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Original Article

Anthropisation and Sustainable Management of the Sorobouly and Pâ Classified Forests in the Balé Province

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ABSTRACT

The aim of this research is to study the dynamics of land use in the Sorobouly and Pâ classified forests and the factors responsible for these dynamics. These factors are both natural and anthropogenic. In the province of Balé, demographic and pastoral pressures have increased the level of degradation of the classified forests to over 20%. The methodology used is based on a diachronic analysis of Landsat images from 1998 to 2017 and on field surveys. A projection of land-use dynamics using the Markov and CA Markov cellular automaton was carried out with a view to providing decision-makers with the necessary data for decision-making. The results of image processing in 1998, 2007 and 2017 show a faster rate of degradation in the Sorobouly classified forest than in the Pâ classified forest. Dwellings and fields occupied 53.6% of the Sorobouly classified forest in 2017. Numerous human and natural factors are responsible for this regressive change in vegetation cover. The land-use simulation predicts a vegetation cover of 32.16% of the Sorobouly CF and 97% of the Pâ CF by 2027, according to the trend scenario. The green environmental and economic scenarios developed offer sustainable management alternatives for the Sorobouly classified forest.

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INTRODUCTION

Natural resources help to drive the economies of Sub-Saharan African countries. Burkina Faso's forests cover 3.9 million ha, equivalent to 14% of the country, spread over 77 classified areas (MECV, 2007). These forests are used to meet the basic needs (food, health, equipment, etc.) of the local population. Projects and programmes are therefore being implemented to protect the environment and use it rationally (Sodoré et al., 2021). Despite this, the vegetation cover is deteriorating because of climatic variation and anthropogenic pressures.

As the population grows, so does the need for land. As a result, the rate of growth in cultivated areas, which was 61,357 ha per year between 1992 and 2002, worsened between 2011 and 2015 (Hien et al., 2017).

In the province of Balé, the annual increase in sown areas was 1,638.88 ha between 1992 and 2002, compared with 4,527.75 ha between 2002 and 2014 (IGB, 1992, 2002, and 2014). This expansion of the agricultural front is exerting strong pressure on the classified areas (Amani, 2011) to such an extent that the boundaries are sometimes seen to be retreating. Indeed, the surface area of the Pâ CF fell from 15,625 ha in 1937 to 11,000 ha in 1976 (IUCN, 2009) and that of the Deux Balé CF from 139,000 ha in 1954 to 80,600 ha in 1968 (Issoufou, 2009). This shows that the Bale province is subject to strong pressures that tend to degrade the environment. This regressive dynamic requires regular monitoring to prevent its disappearance.

In the Bale province, the classified areas are under considerable pressure from human activity. Forest resources are subject to livestock grazing, agriculture and various forms of harvesting. The Sorobouly classified forest is home to several settlements spread over 2/3 of its surface area. The farming hamlets are scattered from the village of Sécaco to the south of the classified forest.

For a long time, the Balé province was a favoured destination for migrants from the north and central part of the country due to the major droughts that hit the Sahel region. The choice of this destination is explained by the availability of resources. It has several classified forests, which form part of the Boucle du Mouhoun forest corridor. Unfortunately, this dynamic has led to an increase in demand for arable and pastureland. In some cases, the classified forests have been colonised by migrants (Sanou, 1992).

This is the case of the Pâ and Sorobouly classified forests, which have lost around 10% and 20% of their area, respectively because of anthropogenic pressures (MECV, 2007). The work of Tankoano et al. (2016) and Zoungrana (2016) has also shown that these classified areas have been degraded following the development of agro-pastoral activities around and within them. Vegetation fires have also played an important role.

The local people have been supported by projects and programmes to mitigate degradation through awareness-raising and reforestation activities since 2012. The people living in the areas surrounding the classified forests (CF) are involved to a greater or lesser extent, with a view to slowing down the rate of degradation of the plant cover. Thus, from exclusive conservation by the state to participatory approaches, the low level of involvement of local people is keeping the plant cover in decline. As a result, the intrusions of local populations into the CF are calling into question management approaches (Gautier & Compaoré, 2006). This situation prompted the research question of this study: how has the vegetation cover of the Sorobouly and Pâ classified forests changed over the last twenty years? The aim of this research is to study the factors responsible for the change in land use in the Pâ and Sorobouly classified forests, the intervention zone of the Forestry Intervention Programme (PIF).

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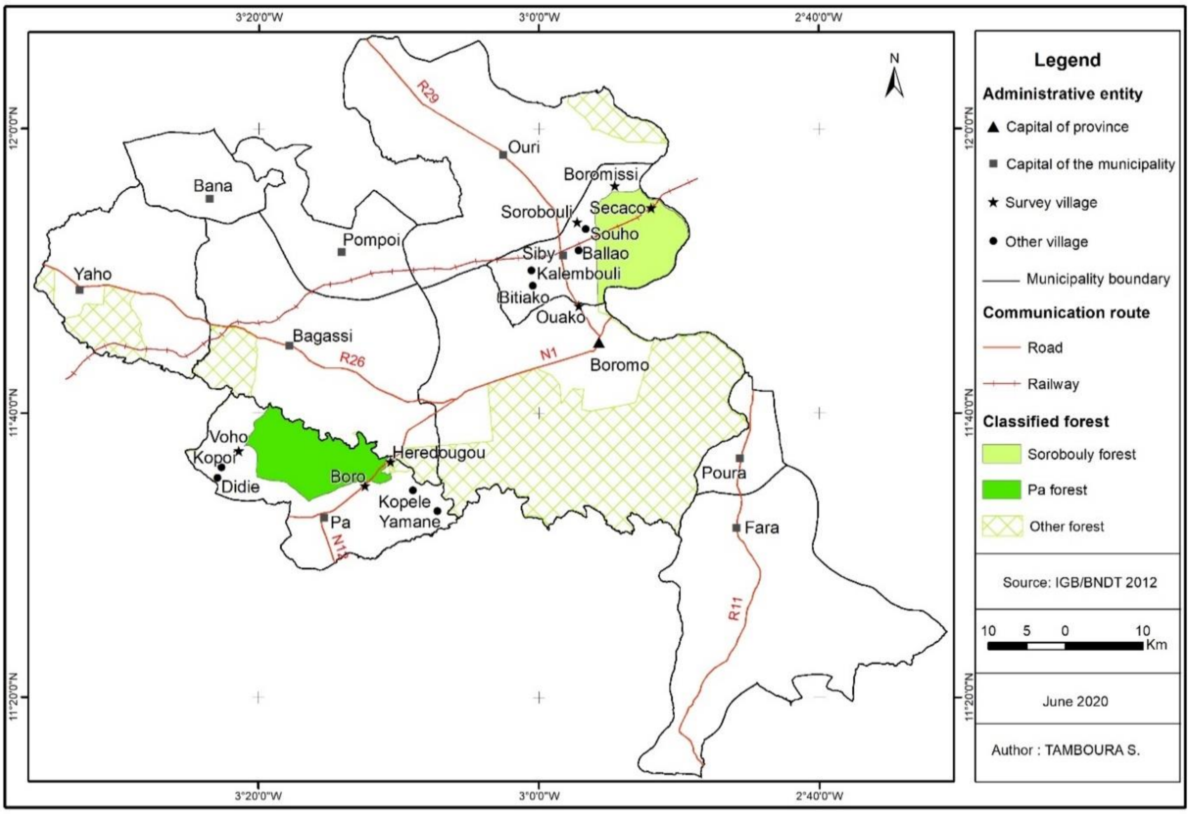
METHODOLOGY

The Study Area

This study focuses on the classified forests of Sorobouly (CFS) and Pâ (CFP) in the communes of Siby and Pâ, respectively, in the province of Balé. Field investigations were carried out in 07 villages located less than 5 km from the CF, including 3 villages around the CFP and 5 villages around the CFS. These villages are Boro, Hèrèdougou and Voho around the Pâ CF and Boromissi, Sécaco, Sorobouli and Ouako around the Sorobouly CF (*Figure 1*).

Six classified areas are in the Balé province. The level of degradation varies from one area to another, as does the management method. Some have forest management groups, while others have management committees (Pâ and Sorobouly CFs). These management methods influence the conservation of forest resources in the classified areas concerned.

Figure 1: Location of the Sorobouly and Pâ classified forests in the Balé province.



The climate in the study area is of the Sudano-Sahelian type, characterised by a dry season (October to April) and a rainy season (May to September), with an average annual temperature of 30°C. During the decade 2008-2017, average annual rainfall fluctuated between 800 and 1,150 mm, spread over 67 to 90 rainy days, according to data from the Boromo meteorological station (ANAM, 2018). This relatively abundant rainfall is conducive to the development of savannah-type vegetation, ranging from shrub savannah to tree savannah, with a strip of gallery forest along the watercourses. The Balé province belongs to the southern Sudanian phytogeographic domain. Its classified areas form the southern part of the chain of classified areas along the river Mouhoun.

The availability of resources in the study area has facilitated the installation of agropastoralists, encouraging the growth of agricultural areas and pastoral pressure. The population of the Deux Balé province rose from 213,423 in 2006 to 297,367 in 2019, representing an average annual growth rate of 2.58%. In 2006, the proportion of immigrants was 18.9% (INSD, 2008). The importance of migratory arrivals in this area is due

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to the availability and accessibility of resources for agro-pastoral production. In addition to cereal crops (millet, sorghum, maise, etc.), with production areas ranging from 2 to 10 ha, the area is also used for cotton production, which has a significant environmental impact. However, the actions of the Société de Fibres et de Textiles (SOFITEX) have for a long time contributed to the increase in agricultural land to the detriment of plant cover. In addition to these agricultural activities, there is mining, whose rapid expansion is posing a major threat to the environment.

Data Collected

To achieve the objectives of this study, several types of data were collected: quantitative, qualitative, and cartographic data. Quantitative and qualitative data were acquired using questionnaires and interview guides administered respectively to local people and administrative and community leaders in the study area. These tools helped to collect data on the factors influencing the dynamics of the land cover and the management of these factors by local stakeholders.

The questionnaire was sent mainly to farmers and herders. Heads of households over the age of 25 responded to the questionnaires because of their involvement in the management of community resources. In 2017, the populations of the rural communes of Pâ and Siby were estimated at 28,563 and 19,732 inhabitants, respectively, making a total of 48,295 inhabitants grouped into 3,408 households with an average of 5.9 people per household (INSD, 2017). In order to reach a representative proportion, a sample was calculated using the following formula

$$n = \frac{tp^2 * p(1-p) * N}{tp^2 * p(1-p) + (N-1) * y^2}$$

Where n represents the sample size, N represents the population size, tp^2 is the accepted precision level (1.65 is the value corresponding to the 90% precision level), p is the proportion of people with the behaviour whose precision is estimated (p=n/N). The maximum proportion of 50% was used in this study; y^2 is the margin of error set at 0.05.

The application of this formula made it possible to collect data from 256 heads of households in villages located (*Table 1*) around the Sorobouly and Pâ classified forests. Interviews were conducted with 6 forest management groups, 1 livestock breeders' group, 2 forest station chiefs and 2 municipal authorities.

Table 1: Distribution of households surveyed by village

Commune	Village	Ménages estimés en 2017	Taille de l'échantillon
Siby	Boromissi	577	43
	Sorobouli	145	11
	Sécaco	593	44
	Ouako	195	14
Pâ	Boro	685	51
	Hèrèdougou	884	65
	Voho	329	24
Total		3408	**252**

Source: INSD, 2017

Spatial data were obtained from the national topographic database and the land-use databases produced by the Institut Géographique du Burkina in 2012 and 2014 respectively. These data were used to locate the study area and to help process the satellite images. The latter mainly consists of Landsat images from the TM, ETM+ and OLI-TIR sensors belonging to scene 196/052 and recorded in 1998, 2007 and 2017. Images from before and after rainy seasons were used to better discriminate between occupation units and reduce the risk of confusion due to the strong influence of rainfall on plant development.

To validate the results of the satellite image classification, control points were collected in the Sorobouly and Pâ classified forests using a GPS.

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This tool was also used to geo-reference residential areas and harvesting and/or offence sites in classified areas. Direct observation made it possible to collect data useful for achieving the objectives of this research.

Data Processing and Analysis

Given the diversity of the data, several methods were used to process and analyse it. The quantitative and qualitative data collected in the field were entered into the SphinxPlus software and then cleaned. Averages and frequencies were calculated to deduce general trends in people's opinions. The qualitative data was used primarily to reinforce the arguments developed and to analyse the results of the quantitative data in greater depth.

The satellite images were processed using QGis and ENVI software. The processing involved several steps, including pre-processing, processing, and post-processing. The pre-processing consisted of atmospheric corrections, importing the bands, stacking them, and extracting the study area. Next, the near-infrared/Red/Green colour composition was developed to facilitate the identification of vegetation classes. Six (6) land use classes were identified: gallery forest, wooded savannah, shrub savannah, water body, cultivated land and bare soil, in accordance with the national nomenclature. The Random Forest algorithm was used to classify the images. The 'habitat' class was then digitised on Google Earth and combined with the classification results using the ArcGIS 'merge' command. Control points collected in the field were used to verify the classification results. Post-processing essentially involved filtering and polygonising the classification results.

The rate of change of land use units (equations 1 & 2) was calculated using the following formula from Djohy et al. (2016):

$$TV(\%) = \left[\frac{S2}{S1} - 1\right] * 100$$

where S1 is the area in year t_0, and S2 is the area in year t_{+1}.

$$TCa(\%) = \left[\frac{\mathrm{TV}}{\mathrm{t+1-t0}}\right]$$

TV refers to the rate of change, and *TCa* to the annual growth rate.

The data collected through direct observation led to photographs being taken to illustrate the arguments developed in this work.

Predicting the Dynamics of the Vegetation Cover

The "Markov" and "Ca_Markov" tools in the Idrisi software were used to predict vegetation cover dynamics. Markov tool compares two maps of different dates to calculate the areas of the classes by counting the pixels to generate the probabilities of change from one class to another. In this way, it determines the spatial evolution of the land-use classes. To test the model, projections were made for the year 2017 based on previous data (1998 and 2007) for comparison with the actual situation. The different convertible and stable areas were worked out and the results show a maximum difference of 4.5%. This variation shows that the model can be validated, given the small differences between it and the actual situation.

The implementation of this methodology has produced several results, which are presented in the following section.

RESULTS

Dynamics of the Land Use in the Sorobouly and Pâ Classified Forests from 1998 to 2017

By classifying the images and checking them against the control zones, it was possible to calculate the Kappa index for the results for 1998, 2007 and 2017 successively. These indices are 0.85, 0.80 and 0.87, then 0.84, 0.83 and 0.88, respectively, for the Pâ and Sorobouly classified forests. This shows that the results can be validated.

Dynamics of the Sorobouly Classified Forest

The CFS has changed significantly since 1998. Anthropogenic formations have grown strongly to the detriment of natural formations. The latter, consisting mainly of tree and shrub savannahs, are

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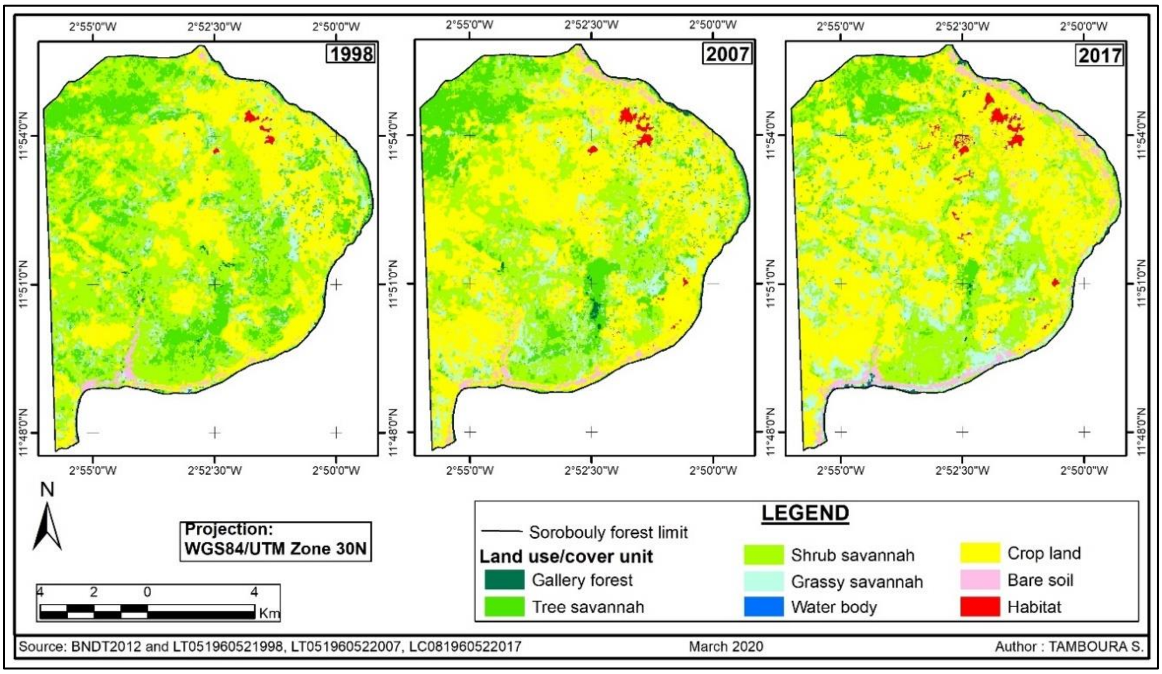
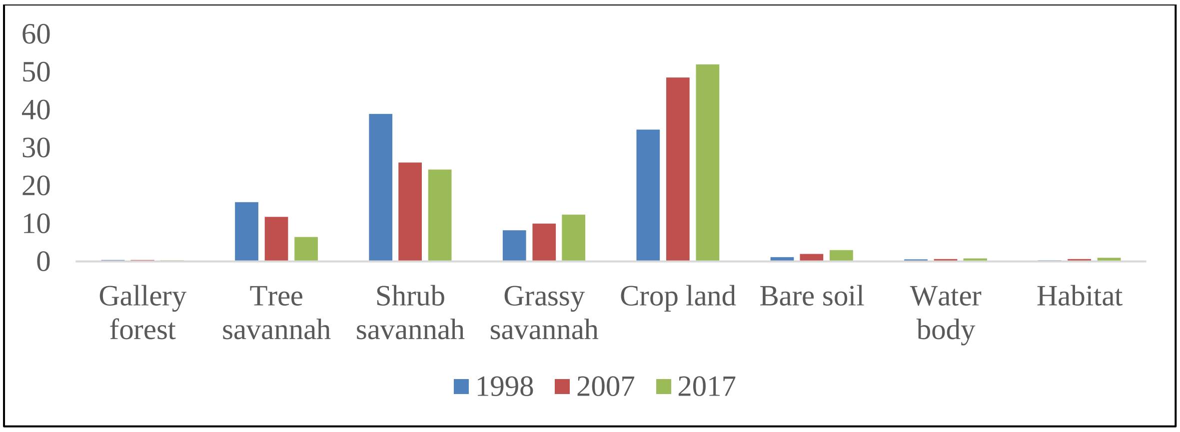
located to the northwest and south of the classified forest (*Figure 2*).

Figure 2: Dynamics of CFS land use units between 1998 and 2017



Vegetation cover is declining. Tree and shrub savannahs gradually declined by -59.01% and -37.85% between 1998 and 2017. The average annual change is estimated at 3.10% and 1.99%. Despite the protection of these resources, they are undergoing a remarkable deterioration, with an increase in the area under cultivation. The area under cultivation increased from 4,330.96 ha to 6,480.62 ha between 1998 and 2017, representing a growth rate of 49.63% and an average annual increase of 2.61%. *Figure 3* shows the changing dynamics of the Sorobouly Forest land-use units.

Figure 3: Changes in CFS land use units from 1998 to 2017



Source : LT05_196/052_1998, LT05_196/052_2007 et LC08_196/052_2017

The reduction in forest land (gallery forest, wooded savannah, and shrub savannah) is supported by an increase in agricultural land (crops), grassland (grassy savannah), other lands (bare soil) and human settlements (habitat). This dynamic shows a profound change in the structure of the classified area. Areas of dense vegetation are gradually giving way to areas of sparser vegetation. The changes have taken place in most of the land-use units over the last 10 years (*Table 2*).

Table 2: Transition matrix of Soroboly classified forest between 1998 and 2017 in percentage terms.

Land use unit		2017 (%)								Total 1998
		Gf	Ts	Ss	Gs	Cl	Bs	Wb	Ha	
1998 (%)	Gf	0,02	0,04	0,16	0,05	0,02	0,00	0,12	0,00	0,42
	Ts	0,09	2,91	6,67	2,11	3,84	0,01	0,03	0,02	15,68
	Ss	0,09	2,69	12,36	6,41	17,03	0,18	0,05	0,13	38,94
	Gs	0,04	0,24	1,80	1,53	4,27	0,22	0,04	0,06	8,20
	Cl	0,03	0,54	3,14	2,20	26,56	1,74	0,03	0,52	34,75
	Bs	0,01	0,00	0,03	0,04	0,28	0,80	0,01	0,00	1,16
	Wb	0,00	0,00	0,04	0,02	0,00	0,00	0,50	0,00	0,57
	Ha	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,27	0,27
Total 2017		0,29	6,43	24,20	12,35	52,00	2,96	0,77	1,00	100

Gf: Gallery Forest, Ts: Tree savannah, Ss: Shrub savannah, Gs: Grassy savannah; Cl: Cropland, Ha: Habitat, Bs: Bare soil, Wb: Waterbody

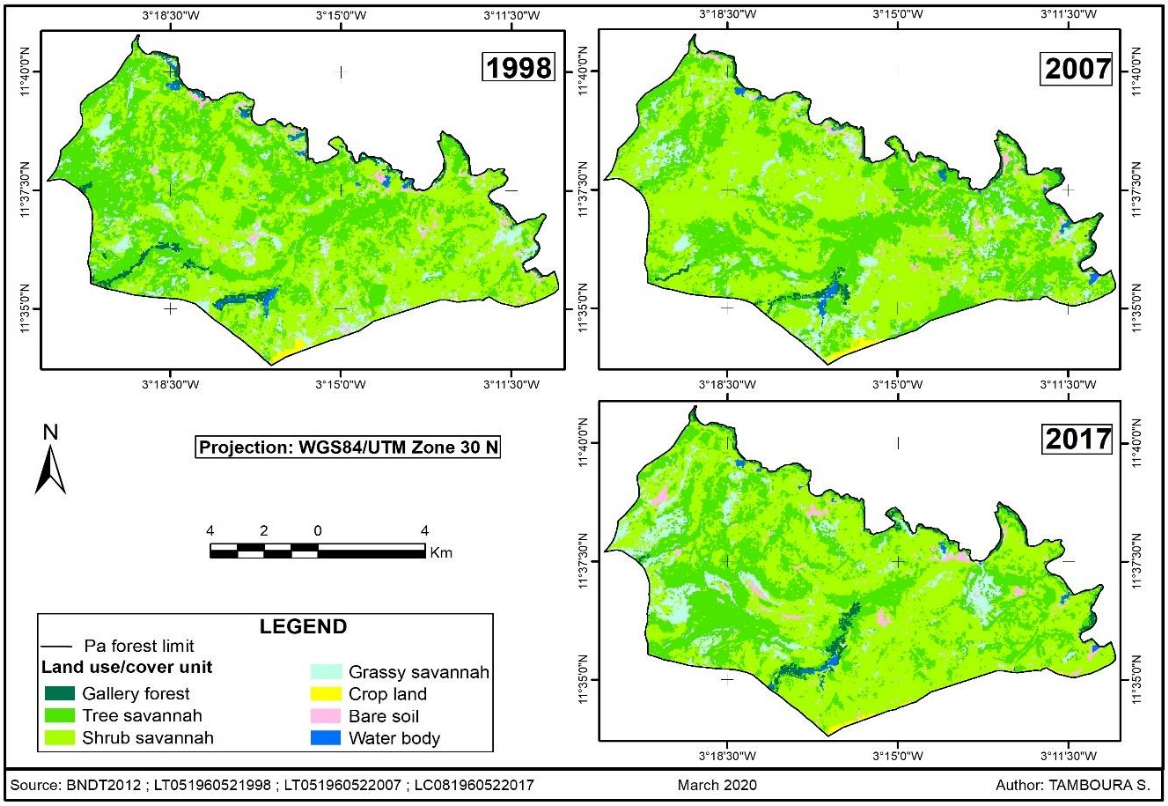
Source: Landsat image processing, 1998, 2017

Overall, the table shows a degradation of vegetation cover in favour of crops, bare soil, and habitat. The strong changes between crops and shrub savannah show that farmers have a good capacity to colonise sparsely wooded areas. The gallery forests have also undergone major changes because of exchanges with other land-use units.

Dynamics of the Pâ Classified Forest

Pâ classified forest underwent a disturbance of its vegetation cover over the period from 1998 to 2017. Tree savannahs have mainly been converted to shrub savannahs. However, no forest resources have been converted into habitat (*Figure 4*).

Figure 4: Land use dynamics in Pâ CF between 1998 and 2017



Land use mapping shows a few changes resulting in significant spatial mobility of land use units. Overall, the density of vegetation in the CFP has declined. Gallery forest and wooded savannah declined by 0.4% and 5.9%, respectively, while shrub savannah increased by 7.2%. Shrub

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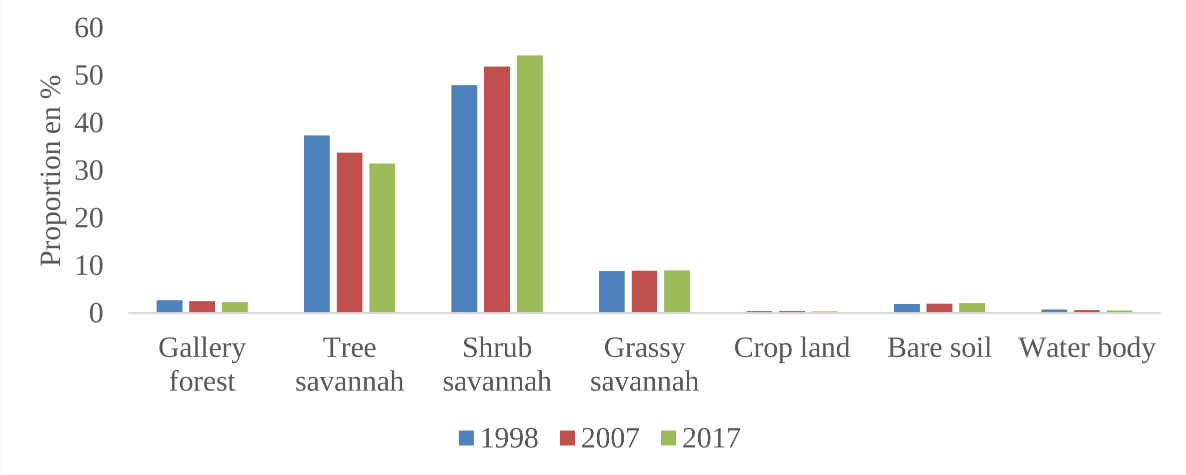
savannah grew at an average annual rate of 0.4%. The agricultural area fell between 1998 and 2017, from 56.1 ha to 34.4 ha. *Figure 5* shows changes in land use units between 1998 and 2017.

Figure 5: Changes in land use units in Pâ CF from 1998 to 2017



Source : LT05_196/052_1998, LT05_196/052_2007 et LC08_196/052_2017

The level of degradation of the vegetation cover in the CFP remains relatively low in view of the simultaneous evolution of the tree savannah and the shrub savannah. This evolution shows that exchanges between these two units are important. *Figure 5* also shows little change in the gallery forest and grassy savannah. *Table 3* shows the transitions between land use units.

Table 3: Transition matrix of Pâ classified forest between 1998 and 2017 in percentage terms.

Land use unit		2017 (%)							Total 1998
		Gf	Ts	Ss	Gs	Cl	Bs	Wb	
1998 (%)	Gf	0,98	1,27	0,37	0,04	0	0,02	0,06	2,73
	Ts	0,67	17,81	15,47	3,21	0	0,11	0,08	37,35
	Ss	0,50	10,21	31,65	3,60	0,04	0,89	0,22	47,11
	Gs	0,10	1,85	5,08	1,87	0,02	0,59	0,04	9,55
	Cl	0	0,01	0,19	0,00	0,21	0,04	0,00	0,45
	Bs	0,00	0,08	1,05	0,18	0,01	0,31	0,03	1,66
	Wb	0,07	0,20	0,50	0,10	0	0,11	0,16	1,15
Total 2017		2,32	31,43	54,31	9,00	0,28	2,07	0,60	100

Gf: Gallery Forest, Ts: Tree savannah, Ss: Shrub savannah, Gs: Grassy savannah; Cl: Cropland, Ha: Habitat, Bs: Bare soil, Wb: Waterbody

Source : image classification LT05_196/052_1998 et LC08_196/052_2017

Land-use units that have undergone major changes between 1998 and 2017 are tree, shrub, and grassy savannahs. *Figure 5* shows that exchanges between these units are the most significant. Thus, 10.21% of the shrub savannah was converted to tree savannah, while 15.47% of the latter was transformed into shrub savannah. There are also significant exchanges between shrub savannah and grassy savannah. This dynamic reflects the anthropogenic influence on the classified area.

Land Use Dynamic Factors

Settlement Dynamics Due to Migration

The CFS was created in 1938 by classification order no. 3320-SE/SF issued by the colonial government. At the time of its creation, the area was so rich in shea butter that the colonial authorities decided to build a factory there called SECACO (Société d'Exploitation de Carburant Colonial), which later took the name of the

Article DOI: https://doi.org/10.37284/eajfa.6.1.1568

village. An enclave of 115.85 hectares was demarcated for the workers' use.

When the factory closed (around 1960), the local people took up farming. As the area of the enclave dwindled in the face of the population's growing need for arable land, forestry officials signed time-limited cultivation contracts. The forestry service was unable to enforce either the contractual conditions or the general conditions governing the use of the fields. As a result, the fields gradually multiplied and expanded in the CFS.

Beyond this particularity, it should be noted that the study area is a favoured destination for migrants. In fact, more than half the people interviewed in the communes of Siby and Pâ (55.2%) were migrants. They come from the country's northern regions, including Yako (33.7%), Koudougou (16.8%) and Kongoussi (12.9%). In 2006, the migration rate was 18.9% in the province of Balé (INSD, 2008). Within the Sorobouly CF, in Sécaco, migrants account for 86.3% of the population.

For a long time, migration in the study area was fuelled by recurrent droughts, which have led to a fall in land productivity since the 1970s. Today, migration is fuelled by gold panning. This environmentally damaging activity is more important as the CFS has a gold-panning trading post within its boundaries and a second on the outskirts between Siby and Souho.

Increasing Land Pressure

Classified forests are considered like plant resource reserves for local populations. They are overflowing with arable land and forest products that attract local populations. Communities find reserves of grazing land and farmland. However, these reserves are under heavy pressure from the rapid population growth around and within the two classified forests. These pressures are reflected in relatively high population densities (101 inhabitants/km² and 45 inhabitants/km² in 2019 for the communes of Siby and Pâ, respectively). This density reflects the growing demand for farmland and grazing land. In Sorobouli, 56% of respondents said they were interested in the CFS for agro-pastoral production reasons. In addition to the installations within the classified area, there is a strong trend towards increasing the area under cultivation. Thus, 44.64% of those interviewed had cleared fields in the Sorobouly CF (*Plate 1*).

Plate 1: Clearing in the Sorobouly classified forest

Image capture: Tamboura S., 2019.

The first image shows an old field, and the second, a new open field inside the Sorobouly classified forest. This shows that the degradation of the classified area is still ongoing.

In contrast, the CFP has no agricultural influence, even though its outskirts are bordered by fields. In fact, the agricultural front is very dynamic in the southern and western peripheries of the CFP.

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Land and agricultural dynamics inside and outside the two CFs are the combined result of demographic pressure and farming practices in the study area. The latter, dominated by cotton production, is a threat to nature conservation because of its extensive nature.

Increased Need for Pastoral Resources

The need to exploit the pastoral resources of the two classified forests to feed livestock was expressed by 50.27% of those interviewed. The increase in the number of cattle in the Balé province is indicative of growing pressure and demand on the classified areas. Unfortunately, the CFs, which play an important role in feeding livestock, have no sustainable management tools, which increases the pressure on them. Even though, according to the classification texts, the CFs recognise the right to graze livestock, the flow of animals today can compromise the survival of these entities.

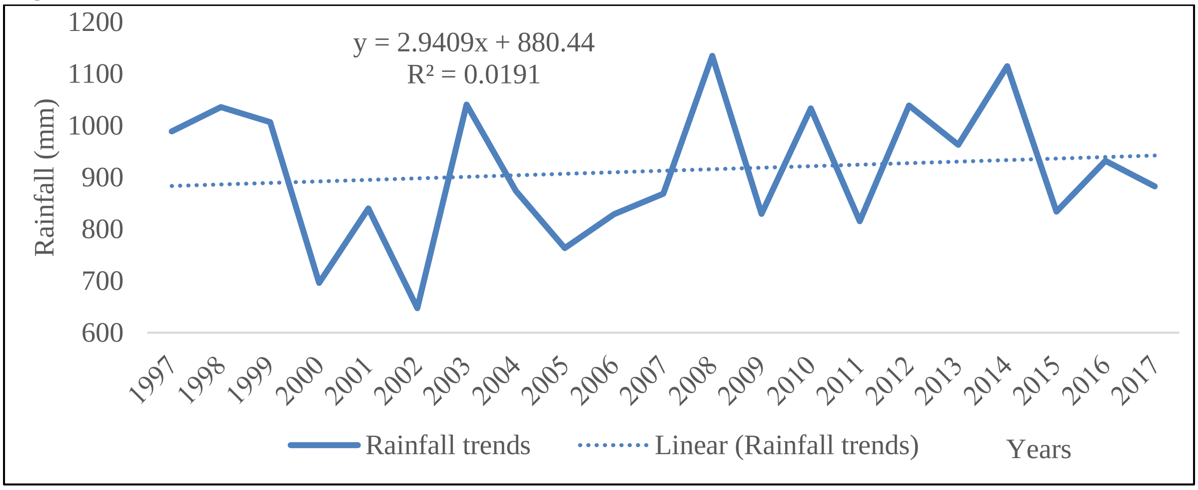
Thus, as the Sorobouly CF is populated by migrants, cattle graze there. Similarly, the livestock of the forest dwellers exploit the same resources. At Pâ, the abundance of fodder resources makes the CF a coveted area. 15.3% of those interviewed said that their livestock graze in the CF. Of these, 53.3% live close to the CFP. Livestock farming is therefore one of the main factors in the degradation of classified areas in terms of changes in livestock numbers. According to the INSD (2017), the number of cattle in Balé province rose from 69,910 in 2010 to 80,300 in 2016, representing a growth rate of 14.9% in 6 years.

It should be noted, however, that the dynamics underway around the two CFs are significant and do not fully reflect the statements made by residents. In fact, the reluctance of local people to declare their activities within classified areas means that it is not possible to know the exact situation regarding infringements.

A Constantly Variable Climate

The climate in the study area is of the northern Sudanian type, characterised by a rainy season lasting around 5 to 6 months (May to October), while the dry season lasts 6 to 7 months. This short rainy season suggests periods of heavy pressure on available resources. The high spatial and temporal variation in rainfall, despite its increasing trend (*Figure 6*), is at the root of low production levels.

Figure 6: Rainfall trends from 1997 to 2017.



Source: ANAM, 2018

Figure 6 shows the strong inter-annual variation in rainfall between 1997 and 2017. From 1997 to 2017, rainfall followed a sinusoidal pattern from April onwards. Maximum rainfall was recorded in 2008 and minimum in 2002 (*Figure 6*).

Figure 6 shows heavy rainfall in 2008 and 2014, while 2000 and 2002 saw little rainfall. From 2007 to 2017, the number of rainy days varied between 67 and 90 days, according to rainfall data from the Boromo weather station. This variable rainfall

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pattern has an impact on vegetation growth in the region. However, rainfall levels in the Balé province are favourable to natural plant growth.

Stakeholders with Varying Degrees Of Organisation and Dedication to the Cause Of The Environment

Numerous stakeholders are involved on the outskirts of the Sorobouly and Pâ classified forests. These include forestry services, local collectivities, non-governmental organisations (NGOs), projects and programmes, and local people organised into Forest Management Groups (FMGs). Despite this diversity, the two classified areas are under constant pressure, which the various stakeholders are trying to control through natural resource management projects and programmes. The implementation of these actions relies mainly on local stakeholders organised around the GGFs.

In each village around the classified forests, groups have been set up to help manage the classified areas. Involving local people in environmental management is a government initiative aimed at improving the way resources are exploited without damaging them. As a result, the GGFs receive a wide range of support for restoration, recovery, monitoring and even renewal of protected areas. Field surveys have shown that the Sorobouly groups around the CFS are highly involved, as assessed by local people. Indeed, 77.5% of those surveyed were positive about the actions of the GGFs, compared with only 19.44% in Pâ. In the commune of Siby, the GGFs and herders' groups set up in villages and farming hamlets such as Boromissi, Sorobouli, Souho, Ballao, Sécaco, Kiènè and Ouako are better organised than the GGFs in the commune of Pâ. This is justified by the strong involvement of the communities in decision-making relating to the Sorobouly classified forest. In Pâ, although GGF groups have been set up in the villages bordering the CFP, their involvement remains relatively low in development, reforestation, and fire management activities.

The difference in involvement around the Sorobouly and Pâ classified areas is essentially explained by the support provided by the Forest Investment Programme (PIF) and the NGO Wend-Puiré in laying the foundations for sustainable management of forest resources and training local people to make better use of non-timber forest products. The high level of investment in the CFS in the commune of Siby is justified by its advanced state of degradation, which needs to be quickly and effectively addressed. To this end, GGFs have been installed in all the villages interacting with the classified forest, apart from Pâ. They are involved in CFS development work and related activities.

In the commune of Siby, a communal management committee made up of GGFs and groups of village herders has been set up. The committee is the highest decision-making body for actions undertaken in the CFS and for raising community awareness via the GGFs. It works towards good forest management.

All these factors, without being exhaustive, contribute in one way or another to the dynamics of the CF. Their evolution determines to some extent the future state of the two classified areas. Thus, considering that the current dynamics continue, the following lines present the probable future state of the classified areas.

Dynamics of the Sorobouly and Pâ Classified Forests to 2027

Future trends in the Pâ Classified Forest up to 2027

In the next decade, the evolution of Pâ CF will see fewer major changes. The general trends of change persist, with the expansion of wooded savannah in the west and shrub savannah in the centre. There has also been an increase in bare soil (2.20%) and grassy savannah (9.23%) (*Figure 7*).

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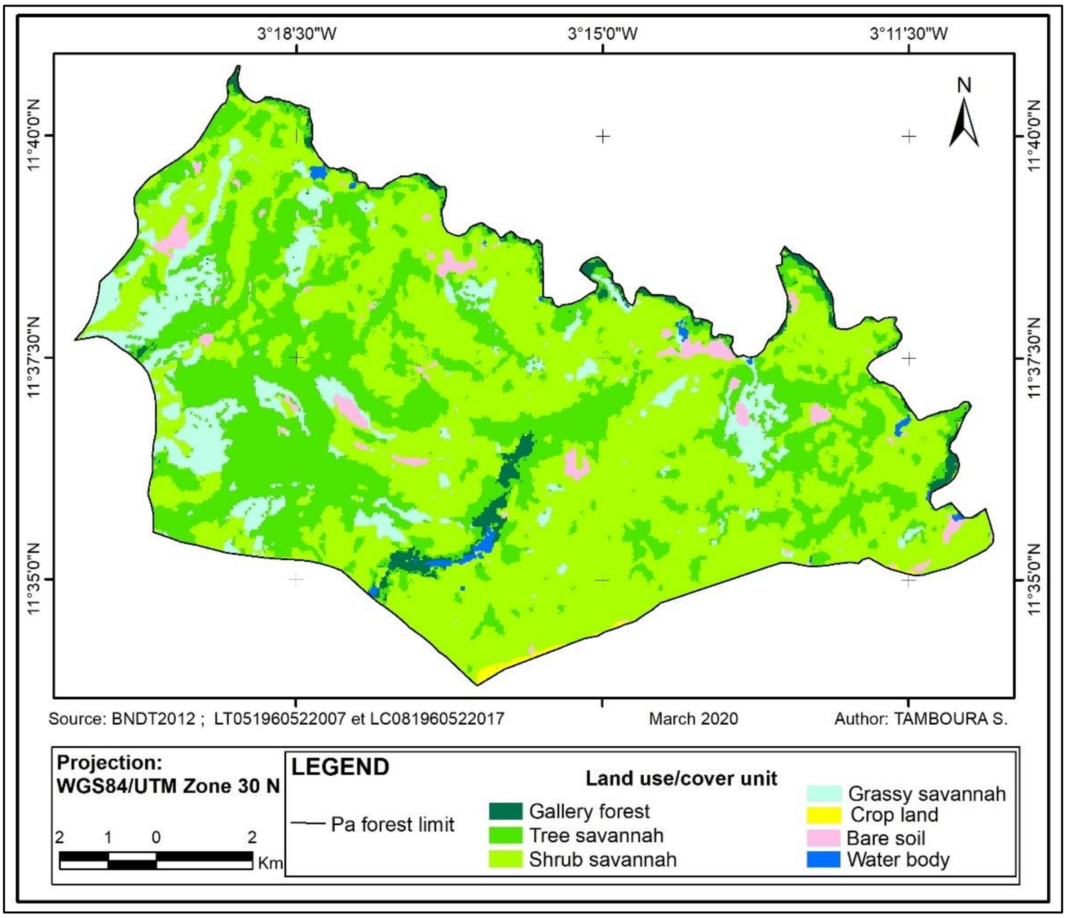
Figure 7: Predictive land use evolution of Pâ classified forest in 2027



The predominance of grassy savannah implies that the classified area will be more coveted by agropastoralists. This could be a major factor in degradation, given the trends in livestock numbers. Contrary to the weak evolutionary trend of the CFP, the CFS, which is experiencing strong dynamics, shows a general trend towards degradation but with scenarios of a possible recovery of the classified area.

Evolution of the Sorobouly Classified Forest.

Because of the dynamics of the CFS, three scenarios have been developed. Thus, up to 2027, the three trends show a deterioration in vegetation cover but at different levels. Bare soil will overtake vegetation and water. Demographic pressure will lead to habitat sprawl, to the detriment of fields and shrubby savannahs. The tree stratum will occupy exclusively the south of the CFS, with shrub savannahs predominating (*Figure 8*).

Figure 8 shows that if current trends continue, vegetation will be reduced to an occupancy rate of 39.52%, while agricultural land will account for 55% of the CFS by 2027. Degraded soils will occupy 3.66% of the CFS. Current trends, therefore, highlight the risk of the classified area disappearing if drastic measures are not taken quickly. The presence of a diverse range of players is currently an asset for implementing actions to recover the CFS. This is why reverse scenarios have been developed to guide decision-making.

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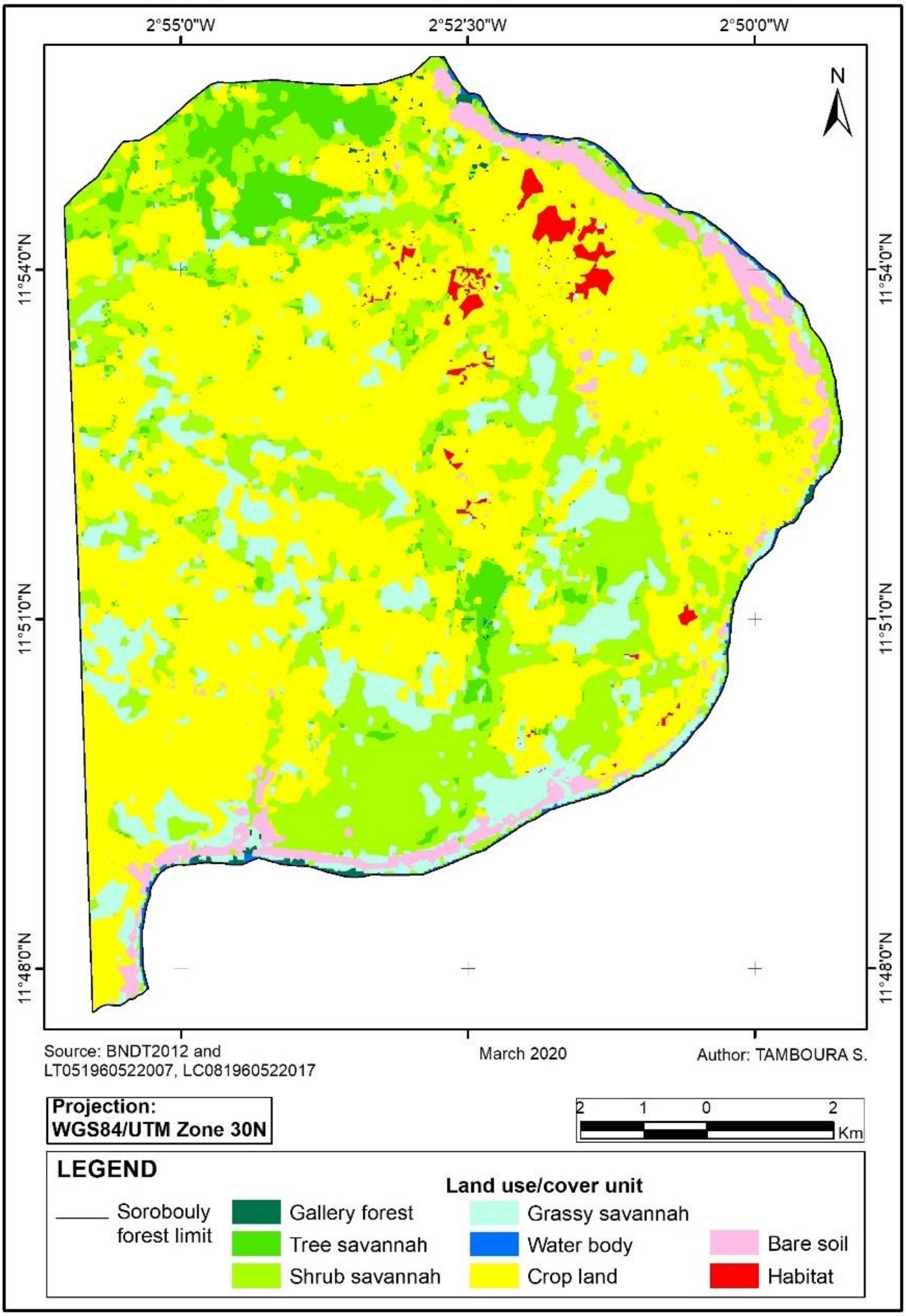
Figure 8: Predictive land use evolution of Soroboly classified forest in 2027



Article DOI: https://doi.org/10.37284/eajfa.6.1.1568

Figure 9: Prediction to 2027 according to environmental scenario

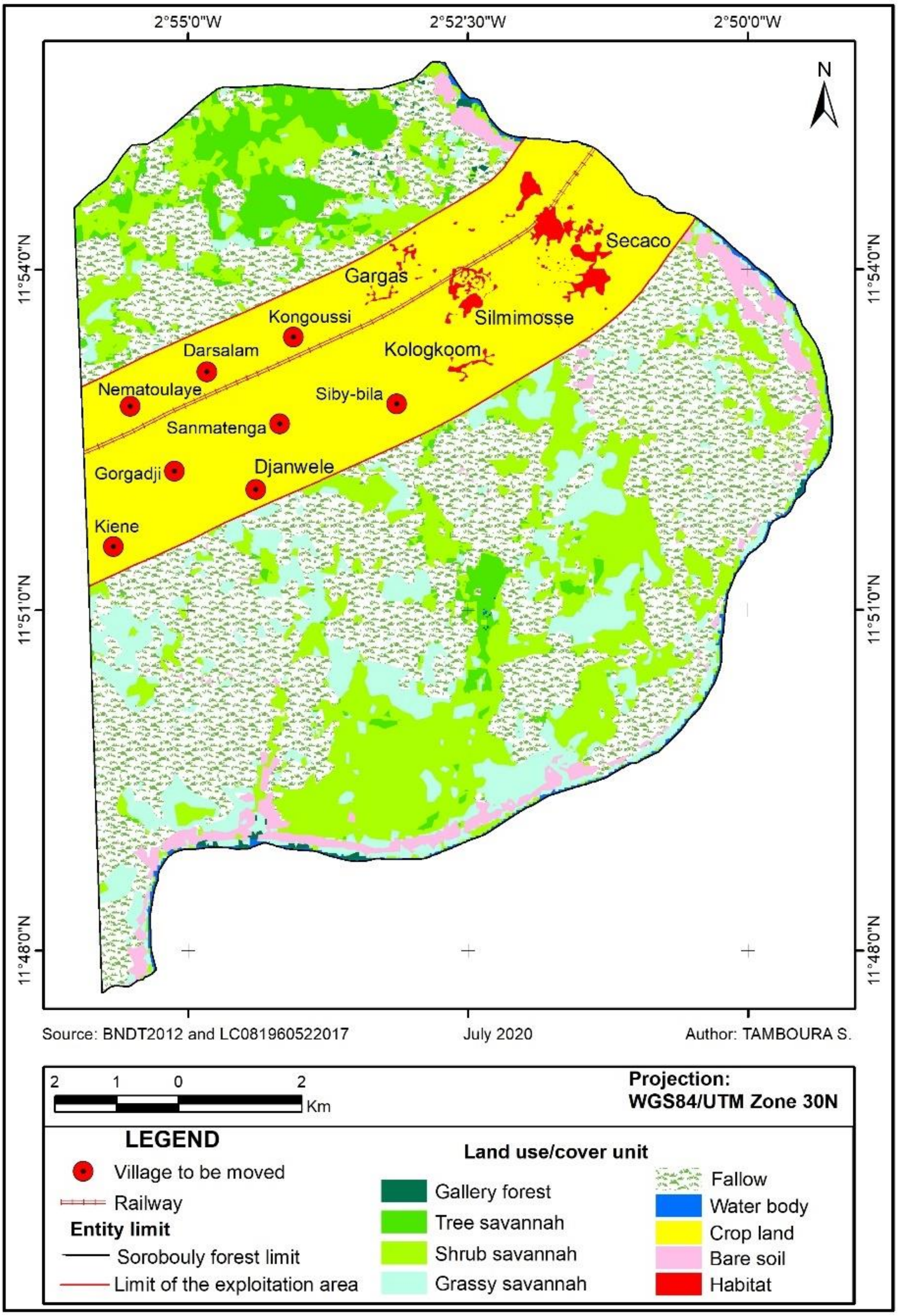


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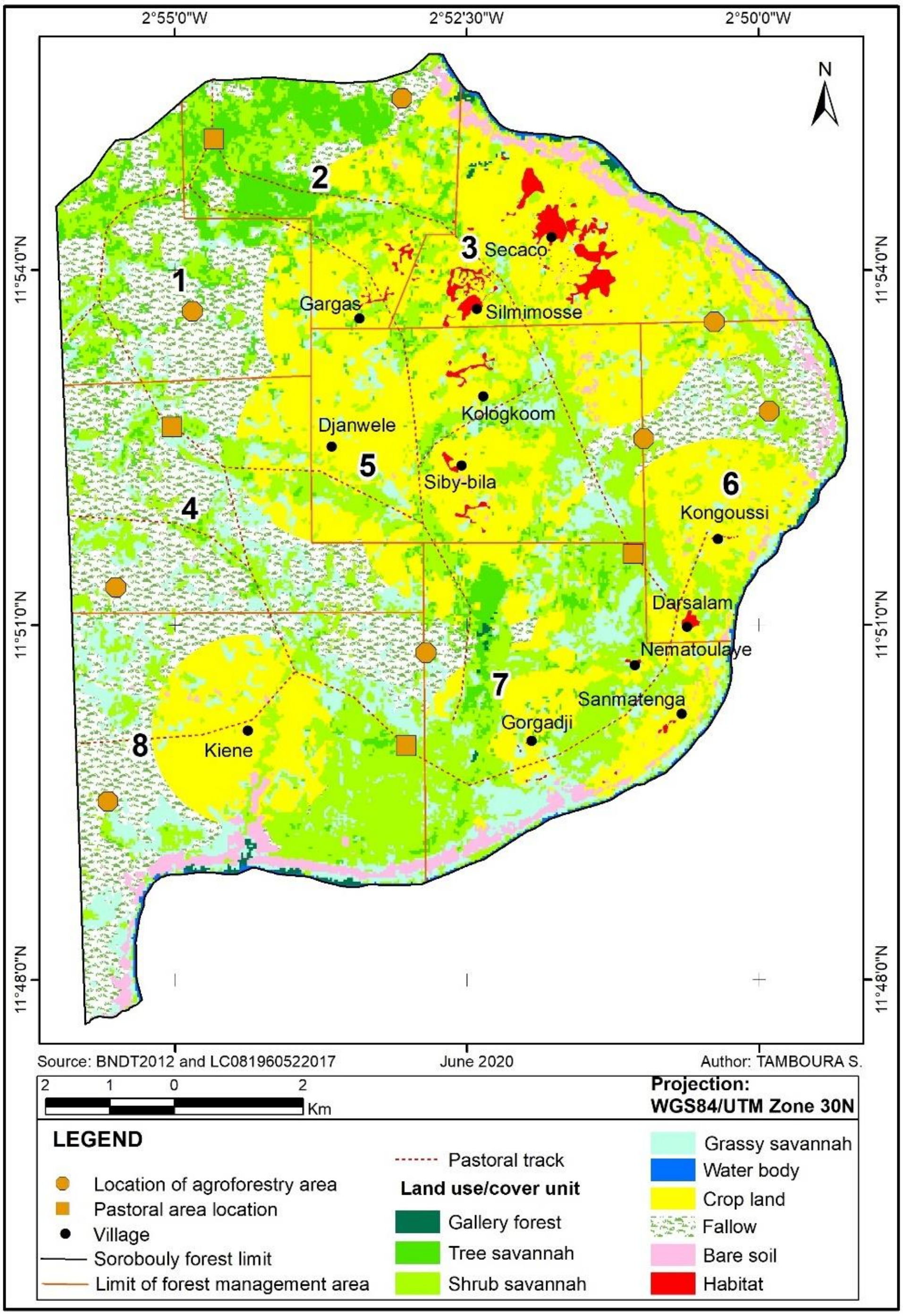
Figure 10: Prediction to 2027 based on the green economic scenario



The environmental scenario involves a reorganisation of agricultural activity along the railway line. This initiative presupposes a regrouping of the population to better control the dynamics. The decline in plant cover is then mitigated by the reduction in uncontrolled farming. All the localities and farms will be contained within this trench, which is 3 kilometres wide and covers an area of 3,039 hectares. As a result, 124.5 ha will be allocated to housing and the remaining 2914.5 ha (44.5% of the original fields) to agriculture. This scenario supports the abandonment of fields by local populations and the gradual reduction in the number of people living in the CF.

The green economic scenario requires an appropriate reorganisation of the CFS by subdividing the classified area into eight (8) FMUs (Forest Management Units) of 1557.88 ha

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on average. To this end, the fields will occupy an area with a radius of one and a half kilometres around the dwellings. The rest of the fields will be left fallow for reforestation and timber harvesting. Pastoral areas and cattle tracks are also created to reduce the risk of land conflicts.

The aim of developing these scenarios is to help decision-makers make better decisions and manage the classified area, which is currently under heavy pressure from migrants.

DISCUSSION

Observing the dynamics of land use remains an important issue in light of current environmental and climate-related challenges. Classified areas are at the heart of this issue. The role of remote sensing in monitoring these dynamics no longer needs to be demonstrated, as it enables periodic monitoring of CF forest resources (Beguet, 2015; Lambert, 2014). Satellite images from 1998, 2007 and 2017 were used for this purpose. The data were interpreted using appropriate software. The maximum likelihood method is used by several authors (Kapiri et al., 2023; Joshua et al., 2023; Sanou et al., 2022). Similarly, Idrisi's Markov algorithm is used by several authors for its prediction performance (Djaouga et al., 2022; Maestripieri & Paegelow, 2013). Although this is the application that performs best in predicting changes in land cover, it does not consider the environmental and socio-economic variations that can influence the current dynamics.

The results obtained show a degradation of the vegetation cover in the two classified areas, but at different rates, given the importance of the degradation factors involved. The CFS is experiencing an impressive rate of degradation that threatens its survival in the medium to long term. Yet, for a long time, protected areas were seen as an effective means of preserving nature, especially in Sub-Saharan Africa, given the strong pressures on natural resources (Gansaonré et al., 2018). Indeed, the evolution of plant cover in general is marked by regression in Burkina Faso. This regression is essentially explained by the increase in field area. These results are like those of several authors (Tankoano et al., 2015; Kaboré, 2013) who point out that appropriate action needs to be taken to curb the factors causing this degradation.

The study showed that several factors are responsible for the decline in plant cover. It should be noted that rural communities practise rudimentary activities that are highly dependent on natural resources. In particular, extensive farming is dominated by cotton and cereal production (Soulama et al., 2015). This agricultural characteristic has led many farmers to clear land near and within the protected area. Similar cases were noted by Dipama (2009) around the Tambi Kaboré National Park (PNKT) in Burkina Faso. Clandestine grazing by domestic animals also leads to poor pastoral practices in classified areas, such as the pruning of trees by herders in Pâ CF (Sawadogo, 2009). According to the Ministry of the Environment and Sustainable Development (MEDD) cited by Kambiré (2016), 35% of the plant biomass consumed by livestock annually comes from forest sources. In fact, the extensive production system where animals graze freely in search of natural pasture. This system exerts strong pressure on forest resources. In addition, population growth has led to an increase in needs, exacerbating the pressure on resources. The major differences in degradation between the two classified areas are essentially due to the presence of migrants and the development of gold panning. Migration exacerbates agricultural pressure and leads to land saturation (Konan et al., 2016). It is a cause of the degradation of the Sorobouly and Baporo CFs. The presence of people in classified forests also accelerates their degradation (Bamba et al., 2010; Konan, 2009).

In addition to direct anthropogenic factors, indirect natural factors are also involved in vegetation dynamics. Climatic variations play an important role in land-use change. In Burkina Faso, rainfall has fluctuated widely, with a downward trend (Karambiri & Gansaonré, 2023). This trend is having a negative impact on agricultural yields and is leading to an expansion

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in the size of fields from year to year. It also affects vegetation development capacity.

This is why a prospective study of the dynamics of the vegetation cover is relevant to help decision-making. Land-use forecasting is a key parameter in land-use planning. In light of current trends, future dynamics show a sharp deterioration in the CFS, in contrast to the CFP. The Ca_Markov model used by Guelbéogo (2017) corroborates the results obtained and shows a future growth of fields to the detriment of vegetation. Also, the disappearance of vegetation formations in favour of fields and built-up areas increases by 2016, 2025 and 2034 (Oloukoi, 2013). Al-Karkouri et al. (2014) have shown a worrying increase in agricultural land in northwest Morocco by 2020. In this case, anticipatory measures need to be taken to change the trajectory of land use change. The results of this study show that specific action is needed around the CSF. For this reason, many players are involved in reducing the impact of anthropogenic action in the classified area.

CONCLUSION

Remote sensing techniques were used to highlight changes in the vegetation cover of the Sorobouly and Pâ classified forests by way of land-use maps for 1998, 2007 and 2017. The trends show a deterioration in the classified areas, with a strong trend in the Sorobouly classified forest. Several anthropogenic and climatic factors explain this dynamic. Among these factors, the migration of agropastoralists plays a very important role. The serious degradation of the Sorobouly classified forest is explained by the settlement of migrants in and around the classified area. Despite certain recovery actions, the degradation process continues. This is why it has proved relevant to understand the possible future evolution of these classified areas. Projections have shown that the Sorobouly classified forest is at risk of disappearing. To this end, coercive scenarios have been developed to help decision-making. These are the environmental and green economic scenarios. These offer decision-makers prospects for reducing trends.

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