which could be attributed to a natural cause than human intervention (Fig. 5).

In the third interval (2009-2019), the significant changes were the conversion of open forest and sparse vegetation to settlement and dense forest. Although sparse vegetation lost to settlement and dense forest, it also gained from open forest (Fig. 5). Bare areas gained from open forest and sparse vegetation, a sign of intense human activities that has removed vegetation totally either through a consistent process or at once. The land cover class that suffered heavy loss (conversion) was open forest (Fig. 5). Anthropogenic activities increased in the third interval and were higher than the first interval.

Discussion

LULC analysis in the study area revealed loss of forest cover (dense and open forest) during the assessed years. This is due to the increasing conversion of forest cover (dense and open forest) to sparse vegetation (shrub and grass cover) which can be associated with anthropogenic pressures and climatic disturbances. The transformation of forest cover to sparse vegetation has been described as a progressive degradation of the forest, mostly driven by grazing pressures, repeated fires, regeneration failures and climate change impact (Benmostefa 2004; Derbal 2006; Ghalem 2006; Letreuch-Belarouci 2009). Henaoui and Bouazza (2012), reported that anthropogenic pressures coupled with mild temperatures have created favourable environment for the establishment and dominance of non-woody species (therophytes), ahead of more nutrient and water demanding woody species in the region of Tlemcen. This was further emphasised by Felidj et al. (2014), who highlighted that over the years, the area has experienced increasing anthropogenic pressure and climatic variation posing serious challenge for resource managers. Currently, one of the world's pressing issues is climate change (Sousa-Silva et al. 2016) and the cork oak forest is vulnerable due to its geographical location with limiting climatic and natural conditions, influenced by severe drought and topography with intensity changing from one year to another (Braun-Blanquet et al. 1952; Quezel and Bonin 1980). The current climate change appears as a factor aggravating the decline of cork oak. According to WWF (2004) report, only a quarter of the previously 3 million hectares of cork oak forests in the Maghreb (North Africa) countries remain.

In our analysis of the land cover change, one of the remarkable finding was the huge decline of forest cover in the 2009 from 1999. The result showed that most of the conversion during this period was from dense forest to open forest and sparse vegetation. A possible reason for the excessive loss of the dense forest could have been the overexploitation of forest resources during the Algerian instability period. Studies have shown that during wars, strict controls of national/state properties such as forest resources are weakened creating open access situation. Letreuch-Belarouci et al. (2010), described 1994 and 1995 periods in Algeria as most disastrous years for the cork oak formations both in terms of cork yield and their future due to the insecurity Algeria experienced over a decade. Another possible cause for the decline could have been the death of cork oak trees in the Mediterranean basin at the beginning of the 21st century due to forest dieback (Brinsi 2004). According to Bouchaour-Djabeur (2001), the cork oak trees of Hafir-Zariffet forest recorded high tree mortality due to the occurrence of dieback. Although, dense forest recorded loss in the first two consecutive periods, in the final period (2009-2019) of the study, there was an appreciable recovery.

A number of factors could have contributed to the gradual recovery of the forest area observed in 2019. These include but are not limited to advocacy campaigns, rehabilitation measures and alternative energy sources. Studies in similar Mediterranean countries have also recorded forest recovery in the Mediterranean environment through succession (Schulz et al. 2010; Serra et al. 2008).

Our analysis further revealed that, sparse vegetation was the dominant land cover for the entire period. Although sparse vegetation was the dominant land cover, a relatively high amount of sparse vegetation was lost as a consequence of conversions to settlement and to a lesser extent, bare areas in the first and third intervals. The conversion of sparse vegetation to settlement and bare areas further reinforces the degraded state of forest and forest encroachment. Hafir-Zariffet forest which forms part of the Tlemcen National park has been described as a heterogeneous landscape interspersed with forest, agricultural and urban stains (Bencherif and Bellifa 2017).

Water class was the lowest cover with a decreasing pattern. The decreasing pattern of the water class can be associated with increasing riparian population and climatic disturbances in the study area. Several climate studies and modelling projections have indicated that severe climatic conditions due to climate variations are escalating (IPCC 2013). Mediterranean region has been identified as one of the climate-change hotspots. In the Mediterranean basin, the annual mean temperature by the end of the century is projected to increase by 2- 4.5° C whiles average summer precipitation is also predicted to decrease by 20% (Team et al. 2007). In Algeria, the increase in temperature in the twentieth century is between 1.5° and 2° C whiles the decline of precipitation varies between 10% and 20% (Bencherif and Bellifa 2017). The precipitation decline according to Ghenim and Megnounif (2013) has diminished water flow from 37% to more than 70% from the East to the West of Algeria. In Hafir-Zariffet forest, Ghenim and Megnounif (2013), assessed the extent of drought in Meffrouche dam catchment area and reported the increase of precipitation from 289 mm in 2007-2008 period to 871mm the following year. The increase in precipitation in 2009 could be the reason for the regeneration of dense and open forest in the 2009 – 2019 (Fig. 5). The same author described 1999 year as the driest period for the catchment area. This was evident in our study as water declined in 1999 and increased in the 2009. The water loss patterns consisted mainly of the conversion of water cover class to sparse vegetation, settlement, bare areas and agriculture. According to Pakistan (2005) report, rapid expansion of urbanization and agriculture practices not only depletes the water quantitatively but also plays a leading role in polluting the water. Polluted water especially when muddy may be recognized as bare areas from satellite images. Bouhraoua (2003), also found that the actions of the riparian population of Hafır-Zariffet forest are not only limited to arson but other forms of degradation such as land clearing to expand enclaves, incessant grazing by herds, lopping trees to feed livestock, cutting trees down to make charcoal and stealing breeding cork to make hives.

In the study area, agriculture increased gaining from open forest. The observed pattern can be explained by the fertile nature of the forest land which is suitable for tree crop cultivation such as olive plantation and fruits orchards. Most farmers prefer clearing forest lands which are more fertile than sparse vegetation and bare area. In line with this finding, Bouhraoua (2003), indicated that the area consist of 24 cultivated enclaves totalling about 170 ha and 200 ha of undeveloped land with the latter generally rocky or degraded and covered with low or bushy vegetation, unsuitable for planting. In Tunisia, a robust study by Touhami et al. (2019), attributed the decline of cork oak forest in the Mediterranean basin to land clearing for agricultural purposes, overgrazing, maquis formation, and cutting off even large trees, with a strong natural pressure (extreme droughts, summer heat, water deficit and orographic factors).

Conclusion

This study assessed the evolution of Mediterranean forest ecosystems and the impact of natural and anthropogenic disturbances using Landsat data between 1989 and 2019. For the entire 30-year study period, it is clear that the cork oak forest of Hafır-Zariffet has undergone changes. Analysis revealed a decline of dense forest (-3.22%), sparse vegetation (-6.01) and water (-0.30) while open forest (6.96%), bare areas (0.37%), settlements (1.99%) and agricultural (0.21%) increased. The findings show that the cork oak forest of Hafır-Zariffet is exposed to multiple pressures, causing degradation of this beautiful natural heritage. Considering the present condition of the cork oak forest, adopting an integrated approach in implementing conservation policies and strategies related to forest resources management should be a key prioritizing issue.

Abbreviations

LULC: Land use and land cover change, USGS: United States Geological Survey, GLOVIS: Global Visualisation Viewer, ESA: European Space Agency, SCP: Semi-Automatic Classification Plugin and LCM: Land Change Modeller

Declaration

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Availability of data and materials

The datasets used in this study are available from the corresponding author on request

Authors' contribution

All authors were involved in the manuscript preparation. EB and BDA were involved in the acquisition of the satellite imageries, image analysis and interpretation of data. MB provided site data and technical support for the research. BGL reviewed the manuscript and applied the final format which was agreed by the authors.

Authors' information

All the authors that participated in this study are researchers in environment and natural resources field. BDA is a PhD student at University of Tlemcem, Algeria, BGL is a lecturer at University of Tlemcen, MB is a researcher at National Institute of Forestry Research (INRF) Tlemcen- Algeria and EB is a Lecturer at the Department of Agricultural and Biosystems Engineering Kwame Nkrumah University of Science and Technology, Kumasi, Ghana.

Ethics approval and consent to participate

Not applicable

Consent for publication

Not applicable

Competing interest

The authors declare that they have no competing interest

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Figures

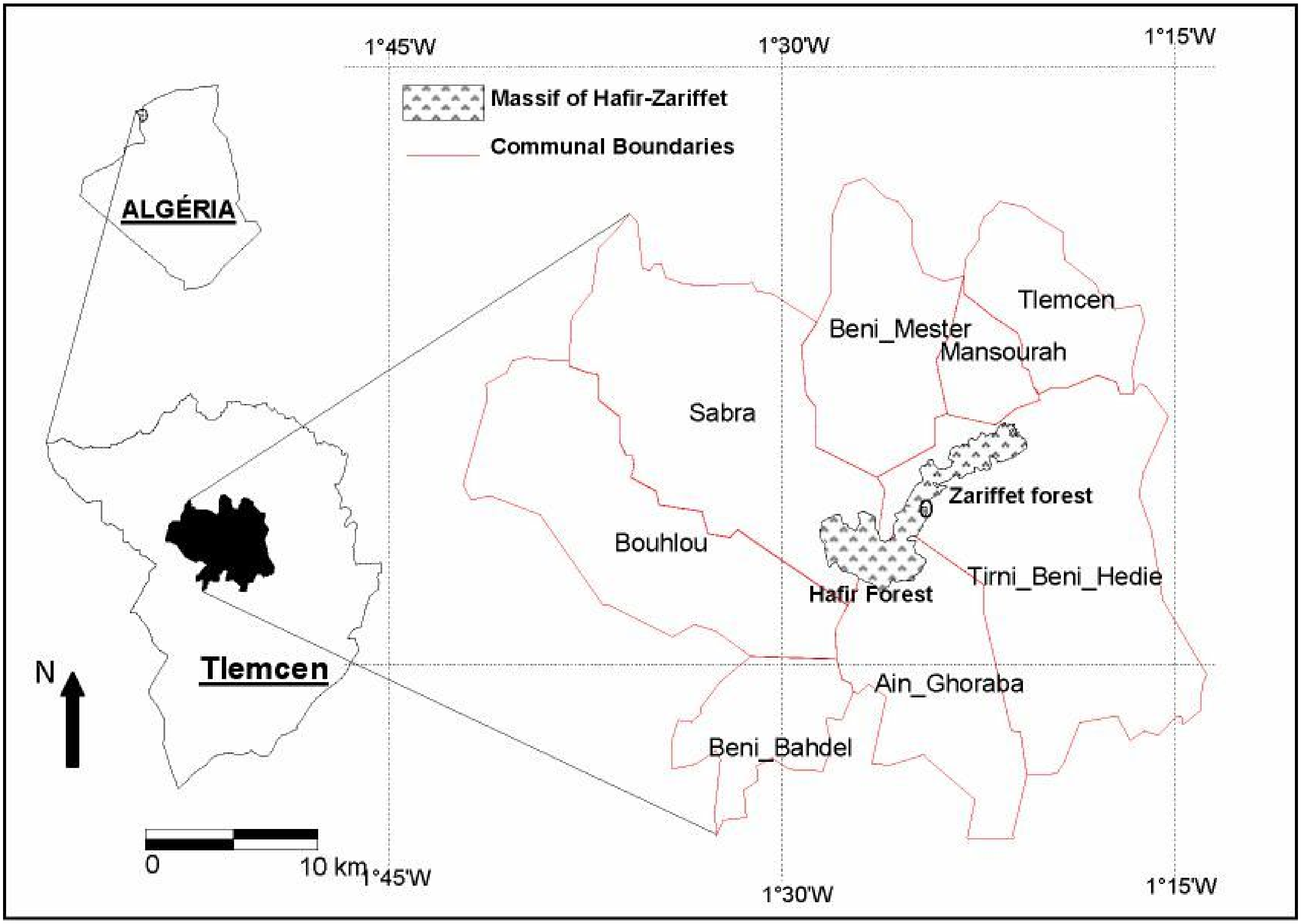


Figure 1

Location of the study area which forms part of the National Park of Tlemcen, adapted from Letreuch-Belarouci et al. (2010).

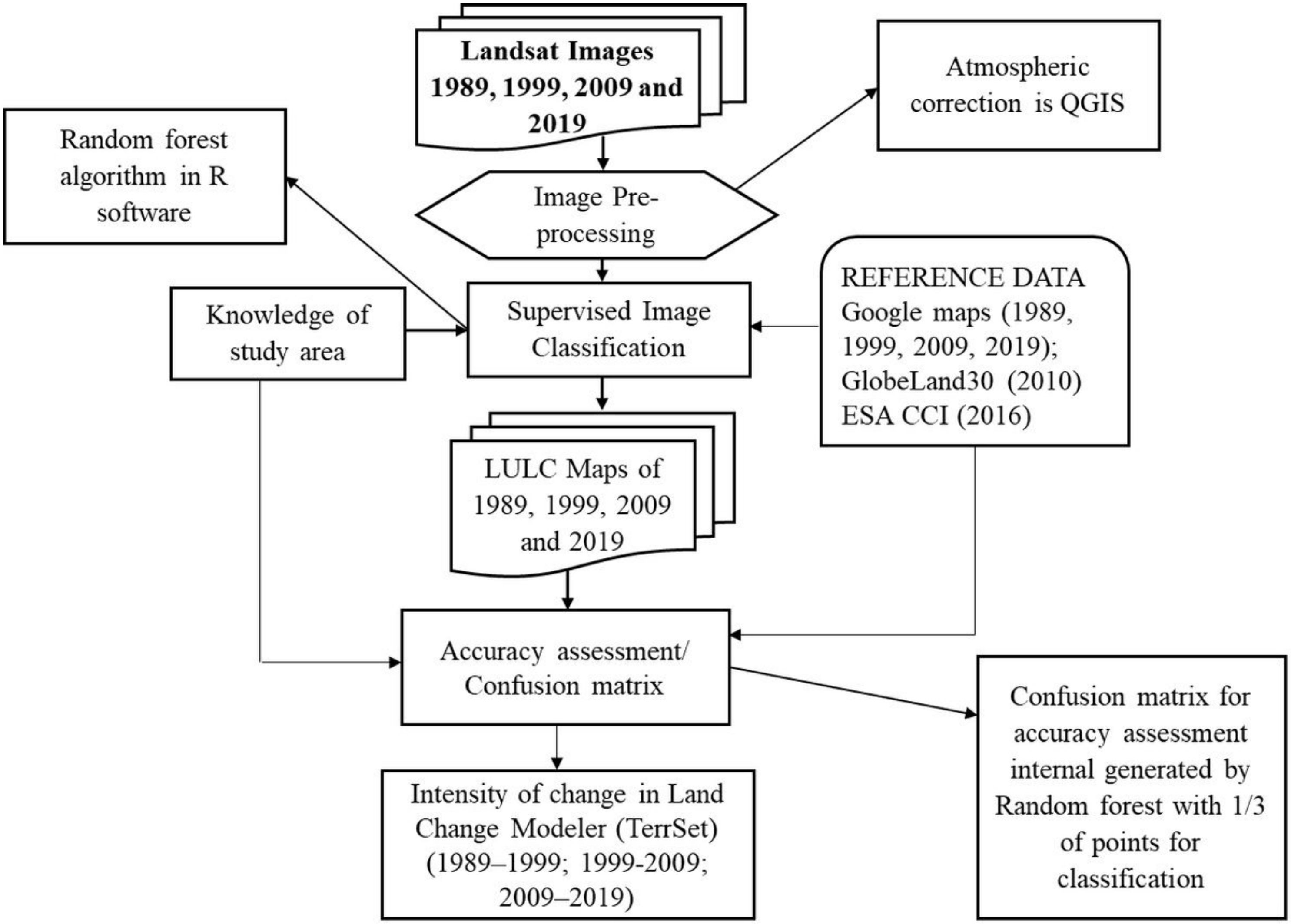


Figure 2

Conceptual framework for the study.

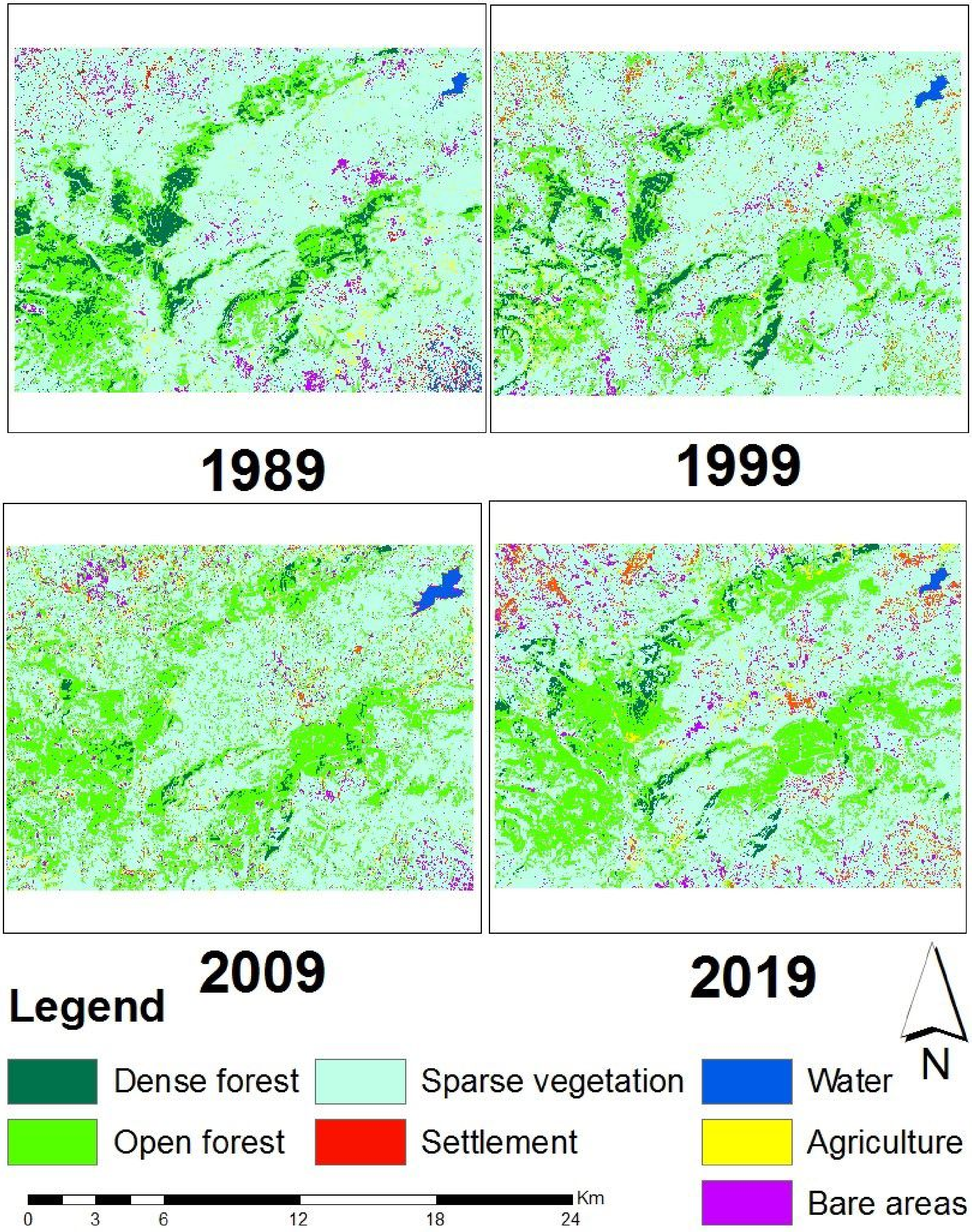
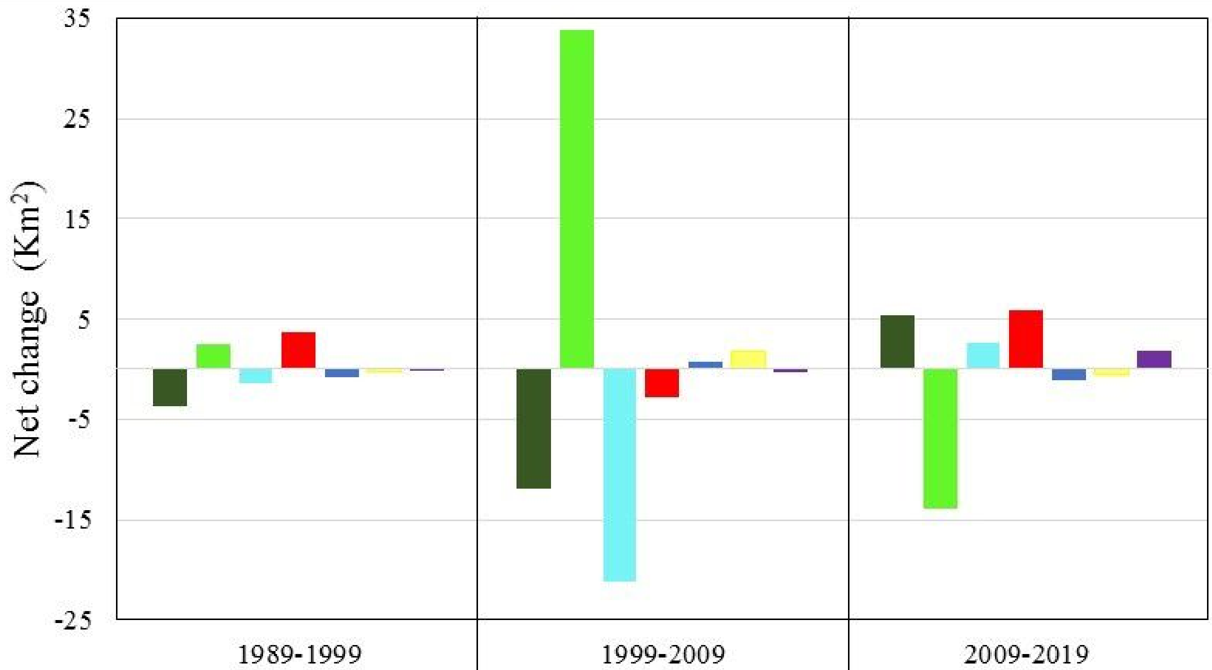


Figure 3

Land cover maps of the study area (1989-2019)



LULC Classes (Km^2)	Gains	Losses	Gains	Losses	Gains	Losses
Dense forest	8.43	12.21	1.12	13	7.62	2.25
Open forest	34.81	32.29	56.09	22.33	31.92	45.9
Sparse vegetation	44.39	45.76	37.75	58.96	52.94	50.4
Settlement	6.98	3.23	4.19	6.98	9.68	3.85
Water	0.36	1.15	0.75	0.04	0.01	1.04
Agriculture	2.72	2.97	4.5	2.72	3.87	4.43
Bare areas	10.8	10.89	10.38	10.73	11.84	10.03

Figure 4

Net change (i.e. gains minus losses).

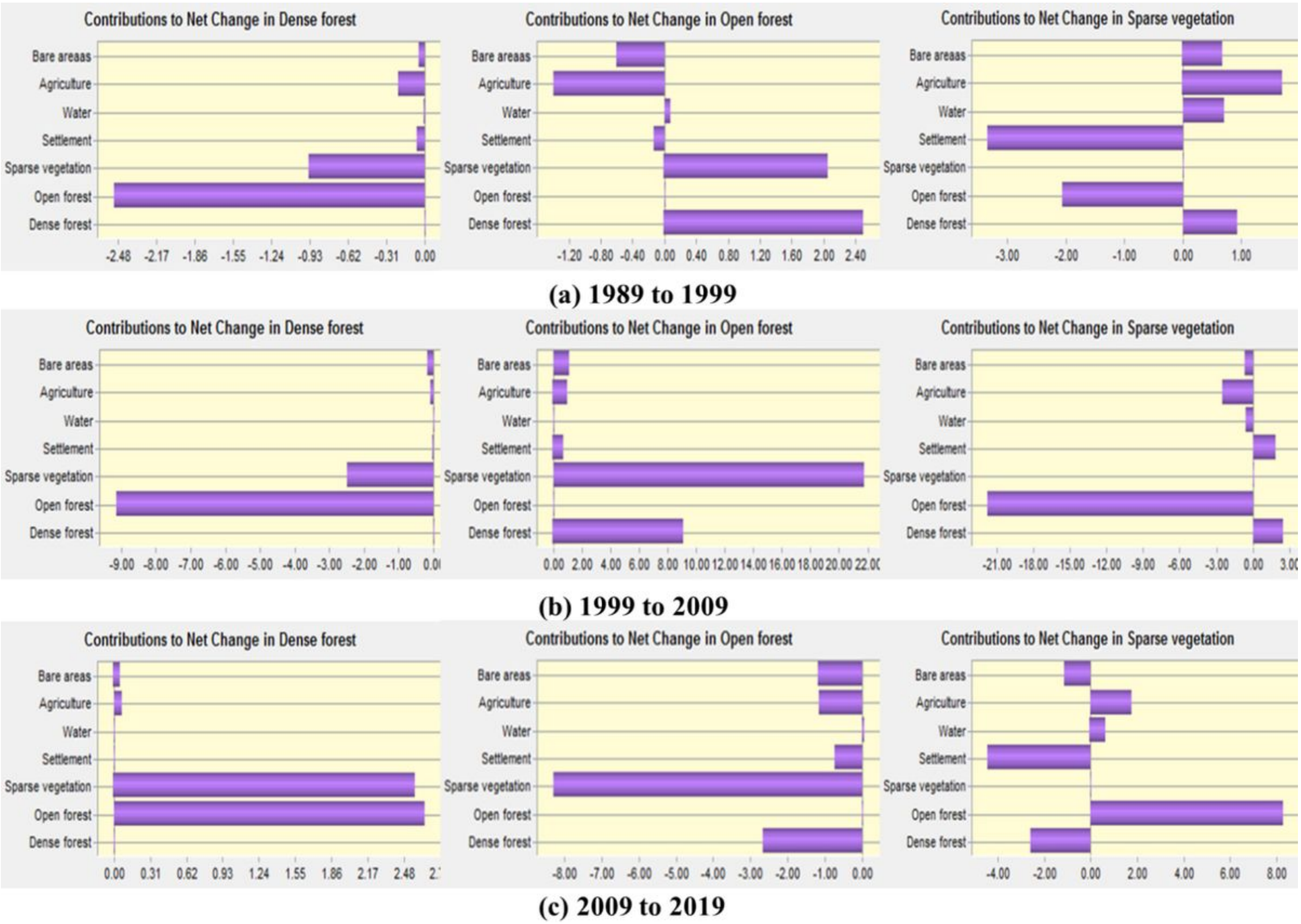


Figure 5

Three interval transition of dense forest, open forest and sparse vegetation in the study area.