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Monitoring Land Use/Land Cover Dynamics in the Province of Constantine, Algeria using Remote Sensing and GIS

Mohamed Gana[1]*, Mohamed El Habib Benderradji[1], Thierry Saint-Gerand[2] and Djamel Alatou[1]

[1]Laboratory of Development and Valorisation of Phyto-Genetics Resources, Department of Biology and Ecology, University of Freres Mentouri Constantine, 25000, Algeria; gana.mohammed@umc.edu.dz, benderj.med35@gmail.com, djalatou@yahoo.fr

[2]IDEES-Caen Laboratory, UMR IDEES 6266 CNRS, University of Caen Basse-Normandie, Caen, France; thierry.saint-gerand@unicaen.fr

Abstract

Objectives: The present study aims to investigate and analyse the dynamics of land use/land change over time in the province of Constantine, Algeria, using multi-temporal Landsat imagery and ancillary data. **Methods/Statistical Analysis**: A supervised classification technique using Maximum Likelihood algorithm was used for land use/land cover classification, to generate thematic maps, with six major classes. The accuracy assessment was applied for each maps based on stratified random method. Furthermore, post-classification technique was achieved to provide a detailed matrix of "from-to" change between 1987 and 2015. **Findings:** The results showed that the landscape patterns in the province of Constantine, Algeria, have been changed. The built-up areas and agricultural lands have increased by 375%, and 13% respectively. However, significant spatial reduction in vegetation areas was observed. Both of grasslands and forestlands were decreased by 54% and 9.11%, respectively, especially in the eastern part of the province. **Application/Improvements:** The dramatic decline in vegetation covers in the most mountainous areas, indicating the necessity to create new policies based on protecting and enhancing the natural vegetation.

Keywords: Constantine, Land Use, Monitoring, Remote Sensing, GIS

1. Introduction

The rapid development of remote sensing technology and Geographic Information Systems creates new opportunities to monitor land use/land cover dynamics and quantify their changes over time. In light of the recent environmental degradation in Algeria, the Information on land use/land covers over time is considered as an effective way to study the environmental change and dealing with the distribution of natural resources and energy management[1,2]. In that respect, Landsat data represent a potential source to record changes in the earth's surface during the last decades; furthermore, the entire Landsat archive is now available at no cost to the users via the Internet.

For the past 30 years, the province of Constantine has been one of the fastest growing metropolitan areas in the Algeria, as it emerged to become the first industrial, commercial, and transportation centre of the north-eastern Algeria, the study area has developed in size as suburbanization consumes large areas of agricultural, forest and grasslands. The population has increased by 41% (from 662 330 in 1987 to 938 475 in 2008) with a density of 427 per/km[23]. The anthropogenic drivers, coupled with the biophysical forces, have stimulated rapid land cover changes.

In that respect, monitoring land cover changes in Constantine has become a key issue in any planning process and management programmes.

*Author for correspondence

In Algeria, A lot of research has been conducted to assess land cover change based on remote sensing data sets and geographic information system (GIS), especially by usingsatellite imagery to evaluate desertification processes and Land degradation over semiarid areas[4,5]. Other work depicted aspects of vegetation cover change in mountain areas and landslide susceptibility zonation using very high resolution satellite, or ortho-photographat a district level. However, very few studies have focused on the rapid growth of urban areas and change of vegetation in metropolitan areas at the entire Provence level, which have not received adequate attention to assess the patterns of land cover change over time, and their ecological effects in the whole province.

In that regard, the aims of this study are: (1) to monitor and analyse land use and cover changes for 1987, 2000 and 2015 in the province of Constantine, based on remote sensing data and GIS techniques, (2) determine the shift from one land cover category to another using a post-classification technique, and finally (3) investigate the preliminary elements and driving forces of land use/land cover Changes.

The adequate knowledge of land and land cover changes play an important role in any planning process; and provide a valuable source of information for land managers' and policy makers[6].

2. Materials and Methods

2.1 The Study Area

The present study has been carried out on Constantine province in north-east of Algeria. The studied area is located between the 36°05′35″N and 36°37′27″N latitudes and 06°18′34″E and 07°02′57″E longitudes (Figure 1), at altitudes ranging from 167 to 1364 m above sea level, and extends over 224.549 hectares. The study area is divided into 6 districts and comprises varied land cover including agricultural land, grassland, forest land, built-up, rocks, and water body.

Geographically, Constantine can be divided into two regions: the mountainous region and the High Plains. The mountainous regions are located in the north, which is an extension of the Tell chain, and dominated by mount Chetaba and massive of Jebel Ouahch. The highest elevation is the mount SidiDriss (1364 m above sea level), however, the high plains are located in the southeast of Constantine between the chains of the Tell Atlas and Saharan Atlas, and extends to the district of A in Abid and Ouled Rahmoune.

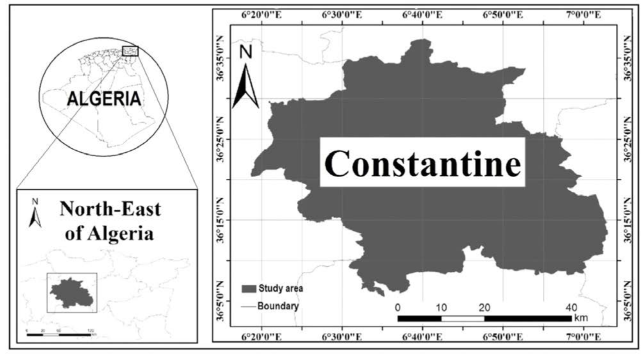

Figure 1. Geographic location of the study area.

Constantine has a sub-humid climate in north and semi-arid in south. The rainfall patterns over the study area are irregular in time and space with annual rainfall ranging from 500 mm to 700mm/year, the highest temperatures usually occur in June to August with an average maximum temperature range from 27 to 33 °C, while The period from December to February is considered to be a cool season, with a mean temperature of 7 to 8°C.

2.2 Data Sources

The data used for this study include: satellite images, ancillary data, and data collected from fieldwork (Table 1). Landsat Surface Reflectance Climate Data Record (Landsat CDRs) was utilized. The U.S. Geological Survey (USGS) is using the valuable 40year Landsat archive to create CDRs that can be applied to document changes in terrestrial ecosystems[7]. Landsat CDRs data are geometrically and atmospherically corrected at global level.

From the available Landsat surface reflectance CDRs data, three scenes covering the study area (Path 193/Row 35) acquired on 16 June 1987 (Landsat 4-5 TM), 14 August 2000 (Landsat 7 ETM+), and 15 July 2015 (Landsat 8 OLI), with pixel resolution of 30*30 m, were obtained, which are available as options when requests from website of United States Geological Survey (USGS) (earthexplorer.usgs.gov/), the clouds were observed in some scenes, but they were mostly concentrated in specific areas. We selected the images from July-August period, to reduce variations in solar elevation angles, and minimize the possible occurrence of environmental condition.

Table 1. Summary of data descriptions

Type	data	Acquisition date	Spatial Scale (m)	Source
satellite images	Landsat 4-5 TM	16June 1987	30 × 30	U.S. Geological Survey(USGS) (http://earthexplorer.usgs.gov)
	Landsat 7 ETM+	14 August 2000	30 × 30	
	Landsat 8 OLI	15 July 2015	30 × 30	
Ancillary data	Topographic maps	2005	1:25 000 1:50 000	National Institute of Cartography and Remote Sensing (INCR)
	aerial photographs	1987,2003	1:10.000 1:20.000	
	Google Earth	/	0.5	Google Inc.
	Statistic data	1985 to 2016	/	National Statistics Office
	Field data	/	/	Fieldwork (67 field trips)

Table 2. Land cover classification scheme

Land cover classes	Description
Agriculture	Includes cultivated land, crop fields, and land being prepared for raising crops, or chards and fallow lands.
Built-up	Covered by structures where there is permanent concentration of people, and activities. Included: cities, villages, Industrial and Commercial complexes as well as large open transportation facilities (roads, airports, parking lots…)
Forest	woodland areas where the most trees are about 6 m tall and more than 40% of total vegetation cover, including : coniferous, deciduous, and mixed forests .This class also include the shrubland (more than 2 m tall)
Grassland	Areas dominated by herbaceous plants, which occupied more than 80% of the total vegetation areas, including lands that are regularly grazed by livestock and city parks.
Barren Land	Land areas of exposed soil or areas with very little vegetation cover. Included : bare rocks, Quarries, and Gravel Pits,
Water	All areas of open water, generally with greater than 90% cover of water, including lakes, Dams, rivers, and reservoirs.

The ancillary data used in this study includes: (1) a topographic maps at a scale of (1/25 000) and (1/50 000) produced from aerial photography taken in 2003, (2) black and white aerial photographs at a scale of (1/10 000), (1/20 000) acquired in 1987 and 2003; (3) Google Earth© images; (4) Statistic data, and (5) data collected from fieldwork (Table 1).

The Arc GIS (10.2) and ENVI (5.1) software's packages were used for data pre-processing, viewing, editing, and also for spatial analysis.

2.3 Image Classification

The nature of our research required to employ a variety of methods to develop reference data sets for training and for accuracy assessment.

Before the classification, training samples were selected by choosing several polygons for each classes of land cover from reference data, which were independent from those used for accuracy assessment. A combination of different data types were applied as references for calibrating the classification and increasing the classification accuracy: Google Earth software, aerial imagery, topographic maps, and fieldwork were used for training sites. The classification system developed by Anderson[8] was used for land use and land cover classification and change analysis.

Supervised classification technique based on the maximum likelihood classifier was used for extracting each land use/land cover maps independently. Land cover classification should be unified to ensure that the classification of the multi-temporal, Landsat images is compatible to each other[9].

The maximum likelihood classifier is one of the most popular classification algorithms and provides the best results from remotely sensed data[10,11]. It is a supervised statistical approach to pattern recognition. It estimates the probability of a pixel belonging to each of a predefined set of classes, and then allocates each pixel in the right class with highest probability[12]. Finally, six land cover classes were extracted: (1) Agriculture; (2) Built-up; (3) Forest Land; (4) Grassland; (5) Barren Land; and (6) Water body. Detailed description of each class is provided in (Table 2).

2.4 Classification Accuracy Assessment

The accuracy assessment of a land cover classification is an important process when using reference data collected at or near the date of the satellite imagery[13]; Accuracy assessment involves the verification of the labelled pixel identity against the ground truth at the time of sensing at representative sample points[14], however, finding simultaneous ground trothing data, for accuracy assessment, over a long period of time are very difficult, particularly in African countries[15].

The aerial photography (1/10.000) acquired in 1987 were used as reference data for the 1987 classification accuracy assessment, while the combination of topographic maps (1/25.000 and 1/50.000), Google Earth, and fieldwork data were used as reference in 2000 and 2015.

In order to build the confusion matrix of land cover maps extracted from satellite datasets, stratified random sampling technique was employed. This sampling design should be taken properly to ensure that all classes are adequately represented and well distributed over all the study area[16]. Overall accuracy, user's and producer's accuracies, and kappa statistics were then calculated to estimate classification performance.

Table 3. Summary of accuracy assessment of land use/cover maps in the province of Constantine

Land use/ land cover class	***1987***		***2000***		***2015***	
	User's (%)	Producer's (%)	User's (%)	Producer's (%)	User's (%)	Producer's (%)
Agriculture	0.85	0.85	0.89	0.88	0.9	0.91
Grassland	0.77	0.79	0.85	0.83	0.84	0.84
Forest	0.81	0.8	0.86	0.87	0.87	0.86
Built-up	0.81	0.84	0.82	0.78	0.92	0.95
Barren Land	0.79	0.82	0.82	0.78	0.88	0.82
Water	0.88	0.88	0.9	0.98	0.93	0.97
Overall accuracy	81.45		85.6		88.6	
Kappa statistics	77.49		82.45		86.01	

Table 4. Summary of land cover change statistics from (1987- 2015)

land cover categories	***1987***		***2000***		***2015***		***the change in Land cover (%)***		
	Area (ha)	**%**	**Area (ha)**	**%**	**Area (ha)**	**%**	**1987-2000**	**2000-2015**	1987-2015
Agriculture	122.558	*54.58*	116.375	*51.83*	138.521	*61.69*	*-2.75*	*9.86*	*7.11*
Built-up	4.741	*2.11*	9.851	*4.39*	22.548	*10.04*	*2.28*	*5.65*	7.93
Forest	24.229	*10.79*	21.245	*9.46*	22.021	*9.81*	*-1.33*	*0.35*	*-0.98*
Grassland	64.082	*28.54*	59.341	*26.43*	29.462	*13.12*	*-2.11*	*-13.31*	-15.42
Barren Land	8.860	*3.95*	17.637	*7.85*	11.358	*5.06*	*3.9*	*-2.79*	*1.11*
Water	78	*0.03*	101	*0.04*	638	*0.28*	*0.01*	*0.24*	0.25
Total	**224.549**	**100**	**224.549**	**100**	**224.549**	**100**	-	-	-

3. Results and Discussion

3.1 Classification Accuracy Assessment and Land Use/Cover Mapping

In the first part of the results, an analysis of separability of spectral signatures was undertaken to examine the quality of training, and confirm minimal confusion of classes of interest before performing the classification. The spectral separability of the training class pairs was examined by computing the Jeffries-Matusita (J-M) distance. The values of the J-M distance range from 0.0 to 2.0, where values greater than 1.9 indicate that training class pairs have good separability[17]. Based on the results of separability test between training class pairs of the images of years 1987, 2000 and 2015, it could be concluded that most classes could be separated from each other, since all the values were above 1.9, except few that exhibited overlap to some extent. These classes were Grassland and Forest, where spectral separability ranged between 1.71 and 1.91.

The overall accuracy of the land cover maps for TM 1987, ETM+ 2000, and OLI 2015 was 81.45%, 85.6% and 88.6% with corresponding kappa coefficients of 77.49%, 82.45%, and 86.01% respectively. User's and producer's accuracy were also calculated for each land cover maps (Table 3).

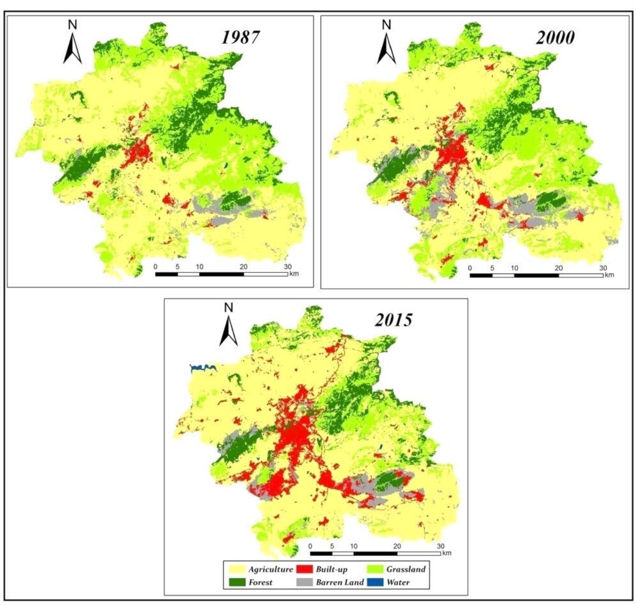

Figure 2. Land use/land cover maps of Constantine in 1987, 2000, and 2015.

The classified land use/cover maps of Constantine Province for 1987, 2000 and 2015 images, obtained after pre-processing and supervised maximum likelihood classifier are given in (Figure 2). Moreover, the surface area of each land cover class was estimated (Table 4).

The results obtained through the analysis of multi-temporal satellite imageries, illustrate a substantial change in the landscape, and provide much information about the land use and land cover pattern in the study area. There is no doubt that human activities have profoundly changed land cover in Constantine Province during the past three decades. Generally, land use/cover between 1987 and 2015 is characterized by the expansion of urban area (from 2.11% to 10%) and agriculture (54.58% to 61.69%) and decrease of grassland (28.54% to 13.12%) and forest (10.79% to 9.81%) of the total area.

The agriculture and grassland areas were the dominant land use/cover classes, computed percentages of land use/cover classes show that in 1987, agriculture, grassland and forest occupied 54,58%, 28.54% and 10.79%, respectively, while built-up, barren land and water areas occupied only 2.11%, 3.95%, and 0.03%, of the study area (Table 4). However, significant spatial expansion in urban area (from 4.741 ha to 9.851 ha) and decline in forest land (from 24.229 ha to 21.245 ha) were observed in the 2000. Moreover, the area of agriculture and grassland decreased by 6.183 ha, and 4.742 ha, respectively, while barren area was increased by 8.776 ha (Figure 3).

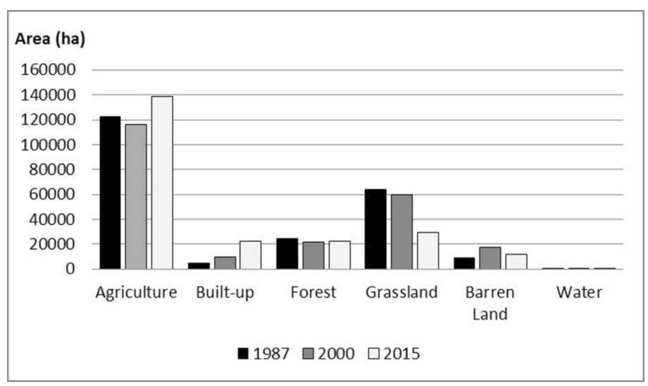

Figure 3. Summary of trends amongst land cover classes from 1987 to 2015.

In 1987, the major land cover classes were agriculture and grassland, the results show that agriculture, grassland and forest occupied 54.58%, 28.54% and 10.79%, while built-up, barren land and water body occupied 2.11%, 3.95%, and 0.03%, respectively (Table 4), however, enormous growth in urban area (from 4.741 ha to 9.851 ha) and decline in forest land (from 24.229 ha to 21.245 ha) were observed in 2000. Moreover, both of agriculture and grassland decreased by 6.183 ha and 4.742 ha respectively, while barren land was increased by 8.776 ha (Figure 3).

From 2000 to 2015, urban area increased by 12.697ha (5.65% of the total surface area), and the expansion of agricultural land mainly takes place in the grassland and barren area. Both of grasslands and barren lands were decreased by 29.878 ha and 6.278 ha, respectively, relatively, forests and water body were increased by 776 ha and 537ha.

3.2 Change Detection Analysis Over Different Time Scales

Change detection analysis is performed not only to detect changes over different time scales, but also to identify the nature and spatial pattern of those changes by comparing satellite imagery of the area taken at different times[18]. In order to estimate the rate of conversions from land use category to another and their corresponding area over the evaluated period, post-classification analysis on a pixel by pixel basis was conducted. A spatio-temporal quantification and graphical representation of the different changes in land cover for 1987, 2000, and 2015 are demonstrated in (Table 5) and (Figure 4), the results showed that both of negative and positive changes are occurred in the land cover patterns of Constantine during the last three decades.

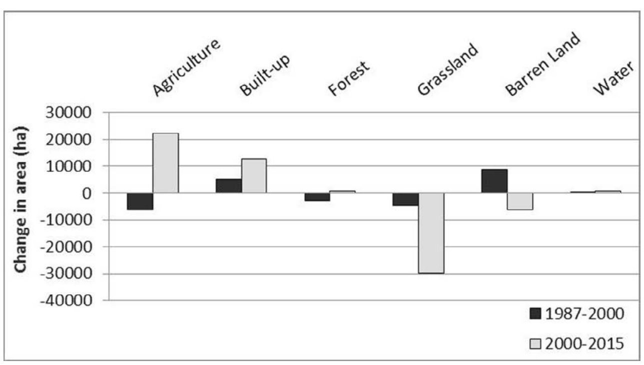

Figure 4. Diagrammatic illustration of land cover change in Constantine from 1987 to 2015.

3.2.1 Land Use/Cover Change during 1987-2000

The cross tabulation analysis, (Table 5), shows the nature of change of different land cover classes. Out of the 122.558 ha that was agriculture area in1987, 95.713 ha (78.1%) was still Agriculture area in 2000, but 8.839 ha (7.21%) was converted to Bare land, 13.603 ha (11.1%) to grassland and the rest to Settlements (3.56%) and water body (0.03%). at the same time the increase of settlements was mainly from agriculture area (lose nearly 4361 ha of agricultural land for built-up area). Change detection analysis also reveals that:

- The area of forests decreased from 24.229 ha in 1987 to 21.245 ha in 2000. It retained approximately 19.791 ha (81.68%), and the rest was mainly converted to grassland (16%) and agriculture (1.16%).
- The grassland class retained 40.547ha (63.27%) of the total 64.082 ha in 1987. It was reduced by 7.39% in 2000, and replaced by Agriculture (28.55%), and barren land (5.5%).

3.2.2 Land Use/Land Cover Change during 2000-2015

Based on the analysis, approximately 73.9% of the total area of the province of Constantine remained unchanged from 2000 to 2015, while (26.1%) underwent conversion between different lands cover types. The major changes include gains of agriculture (9.86%), built-up (5.65%), forest (0.35%), and water (0.24%), and loss of grassland (13.31%) also, Change detection analysis reveals that:

- About 25.382 ha (42.77%) of grassland has been replaced by agriculture, 1.733 ha (2.98%) into built-up area and 3.247 ha (5.47%) into barren land.
- 105.095 ha (90.31%) of agriculture class remained unchanged from 2000 to 2015, but (5.43%) has been converted to built-up area, (2.11%) into grassland, (1.72%) into barren land, and (0.43%) into water body; at the same time the increase of built-up area was mainly from agriculture (6.324 ha) and barren land (4.075 ha).
- (88.66%) of forest class remained unchanged, but (7.14%) have been converted into agriculture, (2.66%) into built-up area, (1.16%) into barren, and (0.01%) into water body.

3.2.3 Land Use/Land Cover Change during 1987-2015

Considering the entire study period, 1987-2015, at once, (68.12%) of the total area of Constantine remained

Table 5. Matrix of land cover change distribution (%), in Constantine from 1987 to 2015

Period 1987–2000		**Year 1987**					
		Agr	***Blt***	***For***	***Gras***	***Barr***	**Wat**
Year 2000	Agr	**78.10**	0.00	1.16	28.55	23.32	22.65
	Blt	3.56	**99.99**	0.12	0.50	4.52	0.00
	For	0.00	0.00	**81.68**	2.16	0.80	0.00
	Gras	11.10	0.00	16.05	**63.27**	14.55	14.20
	Barr	7.21	0.00	0.98	5.50	**56.80**	0.00
	Wat	0.03	0.00	0.00	0.02	0.00	**63.15**
	Total	100	100	100	100	100	100
Period 2000-2015		**Year 2000**					
		Agr	Blt	For	Gras	Barr	Wat
Year 2015	Agr	90.31	0	7.14	42.77	37.01	0
	Blt	5.43	**99.99**	2.66	2.92	23.11	0
	For	0	0	**88.66**	4.64	2.44	0
	Gras	2.11	0	0.38	**44.14**	4.16	0
	Barr	1.72	0	1.16	5.47	**33.27**	0
	Wat	0.43	0	0.01	0.05	0	**99.99**
	Total	100	100	100	100	100	100
Period 1987-2015		**Year 1987**					
		Agr	Blt	For	Gras	Barr	Wat
Year 2015	Agr	**83.45**	0	6.67	50.2	27.73	10.88
	Blt	10.05	**99.99**	2.3	4.75	21.26	0
	For	0.17	0	**79.93**	3.66	1.16	0
	Gras	3.39	0	10.22	**35.07**	4.03	0
	Barr	2.54	0	0.87	6.2	**45.81**	0
	Wat	0.4	0	0.01	0.11	0	**89.12**
	Total	100	100	100	100	100	100

(The **diagonal values** represent the proportion of each land cover class that didn't change, while the other values indicate reduction or expansion of the classes)

unchanged, while (31.87%) underwent conversion between the land use and land cover categories; About 83.45% of agricultural lands remained stable, and the new cultivated land were created at the expense of grassland (50.2%), barren land (27.73%), and forest (6.67%), furthermore, 12.319 ha which represent (10.05%) of agricultural area was converted into built-up area, (3.39%) to grassland, (2.54%) to barren land, and (0.4%) to water body. The built-up area had increased by 375.55% from 1987 to 2015, mostly from cultivated lands, as mentioned before, with an average rate of 614 ha/year. Moreover, both of grass lands and forest experienced significant reduction by 34.619 ha and 2.208 ha, respectively, on the other hand, 83.45% of agricultural lands remained stable, and the new cultivated land were created at the expense of grassland (50.2%), barren land (27.73%) and forest (6.67%), furthermore, 12.319 ha which represent (10.05%) of agricultural land was lost to built-up areas, (3.39%) to grassland, (2.54%) to barren land, and (0.4%) to water body. the built-up area class had the net expansions, it was the class that expanded the most over other land types (375.55% from 1987 to 2015), with an average rate of 614 ha each year, and mostly from cultivated lands as mentioned before. During this period of 28 years, the areas of grass lands and forest experienced significant reduction, with 34.619 ha and 2.208 ha, respectively, while water body has increased by 723%, (from 77.56 ha in 1987 to 638 ha in 2015), and accounts approximately 0.4% of the total area which mostly extent from agricultural lands.

3.3 Driving Forces of Land Use/Land Cover Changes

The drivers of land use/land cover change is a valuable information source to minimize and manage the impacts of multiple causes and consequences of land use/land cover changes over time[19,20]. In this study, some preliminary elements can be mentioned based on existing statistics and previous investigations. The land cover changes that were detected in all study areas supported, in general, the above mentioned facts that natural vegetation area (forests and grasslands), decreased dramatically over the past 29 years. According to Forest Conservation Department of Constantine, the major cause of forest decline are the forest fires and human activities, based on the more than 4.300 hectares of forest land were significantly affected by fire from 1987 to 2015, particularly in summer, with an average rate of 148 ha each year.

In addition to forest fires, deforestation for agricultural expansion, over grazing, cutting of fuel wood by the local communities, mismanagement and forest diseases also play an important role in vegetation decline. At the same time, grassland change was also triggered by various factors that undermine the sustainable potential of these lands. About 54% of grassland has been converted to other uses, especially cropland, due to farmland expansion strategy and exponential population growth. This kind of practices could make grasslands vulnerable and negatively influenced on forest generation as well.

According to the information revealed by classification results, the settlements or built up area showed 375% increase (from 2.11% to 10.04% of the overall area during the study period). This increase was due to rapid expansion of cities and villages, and new resettlement programs (buildings new cities such as Ali Mendjeli and Ain Nahas). Along with these developments, there is much more needs to build new roads, highways and other Infrastructures, the growth of the built-up area was also correlates with 41% increase in population, the rapid expansion of urbanization is usually at the expense of the agricultural land, which, at the same time, faced an increment in the total area by (13.03%), due to conversion in grasslands, forests, and barren lands, with an average rate of 550 ha each year. New legislation, policies and development programmes designed for enhancing food security, by strengthening agricultural investments and rural financial services to expand and reclaim farmland and improving agricultural performance, furthermore, the area covered by Water class has been increased remarkably. This increase in the water body was due to construction of new dam (BniHaroun in the north), many artificial lakes were also constructed for industrial or agricultural use (Taisinga, El biar, Boudeme ……).

4. Conclusion

This study is considered to be an attempt for monitoring land use/land cover changes in the province of Constantine based on remote sensing and GIS techniques, the thematic maps were prepared and accuracy assessment results are considered satisfactory. The post classification results demonstrate the patterns and magnitude of change, such data are crucial to land management and policy making.

The rapid economic and population growth were parallel with vegetation cover degradation and agricultural expansion, as result of socio-economic factors, the land cover shift in the Constantine was evident by the decline of grasslands and forests due to agricultural expansion, forest fires and over grazing…., at the same time. The agriculture was increased due to conversion in natural vegetation and barren land. Moreover, built-up area has been increased dramatically due to the new resettlement programs. The area under water body has also increased over constructing of new dams and artificial lakes for industrial and agricultural use. Furthermore, the results demonstrate the potential of multi-temporal Landsat imageries to provide accurate maps and to analyse land cover changes in less time, low cost, and with better accuracy.

Finally, based on the drivers identified in this study, it is important to conduct more studies by using images with higher spatial resolution at a local scale to formulate intervention strategies and minimize the impact of this changes, especially on the natural vegetation, in order to insure the sustainability for both society and environment, and reduce the risks associated with land use and land cover dynamics aver time.

5. Acknowledgement

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