INNSPUB

Journal of Biodiversity and Environmental Sciences | JBES
ISSN: 2220-6663 (Print); 2222-3045 (Online)
Website: https://www.innspub.net
E-mail contact: info@innspub.net
Vol. 28, Issue: 4, p. 129-138, 2026

RESEARCH PAPER

OPEN ACCESS

Comparative assessment of plant biomass in the climatic zones of Burkina Faso

Alimata Zorom*, **Yélézouomin Stéphane Corentin Somé**

Laboratory for Research in Human and Social Sciences (LABOSHS), Norbert Zongo University, Koudougou, Burkina Faso

Key words: Burkina Faso, Climatic zones, Biomass, Herbaceous, Woody

Received: 27 March, 2026 **Accepted:** 10 April, 2026 **Published:** 15 April, 2026

DOI: https://dx.doi.org/10.12692/jbes/28.4.129-138

ABSTRACT

Plant biomass plays an important role in the sustainability of agropastoral systems. In Burkina Faso, climatic diversity suggests high variability in plant production across zones. This research compares herbaceous and woody biomass yields across the country's three climatic zones using data collected from 2017 to 2019 by the Ministry of Agriculture, Animal and Fishery Resources. The methodology is based on non-parametric statistical tests (Kruskal-Wallis and Dunn) and spatial analysis (Kriging). The results show that the climatic zone significantly influences woody biomass production across all three zones. For herbaceous biomass, no significant difference is observed between the Sahelian and sudano-sahelian zones (p=0.112), while the sudanian zone stands clearly apart from the other two. The spatial representation reveals a northward-to-southward increasing productivity gradient, more pronounced woody biomass than for herbaceous biomass. These findings highlight the vulnerability of the Sahelian and sudano-sahelian zones to climate variability and provide a quantitative basis for guiding the management of pastoral resources in Burkina Faso.

***Corresponding Author:** Alimata Zorom ✉ alimazorom26@gmail.com

INTRODUCTION

Plant biomass is a major source of renewable natural materials (Rinaudo, 2008). Rinaudo, (2008), estimates in his work that by 2050, half of the raw materials for the chemical industry in the United States will come from plants. Furthermore, plants play a key role in the environment by absorbing CO2 and producing oxygen necessary for life (Knauer *et al.*, 2023). According to Zhao *et al.*, 2019, they also contribute to climate regulation and air purification. At the same time, they contribute to reducing greenhouse gases worldwide (Ndehedehe and Ferreira, 2019). In Africa, savannas occupy 65% of the territory and are composed of herbaceous carpets associated with scattered trees and shrubs (Huntley *et al.*, 1982 in Grouzis and Akpo, 2006). In the Sahelian zones, vegetation is mainly composed of annual herbaceous plants with some perennial species such as grasses, shrubs and trees (Hiernaux and Le Houérou, 2006b). This vegetation is essential for human and animal nutrition, and to maintain the balance of ecosystems (Morton, 2007; Thornton *et al.*, 2009). In Sub-Saharan Africa, herbaceous plants are the main source of food for livestock, especially during the rainy season when annual grasses dominate animal feed (Assouma *et al.*, 2018). Wood provides timber, fodder and environmental services such as carbon storage and soil protection (Brandt *et al.*, 2015).

Located in the heart of the West African rainfall gradient, Burkina Faso presents a mosaic of natural environments characterized by great climatic, soil and floristic heterogeneity. Its territory is shared by two major phytogeographical domains (Fontès and Guinko, 1995).

However, these vegetation areas are subject to increasing anthropogenic and climatic pressures that compromise their sustainability (Dimobe *et al.*, 2017). The available research shows a strong regression of wooded formations. Between 2001 and 2013, the area of wooded savannas decreased by 22.30%, while cultivated areas gained nearly 167.87% of additional surface area (Dimobe *et al.*, 2017).

Despite the recognized importance of plant biomass, studies conducted in Burkina Faso remain fragmented, generally limited to a single plant component or a restricted portion of the territory (Akoudjin *et al.*, 2016; Sanou *et al.*, 2023). The simultaneous comparison of herbaceous and woody biomass at the scale of the three climatic zones of the country remains therefore little explored in the available scientific literature. It is to address this lack that this research was conducted. Its general objective is to compare biomass yields in the three climatic zones of Burkina Faso. Specifically, it involves: i) comparing herbaceous and woody biomass in the three climatic zones and ii) analyzing the spatial distribution of biomass in the same zones.

MATERIALS AND METHODES

Study area

Burkina Faso is a landlocked Sahelian country in the heart of West Africa (Fig. 1a). It covers an area of 274,200 km² and is framed between the 9th and 15th degrees of north latitude, and between 2°20' East and 50°3' West longitude. Its climate is a tropical one, characterized by two contrasting seasons: a dry season (about seven months) and a rainy season (about five months, shorter in the northern part of the country). Rainfall varies considerably from northeast (350 mm) to southwest (1200 mm) (Kabore *et al.*, 2017). The country is subdivided into three climatic zones: the Sahelian zone, the Sudano-Sahelian zone and the Sudanese zone (Fig. 1b). From a phytogeographical point of view, Burkina Faso belongs to the Sudano-Zambezian region (Fontès and Guinko, 1995), divided into domains (Sahelian and Sudanian), each subdivided into two sectors (Fig. 1c).

Data source and sampling

The plant biomass data used in this study come from national system for evaluating pastures, supervised by the National Scientific Committee to support the Ministry of Pastoral Resources Monitoring and Evaluation (COSSERP) Agriculture, Animal Resources, and Fisheries (MARAH). This committee is responsible for validate the methodology used and ensure the quality of the data collected in the field.

These data concern herbaceous biomass and woody biomass. The measurements were evaluated at the end of the rainy season (October–November) on plots of 1 m². This period corresponds to the peak availability of biomass. The collection method combines visual estimation and weighting cut-off. Yields are estimated in g/m². The collection period covers three consecutive years from 2017 to 2019. The sample includes 159 observation sites distributed between the three climatic zones.

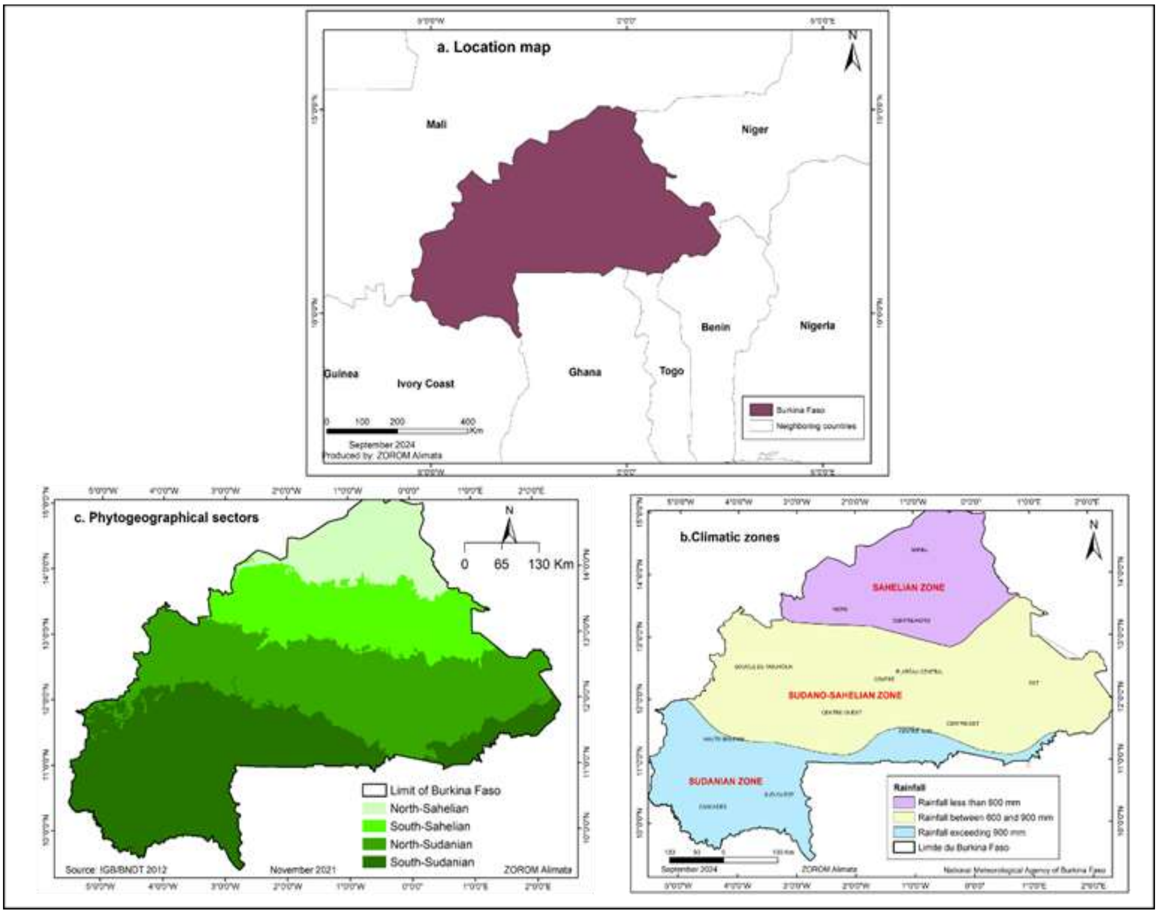

Fig. 1. Location of the study area

Statistical analysis

The verification of the application conditions of statistical tests was based on the Shapiro–Wilk normality test (threshold $\alpha = 0.05$), selected for its good power properties among the available normality tests (Oztuna, 2006; Ghasemi and Zahediasl, 2012), and on the Bartlett test for homogeneity of variances ($\alpha = 0.05$ threshold). In case of non-compliance with the normality condition, the non-parametric Kruskal–Wallis test was applied to compare biomass production between climatic zones (threshold $\alpha = 0.05$). This test evaluates whether the samples come from the same population, without presupposing a normal distribution of data, ensuring robust comparison despite deviations from parametric statistical assumptions in datasets.

When the Kruskal–Wallis test is significant, multiple pairwise comparisons are made using the Dunn's test, with Bonferroni correction to control for error risk (corrected threshold $\alpha/3 = 0.0167$). This test specifically identifies pairs of zones that differ significantly in terms of biomass production.

Spatial analysis

Kriging was used for the spatial distribution of herbaceous and woody biomass. This geostatistical method is recognized for its robustness in estimating environmental variables from unevenly distributed point data and is the most frequently used (Gratton, 2002), as it is a better estimator and minimizes bias (De Lozzo, 2017).

RESULTS

Comparison of herbaceous biomass between climatic zones

The Shapiro-Wilk normality test applied to herbaceous biomass reveals that the distributions of the Sudanian and Sudano-Sahelian zones do not follow a normal distribution ($p < 0.05$), which justifies the use of the non-parametric Kruskal-Walis test (Table 1).

The Kruskal-Wallis test confirms a significant influence of the climatic zone on herbaceous biomass production (p=0.004) (see Table 2). This means that the climate affects the production of herbaceous biomass, which differs according to the climatic zone.

Multiple pairwise comparisons according to the Dunn procedure reveal two distinct homogeneous groups (see Table 3). The Sahelian zone and the Sudano-Sahelian zone belong to the same group (group A), while the Sudanian zone forms group B.

The difference in herbaceous biomass production is presented in Table 4. A highly significant difference is observed between the Sudanian and Sahelian zones (p = 0.001) and between the Sudanian and Sahelian zones (p =0.015). No significant difference was observed between the Sahelian and Sahelian zones (p =0.112). This lack of difference could be explained by the similarity of climatic and soil conditions between these two areas.

Table 1. Shapiro-Wilk normality test of the three climatic zones of Burkina Faso

Climatic zones	Statistic W	*p*-value	Threshold (α)	Normality
Sahelian zone	0.959	0.330	0.05	Oui
Sudanian zone	0.875	0.001	0.05	Non
Sudano-sahelian zone	0.961	0.006	0.05	Non

Table 2. Kruskal-Wallis test results

Parameters	Value
K (observed value)	11.196
K (critical value)	5.991
DDL	2
p-value (unilateral)	0.004
Alpha	0.05

Table 3. Multiple pairwise comparisons following Dunn's procedure

Zone	Sample size	Sum of ranks	Mean rank	Groups	
Sahelian	28	17345	61.46	A	
Sudano-sahelian	94	73030	77.91	A	
Sudanian	37	36825	99.27		B

Table 4. Significance test of herbaceous biomass by climatic zone

Zones	Sahelian	Sudanian	Sudano-sahelian
Sahelian	1	0.001	0.112
Sudanian	0.001	1	0.015
Sudano-sahelian	0.112	0.015	1

Bonferroni-corrected significance level: 0.0167

Table 5. Shapiro-Wilk normality test

Climatic zones	Statistic W	*p*-value	Threshold(α)	Normality
Sahelian zone	0.932	0.071	0.05	Oui
Sudanian zone	0.938	0.040	0.05	Non
Sudano-sahelian zone	0.941	0.000	0.05	Non

The distribution of herbaceous biomass values (Fig. 2) illustrates these trends. The Sahelian zone and the Sahelian Sudano zone record more similar values, while the Soudanian zone has the highest values (maximum 199.5 g/m² and a minimum of 102.5 g/m²) with little dispersion. This low dispersion shows a good regularity of the herbaceous biomass in this area. The Sahelian zone has values between 65.2 g/m² and 157.5 g/m², while the Sudano-Sahelian transition zone has values between 45.5 g/m² and 195.5 g/m² with a median of 1254 g/m².

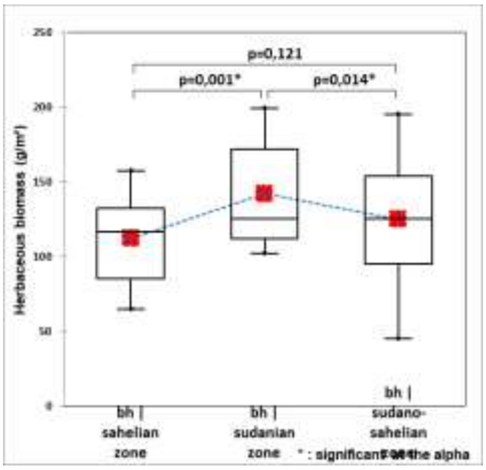

Fig. 2. Dispersion of herbaceous biomass in the three climatic zones of Burkina Faso
Bh: Herbaceous biomass

Comparison of woody biomass between climatic zones

The analysis of normality by the Shapiro-Wilk test indicates a normal distribution only for the Sahelian zone (p=0.071 > 0.05). The Sudanian (p=0.040) and Sudano-Sahelian (p < 0.001) zones show non-normal distributions. The rationale for using the Kruskal-Walis test (Table 5). The Kruskal-Walis test reveals a highly significant influence of the climatic zone on the production of woody biomass (K=31.343; p < 0.0001; ddl=2) (Table 6). Multiple pairwise comparisons according to the Dunn procedure identify three distinct homogeneous groups (Table 7). Group A for the Sahelian zone; Group B for the Sudano-Sahelian zone and Group C for the Sudanian zone.

Differences between all zone pairs are statistically significant (Table 8). The differences between the Sahelian zone and the Sudanian zone (p > 0.0001) and between the Sahelian zone and the Sahelian zone (p < 0.0001) are very highly significant. A significant difference is also observed between the Sudanian and Sahelian zones (p=0.005), although less marked.

The statistical distribution of woody biomass values (Fig. 3) confirms this gradient. The Sudanian zone has the highest values (88.6-194 g/m²) with low dispersion. This means that the area has stable and favorable rainfall conditions. The Sahelian zone shows significantly lower values (20.5-178.3 g/m²) with a high variability that could be explained by the instability of climatic conditions. Between these two zones exists the Sudano-Sahelian one, which is a transition zone. In this area, the dispersion is more moderate with values ranging from 43.7 g/m² to 179 g/m². The results confirm the existence of a north-south increasing wood productivity gradient determined by the national climate gradient.

Table 6. Kruskal-Wallis test / Two-sided test (Biomass)

Parameters	Value
K (observed value)	31.343
K (critical value)	5.991
DDL	2
p-value (unilateral)	<0.0001
Alpha	0.05

Table 7. Multiple pairwise comparisons following Dunn's procedure

Zone	Sample size	Sum of ranks	Mean rank	Groups
Sahélienne	28	11730	41.93	A
Soudano-sahélienne	94	76120	80.79	B
Soudanienne	37	39350	106.51	C

Table 8. Significance test (p-value)

Zones	Sahelian	Sudanian	Sudano-sahelian
Sahelian	1	<0,0001	<0.0001
Sudanian	<0.0001	1	0.005
Sudano-sahelian	<0.0001	0.005	1

Bonferroni-corrected significance level: 0.0167

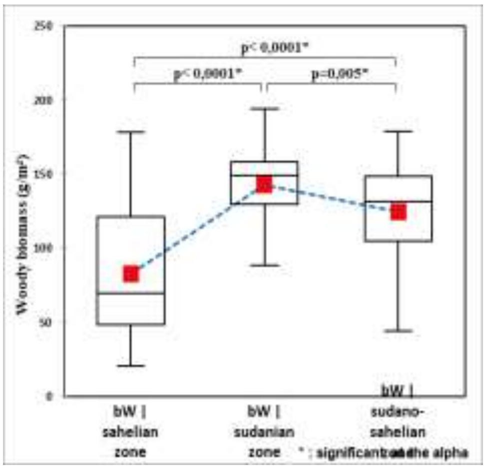

Fig. 3. Dispersion of woody biomass in the three climatic zones of Burkina Faso
bW: Woody biomass

Spatial distribution of herbaceous biomass

The spatial distribution map of herbaceous biomass (Fig. 4) shows values ranging from 56 to 128 g/m² over the period 2017-2019. The Sahelian zone has the lowest values (56-81 g/m²), as do the regions of Kadiogo, Oubri and part of the Yadga. High-production areas (102-128 g/m²) occupy the Guiriko, a large portion of Bankui, Nazinon and Gulmu, and a small part of the Djôro.

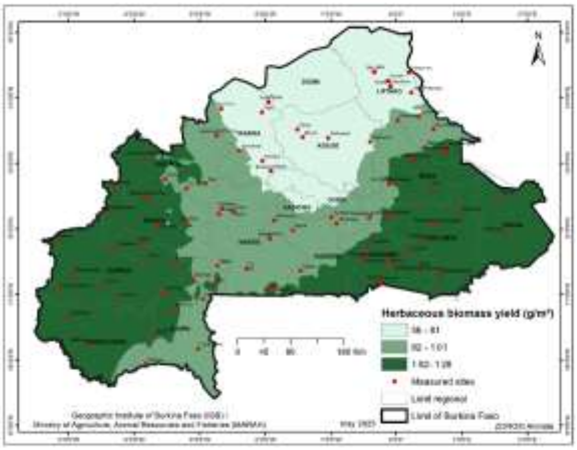

Fig. 4. Spatial distribution of herbaceous biomass in Burkina Faso

Overall, the distribution follows an increasing gradient from north to south, consistent with the national rainfall gradient. This spatial gradient, although clearly visible on the map, contrasts with the lack of significant difference observed between the Sahelian and Sudano-Sahelian areas during statistical comparisons (p=0.112). This means that the spatial structure of the data allows us to differentiate areas beyond what point distributions reveal.

Spatial distribution of woody biomass

The spatial distribution of woody biomass (Fig. 5) follows a pattern broadly similar to that of herbaceous biomass, but with a more pronounced north-south gradient. The Sahelian zone has very low wood production values. As we move south, wood production increases significantly. The Sudanian zone shows high yields throughout the country (124-156 g/m²). In the Sahelian Sudano zone, the regions of Nando, Kadiogo, Nazinon and Bankui also show high yields while the part is present with average yields 86-123 g/m²).

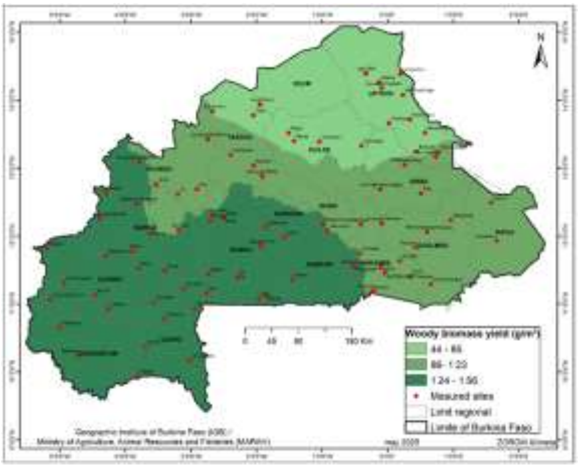

Fig. 5. Spatial distribution of woody biomass production in Burkina Faso

DISCUSSION

Plant production in Burkina Faso exhibits significant variability from north to south. This variation is directly related to climatic zones, delineated by isohyets of annual rainfall ranging from 600 mm to 900 mm (Johnson *et al.*, 2023). In the north, within the Sahelian zone, annual rainfall is less than 400 mm, and the rainy season is very short, lasting approximately three months. In the south, within the Sudanian zone, annual rainfall exceeds 900 mm, with a longer rainy season. This rainfall gradient results in increased vegetation cover and production from north to south (Somé *et al.*, 2023). These findings are consistent with the increasing gradient of plant productivity from north to south in the Sahel observed by Anchang *et al.* (2019). The correlation between rainfall and vegetation production is well established in the literature. In arid Sahelian environments, Herrmann *et al.* (2005) consider rainfall to be the primary constraint on vegetation growth. The rainfall-biomass relationship is confirmed in the work of De Leeuw et Nyambaka (1988) in East Africa, which demonstrates that with 300 mm of rainfall, the predicted biomass could reach 1200 to 2000 kg DM ha^{-1}, while with 500 mm of rainfall, the predicted biomass varies between 2100 and 3900 kg DM ha^{-1}. The work of Akoudjin *et al.* (2016) shows that the average production of herbaceous biomass reaches 321 g/m^2 in the Sudanian zone compared to only 95 g/m^2 in the Sahelian zone. This difference is explained by the progressive reduction of rainfall from south to north and the decrease in perennial species in favor of short-cycle annual species (Somé *et al.*, 2023). The effect of rainfall on vegetation typology becomes particularly discriminating below the 600 mm isohyet, which, according to Akoudjin *et al.* (2016), marks the biological separation between the savanna and Sahelian steppe zones.

Contrary to the lack of biomass difference observed in this research between the Sahelian and Sudanian-Sahelian zones, Akoudjin *et al.* (2016) demonstrate that there is a difference in herbaceous biomass production between these two climatic zones. This divergence between the two studies warrants careful methodological analysis. Indeed, the Kruskal-Wallis and Dunn statistical tests compare point value distributions independently of their geographic location. These tests provide information on differences in average production levels between zones. However, the herbaceous biomass distribution map reveals a pronounced north-south gradient. Kriging interpolation explicitly incorporates the spatial autocorrelation structure of the data, which allows for the capture of a continuous gradient even when point distributions are statistically similar. Thus, statistical equivalence between two zones does not preclude the existence of a spatial organization visible in geostatistical interpolation. These two approaches are complementary. Statistical tests characterize production levels by area, while spatial analysis reveals how these productions are organized geographically. According to Brandt *et al.* (2019), the production of the herbaceous layer, composed mainly of annual plants, is closely linked to the seasonal distribution of rainfall. These same authors cite Zhang *et al.* (2018), who emphasize that in the Sahel, prolonged dry spells of more than 14 days during the growing season significantly reduce herbaceous production. The availability of forage resources, particularly herbaceous plants, is strongly affected by climate variations, which cause a qualitative and quantitative decline in forage and a degradation of pastures (Djohy *et al.*, 2022). Any decrease in rainfall leads to a direct reduction in the productivity of natural pastures (Djohy *et al.*, 2022). This is also observed in the Sahel, where seasonal changes affect herbaceous biomass (Delon *et al.*, 2015). (Brandt *et al.*, 2019), find with the monitoring of biomass in the Sahel over 30 years a contrasting dynamic between woody and herbaceous biomass, with woody biomass growing much faster than herbaceous biomass.

Contrary to herbaceous biomass, whose response to the climatic gradient is attenuated between the Sahelian and Sudanian-Sahelian zones, woody biomass exhibits a more pronounced sensitivity to north-south variations. In the Sahelian zone, low production is explained by insufficient rainfall and high interannual variability (Zorom *et al.*, 2022). The low production in the north is also explained by sparse stands, dominated by a few species well adapted to arid conditions, such as Acacia senegal, Balanites aegyptiaca, and Ziziphus mauritiana (Sanou *et al.*, 2023). The harvesting of firewood and overgrazing exacerbate the degradation of Sahelian woody plants (Vincke, 1994). In the Sudanian zone, rainfall exceeding 900 mm per year (Coulibaly *et al.*, 2023) and soils rich in organic matter promote abundant and homogeneous woody production (Bationo *et al.*, 2007). This difference is explained by the fact that the increase in rainfall observed since the 1980s benefits tree cover more than herbaceous vegetation (Anchang *et al.*, 2019).

Beyond rainfall, which is the dominant explanatory factor for the observed production gradient, other climatic factors also play a role. Faurie *et al.* (2011) estimate that vegetation development depends on potential evapotranspiration (ETP) and relative humidity (RH).

Hiernaux and Le Houérou (2006) also explain that the availability of herbaceous plants is conditioned by parameters such as rainfall, solar radiation, temperature, and humidity. In addition to these climatic factors, other factors also influence vegetation dynamics. These include, for example, protected forests, orchards, sacred sites, and watercourses (Diallo *et al.*, 2020). Furthermore, Cissé *et al.* (2015) also demonstrate that soil type and plant floristic composition are factors that influence vegetation dynamics. Poor soils and high human pressure can also contribute to low herbaceous biomass production. The high productivity observed in the Sudanian zone is explained by favorable conditions, notably rainfall often exceeding 1000 mm/year and deep soils rich in organic matter (Bationo *et al.*, 2007).

CONCLUSION

This study compares the production of herbaceous and woody biomass in the three climatic zones in Burkina Faso, based on data covering the period 2017 to 2019. The results highlight a productivity gradient increasing from north to south, whose intensity differs according to the plant stratum considered. For the woody biomass, three distinct homogeneous groups are identified. For the herbaceous biomass, only the Sudanian zone differs from the other two, while no significant difference is observed between the Sahelian and Sudano-Sahelian zones. This reveals that the seasonal distribution of rainfall is more important than the annual total. However, spatial mapping shows that this statistical equivalence does not preclude a progressive spatial organization from north to south.

In the future, this study will be combined with climatic parameters to determine, in addition to rainfall, what other parameters determine each type of plant biomass in the different zones.

ACKNOWLEDGEMENTS

We are grateful the National Scientific Committee for Support to the Monitoring and Evaluation of Pastoral Resources (COSSERP) as well as all the technical staff involved in the collection and validation of field data.

REFERENCES

Akoudjin M, Kiema S, Sangare M, Cesar J, Bouyer J, Kaboré-Zoungrana C. 2016. Influence des activités agricoles sur la végétation le long d'un gradient pluviométrique nord-sud du Burkina Faso. Vertigo **16**, 1–19. https://doi.org/10.4000/vertigo.17015

Anchang JY, Prihodko L, Kaptué AT, Ross CW, Ji W, Kumar SS, Lind B, Sarr MA, Diouf AA, Hanan NP. 2019. Trends in woody and herbaceous vegetation in the savannas of West Africa. Remote Sensing **11**(5), 576. https://doi.org/10.3390/rs11050576

Assouma MH, Lecomte P, Hiernaux P, Ickowicz A, Corniaux C, Decruyenaere V, Diarra AR, Vayssières J. 2018. How to better account for livestock diversity and fodder seasonality in assessing the fodder intake of livestock grazing semi-arid sub-Saharan Africa rangelands. Livestock Science **216**, 16–23. https://doi.org/10.1016/j.livsci.2018.07.002

Bationo A, Kihara J, Vanlauwe B, Waswa B, Kimetu J. 2007. Soil organic carbon dynamics, functions and management in West African agro-ecosystems. Agricultural Systems **94**(1), 13–25. https://doi.org/10.1016/j.agsy.2005.08.011

Brandt M, Hiernaux P, Rasmussen K, Tucker CJ, Wigneron JP, Diouf AA, Herrmann SM, Zhang W, Kergoat L, Mbow C, Abel C, Auda Y, Fensholt R. 2019. Changes in rainfall distribution promote woody foliage production in the Sahel. Communications Biology **2**(1), 133.

Brandt M, Mbow C, Diouf AA, Verger A, Samimi C, Fensholt R. 2015. Ground- and satellite-based evidence of the biophysical mechanisms behind the greening Sahel. Global Change Biology **21**(4), 1610–1620. https://doi.org/10.1111/gcb.12807

Cissé S, Eymard L, Ndione JA, Gaye AT. 2015. Analyse statistique des relations pluie-végétation au Ferlo (Sénégal). Actes du colloque international de climatologie, 307–312

Coulibaly ND, Traore I, Combary O. 2023. Extrêmes climatiques et production du maïs dans les zones soudano-sahélienne et soudanienne du Burkina Faso. Sciences Naturelles et Appliquées **40**(1), 73–87

De Leeuw PN, Nyambaka R. 1988. Prévision de la production des pâturages à partir des données pluviométriques en Afrique de l'Est aride et semi-aride. In: Actes du troisième atelier PANESA, Addis-Ababa, 260–268.

Delon C, Mougin E, Serça D, Grippa M, Hiernaux P, Diawara MO, Galy-Lacaux C, Kergoat L. 2015. Modelling the effect of soil moisture and organic matter degradation on biogenic NO emissions from soils in Sahel rangeland. Biogeosciences **12**(11), 3253–3272. https://doi.org/10.5194/bg-12-3253-2015

Diallo MS, Sacko I, Diallo BS. 2020. Etude de la dynamique du couvert végétal par télédétection en relation avec la pluviométrie en Moyenne Guinée. Afrique Science **16**(6), 135–147

Dimobe K, Goetze D, Ouédraogo A, Forkuor G, Wala K, Porembski S, Thiombiano A. 2017. Spatio-temporal dynamics in land use and habitat fragmentation within a protected area. Journal of Landscape Ecology **10**(1), 75–95. https://doi.org/10.1515/jlecol-2017-0011

Djohy LG, Sounon Bouko B, Jésutin Dossou P, Boni Y, Afouda Yabi J. 2022. Perception et adaptation des éleveurs de bovins aux changements climatiques au Bénin. Tropicultura **40**, 1–25. https://doi.org/10.25518/2295-8010.2135

Faurie C, Ferra C, Medori P, Devaux J, Hemptinne JL. 2011. Écologie: approche scientifique et pratique. Lavoisier, Paris, 540 p.

Grouzis M, Akpo LE. 2006. Interactions arbre-herbe au Sahel. Sécheresse **17**(1–2), 318–325.

Herrmann SM, Anyamba A, Tucker CJ. 2005. Recent trends in vegetation dynamics in the African Sahel and their relationship to climate. Global Environmental Change **15**(4), 394–404. https://doi.org/10.1016/j.gloenvcha.2005.08.004

Hiernaux P, Le Houérou HN. 2006. Les parcours du Sahel. Sécheresse **17**

Johnson JM, Becker M, Dossou-Yovo ER, Saito K. 2023. Farmers' perception and management of water scarcity in irrigated rice-based systems in West Africa. Agronomy for Sustainable Development **43**, 32. https://doi.org/10.1007/s13593-023-00878-9

Kabore B, Kam S, Ouedraogo GW, Bathiebo D. 2017. Etude de l'évolution climatique au Burkina Faso. Arabian Journal of Earth Sciences **4**(2), 50–59.

Knauer J, Cuntz M, Smith B, Canadell JG, Medlyn BE, Bennett AC, Caldararu S, Haverd V. 2023. Higher global gross primary productivity under future climate. Science Advances **9**(46).

Morton JF. 2007. The impact of climate change on smallholder agriculture. Proceedings of the National Academy of Sciences **104**(50), 19680–19685. https://doi.org/10.1073/pnas.0701855104

Ndehedehe AL, Ferreira VG. 2019. Assessing land surface processes and vegetation dynamics using satellite observations. Remote Sensing of Environment 232, 111309. https://doi.org/10.1016/j.rse.2019.111309

Rinaudo M. 2008. La biomasse végétale, source de molécules organiques. L'actualité chimique **319**, 45–48.

Sanou L, Ouédraogo S, Koala J, Delma J, Thiombiano A. 2023. Productivité intra-annuelle des parcours naturels dans la zone sahélienne du Burkina Faso. Revue d'élevage et de médecine vétérinaire des pays tropicaux **76**, 1–7. https://doi.org/10.19182/remvt.36966

Somé YSC, Zorom A, Somé W, Ouoba PA. 2023. Analyse de la dynamique de la végétation du Burkina Faso. International Journal of Progressive Sciences and Technologies **38**(1), 287–301. https://doi.org/10.52155/ijpsat.v38.1.5191

Thornton PE, Doney SC, Lindsay K, Moore JK, Mahowald N, Randerson JT, Fung I. 2009. Carbon-nitrogen interactions regulate climate-carbon cycle feedbacks. Biogeosciences **6**(10), 2099–2120. https://doi.org/10.5194/bg-6-2099-2009

Vincke C. 1994. La dégradation des systèmes écologiques sahéliens. 87 p.

Zhang W, Brandt M, Fensholt R, Rasmussen K, Tian F, Mbow C. 2018. Climate variability and vegetation dynamics in the Sahel: insights from remote sensing. Global and Planetary Change **161**, 1–13.

Zhao H, He N, Xu L, Zhang X, Wang Q, Wang B, Yu G. 2019. Variation in nitrogen concentration in vegetation in China. Ecological Indicators **96**, 496–504. https://doi.org/10.1016/j.ecolind.2018.09.031

Zorom A, Ouoba PA, Somé W, Somé YSC. 2022. Relationships between rainfall and vegetation production in Burkina Faso. **35**(1), 305–314.