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Multispectral Satellite Datasets for Detection and Mapping of Land Cover Change in a Mediterranean Area of North Africa, Belezma (Algeria)

Rachid Ait Medjber*[1, 2], Hassen Ben Messaoud[2], Hana Soualah Alila[3, 4]

[1] Department of Ecology and Environment, Faculty of Natural and Life Sciences, Mostefa Ben Boulaïd (Batna 2) University, Algeria

[2] Laboratory for the Improvement of Agricultural Production and Protection of Resources in Arid Zones, University of El Hadj Lakhdar Batna 1, Algeria

[3] Biology Department, Mouhamed Cherif Messadia University, Algeria

[4] Environmental Research Center, Algeria

***Corresponding author:** becologie@yahoo.com

Multispectral satellite images are valuable sources of information for ecologists, agriculture climatologists, or environmentalists. Handling satellite images represents a challenge for better understanding the global change. The Belezma massif by its exceptional geographical position in the Mediterranean region of Northeast Algeria constitutes a fragile hot spot ecosystem with all the degradation factors that directly affect all landcovers.

The objective of this study is to determine the contribution of satellite images in the detection of land cover global changes between 1986 and 2021 and landscape monitoring in Belezma region.

The methodology adopted is the spatial remote sensing of the evolution of forest stands and the change in land cover, from the processing of Landsat images (L05 TM 1986, L07 ETM+ 2001 and L08 OLI_TIRS 2021) and sampling work for confrontation with the reality on the ground.

The outcomes of this investigation demonstrate a general regression rate in the natural vegetation cover that the cedar forest, the steppe, and the wetlands lost 42%, 49%, and 97%, respectively, of their areas between 1986 and 2021, while the degraded and anthropic occupations have increased in favor of market gardening, bare soil, urban areas, and arboriculture by 836%, 158%, 131%, and 50%, respectively, over the same period. This study made it possible to identify and analyze 13 main land uses and plant formations over a period of 35 years, which can be used as a decision-making aid model for the managers of these territories.

Keywords: remote sensing, multispectral, global change, land cover, Belezma.

Introduction

Our Earth is ever-changing. Continental plates shift, ocean levels rise and fall, mountains and shores erode, deserts and glaciers move, and natural disasters change the face of the globe. These are natural processes that have been shaping the surface of the Earth for billions of years. However, humans are different in that they have not only sought actively to control their surroundings, but they have managed to colonize every habitable surface ecosystem on the planet, from high mountains to low valleys. As the population of humans has grown and their social structures have become more complex, the effect of these creatures on the surface of the Earth has become more noticeable (Parcak, 2009).

Satellite remote sensing in combination with geographic information systems (GIS) has provided spatiotemporal information for mapping and detecting changes on the Earth's surface from regional to global scales (Kong et al., 2016; Kerr and Ostrovsky, 2003; Pfeifer et al., 2012). Remote sensing allows us to monitor our environment over large areas and make comparisons over time and space in order to understand the functioning of ecosystems (Tidjani et al., 2009). Studies on land changes have a great importance because they provide information on current trends in the processes of deforestation, degradation, desertification, and biodiversity loss (Lanbin et al., 2001; Noyola-Medrano et al., 2013). All forms of remote sensing are concerned with the identification of anthropogenic landscape problems.

In recent decades, several authors have investigated the evaluation of land use in Algeria (Abdessemed, 1981; Maniere, 1993; Ansar, 2002; Bensaid, 2006; Labani, 2006; Benmessaoud, 2009; Bouiadjra et al., 2011; Bouzekri, 2015; Cheret, 2016; Boultif et al., 2017; Smaihi et al., 2017; Barbache et al., 2018; Bezzih et al., 2021; Khaldi et al., 2021). Belezma region is one of the last bastions of biodiversity, because of its exceptional geographical position near the desert, its fragile ecosystems, and important biodiversity exposed to anthropogenic and natural changes.

Among the data from remote sensing is land cover which is the result of a supervised classification from three Landsat images, which come for mapping and analysis of the different land uses and the dynamics of plant formations in time.

The objective of this study is to determine the contribution of satellite images in the detection of global changes between 1986 and 2021 and landscape monitoring in the Belezma region (North-East of Algeria) to identify the spatial and temporal evolution and changes of land use in the study area.

Materials and Methods

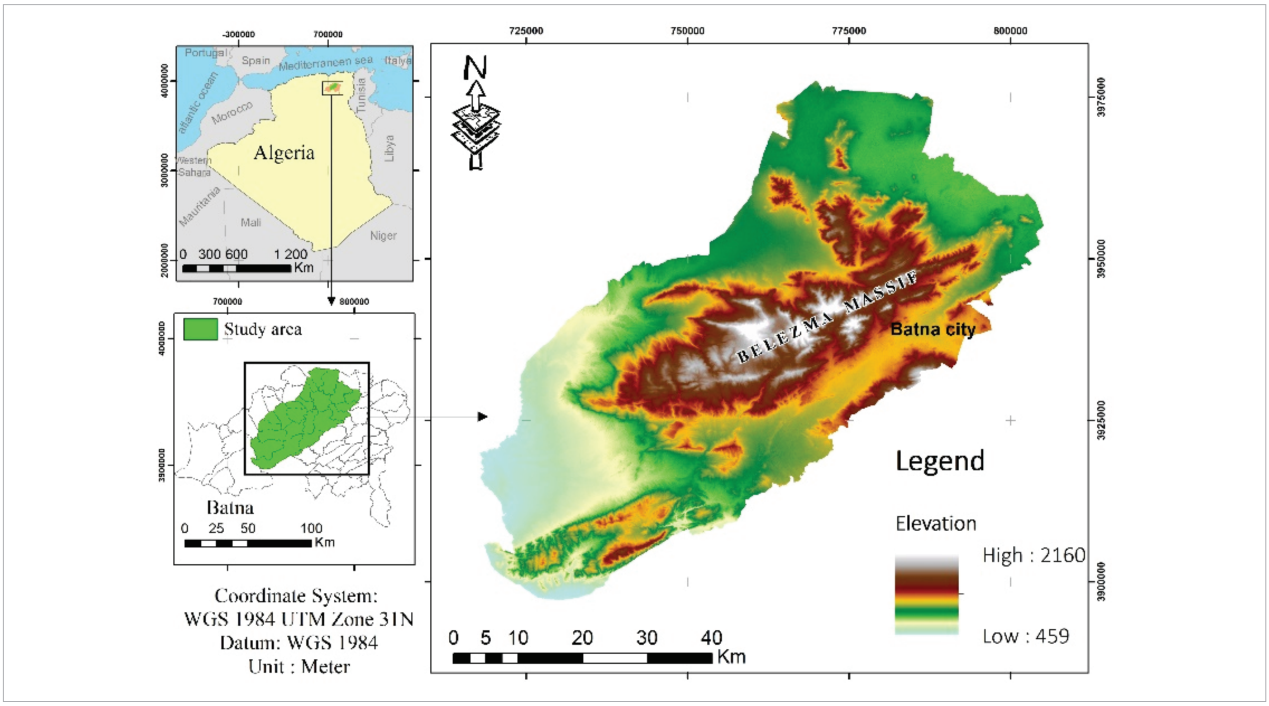
Study area and data

The study area is in the Batna region northeast of Algeria (35°54′32.64″N, 5°86′68.48″E (*Fig. 1*), located around Belezma massif which is a part of the Aures massive northwest of Batna city on an area of 339 870.78 ha. The study region is characterized by its semi-arid Mediterranean climate, its changes from sub-humid with cold winter to sub-humid and humid with a very cold winter in the high altitudes and from semi-arid climate with cool winter to cold and arid with cool winter in the low altitudes and on the southern slope. The average temperatures are 6.56°C in January and 28.43°C in July. The average rainfall is 348 mm/year, with an altitude variation between 459 m and 2160 m above sea level. Landscapes are dominated by forests in high altitudes *(Cedrus atlanticus, Pinus halepensis)* and grassland, agricultural, and shrub *(Juniperus phoenicea, Quersus ilex)* in low altitudes.

Data sources

The approach adopted for our study is based on the use of remote sensing data to carry out a diachronic analysis study.

Fig. 1. *Localization of the study area (Belezma region in northeast of Algeria)*



Multispectral satellite images acquired by Landsat 5, 7, and 8 were downloaded from EarthExplorer platform (2022).

Image processing and analysis software ArcMap 10.8 and Google Earth Pro were used to realize this study. Terrain data are required by GARMIN 76CX GPS, Garmin Oregon 650, and a camera.

Overall, the combination of powerful computer systems, image processing software, GIS applications, and data collection devices played a crucial role in the successful execution of this study.

Methods

The approach adopted in this study is based on the use of remote sensing data with measurements and observations made in the field, where the only satellite images available over 35 years were used with an average spatial resolution of 30 meters from Landsat, which is acceptable to carry out a diachronic analysis study detailing different types of land use and plant formations. The principle of this method is based on the supervised classification of such images. Spatial and spectral resolutions of satellite images do not identify habitats for fine levels (Cheret, 2016).

It should be noted that the chosen methodology has already been adopted in the Aures region (Benmessaoud et al., 2009; Beghami et al., 2013; Garah et al., 2016), and for the Belezma region, it is the first time that this method was adopted in this way with 13 classes and taking into consideration all the socioeconomic environments.

For the use of remote sensing images in the processing and diachronic analysis of land cover, we pursued three main steps.

1 The multispectral satellite images were downloaded available with minimum clouds taken in the spring season in the full photosynthetic activity period, where one can distinguish the different types of land cover: May 19, 1986, Thematic Mapper TM/ LT05), April 2, 2001 (Enhanced Thematic Mapper ETM+ / LE07 sensor), May 19, 2021 (Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) LC08 Landsat Collection 8). A series of geometric, atmospheric, and radiometric pre-processing corrected the geometric and radiometric deformations of the specific platforms and sensors and improved the readability of the images by removing all the atmospheric effects (Jofack, 2016) which led to a first photointerpretation of the different types of land use in the area. The images are acquired with a certain coverage and dimension which depends on the satellite sensor. In our case, the study area is larger. However, image stitching is required for both

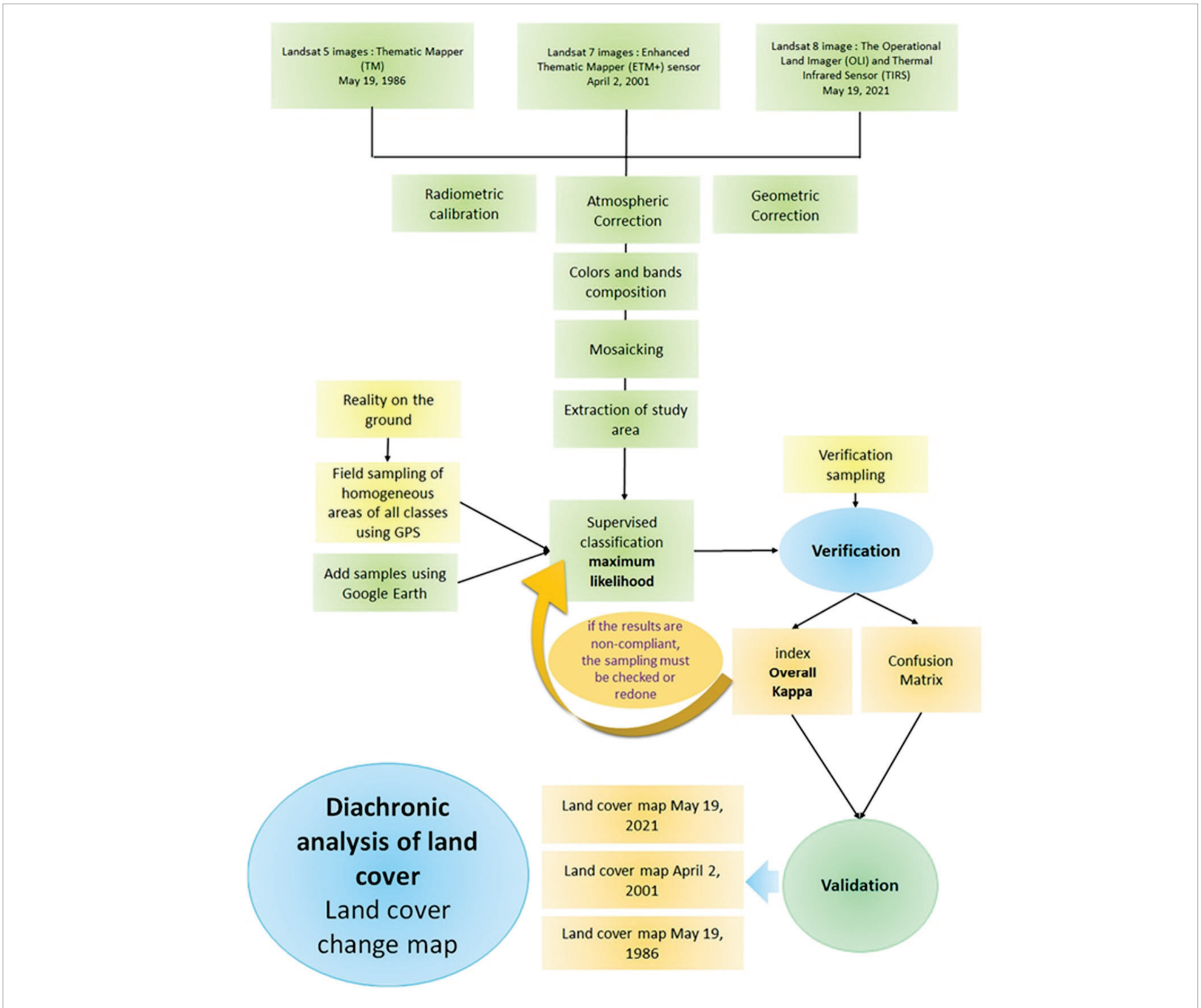
Landsat 5 and 7 images to cover the entire survey area. The combination of spectral bands used in our study is near-infrared, red, green, and blue, which makes it possible to clearly highlight the different classes of land use and plant formation. From the administrative limits of the study area and the satellite images, we were able to cut out and extract our study area.

2 A supervised classification was carried out on the area extracted by the algorithm used from the classification tool of maximum likelihood of ArcMap, which is based on two principles:
- the cells in each example class in multidimensional space distributed normally;
- the Bayes theorem of decision making.

The tool considers both the means and the covariances of the class signatures when assigning each cell to one of the classes represented in the file.

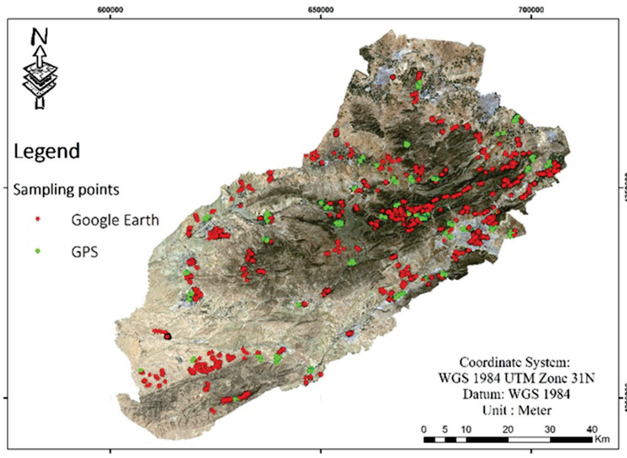
3 Highlighting the changes in land use of the three selected dates (*Fig. 3*). More than 30 exploration and sampling missions in the field were carried out for the location and knowledge of the different types of representative land cover in the area of study. These field missions were carried out in the period 2016–2021 in the spring season. It includes the collection of a set of points on the ground by the GPS (GARMIN 76CX and Garmin Oregon 650). These points are geo-referenced in longitude and latitude and communicate land use information divided into 13 classes relevant to our study objectives presented in *Fig. 4*.

Fig. 3. *Hierarchical structure methodology*



We used the Google Earth program to complete our knowledge of the field, for the places difficult to access by the causes of insecurity and inaccessibility of the land presented in *Fig. 2*. For each Landsat image, different samples were used for the changing land cover classes, taking 300 points using GPS and 1390 by Google Earth as sampling and reference points for the supervised classification and validation of the latter.

Fig. 2. *Distribution of the sample points*



The classification consists in classifying the pixels according to the similarity of spectral signature with the numerical counts of reference geographical objects previously determined on the image (training plots) and validated by field surveys (El Garouani et al., 2007). This makes it possible to make a spatial and quantitative assessment of change by identification of land use features or natural habitats.

A maximum likelihood classifier (MLC) was used to perform the classification. The MLC was found to be the most accurate for image classification. The MLC is based on the decision rule that pixels of unknown class membership are allocated to those classes with which they have the highest likelihood of membership (Foody et al., 1992). The Kappa coefficient, the statistical measure of classification accuracy and quality, was also obtained.

Results

Thirteen (13) classes were distinguished of land use from multispectral Landsat images with the supervised classification by maximum likelihood. The classifications are reported in *Fig. 4*.

Fig. 4. *Landscapes of different classes*

The confusion matrices show the main confusions of each class made during the supervised classification of the images, which shows well-classified pixels and poorly classified pixels, and the results obtained show Kappa values of 97% (1986), 91% (2001) and 75% (2021) recorded, which allows us to conclude that the results of these classifications are statistically very acceptable. For each classification, the same method and number of samples were used (in 1986 and 2001) based on the current samples and class appearances on satellite images while using and supporting history and information about this region. However, the results obtained from this classification should be used with caution (Pontius, 2000).

The dynamics of these 13 classes between 1986 and 2021 (*Fig. 5*) detect the resilience of vegetation formation due to natural and anthropogenic factors. We were able to detect a surface area decrease in Cedrus forest by 42%, and an increase in surface in arboriculture (50%), vegetable growers (836%), bare ground (158%), and urban zone (131%) (*Figs. 5, 6*).

Fig. 5. *Land cover of the study area over 1986, 2001, and 2021*

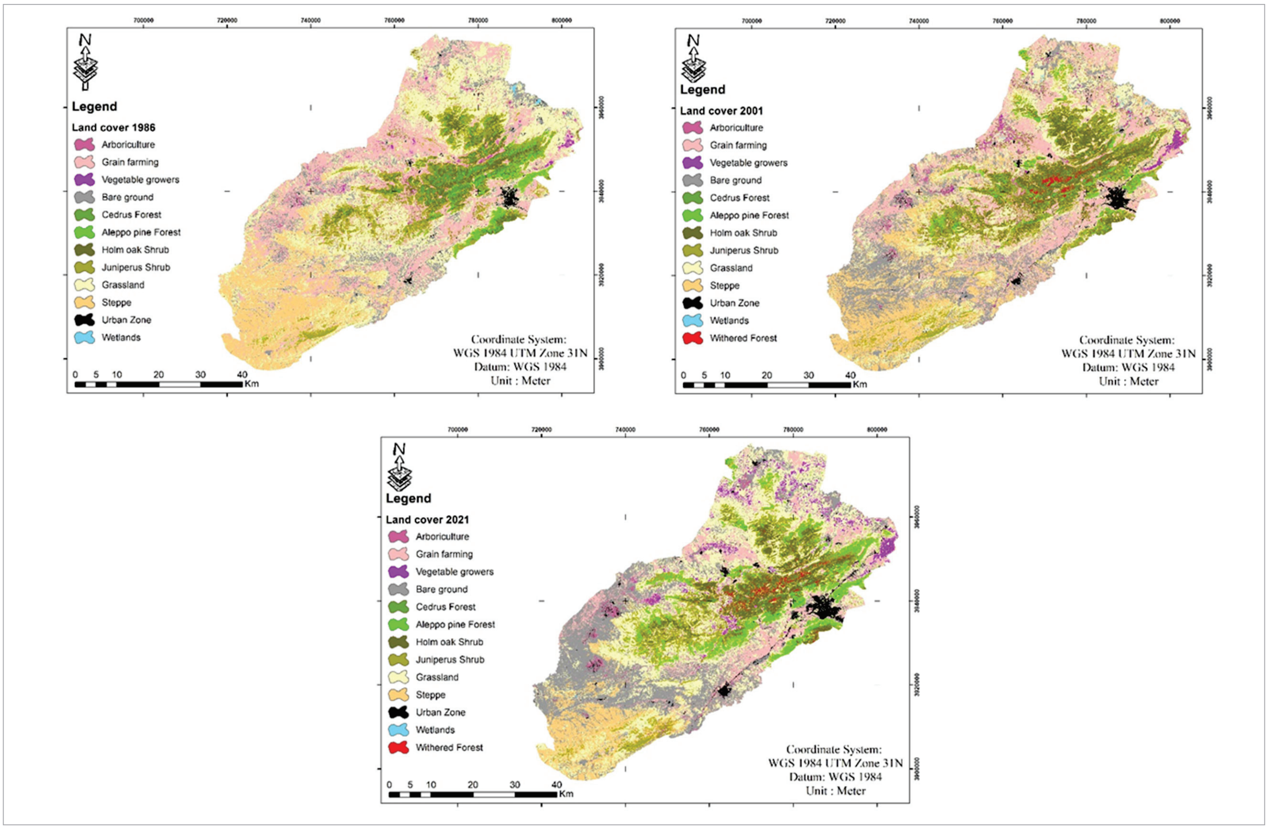
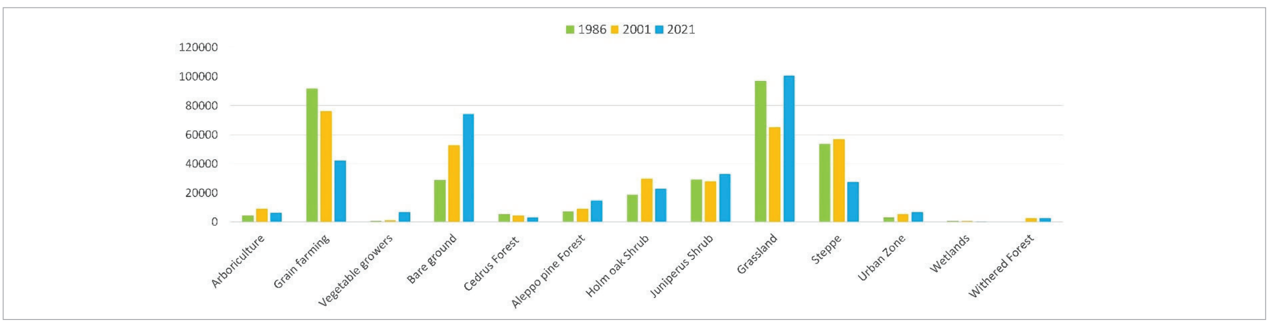
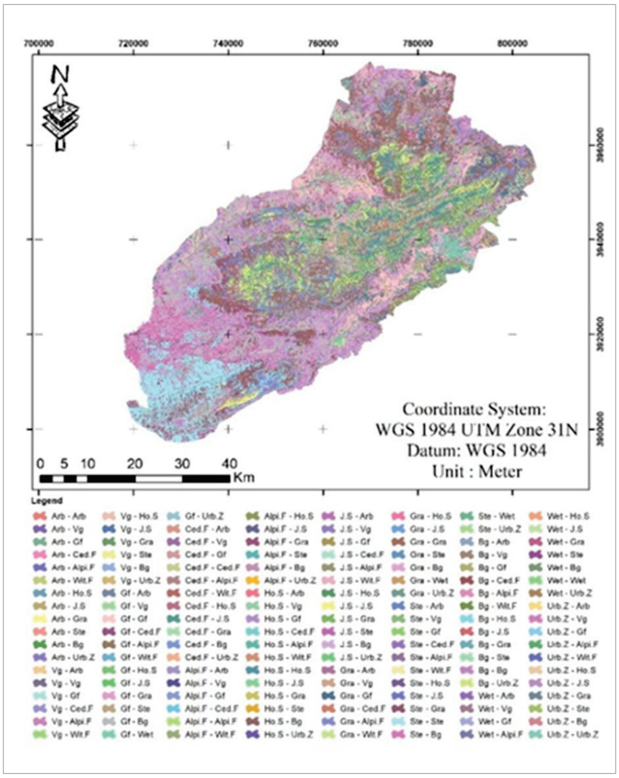


Fig. 6. *Land cover surface according to classes over 1986, 2001, and 2021*



Remote sensing data by supervised classification and phenological information (35 years) analysis of three land use maps (*Fig. 7*) show deferential changes across 13 classes between 1986, 2001, and 2021.

Fig. 7. *Land cover change of the study area between 1986 and 2021: Arb (arboriculture), Gf (grain farming), Vg (vegetable growers), Bg (bare ground), Ced.F (cedrus forest), Alpi.F (Aleppo pine forest), Ho.S (holm oak shrub), J.S (Juniperus shrub), Gra (grassland), Ste (steppe), Urb.Z (urban zone), Wet (wetlands), Wit.F (withered forest).*



Discussion

In the study region, classes were labeled as land cover based on visual interpretation of the Landsat images and georeferenced field data collected. Our investigation results and analyses indicated that:

- Agricultural practices were controlled by the Algerian government through rural development programs and adapted to local climatic conditions. We recorded an increase surface area of arboriculture in 1986 from 4117 ha to 8845 ha in 2001 and then a decrease to 6171 ha in 2021. This shows that surface areas increased by 50% for 35 years.
- On the other hand, grain farming decreased from 91 706 ha in 1986 to 76 236 ha in 2001, and 42 106 ha in 2021. Grain farming was reduced by 54% for 35 years because of the precipitation diminution and fluctuation, upon which this agriculture relies, the expansion of urban areas by the creation of new cities, as well as the change of land use towards arboriculture and vegetable crops, and even the abandonment of land.
- Vegetable growers were increasing rapidly since 1986, from 720 ha to 1218 ha in 2001 and 6746 ha in 2021, with 836% of areas increasing in 35 years. Vegetable growers have taken a big area of wetlands and other land cover.
- Bare ground shows a very significant increase in area from 1986 by 28 740 Ha to 2001 to 52 854 ha and 74 202 ha in 2021. This change is due to climatic change and degradation of other classes such as steppe, as well as the growth of the aggregate's quarries and cement surface.
- Cedrus forests were declining with remarkable degradation of 42.86% from 5271 ha in 1986 to 4185 ha in 2001 and 3012 ha in 2021. This degradation is directly related to the water deficit according to Slimani et al. (2021). The phenomenon was mainly triggered by that water deficit occurred between 1999 and 2002 (Touchan et al., 2008, 2011, 2016; Kherchouche, 2013; Kherchouche et al., 2012, 2013; Slimani, 2014; Slimani et al., 2021).
- Aleppo pine forests increased from 7042 ha in 1986 to 8912 ha in 2001, and 14 718 ha in 2021 due to the maturity of old reforestation and expansion of this formation due to its elastic characteristics, such as the pine forest that spreads to the detriment of the Cedrus withered in the mount of Boumerzoug.
- Holm oak shrub had a very significant increase from 18 929 ha in 1986 to 29 858 ha in 2001 and then a decrease in 2021 to 22 787 ha. Juniperus shrub demonstrated a decrease from 29 090 ha in 1986 to 27 618 ha in 2001 and an increase in 2021 to 33 079 ha. Despite the hardiness of scrubs they remain sensitive to droughts periods, diseases, and repetitive fires (e.g., Kasserou fire in 1995 that took 900 ha).
- Grasslands in general remain stable decreasing from 96 894 ha in 1986 to 65 087 ha in 2001 and increasing in 2021 to 100 473 ha.
- Drought and anthropogenic activities play an important role in the decline of the steppes area which increased from 53 874 ha in 1986 to 56 910 ha in 2001, and then there was a serious decrease in 2021 to 27 454 ha.

- Urban zone was increasing from 2863 ha in 1986 to 5127 ha in 2001, and 6637 ha in 2021, due to rural exodus in the 1990s and demography excess (from 375 955 habitants in 1987 to 736 013 habitants in 2020 in Batna).
- Wetlands increased from 618 ha in 1986 to 721 ha in 2001 and then significantly decreased by 97% of the surface in 2021 to 15 ha, due to drought and anthropogenic activities.
- Forest withered is a new class that appeared in 2001 with 2294 ha and took 2465 ha in 2021, related to the drought period that played an important role in the decline of the Cedrus forests through massive mortality. Three major periods of severe drought were recorded and contributed to the Cedrus forest decline: the first one in 1876 and 1881, the second in 1977 to 1978, and the last and most intense was recorded at the end of the 20th and the beginning of the 21st century (Lapie, 1909, in Abdessemed, 1981; Boudy, 1955; Abdessemed, 1981; Bentouati, 2008; Touchan et al., 2008; Slimani, 2014; Kherchouche et al., 2021).

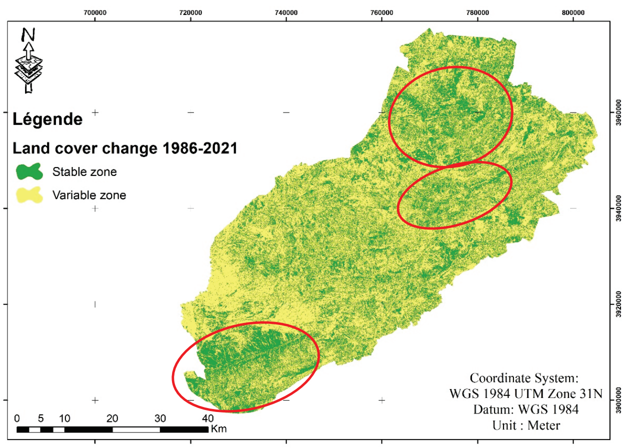
The results show that 61.86% of this area demonstrated important changes over the three decades and 38.14% of it remains stable. *Table 1* and *Fig. 8.* Illustrate the class data between 1986 and 2021.

Remote sensing and mapping according to the spatial and temporal variables are used to survey landscape change. Each change in landscape type is the result of different global environmental factors, mainly due to climatic changes and secondarily due to local factors such as desertification, droughts periods, diseases, fires, extension of urbanization and agriculture. These changes impose the urgent need for improved conservation nature plans.

Table 1. *Classes evolution*

Classes that have a significant progression		Classes with average growth		Classes that have a great degradation	
Vegetable growers	+836%	Holm oak Shrub	+20%	Grain farming	−54%
Bare ground	+158%	Juniperus Shrub	+13%	Cedrus Forest	−42%
Urban Zone	+131%			Wetlands	−97%
Arboriculture	+50%	Grassland	+3%	Steppe	−49%
Aleppo pine forest	+108%				

Fig. 8. *Stable and variable zones of the study area between 1986 and 2021*



Conclusion

Diachronic analysis of land use in the study area using Landsat images in 1986, 2001 and 2021 allowed us to observe profound changes in land cover. Agricultural activities in this region converted grain farming to vegetable growing and arboriculture to bare ground, which is generally increasing. Cedrus forests, steppe, and wetlands suffered severe degradation to the benefit of classes of withered forests and bare ground. Holm oak shrubs, Juniper shrubs, and grassland surfaces were fluctuating but generally stable. Aleppo pine forest was expanding at the expense of other classes showing its elasticity and its resistance to different risks. Natural and anthropogenic factors make the main cause of the degradation of the natural environment in study area which leads to significant damage to ecosystems, biodiversity, and natural resources. We noted that the most significant land use changes occurred in two inverse-related groups: natural for Cedrus forest, steppe, and wetlands that are in continuous degradation. Anthropogenic changes for the urban zone, bare ground, vegetable growers, and arboriculture are in continuous progression.

The use of high spatial, temporal, and spectral resolution satellite imagery improves knowledge of land use in space and time and provides a better understanding of interactions in terrestrial ecosystems. This study conveys the reality of the field so that we are able to predict the scenarios that help decision makers to do what they can to safeguard biodiversity through reliable and sustainable management.

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