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Spatio-Temporal Dynamics Analysis of the Tabalak Watershed

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Abstract

The objective of this study was to assess how land degradation through human livelihood affects Tabalak watershed dynamics. Data was collected from three sample sites along the Tabalak watershed to identify the morphological units and their socio-economic activities area. Satellite images and GPS coordinates were used. Our findings showed that in the last 40 years (1980-2020) there has been an increase in field surface areas and a decrease in the natural vegetation surface areas. From 1990 onwards, field areas appeared in the natural vegetation zone, which decreased from 25% to 18% of the total watershed area. From 1999 onwards, the dynamics adopted a relatively stable rate until 2020, the area of Fields which has increased from 42% to 55% of the total area has remained constant, as has the area of vegetation which has remained constant at 10% of the total area.

Keywords: Wetland, Watershed, Land Use, Land Cover Maps and Tabalak.

Introduction

Sahel region of tropical Africa is increasingly facing harsh climatic conditions that aggravate food insecurity coupled with high population growth, with insufficient agricultural and pastoral resources due to soil fertility decline (Ichaou, 1996). Recent research by the United Nations (World Water Development, 2015) has demonstrated that several forces continue to seriously affect the natural water resources in the Sahel (**Soro**, et al. **2014**). According to the Ramsar Convention's World Wetlands Report, over the last thirty years, several wetlands have disappeared. These areas are disappearing at an alarming rate, three times faster than forests, with serious consequences for the future of local and surrounding populations. Indeed, between 1970 and 2015, about 35% of the world's wetlands disappeared and the rate of loss has accelerated sharply (Ramsar, 2018). The degradation and retreat of wetlands are hindering the development of the country. This degradation has some causes: environmental pressures and human pressures (natural resource exploitation methods remain largely traditional and are not consistent with sustainable exploitation, unregulated fishing, uncontrolled land clearing, bushfires, excessive forest clearance, and overuse of chemical fertilizers and pesticides) (Ministry of Environment and Fight against Desertification, 2009). In the watershed level approach, the assessment of wetland ecological functions, impacts of land degradation, and agriculture or livestock use is needed. Site-specific, detailed ecological information is required before any sustainable management of wetlands (Ministry of Environment and Fight against Desertification, 2009).

Material and methods

The study was conducted in the watershed of Tabalak wetland (figure 1) in the Tahoua region. The waterhole runs along the uranium road (Tahoua-Arlit road) for about ten kilometers, from the village of Kéhéhé to Tsaouna, passing through Tabalak. The waterhole is fifty (50) km from the town of Tahoua, around the geographical coordinates 15°05' North latitude and 05°39' East longitude (National Institute of Statistics NIS, 2012). The surface area of the water body varies according to the season from 50 ha to almost 1000 ha with an average depth of 2 m. The watershed is part of

the Ader-Doutchi-Maggia plateau area. The average altitude of the watershed is between 300 and 500 m with a high point reaching 746 meters (CDP Tabalak, 2010).

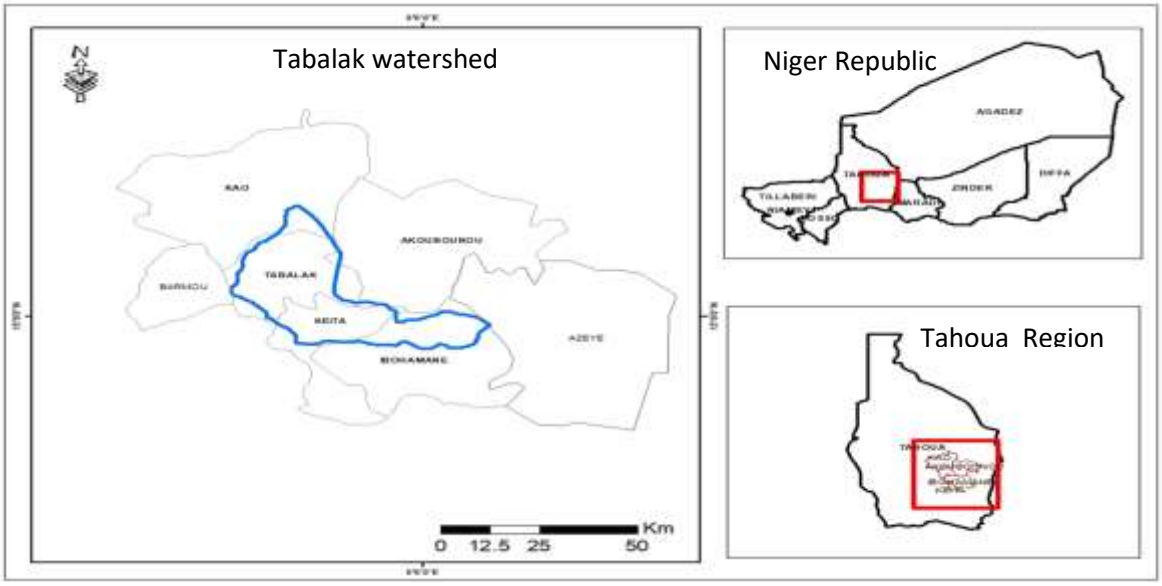


Figure 1: Watershed of Tabalak Wetland

Selection of the Study Area and Sampling

The locations for data collection (Figures 2 and 3) were selected through literature review and field visits which made it possible to detect the major environmental issues due to land degradation and human activities in the watershed.



Figure 2: delimitation of the study area on the Landsat image

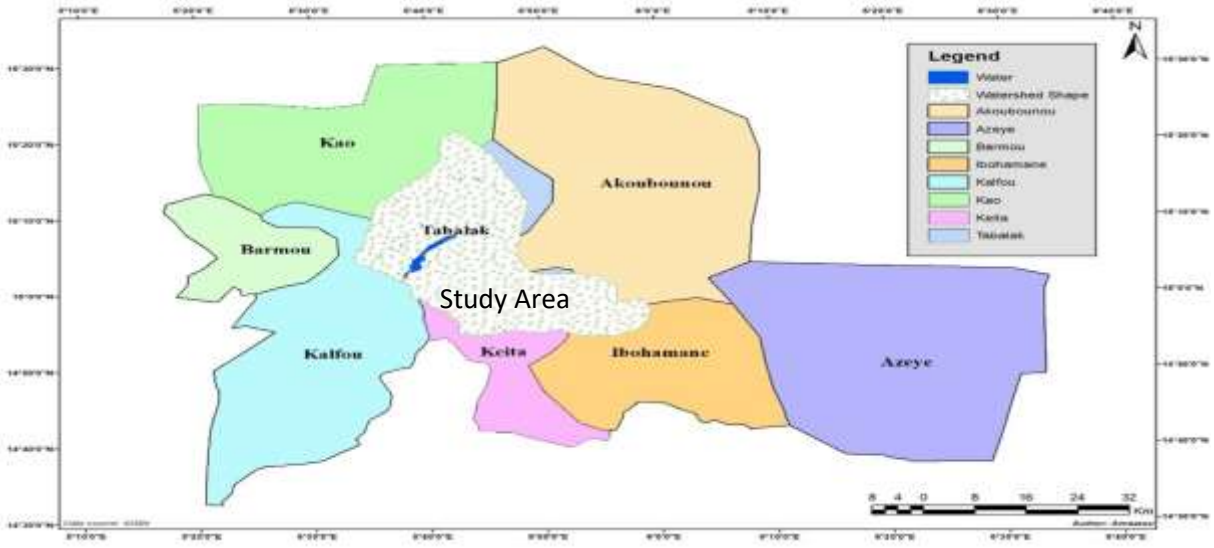


Figure 3: The study area in the Tabalak watershed

Methods

The methodological approach used in this study is a longitudinal approach from 1980 to 2020**.** The Manual approaches with supervised classification were also used.

Material

The Landsat multi-spectral geo-referenced satellite images without cloud cover of the US Space Agency (NASA), which operates at an average altitude of 705 km in near-polar circular orbits with an inclination of 98.2°, were used in this study. The land use/land cover map for the year 2021 from the sentinel imagery of 10 m resolution was also used as its table of statistics. Six sets of GPS readings of 5 points each (30 points in total) collected in the field representative of each land use class, were used for the validation of the classification results.

Data Processing and Analysis

a. Pre-Processing of Satellite Images

Before proceeding with the thematic classification of the satellite images, a series of pre-processing operations were carried out to facilitate their use. These include combining the bands to obtain a single multispectral image. The Landsat images are designed as individual grey level bands in GeoTIFF format, all the bands were combined in ENVI software using the Layer Stacking module.

b. Supervise Classification

The method of classification by an object, used in this study, is a method of supervised classification under the image processing software ArcGIS (Version 10.3). The supervised classification is practiced if the class domains are already known. Supervised methods consist of two phases: the training phase and the classification phase. In the first phase, using samples of pixels including the membership class known, training zones are established for each class. A training area is an area of the image with known ground cover of the user. In the second phase, the pixels of the entire image are classified by comparison of each pixel with known domains. The classes chosen are defined as follows:

- ✓ Water: Includes all water-covered surfaces at the date of acquisition image;
- ✓ Habitation: includes dwellings, Villages, markets, hamlets, and any other construction;
- ✓ Vegetation: including Natural or artificial vegetation
- ✓ Fields: includes market gardening, arboriculture, park cultivation
- ✓ Bare soil: includes all surfaces with no vegetation (including rocky terrain, glaciers and sand dunes);
- ✓ Koris (Watercourse): includes all surfaces of dry, non-permanent, moving open water on the date of the image acquisition.

c. Post-Classification Processing and Validation

Once the classification was completed, processing was carried out to refine, evaluate the accuracy, and validate the results. The validation of classification is done by analyzing a confusion matrix.

d. Statistical Analysis of Land Cover Change

The areas of different land use/ land cover classes were calculated from the intersection of the 1980, 1990, 1999, 2010, and 2020 land use/ land cover maps using the 'Intersect' function in ArcGIS 10.3 software. Calculation of the rates of change (or conversion) overall change rate (OCR) and annual change rate (ACR) in an Excel spreadsheet, were determined respectively through the equation proposed by FAO (1996) (I) and the Noyola-Medrano et al (2009) (II) (Olalekan et all, 2011; Soro, 2014); and provide a measure of the magnitude of the trend in terms of improvement (progressive trend),

stability (inertia) and degradation (regressive trend). $OCR = \frac{S2-S1}{S1} * 100$ (I) ; $ACR = \frac{(\ln S2 - \ln S1)}{(t2-t1)\ln e} * 100$ (II)

With S1 the area of a class unit at date t1; S2 the area of the same class unit area at; date t2 (t1 +10); ln the neperian logarithm, e the base of the neperian logarithms (e =2.71828) The overall change rate and the annual change rate are appropriate tools to monitor and quantify the changes in a land use class over time.

Results

a) Level of Mapping Accuracy

The level of validity of these maps is expressed by the Kappa coefficient (KC) and the overall accuracy index (OAI) gives a measure of the level of reliability of these maps (Table 1).

Table 1: Assessment of the level of validity of the mapping work

Years	1980	1990	1999	2010	2020
OAI (%)	70.14	61.08	73.25	78.31	90.05
K C (%)	85.1	63.45	70.34	66.62	89.3

Source: calculated values, 2022

Overall, the maps show a statistically acceptable level of accuracy above 50%. The criteria used to select the satellite image scenes and the approach used in the production of the maps can be used as a basis for the analysis of landscape dynamics.

b) Tabalak Watershed Land Cover Change between 1980 and 1990

The Tabalak watershed dynamics analysis has mainly concerned woody vegetation and fields. The results for the Landsat images classification to 1980 and 1990 are shown in Figure 4. However, the decade 1980-1990 is characterized by a decrease in the vegetation class and an increase in the fields class.

Thus the vegetation area decreased from 25.24% of the total area in 1980 to 18% in 1990 and the field area increased from 42.3% in 1980 to 48.26% in 1990.

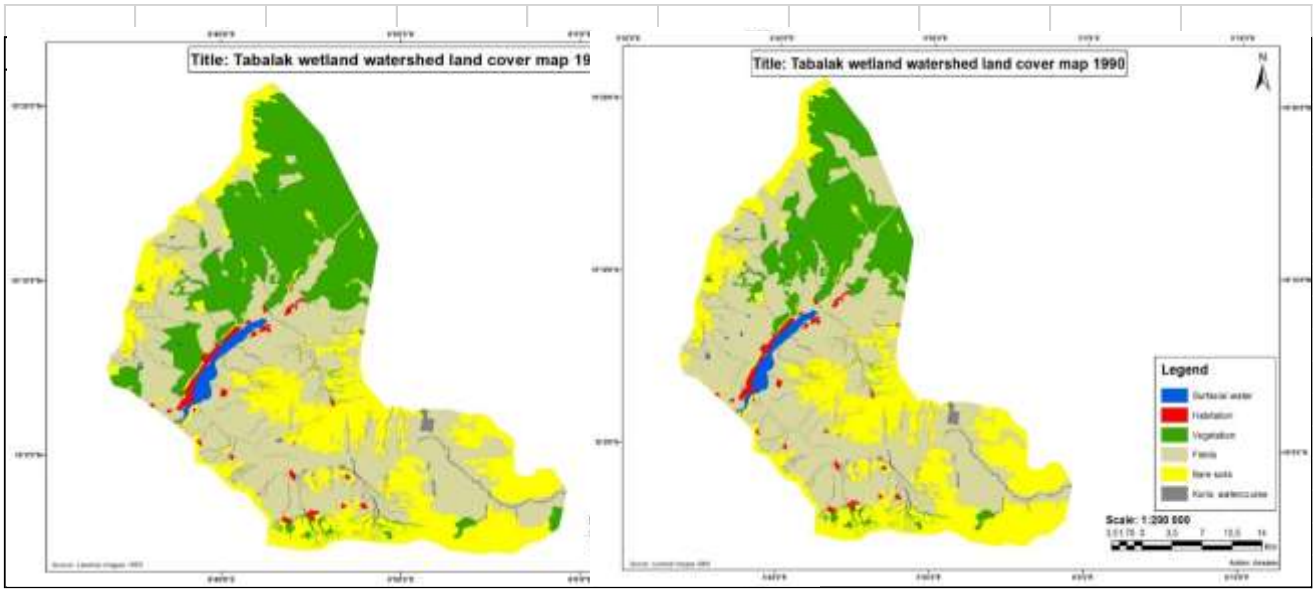


Figure 4: Comparison between land use/land cover maps in 1980 and 1990

The analysis of Figure 4 showed that the dynamics of environmental degradation and land cover changes have taken place throughout the Tabalak watershed during the decade 1980 - 1990. However, it can be seen that the northern part, which is known as a pastoral area, is the most affected by the expansion of fields. This is a progression of the agricultural front towards the north despite its status as a pastoral area since the 1960s. This could be seen as an adaptation strategy for the populations to cope with the effects of climate change. This adaptation strategy could be a source of conflict with the increase in trap fields in a fully pastoral area.

c) Tabalak Watershed Land Cover Change from 1990 to 2020

The decades 1990-1999; 1999- 2010 and 2010 - 2020 show relative stability for the vegetation and field classes as shown on the land cover maps (Figure 5). The vegetation cover is still 10707, 59 ha in 1999, 10952, 99 ha in 2010 and 10953 ha in 2020.

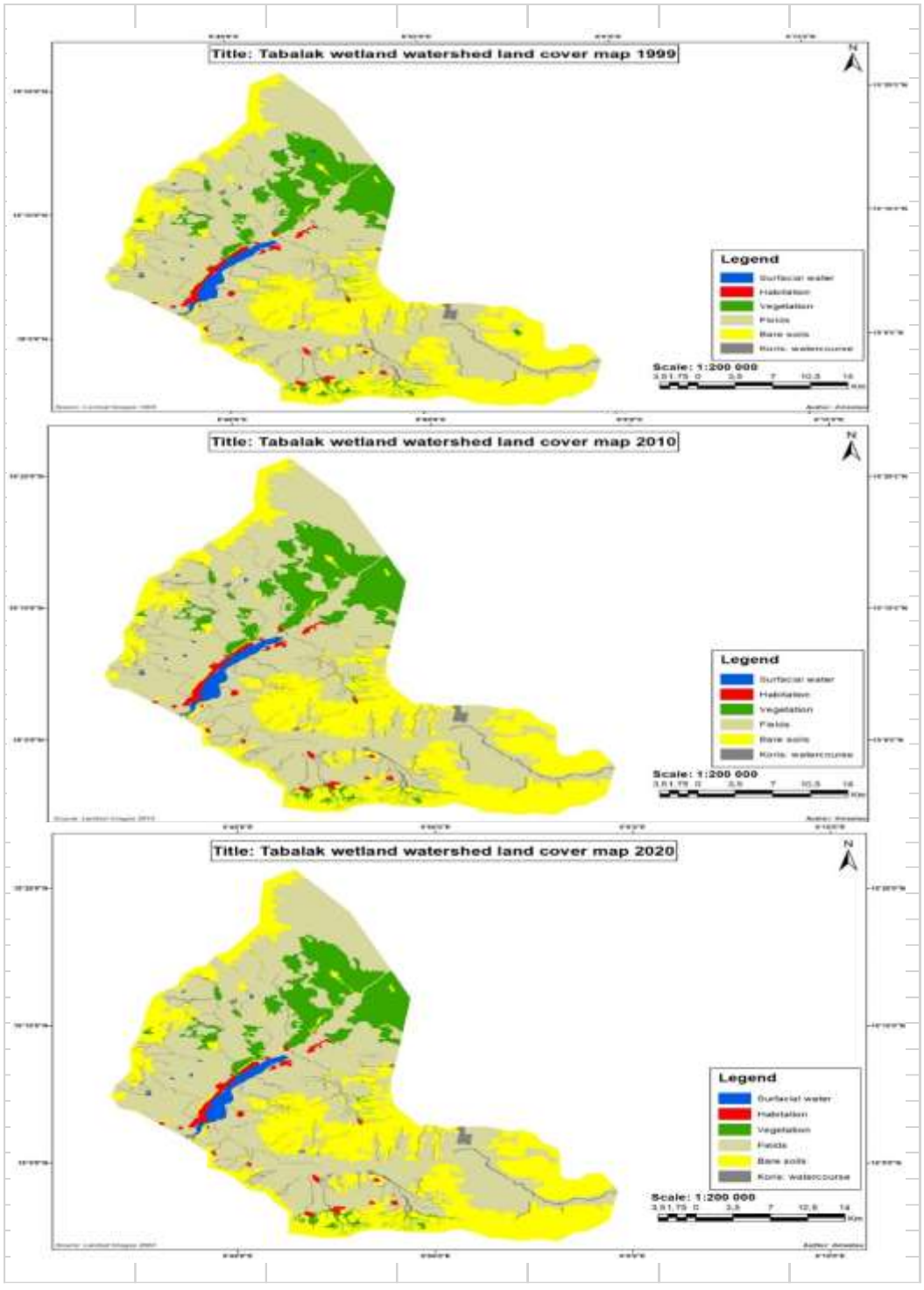


Figure 5: Comparison between land use/land cover maps in 1999; 2010 and 2020

The analysis of Figure 5 showed that all land use classes have remained almost unchanged over the three decades, this can be explained by the total occupation of pastoral areas (natural vegetation) by crops and sand dunes.

d) Tabalak Watershed Land Cover Statistical Change

The nature of conversion between land cover classes does not by itself explain the watershed dynamics. The land cover pattern is a determining factor in the evolution of the watershed configuration. It is therefore necessary to complete this analysis by focusing on the dynamics of each class. Tables 2 and 3 show the distribution of the Overall Change Rate (OCR) and Annual Change Rate (ACR) values by decade in the Tabalak watershed.

Table 2: Extent of overall change

Land Cover Units	Overall Change Rate (%)			
	1980-1990	1990-1999	1999-2010	2010-2020
Water	0,12	1,94	-2,1	0
Habitation	0,11	-0,11	0	0
Vegetation	-41,06	-78,87	2,24	0
Fields	12,35	12,2	0,19	-0,45
Bare soil	4,82	4,01	-0,98	0,99
Koris	0,1	-0,36	-0,64	-1,99

Source: calculated values, 2022

Table 3: Extent of annual change

	Annual Change Rate (%)			
Land Cover Units	1980-1990	1990-1999	1999-2010	2010-2020
Water	0,01	0,22	-0,22	0
Habitation	0,01	-0,01	0	0
Vegetation	-3,45	-6,46	0,21	0
Fields	1,32	1,44	0,02	0,24
Bare soil	0,49	0,46	-0,1	-0,55
Koris	0,01	-0,04	-0,06	0,11

Source: calculated values, 2022

The analysis of Table 2 shows that during the decade 1980-1990 the area of vegetation decreased by 41,06% while that of fields increased by 12,35 %.

The decade 1990-1999 is characterized by more decrease in the vegetation area 78, by 87 % (almost double the vegetation area lost in the first decade) this can be explained by the droughts of the years 1990, 1993, 1996, and 1997 that the watershed experienced.

Table 3 shows that the evolution of ACR values for the four decades follows quite clearly that of OCR. It is therefore necessary to check this evolution on the global angle by focusing on the cumulative values of the ACR (Figure 6) and, OCR (Figure 7) since they guarantee a greater visibility on the global trends in the watershed.

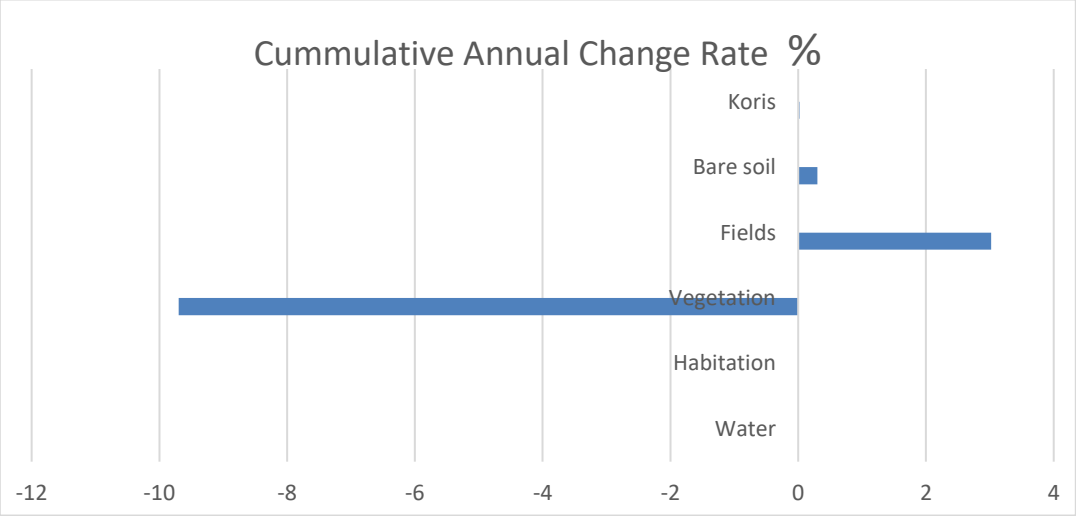


Figure 6 Cumulative ACR of land use units from 1980 to 2020

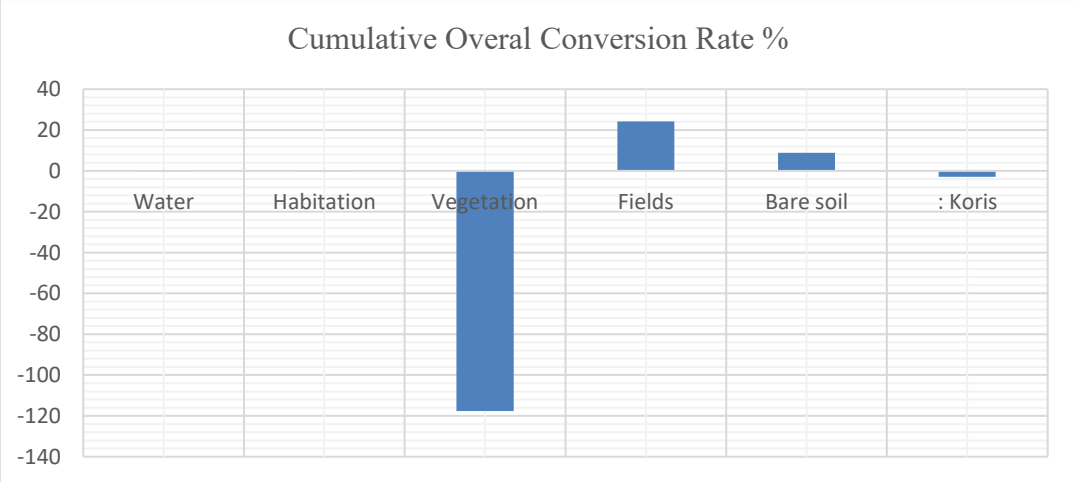


Figure 7: cumulative OCR of land use units from 1980 to 2020

The analysis of figures 6 and 7 shows that the area of vegetation decreased by 10 % per year while that of fields increased by 3 % per year.

Discussion

The analysis of, the overall and annual change rate showed an important decrease in vegetation cover from 1980 to 2020. From 1990 onwards, field areas appeared in the natural vegetation zone, which decreased from 25 % to 18 % of the total watershed area. From 1999 onwards, the dynamics adopted a relatively stable rate until 2020, the area of Fields which has increased from 42 % to 55 % of the total area has remained constant, as has the area of vegetation which has remained constant at 10 % of the total area. The decade 1990-1999 is characterized by more decrease in the vegetation area by 78.87 % (almost double of the vegetation area lost in the first decade). The analysis shows that the area of vegetation decreased by 10 % per year while that of fields increased by 3 %. Per year.

Conclusion

The Tabalak Lake is threatened by silting up due to the loss of vegetation cover in the watershed, which may eventually lead to its disappearance.

The land degradation analysis showed that the Tabalak watershed was in a considerably degraded state. From 1990 onwards, Fields areas appeared in the natural vegetation zone, which decreased almost double of area lost in the first decade (after 10 years). The Watershed restoration produces many economic, social, and environmental benefits. In the environmental field, it allows the conservation of 999 rations of water, soil, and biodiversity and helps people mitigate and adapt to climate change and variability.

Acknowledgments

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