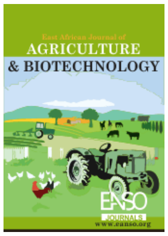

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Original Article

Fodder Potential Evaluation of Agro-Pastoral Sites Using Spatial Imagery Technology in the Cotton Production Zone of Mali, West Africa

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Herbaceous Fodder, Google Earth Image, Land Use Unit, Cotton Zone, Mali

ABSTRACT

In the cotton production zone of Mali, the pastoral ecosystems dynamics is being observed over the last decades, its impact on animal production and rural household welfare raisin the issue of space management particularly from agriculture practices increase participation in the dynamics of these resources. Additionally, in the zone the livestock feed materials are largely based on the use of natural fodders. However, other resources available for livestock include crop residues and industrial concentrated livestock feeding product for alimentary extra portion. This study aimed to evaluate the forage potential of six sites in the cotton zone of Mali using spatial imagery technology and to establish a forage balance sheet at the scale of these pastoral zone. The chosen approach is about the use of Landsat images acquired via Google Earth. Digital processing of these images by using the color composition technic was performed to establish the land use dynamics from 1990 to 2019. The results showed a sharp decrease in the rangelands area in favor of agricultural practices land use. Between 1990 and 2019, the areas dedicated to rain-fed crops increased by 77, 131, 123 and 110 % respectively in Benguéné, Ziguéna, Nafégué and Kokélé. During the same period, fallow areas decreased by -36% in Ziguéna, -23% in Nafégué and -13% in Kokélé. In Benguéné village which is an old cotton production zone, the situation is the most striking (-42% of fallows areas decrease during the same period). The results confirmed that animals daily feeding needs are not met in the villages of Nafégué, Ziguéna and Benguéné.

Moreover, the carrying capacity decreased in all these sites from 1990 to 2019 except Benguéné village where agricultural areas occupied more than 60% of the total area. In that village the carrying capacity is ensured by half.

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INTRODUCTION

Mali is located in the south of the Sahara, with an economy mainly relied on the agricultural sector which occupies nearly 80% of the population and more than 40% to the Gross Domestic Product (GDP) and 3/4 of exports product (MEADD, 2017). Agriculture alone accounts for 45% of the Gross National Product (GNP) and employs about 80% of the working population (MEADD, 2017). Livestock accounts for 31% of the primary sector's contribution to the GDP. It plays an important role in the economy, social and cultural life and contributes to 18% of the income of rural populations. The income in exclusively livestock farming areas is said to be 80% (PRAPS, 2015).

The country owns a significant livestock potential with an estimated animals' population in 2019 of 12,111,128 cattle, 19,183,500 sheep, 26,486,240 goats, 584,184 horses, 1,144,336 donkeys, 1,241,093 camels, 86,182 pigs, and 49,617,572 poultry (DNPIA, 2020).

The livestock production system is dominated by an extensive kind. It is stated that 75% of Malian livestock are transhumant herds (MEADD, 2017). These animals draw most of their nutrition from fodder resources such as cereal straws, legume tops, herbaceous, and woody forages. The Total forage production available for livestock was 36,780,280 tons of Dry matter (DM) for 2018-2019 season (DNPIA, 2020). This production is characterized by an estimated herbaceous mass production of 21,500,714 tons of DM, 40,259 tons of cultivated forage plus 15,239,307 tons of crop residues. Mali's cotton production zone has been observed to become a livestock production zone too (Kébé et al., 1999; Coulibaly et al., 2017). Thus, Sikasso region which makes up the two-thirds of this area, is been now the second largest livestock production region in Mali after Mopti with 2,030,135 heads of cattle and 2,383,379 heads of small ruminants (DNPIA, 2020).

In the zone, the main source of fodder is rangelands (grass and woody), crop residues, and concentrated

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feeds used only in the dry season to meet seasonal fodder deficits need. Despite their important roles in feeding animals, these food resources are being impacted by many factors including anthropogenic and climate change.

The high level of forage availability is a major constraint in livestock production in our latitudes (Hiernaux et al., 2015). Indeed, without an adequate diet, animals are unable to express all their genetic potential even in a normal physiological status. Moreover, animals face difficulties caused by a quantitative and qualitative shortage of forage (Diawara et al., 2018).

Ultimately, the consequences are overgrazing, expansion of bare areas, and reduction of the most palatable forage species (Yaméogo et al., 2013). In addition, the authors argued that, there is a remarkable decrease in the body weight of animals. These feeding constraints varies according to the diversity of agro-climatic conditions.

The management of the latest often causes conflicts between farmers (Coulibaly et al., 2009). Their natures vary considerably within a community depending on location and time. The conflicts self-manifestation comes in several ways including violation of rules, non-compliance with existing regulations or act of sabotage and violence (FAO, 2001). Finally, in the cotton production zone of Mali these seasonal fodder deficits have worsened considerably in recent years due to a combination of several factors, including climatic hazards, human pressure, and migration of herders from the north to this zone (DNPIA, 2020).

The objective of this study was to evaluate the fodder potential of agro-ecosystems in the cotton production zone of Mali and the coverage rates of animal feed requirements through feed balances at the scale of agropastoral areas.

MATERIALS AND METHODS

Study Area

The cotton production zone is the main agricultural region and the driver of agricultural activity development in Mali. The zone is under the supervision of the Compagnie Malienne pour le Développement du Textile (CMDT) and the Office de la Haute Vallée du Niger (OHVN). It covers the entire administrative region of Sikasso, the south of the Ségou and Koulikoro regions and the southeast of the region of Kayes. With an area of approximately 150 000 km².

Considered as the granary of Mali due to its large cereal production area, Sikasso is the second largest livestock production region after Mopti (Blanchard, 2010; Ba, 2011). The Characterization of Agrarian Dynamics in Mali's Cotton Zones (PASE I) project divided the cotton zone into five agro-ecological regions: the new cotton zone in the northwest, the Haute Vallée du Niger, Sikasso and Bougouni zone in the center, the southern extension zone, and the old basin in the northeast (Soumaré et al., 2008).This study was carried out within the framework of the PASE II Project "Projet d'Appui à l'Amélioration de la Gouvernance de la filière coton dans sa nouvelle configuration institutionnelle et à la productivité et à la durabilité des Systèmes d'Exploitation en zone cotonnière". The villages choice was based on the results of the first phase of the project (Soumaré et al., 2008). In the North-South gradient, the villages of Benguéné (1082±118mm), Ziguéna (1132±107mm), and Nafégué (877±34mm) were chosen. In the east-west gradient, the villages of Kafara (951±81mm), Kokélé (1182±152mm), and Katabantankoto (835±254mm) were selected (*Figure 1*).

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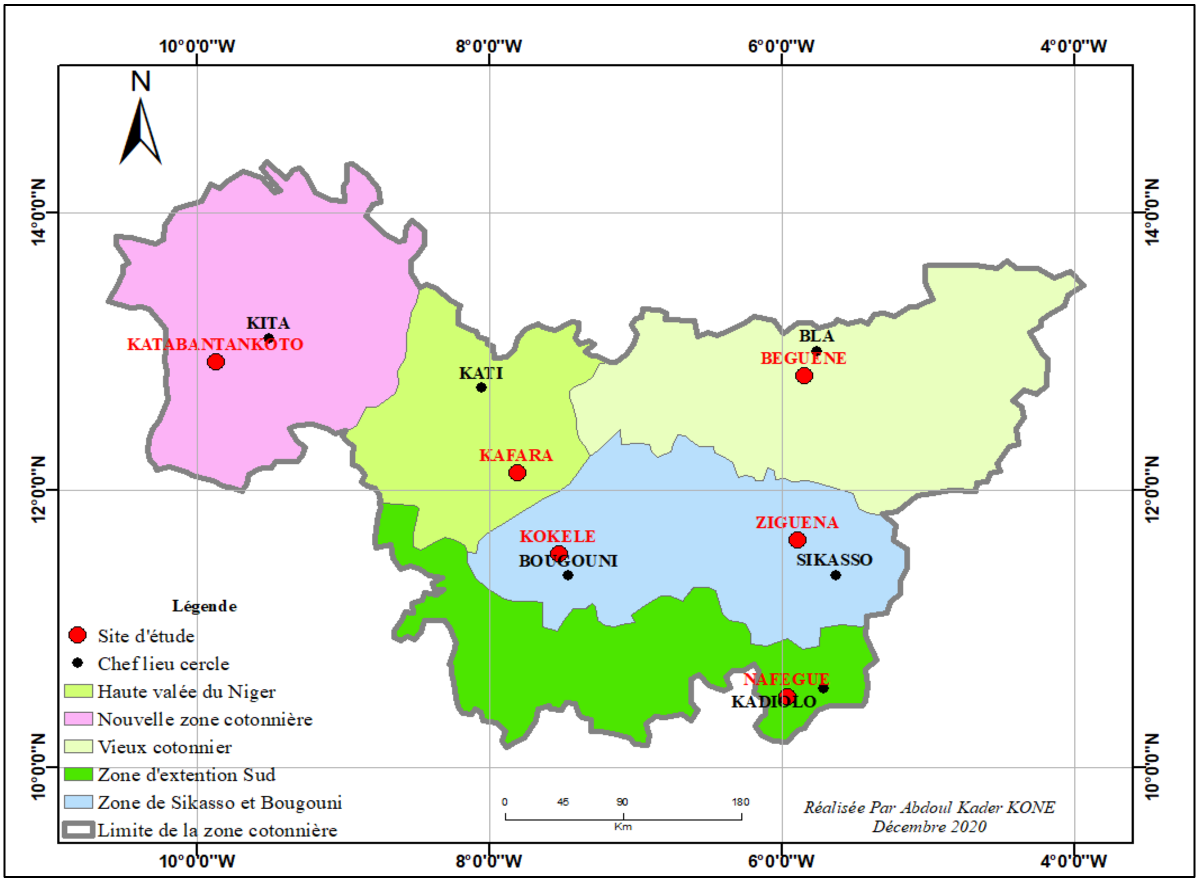
Figure 1: Location of the study area in South Mali



Delimitation of Land Use Units

The mapping database produced as part of the implementation of the PASE II project (Soumaré et Traoré, 2019) was mobilized in this study. These include maps of land boundaries and land use. To estimate the spatiotemporal dynamics of forage resources, delineation of land use units from 1990 to 2019 was performed. It is based on a digitization of high-resolution images on Google Earth. The main features digitized include rangelands, cultivated areas, waterways, and built-up areas. They were done in seven dates namely 1990, 1995, 2000, 2005, 2010, 2015 and 2019 at all the study sites. To facilitate spatial analysis and management of the collected data, the Keyhole Markup Language (Kml) files were converted to Shapefile (Shp) format under ArcGis 10.3 software to standardize the layers. All files were projected in UTM WGS 84 zone 29 in order to facilitate the analyses (unit areas). To obtain the land use maps, the parcels digitized on Google Earth were crossed between them. These crossings were made using the "Union" tool under the ArcGis software. The units retained are: cultivated areas, water, built-up areas, and the others are considered as rangelands. These treatments have made it possible to understand the transformations that have occurred over the last three decades in the cotton production zone of Mali.

Estimation of Herbaceous Mass

The integral harvesting method used by Coulibaly et al. (2009) was used to estimate the herbaceous mass. Sixteen 1x1 m plots were randomly selected so that half of the samples were in the middle class (M1, M2, M3, M4, M5, M6, M7, M8) and a quarter in each of the extreme class, low (F1, F2, F3, F4) and high (H1, H2, H3, H4). Within each plot, the

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mass was harvested flush with the ground and placed in cretonne bags containing a label with all the information (survey number, parameter, fresh weight, soil type, locality). The green weight of the phytomass of each plot was weighed individually. A 500g composite sample of the phytomass mixture from the surveys of each herbaceous class was taken. They were oven dried at a temperature of 70°C for 72 hours in the laboratory to determine the dry matter (DM) weight. The stratification performed at the margin of mowing was used to weight the average masses obtained for each class for each site (Hiernaux et al., 2009). These average masses were extrapolated to the grazing areas for each year. The procedure explained made possible to estimate the availability of herbaceous forage in time and space for each village area.

Estimation of the Theoretical Stocking Rate

Stocking rate is the result of an analysis between forage availability, the consumable fraction of forage, the daily feed intake of a Tropical Livestock Unit (TLU), the number of grazing days, and the number of livestock (Boudet, 1968; Diawara et al., 2020). To the estimated 2016 livestock numbers presented in *Table 1*, we applied the average annual growth rates estimated by DNPIA (2020) to be 3% for cattle, 5% for small ruminants, and 2% for donkeys. The standard established by Boudet (1968) was used. In which the daily feed intake is estimated to have a TLU at 6.25 kg DM. The theoretical feed intake of the animals was calculated, then the stocking rate in TLU/ha for 3 months, 6 months and one year for all the study sites. Only herbaceous mass and crop residues were considered as available food resources for livestock.

Table 1: Animal population at study sites in 2016

Village	Number of head	TLU Cattle	TLU Goat	TLU Sheep	TLU Asin	TLU Total
Nafégué	69	1177.9	53.6	57.9	55.5	1344.9
Ziguéna	66	1361.2	39.4	37.3	68.5	1506.4
Benguéné	65	574.8	56.8	46.7	54.5	732.8
Kafara	54	304.7	30.1	27.5	57	419.3
Kokélé	121	330.6	42.4	33.8	71.5	478.3
Katabantankoto	75	493.5	46.9	25.4	34.5	600.3

RESULTS AND DISCUSSION

Land Use Dynamics in the Cotton Zone of Mali

Figure 2 shows the dynamics of land use in the study area between 1990 and 2019. During this period, the cropping fields area increased in Ziguéna, Nafégué, and Kokélé by 131%, 123%, and 110% respectively compared to the area for other activities.

In contrast, rangelands decreased by 36% in Ziguéna (*Figure 2b*), 23% in Nafégué (*Figure 2a*) and 13% in Kokélé (*Figure 2e*). Nevertheless, in Benguéné, rangelands have decreased considerably by 42% while the area of agricultural land has increased by 77% (*Figure 2c*).

The number of Buildings infrastructure increased slightly in the villages of Nafégué, Ziguéna and Katabantankoto. The results showed that, surface water levels decreased in Kokélé and Ziguéna. However, the decrease of water table is related to the progressive utilization of the lowlands in agricultural areas Soumaré et al. (2019). In the village of Ziguéna, a decreased in rangelands of about -55% between 1986 and 2013 was found.

This rate is higher than our result of -36%. This difference may be due to the method of analysis of satellite images. The present study focused on the

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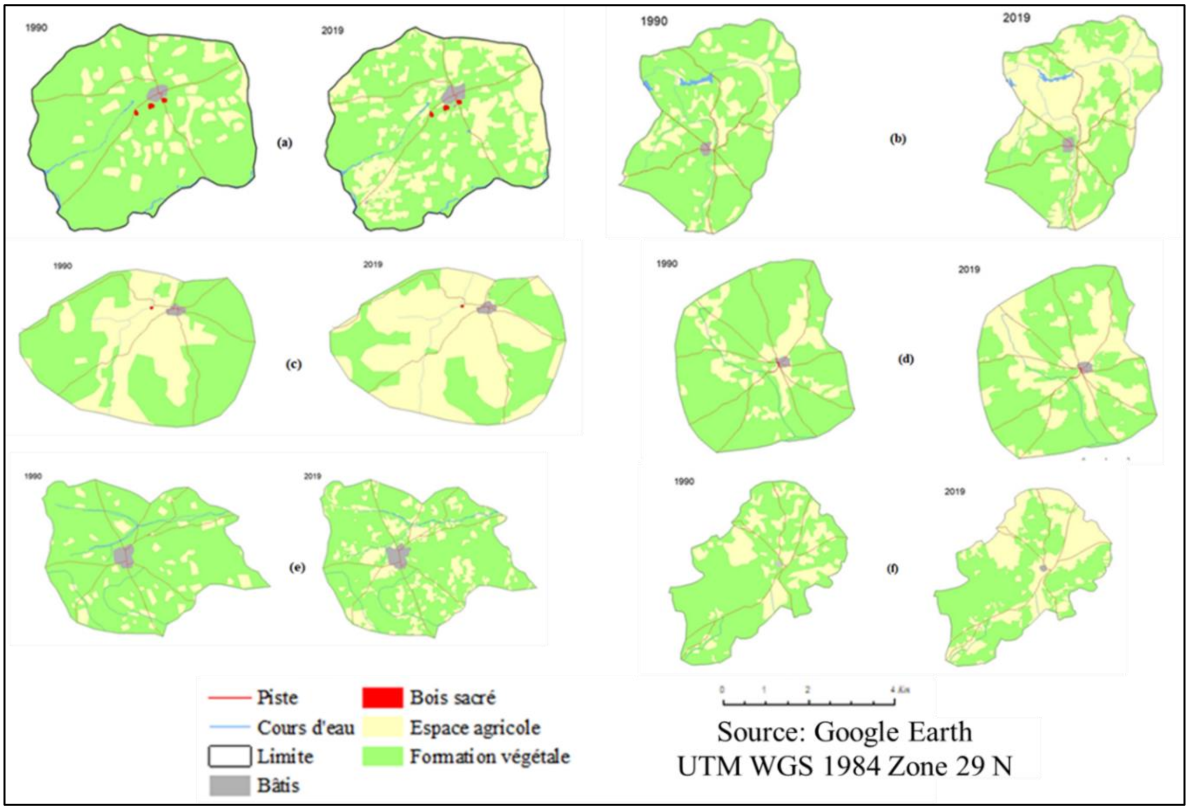
digitization of images in favor of digital classification algorithms. Louvet et al. (2018) in the Bani watershed in Mali between 1986 and 2000 found evolution rates of 50.3% for agricultural areas - 48.8% for bare soil and -8% for rangelands. This finding on rangelands is comparable to those in Kokélé which was -13%. The rate of change in agricultural areas in Benguéné (77%) is higher than the result found by Louvet et al. (2018).

Figure 2: Land use dynamics in the cotton zone of Mali from 1990 to 2019. The maps show, from top to bottom, the land use units of Nafégué, Ziguéna, Benguéné, Kafara, Kokélé and Katabantankoto sites.



Availability of Crop Residues

The availability of crop residues is greater and highly variable in Nafégué and Ziguéna, where maize is the dominant annual crop (*Figure 3*). Conversely, the availability of rice straw is low in all the villages. The areas reserved to this crop are very modest. Moreover, there are grown mainly in the lowlands (Dembélé, 2008). The finding showed that, maize straw is the main crop residue present in all studied villages except Kafara village where sorghum has been found to be the most common crop. A similar situation of preference over the maize stubble was observed in a study conducted by Harvard & André (2001) in Cameroon. The difference in crop residue productivity observed could be related to the modesty of fallows in the villages of Nafégué and Ziguéna but also to the spatiotemporal variability of rainfall pattern in the cotton production zone (Soumaré et al., 2019). The result confirmed that, millet stubble is derisory in the area which may be related to the small size of land portion reserved to its cultivation. Again, this forage material type resource is barely used by agro-pastoralists in the zone because of it highly lignification state and its poor content in nutrients as argued by Dembélé (2008).

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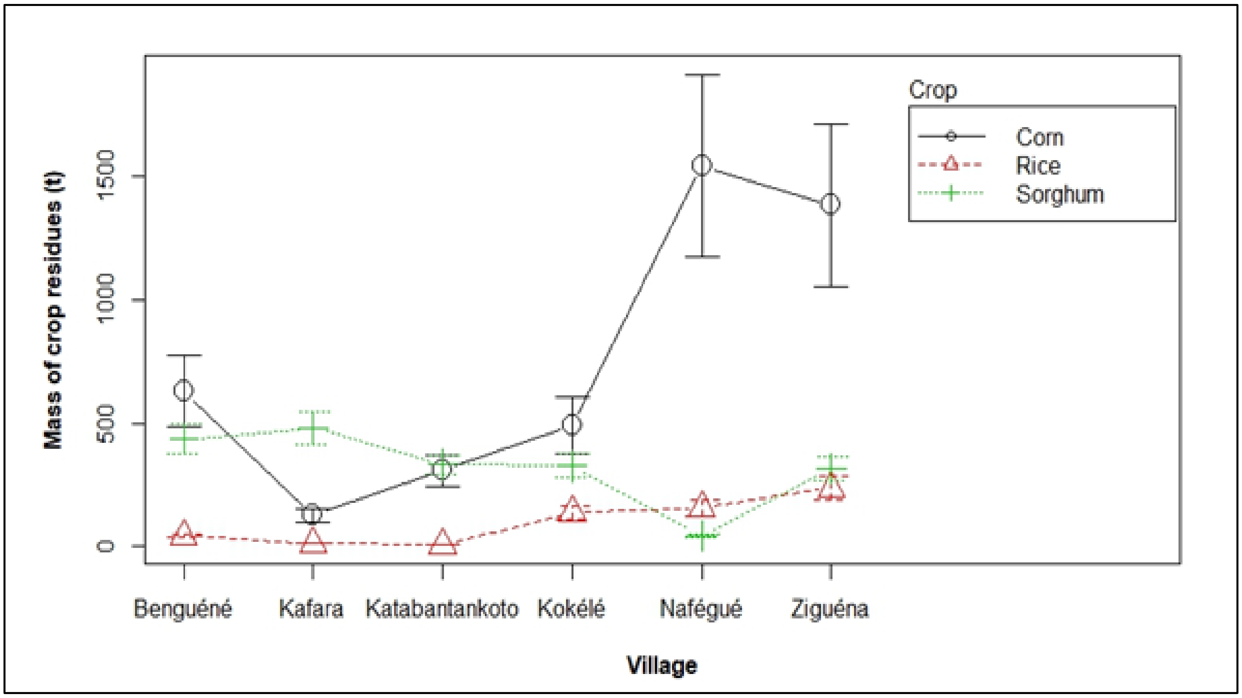
Figure 3: Change in availability of crop residues



Spatio-Temporal Variation in Herbaceous Mass Production

The herbaceous mass production in the study sites between 1990 and 2015 showed a great disparity in production quantity varying from one to five times, as shown by the difference in production between the one in Benguéné and Kokélé vegetation sites (*Figure 4*). It has been shown that, the herbaceous mass production has declined in all vegetation sites over the past three decades. These decreases are not constant over time, they are also very heterogeneous from one location to another. In Kokélé, the decline in production is estimated to be 13% compared to 42% gotten in Benguéné between 1990 and 2019. This overall downward trend in herbaceous biomass production is related to the rainfall pattern regime in the study area but also under the effect of the high level of anthropogenic pressure on agroecosystems (Bagayoko et al., 2005).

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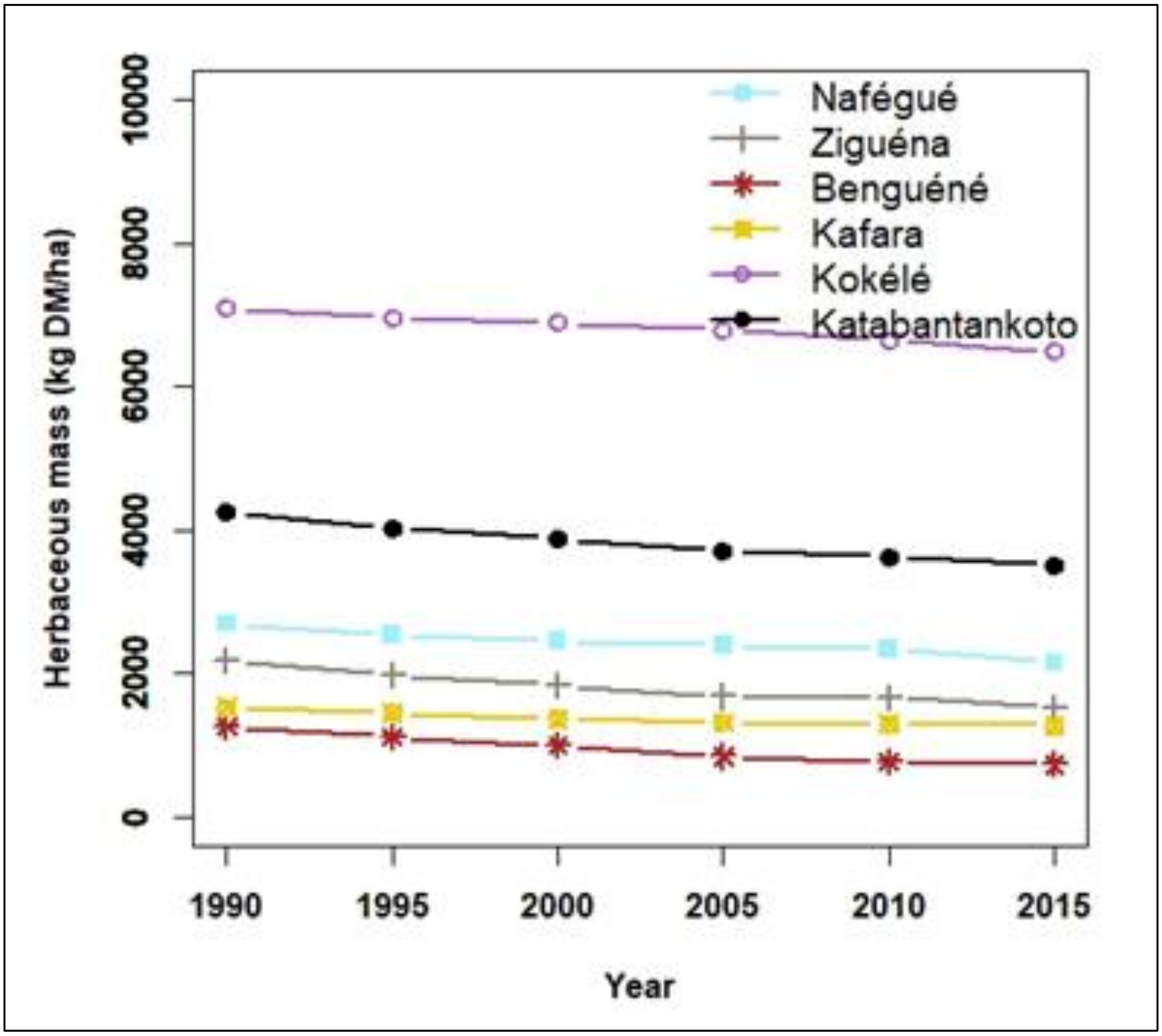
Figure 4: Spatio-temporal dynamics of herbaceous mass production



Variation in Stocking Rate

The variation in stocking rates presented in *Figure 5* showed a non-significant difference at the 5% threshold related to vegetation site (df = 5, p-value = 0.45 from Bartlett's test). With an average stocking rate of 0.22, 0.19, and 0.17 TLU/ha for Ziguéna, Benguéné, and Nafégué, respectively, the so-called Level 1 sites are the most grazed. Around the level 2 villages, the average stocking rates are 0.15, 0.13, and 0.10 for the villages of Katabantankoto, Kafara, and Kokélé respectively. The analysis of variance showed a highly significant differences between the stocking rate obtained in Kokélé and Benguéné, between Ziguéna and Kafara, and between Ziguéna and Kokélé ($P<0.001$). These stocking rates are higher than those obtained in the finding led by Diawara et al. (2020) in the eastern Sahel of Mali but lower than the 0.45 TLU/ha estimated at Dentiola in southern Mali (Richard & Guerin, 2010).

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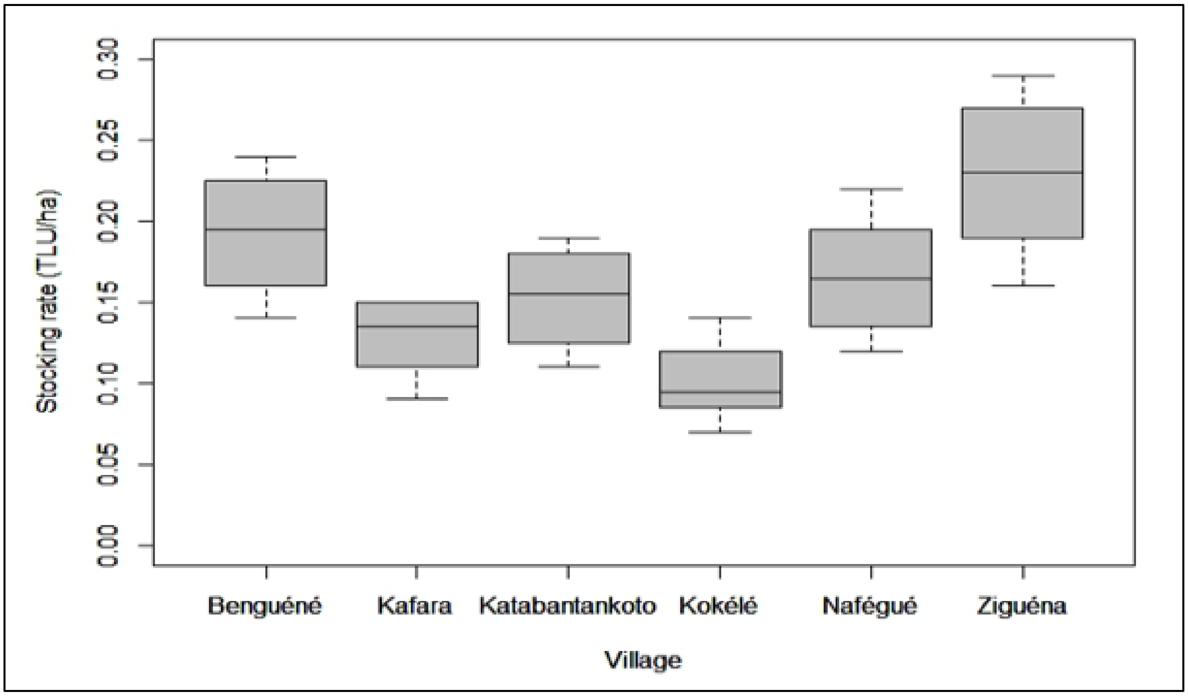
Figure 5: Variation in stocking rate at the study sites



Feed Balance Sheet

In Nafégué, Ziguéna and Benguéné, the feed balance sheet showed a recurrent deficit (*Figure 5*). The situation is worse in Benguéné since 2000. In Nafégué, the availability of fodder ceased to cover animals' feed requirements in 2015. In Ziguéna, the forage deficit is found to be practically endemic. In that site, the livestock feed requirements were covered only in 1990. Globally in the study area, the coverage of animals' feed requirements has increased by more than 50% during the period under consideration. These seasonal forage deficits are not exceptional in the agro-pastoral systems as shown by Hiernaux et al. (2015).

The availability of fodder (herbaceous mass and crop residues) in Kafara, Kokélé, and Katabantankoto sites is sufficient to cover the needs of local livestock despite the decline in mass production over the past three decades (*Figure 6*). Therefore, the disparity observed between the vegetation sites of the two levels could be explained by the distribution of rainfall pattern, which is very uneven in the area, but also by the difference in size of the resident herds. It is important to note that, the feed requirements of outsider's herds were not estimated in this study because of the low mobility of livestock.

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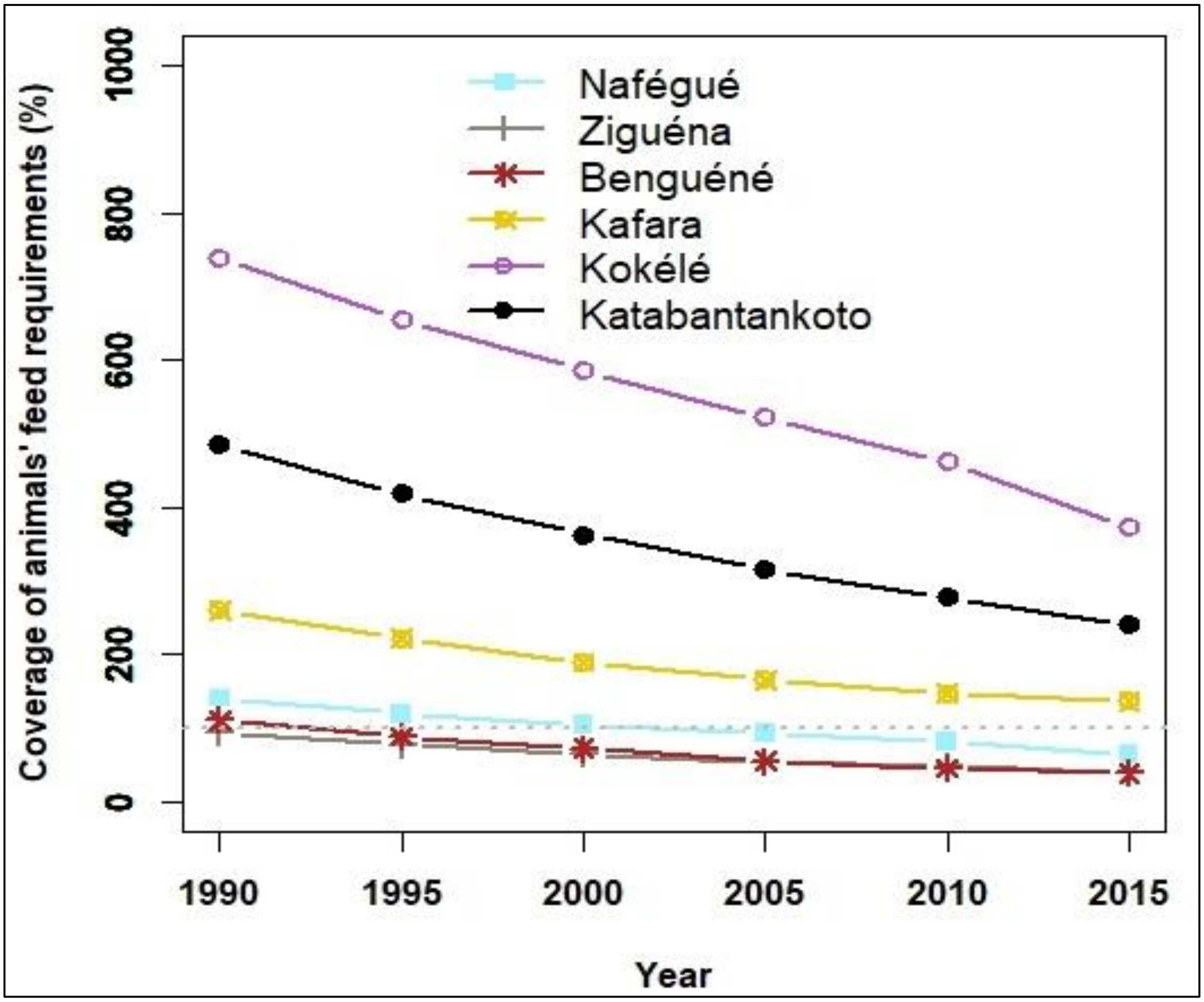
Figure 6: Coverage of animals' feed requirements at the study sites



CONCLUSION

From this study, it appears that the area dedicated for agricultural activities has doubled in the sites of Nafégué, Ziguéna, and Kokélé in 30 years at the expense of fallow unit. The rangelands units which constitute the main feeding resource for livestock have regressed in level 1 villages with -42% in Benguéné, -36% in Ziguéna, and -23% in Nafégué.

Additionally, the herbaceous biomass production has declined in all the vegetation sites over the past three decades. These decreases not constant over time are very heterogeneous in space. It appears that, Maize and sorghum stalks constitute a supplementary resource on which cattle breeding is based in the cotton production zone. However, the feed balance shows a very contrasted situation in the livestock feed requirements. For instance, about level 1 sites the forage stocks built up at the end of the rainy season can no longer cover the needs of the animals because of its low quantity, whereas for level 2 sites the feeds requirements are covered by the materials available. The reduced livestock numbers and/or increased livestock mobility could reduce the forage constraint observed at some sites. The implementation of information services on the availability and quality of phytomass in the cotton production zone, such as the GARBAL information service used in northern Mali, can reduce stocking rates and improve the productivity of livestock in the zone.

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CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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