Int. j. adv. multidisc. res. stud. 2025; 5(4):354-359

Received: 25-05-2025
Accepted: 05-07-2025

International Journal of Advanced Multidisciplinary Research and Studies

ISSN: 2583-049X

Spatio-Temporal Dynamics of Dry Matter Productivity (DMP) from Satellite Imagery in the Mouhoun Province, Burkina Faso: Communal-Level Analysis for the Years 2001, 2011, and 2021 in a Context of Climate Change and Increasing Anthropogenic Pressure

[1] Zan Amadou, [2] Sampebgo Abdoul-Azize, [3] Sawadogo Boureima, [4] Bonkoungou Joachim

[1, 2, 3] Department of Geography, Norbert Zongo University, Human Sciences Research Laboratory, UFR/SH, P.O. Box 376, Koudougou, Burkina Faso

[4] Institute of Environment and Agricultural Research (INERA), Center for Environmental, Agricultural Research and Training (CREAF), Burkina Faso

DOI: https://doi.org/10.62225/2583049X.2025.5.4.4599

Corresponding Author: **Zan Amadou**

Abstract

In the face of climate change and increasing human pressure, monitoring ecosystem productivity is essential for the sustainable management of natural resources. The Mouhoun Province, located in western Burkina Faso, is undergoing significant ecological transformations that affect vegetation production. This study aims to analyze the spatio-temporal dynamics of dry matter productivity (DMP) at the communal level for the years 2001, 2011, and 2021. The methodology is based on the use of satellite images from the Copernicus/NDVI database, reprocessed to estimate DMP in kg DM/ha. The approach involved aggregating values by commune from time series data, extracting trends, and mapping spatio-temporal changes using a Geographic Information System (GIS). Additionally, field observations were conducted. This paper seeks to identify communes affected by a decrease or increase in DMP and to analyze the underlying explanatory factors. The results reveal significant heterogeneity in vegetation productivity across the Mouhoun Province. Some communes, such as Safané and Dédougou, show a downward trend in DMP between 2001 and 2021, while Kona shows a slight improvement. These variations are closely linked to the expansion of agricultural frontiers, land pressure, and climatic variability. The study highlights the relevance of satellite imagery as a decision-support tool and opens avenues for integrating DMP into local climate change adaptation policies.

Keywords: Dry Matter Productivity, Remote Sensing, Climate Change, Mouhoun Province, Sustainable Natural Resource Management

1. Introduction

The Mouhoun Province, located in the Sudanian savanna of western Burkina Faso, is experiencing increasing pressures related to climate change and variability, soil erosion, and the intensification of land use (West *et al*., 2020 [10]; Kadeba *et al*., 2015 [9]; Agrhymet, 2001). The use of satellite remote sensing to estimate biomass productivity in terms of Dry Matter Productivity (DMP) now makes it possible to monitor spatio-temporal changes in vegetation at the municipal level (Diouf *et al*., 2015; Zoungrana *et al*., 2018) [7, 8]. Research conducted in the Sahel and across West Africa has demonstrated the effectiveness of FAPAR in detecting trends of vegetation degradation or recovery, given that these indicators are sensitive to vegetation cover and leaf biomass (Bamba *et al*., 2015; Diouf *et al*., 2015; Lobell *et al*., 2004) [6, 7, 4]. In Burkina Faso, analyses of vegetation cover and diversity variation highlight differing dynamics among municipalities, which are associated with land management, agro-pastoral activities, and unpredictable hydrometeorological events (Kadeba *et al*., 2015) [9]. However, few studies have specifically focused on dry matter productivity (DMP) at the municipal scale over multiple decades. This indicator allows for the quantification of plant production in kg DM/ha. As such, it offers both ecological and economic value for land-use planning, natural resource management, and climate change adaptation policies.

2. Methodology

2.1 Spatial and Temporal Framework and Data Sources

This study was conducted at the scale of Mouhoun Province, located in the Boucle du Mouhoun region of Burkina Faso. This agro-ecological region is characterized by a climate that ranges from Sudanian-Sahelian to Sudanian, intense human pressure, and a variety of land uses. Administratively, the province comprises various rural and urban municipalities, which serve as the units of analysis for this study. The province was selected due to its important role in national agro-pastoralism and the significant variation in its vegetation productivity. From a phytogeographical perspective, Mouhoun Province lies at the transition zone between the northern and southern Sudanian sectors. More specifically, the study area is located within the northern Sudanian sector, in the Mouhoun district (Guinko, 1984). This sector is marked by a climate with two well-defined seasons (Traoré, 2018, p. 12): a long dry season lasting from October to May, dominated by the Harmattan—a dry, dust-laden wind—and a rainy season from June to September, heralded by the arrival of the monsoon (a cool and humid wind). According to Zan (2025, p. 126), average annual rainfall varies from 700 mm in the northern part of the region to 900 mm in the south, while average seasonal temperatures range between 24 and 25 °C. Fig 1 illustrates the climatic zones of Burkina Faso and highlights the Mouhoun Province.

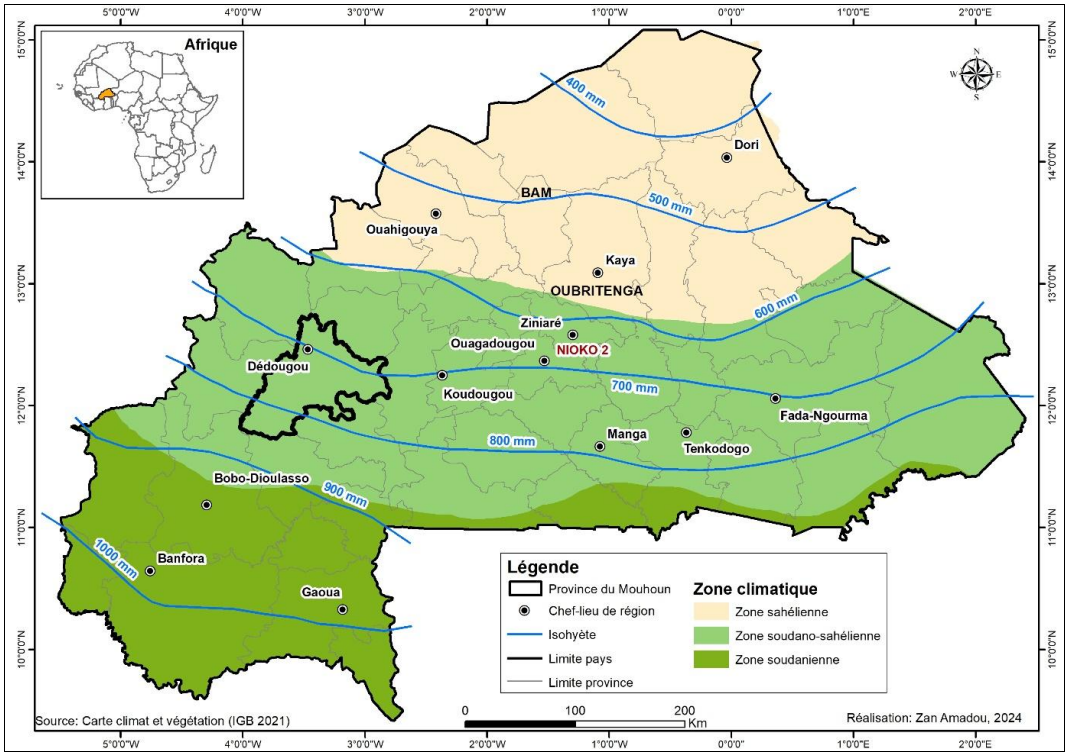


Fig 1: Climatic zones of Burkina Faso and the highlighting of Mouhoun Province

Three key years were selected for this study: 2001, 2011, and 2021. These ten-year intervals are used to assess the progression of dry matter productivity (DMP) in the context of climate change and land use. They also correspond to years for which satellite data are both available and usable, ensuring a relevant comparative analysis. The primary data used come from satellite imagery acquired by SPOT-VGT sensors for years prior to 2014, and by PROBA-V sensors for more recent years. These datasets, accessible via the Copernicus Global Land Service platform https://land.copernicus.eu, provide estimates of DMP in kilograms of dry matter per hectare. In addition to these raster data, vector layers delineating municipal administrative boundaries were provided by the Burkina Faso Geographic Institute (IGB), thereby facilitating spatial analysis at the administrative unit level.

2.2 Data Processing, Analysis, and Representation

Data processing was carried out using QGIS software (version 3.28), which enabled the overlay of DMP maps with the administrative boundaries of the municipalities. For each reference year (2001, 2011, and 2021), annual average dry matter production values were calculated for each municipality. Data extraction was performed using vector-based zoning on the monthly cumulative raster datasets, resulting in a database organized by year and municipality. A comparative analysis was conducted across the three selected periods, highlighting both absolute and relative (percentage) changes in vegetation productivity. This analysis made it possible to identify the spatio-temporal dynamics of DMP in the various municipalities of the province. Productivity differences were interpreted in light of climatic conditions, land use practices, and natural resource management policies implemented during each decade. The results of the analysis were presented in the form of thematic maps, allowing for the visualization of DMP trends by municipality and by year. Additionally, the maps produced in QGIS highlighted the spatial distribution of production levels. These visual representations contributed to a clear and concise understanding of the contrasts and changes in vegetation ecosystem productivity across Mouhoun Province.1.3. Validation, limites et perspectives méthodologiques.

Remote sensing analysis offers the advantage of covering vast territories like Mouhoun Province with consistent temporal continuity. This is particularly useful for monitoring trends in vegetation biomass. In addition, field validation was carried out to refine the results. Although this study relied on secondary data, partial verification of the findings through consultation of national reports (such as those from the Ministry of Agriculture and Hydro-Agricultural Development [MAAH] or the Ministry of Animal Resources [MRA]) and previous research helped strengthen the credibility of the interpretations. The methodological limitations are primarily related to the spatial resolution of the data (1 km), which may obscure certain local disparities. Furthermore, errors related to atmospheric conditions (e.g., cloud cover, aerosols) as well as to the processing algorithms can affect the accuracy of the estimates. To strengthen future research prospects, the integration of climatic data (rainfall, temperature) and local socio-economic data is envisioned. Likewise, participatory surveys with farmers and herders could enrich the analysis with a qualitative approach and allow for the comparison of local perceptions with satellite-observed trends.

3. Results

3.1 Status of Dry Matter Productivity in 2001

In the context of increasing climate change and growing anthropogenic pressures, monitoring ecosystem productivity has become a key requirement for the sustainable management of natural resources. In 2001, Mouhoun Province recorded relatively high levels of dry matter productivity (DMP), with values ranging from 3,657.72 kg DM/ha in Tcheriba to 3,971.34 kg DM/ha in Bondokuy. The municipalities of Bondokuy, Ouarkoye, and Kona exceeded 3,890 kg DM/ha, reflecting satisfactory vegetation cover—likely due to favorable ecological conditions (rainfall, soil types, forest-river systems). In contrast, Dédougou and Tcheriba showed slightly lower-than-average levels, suggesting more intensive land use dynamics. The provincial average estimate was approximately 3,809.4 kg DM/ha, serving as a baseline for assessing future changes. This situation reflects a relatively stable ecological functioning, prior to the intensified impacts of climate variability and human activities. Fig 2 illustrates the distribution of phytomass in 2001 (DMP).

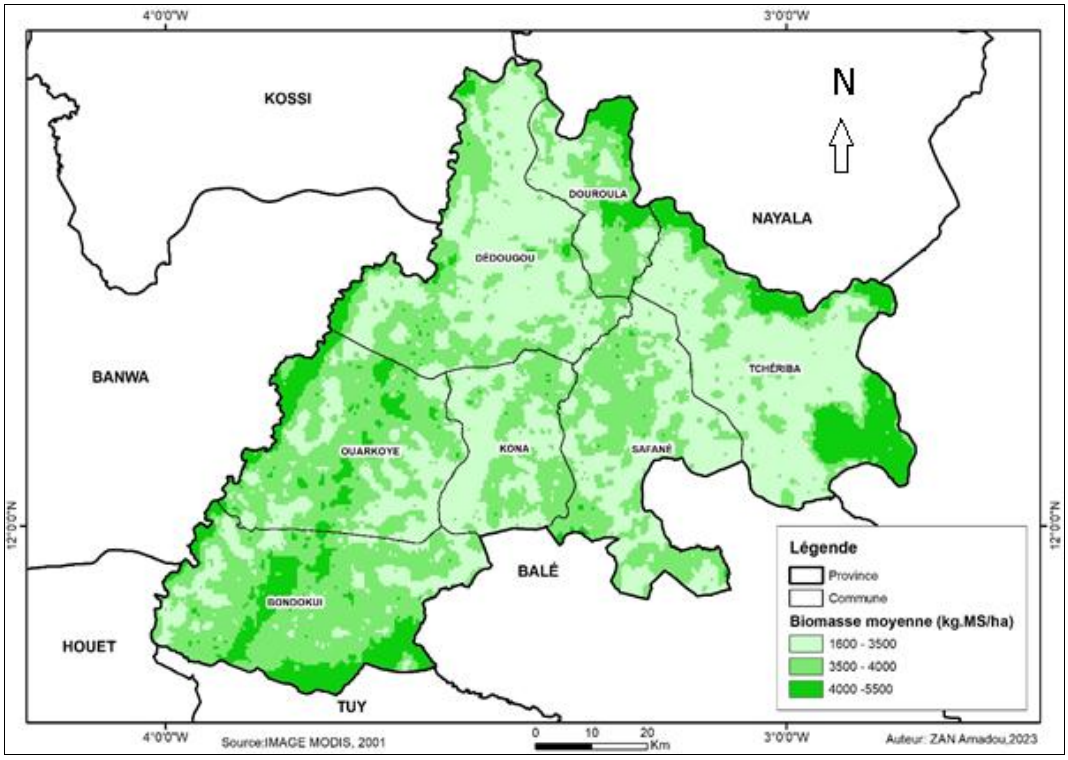


Fig 2: Phytomass distribution in 2001 (DMP)

3.2 Moderate but Differentiated Change in 2011

In 2011, a slight overall decline in productivity was observed across most municipalities, although some showed slight increases. The provincial average dropped to 3,733.1 kg DM/ha, representing an average decrease of 2% compared to 2001. This trend reflects a moderate deterioration in vegetation growth conditions, likely linked to localized drought events or a gradual increase in land pressure. The municipalities of Douroula (+0.65%) and Ouarkoye (+0.26%) maintained or slightly improved their DMP, which may indicate better ecosystem resilience or reduced human disturbance. In contrast, Kona and Safané recorded the most significant declines, with -6.21% and -2.53% respectively, indicating more pronounced degradation. This heterogeneous trend shows that not all municipalities respond uniformly to environmental stress factors. It highlights the need to tailor land management strategies to the specific local realities. Fig 3 illustrates the distribution of phytomass in 2011 (DMP).

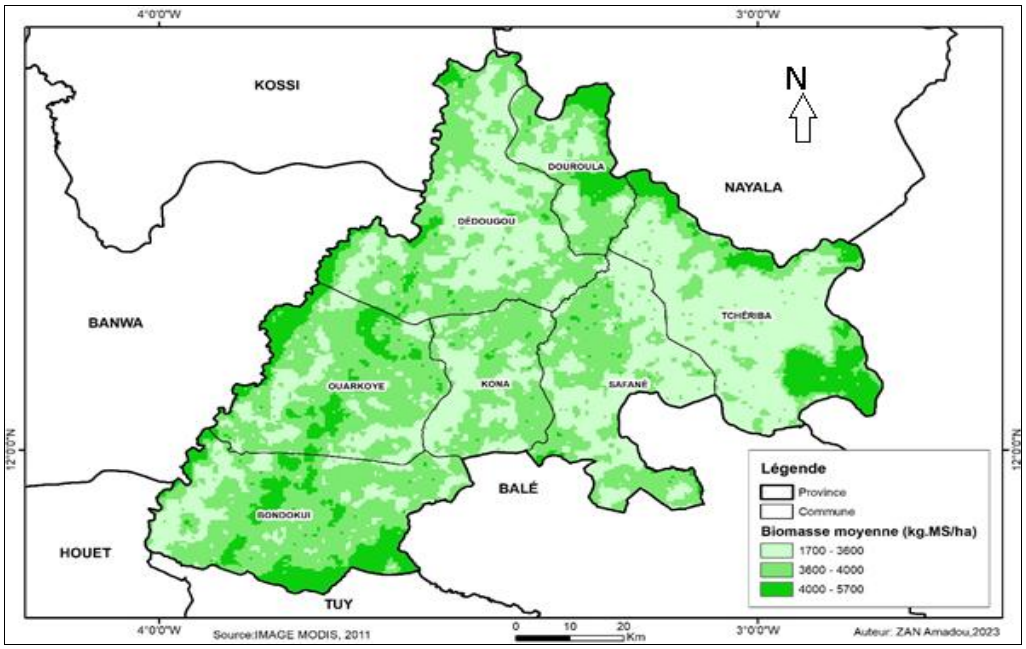


Fig 3: Phytomass distribution in 2011 (DMP)

3.3 Generalized Decline in Productivity in 2021: An Ecological Warning Signal

In 2021, the situation significantly worsened, with a widespread decrease in DMP across all municipalities in the province. The provincial average fell to 3,573.1 kg DM/ha, representing a 6.2% decline compared to 2001. This trend reflects the combined impact of climate change, deforestation, reduced fallow land, and increasing demographic and anthropogenic pressures. The largest declines were observed in Kona (-13.1%), Dédougou (-6.7%), and Safané (-7.1%). Even historically productive municipalities like Bondokuy and Ouarkoye experienced losses of -3.3% and -5%, respectively. These figures highlight a widespread decrease in biomass production capacity, affecting the sustainability of local agricultural and pastoral practices. This rapid degradation of vegetation productivity constitutes an ecological warning signal. It underscores the urgent need to strengthen ecological monitoring systems, promote sustainable land management, and encourage resilient agroforestry and pastoral systems within Mouhoun Province. Fig 4 shows the phytomass distribution in 2021 (DMP), while Fig 5 presents the average annual biomass in kilograms of dry matter per hectare (kg DM/ha) by municipality for the years 2001, 2011, and 2021.

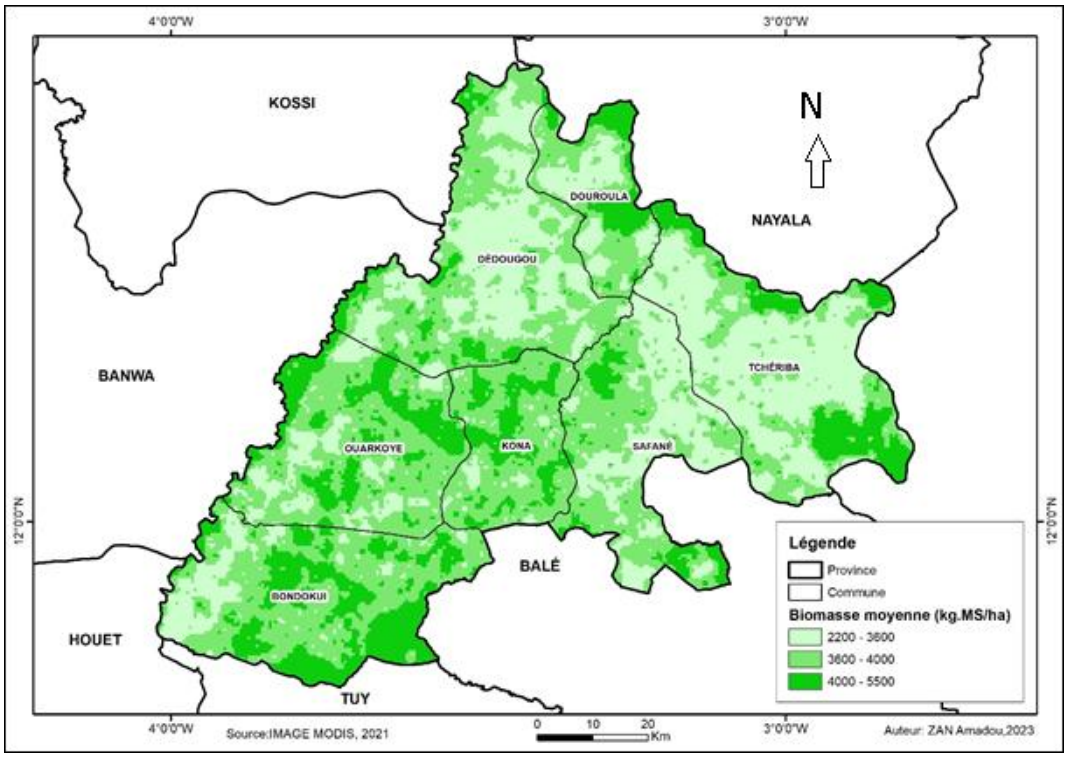
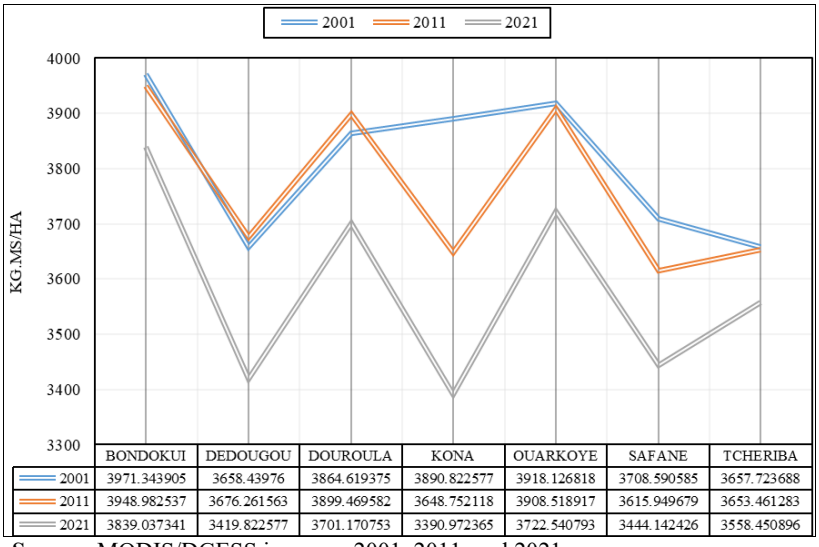


Fig 4: Phytomass distribution in 2021 (DMP)



	BONDOKUI	DEDOUGOU	DOUROULA	KONA	OUARKOYE	SAFANE	TCHERIBA
2001	3971.343905	3658.43976	3864.619375	3890.822577	3918.126818	3708.590585	3657.723688
2011	3948.982537	3676.261563	3899.469582	3648.752118	3908.518917	3615.949679	3653.461283
2021	3839.037341	3419.822577	3701.170753	3390.972365	3722.540793	3444.142426	3558.450896

Source: MODIS/DGESS imagery, 2001, 2011, and 2021

Fig 5: Average annual biomass in kilograms of dry matter per hectare (kg DM/ha) by municipality in 2001, 2011, and 2021

4. Discussion of the Results

In Mouhoun Province, data indicate dry matter productivity (DMP) exceeding 3,600 kg DM/ha between 2001 and 2021, with an average of 3,809.4 kg DM/ha in 2001 compared to 3,573.1 kg DM/ha in 2021. These figures are significantly higher than those reported by Diatta *et al*. (2023, p. 5) for the Sahelian region of Senegal, where DMP decreased from 1,993 kg DM/ha in 2018 to 1,800 kg DM/ha in 2019 despite anticipated rainfall. This disparity may be due to the differing agro-ecological conditions between the Sahel and the Sudanian-Sahelian region of Mouhoun, which is more conducive to plant growth. The importance of spatial variability in DMP is supported by Kaboré-Zoungrana and Sana (1998, p. 59) [3] and Lobell, David *et al*. (2004) [4], who emphasize the influence of pedoclimatic factors and land management. These findings corroborate several earlier studies, such as those by the Ministry of Animal Resources (MRA, 2016, p. 16), which highlight strong regional differences in dry matter production across Burkina Faso. The North-South gradient documented by the Ministry of Agriculture and Hydro-Agricultural Development (MAAH, 2022, p. 28), with values exceeding 2,000 kg DM/ha, supports the results obtained in Dédougou (3,676.26 kg DM/ha in 2011), well above the national averages in northern areas. Beyond quantities, forage quality is also a central issue in dry matter productivity. Bechir and Kaboré-Zoungrana (2012, p. 212) [1] demonstrated that fresh forage has a higher nutritional value than hay, with crude protein content of 19.56% compared to 14.16–18.65% in hay dry matter. This finding highlights that variations in DMP also affect the quality of animal feed, a key factor for agropastoral systems.

Other studies confirm these observed trends. For example, Hien *et al*. (2020) [2] revealed a decline in vegetation productivity in the Centre-North region of Burkina Faso due to irregular rainfall and land degradation. This phenomenon was also documented by J. Memmott *et al*. (2007, p. 1469) [5], who warned of ecological consequences such as the loss of ecosystem services like pollination. Similarly, Lemoalle *et al*. (2012) showed that West African wetlands are subject to significant interannual variability in plant biomass, which notably impacts hydrological regimes. Finally, the results underscore the urgent need to strengthen remote sensing monitoring tools, as they enable fine-scale spatial and temporal analysis of productivity within a sustainable natural resource management framework. These resources are particularly vulnerable in areas experiencing increasing human pressure.

5. Conclusion

In a context marked by climate change and increasing anthropogenic pressures, this study evaluated, using satellite imagery, the spatio-temporal evolution of dry matter productivity (DMP) in Mouhoun Province over the years 2001, 2011, and 2021. The results indicate a general downward trend in DMP, although some municipalities such as Douroula and Ouarkoye show more stable productivity levels. This dynamic reflects both the effects of climatic hazards, harmful land use practices, and the relative resilience of certain ecosystems. Compared to findings from other Sahelian areas (such as Senegal), the levels of DMP observed in Mouhoun remain relatively high, highlighting the province's more favorable agro-ecological position. However, the degradation observed between 2001 and 2021, especially in Kona and Safané, raises serious questions about the effectiveness of local sustainable natural resource management policies. These results underscore the value of remote sensing as a decision-support tool for monitoring vegetation productivity. They call for integrating this data into territorial planning and ecological resilience frameworks. Further analyses considering precipitation, land use, and forage nutritional quality are recommended to provide a more integrated understanding of the sustainability of pastoral and agropastoral ecosystems in the province.

6. Remerciement

Les auteurs tiennent à exprimer leur profonde gratitude à toutes les institutions et personnes ayant contribué à la réalisation de cette étude. Nos remerciements s'adressent aux différents CVD et chefs de villages, pour leur assistance sur le terrain.

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