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Research Article

DYNAMICS OF LAND USE CHANGES IN THE MUNICIPALITY OF KANGALA IN BURKINA FASO

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Abstract

Changes in land use and land cover are one of the indicators of the biophysical state of the environment. These are fundamental variables for mapping inventories and monitoring of environmental phenomena. The present study aims to analyze the spatio-temporal dynamics of land-use changes between 1990 and 2018 in the municipality of Kangala. To do this, the 1990, 2000, 2010 and 2018 Landsat images were used. The methodology used combines both socio-economic survey data and digital processing of satellite images. For class discrimination, the supervised classification approach was performed with the maximum likelihood algorithm. The transition matrix highlighted the changes in the land use classes. Field areas increased from 18.57% in 1990 to 22.18% in 2018. Orchards almost tripled in size. From 10.68% in 1990 they reach 35.32% in 2018. Riparian vegetations, savannas, water bodies and bare areas decreased by 4.76%; 63.76%; 0.23% and 2% respectively in 1990 to 2.22%; 40.14%; 0.02% and 0.13% in 2018. The diachronic analysis of land use from 1990 to 2018 showed an annual average regression of 9.86% for bare areas, 8.69% for river formations, 2.73% for water points and 1.65% for savannas. Orchards and fields recorded an average increase of 4.27% and 0.63% respectively in 2010. The study shows that the areas of savannas and riparian formations decrease in favor of fields and orchards in the municility of Kangala.

Keywords: Mapping, Changes in land use, Municipality of Kangala, Burkina Faso.

INTRODUCTION

Changes in land cover and land use are the result of changing interactions between social and environmental systems (Corgne, 2004). Today, man is responsible for most of these transformations that affect terrestrial ecosystems, while biophysical and climatic phenomena were for a long time the main drivers of land surface changes (Hountondji, 2008). For (Corgne, 2004; Corgne, 2014; Miandad *et al.,* 2020) mutations, whether they are conversions, designating the passage from one category of occupation or use to another, changes that represent a dynamic within the same category related to changes that affect its physical or functional attributes in land use and land use patterns, influence the mechanisms that control ecosystems. Changes in land use and cover are essential components of regional and local planning. They also participate in the study and understanding of the environment (Foody, 2002; Ouattara *et al.,* 2006). They affect the biogeochemical circulation of water and the atmosphere, alter the physico-chemical characteristics of soils and lead to biodiversity degradation (Ouattara *et al.,* 2006; Houet, 2006; Lambin *et al.,* 2003). They are one of the indicators of the state and quality of the biophysical environment. For this reason, changes in land use and occupation are an unconditional subject in cartographic inventories and monitoring of environmental phenomena (Ouattara *et al.,* 2006; Soro *et al.,* 2014; Sarr, 2017). They have become an essential component of current strategies for characterizing natural resources and environmental change. Remote sensing is the preferred tool for their study (Kaul and Sopan, 2012; Juliev *et al.,* 2019). In Burkina Faso, climatic variations from the 1970s to the 1990s led to rapid changes in social and ecological systems.

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In the west and south-west, large areas of savanna have been converted into agricultural areas with fragmentation of natural habitats and significant loss of biodiversity (Béné and Fournier, 2014). In the municipality of Kangala, due to the climatic hazards, the producers have turned to new farming practices including arboriculture to the detriment of commercial rain crops and food crops such as cotton. In addition, the recurrence of droughts has forced farmers to exploit the shallows, the edges of water bodies and marginal or formerly reserved lands for pastoralism (Ouédraogo *et al.,* 2015; Kékélé, 2013). Landscape configuration is determined by human activities to meet socio-economic needs and climate variability (Ouédraogo *et al.,* 2015; Brandt *et al.,* 2014; Fahrig, 2003). The objective of this study is to analyze the dynamics of land-use changes in the municipality of Kangala between 1990 and 2018.

MATERIALS AND METHODS

Study area: The municipality of Kangala is located in west of Burkina Faso, precisely in south-west of the province of Kénédougou. It lies between latitude 10°54’10’’ and latitude 11°6’40’’ North and longitude 5°20’50’’ to longitude 5°4’10’ West (Fig. 1). The municipality consisted of 15 villages: Bama, Bakaribougou, Dioforma, Kafiguila, Kagnabougou, Kangala, Kotoura, Lanfiera, Mahon, Moussabougou, Niampédougou, Ouolokoto, Sayaga, Sokouraba et Ziwahiri; with Kangala as chief common place. It belongs to south sudanese region characterized by annual rainfall varying between 900 and 1200 mm. Kangala has a dry tropical climate of sudanese type with two contrasting seasons, one of which is wet and lasts about six months, runs from May to October and the other dries from November to April, also covering six months.

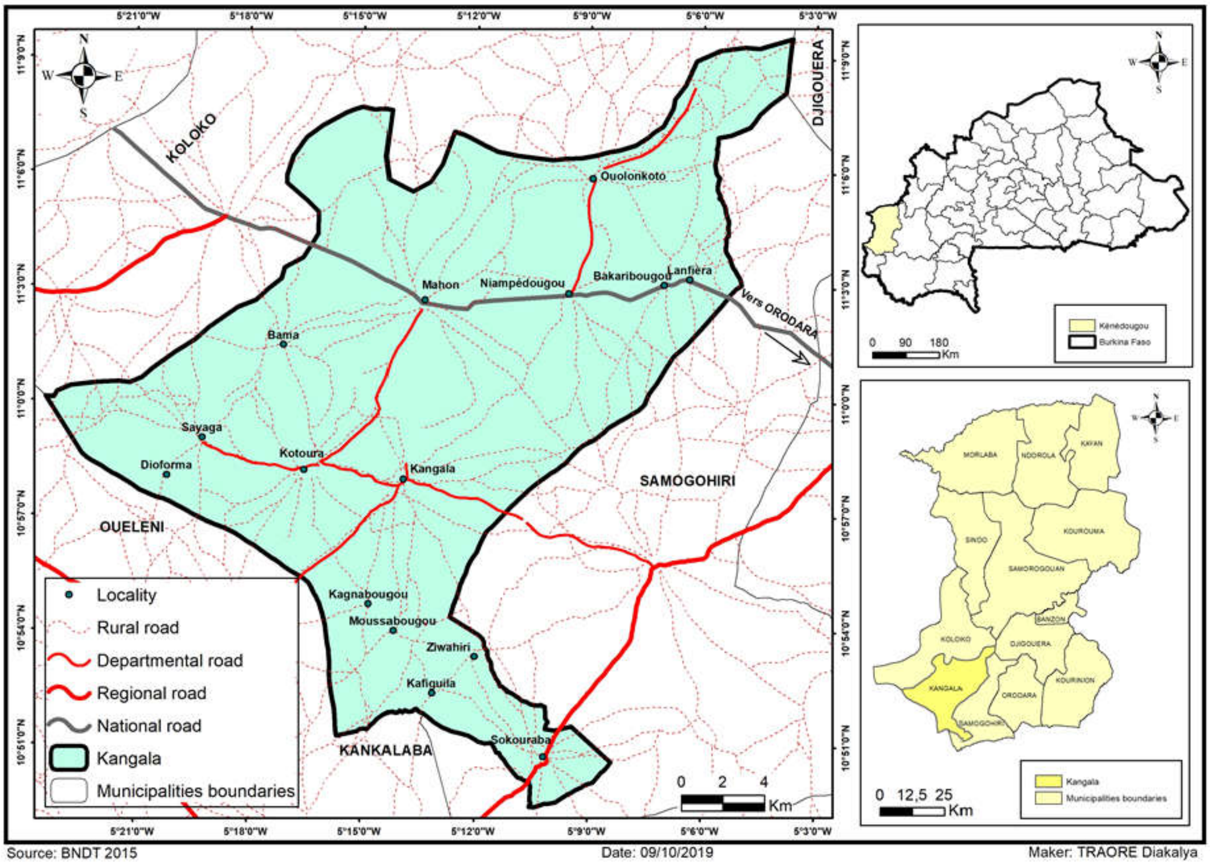

Figure 1. Location of Kangala municipalicity

Monthly mean temperatures, ranging from 1987 to 2017, range from 25.46°C to 31.17°C. The thermal range is 5.71°C and the average temperature is 27.8°C. Plant formations of the municipality of Kangala are the savanna type and their physiognomy is dependent on the impacts of anthropogenic activities, the physicochemical nature of the soils and the geomorphology (Sawadogo, 2011). In 2004, the "Bureau National des Sols du Burkina", based on the morpho-pedological study carried out by the Soil Mapping and Pedology Commission, identified eight soil types in the municipality. These are hydromorphic leached tropical ferruginous soils, shallow leached induced ferruginous soils, superficial leached tropical ferruginous soils, leached tropical soils with stains and concretions, weakly desaturated typical modal ferrallite soils, low-humus to pseudogley hydromorphic soils, cuirass lithosols and lithosols on sandstone.

Data and materials

The analysis of land use trends was essentially based on four satellite images of different dates: Landsat images of 1990 Thematic Mapper (TM), Landsat images of Enhanced Thematic Mapper Plus (ETM+) 2000, 2010 and 2018 with 30 m of resolution. The scenes used in this study are 197/52 and 197/53 as they cover the study area. Image processing, mapping and tables were done with Envi 4.8, ArcGIS 10.3.1 and Excel software respectively.

Methods

For this study, the supervised classification was used to identify the land use units of the municipality of Kangala from 1990 to 2018. It is a method which consists in assigning pixels to the nearest samples, according to a so-called Bayesian distance which is based on the probability that a pixel has to belong to a given occupation class (Soro *et al.,* 2014; Ouédraogo *et al.,* 2015). It was based on the so-called maximum likelihood algorithm (Juliev *et al.,* 2019). For the colour composition, channels 4, 3 and 2 were selected because of the high discrimination capacity of the vegetation-sensitive band 4 (Sarr *et al.,* 2017; Ouédraogo *et al.,* 2015). To measure the accuracy of the classification performed, statistical tools such as the Kappa index and the confusion matrix were used. To assess the dynamics of land cover, the annual rate of change was determined for each class according to equation was used (Oloukoi *et al.,* 2006):

$$T = \frac{lnS1 - lnS2}{tlne} * 100$$

Where T explains change rate, S1 the class area on date t1, S2 designs class area on date t2, t of number of years of change between the two dates, ln explains Neperian logarithm, e is the base of the Neperian logarithms which value is 2.71828.

RESULTS AND DISCUSSION

Classification accuracy assessment

From the image classification, six categories were identified. The validation of these classes was examined by the Kappa coefficient and the confusion matrices (Table 1, 2, 3 and 4). The analysis shows that the four images have a good overall accuracy. The overall accuracy of the 1990 image is 83.28% with a Kappa index of 0.79. It is 86.38%; 92.59% and 77.79% for 2000, 2010 and 2018. The Kappa coefficient is 0.86, 0.90 and 0.72 respectively for the same years. These results indicate good image processing. However, some classes are better classified than others. Looking at table 1, it appears that the field category has an accuracy of 97.84%. It is followed by bare areas, savannas, water points, orchards and finally river formations with 96.98%; 92.84%; 86.89%, respectively; 75.91% and 51.07%. As shown in table 2, the accuracy is 98.65% for the bare zone class, 94.38% for water points, 90.1% for fields, 81.01% for orchards, 75.8% for river formations and 70.8% for savannas. The class of river formations observed the lowest accuracy in 1990.It is 4.35% confusing with orchards and 42.56% confusing with savannahs. On the other hand, the confusion is 20.54% with savannas and 5.47% with orchards in 2000. In 2000, low precision was achieved by savannas. This category was 5.47% confused with orchards and 16.54% with river formations. In 2010, the water points class was 98.15% accurate, followed by eroded areas and fields with 97.37% and 97.2%, followed by orchards and savannahs with 91.12% and 85.96% respectively, and finally riparian vegetations with 84.2% accuracy. For 2018, accuracy increased to 81.18%; 92.8%; 97.3%; 65.18%; 57.33% and 40.58% respectively for water points, eroded areas, fields, orchards, savannas and river formations. The orchard class is 17.91% confused with savannas and 20.03% with river formations. The strong confusion between orchards and river formations is justified by the agricultural colonization of the last unit. Current strategies for conversion of river formations do not observe any easement bands along the waterways. The orchards of *Bixa orellana*, *Mangifera indica* and *Anacardium occidentale* extend to the banks (photo plate 1).

Photo a. Orchard of Bixa orellana

Photo b. Plantation of Anacardium occidentale

At maturity, it is difficult to distinguish the spectral signature of these species from those of certain natural species provided that they are preserved. Since 22% of the natural species surveyed have a plantation of cashew trees located on the lower slopes of glacis. In addition, 26.5% and 23.8% of arborists sow the same topographic unit by mango trees and orange trees respectively. The results of the various precision indicators attest to both the good quality training areas and the good correspondence between the classifications and the spatial reality contained in the images. Studies of the occupation of lands are only validated when the Kappa index is between 50% and 75% (Oloukoi *et al.,* 2006). In this research, this index is 72%, 79%, 82% and 90% respectively for 2018, 1990, 2000 and 2010 images. These values confirm the validity of the supervised classification of the processed images. In 2015, (Ouédraogo *et al.,* 2015) processed the 2002 and 2011 images and obtained Kappa coefficients of 0.94 and 0.81 respectively. The values obtained by (Bissour *et al.,* 2016) are also within this range. They are in the order of 0.69 and 0.92 for 1984 and 2014. For (Soro *et al.,* 2014) the results of an image analysis are exploitable and good when the value of the Kappa index is greater than 50%. For this coefficient, they obtained values of 85.84% for 1986 and 88% for 2002. They then concluded the statistical acceptability of these results. These different conclusions are similar to those of the present study as they are also above the 50% threshold for the Kappa index.

Changes in land use from 1990 to 2018 in the municipality of Kangala

The processing of the 1990, 2000, 2010 and 2018 Landsat images resulted in land use maps (Figure 2). They illustrate quantitatively and spatially the surface conditions observed in the municipality of Kangala during the period considered. The treatment has also made it possible to discriminate against six classes of occupation which are: water points, river formations, savannas, orchards, fields and bare or eroded areas. Land use or land cover maps (Figure 2) have presented different configuration belong years. Indeed, in 1990 the savanna was representative throughout the area of the village spotted with fields. It dominated the other classes by occupying 33,317.58 ha or 63.76% of the total area of the municipality. It is closely followed by fields with a proportion of 9,703.63 ha or 18.57%. Riparian formation represents 4.76%; orchards 10.68%. At this date, units occupying a marginal area, are eroded or bare areas and bodies of water. These units account for 2% and 0.23% respectively (Table 5). The farming systems were characterized by self-sufficiency, less mechanized and using little chemical fertilizer, pesticide and herbicide in the commune of Kangala. The main speculations were millet, sorghum, maize and cotton, grown by 28.8%, 35.3%, 11.8% and 24.1% of farmers respectively. Agriculture, of extensive type used daba or hoe as the main tools for sowing and ploughing with nearly 2.3% of the population surveyed having a pair of oxen for traction. Also, 14.65% of the farmers had an orchard of orange trees and mango trees rarely exceeding an area of one hectare. As for the cashew nut, it existed in isolated feet before taking the form of plantations during the 1990s.This physiognomy described above and characterized was modified in 2000 since, from the center to the south, the agricultural spaces took the upper hand on the savannahs. At that time, the savannas still dominate with 29,583.28 ha or 56.61% of the communal territory. The fields cover 27.48% of the commune followed by orchards which are at 10.34%. Moreover, river formations, bare areas, water points occupy respectively 3.11%; 2.17% and 0.29%. From 1990 to 2000, farmers who produced only cereals accounted for 1.3% of the population while 63.4% produced cereals and cotton and 25.2% practised cereals and arboriculture.

Table 1. Confusion matrix of Landsat image of 1990

Land use classes	Bare / eroded areas	Fields	Orchards	Savannas	River formations	Water bodies
Bare / eroded areas	96.98	0	4.29	0	0	1.64
Fields	1.03	97.84	1.54	0.08	2.01	0
Orchards	1.45	0.56	75.91	1.69	4.35	0
Savannas	0.54	1.6	6.71	92.84	42.56	9.84
Riparianvegetations	0	0	11.55	5.39	51.07	1.64
Water bodies	0	0	0	0	0	86.89
Total	100	100	100	100	100	100
Kappa index	0.79					
Overall occuracy	83.28 %					

Table 2. Confusion matrix of Landsat image of 2000

Land use classes	Water bodies	Bare / eroded areas	Fields	Orchards	Savannas	River formations
Water bodies	94.38	0.57	0	0	0	0
Bare / eroded areas	4.69	98.65	1.81	0	6.45	1.83
Fields	0	0.,11	90.1	8.04	1.51	0.46
Orchards	0	0	3.34	81.01	0.7	4.98
Savannas	0	0.57	4.75	5.47	70.8	16.93
Riparian vegetation	0.94	0.11	0	5.47	20.54	75.8
Total	100	100	100	100	100	100
Kappa index	0 .82					
Overall occuracy	86.38 %					

Table 3. Confusion matrix of Landsat image of 2010

Land use classes	Water bodies	Bare /eroded areas	Fields	Orchards	Savannas	River formations
Water bodies	98.15	2.15	0	0	0	0
Bare / eroded areas	1.16	97.37	0	0	0,22	0
Fields	0	0	97.2	0.75	0.17	0.54
Orchards	0	0	0.9	91.12	0.25	2.54
Savannas	0.69	0.48	1.9	7.4	85.96	12.73
Riparian vegetation	0	0	0	0.72	13.39	84.2
Total	100	100	100	100	100	100
Kappa index	0.90					
Overall occuracy	92.59					

Table 4. Confusion matrix of Landsat image of 2018

Land use classes	Water bodies	Bare /eroded areas	Fields	Orchards	Savannas	River formations
Water bodies	81.18	3.8	0	0	0	0
Bare /eroded areas	6.84	92.8	0.18	0.12	1.05	0.11
Fields	0.51	0.59	97.3	1.18	3.72	3.14
Orchards	0.17	0	0	65.18	17.91	20.03
Savannas	9.5	2.8	2.52	16.04	57.33	36.13
Riparian vegetation	1.8	0	0	17.47	20	40.58
Total	100	100	100	100	100	100
Kappa index	0.72					
Overall occuracy	77.79 %					

Table 5. Etat de l'occupation des terres en 1990, 2000, 2010 et en 2018

Land use classes	1990 areas		2000 areas		2010 areas		2018 areas	
	Ha	%	Ha	%	Ha	%	Ha	%
Fields	9703.63	18.57	14360.40	27.48	17852.48	34.16	11588.80	22.18
Riparian vegetations	2489.67	4.76	1626.31	3.11	1457.34	2.79	1159.09	2.22
Water bodies	120.57	0.23	149.22	0.29	6.84	0.01	10.57	0.02
Savannas	33317.58	63.76	29583.28	56.61	24743.33	47.35	20974.09	40.14
Orchards	5579.53	10.68	5401.99	10.34	7567.71	14.48	18456.48	35.32
Bare / eroded areas	1044.08	2.00	1133.86	2.17	627.35	1.20	66.05	0.13

This situation is linked to the advent and development of animal traction not only but also to the intensificationof cotton cultivation. In 2010, fields and orchards mark the physiognomy of the communal landscape especially in the southern part unlike the north which is sufficiently savanicole. This observation can be characterized by observing the data in Table 5. The artificialized zones consisting of fields (34.16%) and orchards (14.48%), account for 48.64% of the commune against 50.14% for river formations (2.79%) and savannas (47.35%). From 2000 to 2010, almost 49.6% of farmers produced only cereals and cotton, compared to 50.4% of producers who used to combine fruit and cereal production. In 2018, the landscape of the municipality of Kangala is dominated by fields and orchards that colonize savannas and river formations. Agricultural areas occupied 11,588.80 ha, or 22.18% of the commune. They were accompanied by orchards with an area of 18,456.48 or 35.32%. The two anthropized areas account for 67.50% of the communal area. Savannas occupied 40.14% or 20,974.09 ha. In addition, riparian formations, water bodies and eroded areas took 2.22% and 0.02% and 0.13% respectively. In general, from 1990 to 2010, natural formations including savannas and river formations dominate the physiognomy of the commune of Kangala. On the other hand, starting in 2010, artificialization took precedence over these two occupation classes. This new dynamic of land use is linked to the renewed interest in arboriculture, in particular the Western Anacardium plantations. A similar study was carried out by (Juliev *et al.,* 2019) in Bostanlik, Uzbekistan. These authors also used Landsat TM/ETM+ images from 1989 and 2017.

Table 6. Land cover transition matrix in ha between 1990 and 2018

2018 1990	Fields	River formations	Water bodies	Savannas	Orchards	Bare/eroded area	Total 2018
Fields	2382.23	469.06	36.99	7274.92	1223.80	201.80	11588.78
River formations	91.65	190.11	1.02	755.41	118.71	2.18	1159.09
Water bodies	0.61	0.18	2.25	6.43	0.29	0.81	10.57
Savannas	3123.28	1133.25	62.09	14131.81	2188.78	334.87	20974.09
Orchards	4105.85	697.00	18.23	11100.82	2046.92	487.67	18456.48
Bare/eroded area	0	0.7	0	48.20	1.03	16.75	66.05
Total 1990	9703.63	2489.67	120.57	33317.58	5579.53	1044.08	52255.06

Table 7. Average annual growth of occupancy units 1990-2018

Land use/cover classes	1990-2000	2000-2010	2010-2018	1990-2018
Fields	3.92	2.18	-5.40	0.63
Riparian vegetation	-4.26	-1.10	-2.86	-2.73
Water bodies	2.13	-30.83	5.44	-8.69
Savannas	-1.19	-1.79	-2.07	-1.65
Orchards	-0.32	3.37	11.14	4.27
Bare/eroded area	0.82	-5.92	-28.14	-9.86

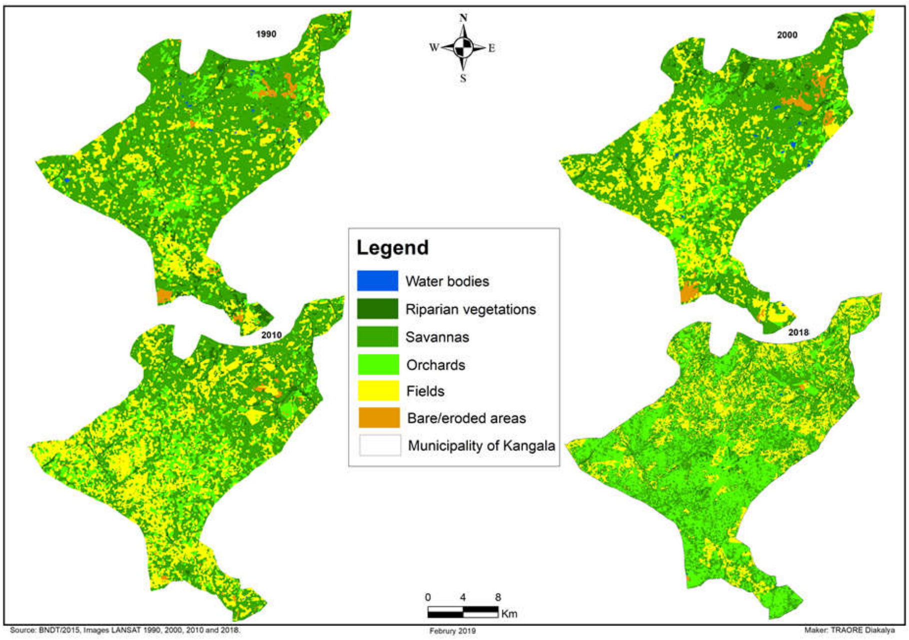

Figure 2. Trends in land use in the municipality of Kangala, 1990 to 2018

They discriminated against six classes: snow cover, bare/rocky soil, forest, water bodies, residential areas and agricultural areas. The results showed a decrease in snow cover and bare soil while classes of forests, agricultural areas and agglomerations increased. This is justified by the implementation of projects to protect flora and fauna, but also by reforestation policies. This forest dynamic is contrary to that of the commune of Kangala where the savannas have begun a continuous decline since 1990 and do not know any management policy. For (Liu *et al.,* 2009) forestland decreased, however an increase was observed in grasslands, shrubby savannahs and agricultural areas from 1974 to 2000 in Minjiang, China. Forest lost 13.33% of its area and farmland increased by 12.61%. Only the lake or marsh area remained relatively stable while the shrub area and grasslands increased. This trend is linked to the disproportionate use of natural resources. It depends in particular on continuous deforestation and overgrazing, which create a series of ecological problems. In fact, it increases soil erosion and biodiversity loss. In the Vishav watershed, dense forest has increased from 16.66% in 1990 to 12.14% in 2010 (Nanda *et al.,* 2014). It showed a regressive trend of 2.12% over the study period. These authors agree with the precedents. They link the dynamics of forest resources to the exploitation of timber-energy and construction that accelerate the process of deforestation.

Changes in land use from 1990 to 2018 in the municipality of Kangala

The analysis of the transition matrix (Table 6) reveals that from 1990 to 2018, 36.88% of the communal area, or 19270.07 ha, remained unchanged; this part of the land use classes did not undergo conversion. In fact, the transition matrix showed that 2382.23 ha of fields, 190.11 ha of riparian formations, 14131.81 ha of savannas, 2046.92 ha of orchards, 2.25 ha of water bodies and 16.75 ha of eroded areas remained stable. However, 469.06 ha of riparian formations, 36.99 ha of water body, 7274.92 ha of savannas, 1223.80 ha of orchards and 201.80 ha of bare area were converted into fields. The fields have a total gain of 9206.55 ha, especially since their areas increased from 9703.63 ha in 1990 to 11588.78 ha in 2018. Moreover, the area of orchards which was 5579.53 ha in 1990 reached 18456.48 ha in 2018. The area obtained on the other occupancy units is 16409.56 ha. The fields, the riparian formations, the bodies of water, the savannas, the eroded zones concede respectively 4105.85 ha; 697 ha; 18.23 ha; 11100.82 ha and 487.67 ha to the orchards. The savanna area decreased sharply from 33317.58 ha in 1990 to 209774.09 ha in 2018. This regressive change in savanna area is related to the fact that a part of the unit is converted into fields, river formations, water bodies, orchards and bare areas. In fact, 3123.58 ha; 1133.25 ha; 62.09 ha; 2188.78 ha and 334.87 ha of savannas mutated into fields, river formations, water bodies, orchards and eroded areas respectively. These changes can be explained by the evolution of agrarian systems. Indeed, the municipality of Kangala is part of the practice of subsistence agriculture based on the production of cereals, arboriculture through the cultivation of cotton. Agrarian dynamism was first marked by the revival of cotton farming from 1985 onwards, breaking with the old practices of combining cotton farming with cereals and relegated to the background. Cotton cultivation has been revived thanks to the integration of the sector into the international market economy. During the 1980s 52.66% of the respondents had at least one hectare of cotton, the main objective being to meet economic needs. Between 1990 and 2000, farmers who produced only cereals accounted for 1.3% of the population, while 63.4% produced cereals and cotton and 25.2% cultivated cereals and arboriculture. From 2000 to 2010 and from 2010 to 2018, grain and cotton producers went from 49.6% to 5.9% respectively, compared to 50.4% and 91.1% of fruit and grain producers for the same period. As a result, some producers have abandoned the cultivation of cotton because of the instability of its course and others have increased the acreage of the arboreal spaces or the association between arboriculture and cereals to the detriment of cotton. (Sutter, 2010) concludes that tree-based speculation such as citrus, mango, and especially cashew tree has had a resurgence of interest in varying activities and incomes.

Dynamics of land-use change in the municipality of Kangala

Looking at Table 7, there are two trends for the period 1990-2018: on the one hand, an average progressive dynamic of 4.27% and 0.63% for orchards and fields respectively, and on the other, a regressive dynamic for the other occupation classes. Savannas experienced an average annual decrease of 1.65% and bare areas 9.86%.As for river formations and water points, these units decreased by 2.73% and 8.69% per year. However, agricultural areas decreased sharply between 2010 and 2018. A significant proportion of these areas are converted into orchards. During this period, they recorded a regressive dynamic of 5.40%. This is easily seen by the rate of change in orchards, which went from 3.37% between 2000 and 2010 to 11.14% during the 2010-2018 decade. The results of this section corroborate those of (Ouédraogo *et al.,* 2015) according to which the change rate is negative for occupation classes such as riparian formations (-7.82%), treed steppe (-2.06%) and shrub steppe (1.27%). According to these authors, the changes in land occupancy in the Yakouta basin are due to the installation of the dam in 2011. The development of this structure stimulated agricultural production and led to a decline in shrub steppes. This rate is positive for crops (1.59%), grassy steppe (1.55%), bare soils (3.46%) and water bodies (15.71%). On the other hand, water bodies decreased annually by about 8.69% in the municipality of Kangala. In addition, (Zakari *et al.,* 2018) found in their study area that wooded and shrubby savannas approximately 7% loss. Clear forests and wooded savannas lost 25% of their area between 2009 and 2013, compared to 18% gain for crop mosaic and fallow.

Conclusion

The mapping of the spatio-temporal evolution of land-use mutations, from 1990 to 2018, in the municipality of Kangala revealed a regressive dynamic of savannas, river formations, water points and eroded areas to the benefit of fields and orchards. The maps presented a landscape dominated by continuous savannahs in 1990 and 2000. In 2010, the anthropization of natural formations was manifested by the spatial expansion of the fields. A significant proportion of these classes were converted to orchards in 2018.

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