OPEN JOURNAL SYSTEMS
ISSN: 2675-3065

Meio **A**mbiente (Brasil), v.8, n.1. 079-090 (2026)

Meio Ambiente (Brasil)

Caueto et al

Study of the agrogeological impacts of land use and occupation in the commune of Kapangombe, Bibala Municipality (Angola)

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Histórico do Artigo: Submetido em: 19/08/2025 – Revisado em: 12/12/2025 – Aceito em: 24/01/2026

A B S T R A C T

Changes in land use and land cover have emerged as one of the main drivers of environmental degradation in rural and global contexts. However, there remain significant gaps in studies that correlate these patterns with soil degradation in the municipality of Kapangombe. This study aims to address these gaps through an integrated geoprocessing analysis, using satellite imagery processed with Quantum GIS and Global Forest Watch to assess vegetation cover dynamics. Soil erosion was characterised using the Visual Soil Assessment methodology, while the agroecological soil quality in relation to land use and land cover was evaluated through the Rapid Farmer-Friendly Agroecological method. The results revealed a progressive replacement of forested areas by pastures, with agriculture standing out as the land use most vulnerable to erosion. In contrast, forested areas exhibited the highest soil quality indices, highlighting the protective role of native vegetation in maintaining soil properties. The indicators obtained such as patterns of vegetation loss and erosive vulnerability provide technical support for public policies on land-use planning, degradation mitigation, and the promotion of resilient agroecosystems. This research reinforces the urgency of strategies that reconcile agricultural production with environmental conservation, serving as a model for regions facing similar socio-environmental challenges.

Keywords: land use, vegetation, and erosion.

Estudo dos Impactos Agrogeológicos do Uso e Ocupação do Solo na Comuna de Kapangombe, Município da Bibala (Angola)

R E S U M O

As mudanças no uso e ocupação do solo emergem como um dos principais vetores de degradação ambiental em regiões rurais e global. Com tudo, persistem lacunas de estudos que correlacionem esses padrões à degradação edáfica no município de Kapangombe. Este estudo visa suprir essas lacunas mediante analise integrada de geoprocessamento, utilizando imagens de satélites, processados pelo Quantum Gis e Global Forest Whact na avaliação da dinâmica da cobertura vegetal. A erosão do solo é caraterizados pela metodologia Visual Soil Assessment, enquanto a qualidade edáfica agroecologica do uso e ocupação do solo foi caraterizada por Rapid farmer friendly agroecological. Os resultados evidenciaram substituição progressiva de florestas por pastagens, com agricultura destacando-se como uso do solo mais vulnerável a erosão. Em contrapartida áreas florestais apresentaram os maiores índices de qualidade do solo, sublinhando o papel protetivo da vegetação nativa na manutenção das propriedades edáficas. Os indicadores obtidos como padrões da perda vegetacional vegetação e vulnerabilidade erosiva oferecem subsídios técnicos para políticas publicas de ordenamento territorial, mitigação da degradação e promoção de agroecossistemas resilientes. Esta pesquisa reforça a urgência de estratégias que conciliem produção agrícola e conservação ambiental, servindo como modelo para regiões com desafios socioambientais análogos.

Palavras-chave: usos do solo, vegetação e erosão.

Caueto, M. L., Capolo, A. J., Sawambo, H., Kussumua, S. J. F., & Mutumba, F. A. (2026). Study of the agrogeological impacts of land use and occupation in the commune of Kapangombe, Bibala Municipality (Angola). **Meio Ambiente (Brasil)**, v.8, n.1, p.79-90.

Estudio de los Impactos Agrogeológicos del Uso y Ocupación del Suelo en la Comuna de Kapangombe, Municipio de Bibala (Angola)

R E S U M E N

Los cambios en el uso y la cobertura del suelo han surgido como uno de los principales impulsores de la degradación ambiental en contextos rurales y globales. Sin embargo, aún existen lagunas significativas en los estudios que correlacionan estos patrones con la degradación del suelo en el municipio de Kapangombe. Este estudio tiene como objetivo abordar estas lagunas mediante un análisis integrado de geoprocesamiento, utilizando imágenes satelitales procesadas con Quantum GIS y Global Forest Watch para evaluar la dinámica de la cobertura vegetal. La erosión del suelo se caracterizó utilizando la metodología de Evaluación Visual del Suelo (Visual Soil Assessment), mientras que la calidad agroecológica del suelo en relación con el uso y la cobertura del suelo se evaluó mediante el método Agroecológico Rápido y Amigable para Agricultores (Rapid Farmer-Friendly Agroecological method). Los resultados revelaron una sustitución progresiva de áreas boscosas por pastizales, destacándose la agricultura como el uso del suelo más vulnerable a la erosión. En cambio, las áreas forestales mostraron los índices más altos de calidad del suelo, lo que resalta el papel protector de la vegetación nativa en el mantenimiento de las propiedades del suelo. Los indicadores obtenidos, como los patrones de pérdida de vegetación y la vulnerabilidad erosiva, proporcionan soporte técnico para las políticas públicas sobre ordenamiento territorial, mitigación de la degradación y promoción de agroecosistemas resilientes. Esta investigación refuerza la urgencia de estrategias que reconcilien la producción agrícola con la conservación ambiental, sirviendo como modelo para regiones que enfrentan desafíos socioambientales similares.

Palabras clave: uso del suelo, vegetación y erosión.

1. Introduction

Vegetation cover plays a crucial role in stabilizing the geo-environment in the municipality of Bibala, as it protects the soil from erosive processes, facilitates the distribution, infiltration, and accumulation of rainwater, and influences local climatic conditions (Martins *et al*., 2022). Vegetation is a key geo-environmental indicator, as it is influenced by climatic, edaphic, and biotic factors (Almeida & Iv, 2013).

Burning is a common agricultural practice, frequently used for pest control, land clearing for planting, and pasture renewal. The absence of vegetation cover leaves the soil exposed to wind and water action, accelerating the erosion process, particularly on sloping areas or near watercourses (Prado et al., 2010). However, when applied frequently or without proper management, it can contribute significantly to soil degradation, particularly in semi-arid regions such as Kapangombe. According to Prevedel (2021), soil degradation may result from both natural factors, such as low rainfall, high temperatures, and erosion. In localities like Kapangombe, where agricultural land is limited and pressure on natural resources is high, indiscriminate use of fire can exacerbate the loss of soil organic matter and reduce soil fertility.

Assessing land use and occupation is essential for understanding the environmental and socioeconomic dynamics of a territory, enabling the formulation of public policies and sustainable land management strategies. This study identifies patterns of environmental degradation and proposes mitigation measures for soil conservation (Cavalcante *et al.,* 2021). Brito (2020) emphasizes that integrated soil analysis and its changes over time contribute to natural resource preservation and efficient urban planning. Additionally, the LADA (Land Degradation Assessment in Drylands) methodology, developed by FAO (2004), provides a global approach to assessing and mapping soil degradation in arid regions, identifying land use impacts and formulating sustainable solutions.

In Angola, soil degradation is a growing concern due to inadequate land use practices, including deforestation, unsustainable agriculture, overgrazing, and mining. These activities accelerate erosion and desertification. Deforestation, often carried out to create space for agriculture or to obtain firewood, reduces vegetation cover and compromises the soil's capacity to retain water and nutrients, increasing its vulnerability to erosion. These processes have direct impacts on ecosystems and local populations, including reduced land productivity, loss of biodiversity, and heightened food insecurity, as highlighted in Presidential Decree No. 46/14 of 25 February 2014 (Vaga, 2017).

Global studies, such as Afuye *et al.* (2024), show a significant increase in research on land use and cover changes, driven by urbanization, agricultural expansion, deforestation, and climate change. These trends directly impact areas like Kapangombe, where land use changes intensify erosive processes and environmental degradation.

Changes in land use and land cover stand out as one of the main causes of environmental degradation in various rural regions and on a global scale (Fatmawati *et al*., 2023 Despite the relevance of the topic, there is a lack of studies correlating soil degradation with land use patterns in Kapangombe. Remote sensing emerges as a fundamental tool for environmental monitoring, effectively identifying degradative processes such as native vegetation loss and increased bare soil areas (Rong & Fu, 2023).

Geoprocessing techniques in Kapangombe can assess land use impacts on soil erosion, providing technical support for territorial planning and mitigation strategies (Mashala *et al*., 2023). Satellite imagery and land cover classification help understand territorial dynamics, offering precise data to identify anthropogenic-induced changes, such as agriculture and deforestation, which are recurrent in the region.

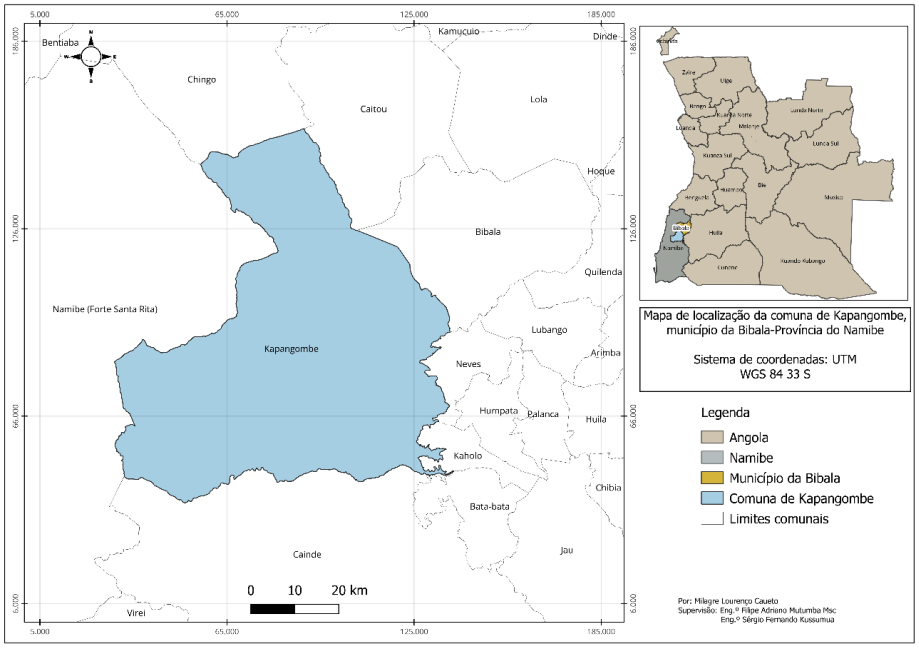
This study aims to evaluate soil degradation based on land use patterns, analyzing erosive impacts and trends in land use changes. It also considers agrogeological factors influencing degradation processes. The research advances scientific knowledge by integrating land use and vegetation cover analysis, generating applicable insights for regions with similar socio-environmental challenges.

2. Materials and Methods

2.1 Study Area

The study was conducted in Mangueirinhas, located 112 km from the city of Moçâmedes, covering approximately 2,537 km², with geographic coordinates: 16°6'0" S; 13°8'0" E and an elevation of 909 meters (2,982 feet).

Image 1 – location de map of the study area



Source: author

Kapangombe is a commune in the Bibala municipality, Namibe Province, Angola. Bibala spans 7,612 km² and has about 57,000 inhabitants (Mapcarta, 2025), It is bordered by Camucuio to the north, Quilengues, Cacula, Lubango, and Humpata to the east, Virei to the south, and Moçâmedes to the west.

The selected sampling area is the locality of Mangueirinhas, located in the commune of Kapangombe, Bibala Municipality. Within this locality, three types of land use were selected, namely: Forests, Agricultural Areas, and Pasture Areas. The following procedures were followed for selecting the sampling zones: (i) Field observation and verification of land degradation (LD) indicators; (ii) Confirmation of the existence of different land use types in the locality, considering their organizational level and importance as units for implementing land degradation monitoring.

Table 1 – Principal land use and land cover classes

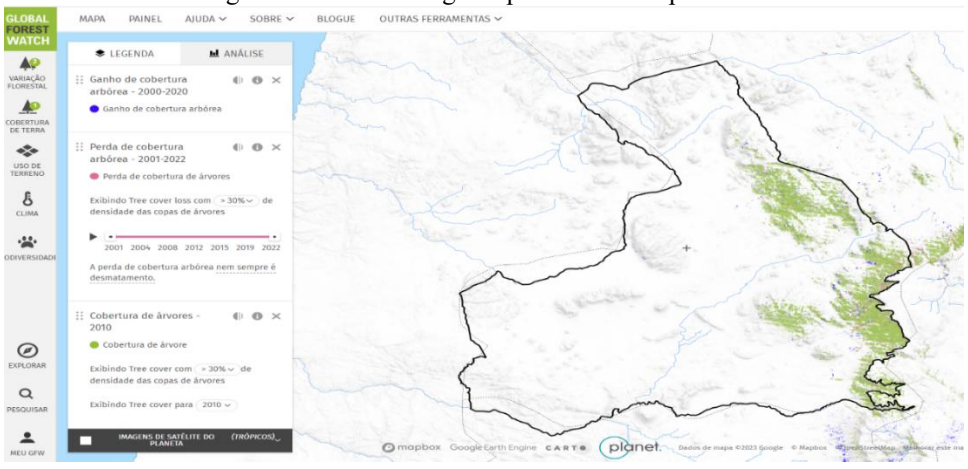
Categories	**Classes**
1ª	Agriculture
2ª	Forests
3ª	Pastures

The sampling area selected for this study was the Mangueirinhas locality, located in the Kapangombe commune, Bibala municipality. Within this locality, three land use and land cover types were identified: agricultural land, comprising cultivated plots located in low-lying areas near watercourses and typically cultivated during the dry season; forest areas, characterised by intact vegetation with a high density of native tree species; and pastureland, consisting of areas situated near residential zones and used for grazing, as presented in Table 1 (Principal land use and land cover classes).

2.2 Methodology

The selection of sampling zones followed a set of defined procedures: (i) field observations combined with the identification of land degradation (LD) indicators; and (ii) confirmation of the occurrence of distinct land use and land cover types within the locality, considering their degree of organisation and their relevance as operational units for soil degradation monitoring

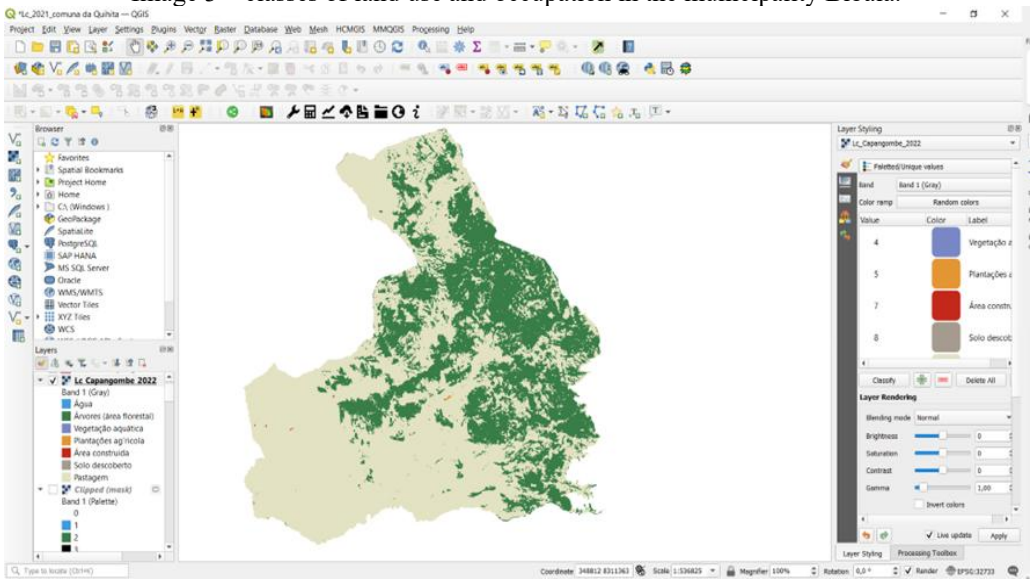
Image 2 – Forest coverage map of the municipal Bibala.



Source: Adapted by the author from data from Global Forest Watch

The vegetation cover analysis was conducted on the Global Forest Watch (GFW) platform. It is an online platform that provides data and tools for forest monitoring. Using cutting-edge technology, GFW allows access to near real-time information about where and how forests are changing. Access link: https://www.globalforestwatch.org/ . As can be seen in the image 2, Forest coverage map of the municipal Bibala.

Image 3 – classes of land use and occupation in the municipality Bibala.



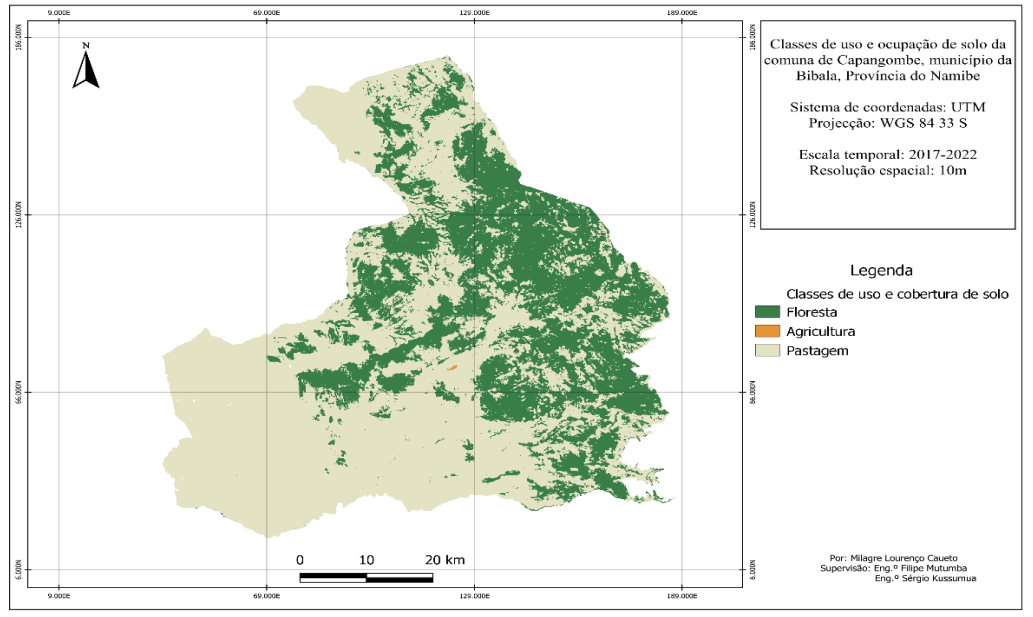
Source: author

Given the importance of environmental data for natural resource management in the study area, the land use and land cover (LULC) classification of Kapangombe commune provided critical insights into different LULC classes and their respective spatial coverage.

The analysis was conducted using data from 2017 to 2022, obtained via the Global Forest Watch (GFW) platform. Only certain classes, were clearly distinguishable on the map due to their larger spatial extent. Other land use categories, which occupy smaller and more fragmented areas, were not easily detectable because they fell below the spatial resolution of the sensor used.

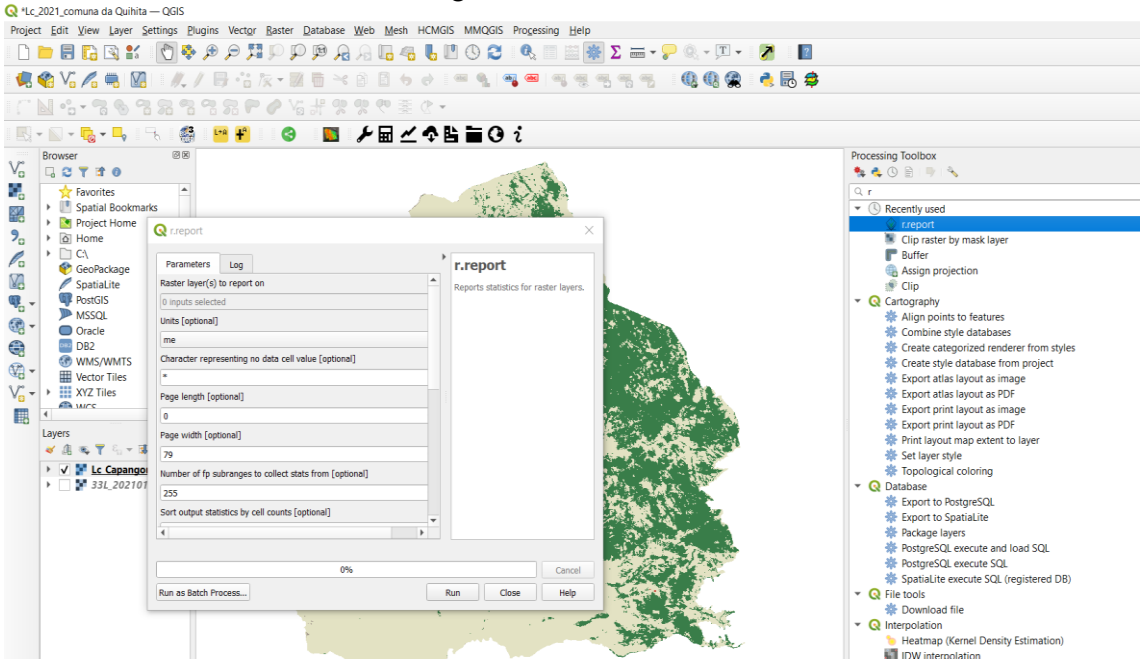
The pixel size limitation affected the detection of smaller or scattered landscape features, leading to less accurate representation of these classes in the mapping process. The land use and land cover classification imagery was sourced from the Global Forest Watch (GFW) platform. Access Link: (*https://www.globalforestwatch.org/. (2025).*

Image 4 – land use class map.



Source: author

Figure 5 – land use class



Source: Author.

For calculating vegetation cover area and other land use classes, the r.report tool in QGIS software was applied to the thematic land use and land cover data. From a statistical perspective, information such as

vegetation cover and the corresponding area for each class was analyzed. As presented in the Image 4, land use class map and Image 5, land use class above.

Soil erosion was assessed using the Visual Soil Assessment (VSA) methodology described in the LADA framework (Land Degradation Assessment in Dryland Areas). The LADA methodology was developed in response to the global need to address information gaps about land degradation, initiated by FAO in 2004. This approach enabled the classification of wind and water erosion status. Through direct field observations, each case was recorded according to erosion type, current state, spatial extent, and severity level - key parameters for quantifying soil loss rates and volumes in the study areas. Based on the VSA erosion classification system: scores of 0-1 indicate negligible erosion; 2-5 = low; 7-10 = moderate; 10-12 = severe; and scores above 13 are classified as very severe erosion.

For the agroecological classification of land use and land cover, we employed the Rapid Farmer-Friendly Agroecological methodology (Nicholls et al., 2004). This approach enabled the integration and classification of key indicators of biological, chemical, and physical soil properties through qualitative observations. These indicators were scored, summarized, and concluded with an overall soil health rating.

The indicators were evaluated separately according to land use type, with assigned values ranging from 1 to 10 based on observed soil attributes (where 1 represents the least desirable, 5 moderate and 10 the most desirable condition). The assessment included the following parameters: soil structure, compaction, depth, color, moisture retention, ground cover, erosion status, and presence of invertebrates.

3. Results and Discussion

3.1 Land Use and Occupation

Based on the thematic map of land use and land cover classes, we calculated the area corresponding to each category within the study region. The results reveal that Kapangombe commune is predominantly covered by grasslands, totaling 24,073,722 hectares - representing 64.63% of the analyzed surface area. The second largest class comprises forest cover (trees), occupying 13,149,600 hectares (35.30% of the total area) (Table 2).

Table 2 – land use and occupation

Categories	**Area (ha)**	**Total (%)**
Water	2 95	0,00%
Trees (Forest)	13 149 600	35,30%
Aquatic Vegetation	2	0,00%
Agriculture	6 234	0,02%
Built-up Areas	4 121	0,01%
Bare Soil	13 876	0,04%
Pasture	24 073 722	64,63%
Total	65 667 105	100,00%

Source: Author

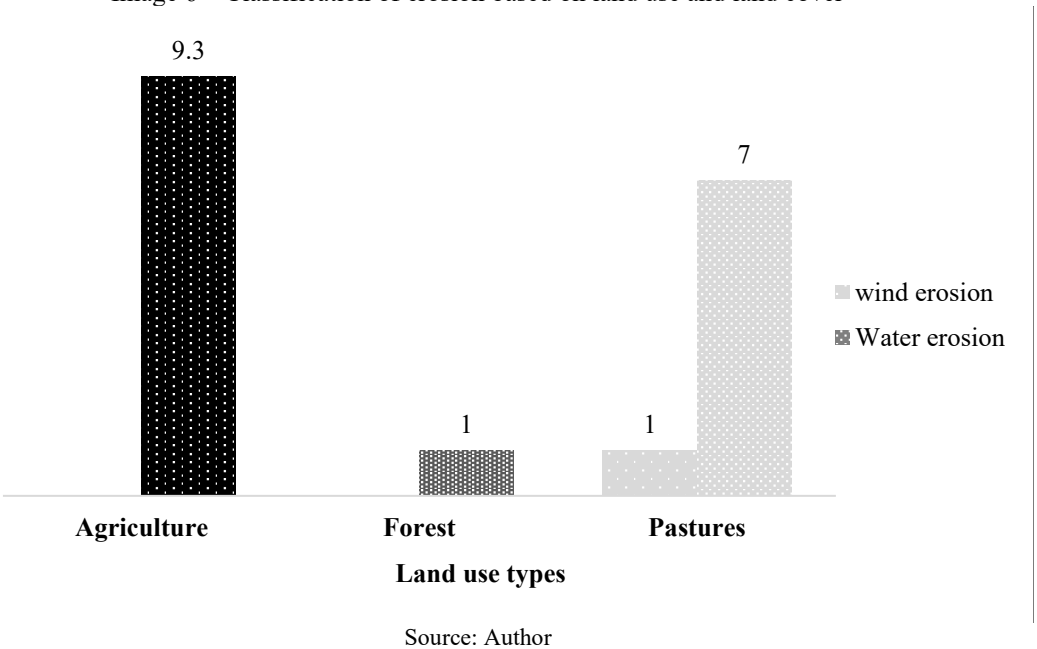
In comparison, the study conducted by (Pimentel *et al.,* 2021), which analyzed land use and land cover in the municipality of Belize in the province of Cabinda, revealed a distinct distribution: forest cover accounts

for approximately 62% of the area, followed by shrubland (18%), agricultural areas (12%), and other classes (8%). These findings contrast with the results obtained in the present study, particularly regarding the predominance of grasslands in Kapangombe, highlighting local particularities in land use patterns. Table 2 provides a detailed breakdown of the percentage distribution of each identified class in the commune.

3.2 – Classification of erosion based on land use and land cover

Based on the results presented in image 6, Classification of erosion based on land use and land cover, significant differences in soil erosion occurrence can be observed among the three main types of land use analyzed, as well as between the two types of erosion identified in the study.

Image 6 – Classification of erosion based on land use and land cover



Source: Author

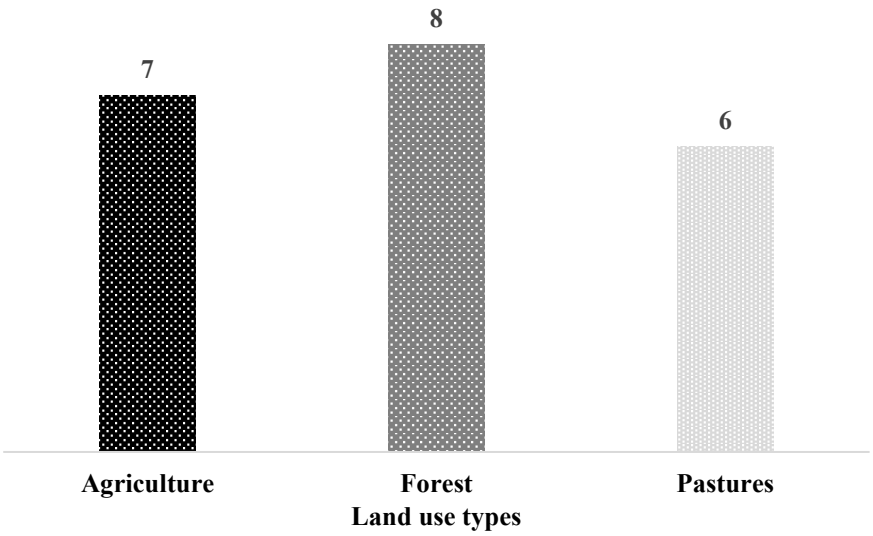
The best results were achieved in the forest zone, where erosion values range from 0 to 1, classified as negligible. The zone with the highest severity is the agricultural area, with a value of 9.3, classified as moderate. The pasture zone is the only area with both types of erosion: wind erosion has a value of 1 (negligible), while water erosion has a value of 7 (moderate). The data indicate that the forest zone is less susceptible to erosion due to the presence of vegetation cover, which acts as a protective shield for the soil against strong winds and intense rainfall, thereby helping prevent partial or complete degradation of the soil structure. This finding is consistent with studies conducted by (Bahia, 2019), Soil cover significantly reduces erosivity effects and the loss of physical, chemical, and biological soil properties.

The study conducted in the Greater Sekhukhune municipality in South Africa by (Kgaphola *et al*., 2023), The findings emphasize the crucial role of vegetation in preventing soil erosion in semi-arid zones. Vegetation cover loss accelerates soil degradation, enhances erosion processes, and promotes desertification. This pattern mirrors conditions observed in Kapangombe commune, where agricultural encroachment, deforestation, and disordered land occupation have diminished native plant cover, exacerbating soil deterioration. Prioritizing vegetation as a critical component in sustainable land management is essential to mitigate these effects and safeguard natural resources (Gitima *et al*., 2023).

3.3 Agroecological land use and land cover classification

Regarding the agroecological classification of land use, statistically significant differences were observed among the three analyzed plots. The best soil quality was recorded in the Forest Zone, with a score of 8, classified as desirable. The Agriculture Zone scored 7, also falling under the desirable category, while the Pasture Zone received a score of 6, classified as moderate. The image 7 illustrates the distribution of results for Agroecological classification of land use and occupation.

Image 7 – Agroecological classification of land use and occupation.



Source: Author.

These findings highlight the direct impact of land use and land cover patterns on soil ecological quality. The forest zones stood out for having vegetation cover exceeding 50%, high concentrations of organic matter (OM), and a significant presence of invertebrates such as earthworms and other soil microfauna responsible for bioturbation processes and the transformation of organic matter into humus. These factors contribute to improved soil structure, increased water retention capacity, greater biological activity, and nutrient cycling - all fundamental aspects for maintaining soil health. Research like that conducted by Mendanha *et al*. (2022), While previous qualitative assessments of P1 (Pasture) and P2 (Forest) areas yielded scores of 6.7 and 6.5 respectively, our results show the forest area scoring significantly higher (8), underscoring natural vegetation's crucial role in soil conservation. These variations likely stem from site-specific factors including soil characteristics, precipitation regimes, human disturbance levels, and vegetation preservation status. These variations could be attributed to site-specific factors including soil characteristics, rainfall regimes, levels of human disturbance, and vegetation preservation status (Rocha *et al.,* 2022).

The findings collectively underscore how preserving vegetative cover and implementing sustainable land management approaches (including agroforestry, silvopastoralism, and conservation agriculture) can effectively reduce soil deterioration, boost ecosystem adaptive capacity, and control erosion mechanisms (Mathewos *et al.,* 2023). The prioritization of agroecological indicators is fundamental for land-use planning and the formulation of public policies targeting sustainable natural resource governance (Mamo & Wedajo, 2023).

4. Conclusion

This study addressed the lack of analyses correlating land-use changes to soil degradation in the commune of Kapangombe a critical gap for environmental planning in the region. The results demonstrate that land-use and land-cover patterns are intrinsically linked to environmental degradation, with direct impacts on vegetation cover and the intensification of soil erosion. The findings revealed three critical outcomes: (1) the progressive replacement of native forests by pastureland, evidenced by satellite imagery analyzed in Quantum GIS and Global Forest Watch; (2) agriculture as the land-use most vulnerable to erosion, with significantly elevated severity; and (3) the superior soil quality in forested areas, confirming the protective role of native vegetation.

These findings have urgent implications for land-use management. The adoption of practices such as agroforestry systems, conservation agriculture, and natural habitat restoration emerges as a priority strategy to mitigate soil degradation. Furthermore, the generated indicators, provide a technical foundation for public policies aimed at enhancing the sustainability of agroecosystems.

In a global context of climate crisis and biodiversity loss, Kapangombe represents a microcosm of environmental challenges exacerbated by unsustainable land use. This study not only highlights the urgency for local action but also establishes a replicable analytical framework for regions facing similar scenarios. Transitioning to a development model that harmonizes agricultural production with environmental conservation is no longer an option.

5. Acknowledgements

This study was supported by the Department of Agronomy and Animal Science of the Polytechnic Institute of Huíla at Mandume Ya Ndemufayo University. The authors gratefully acknowledge the technical support provided by Tecnagro and Ecogis companies. We also express our sincere gratitude to the anonymous reviewers for their careful reading and valuable suggestions, which significantly contributed to the improvement of this manuscript.

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