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RESEARCH ARTICLE

DETECTION OF FOREST CHANGES BY REMOTE SENSING, NUMERIC CARTOGRAPHY AND TRANSITION MATRIX: CASE OF ZOUZOUNKAN IN THE TRANSITION ZONE BETWEEN THE CRYSTAL AND THE SEDIMENTARY IN BENIN

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ABSTRACT

Forest formations in Zounzounkan have undergone two major periods of their degradation. Anthropogenic pressures have contributed to 63, 26 % degradation of the forest cover between 1990 and 2000, while climate risks of erosion contributed to 16,68%. Between 2000 and 2010, major anthropogenic pressures are expressed by baresoil with a relative contribution of 31,65% to the degradation of forest cover, 19,14% for climate risks represented by erosion. From vegetation matrix transition, we notice that between 1990 and 2000, woodlands and wooded savannahs have been replaced by the tree and shrub savannah (37,98 %), grassland and saxicolous (20,41 %), the mosaics of crops and fallow (32,11 %), bare soil (3,85 %), wetlands (1,45 %), and soil altered by erosion (4,20 %). During this period, tree and shrub savannas were replaced by woodland and savanna woodlands (26,91 %), grassland and saxicolous (30,54 %), mosaics of crops and fallow (15,34%), bare soil (31,65%), wetlands (5.94 %) and soils altered by erosion (16,54 %). From 2000 to 2010, woodlands and woodlands have been replaced by the tree and shrub savannah (29,27 %), grassland and saxicolous (4,73 %), mosaics of crops and fallow (10,83%), bare soil (31,15 %), wetlands (7,34%), and soil altered by erosion (16,68 %). During this same period, tree and shrub savannas were replaced by woodland and savanna woodlands (16,10%), grassland and saxicolous (34,43%), mosaics of crops and fallow (16,64%), bare soil (18,80%), wetlands (10,98%) and soils altered by erosion (19,14%).

INTRODUCTION

DARWINestimated thatmatterevolves (DARWIN, cited by GOUX., 2008). Forest resources are not excluded. Zouzounkan massive has been investigated in this study. Vladimir Vernadsky, quoted by Yu NOVIKOV in "Environmental protection" think that the radical transformation of the biosphere is due by the noosphere, which is the sphere of human intelligence. This human intelligence will now stack to climate pressures. In Vertigo journal (2011), TERRIE & *al* argue that "climate change is in the heart of new concerns among forest managers" in their research synthesis. In front of the natural and anthropogenic vulnerability, it is necessary to intiate this study on Zouzounkan, which has been realised by fieldwork combined to land change detection in satellite imagery. According to the 2007 IPCC report (Inter Governmental Panel on Climate Change), "Climate change is beginning to affect natural environment and environment." This situation doesnot spare Zouzounkanwhich undergoes intensede formation of soil and climatic stress expressed by the significant presence of *Combretaceae*. To detect changes from satellite image, many methodological options were possible: photo interpretation, analysis of digital counts pixels (algebra images, statistical analysis of multitemporal compositions) or post-classificatory comparison (MAS., 2000). Finally, post-classificatory comparison method was chosen (MAS., 2000; INGLADA., 2001; ERWANN *et al*., 2007).

MATERIALS

The material used for this work are: software (Arcgis 10.1 Envi 5, PCL Geomatica, Excel, Word, and Qgis Idrisi Selva) and laptop HP 320 GB hard drive with 4GB Ram memory. The Global Positioning System (Garmin) has allowed to identify of control points. Landsat TM (Thematic Mapper) and ETM+ (Enhance Thematic Mapper) scenes from path 192, row 55 were downloaded from the website of the United State Geological Survey (USGS):www.earthexplorer.usgs.gov and the Global Land Cover Facility (GLCF) on http://glcf.umd.edu/.

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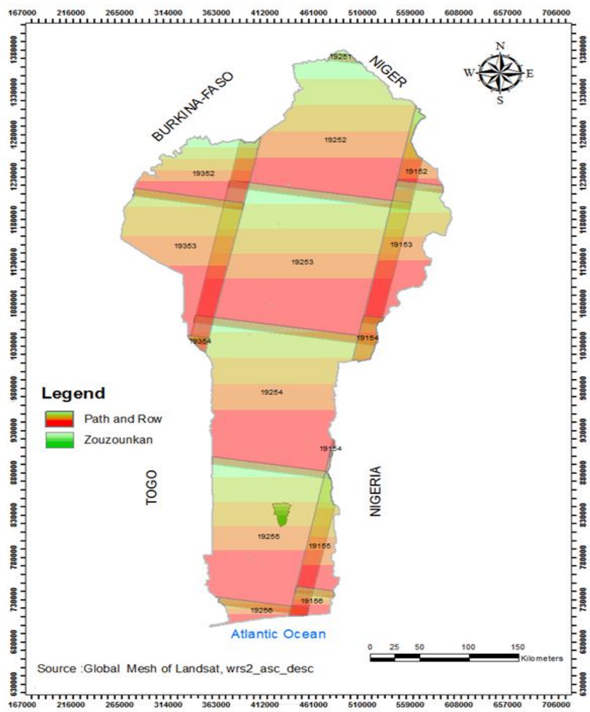

Figure 1. ZOUZOUNKAN location in the LandsatScenes of Benin

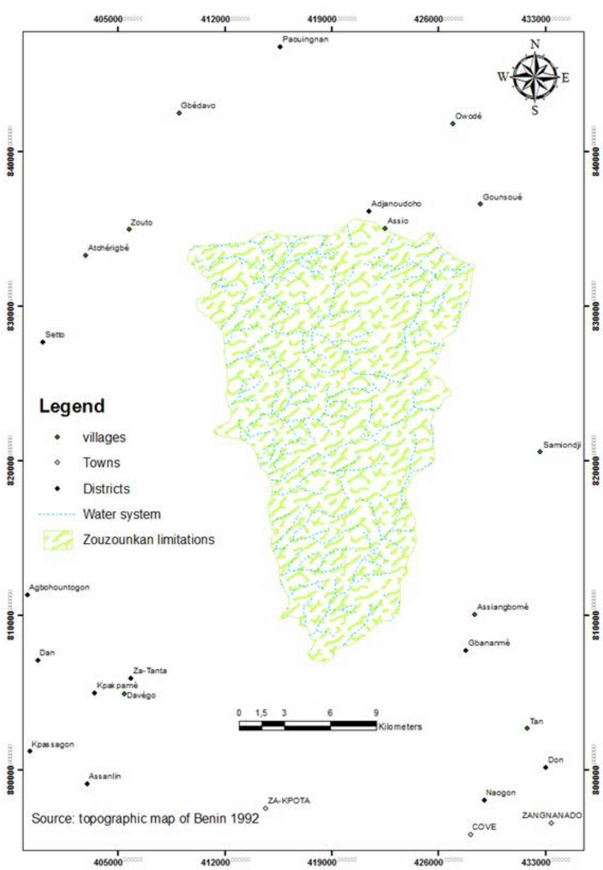

Figure 2. Location of Zouzounkan massive Forest in Benin

METHODS

GPS points whish were used to identify pixels corresponding to the classes were collected in the field, and were then projected into an image treated in infrared composite 7-4-2. The spectral response of units occupation are recorded and used in the maximum likelihood classification. This allowed the one hand a more realistic identification of class and others limiting errors confusion class. Then it is carried on the images in Envi 5, change detection and thematic change detection. After this procedure, Dbf files obtained are processed in Excel for subsequent analysis for a summary of test results. The landscape are seen as a set of pixels, each of which can be classified in a class of landscape. Each pixel can change state during the study period (1990-2010) following specific transitional rules. The transition matrix is used to describe a condensed manner, pixels changes states in a given period (SCHLAEPFE., 2002). It was used to construct a probability matrix that contains the observed transitions (URBAN & WALLIN., 2002).

RESULTS

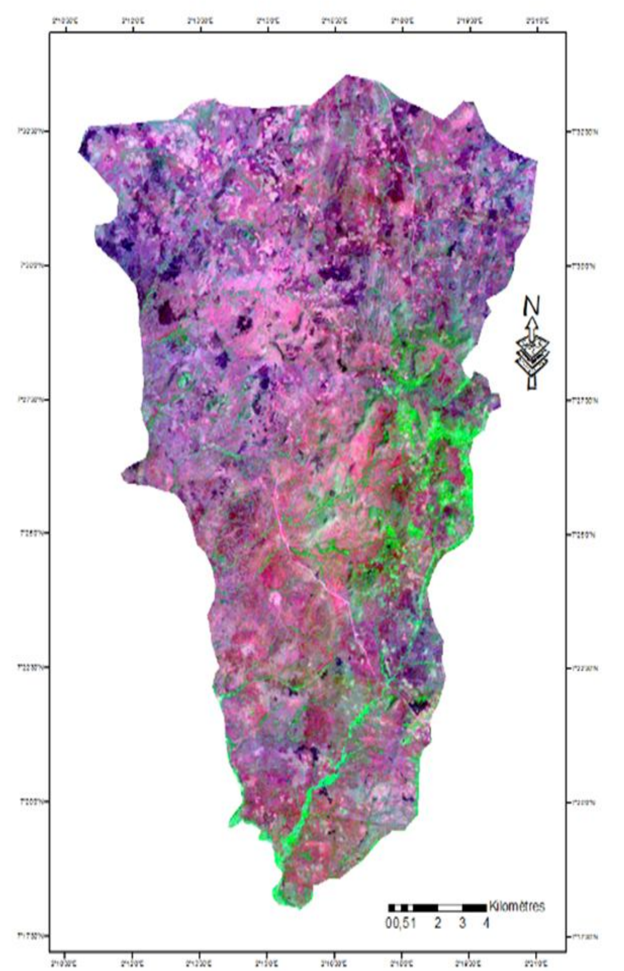

Figure 3. Satellite image processed in combination 7-4-2, 1990 Massif Zouzounkan

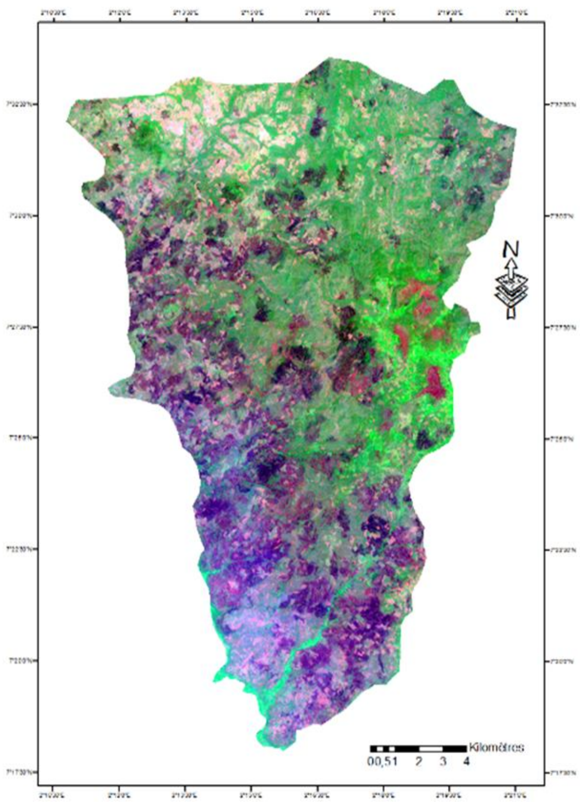

Figure 4. Satellite image processed in combination 7-4-2, 2000 Massif Zouzounkan

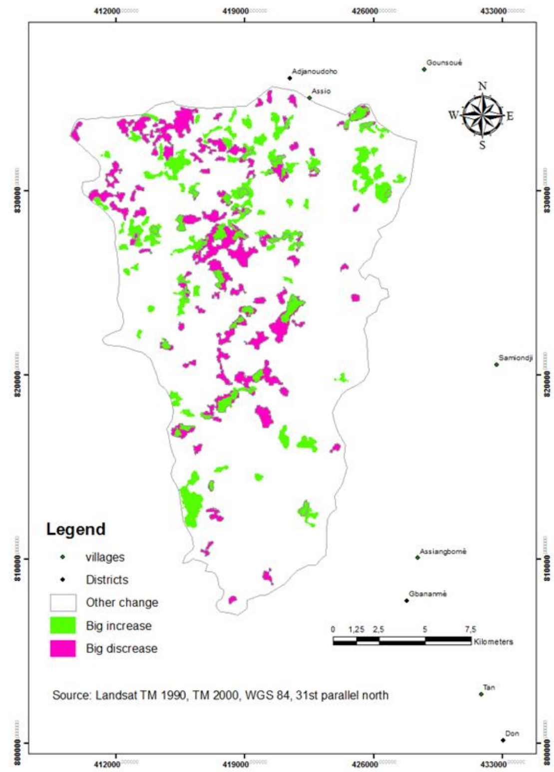

Figure 6. Spatial distribution of major detected changes in land use at Zouzounkanfrom 1990 to 2000

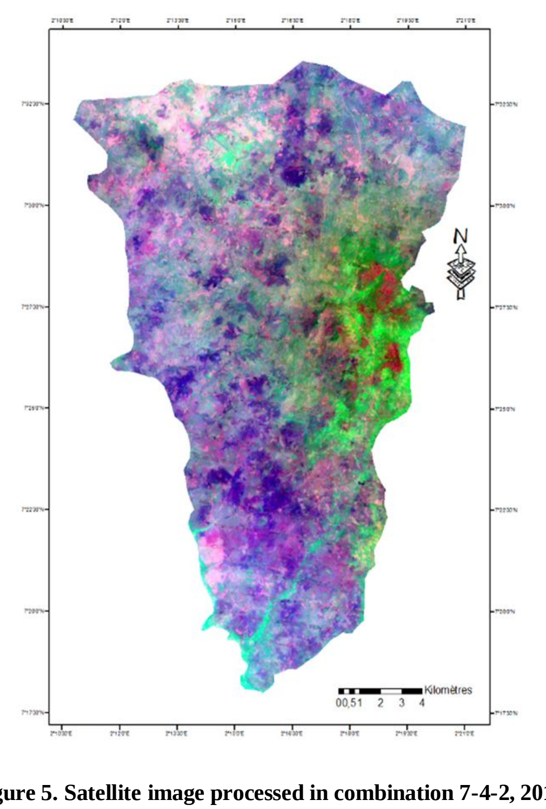

Figure 5. Satellite image processed in combination 7-4-2, 2010 Massif Zouzounkan

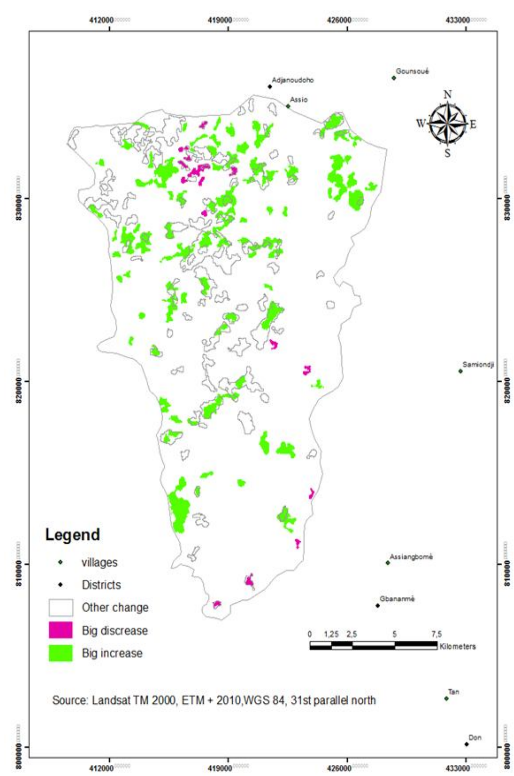

Figure 7. Spatial distribution of major detected changes in land use at Zouzounkanfrom 2000 to 2010

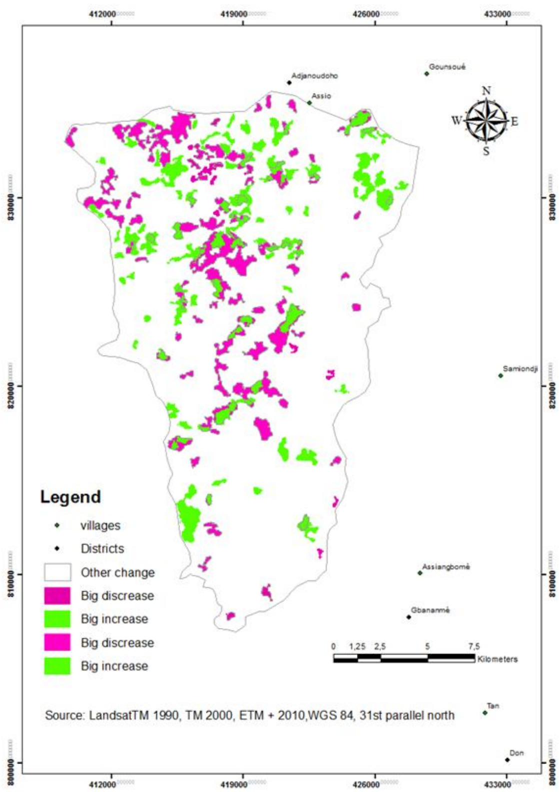

Figure 8. Spatial distribution of major detected changes in land use atZouzounkanfrom 1990 to 2010

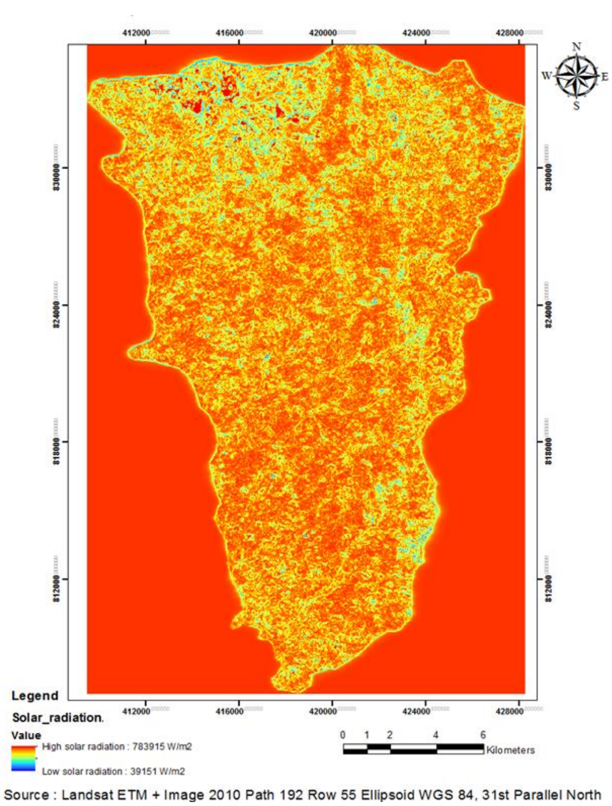

Figure 9. Spatial distribution of solar radiation in Zouzounkan massive forest

DISCUSSION

Major changes in Zouzounkan land cover have occurred mainly in the period 1990-2000. The areas between Samiondji and Assio latitude are the most vulnerable to these changes as spatial distribution maps of the detected changes. The center of this area is the most affected and mostly by regressive changes. Fieldwork confirmed that these changes are real and are related to soil degradation (erosion, and human activities), and the vegetation cover. By cons, from 2000 to 2010, minor regressive changes are observed between the South and Gbanamé Assiangbomè the center in the latitude of Samiondji farm, and Southwest at Assio. The sunshine made map reveals that all vulnerable sites regressive changes is under the control of a gradient of high insolation, and an unequal distribution of radiation. It arises in this regard the issue of unequal spatial distribution of the radiation balance along the massif Zouzounkan. 25,28 % of the changes in terms of growth in the occupation are observed from 1990 to 2000 and 74,72 % from 2000 to 2010. By cons, 91,19 % regressive changes are observed at Zouzounkan from 1990 to 2000, and 8,81% from 2000 to 2010.

In the vegetation transition matrix, we notice that from 1990 to 2000, woodlands and wooded savannahs have been replaced by the tree and shrub savannah (37,98 %), grassland and saxicolous (20,41 %), the mosaics of crops and fallow (32,11 %), bare soil (3,85 %), wetlands (1,45 %), and altered soil erosion (4,20 %). During this same period, tree and shrub savannas are replaced by woodland and woodlands savannah (26,91 %), grassland and saxicolous (30,54 %), mosaics of crops and fallow (15,34%), bare soil (31,65%), wetlands (5,94 %) and soil altered by erosion (16,54 %).

From 2000 to 2010, woodlands have been replaced by the tree and shrub savannah (29,27 %), grassland and saxicolous (4,73 %), mosaics of crops and fallow (10,83%), bare soil (31,15 %), wetlands (7,34%), and soil altered by erosion (16,68 %). During this same period, tree and shrub savannas are replaced by woodland and savanna woodlands (16,10%), grassland and saxicolous (34,43 %), mosaics of crops and fallow (16,64 %), bare soil (18,80%), wetlands (10,98%) and soils altered by erosion (19,14%).

From this analysis it appears that Zounzounkan massive forest formations have undergone two major periods of their degradation. Woodlands and wooded savannahs were mostly destroyed between 1990 and 2000 to be largely replaced by mosaics of crops and fallow (32,11%), bare soil (31,15%), grassland and saxicolous (20, 41%), and soil altered by erosion (16,68 %). Meanwhile, tree and shrub savannas are replaced mainly by grassland and saxicolous (34,43%) and mosaics of crops and fallow (16,64%) between 1990 and 2000, followed by bare soil (31,65%) and soils altered by erosion (19,14%) between 2000 and 2010. Anthropogenic pressures and contributed to 63,26 % of Zouzounkan massive forest cover degradation between 1990 and 2000, while the climate risks of erosion contributed to 16,68%. From 2000 to 2010, the major anthropogenic pressures are expressed by soil alteration with a relative contribution of 31,65% to the degradation of forest cover against 19,14% for climate risks posed by erosion at 19,14%.

Table 1. Spatial changes in the morphology of Zouzounkan massive forestfrom 1990-2010

Type of changes Years	Increase (m^2)	Discrease(m^2)	Other changes (m^2)	Total (m^2)
1990 à 2000	9265961	21355165	9265961	39887087
2000 à 2010	27393919	2063901	27393919	56851739
Total	36659880	23419066	36659880	96738826
% 1990 à 2000	25,28	91,19	25,28	
% 2000 à 2010	74,72	8,81	74,72	
% Total	100	100	100	

Table 2. Transition matrix of vegetation areas based on occupancyunits in the forest of Zouzounkanfrom 1990 to 2000

2000 1990	Woodland and savannawoodland(m^2)	Savannatree and shrub(m^2)	Grassy savannah (m^2)	Mosaics of crops and fallow(m^2)	Floorbare (m^2)	Wetlands (m^2)	Flooraltered by erosion (m^2)	Total (m^2)
Woodland and savanna Woodland(m^2)		20710084	11131029	17508904	2101688	788133	2290624	54530462
Savannatree and shrub(m^2)	12090104		13717653	6891665	14216984	2669396	7429683	44925381
Grassysavannah (m^2)	15556630	9940732		5890305	10478750	2441773	20641707	49393267

Table 3. Transition matrix of plant training areas based on occupancyunits in the forest of Zouzounkanfrom 2000 to 2010

2010 2000	Woodland and savannawoodland(m^2)	Savannatree and shrub(m^2)	Grassysavannah (m^2)	Mosaics of crops and fallow(m^2)	Floorbare (m^2)	Wetlands(m^2)	Flooraltered by erosion (m^2)	Total (m^2)
Woodland and savannawoodland(m^2)		18207132	2944703	6733319	19374036	4564154	10371686	62195030
Savannatree and shrub(m^2)	7644710		16353760	7902923	8930375	5213734	9093219	47494011
Grassysavannah (m^2)	7725683	23469449		4600142	10584014	702662	7077002	46433269

Table 4. Transition matrix of area percentages of vegetationdepending on occupancyunits in the forest of Zouzounkanfrom 1990 to 2000

2000 1990	Woodland and savannawoodland (%)	Savannatree and shrub(%)	Grassysavannah (%)	Mosaics of crops and fallow (%)	Floorbare (%)	Wetlands (%)	Flooraltered by erosion (%)	Total
Woodland and savannawoodland (%)		37,98	20,41	32,11	3,85	1,45	4,20	100
Savannatree and shrub (%)	26,91		30,54	15,34	31,65	5,94	16,54	100
Grassysavannah (%)	31,50	20,13		11,93	21,21	4,94	41,79	100

Table 5. Transition matrix of area percentages of vegetationdepending on occupancyunits in the forest of Zouzounkanfrom 2000 to 2010

2010 2000	Woodland and savannawoodland(%)	Savannatree and shrub(%)	Grassysavannah (%)	Mosaics of crops and fallow (%)	Floorbare (%)	Wetlands (%)	Flooraltered by erosion (%)	Total (%)
Woodland and savannawoodland(%)		29,27	4,73	10,83	31,15	7,34	16,68	100
Savannatree and shrub(%)	16,10		34,43	16,64	18,80	10,98	19,14	100
Grassysavannah (%)	16,64	50,54		9,91	22,80	1,51	15,24	100

Conclusion

Zouzounkan massive forest is in the vulnerability of a very significant anthropogenic pressure (63.26 % between 1990 and 2000, and 31,65% between 2000 and 2010). Erosion is the major natural hazard diagnosed at Zouzounkan. Policies and appropriate measures should be instituted to preserve forest ecosystem housed in this massive for a durability of its animal biodiversity (warthogs and others), and plants. Fieldwork in the investigations revealed an intense soil degradation by erosion, and intense and uncontrolled deforestation for purposes of pensions (charcoal, and marketing of species). The significant presence of species of the family Combretaceae, confirm a forest sahelisation. The visual expression of B horizon in surface layer, with a hardened ferralitic ground is a risk of water infiltration and root deficit. Adaptation measures, seasonal planting, and forestry uses regulation are needed with a real management.

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