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EDITED BY
Sarah Robinson,
University of Giessen, Germany

*CORRESPONDENCE
Ghislain Tontibomma Bambara,
ghislain.bambara@gmail.com

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Dynamics of sudanian pastures: the case of Niassa pastoral zone in Burkina Faso

Ghislain Tontibomma Bambara[1]*, André Kiema[1], Valérie M. C. Bougouma-Yameogo[2], Adama Ouedraogo[3] and Abroulaye Sanfo[3]

[1]Institute of Environment and Agricultural Research, Ouagadougou, Burkina Faso, [2]Institut du Développement Rural, Université Nazi Boni, Bobo-Dioulasso, Burkina Faso, [3]Ministry of Animal and Fisheries Resources, Ouagadougou, Burkina Faso

In Burkina Faso, as in other Sahelian countries, natural pastures are a key element in managing livestock productivity, as they are the main source of feed. This is why, after the droughts of 1970, the government of Burkina Faso created pastoral zones to boost livestock productivity. However, the results of this project remain unsatisfactory. This study therefore aims to assess pastoral resources by analysing the dynamics of pastoral landscapes in the Niassa pastoral zone. To this end, remote sensing and perception surveys of pastoralists were used. From 2000 to 2020, the dynamics of land use shifted away from grazing areas. Indeed, the rate of occupation of cropland rose from 15.35% in 2000 to 39.33% in 2020 and that of bare lands from 2.46% to 7.62% with a decrease of 46.95% in pastureland. This has a negative impact on pasture biomass production and herd management. Thus, 91% of the pastoralists surveyed perceive this dynamic through the low availability in quantity and quality of fodder resources. They believe that herbaceous species of high value to livestock are disappearing. They are *Andropogon gayanus*, *Andropogon ascinodis* and *Vetiveria nigritana* according to respectively to 83%, 80%, and 78% of respondents. These species have been replaced by less valuable or with low biomass production species such as *Senna obtusifolia, Hyptis suaveolens, Loudetia togoensis*, *Microchloa indica and Zornia glochidiata* according respectively to 100%, 90%, 90%, 95%, and 65% of respondents. According to respondents, the endangered woody species are *Pterocarpus erinaceus* (88.4%), *Afzelia africana* (64%), *Bombax costatum* (58%), *Vitex doniana* (55%) and *Khaya senegalensis* (55%). The reduction in pastureland, forage species and forage availability are indicative of the degradation of the pastoral zone. This is leading to a drop in livestock productivity and, consequently, the impoverishment of pastoralists and agropastoralists.

KEYWORDS

pastoral zone, depletion, pastoral resources, pasture dynamics, Burkina Faso

Introduction

Livestock sector is very important for Sahelian countries economy, contributing almost 40% of agricultural Gross Domestic Product (GDP) and 15% of the global GDP (Hiernaux, 2018). Depending on the Sahelian country, livestock products occupy the second or third largest item of income (Hiernaux, 2018). This livestock sector contributes also to food and nutritional security. Indeed, livestock directly produce foodstuffs (meat, milk and by-products, eggs), as well as providing energy for agricultural work (animal traction) and essential inputs (manure) for crop production (Bénagabou et al., 2017). Extensive livestock system accounts for 90% of this production (Ministère des Ressources Animales et Halieutiques, 2022). This system is based essentially on mobility in order to exploit pastoral resources. However, it faces many constraints that undermine its development. These constraints are linked to climatic factors and human activities. Indeed, the adverse effects of climate and antrophic change are hampering the livelihoods of pastoralists through loss of biodiversity, soil degradation and degradation of vegetation cover (Lambin et al., 2001). Droughts have caused huge losses in pastoralist herds with massive and exceptional mobility (Bonnet and Guibert, 2014). Beyond the unpredictable weather, demographic pressure leads to an expansion of crop lands and an anarchic occupation of land, which limits the access of natural resources to pastoralists and agropastoralists through the reduction of pastureland. As the main fodder resource in pastoral systems, vegetation cover is a key element in herd management and survival. That is why the government of Burkina Faso has taken steps since the unfavorable climatic events of the 70s and 80s, in particular the droughts, to create areas favorable to livestock farming, known as "pastoral zones." These zones, created in the southern region of the country, particularly in the Sudanese zone, are ecosystems that offer pastoral resources in quality and quantity. However, over time, these areas are under multiple pressures, both climate-related and anthropogenic, resulting in the depletion of pastoral resources and their undermining. According to Kiema (2015), Ministère des Ressources Animales et Halieutiques (2018) and Sieza et al. (2019), pastoral areas are gradually shrinking due to the increase of croplands and bare soils. The reduction of pasturelands coupled with the decline in fodder supply are challenges for livestock feeding and management. This is why it is so important to analyze the occupation and use of land in pastoral areas in order to propose actions to improve the management of these pastoral resources. The aim of this study is to assess the situation of pastoral resources in the Niassa pastoral zone. Specifically, it involves 1) a diachronic analysis of land use and pastoral resources from 2000 to 2020 and 2) an analysis of the management methods used by stakeholders.

Material and methods

Study area

The pastoral area of Niassa, created in 2000 under Joint Decree No. 2000-37/MRA/AGRI/MEE/MEF/MATS/MEM/MIHU of 21/7/2000, is located east of the Department of Gogo, province of Zoundwéogo [Ministry of Animal Resources (MRA), 2006]. It lies between latitude 11°30 35′ and latitude 11°39′13″ N and longitude 0°47′25″ and longitude 0°52′54″ W. It is bounded on the east and north by Lake Bagré, on the south by the Koulwoko river and on the west by the territories of Samtenga, Yirpala, Kopelin and Nagrigré.

It covers an area of 6,386 ha divided into two (02) separate blocks separated by an agricultural front approximately 7 km wide. The first block covers an area of 4,374 ha and the second block, located to the north, covers an area of 2,012 ha (Figure 1). It is made up, on the one hand, of areas known as "*smallholding*," which are made up of housing, food crops and fodder crops. Each *smallholding* should have a surface area of around 5 hectares for a pastoralist based in the pastoral zone. There is also a pasture area for livestock. The occupancy rate of the total area within the pastoral zone should be no more than 15% for the housing and food crop zone, and at least 85% for the pasture area. To set up in the zone, you need to be a livestock farmer with at least 20 head of cattle and a license.

This zone constitutes a privileged ecosystem to support pastoralists in their quest for quality and quantity of pastoral resources. By creating this pastoral zone, the Country aimed to rationalise access to pastoral resources, to promote the adaptation of pastoralists to the effects of climate change while promoting peaceful cohabitation of agricultural and livestock activities. However, these areas have been depleted over the years due to the lack of fodder supply in terms of quantity and quality, colonization by croplands and landowners' questioning. This undermines the original objectives assigned to them.

Satellite data used

For a study of the dynamics of land use, satellite imagery is an important element for describing and monitoring environmental changes over time and space. This study used Landsat satellite imagery from three (03) years: 2000, 2010 and 2020, i.e., a depth of 20 years. This gives a clear picture of changes in land use and, consequently, changes in vegetation cover.

The following materials and tools have been used:

– Six (06) wet-season satellite images were used at a rate of two images per year. These are Landsat images of October and November selected based on their availability on the site and their quality in the study area. The spatial

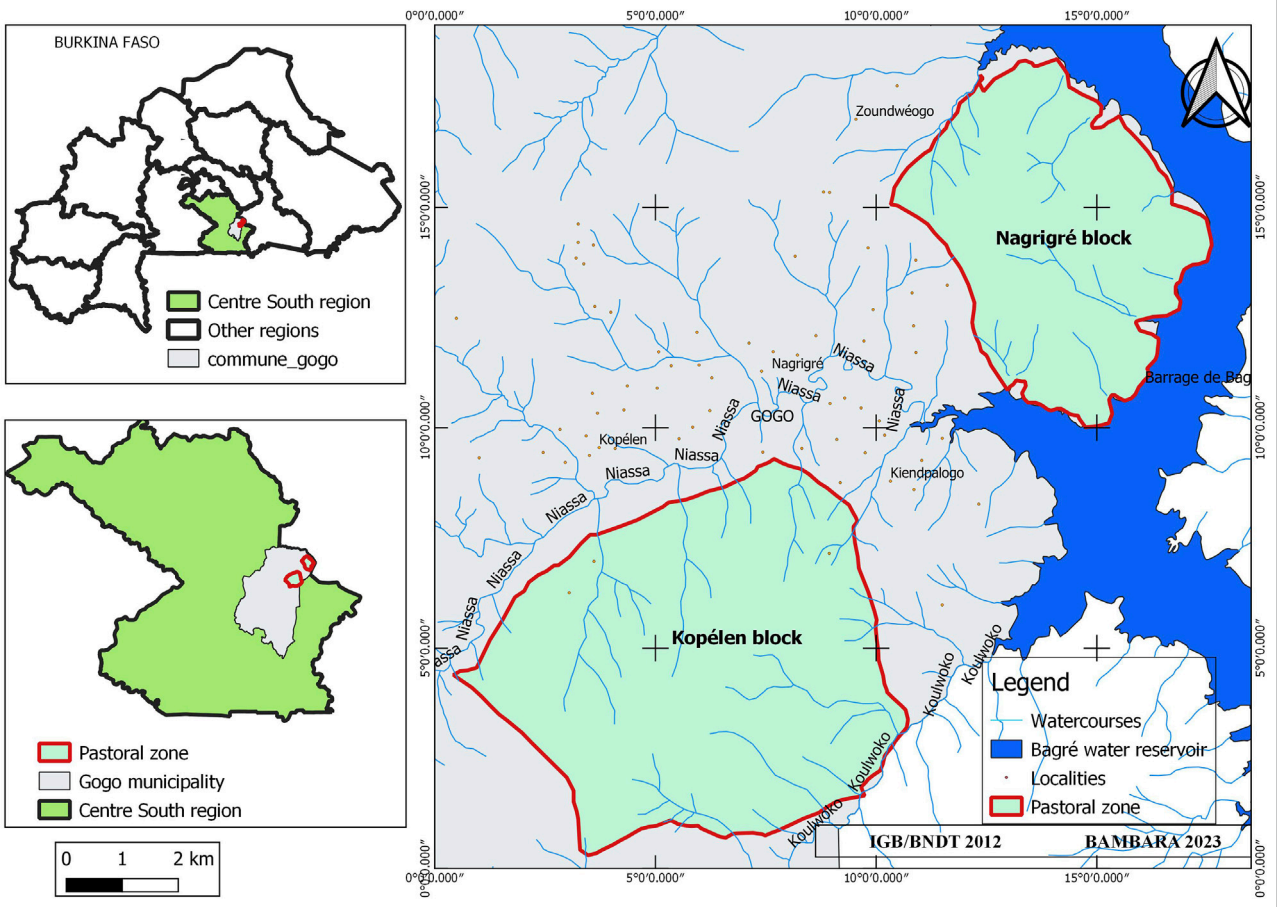

FIGURE 1
Map of the Niassa pastoral zone.

TABLE 1 Characteristics of satellite images.

Parameters	Image type	
	Landsat ETM + image	Description of landsat OLI_TIRS follows
Path/Row	194/052	194/052
Spatial resolution	30 mths	30 m
Format	Geotiff	Geotiff
Projection	WGS 1984 UTM Zone 30N	WGS 1984 UTM Zone 30N
Acquisition Period	October 2000; November 2010; November 2020	
Sources	USGS	USGS

resolution of the images is 30 m. The October and November periods were targeted due to low cloud cover, good vegetation expression and low absence of bushfires. These images come from Landsat ETM+ (Enhanced Thematic Mapper Plus) sensors for the years 2000 and 2010 and OLI_TIRS for the year 2020 (Table 1). They were acquired free of charge from the National Observatory for Sustainable Development (NOSD) through its Division for Capacity Development, Information and Environmental Monitoring (CDIEM). Vector data were also mobilized from the General Directorate of Pasturelands Management (DGEAP) for mappings.

TABLE 2 List of villages selected, and number of households surveyed.

Selected villages and farming hamlets	Number of households		
	Pastoralists	Agropastoralists	Total
Villages bordering the pastoral zone			
Kopelin	6	14	20
Nagrigré	3	17	20
Samtenga	1	14	15
Hamlets in the pastoral zone			
Kopelin zone pastorale	36	4	40
Tansablego	9	2	11
Wapassi	14	2	16
Zomnongo	14	2	16
Mbouta	10	1	11
Sao	18	0	18
Ragordgande	15	3	18
Ragordguibi	9	2	11
Total	**135**	**61**	**196**

Bold values highlights the total number of respondents per stakeholder.

- Garmin 64 S GPS was used to locate the different land-use classes, especially those of the different vegetation types in the field and to validate 60 zone points from image processing in the ground.
- Smartphone with KoBoCollect V1.30.1 application for socio-economic data collection.
- ENVI 5.0 software was used for image classification.
- and ArGis 10.5 software was used to create the 5 km buffer around the pastoral area, map and calculate the areas.

Pastoralists and agropastoralists perception

This component was conducted through a survey in the three (03) villages bordering the pastoral zone as well as in the farming hamlets established in the pastoral zone. These were the villages of Kopelin, Nagrigré and Samtenga. The farming hamlets are Tansablego, Kopelin pastoral zone, Wapassi, Zomnongo, Mbouta, Sao, Ragordgande and Ragordguibi. These villages were chosen based on the following criteria: proximity to the pastoral zone, local people's support for the creation of the zone and their use of pastoral resources. Here, a household is made up of one or more people sharing one or more fields of crops or herds of cattle. Households were selected using a purposive sampling method based on the following criteria: 1) ownership of cattle and small ruminants for livestock farming, 2) consent of the household to be surveyed, 3) at least 30 years of residence in the study area to provide a history of phenomena and changes for pastoral resources since the creation of the pastoral zone in 2000. The survey was conducted in two (02) phases, the first phase took place from 03 April to 01 May 2022 and the second phase from 27 March to 15 April 2023. In some 196 households were surveyed on the basis of consent (Table 2).

It was conducted using an interview guide and a questionnaire through Kobocollect application. They consisted in seeking herders' perceptions of the evolution of pastoral resources in the Niassa pastoral zone over the past 20 years. The aim was to get their opinion on pastoral resource trends. The various data collected from pastoralists and agropastoralists covered 1) the socio-economic and professional characteristics of households, such as level of education, main activity, secondary activity and sources of income; 2) the perception of pastoralists and agropastoralists of changes in natural resources, such as plant species that are becoming extinct or have appeared in the area, and changes over time in fodder and surface water resources. In addition, data on how the area is managed have been collected.

Data processing

Satellite images

The images acquired were processed and analysed using Arcgis 10.5 and Envi 5.0 software. Before proceeding to the

thematic classification of the images, a series of pre-processing operations were carried out to facilitate their exploitation. These are:

- Combining bands to obtain a single multispectral image. Landsat images are designed as individual grey-scale bands in Geotif format. ENVI's Layer Stacking tool was used to combine all the bands into a single multispectral image.
- Enhancing images to improve their appearance and facilitate visual interpretation and analysis of scenes.
- Extraction of the study area from the obtained multispectral images, according to the limits of the study area by the Resize data tool in Basic Tools under ENVI.

The actual processing phase consisted of selecting the test sites, classifying the images, evaluating and validating the classifications, and carrying out the post-classification work. Using ENVI image processing software, the digital image classification process involved choosing the colour composition (453), filling in the *Region Of Interest* (ROI), selecting the test plot samples, describing and filling in the various classes and choosing the classification algorithm. To this end, six (06) land use classes were defined, namely: croplands, bare lands, wooded savannah, shrub savannah, gallery forest and water body. Croplands areas are characterised by the areas sown to annual crops. Bare lands are areas of soil devoid of vegetation (absence of vegetation). Waters bodies, as the name suggests, are areas of water reservoirs such as marshes, ponds, etc., wooded savannahs are characterised by a dominant tree layer with few shrubs and herbaceous cover. Shrub savannahs are characterised by a predominance of shrubs scattered throughout an herbaceous carpet. Gallery forests are riparian belts of trees located along temporary or permanent watercourses. In addition, a sample of 60 points from the various land-use classes in the 2020 image (10 verification points per class) was visited in the ground. This reconnaissance enabled the choice of land-use classes to be reoriented before moving on to classification. It also facilitated visual interpretation and the selection of test sites on the *Region Of Interest* (ROI) images. "*Compute ROI Separability*" was also used to check separability between the different classes. Knowledge of the terrain guided the choice in favour of supervised classification, which consists of applying the same treatment to each pixel, independently of neighbouring pixels. The "*Maximum Likelihood*" algorithm was chosen for image classification. This tool calculates the probability of a pixel belonging to a given class rather than another. Pixels are assigned to the class with the highest probability. Subsequent processing involved filtering the image using the "*sieve*" and "*majority/minority*" tools, to eliminate isolated pixels. To validate the images, the confusion matrix and *Kappa index* (KI) of each image were calculated. Indeed, they are a reliable measure in the evaluation of thematic classifications because it considers both omissions and commission errors. Once the classification was complete, the raster image was vectorised. Vectorisation is the final stage in image processing. It consists of converting the classified images from raster mode to vector mode (polygons) in order to facilitate their management in the GIS analysis software.

Land use dynamics were assessed through a series of transformations. The relationship between the same class on two different dates makes it possible to identify the "stable," "regression" and "progression" zones of that class. It is assumed that **St0** represents the area occupied by the land cover classes at date **t0**, and that **St1** is the area of the land cover classes at date **t1.** To quantify land use class changes, the methodology used by FAO (1996) and Kpédénou et al. (2016) was used. It consisted in calculating the overall rate of change from the following formula:

$$Tg = \left[\frac{(St1 - St0)}{(St0)}\right] * 100$$

With:

- **Tg**: overall rate of change.
- **St0**: area at final date t0;
- **St1**: area at initial date t1;

Perceptions of livestock farmers

The Excel spreadsheet and SPSS version 21 software were used to process and analyse the collected data. As such, the proportions of respondents by question were calculated using SPSS and the tables and figures were produced using Excel.

Results

Socio-economic characteristics of farmers

The herders interviewed belong to two (02) ethnic groups, namely, Fulani (67.27%) and Mossi (32.72%), with 2.3% women and 97.7% men. Natives account for 20% and non-natives 80%, who come from localities in the Centre Nord, Plateau Centrale and Centre regions. Depending on the type of main or secondary activity carried out, there are two main actors: pastoralists who account for 69% of the respondents and agropastoralists 31%.

The age of those interviewed is between 32 and 80 years. The most important age group is between 41 and 50 years. It represents 35.5% of respondents and is followed by the 30–40 age group, which represents 25.5% of respondents (Table 3).

In terms of educational attainment, 50% of respondents attended Koranic school; 27% were able to take literacy

TABLE 3 Age groups, level of education and sources of income of respondents.

Indicators	Percentage (%)
Age group	
[30; 40]	26
[40; 50]	36
[50; 60]	21
[60; 70]	11
[70; +]	6
Level of education	
Koranic school	50
Literacy in local language	27
Primary school	5
Secondary school	1
None	17

TABLE 4 Different sources of income for pastoralists and agropastoralists.

Sources of income	Pastoralists	Agropastoralists
Sale of cattle	100	100
Sale of small ruminants	98	100
Sale of poultry	92	100
Sale of milk	88	2
Sale of agricultural products	3	80
Small-scale trade	6	51
Gold panning	5	20
Sale of donkeys	2	12
Pastoral labour	3	0
Masonry	0	7
Agricultural labour	0	3
Crafts	0	3

courses in Fulfulde or Mooré; 5% reached primary school and very few reached middle school (1%). However, 17% did not have access to any of these types of training (Table 3).

Analysis of Table 4 shows that pastoralists and agropastoralists have several sources of income. Indeed, 100% of pastoralists and agropastoralists sell cattle as a source of income; 100% of agropastoralists and 80% of pastoralists sell small ruminants as a source of income. But the difference is that the sale of milk is much more reserved for pastoralist households (over 80%), whereas agropastoralist households engage in the sale of agricultural products and the small-scale trade.

All the respondents (100%) have cattle (Table 5). Ownership varies with the type of farmer. The analysis of Table 3 shows that agropastoralists have fewer number of animals than pastoralists whatever the type of species. On average, pastoralists have 54 ± 26 cattle, 32 ± 12 sheep and 36 ± 16 goats. Agropastoralists have an average of 10 ± 4 cattle, 25 ± 8 sheep and 15 ± 8 goats.

As far as breeds of livestock are concerned, Fulani zebu is the only breed of cattle owned by farmers. For the other species, Figure 2 shows that several breeds are bred. Mossi goats, which account for 87.2% of goats, are the most popular breed, while Mossi sheep are the most popular breed, accounting for 78% of sheep.

Analysis of Table 6 showing changes in livestock numbers in the zone from 2012 to 2021 shows that the number of animals has increased significantly

Management rules for the pastoral zone

Since the creation of this zone, it has been noted that the stakeholders in charge of technical management have not implemented the project to plan the distribution of the occupation of the zone, as there was no management tool. It was only six (06) years after its creation in 2006 that the management plan and specifications were drawn up. And a management committee has been set up to ensure compliance with the rules laid down in the specifications and the management plan. This observation reveals a shortcoming since its creation, because farmers have settled there without any basic rules being established, without any management plan.

Although management tools have been developed, the herders do not scrupulously respect the management rules governing access to the area and pastoral resources. According to the results of the survey, only the rules laid down for the management of water wells and vaccination pens are respected by the livestock farmers. Respondents were unanimous in stating that use of the area's resources is free and open to all. In fact, 98.8% of those questioned said that they had access to pasture areas, compared with 1.2% who were sceptical, blaming the uncontrolled installation of housing and farms that reduce the pasture area. Cattle tracks are opened to facilitate internal and external livestock movements. However, 57.7% of the farmers interviewed said that these access corridors are not functional, especially in the rainy season when they are obstructed by crop fields.

Most of the farmers interviewed (87.95%) acknowledged the existence of a management committee for the pastoral zone but felt that it did not play its role properly. They pointed to a number of shortcomings of the management committee: 1) the lack of organisation and cohesion between a management committee members, 2) the lack of a framework for discussion with producers, 3) the lack of supervision of the installation of livestock-raising households in the zone, 4) the lack of a

TABLE 5 Average number of species reared by type of livestock farmer.

Number of head per species type of livestock farmer	Cattle	Sheep	Goats
Pastoralists	54 ± 26	32 ± 12	55 ± 16
Agropastoralists	10 ± 4	25 ± 8	15 ± 8

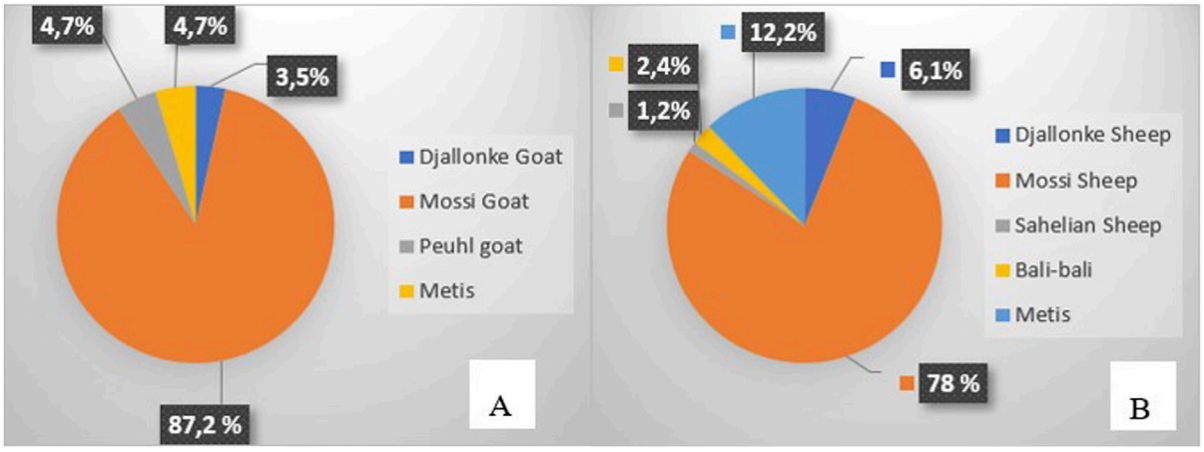

FIGURE 2
Composition goat **(A)** and sheep **(B)** species.

TABLE 6 Livestock numbers in the pastoral zone from 2012 to 2021.

Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Cattle	9,518	9,626	9,736	9,847	9,959	10,072	10,314	10,561	10,814	11,073
Sheep	5,220	5,326	5,435	5,546	5,659	5,774	5,906	6,041	6,179	6,320
Goats	4,029	4,080	4,132	4,185	4,238	4,292	4,498	4,714	4,941	5,179
Donkeys	199	206	213	220	227	234	244	254	264	275

Source: Pastoral zone management service/2022.

mechanism for receiving and installing transiting pastoralists, and 5) the lack of awareness-raising, monitoring and repressive measures. The interviewees felt that all these shortcomings were exacerbated by the lack of firmness and support from the authorities in charge of livestock farming. And secondly, with the advent of terrorism, where members of the management committee and surveillance units are regularly threatened.

Dynamics of the units of land use in the pastoral area

The results of the satellite image processing enabled us to distinguish six (06) land use classes in the Niassa pastoral zone. These are woody savannahs, shrub savannahs, gallery forests, croplands, water bodies and bare land. From analysis of Table 7, the Kappa indices obtained for the three (03) treatments are respectively 0.92 for 2000, 0.97 for 2010 and 0.90 for 2020.

Table 7 shows that the overall accuracies of the confusion matrix are 93%, 97% and 93% respectively for the years 2000, 2010 and 2020. This proves that over 90% of the pixels in the three (03) images were correctly classified. In short, the values of the various supervised classification accuracy indicators obtained for the different images reflect the good quality of the classification results.

Figure 3 and Table 8 present the situation of the units of land use in the pastoral area. According to the reference

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TABLE 7 Confusion matrix for the classification of years 2000, 2010 and 2020.

Year 2000						
Land cover categories	**Cropland**	**Bare lands**	**Wooded savannah**	**Shrubby savannahs**	**Gallery forests**	**Water body**
Cropland	**90**	2	0	3	0	0
Bare lands	2.5	**98**	0	0	0	0
Wooded savannah	0	0	**88**	6	10	0
Shrubby savannahs	7.5	0	5	**91**	0	0
Gallery forests	0	0	7	0	**90**	0
Water body	0	0	0	0	0	**100**
Overall accuracy 93%						
Kappa coefficient 0.92						
Year 2010						
Cropland	**95**	0	0	5	0	0
Bare lands	0	**100**	0	0	0	0
Wooded savannah	0	0	**92**	0	3	0
Shrubby savannahs	5	0	6	**95**	0	0
Gallery forests	0	0	2	0	**97**	0
Water body	0	0	0	0	0	**100**
Overall accuracy 97%						
Kappa coefficient 0.97						
Year 2020						
Cropland	**90**	0	0	3	0	0
Bare lands	2.5	**100**	0	0	0	0
Wooded savannah	0	0	**88**	6	10	0
Shrubby savannahs	7.5	0	5	**91**	0	0
Gallery forests	0	0	7	0	**90**	0
Water body	0	0	0	0	0	**100**
Overall accuracy 93%						
Kappa coefficient 0.90						

Bold values highlights the value of the confusion matrix for the image of the same land cover class.

period of 2000, the pastoral area is dominated by the woody savannah, the cultivation areas, and the gallery forest. These three (03) classes occupied more than 86% of the study area with 54.68% for woody savannahs; 15.54% for forest galleries and 15.35% for cropland. While in 2010, it was dominated by croplands with 36.01% followed by woody savannahs (28.44%) and forest galleries (17.39%). Likewise, in 2020, these units maintained the same ranks of occupancy in varying proportions.

Assessment of the evolution of land use units

The analysis in Table 9 shows that:

- Croplands classes increased significantly by 134% over the period 2000-2010. Similarly, over the period 2010–2020, they increased but less than in the first period (9%). Overall,

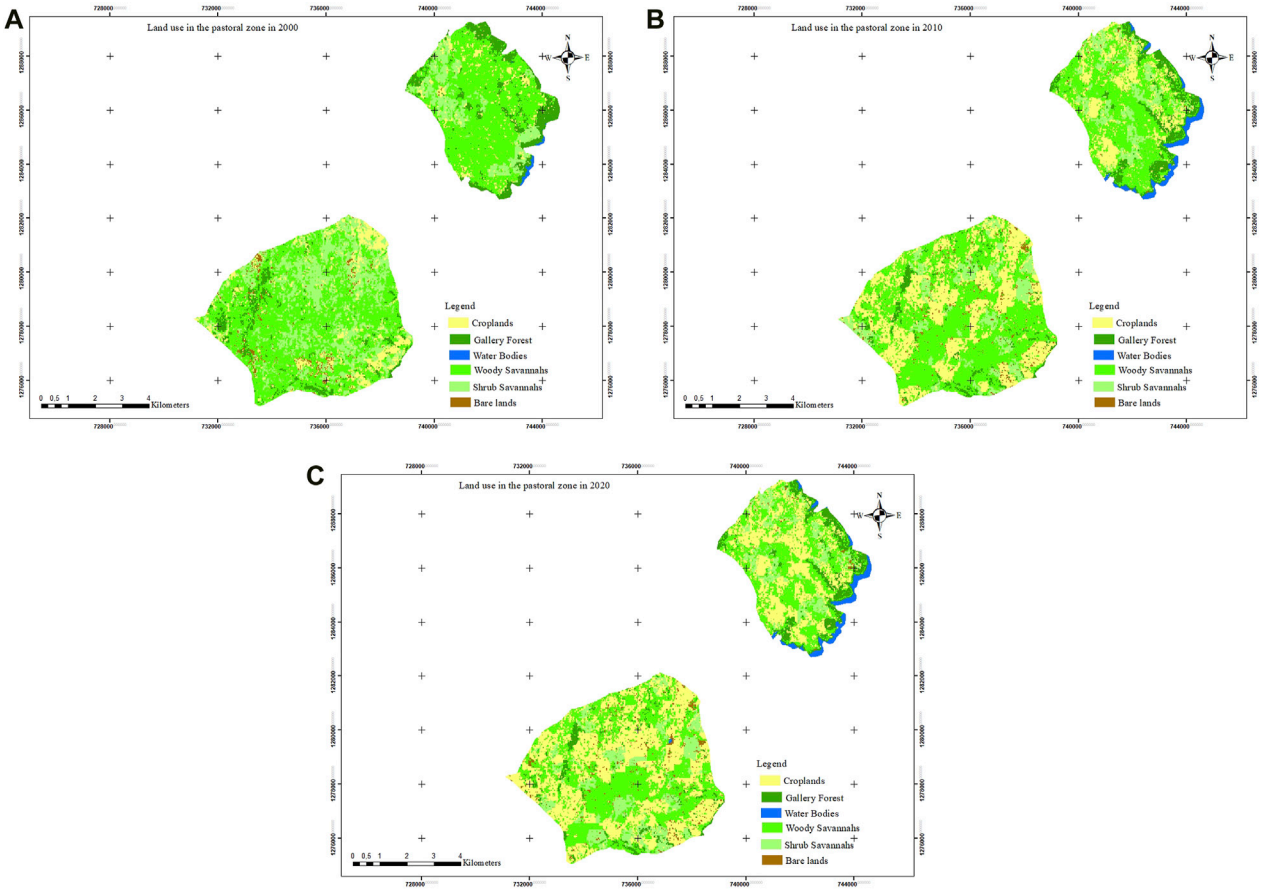

FIGURE 3
Land use situation in 2000 **(A)**, 2010 **(B)** and 2020 **(C)**.

TABLE 8 Situation of land-use units in the pastoral zone.

Year	2000		2010		2020	
Unit	Area (ha)	Propor (%)	Area (ha)	Propor (%)	Area (ha)	Propor (%)
Copland	967.96	15.35	2266.16	36.01	2472.02	39.33
Bare lands	155.02	2.46	385.54	6.13	479.21	7.62
Woody Savannah	3448.59	54.68	1790.00	28.44	1579.30	25.13
Shrub Savannah	746.67	11.84	735.17	11.68	808.58	12.87
Gallery Forest	980.36	15.54	1094.77	17.39	909.91	14.48
Water Body	8.22	0.13	21.83	0.35	35.81	0.57

Propor (%): proportion %.

they have more than doubled their initial surface area, with an increase of 155%.

- Bare lands experienced the same evolutionary trends as croplands classes; an increase of 149% over the period 2000–2010, 24% over the period 2010–2020 which is not insignificant and 209% over the whole period.
- The classes of the water bodies increased by 166% of their area in the period 2000–2010, by 64% in the period 2010–2020 and 336% over the period 2000–2020.
- the woody Savannah classes declined over all periods. Their area decreased by 48% in the first period, by 12% in the second and 54% over the whole period.

TABLE 9 Rate (%) of change in land-use units in the pastoral zone.

Units	Cropland	Bare land	Water body	Woody savannah	Shrub savannah	Gallery forest
Period						
2000–2010	134.12	148.70	165.52	−48.09	−1.54	11.67
2010–2020	9.08	24.30	64.01	−11.77	9.99	−16.89
2000–2020	155.38	209.13	335.50	−54.20	8.29	−7.19

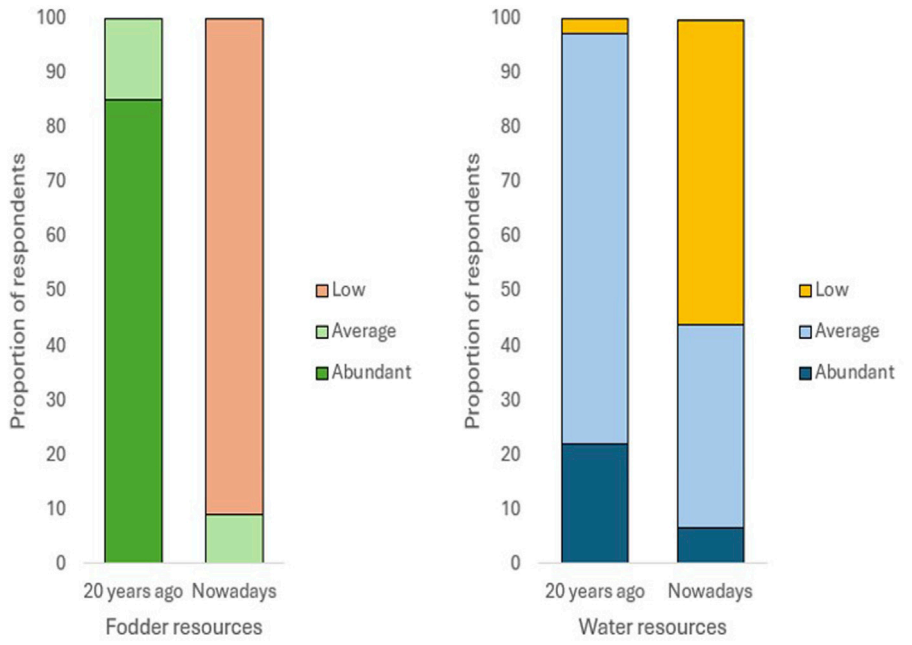

FIGURE 4
Farmers' perception of the dynamics of fodder and water resources.

- Shrub savannahs experienced a slight decline of 2% over the period 2000–2010 and an increase of 10% over the period 2010–2020. Overall, they increased by 8%.
- The evolution of gallery forests has been unstable. As a result, they increased by 11.67% over the period 2000–2010 and decreased by 17% over the period 2010–2020. But overall, they decreased by 7% over the period 2000–2020.

Livestock farmers' perceptions for natural resources trends

Trends in forage resources

The pastoralists interviewed are unanimous that from 1 year to the next, the pastoral resources are decreasing. Indeed, 85% of them believe that 20 years ago fodder resources were abundant, but today they are totally depleted (Figure 4). Almost all farmers (91%) consider that the availability of fodder resources has become low or very low. In short, all those respondents stated that they had observed a significant drop in the productivity of these resources, to the point where livestock' feed requirements were no longer covered.

Regarding the evolution of surface water availability, the majority of respondents (76%) say that 20 years ago water resources were moderately available and 22% say they were abundant. However, opinions are divided on the availability of water resources today. Indeed, 56% of them believe that the availability of water resources has become low and 37% believe that it is average, while a minority (6%) are convinced of its abundance (Figure 4).

Dynamics of plant diversity

Endangered plant species in the pastoral zone

The results revealed a change in the plant diversity of the pastoral area. Many palatable, medicinal, or edible plant species

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TABLE 10 Endangered or extinct plant species in the grazing area.

Herbaceous		Woody	
Species	CP (%)	Species	CP (%)
Andropogon gayanus	83	*Pterocarpus erinaceus* Poir.	88
Andropogon ascinodis C.B.Clarke	80	*Afzelia africana* Sm. & Pers.	64
Vetiveria nigritana Benth. Stapf	78	*Bombax costatum* PROTA	58
Penissetum pedicellatum	50	*Vitex doniana* PROTA	55
Hyparrhenia involucrata Stapf	42	*Khaya senegalensis*	55
Sporobolus pyramidalis P.Beauv.	42	*Anogetissae leiocarpus* DC	28
Rottboellia exaltata L.f.	22	*Securidaca longepedunculata* Fresen	27

CP, citation percentage.

are rare, and others have disappeared entirely along the way. This phenomenon was observed by farmers 15.7 ± 3.8 years ago in the pastoral area. These are mainly herbaceous and woody plants which are important for livestock feeding in all seasons and during the pastoral lean season. The herbaceous forage species in danger of disappearing, in terms of frequency of mention by respondents, are: *Andropogon gayanus* (83%), *Andropogon ascinodis* C.B.Clarke (80%), *Vetiveria nigritana* Benth. Stapf (78%), *Penissetum pedicellatum* (50%), *Hyparrhenia involucrata* Stapf (42), *Sporobolus pyramidalis* P.Beauv., (42%), *Rottboellia exaltata* L.f. (22%). Most woody species affected by this phenomenon are: *Pterocarpus erinaceus* Poir. (88.4%), *Afzelia africana* Sm. & Pers. (64%) Bombax costatum (PROTA) (58%), *Vitex donania* (PROTA) (55%), *Khaya senegalensis* (55%), *Anogeissus leiocarpus* (DC) (28%), and *Securidaca longepedunculata* (Fresen) (27%) (Table 10). For these respondents, they must travel more than 100 km to obtain these species for livestock or travel through conservation areas such as forests. The scarcity of palatable species has a negative impact on livestock production. Visiting protected forests also poses a conservation problem and is an offence that leads to conflicts between forest guards and pastoralists.

Plant species that have appeared in the pastoral zone

Table 11 gives an overview of the plant species that have appeared in the pastoral zone according to the opinion of the farmers. Nearly all respondents (96.5%) deplored the invasion of the area by plant species that are not or are not eaten very well by livestock. Among these invasive species are *Senna obtusifolia* (L) (100%) and *Hyptis suaveolens* (L) (90%), which would not be very appetising to livestock according to respondents. In addition to these two species, they reported cases of *Loudetia togoensis* (95%), *Microchloa indica* (85%), *Zornia glochidiata* (95%), *Sida acuta* (45%), and *Cymbopogon schoenanthus* (45%).

TABLE 11 Plant species that have appeared in the pastoral zone.

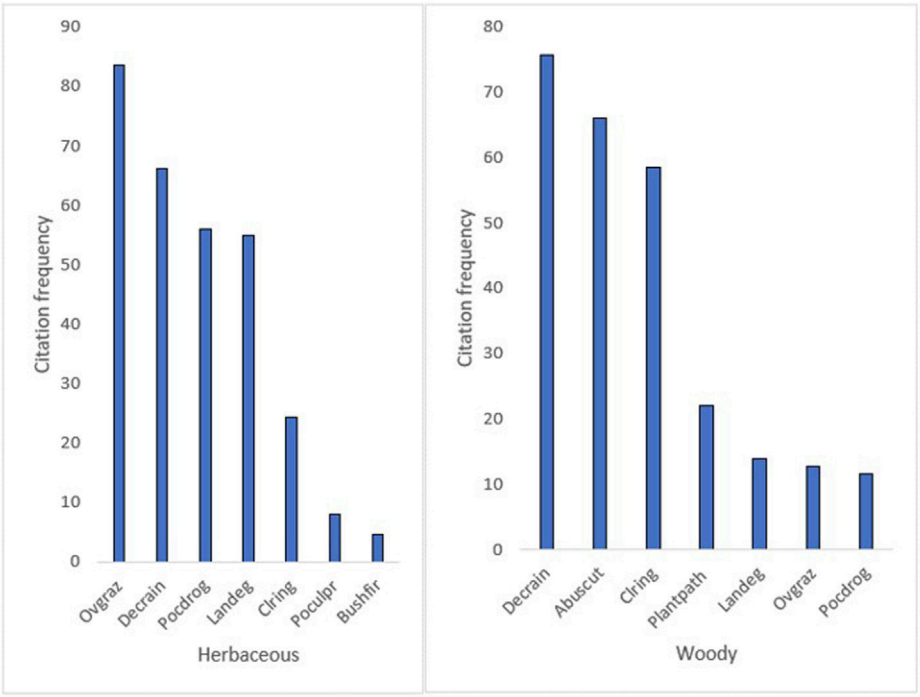
Species	Family	Citation frequency (%)
Senna obtusifolia	Fabaceae	100
Sida acuta	Malvaceae	60
Cymbopogon schoenanthus	Poaceae	45
Hyptis suaveolens	Lamiaceae	90
Zornia glochidiata	Fabaceae	95
Microchloa indica	Poaceae	85
Loudetia togoensis	Poaceae	95

As for the way in which they spread, they state that these species were spread by zoochory according to 87.9% of respondents, by soil impoverishment according to 61.6% of respondents, by their non-palatability by livestock (56%), by hydrochory (11.6%) and by anemochoria (9.3%). In fact, some of these species like *Senna obtusifolia* (L) and *Hyptis suaveolens* (L) have developed thanks livestock refusals. This action allowed them to have a capacity for rapid growth compared to other species. In addition, they have high germination power and abundant soil seed stock. These species appear as soon as it first rains and, because they are not grazed, they gain the upper hand over other species by inhibiting their growth.

As far as woody fodder species appearing in the area are concerned, pastoralists have noted the presence of *Acacia seyal* (Del) and of *Acacia nilotica* (L.)

Factors in the dynamics of fodder resources

Figure 5 shows the various factors causing the degradation of fodder resources. Thus, The causes of the disappearance of forage or utility species are many and vary from one species to another. As such, pastoralists and agropastoralists blame the following



Ovgraz: Overgrazing; **Decrain:** Decrease in rainfall; **Clring:** Clearing; **Pocdrog:** Pockets of drought; **Poculpr:** Poor cultivation practices; **Landeg:** Land degradation; **Bushfir:** Bush fires; **Abuscut:** Abusive wood cutting; **Plantpath:** Plant pathology.

FIGURE 5
Factors in the degradation of fodder resources.

factors for the disappearance or drastic decline of the appetized herbaceous fodder species. According to 83.7% of respondents, this was overgrazing. The reduction in grazing areas and fodder supply leads to a rush into residual fodder, thus creating an overload of pasture. This does not allow rapid regeneration of appetized fodder species due to the intense rhythm of the pasture but favours the development of non-appetized species. As a result, there is a gradual decline of appetite species and sometimes degradation of soil and vegetation cover with the appearance of bare soil as a result of settlement. They also mentioned the fall in rainfall (66.3%) and pockets of drought (55%) that hinder the development and growth of fodder species during the rainy season, hence the decrease in fodder supply in the dry season. Also, land clearance (24.4%), poor agricultural practices (8.1%) and bush fires (4.7%) contribute to the scarcity of fodder species. For them, the lack of land is the cause of the decrease in the rainy season pastures, which leads to overcrowding in non-agricultural areas. As regards poor agricultural practices, it is mainly the use of herbicides that no longer favour the exploitation of post-harvest weeds. They report that bushfires have become rare, but as soon as they occur, the damage is enormous in terms of residual forage losses in the dry season.

In terms of the disappearance or low presence of appetized or utilitarian woody fodder, farmers blamed the following factors: the decrease in rainfall, the abusive wood cutting, the phytopathology, overgrazing, and the pockets of drought respectively from 75.8%, 66.1%, 22.1%, 12.8% and 11.6% of respondents. Four (04) factors emerge from the analysis of the situation as being the most implicated: overgrazing, reduced rainfall, pockets of drought and abusive wood cutting.

Discussion

Dynamics of land use in the pastoral area

The rates of change show a gradual trend for cropland units of bare lands and water bodies over both periods. The increase in the areas of croplands and bare lands in pastoral areas has been observed by many authors Kima et al. (2016) have observed a decline in grazable areas in favor of croplands and bare lands, in the province of Boulgou; Bambara (2019) has also observed the same trends in the progression of cultivable areas and bare lands in the pastoral area of Sidéradougou and Nouhao. The increase in croplands in pastoral areas is due to the failure to comply with the

specification and the development and management plan for the pastoral zone. Indeed, the specification allows each farmer in the pastoral area to exploit up to 5 ha, i.e. 1 ha for his habitat, 1.5 ha for croplands, 1.5 ha for forage crops and 1 ha for fallow land. In general, the gradual trend in cropland units could be explained by the increased need for arable land to meet the high food demand due to the population explosion. In fact, the authorisation and lack of control over the installation of pastoral households has led to an increase in the number and size of households, either through the installation of new households or the creation of households from former households. The increase in the size of the population in the pastoral zone will lead to an increase in the area of housing and arable land for food. In addition, the failure to comply with the specifications has led to the area being coveted by landowners who have set up crop fields. This high demand for land leads to a reduction in the area of pasture by deforestation of the units of woody savannahs, shrub savannahs and galleries forests. Indeed, the work of Powell (2004) showed that the increase in the rate of population has influenced the area of croplands which are growing at the same rate as that of human population, i.e., about 3% per year, and with a slight intensification. As a result, this demographic pressure has led to a high demand for arable land to meet the food needs of the population at the expense of pastures (Kadéba et al., 2019; Dixon et al., 2019). This is consistent with the work of Thierry et al. (2018) in northwestern Benin which explains the high demand for cultivable land and buildings due to the increase in population (Tankoano et al., 2016). The deforestation of these areas allows new fertile land to be taken advantage of and thus increases agricultural production. For some authors, the lack of arable land on the outskirts of pastoral areas and the fertilization of this land by animal excretion could be one of the reasons for its invasion by farmers. As a result, parks or pastoral areas are under anthropogenic pressure to find better land for agricultural activities (Gomgnimbou et al., 2010; Amegnaglo et al., 2019; Bambara, 2019; Sieza et al., 2019). The increase in croplands in and around pastoral areas is one of the causes of conflict between farmers and herders during the rainy seasons because cropland damage by livestock is recurrent. The areas of pasture are fragmented and scattered between cropland, which are becoming difficult to access, and herd surveillance must be very active. Thus, Turner et al. (2016) pointed out that changes in grazing land in cropland often have implications for the community land tenure regime that limits grazing rights. The reverse in turn leaves less productive poor land with bare soils (Schlecht et al., 2006; Hiernaux and Assouma, 2020).

Although cropland can make a significant contribution to livestock feed during the dry season through the use of agricultural by-products (tops, straw, bran) by livestock (Hiernaux et al., 2009; Djohy et al., 2023). The occupation of pastures by fields in the rainy season can lead to overgrazing.

In addition to the high anthropogenic pressure on the vegetation cover, the effects of climatic hazards such as droughts and reduced rainfall would result in the mortality of certain woody and herbaceous species (Kosmowski et al., 2015; Kabore et al., 2019).

The extension of bare land in the area could be explained by poor practices, overgrazing, logging, mining, and the practice of bushfires in a context of population pressure. Many studies point to poor farming practices. Indeed, shortening or absence of set-aside times, slash-and-burn agriculture, overgrazing, and selective logging would account for 70% of land degradation (MRA, 2006; Gomgnimbou et al., 2010; Bambara, 2019; Kadéba et al., 2019). In addition, the combination of reduced and fragmented pastureland results in low pasture production, including animal overload at pastoral interstices during the rainy season. This overgrazing is responsible for the degradation of the pastures through the appearance of low-production and unbred species as well as bare soil. Furthermore, any changes in land use inevitably led to a decline in biodiversity in recent decades (Foley et al., 2005), which may explain the reduction or disappearance of some high-value forage trees. For example, agriculture is responsible for about 80% of deforestation worldwide (Kissinger et al., 2012).

The increase in the units of the water bodies could be explained by the development of the Bagré reservoir and hydraulic infrastructure (02 *boulis*) in the pastoral zone.

Perception of natural resource dynamics

Pastoralists said that pastoral resources have been degraded over the years. This degradation is reflected not only in the low availability of fodder resources but also in the poor quality of pastures. As a result, certain woody and herbaceous species of high importance for livestock and human activities, such as *Pterocarpus erinaceus* (PROTA), *Afzelia africana* (SM), *Andropogon gayanus* (Kunth), *Andropogon ascinodis* (C.B.Clarke) *Mitragyna inermis* (WILLD), *Bombax costatum* (PROTA), *Strophantus sarmentosus* (DC), *Vitex doniana (PROTA*) are on the verge of disappearing, leaving room for other less species importance such as *Senna tora* (L), *Hyptis suaveolens* (L), *Microchloa indica*. The same observation was made by Sarr et al. (2013), who found that species such as *Pterocarpus erinaceus* and *Bombax costatum* are threatened with extinction because they are overexploited. Djohy et al. (2022) have added that floristic diversity is threatened by the loss of several plant species. This is said to be due to the high anthropogenisation of the pastoral zone, pruning and climate factors. The pastoral zone, which is a government estate, has not been exploited in accordance with its development and management plan and its specifications. As a result, other non-pastoral activities have proliferated in the area, such as gold panning, charcoal production, timber exploitation and the expansion of fields. In addition, the increase in the number of animals and the lack of control over the settlement

of pastoralists are contributing to the degradation of pastoral resources through over-exploitation. When the zone was created in 2000, the number of livestock expected to use the area was far exceeded, and now there are more than 10,000 livestock units. For pastoralists, several factors are behind this degradation. These include drought, logging and artisanal gold mining, overgrazing and poor farming practices. The decline in forage and woody species is a result of human activities and the decline in rainfall. These results are consistent with those of Abdou et al (2020) which reported the degradation of fodder availability and the proliferation of unpalatable species such as *Sida cordifolia* and *Cassia mimosoides* that hinder proper development of some grasses. They also blamed insufficient rain and expanding croplands. Also, the work carried out by Coulibaly et al. (2021) in the commune of Diéma in Mali, highlighted the disappearance of *Andropogon gayanus, Dactyloctenium aegyptium and Brachiaria sp*. on the routes as a result of climate change.

Beyond the anthropogenic factors that lead to the degradation of pastures, the effects of climate change also contribute to the loss of fodder species. Fodder supply of rangelands has declined drastically in recent years due to the effect of climate change, pressure from human activities and reduced rainfall (Kanembou et al., 2009; Amegnaglo et al., 2019; Abdou et al., 2020; Djohy et al., 2022).

In fact, overgrazing, poor farming practices and selective logging lead to a degradation of the pastures, and this is reflected in a reduction in forage phytomass, in the pastoral value of the pastures. When the pasture is selective, it does not allow the renewal of grazed species when it is intense. This leads to the proliferation of unbred species by livestock and the reduction or disappearance of palatable species (Botoni, 2003; Anthelme et al., 2006; Bambara, 2010).

Conclusion

The processing of satellite images from the years 2000, 2010 and 2020 made it possible to analyse the dynamics of the land occupancy units in Niassa pastoral area. The results show that croplands and bare lands increased between 2000 and 2020 in favour of the occupation units of the woody savannas, shrub savannas and galleries forests. The reduction in the area of savannahs and forest galleries, which are areas for grazing, leads to a decrease in pastures biomass production and an overgrazing. Overgrazing results in slow renewal or lack of renewal of pasture during the rainy season, which leads to a decrease in fodder production and quality. The causes of the change in units of occupancy are linked to climatic factors and anthropogenic activities that are incompatible with the sustainable management of natural resources. Surveys of farmers confirmed the results of satellite image processing. The majority of farmers attest that the fodder resources of the pastoral area are becoming increasingly scarce. They also highlighted the loss of many fodder species that are eaten by livestock. This shows a degradation of pastoral resources that increases the vulnerability of pastoralists and agropastoralists in Niassa pastoral area.

Beyond the degradation of pastoral resources, the use of pastoral areas by other actors poses a major problem of competition over the use of natural resources. This is bound to lead to conflicts between the various users (pastoralists, agropastoralists, and farmers). In view of the important role played by livestock in the national economy, there is a need to step up awareness-raising campaigns on the role of pastoral zone in the national economy and pasture regeneration strategies. In addition, the development and management plan for the pastoral zone must be implemented and the specifications must be respected. In short, the creation of a pastoral zone must be followed by the development of these management tools and should not be the object of any settlement of pastoralists within it to avoid the creation of a town in a pastoral area.

Ethics statement

Specific ethical approval or consent procedures were not required for the surveys we conducted as part of this study. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

GB conceptualized and designed the project; GB and AO collected and analysed the data; GB and AK wrote the paper; AS corrected the paper; VB-Y supervised the activities. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

References

Abdou, H., Adamou Karimou, I., Harouna, B. K., and Zataou, M. T. (2020). Perception du changement climatique des éleveurs et stratégies d'adaptation aux contraintes environnementales: cas de la commune de Filingué au Niger. *Revue d'élevage de médecine vétérinaire des pays tropicaux* 73 (2), 81–90. doi:10.19182/remvt.31873

Amegnaglo, K. B., Dourma, M., Akpavi, S., Akodewou, A., Wala, K., Diwediga, B., et al. (2019). Caractérisation des formations végétales pâturées de la zone guinéenne du Togo: typologie, évaluation de la biomasse, diversité, valeur fourragère et régénération. *Int. J. Biol. Chem. Sci.* 12 (5), 2065. doi:10.4314/ijbcs.v12i5.9

Anthelme, F., Mato, M. W., de Boissieu, D., and Giazzi, F. (2006). Dégradation des ressources végétales au contact des activités humaines et perspectives de conservation dans le massif de l'Aïr (Sahara, Niger). *VertigO - la Rev. électronique Sci. l'environnement* 7 (2). doi:10.4000/vertigo.2224

Bambara, T. G. (2010). *Effet du changement climatique sur la disponibilité des ressources fourragères naturelles*. Bobo-Dioulasso, Burkina Faso: Université Polytechnique de Bobo-Dioulasso, 71. [Mémoire].

Bambara, T. G. (2019). *Suivi des ressources pastorales à l'aide d'imagerie satellitaire au Burkina Faso*. Bobo-Dioulasso, Burkina Faso: Université Nazi Boni. [Mémoire].76p

Bénagabou, O. I., Blanchard, M., Bougouma Yaméogo, V. M., Vayssières, J., Vigne, M., Vall, E., et al. (2017). L'intégration agriculture-élevage améliore-t-elle l'efficience, le recyclage et l'autonomie énergétique brute des exploitations familiales mixtes au Burkina Faso. *Revue d'élevage de médecine vétérinaire des pays tropicaux* 70 (2), 31–41. doi:10.19182/remvt.31479

Bonnet, B., and Guibert, B. (2014). Stratégies d'adaptation aux vulnérabilités du pastoralisme: Trajectoires de familles de pasteurs (1972-2010). *Afr. Contemp.* n° 249 (1), 37–51. doi:10.3917/afco.249.0037

Botoni, H. E. (2003). *Interactions Elevage-Environnement. Dynamique des paysages et évolution des pratiques pastorales dans les fronts pionniers du Sud-Ouest du Burkina Faso*. Montpellier: Université Montpellier III-Paul Valery, 308.

Coulibaly, M., N'diaye, B., Sarra, M., Coulibaly, M., Sanoussi, A., and Timbely, D. (2021). Vulnérabilité des agropasteurs face à la variabilité et au changement climatique dans la Commune rurale de Diéma, Mali. *Afrique Sci.* 18 (5), 66–85. ISSN 1813-548.

Dixon, J., Garrity, D. P., Boffa, J. M., Williams, T. O., Amede, T., Auricht, C., et al. (2019). *Farming systems and food security in Africa: priorities for science and policy under global change*. New York: Routledge.560p

Djohy, G. L., Bouko, B. S., Djohy, G., Dossou, P. J., and Yabi, J. A. (2023). Contribution des résidus de culture à la réduction du déficit alimentaire des troupeaux de ruminants dans l'Ouémé Supérieur au Bénin. *Cah. Agric.* 13 (32). doi:10.1051/cagri/2023007

Djohy, G. L., Bouko, B. S., Dossou, P. J., and Yabi, J. A. (2022). Productivité des pâturages naturels et pratiques de mobilité pastorale dans un contexte de changements climatiques en Afrique de l'Ouest. *Revue Marocaine des Sci. Agronomiques Vétérinaires* 10 (1), 92–105.

Foley, J. A., Defries, R., Asner, G. P., Barford, C., Bonan, G., Carpenter, S. R., et al. (2005). Global consequences of land use. *Science* 309 (6), 570–574. doi:10.1126/science.1111772

Food and Agriculture Organization (FAO) (1996). *Forest resources assessment 1990-Survey tropical forest cover studies of change processes*, 130p. [FAO Forestry Paper].

Gomgnimbou, A., Savadogo, P., Nianogo, A., and Millogo-Rasolodimby, J. (2010). Pratiques agricoles et perceptions paysannes des impacts environnementaux de la coton culture dans la province de la Kompienga (Burkina Faso). *Sci. & Nat.* 7 (2), 165–175. doi:10.4314/scinat.v7i2.59960

Hiernaux, P. (2018). Au Sahel, maintenir l'élevage pastoral pour s'adapter au changement climatique. Le Monde.fr. Available at: https://www.lemonde.fr/afrique/article/2018/11/26/au-sahel-maintenir-l-elevage-pastoral-pour-s-adapter-au-changement-climatique_5388932_3212.html.

Hiernaux, P., and Assouma, M. H. (2020). Adapting pastoral breeding to global changes in West and Central tropical Africa: review of ecological views. *Revue d'élevage de médecine vétérinaire des pays tropicaux* 73 (3), 149–159. doi:10.19182/remvt.31893

Hiernaux, P., Ayantunde, A. A., Kalilou, A., Mougin, É., Gérard, B., Baup, F., et al. (2009). Trends in productivity of crops, fallow and rangelands in Southwest Niger: impact of land use, management and variable rainfall. *J. Hydrology* 375, 65–77. doi:10.1016/j.jhydrol.2009.01.032

Kabore, P. N., Barbier, B., Ouoba, P., Kiema, A., Some, L., and Ouedraogo, A. (2019). Perceptions du changement climatique, impacts environnementaux et stratégies endogènes d'adaptation par les producteurs du Centre-nord du Burkina Faso. *VertigO* 19 (1). doi:10.4000/vertigo.24637

Kadéba, A., Kagambèga, F. W., Soulama, S., Schmidt, M., and Thiombiano, A. (2019). Dynamique des unités de végétation et réponse des espèces ligneuses a la dégradation des terres en zone subsahélienne du Burkina Faso. *Revue Ivoirienne des Sci. Technol.* 34, 144–162.

Kanembou, L., Ambouta, K. J. M., and Waziri, M. M. (2009). Dynamique des aires pastorales dans le Département de Goure: apport de la télédétection et du SIG. *Rev. Sci. l'Environnement l'Université Lomé (Togo)* 005, 119–143.

Kiema, A. (2015). Etude d'évaluation de l'état général des ressources pastorales au Burkina Faso. Initiative mondiale pour un pastoralisme durable. Projet « Strengthening knowledge and capacity to close the policy implementation gap » (CPIG-DANIDA-WAP). *UICN, Burkina Faso*, 129.

Kima, S. A., Okhimamhe, A. A., and Kiema, A. (2016). Assessing the impacts of land use and land cover change on pastoral. Environment and natural resources research. *Can. Cent. Sci. Educ.* 6 (1), 1927–0496. ISSN 1927-0488 E-ISSN. doi:10.5539/enrr.v6n1p110

Kissinger, G., Herold, M., and De Sy, V. (2012). *Drivers of deforestation and forest degradation: a synthesis report for REDD+ policymakers*. Vancouver Canada: Lexeme Consulting. Report No.: 46.

Kosmowski, F., Lalou, R., Sultan, B., Ndiaye, O., Muller, B., Galle, S., et al. (2015). "Observations et perceptions des changements climatiques: analyse comparée dans trois pays d'Afrique de l'Ouest," in *Les sociétés rurales face aux changements climatiques et environnementaux en Afrique de l'Ouest* (UMR 151 IRD/AMU, Marseille, France: IRD), 89–110. doi:10.4000/books.irdeditions.8946

Kpédénou, K. D., Boukpèssi, T., Tanzidani, T., and Tchamie, et K. (2016). Quantification des changements de l'occupation du sol dans la Préfecture de Yoto (Sud-Est Togo) à l'aide de l'imagerie satellitaire Landsat. *Rev. Sci. l'Environnement*, 137–156.

Lambin, E. F., Turner, B. L., Geist, H. J., Agbola, S. B., Angelsen, A., Bruce, J. W., et al. (2001). The causes of land-use and land-cover change moving beyond the myths. *Glob. Environ. Change* 11, 261–269. doi:10.1016/S0959-3780(01)00007-3

Ministère des Ressources Animales et Halieutiques (MRAH) (2018). *Rapport du suivi et de l'évaluation des ressources pastorales pour la campagne pastorale 2018-2019 au Burkina Faso*. Ouagadougou, Burkina Faso: MRAH, 69. [Rapport].

Ministère des Ressources Animales et Halieutiques (MRAH) (2022). *Enquête nationale sur le cheptel (ENC1) 2019 (1)*, 70p. Ouagadougou, Burkina Faso: MRAH. [Rapport].

Ministère des Ressources Animales (MRA) (2006). *Etude diagnostique de la zone pastorale de Niassa*. Ouagadougou, Burkina Faso: MRA, 281. [Rapport].

Powell, J. M. (2014). Feed and manure use in low-N-input and high-N-input dairy cattle production systems. *Environ. Res. Lett.* 9 (11), 115004. doi:10.1088/1748-9326/9/11/115004

Sarr, O., Ngom, D., Bakhoum, A., and Akpo, L. E. (2013). Dynamique du peuplement ligneux dans un parcours agrosylvopastoral du Sénégal. *VertigO - la Rev. électronique Sci. l'environnement* 13 (2). doi:10.4000/vertigo.14067

Schlecht, E., Hiernaux, P., Kadaouré, I., Hülsebusch, C., and Mahler, F. (2006). A spatio-temporal analysis of forage availability and grazing and excretion behaviour of herded and free grazing cattle, sheep, and goats in Western Niger. *Agric. Ecosyst. & Environ.* 113, 226–242. doi:10.1016/j.agee.2005.09.008

Sieza, Y., Gomgnimbou, A. P. K., Serme, I., and Belem, A. (2019). Etude de la variabilité climatique sur la dynamique d'occupation et d'utilisation des terres à des fins agro-pastorales dans la zone sud-soudanienne du Burkina Faso. *Int. J. Biol. Chem. Sci.* 13 (4), 1980–1994. doi:10.4314/ijbcs.v13i4.6

Tankoano, B., Hien, M., Dibi, N. H., Sanon, Z., Akpa, Y. L., Sokeng, V. C. J., et al. (2016). Cartographie de la dynamique du couvert végétal du Parc National des Deux Balé à l'Ouest du Burkina Faso [Mapping land cover dynamics of Deux Balé National Park, Western Burkina Faso]. *Int. J. Innovation Appl. Stud.* 16 (4), 837–846.

Thierry, A., Martin, P., Ismaïla, T. I., and Brice, T. (2018). Modélisation des changements d'occupation des terres en région soudanienne au Nord-Ouest du Benin. *Eur. Sci. J. ESJ* 14 (12), 248. doi:10.19044/esj.2018.v14n12p248

Turner, M. D., McPeak, J. G., Gillin, K., Kitchell, E., and Kimambo, N. (2016). Reconciling flexibility and tenure security for pastoral resources: the geography of transhumance networks in eastern Senegal. *Hum. Ecol.* 44, 199–215. doi:10.1007/s10745-016-9812-2