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Land Cover/Use Dynamics and Vegetation Characteristics in the Rural District of Simiri (Tillabery Region, Niger)

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1. Introduction

Niger is a landlocked country with an economy largely dependent on the rural sector (Anonymous, 2004). In recent decades this country faced natural resources degradation especially in the Sahelian agro-ecological zones. Climatic and anthropogenic factors were the main causes of this degradation. The western part of the country, including the regions of Dosso and Tillabery (departments of Ouallam, Tillabery and Filingué) belongs largely to the Sahelian zone characterized by difficult climatic conditions (low rainfall, high temperatures, etc.). In this area, overexploitation of cultivated land and other natural resources resulted in serious environmental issues including loss of biodiversity. The pressure on agricultural soils and marginal lands was increasing due to high population growth rate. The remaining areas covered by trees or shrubs were improperly used for agricultural purposes or for domestic energy or for building shelters.

In this area the observatory network ROSELT (ROSELT / OSS, 2004) has set up an observatory called "Tahoua North Tillabéry Observatory" which included the rural commune of Simiri (Department of Ouallam). This Commune is characterized by recurrent droughts episodes with serious consequences on natural resources, the main sources of livelihood for the local population. Indeed, agriculture and animal husbandry are the main activities of the population, often leading to increased wood cut and overgrazing, adding pressure on the limited available natural resources. Measures to reverse trends are therefore needed for environmental protection and restoration as well as to ensure an ecological balance for a sustainable development in that region. However these measures require reliable information on the resources available in the commune. This study was devoted to analysis land cover/use dynamics in the commune of Simiri between 1975 and 2006 and characterize the vegetation to help for decision making on the use of these resources.

2. Material and methods

2.1 Experimental site

The rural municipality of Simiri is located in the Department of Ouallam (Tillaberi). The county town of the Commune is Simiri (14 ° 08'N and 02 ° 08E), located 70 km north of Niamey, Niger's capital. The Municipality covers an area of 2233 km ². It is bounded on the north by the urban municipality of Ouallam, south by the rural municipalities of Hamdallaye, Karma, on the east by the municipalities of Dingazi, Tondi Kandia and, on the west by the rural town of Kurthèye.

The climate is arid (Mahamane et al., 2005) with annual rainfall below 500 mm. The town is located in the western Iullimeden Basin that consists mainly of formations of tertiary Continental Terminal (Ct). Ct is a set of plateaus and hills occasionally separated by valleys. In some places, the valleys host permanent ponds. The altitude varies between 200 and 350 m on average. The south and east of the Commune were covered by dunes and constitute a serious threat for the moist valleys. The soils are of leached tropical ferruginous type.

In terms of phytogeography, Simiri is located in the South Western Sahel compartment (Saadou, 1990), characterized by:

- A substrate formed by sediments of the Continental Terminal (CT3) on lateritic plateaus, fixed sand dunes and sandy terraces occupying the bottom of dry valleys;
- South-Sahelian climate with a rainfall index ranging between 400 and 600 mm, a relative humidity between 20% (February) and 73.5% (August), a mean minimum temperature of 24 ° 35 (January) and mean maximum temperature of 33 ° 64 (April) and a thermal amplitude of 9° 29;
- A vegetation consisting of *Combretum* thickets on lateritic plateaus and steppes on sandy terraces in the dry valleys and on the fixed dunes.

The flora was composed of the following species: *Guiera senegalensis* G. F. Gmel., *Commiphora africana* (A.Rich.) Engl., *Combretum micranthum* G. Don, *Acacia macrostachya* Reich. ex Benth., *Lannea acida* A. Rich., *Croton gratissimus* Buch., *Acacia ataxacantha* DC., *Combretum nigricans* var elliotii (Engl. Ex Diels) Aubrev., *Boscia senegalensis* (Pers.) Lam. Ex Poir., *Boscia angustifolia* A. Rich. on lateritic plateaus and *Hyphaene thebaica* (L.) Mart., *Bauhinia rufescens* Lam., *Annona senegalensis* Pers., *Combretum glutinosum* Perr. ex DC. et *Acacia albida* Del. in the dry valleys. Millet, sorghum and cowpeas were the food crops used in that area.

The municipality of Simiri had 95,727 inhabitants (2005/2006) living in 74 villages. The average density was 43 inhabitants / km². The growth rate of this population was about 3.2% leading to high pressure on natural resources because of an increasing demand for agriculture.

2.2 Mapping methods

The map was developed based on two satellite images: Landsat MSS (Multi Spectral Scanner) 1975 and Landsat TM (Thematic Mapper) 2006 of the studied area and from the IGNN database. UTM coordinates were recorded using a GPS. Data processing was done using softwares for image processing Arcview and Env. 4.2 and Excel.

High resolution Landsat images (30 m x 30 m) covering an area of 500 km^2 were used to extract the study area which covered 2233 km^2 using the satellite imagery processing software ENVI 4.2.

The geographic coordinates of selected points, chosen in the different defined units, were loaded onto a CX Garmin GPS receiver to facilitate their identification. At each of these points, observations were recorded using forms established for this purpose. The coordinates were then used on the satellite images to generate thematic maps including that of land use with the software ArcView 3.2 ArcView GIS 3.2 (Environmental System Research Institute, Inc. 1992-1999).

A table of attributes associated with each class of land cover unit was generated with Arcview, using a stratification of the different land cover units. Assisted classification was used for the digitization of images which were divided into homogeneous zones on the basis of the classification of land cover commonly used as reference for land use mapping. This was followed by a check using field data to make corrections wherever needed on the map.

2.3 Data collection

Data were collected in three units of land occupation: tiger bush, degraded fallow and cultivated lands (ROSELT, Saadou, 2005). Floristic surveys were conducted in plots of 1000 m^2 (20 m * 50 m). In each plot, a complete census of the species was made using a survey form on which was indicated the presence of each species found in the plot. The collected data were then gathered in an absence-presence table of species.

These data were used to determine:

- Systematic diversity including the number of species (or species richness), genus and families;
- Biological types identified according to the classification of Raunkiaer (1916), adapted to Trochain (1966, *In* Saadou, 1984) that was used by several authors in tropical Africa (Saadou, 1984 , 1990; Mahamane, 2005; Oumorou, 2000).
- Phytogeographical types
- Shannon-Weaver diversity index (α) that provides information on the diversity of species in a community and gives an indication on the relationships between species within the community. It is calculated using species richness of plant groups:

$$H' = \sum_{i=1}^{s} pi \log 2pi$$

With Pi= ni/S; ni: frequency of the species i in the group and S: total number of species

- Equitability index of Piélou:

$$E = H' / \log(S)$$

- Diversity β based on floristic communities: index (or coefficient) of Sorensen:

$$K = 2\,C/(A + B)$$

with A = number of species on list a;
B = number of species on list b;
C = number of species common to list a and b.

The collected data were analyzed using Detrended Correspondence Analysis (P. Legendre and Legendre L., 1999) with PC-Ord 5 (McCune and Mefford, 2006) software.

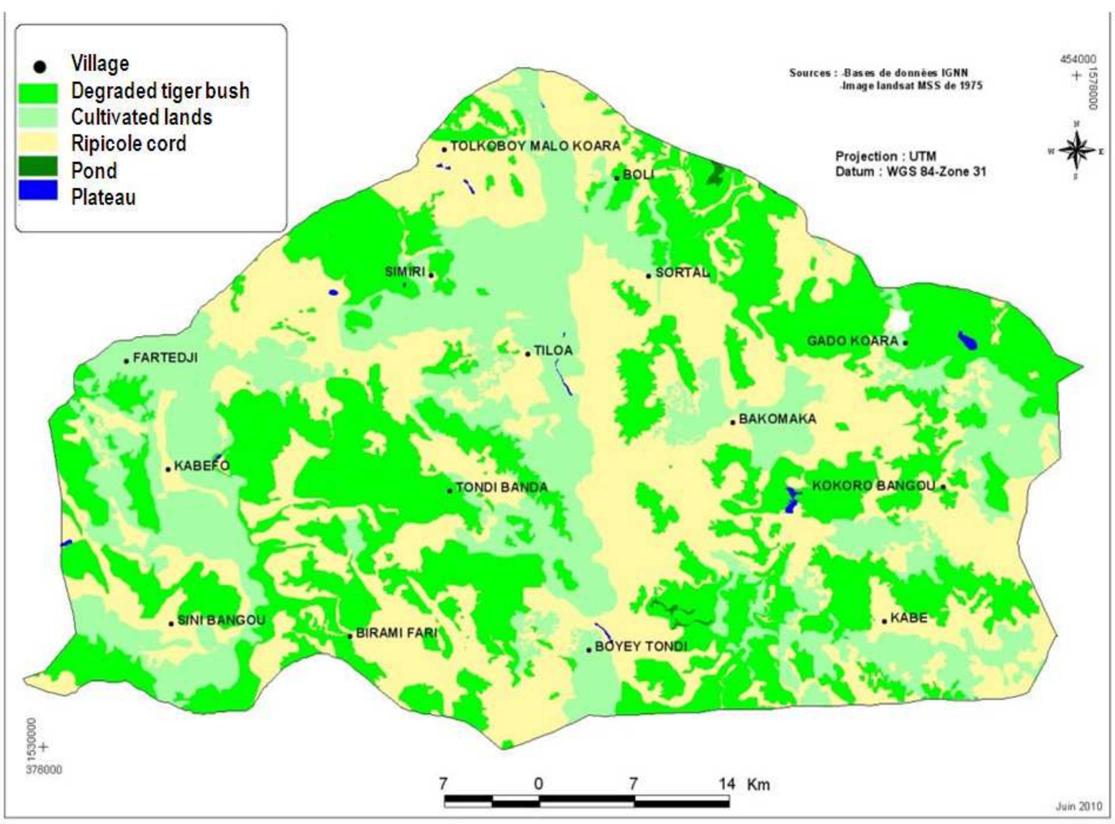
3. Results

3.1 Dynamics of land cover/use

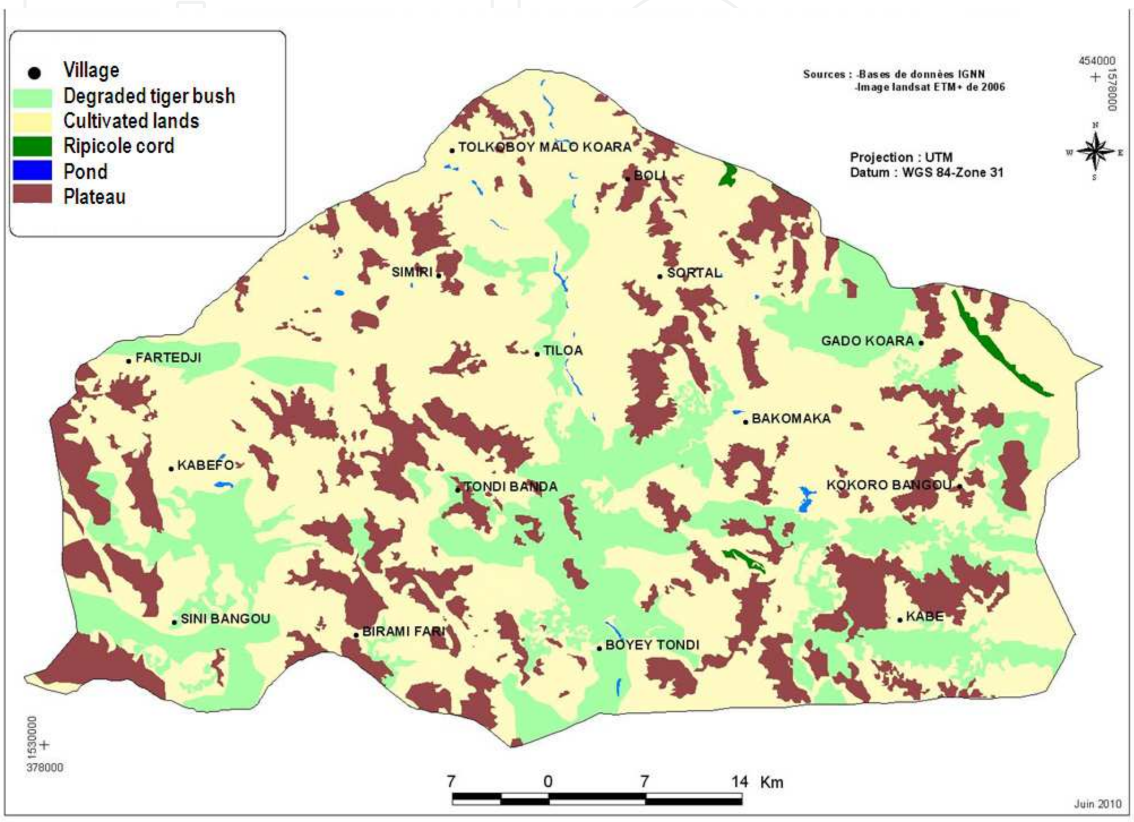
Four maps were developed; two on land cover/use in 1975 and 2006 and two on the status of the tiger bush in 1975 and 2006.

Land cover units in 1975

The distribution of tiger bush, cultivated areas, riparian cords and ponds are shown in Fig. 1a. The tiger bush consisted of a regular tiger bush and a degraded tiger bush. The regular tiger bush is a well-structured unit consisting of wooded and denuded strips (Ambouta, 1997). It covered an area of 90.373 hectares or 34.06% of the total area of the Commune. The degraded tiger bush derived from the regular tiger bush, with degraded structure as a consequence of anthropogenic and climatic effects. It covered an area of 68.738 hectares or 25.91% of the total area of the municipality.



(a)



(b)

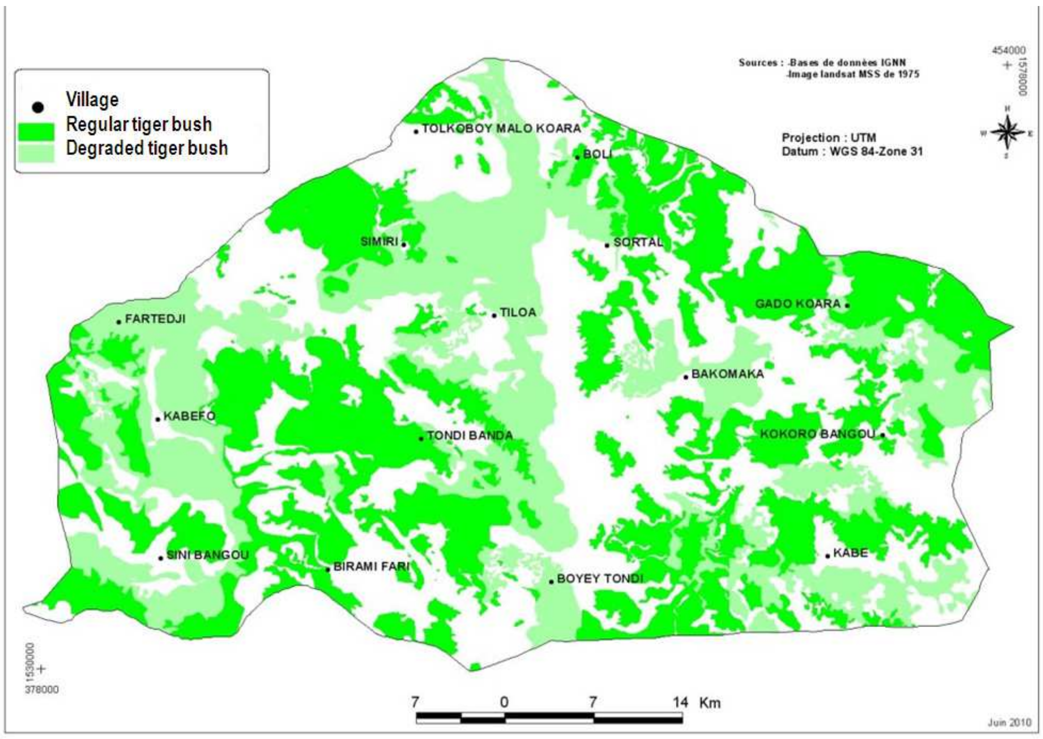
Fig. 1. Land cover in (a) 1975 and (b) 2006.

Regarding rainfed cultivated areas they were located on dunes, sandy skirts and lowlands and covered 105.700 hectares or 39.84% of the area of the municipality. Riparian Cords and ponds represented respectively 0.06 and 0.11% of the Commune area.

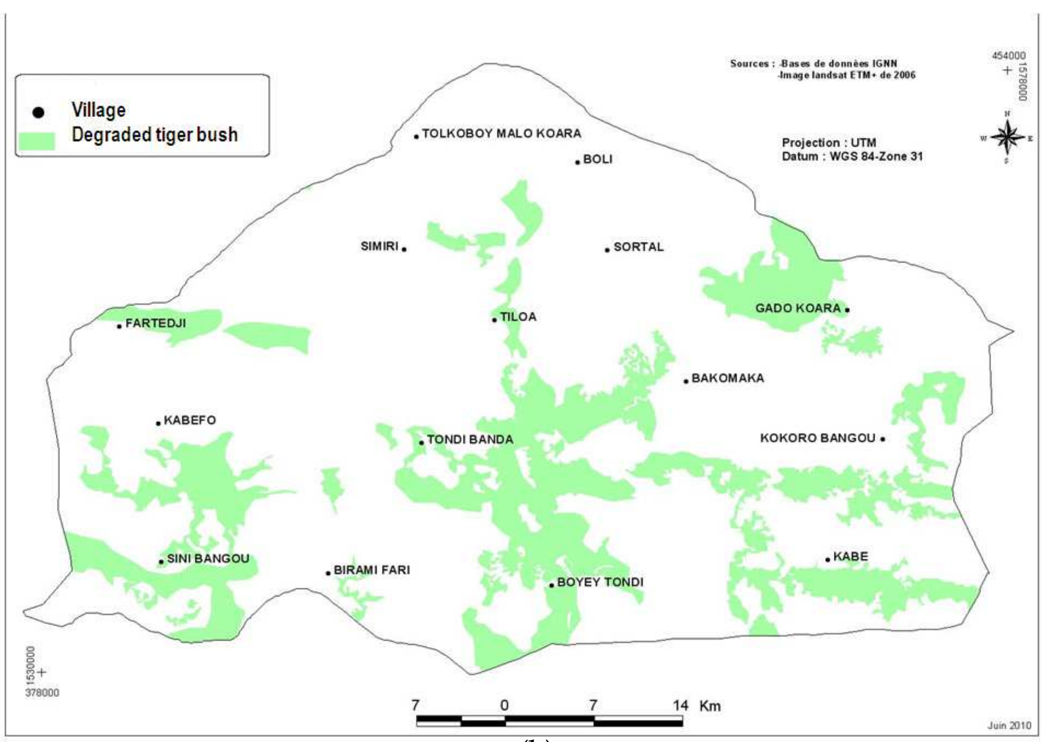
Land cover units in 2006

In 2006, the land cover units were the degraded tiger bush, rainfed cultivated lands, ripicole cords and ponds Fig. 1b. The regular tiger bush disappeared completely. The degraded tiger bush covered 55.691 ha or 20.99% of the total land cover units. Compared to its surface in 1975, there was a reduction of 13.07%. Rainfed cultivated lands accounted for 59.64% of the total area of the municipality. This corresponded to an increase of 19.79% compared to 1975. Riparian cords covered 807 ha representing 0.30% of the total area of land cover units with a slight increase of 0.24% compared to 1975. By contrast, the surface covered by Ponds did not show any significant change between 1975 and 2006.

On the other hand, the plateau appeared in 2006 and consisted of bare soil. This unit covered 18.97% of the Commune. It was located on the lateritic plateau where the tiger bush was replaced by bare soil due to vegetation loss and soil erosion.



(a)



(b)

Fig. 2. Tiger bush status in (a) 1975 and (b) in 2006.

3.2 Dynamics of land cover between 1975 and 2006

The diachronic analysis of land cover units between 1975 and 2006 showed spatial changes in the unit types (Fig. 2 & 3). The regular tiger bush and the degraded tiger bush were both present in 1975. But due to human pressure and drought events (1973 and 1984), the regular tiger bush was completely transformed into a degraded tiger bush Fig. 2. In addition, the area covered by the degraded tiger bush was significantly reduced and in some places replaced by denuded soil.

Cultivated lands were extended as a consequence of both the increase of population and soil degradation. The surface of riparian cords was increased while that of ponds decreased.

Riparian cords covered a larger surface in 2006 than 1975, probably due to important runoff following the destruction of mainly the vegetation of plateaus where drainage into the lowland by several "koris" occured.

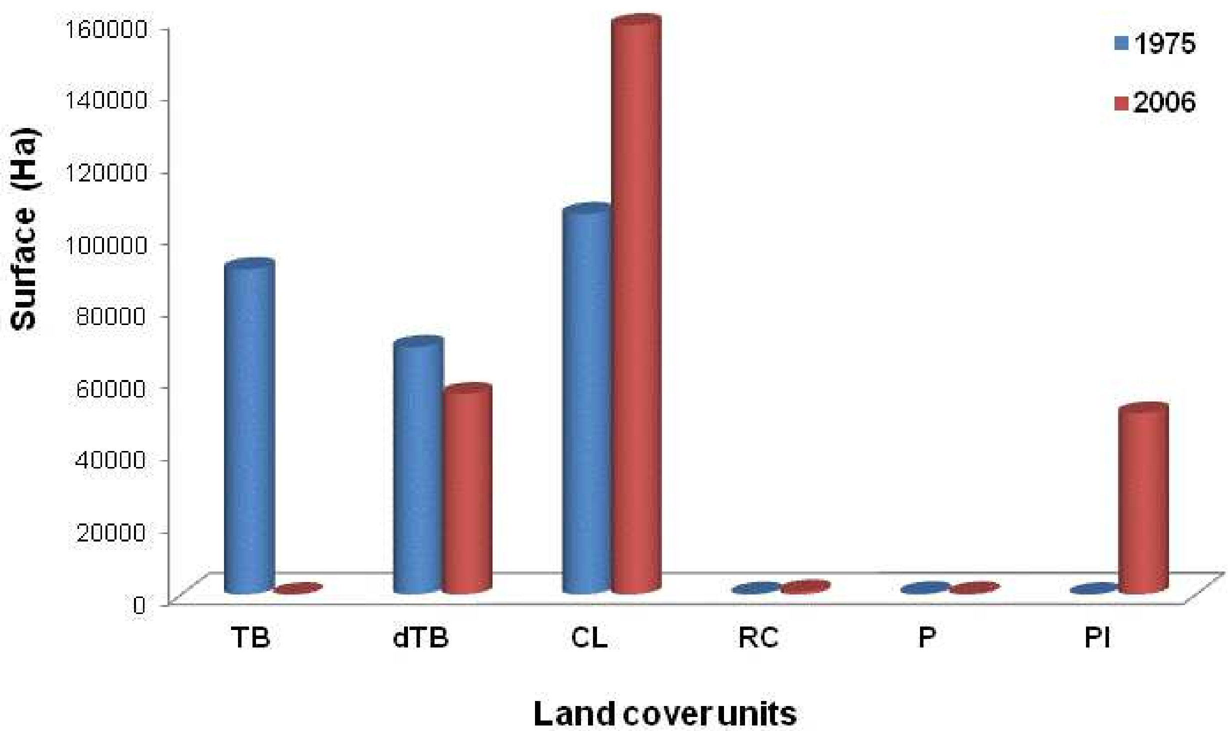


Fig. 3. Evolution of land cover units between 1975 and 2006.
TB: tiger bush; dTB: degraded tiger bush; RP: riparian cord; CL: cultivated lands; P: pond, Pl: denuded plateaus.

3.3 Characteristics of vegetation

Data ordination

A matrix of 38 records associated with 103 species was subjected to detrended correspondence analysis, which pointed out four groups (Fig. 4). Axis 1 contrasted group GI (consisting mainly of records associated with the rainfed agricultural lands) and GII (consisting of records relating to fallows). Axis 1 was therefore a gradient of land use or anthropogenic impact. From a geomorphological point of view these records concerned the sandy skirt, one of the three geomorphological units in Western Niger (Courault et al., 1996).

The axis 2 contrasted groups GIII and GIV. GIII was composed of records located on the sandy skirt while GIV was composed of those on lateritic plateau, an area of the tiger bush (Ambouta, 1984). Axis 2 was therefore a topographic gradient.

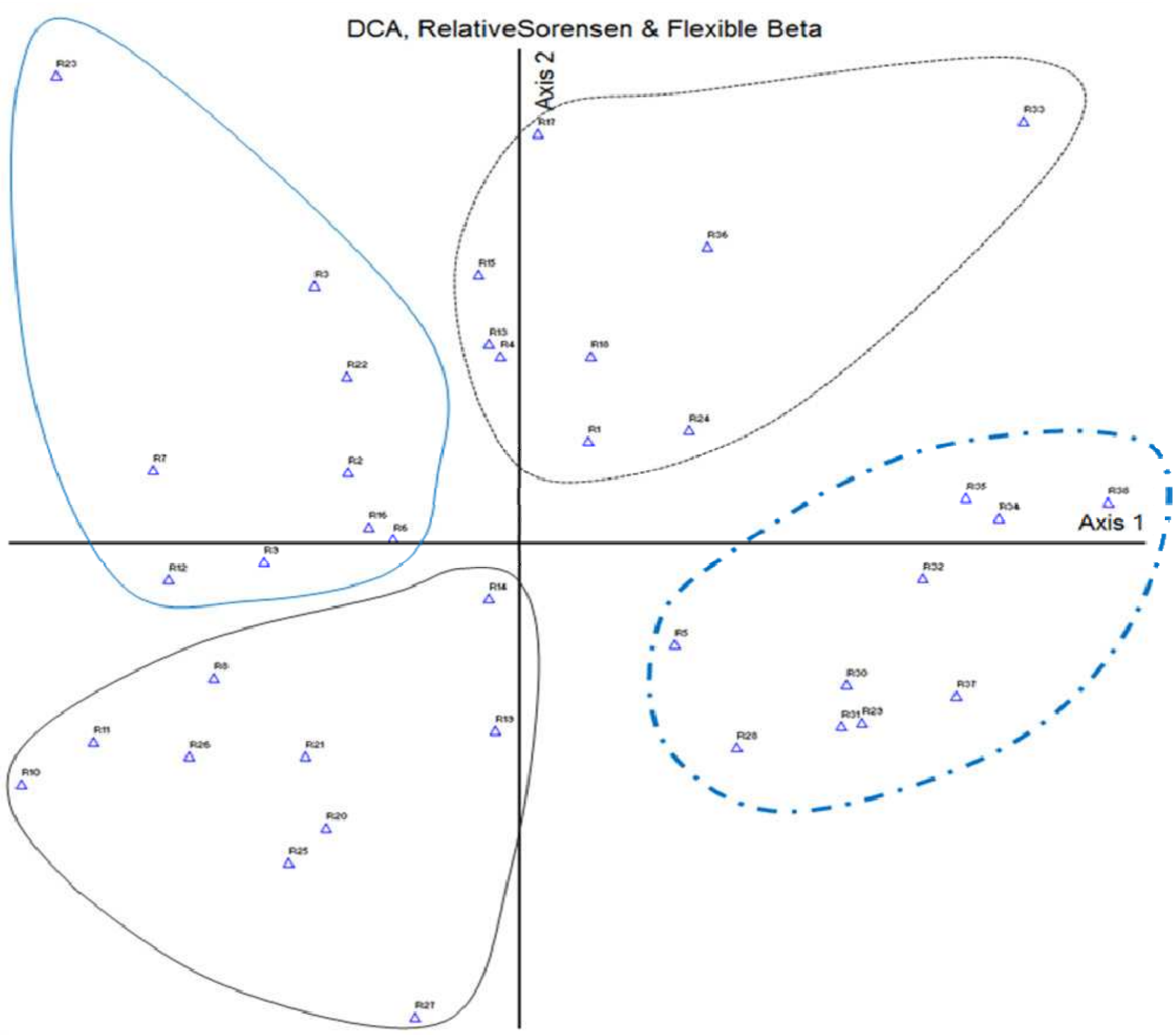


Fig. 4. Detrended Correspondence Analysis (DCA) diagram (axis 1 and 2).

Systematic diversity

In total 113 species were recorded. They were divided into 73 gender and 28 families. The most represented family was Poaceae with 24 species (21.24%) followed by Fabaceae with 18 species (15.93%). The least represented family had a single species (0.88%) (Table 1).

Family	Nb of species	%
Poaceae	24	21,24
Fabaceae	18	15,93
Convolulaceae	8	7,08
Combretaceae	6	5,31
Mimosaceae	7	6,19
Amaranthaceae	5	4,42
Cucurbitaceae	4	3,54
Rubiaceae	4	3,54
Acanthaceae	3	2,65
Caesalpiniaceae	3	2,65
Capparaceae	3	2,65
Commelinaceae	1	0,88
Caryophyllaceae	3	2,65
Cyperaceae	3	2,65
Euphorbiaceae	3	2,65
Malvaceae	3	2,65
Pedaliaceae	2	1,77
Sterculiaceae	2	1,77
Tiliaceae	2	1,77
Annonaceae	1	0,88
Araceae	1	0,88
Asclepiadaceae	1	0,88
Asteraceae	1	0,88
Balanitaceae	1	0,88
Lamiaceae	1	0,88
Molluginacae	1	0,88
Rhamnaceae	1	0,88
Schrophulariaceae	1	0,88
Total	113	100,00

Table 1. Repartition of species per family.

Biological types

The flora of all the studied stations was dominated by Therophytes. The dominance ranged from 52.94% (GII) to 70.15% (GI). They were followed by microphanerophytes regardless of station. The latter had the highest rate in fallow (20%) and lowest in the cultivated areas (11.94%).

Phytogeographical types

The distribution of plant species or phytogeography is presented in Table 2. Species of Guineo-Congolian-Sudano-Zambezian (29.17% to 35.82%) and the Sudano-Zambezian

(26.47 to 37.80%) distribution were dominant regardless of the station. However, those with Sudano-Zambezian distribution were absent on plateaus. These two phytogeographical types were followed by Guineo-Congolian-Sudano-Zambezian-Sudano-Zambezian-Saharo-Sindian and Sudano-Zambezian-Saharo-Sindian types in the first three stations. By contrast, on plateaus introduced species were dominant (31.25%). This was due to restoration activities carried out in that area.

	Biological types (%)									
Stations	CH	H	**Hé**	**Hy**	**LCH**	**Lmp**	LT	mp	**np**	T
GI (Cultivated lands)	2,99	2,99	-	-	-	-	7,46	11,94	4,48	70,15
GII (Fallows)	2,94	4,41	1,47	2,94	1,47	1,47	8,82	20,59	2,94	52,94
GIII (Sandy skirt)	2,44	3,66	1,22	-	2,44	-	9,76	12,20	3,66	64,63
GIV (Plateaus)	4,17	6,25	-	-	-	-	8,33	14,58	6,25	60,42

CH: Chamephytes, H : Hemicryptophytes, Hy : Hydrophytes, LCH : Liana chamephytes, Lmp : Liana microphanerophytes, LT : Liana Therophytes, mp : Microphanerophytes, np : Nanophanerophytes , T: Therophytes.

Table 2. Distribution of biological types (%).

	Phytogeographical types (%)				
Stations	GC-SZ	GC-SZ-Sah.S	i	SZ	SZ-Sah.S
GI (Cultivated lands)	35.82	11.94	1.49	35.82	14.93
GII (Fallows)	32.35	20.59	1.47	26.47	19.12
GIII (Sandy skirt)	30.49	17.07	-	37.80	14.63
GIV (plateaus)	29.17	20.83	31.25	-	18.75

GC-SZ: Guineo-congolese-soudano-zambesian ; GC-SZ-Sah.S : Guineo-congolese-soudano-zambezian-saharo-sindian; i : introduced species ; SZ : Soudano-zambezian; SZ-Sah.S : Soudano zambezian-saharo-sindian.

Table 3. Repartition of phytogeographical types (%).

Alpha diversity, Pielou equitability and specific richness:

Results are presented in Table 4. The diversity index was high regardless of the station. This indicated that all stations were diverse. Indeed, the diversity index varied from 5.17 (plateaus) to 6.02 bits (sandy skirt).

The equitability index ranged from 0.70 to 0.75, confirming the floristic richness of the groups, in other words, there is no dominance of one or few species over others. This index was identical between fallow (0.75) and skirts sandy (0.75) and similar between cultivated lands (0.71) and plateaus (0.70). Unlike the Shannon-Weaver index, equitability index was not dependent on the floristic richness of the station.

The floristic richness (S) was identical between the first two groups (68 species). It was weak on plateaus (48 species) and high in the GIII group. This was explained by the presence of lowland record in the GIII group, where the ground water conditions were more favorable to the development of various species.

Stations	H'	E	S
GI (Cultivated lands)	5.68	0.71	68
GII (Fallows)	5.69	0.75	68
GIII (Sandy skirt)	6.02	0.75	83
GIV (Plateaus)	5.17	0.70	48

Table 4. Diversity index (H '), equitability index (E) and floristic richness (S) per station.

Bêta diversity

β diversity was analyzed by calculating the coefficient of Similarity of Sörensen. This coefficient was relatively high between GI and GII (0.54) and between GIII and GIV (0.51). This indicated a similarity between the cultivated lands and fallows and between the sandy skirts and plateaus. This index was however weak between fallows and plateaus, indicating that these stations do not share the same floristic characteristics.

Stations	GI (Cultivated lands)	GII (Fallows)	GIII (Sandy skirt)	GIV (Plateaus)
GI (Cultivated lands)	**0**			
GII (Fallows)	**0,54**	**0**		
GIII (Sandy skirt)	**0,43**	**0,38**	**0**	
GIV (Plateaus)	**0,49**	**0,31**	**0,51**	**0**

Table 5. Bêta diversity indices.

4. Discussion

Drivers of land cover dynamics

The factors governing landscape dynamics were anthropogenic and climatic conditions. Indeed, the population of the municipality has one of the highest population growth rates in the world: 3.2% (RGP / H, 2001). This population growth resulted in new needs like more agricultural lands and wood with subsequent negative impact on the natural resources of the region. This pressure was coupled with the effects of climate change that resulted in recurrent droughts and heavy runoff leading to ravine, sandy skirts units and the silting of lowlands and pools. As consequence, soils were degraded and the income of the population in the commune was significantly decreased.

Determinants of plant diversity

The flora of the Commune was dominated by therophytes (annual species) and nanophanerophytes. According to Mahamane et al. (2007), annual species are sensitive to changes in rainfall. The nanophanerophytes were found in fallow, tiger bush and lateritic plateaus. Despite the various constraints including climatic conditions in that area, the flora seemed to be significantly diverse as indicated by diversity and equitability indices. This is an indication of the adaptation of local of species to climate change and human pressures. Indeed, the population has no other business than exploiting natural resources (energy, timber, medicines, sale of dry grass to the city of Niamey). The proximity of Niamey as big market is one reason why trees were often cut green, resulting in destruction of natural vegetation of plateaus and fallows.

5. Conclusion

This study showed that the dynamics of land cover in the rural area of Simiri was governed by both anthropic activities and climate change. A fragmentation or even absence of some cover units like regular tiger bush was recorded. However a well adapted flora to both anthropic and climate change pressures appear to remain in the various studied biotopes. Restoration activities with introduced species showed significant positive impact; however, the use of local species better adapted to local conditions would provide better results.

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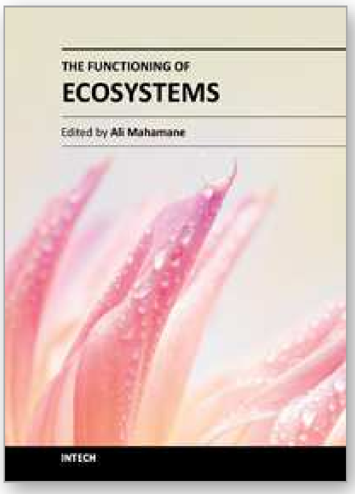

The Functioning of Ecosystems

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The ecosystems present a great diversity worldwide and use various functionalities according to ecologic regions. In this new context of variability and climatic changes, these ecosystems undergo notable modifications amplified by domestic uses of which it was subjected to. Indeed the ecosystems render diverse services to humanity from their composition and structure but the tolerable levels are unknown. The preservation of these ecosystemic services needs a clear understanding of their complexity. The role of the research is not only to characterise the ecosystems but also to clearly define the tolerable usage levels. Their characterisation proves to be important not only for the local populations that use it but also for the conservation of biodiversity. Hence, the measurement, management and protection of ecosystems need innovative and diverse methods. For all these reasons, the aim of this book is to bring out a general view on the biogeochemical cycles, the ecological imprints, the mathematical models and theories applicable to many situations.

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