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EDITORIAL

La création de RIGES résulte de l'engagement scientifique du Département de Géographie de l'Université Alassane Ouattara à contribuer à la diffusion des savoirs scientifiques. RIGES est une revue généraliste de Géographie dont l'objectif est de contribuer à éclairer la complexité des mutations en cours issues des désorganisations structurelles et fonctionnelles des espaces produits. La revue maintient sa ferme volonté de mutualiser des savoirs venus d'horizons divers, dans un esprit d'échange, pour mieux mettre en discussion les problèmes actuels ou émergents du monde contemporain afin d'en éclairer les enjeux cruciaux. Les enjeux climatiques, la gestion de l'eau, la production agricole, la sécurité alimentaire, l'accès aux soins de santé ont fait l'objet d'analyse dans ce présent numéro. RIGES réaffirme sa ferme volonté d'être au service des enseignants-chercheurs, chercheurs et étudiants qui s'intéressent aux enjeux, défis et perspectives des mutations de l'espace produit, construit, façonné en tant qu'objet de recherche. A cet effet, RIGES accueillera toutes les contributions sur les thématiques liées à la pensée géographique dans cette globalisation et mondialisation des problèmes qui appellent la rencontre du travail de la pensée prospective et de la solidarité des peuples.

Secrétariat de rédaction
KOUASSI Konan

COMITE DE LECTURE

Sommaire

ASSESSING PASTORAL POTENTIAL FEED RESOURCES AND THE EFFECT OF INVASIVE UNPALATABLE SPECIES ON PASTURES IN THE DISTRICT OF BOUGOUNI, SOUTHWEST OF MALI

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Abstract

Pastoral feeding resources play an important role in the improvement of pastoral livestock in the southwestern of Mali. Invasive unpalatable species have led to the degradation of pasture quality. This study aims to assess the effect of these species on pastoral feeding resources and livestock productivity in the southwest of Mali based on a semi-structured household survey with 404 agro-pastoralists in four communes and herbaceous vegetation inventory using the point quadrat aligned and yield square method. The findings revealed significant differences in species composition, biomass, and carrying capacity between pasture savannahs and bowals. The majority of households are influenced by invasive species including *Hyptis spicigera, Oximum basillicum, Hyptis suaveolens, Cassia tora, Walteria indica,* and *Sida rhombifolia*. Based on the

survey and phyto-ecological data analysis, the paper provides that invasive species are having a significant impact on pasture quality affecting livestock productivity and rural livelihoods.

Keywords: Pasture, degradation, unpalatable species, livestock productivity, Mali

Résumé
Les ressources pastorales jouent un rôle important dans l'amélioration du bétail pastoral dans le sud-ouest du Mali. Les espèces envahissantes non appétées ont entraîné la dégradation de la qualité des pâturages. Cette étude vise à évaluer l'effet de ces espèces sur les ressources pastorales et la productivité du bétail dans le sud-ouest du Mali. Une enquête semi-structurée auprès de 404 agro-pastoralistes dans quatre communes et un inventaire de la végétation herbacée utilisant la méthode des points quadrat alignés et de la méthode des carrés de rendement ont été réalisés. Les résultats ont montré des différences significatives dans la composition des espèces, la biomasse et la capacité de charge entre les savanes arbustives et les bowals. La majorité des ménages sont influencés par des espèces envahissantes, notamment *Hyptis spicigera, Oximum basillicum, Hyptis suaveolens, Cassia tora, Walteria indica* et *Sida rhombifolia*. Sur la base de l'enquête et de l'analyse des données phytoécologiques, l'article conclut que les espèces envahissantes ont un impact significatif sur la qualité des pâturages, affectant la productivité du bétail et les moyens de subsistance ruraux.
Mots-clés : Pâturage, dégradation, espèces non appétées, productivité du bétail, Mali

Introduction

Livestock products account for 17% of world calorie consumption and 33% of global protein consumption, making them an important agricultural commodity for global food security. Furthermore, livestock production is an important economic sector employing nearly 1.1. billion people and contributing to the livelihoods of the world's poorest (G. A. Bogale & Z. B. Erena, 2022, p.471). This is particularly true in Asia, Africa, and Latin America, where livestock is the sole source of livelihood for at least 20 million pastoral families and an important source of income for at least 200 million farmers (S. Bekele, 2014, p.53). In West Africa, livestock farming provides between 8 and 15% of the overall gross domestic product (GDP), 44% of agricultural GDP, and nearly 50% of the workforce engaged in the sector in West Africa (T. Amole et *al*., 2022, p.26). At least 100 million people among the low-income communities in West Africa rely on livestock as part of their livelihood strategy (T. A. Amole & A. Ayantunde, 2016, p. 41).

This importance of livestock and its productivity as well as its significance for human well-being are directly linked to the availability feed resources availability. During the dry season, many livestock farmers depend on crop residues, in the Sahel zone, which are increasingly becoming the predominant feed resource as rangelands are being converted into crop fields (T. Amole et al., 2022, p. 27). Apart from crop residues and other agro-industrial by-products, he most common types of feed resources in West Africa are rangelands, and browse plants (T. Amole et al., 2022, p. 28), with require livestock mobility in order to maintain to benefit from fodder resources in different areas, varying in quantity and quality in different areas (PRAPS, 2017, p. 6). In extensive livestock farming systems, livestock feed is normally based on natural grazing, which forms the basis or serves as the exclusive feed resource as is estimated that more than 90% of the energy consumed by cattle comes from pasture (M. Oumorou et al., 2011, p. 1262).

In Mali, livestock farming, which is predominantly pastoral, employs 80% of the rural population (PNDEM, 2004). The sector is characterized by a very high diversity of livestock (PROGEBE, 2015) estimated to include more than 12 million cattle, more than 20 million sheep, close to 28 million goats, more than 2 million donkeys and camels, close to 600.000 horses, more than 80.000 pigs and more than 52.000 poultry (DNPIA, 2020, p. 24). In this transhumance or herding system, animal feed comes essentially from the exploitation of natural pastures and requires large areas of pastoral land, placing also a heavy burden on the environment (D. Konare & M. Coulibaly, 2019, p. 204).

Livestock-based farming systems are affected by multiple stressors such as rangeland degradation, uncertain access to water and fragmentation of grazing areas which can interact with and be amplified by climate change (IPCC, 2014, p. 1219). Therefore, climate change is considered as one of the major challenge for the sustainability of livestock production systems in many parts of the world (S. Naqvi & V. Sejian, 2011, p. 19). Specifically, climate change affects pastoral lands and thereby its affects animal productivity in terms of quality as well as quantity of available fodder but also in terms of direct effects from raising temperatures and changes in rainfall patterns on livestock such as heat stress (G. A. Bogale & Z. B. Erena, 2022, p. 476). Consequently, climate change is projected to have the strongest impact on vulnerable pastoral communities relying heavily on livestock production systems in arid environments (S. Oseni & O. Bebe, 2010, p.4). In addition, rising of temperatures impacts negatively rangelands, pastures and cultivated forages, animal feed intake (J. Morton, 2012, p.18 ; S. Tiruneh &

F. Tegene, 2018, p. 53). Climate change driven rangeland degradation is furthermore accelerated by some invasive plant species, which are often less palatable by livestock such as *Hyptis suaveolens* a pantropical, aromatic herb producing vast amounts of sticky seeds and replacing other palatable, partly vulnerable or threatened species (A. Kiema et al., 2014, p. 8; A. Sharma et *al*., 2017, p.156; A. Zaré et *al*., 2022, p. 148). Due to its propagule banks and ability to remain dormant during unfavorable environment conditions it can persist in invaded ecosystems (G. Akomolafe et *al*., 2024, p. 2). In particular in semi-arid rangelands, researchers have recorded declining availability of palatable species due to invasive species with negative impacts on livestock production (A. Zaré et *al*., 2022, p.148). In this research, we aim to assess the effect of these species on pastoral feeding resources and livestock productivity in the southwest of Mali.

1. Materials and methods

1.1. Study area

The district of Bougouni is located in the Sudano-Guinean zone in the southwestern part of Mali, 10°00′ to 12°40′ north and 06°20′ to 08°20′ west. Its climate is of the Sudano-Guinean type, characterized by two of seasons; a dry season of 5 to 6 months (November to April) and a rainy seasons of 6 months (May to October). The average annual rainfall is approximately 1,300 mm (Z. Doumbia, 2009, p. 30; F. Coulibaly, 2008, p. 53). Respectively, August is the rainiest month and the hottest months are April and May. Its livestock population is one the most important of the country (table1). The district of Bougouni is administratively composed of 540 villages in 26 communes, including one urban and 25 rural, distributed in 9 sub-districts (B. Sanogo, 2006, p. 29). It covers an area of approximately 20,000 km^2, or 1.6% of Mali's territory, and is crossed by National Route 7, which places it between the two largest cities Bamako (170 km) and Sikasso (210 km). The district of Bougouni is part of the "Haut Bani Niger" zone located at an average altitude of 350 m above sea level (S. Traoré et al., 2021, p.2). It is bounded to the north by the district of Kati and Dïola (Koulikoro Region); to the northwest by the district of Yanfolila; to the south by the Republic of Côte d'Ivoire and to the southwest by the district of Sikasso and Kolon-dieba (Sikasso Region) (M. Keïta, 2009, p.37; Z. Doumbia, 2009, p.29). This study was conducted in the Bougouni district in four communes, namely Dogo, Koumantou, Garalo and Faragouaran (figure 1).

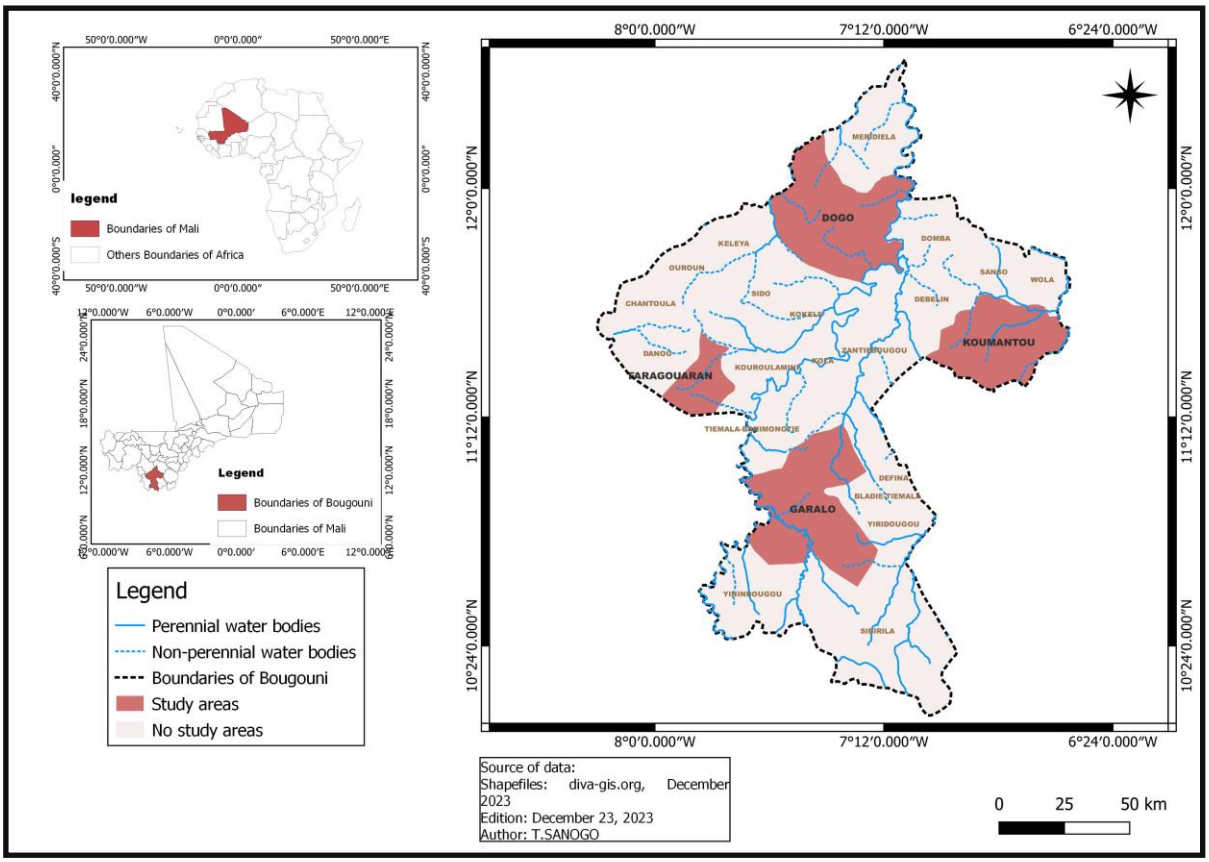


Figure 1. Location of the study areas in the District of Bougouni

Table 1. Evolution of livestock population from 2011 to 2022 in the Bougouni District

Years	Cattle	%	Sheep	%	Goat	%	Horse	%	Donkey	%
2011	380,000	6.36	165,875	6.88	284,922	6.96	34	3.90	13,677	5.28
2012	439,963	7.36	182,011	7.55	310,644	7.59	32	3.67	14,088	5.44
2013	453,160	7.58	191,110	7.93	326,175	7.97	32	3.67	14,510	5.60
2014	453,148	7.58	191,099	7.93	326,166	7.97	32	3.67	21,989	8.49
2015	466,730	7.81	200,694	8.33	342,459	8.37	32	3.67	22,636	8.74
2016	480,732	8.04	210,729	8.74	359,582	8.79	33	3.79	23,315	9.00
2017	510,010	8.53	232,050	9.63	388,722	9.50	100	11.48	25,334	9.78
2018	530,010	8.87	230,150	9.55	392,720	9.60	100	11.48	27,327	10.55
2019	541,069	9.05	255,839	10.61	428,566	10.47	120	13.78	31,104	12.01
2020	557,298	9.32	268,631	11.15	449,996	11.00	120	13.78	32,036	12.37
2021	574,003	9.60	282,050	11.70	481,385	11.77	118	13.55	32,984	12.74
2022	591,223	9.89	296,153	12.29	505,456	12.35	118	13.55	33,975	13.12
Total	5,977,346	100	2,410,238	100	4,091,337	100	871	100	259,000	100

Source: SLPIA-B (2022)

1.2. Data collection

- **Individual survey data** were collected from agro-pastoralist 404 household heads of 30 years or older through individual semi-structured survey during december 2022. The sample was drawn on the basis of the 2022 population data for the District of Bougouni provided by the National Population Directorate of Mali and the sample size was determined using the following formula from D.O. Nyangweso & M. Gede, (2022, p.10):

$$n = \frac{N}{1 + N(e)^2} \quad (1)$$

Where **n** is the sample size, **N** is the finite population, **e** is the significance level or tolerable error limit and **1** is a unit or constant.

The simple random sampling method was used to randomly select respondents (A. Bhattacherjee, 2012, p. 67) assuming a 5% confident level.

- **Phyto-ecological data:**

Herbaceous and woody species data were collected in the communes of Faragouaran and Koumantou during November 2022, which corresponds to the month with the highest standing biomass in sudanian region (J. M. OUADBA, 1974, p. 333; M. Grouzis & P. Levang, 1980, p. 234; P. Hiernaux et al., 2011, p.5; L. Sawadogo, 2009, p. 48).

- **We used the point quadrate aligned method to create a herbaceous vegetation** inventory according to P. Daget & J. Poissonnet (1971, p. 234). For this method, the researcher places a tape or measuring rope over a distance of twenty meters (20 m) above the grass cover, and every 20 cm drivers, an iron thin stem (baguette) vertically into the grass. All present species and their contact (stubbles, leaves, fruits, flowers) with the iron stem are recorded on a pre-established sheet. If no plant is touching the metal rod, the presence of bare soil is noted (O. F. Saidou *et al.,* 2010, p. 155). By convention, each species is noted only once at each of the reading points. The method allows to quantify the floristic composition of a route by measuring, the frequency of all the species listed and by expressing, in particular, these frequencies in terms of ground cover (L. Sawadogo, 2009, p. 46; S. Santi, 2011, p. 45). We assessed the vegetation for 100 point for each plot (L. Sawadogo, 2009, p. 46) and 600 points

in the two sites. We define all species *in situ* following the nomenclature of the International Plant Names Index[1].

Furthermore, we determined the pastoral value of the both areas which is obtained by multiplying the Specifics contributions of each species by the Specific Quality Index and adding the obtained values (P. Daget & J. Poissonnet, 1971, p. 33; O. F. Saidou *et al.*, 2010, p. 157).

The Specific Contribution (CS) calculated by using this formula:

$$\boldsymbol{CSi = FSi / \sum Si * 100} \quad (2)$$

Where Specific Contribution *Cs* is calculated for each species *i* based on the Specific frequency *FS*.

The pastoral value *VP* is computed:

$$VP = 0{,}2 \sum_{i=1}^{n} CS_t \times Is_t \quad (3)$$

Where CS is the specific contribution of species, Is is the Specific quality Index.

The Pastoral value is defined by assigning to each specie a specific quality index. This specific index is obtained by considering the zoo-technical and bromatological values of the species, according to the agro-pastoralist perception based on a Likert scale Between 0 (no pastoral value) and 5 (Very good pastoral value)(F. OUATTARA, 2004, p. 41; O.F. Saidou *et al.*, 2010, p. 156; B. Kanambaye et al., 2022, p. 172).

- **We used the yield square method to estimate herbaceous production** in the research sites (N. Coulibaly, et al., 2022, p. 196). It consisted in taking phytomass samples in three different classes (low, medium and high) on each type of vegetation (shrubby savannah, wooded savannah and bowal). Before harvesting biomass, we describe for each type of substrate 36 samples of 1m x 1m of which 9 in the low class, 18 in the medium class and 9 in the high class (floristic list and visual cover). Subsequently, we put the mowed phytomass in cretonne bags and, measured its weight with an electronic balance to determine the green weight. After air drying until we reach a constant Dry Weight (DW), we determined the dry weight in kg of DM (W. Ouedraogo et al., 2019, p. 3279). We compared average herbaceous phytomass production by soil type and theoretical carrying capacity based on dry

[1] IPI : International Plant Names Index, https://www.ipni.org/ (11 November 2023)

matter production. The empirical formula established by G. Boudet, (1977, p. 176) was used for this purpose:

Number of days (NJ) = phytomass production (kg DM/ha) /3*6.25
Quantity of forage per LU/ha/year (Qf) = NJ*250/365 (4)
Number of LU/ha/year (NA) = Qf/250
Number of ha/TBU/year = 250/NJ

- **We collected data about the woody vegetation based on** 1000 m2 (50 m x 20 m) plots in each site (S. F. Traoré et al., 2022, p.22; B. Kanambaye et al., 2022, p. 170). We recorded the abundance of different woody species, the circumference of the trunk at the height of the chest about 130 cm from the ground using the calipers, the tree height and the projection of the crown using a graduated perch (M. KAREMBE, 2014, p. 43). We also collected information about the phenological state of individual tree (leaves, flowering, fruiting), physical state (living, dead) and how the pastoral land was used (period of use as crop, transhumant paths, herbaceous and woody species diversity).

2. Results

2.1. Socio-demographic characteristics of surveyed population

The majority of respondents have age between 40-49(106; 26.2%) in contrast only (4.7%; 19%) have age greater or equal to 70. The main ethnic groups in the study area are Peulh, Bamabara, Sarakole, Malinke, Senoufo and Bozo. Bambara (220; 54%) and Peulh (136; 34%) are the most dominated. The surveyed actors were able all to talk in Bambara language and are in living symbiosis. The 69% (277) of the surveyed population have less or equal 5 person active in contrast with from 10 to 20 person in charge (311; 77%). The surveyed population are majority male (315; 78.0%) (table2).

Table2. Socio-demographic situation of surveyed population

Indicators	Frequency	%	Rank
Age groups			
30-39	104	25.7	2nd
40-49	106	26.2	1st
50-59	102	25.2	3rd
60-69	73	18.1	4th
≥70	19	4.7	5th
Main Ethnic groups			
Peulh	136	34.0	2nd
Bambara	220	54.0	1st
Sarakole	18	4.0	3rd
Malinke	12	3.0	4th
Senoufo	10	2.0	5th
Bozo	8	2.0	5th
Person active			
≤5	277	69.0	1st
5-10	93	23.0	2nd
<10	34	8.0	3rd
Person in charge			
≥10	15	4.0	3rd
10-20	311	77.0	1st
<20	78	19.0	2nd
Gender			
Male	315	78.0	1st
Female	89	22.0	2nd

Source: individual survey, December (2022)

2.2. Richness of herbaceous for livestock production

We found 40 different species in the research sites. The most dominant species are the A*ndropogon pseudapricus* (43.68%), *Microchloa indica* (28.72%), *Loudetia Togoensis* (19.09%), *Eragrostis aspera* (15.27%), *Schizachyrium exile* (11.04%), *Andropogon gayanus* (9.71%). However, while most palatable plant species have a low contribution as average for whole type of plant formation particularly *Panicum leatum* (2.24%), *Brachiaria ramosa* (1.12%), *Brachiaria xantholeuca* (1.1%), *Stylosanthes erecta* (0.59%), *Borreria scabra* (0.28%), *Sporobolus pyramidalis* (0.29%). This is not the case for *Andropogon gayanus*, one of the

most palatable plant species in the research site has high contribution (26.2%) in the shrubby savannah (table 3).

The average of dry matter of biomass is higher in Faragouaran (1 595.92kg/ha) compare to Koumantou (1 216.40 kg/ha) for the general and especially in the shrubby savannah systems. Pastoral value is higher in Koumantou at the rate of 54.04 % than in Faragouaran (48. 69%). Concerning both research sites, the richness of pasture is very high for the wooded savannah, followed by the bowal and shrubby savannah (table 4).

Table 3. Specific contribution of herbaceous species (%) in the study area

Species	Bowal	Shrubby savannah	Wooded Savannah	Average	SD
Alysicarpus ovalifolius (Schumach & Thonn.) J.Léonard.	11.61	2.54	7.98	7.38	8.65
Andropogon gayanus Kunth.	0.40	26.2	2.53	9.71	8.75
Andropogon pseudapricus Stapf	40.83	53.85	36.36	43.68	8.83
Aristida mutabilis Trin. & Rupr.	23.14	0.00	0.00	7.71	6.09
Borreria scabra K.Schum.	0.83	0.00	0.00	0.28	6.14
Borreria stachydea (DC.) Hutch. & Dalziel	1.66	0.77	7.54	3.32	6.20
Brachiaria ramosa Stapf,	0.83	2.54	0.00	1.12	6.30
Eragrostis aspera Nees	34.71	8.58	2.53	15.27	6.38
Eragrostis pilosa (L.) P.Beauv	0.83	0.00	0.00	0.28	6.14
Eragrostis tremula Hochst. ex Steud.	0.83	0.77	0.00	0.53	6.21
Fimbristylis hispidula (Cherm.) Napper	3.33	0.00	0.00	1.11	6.29
Fimbristylis littoralis Gaudich.	0.83	0.00	0.00	0.28	6.38
Indigofera hirsuta Jacq.	0.83	2.42	0.00	1.09	6.46
Loudetia Togoensis (Pilg.) C.E.Hubb.	33.31	0.00	23.97	19.09	6.56
Microchloa indica Hack. & Stuck.	28.14	14.16	43.86	28.72	5.94
Panicum leatum Kunth	4.96	1.77	0.00	2.24	3.02
Paspalum scrobiculatum bispicatum Hack. ex Merr	0.83	2.65	0.00	1.16	3.08
Pennisetum pedicellatum Trin.	0.83	10.12	11.39	7.44	3.14
Polycarpaea Corymbosa (F.Muell.) Domin	5.83	0.00	0.00	1.94	3.02
Schizachyrium rupestre Stapf	0.83	2.31	0.00	1.05	3.09
Setaria pallide-fusca (Schumach.) Stapf & C.E.Hubb.	0.83	5.19	0.00	2.01	3.16
Sporobolus Festivus Hochst. ex A.Rich.	1.67	0.00	2.48	1.38	3.24
Tephrosia bracteolata Guill. & Perr.	0.83	2.65	0.83	1.44	3.33
Waltheria indica L., Sp.	2.49	0.00	0.00	0.83	3.42

Borreria chaetocephala (DC.) Hepper	0.00	8.73	15.19	7.97	3.51
Aspilia bussei O.Hoffm. & Muschl.	0.00	1.77	0.00	0.59	3.31
Cassia tora (L.) Roxb.	0.00	1.54	0.00	0.51	3.40
Crotalaria retusa (L.) Sp.	0.00	0.77	0.00	0.26	3.50
Digitaria horizontalis Willd.	0.00	18.12	7.59	8.57	3.59
Hyptis suaveolens (L.) Poit.	0.00	10.12	2.09	4.07	3.22
Merremia tridentata hastata Ooststr.	0.00	0.88	0.00	0.29	3.32
Phyllanthus amarus Schumach. & Thonn.	0.00	1.77	0.00	0.59	3.47
Schizachyrium exile (Hochst.) Pilg.	0.00	7.39	25.72	11.04	3.66
Schizachyrium sanguineum (Retz.) Alston	0.00	2.65	6.61	3.09	1.05
Schoenefeldia gracilis Kunth	0.00	0.88	0.00	0.29	0.60
Sida rhombifolia (L.) Sp.	0.00	0.88	0.00	0.29	0.63
Sporobolus pyramidalis P.Beauv.	0.00	0.88	0.00	0.29	0.65
Stylosanthes erecta P.Beauv.	0.00	1.77	0.00	0.59	0.59
Zornia glochidiata Rohb. ex DC.	0.00	5.31	0.00	1.77	0.47
Brachiaria xantholeuca Stapf	0.00	0.00	3.31	1.10	4.23

Source: Author construction, November 2022

Table 4. Estimates Biomass of Dry Master (DM) per Ha and Pastoral Value (PV) in research sites

Sites	Bowal		Shrubby savannah		Wooded Savannah		Averages	
	DM (Kg/ha)	PV (%)	DM (Kg/ha)	PV (%)	DM (Kg/ha)	PV (%)	DM (Kg/ha)	PV (%)
Faragouaran	1197.15	48.83	1972.00	43.85	1618.62	53.39	1595.92	48.69
Koumantou	1273.00	44.20	1415.70	64.25	960.50	53.67	1216.40	54.04

Source: Author construction, November 2022

2.3. A decreasing carrying capacity in the study area

Overall, we found that the theoretical carrying is not significantly varying between different vegetation types (table 5). However, the average number of number of Tropical Livestock Unit (TLU) is slightly higher for the shrubby savannah (0.25TLU/Ha/year) and for the bowal slightly lower (0.18 TLU/Ha/year). The average number of days per year of livestock for pastures exploitation is 90.34 days for the shrubby savannah, 68.78 days for the wooded savannah and 65.87 days for the bowal. The general average is 75 days from the assessment of the year 2022 in the research site.

Table 5. Carrying capacity per type of vegetation

Sites	DM (Kg/ha)	Average number of HA/TLU/year	Average number/TLU/HA /year	Average of FQ/year (Kg)	Average number of days/year
Bowal	1 235.08	4.69	0.18	45.12	65.87
Shrubby Savannah	1 693.85	3.14	0.25	61.88	90.34
Wooded Savannah	1 289.56	4.83	0.19	47.11	68.78
Average	**1 406.16**	**4.22**	**0.21**	**51.37**	**75.00**

Source: Author construction, November 2022

2.4. A ligneous stratum diversified and getting highly degraded

The vegetation cover of wooded species is highly divers and composed by sixteen (16) families of species: anacardiaceae, annonaceae, apocynaceae, asteraceae, caesalpiniaceae, celastraceae, combretaceae, ebenaceae, fabaceae, lamiaceae, malvaceae, mimosaceae, olacaceae, phyllanthaceae, rubiaceae, sapotaceae (table6). From the overall families, the fabaceae is the most important (13 species either 29.55%), followed by the combretaceae (8 species either 18.18%), malvaceae (4 species either 9.09%), anacardiaceae and rubiaceae (3 species either 6.82%). The table7 is announcing the dominance of wooded species per Ha in the research site for the assessment of 2022. The most dominant specie are *Afrormosia laxiflora* (3,990 individuals/ha either 33.61%), *Detarium microcarpum* (1,820 individuals/ha either 15.33%), *Terminalia laxiflora* (1,630 individuals/ha either 13.73 %), *Pteleopsis suberosa* (640 individuals/ha either 5.39%), *Annona senegalensis* (570 individuals/ha either 4.80%).

The structure of wooded plant is divided into three parts: tree, shrub, and regrowth (figure12). This structure has showed that the majority of plant is shrubs (73.14 %) and only 15.43% are tree. From this analysis. This situation is explained multiple stressors to resources including climate hazards, human pressure.

Table 6. Repartition of wooded species per families in the study area

Families	Species	Number of species /family	Dominance (%)
Anacardiaceae	*Lannea acida A. Rich.* *Lannea microcarpa Engl. & K.Krause* *Lannea velutina A. Rich.*	3	6.82
Annonaceae	*Annona senegalensis Pers.* *Hexalobus monopetalus Engl. & Diels*	2	4.55
Apocynaceae	*Saba senegalensis (A.DC.) Pichon*	1	2.27
Asteraceae	*Vernonia amygdalina Delile.*	1	2.27
Caesalpiniaceae	*Cassia sieberiana (DC) Jacques-Félix*	1	2.27
Celastraceae	*Gymnosporia senegalensis (Lam.) Loes.*	1	2.27
Combretaceae	*Anogeissus leiocarpa (DC.) Guil. & Perr.* *Combretum fragrans F.Hoffm.* *Combretum glutinosum Perr.* *Combretum sp* *Guiera senegalensis J.F.Gmel.* *Pteleopsis suberosa Engl. & Diels.* *Terminalia laxiflora Engl.* *Terminalia macroptera Guill. & Perr.*	8	18.18
Ebenaceae	*Diospyros mespiliformis Hochst. ex A.DC.*	1	2.27
Fabaceae	*Acacia macrostachya Rchb. ex G.Don.* *Acacia raddiana Savi.* *acacia seyal Del.* *Afrormosia laxiflora Harms.* *Burkea Africana Hook.* *Daniellia oliveri(Rolfe) Hutch. & Dalziel.* *Detarium microcarpum Guill. & Perr.* *Dichrostachys glomerata Chiov.* *Entada sudanica Schweinf.* *Isoberlinia doka Craib & Stapf.* *Piliostigima reticulatum (DC.) Hochst.* *Prosopis africana Taub.* *Pterocarpus erinaceus Poir.*	13	29.55
Lamiaceae	*Vitex Barbata ex Baker.*	1	2.27
Malvaceae	*Bombax costatum Pellegr. & Vuillet.* *Grewia bicolor Juss.* *Grewia mollis Juss.* *Sterculia setigera Delile.*	4	9.09
Mimosaceae	*Parkia biglobosa Benth.*	1	2.27

Olacaceae	*Ximenia americana f. inermis (Aubl.) Engl.*	1	2.27
Phyllanthaceae	*Hymenocardia acida Tul.* *Securinega virosa (Roxb. ex Willd.) Baill.*	2	4.55
Rubiaceae	*Crossopteryx febrifuga Benth.* *Gardenia erubescens Stapf & Hutch.* *Sarcocephalus latifolius (Sm.) E.A.Bruce.*	3	6.82
Sapotaceae	*Vitellaria paradoxa C.F.Gaertn.*	1	2.27
Total		44	100.00

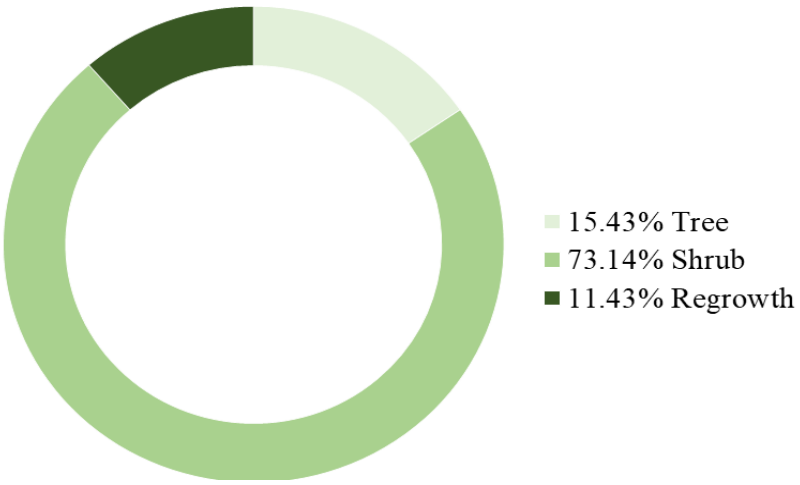
Source: Author construction, November 2022

Table 7. Dominance of woody species per Ha in the study area

Species	Number of Tree/Ha	Relative Dominance (%)
Acacia macrostachya	40	0.34
Acacia raddiana	10	0.08
Acacia seyal	10	0.08
Afrormosia laxiflora	3,990	33.61
Annona senegalensis	570	4.80
Anogeissus leiocarpa	10	0.08
Bombax costatum	20	0.17
Burkea Africana	20	0.17
Cassia sieberiana	300	2.53
Combretum fragrans	440	3.71
Combretum glutinosum	110	0.93
Combretum sp	20	0.17
Crossopteryx febrifuga	250	2.11
Daniellia oliveri	30	0.25
Detarium microcarpum	1,820	15.33
Dichrostachys glomerata	40	0.34
Diospyros mespiliformis	20	0.17
Entada sudanica	10	0.08
Gardenia erubescens	430	3.62
Grewia bicolor	20	0.17
Grewia mollis	20	0.17
Guiera senegalensis	200	1.68
Gymnosporia senegalensis	40	0.34
Hexalobus monopetalus	10	0.08
Hymenocardia acida	10	0.08
Isoberlinia doka	130	1.10
Lannea acida	240	2.02
Lannea microcarpa	10	0.08

Lannea velutina	10	0.08
Parkia biglobosa	20	0.17
Piliostigima reticulatum	120	1.01
Prosopis africana	70	0.59
Pteleopsis suberosa	640	5.39
Pterocarpus erinaceus	20	0.17
Saba senegalensis	80	0.67
Sarcocephalus latifolius	10	0.08
Securinega virosa	140	1.18
Sterculia setigera	10	0.08
Terminalia laxiflora	1,630	13.73
Terminalia macroptera	100	0.84
Vernonia amygdalina	10	0.08
Vitellaria paradoxa	160	1.35
Vitex Barbata	10	0.08
Ximenia americana	20	0.17
Total	**11 870**	**100.00**

Source: Author construction, November 2022



Source: Author construction, November 2022

Figure 2. Characterization of Woody plant structure in the research

2.5. Pastures areas and their main invasive unpalatable species in the study areas

In the research site, livestock has many pastures areas such as forest, used defense land, fallow land, cultivated land, shallows and Bowal. The most visited by animals are forest area (197; 49%); used for the defense land are (70; 17%); Fallow land (59; 15%) and

cultivated land (34; 8%) (Table8). These pasturages areas are undergoing degradation by the frequency of climatic risk related hazards and human behavior. Furthermore, the pasture areas are also affected by the invasive and less palatable plant species that are colonizing its zones. These concerned species are the h*yptis suaveolens* (278; 69%); *Cassia tora* (51; 13%); *Hyptis spicigera* (32; 8%); *Oximum basilicum* (21; 5%); *Walteria indica* (16; 4%); *Sida rhombifolia* (6; 1%) (Table9). The field observation revealed that after the harvest, cultivated land are most colonized by *hyptis spicigera* and *oximum basilicum* and the fallowland by invasion of *Hyptis suaveolens* and *Cassia tora*. The growth of these species less palatable is decreasing the quality of pasturage and livestock productivity. Besides, In the case of chronic shortage feed event, certain animal try to graze these less palatable species.

Table 8. Main pastures areas in the research sites

Pastures areas	Frequency	%	Rank
Forest	197	49	1st
Used for defense land	70	17	2nd
Fallow land	59	15	3rd
Cultivated land	34	8	4th
Shallows	32	8	4th
Bowal	12	3	5th

Source: Individual survey, December (2022)

Table 9. Main invasive unpalatable species colonizing pastures areas

Species	Frequency	%	Rank	Most colonized areas
Hyptis suaveolens	278	69	1st	Fallowland
Hyptis spicigera	32	8	5th	Cultivated land
Cassia tora	51	13	2nd	Fallowland
Sida rhombifolia	6	1	6th	Forest, fallowland
Walteria indica	16	4	4th	Used for defense land
Oximum basilicum	21	5	3rd	cultivated land

Source: Individual survey, December (2022)

3. Discussion

3.1. Richness of herbaceous production in the research sites

At the total forty (40) species have been inventoried for the year 2022 in the research sites. The most dominant species are the *andropogon pseudapricus* (43.68%), *Microchloa*

indica (28.72%), *Loudetia Togoensis* (19.09%), *Eragrostis aspera* (15.27%), *Schizachyrium exile* (11.04%), *Andropogon gayanus* (9.71%). This result is corroborating with those obtained by H. Sanon et al., (2014, p.8) in the soudanian zone of Burkina Faso, reporting that the contribution of *andropogon gayanus* is the most important species in shrubby savannah. In the sudan zone of Burkina faso (Tiogo classified forests) the most contribution species were *Andropogon gayanus, Diheteropogon amplectens, Andropogon ascinodis*, (43%), *Andropogon pseudapricus, Loudetia togoensis, Pennisetum pedicellatum* (35%)(L. Sawadogo, 2009, p.47). According to Zerbo et al., (2016, p.5), In the protected area of West African Savanna Ecosystems, the most important species are *Andropogon gayanus, Andropogon pseudapricus, Hyparrhenia involucrata, Chamaecrista pratensis,and Sorghastrum bipennatum.* However, these results are not corroborated with those fund by N. Coulibaly et al., (2022, p.199) in Niono ranch of Mali reporting that the most dominant species was *Zornia glochidiata* (38.80%), *Schenofeldia gracilis* and *Brachiaria xantholeuca* (16.89%; 16.34%).

The average of dry master biomass is more important in Faragouaran (1,595.92kg/ha) than Koumantou (1,216.40 kg/ha) for the overall and particularly more important in the shrubby savannah, followed by bowal and wooded savannah. The pastures are better in Koumantou at the rate of 54.04 % than Faragouaran (48. 69%). Concerning the both research sites, the richness of pasture is very high for the wooded savannah, followed by the bowal and shrubby savannah. Similar results were fund by D. Konare & M. Coulibaly, (2019, p. 215) in the rural commune of Dabia (south of Mali) illustrating that the dry mater are varying between 2,74 tonne/ha for silty-sandy soils vegetation compared with 1.63 tonne/ha for vegetation on leathery knoll soils, and the pastoral value is fluctuating from 35 to 64.61%. These results are in accordance with A. Alhassane et al., (2018, p.1711) (Niger), who observed that in the Maradi Region of Niger, the herbaceous Biomass were varying between 1.06 T/ha and 0.43T/ha particularly for the north soudanian and south soudanian bioclimatic scale.

3.2. Decreasing carrying capacity in the study area

The average number of number of Tropical Livestock Unit (TLU) is slightly high for the shrubby savannah (0.25TLU/Ha/year) and for the bowal slightly low (0.18 TLU/Ha/year). The average number of days per year of livestock for pastures exploitation is 90.34 days for the shrubby savannah, 68.78 days for the wooded savannah and 65.87 days for the bowal. The general average is 75 days from the assessment of the year 2022 in the research site.). In the soudanian zone of Burkina

Faso, results obtained by H. Sanon et al.,(2014, p. 9) announced that in the shrubby savannah the carrying capacity were 1,559.44 TLU per year for an area of 2,823.4 ha per year either 1.81 TLU/year/ha. In Niger, particularly the Region of Maradi, the carrying capacity were varying between 0.149 TLU/ha/year and 0.042 TLU/ha/year.

3.3. A ligneous stratum diversified and getting highly degraded

The vegetation cover of wooded species is very highly diverse and composed of sixteen (16) families of species: anacardiaceae, annonaceae, apocynaceae, asteraceae, caesalpiniaceae, celastraceae, combretaceae, ebenaceae, fabaceae, lamiaceae, malvaceae, mimosaceae, olacaceae, phyllanthaceae, rubiaceae, sapotaceae (table39). From the overall families, the fabaceae is the most important (13 species either 29.55%), followed by the combretaceae (8 species either 18.18%), malvaceae (4 species either 9.09%), anacardiaceae and rubiaceae (3 species either 6.82%). These results are supported by those found by F. S. Traoré et al.,(2022, p. 23) illustrating that in west Sahel of Mali (District of Niono), the most important family of species was the fabaceae (9 species), followed by the combretaceae (5 species). By contrast, results conclusion found by A. Dione et al., (2020, p. 778) in the center part of Senegal reporting ceasalpiniaceae and mimosaceae were the most represented families of wood species respectively 24% and 21%.

The most dominant species are *Afrormosia laxiflora* (3 990 individuals/ha either 33.61%), *Detarium microcarpum* (1 820 individuals/ha either 15.33%), *Terminalia laxiflora* (1,630 individuals/ha either 13.73 %), *Pteleopsis Suberosa* (640 individuals/ha either 5.39%), *Annona senegalensis* (570 individuals/ha either 4.80%). In the soudanian zone of Burkina-faso, the results similar results were obtained by H. O. Sanon et al., (2014, p. 10) reporting that the *Detarium microcarpum* (632 individuals/ha) and the *Pteleopsis suberosa* (482 individuals/ha) are the most important tree. By contrast, in the savannah ecosystem zones of Burkina Faso, results obtains by S. Santi, (2011, p.60) showed that the highest density of species were *Grewia bicolor* (247 individuals/ha), *Combretum nigricans* (245 individuals/ha), *Detarium microcarpum* (158 individuals/ha), *Grewia mollis* (157 individuals/ha), *Feretia apodanthera* (140 individuals/ha), *Anogeissus leiocarpa* (140 individuals/ha), *Acacia pennata* (106 individuals/ha).

The Characterization of Woody plant structure showed that the majority of plant are shrubs (73.14 %) and only 15.43% are tree. This situation is explained multiple stressors to resources including climate hazards, human pressure. In the Sahelian rangelands of

the Niono Ranch (Mali), contrast results found by N. Coulibaly, et al., (2022, 203) reporting that the number of regrowth trees (76%) is higher than the number of trees and shrubs (16%).

3.4. Pastures areas and their main invasive unpalatable species in the study areas

The most important pasturage zones grazed by animals in the study areas are forest area, the used for the defense land, the fallow land, and cultivated land and the bowal. These results are supported by T. Amole & A. Ayantunde, (2016, p.46) in Maradi and Zinder region (Niger) noticing that the major feed resources in both study sites were natural pasture and crop residues. These pasturages areas are experiencing climatic related hazards at high frequency and human interference. Pastoralists in Borana area indicated that climate change had its effect on their livelihoods through various mechanisms; as prioritized by pastoralists, the four major effects of climate change on livestock production include feed shortage, shortage of water, reduced productivity, and decreased mature weight and/or longer time to reach mature weight in their order of importance (S. Tiruneh & F. Tegene, (2018, p. 43).

The pasture areas are also affected by the invasive and less palatable plant species that are colonizing the rangelands. They are about *Hyptis suaveolens* (69%); *Cassia tora* (13%); *Hyptis spicigera* (8%); *Oximum basilicum* (5%); *Walteris indica* (4%); *Sida rhombifolia* (1%). The field observation reveal that after the harvest, cultivated land are most colonized by *Hyptis spicigera* and *Oximum basilicum* than other areas. The fallowland are invaded by *Hyptis suaveolens* and *Cassia tora*. The growth of these species is decreasing the quality of pasturage and livestock productivity. In the case of chronic feed shortage, certain animal try to graze these low appetizing species. These are support by M. Oumorou et al., (2011, p.1268) in the soudanian zone of Benin reporting that it is unanimously recognized that *Hyptis suaveolens* is not palatable to ruminants and its expansion reduced forage resources even though cattle try to graze them in the event of a chronic shortage. In the northwestern India, the *Hyptis suaveolens*; were the dominant species of the invaded areas. Its high IVI may be attributed to the greater height and biomass in the invaded areas compared to the uninvaded areas (A. Sharma et al., 2017, p. 159)

Conclusion

The present research documented pastoral potential resources, invasive and less palatable plant species assessment for improving livestock productivity in the south

west of Mali. The majority of respondents were aged between 40-49 and dominated by Bambara and Peulh ethnic groups. Forty (40) herbaceous species have been inventoried for the year 2022 in the research sites. The most dominant species are the *Andropogon pseudapricus*, *Microchloa indica*, *Loudetia togoensis*, *Eragrostis aspera*, *Schizachyrium exile*, and *Andropogon gayanus*. The average of dry matter biomass is higher in Faragouaran than Koumantou but the pastoral value referring to pasture quality is higher in Koumantou than Faragouaran. The carrying capacity is slightly high for the shrubby savannah zone than bowal zone. The vegetation cover of wooded species is very riched and composed by sixteen (16) families of species. The fabaceae is the most important species families. The most dominant species are *Afrormosia laxiflora, Detarium microcarpum, Terminalia laxiflora, Pteleopsis suberosa, Annona Senegalensis*. The livestock has so many pasture areas such as forest, used defense land, fallow land, cultivated land, shallows, and Bowal. The most visited by animals are forest areas, used for defense land, fallow land, and cultivated land. The field observation reveals that after the harvest, cultivated land is most colonized by *Hyptis spicigera* and *Oximum basilicum*. The fallowlands are invaded by *Hyptis suaveolens* and *Cassia tora*. The growth of these less palatable plant species is decreasing the quality of pastures and livestock productivity.

Ethical statements

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this submission.

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