Issue 8, 2024, e15641
ISSN: 2594-5033
Article: Thematic Dossier
Editor: Altemar A. Rocha
http://periodicos2.uesb.br/index.php/geo
https://doi.org/10.22481/rg.v8.e2024.e15641.pt

Analysis of land degradation in the Lifidzi River basin in the Angónia Plateau, Tete Province – Mozambique

Análisis de la degradación de la tierra en la cuenca del río Lifidzi en la meseta de Angónia, provincia de Tete – Mozambique

Análise da degradação de terras na bacia hidrográfica do rio Lifidzi no Planalto de Angónia, província de Tete – Moçambique

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Received on: 08/27/2024
Accepted for publication on: 11/03/2024

Abstract

Land degradation is one of the biggest global environmental problems facing humanity today. Human activities that cause land degradation include: tree felling, burning, inadequate agricultural practices, among others. The research aimed to develop a land degradation and risk map, on a scale of 1: 250,000, of the Lifidzi River basin, using geoprocessing in QGIS and ARGIS, with a weighted analysis of the parameters of the natural and cultural environment, seeking to measure the occurrence of land degradation in the study area. The choice of this river basin was due to its pedological and climatic peculiarities, high population density and scarcity of studies of this nature in this district. As a result, it was possible to carry out a qualitative and quantitative analysis of the anthropogenic influence on land degradation in the basin.

Keywords: Angónia, natural erosion potential, risks of environmental degradation, geoprocessing, remote sensing.

Resumen

La degradación de la tierra es uno de los mayores problemas ambientales globales que enfrenta la humanidad en la actualidad. Entre las actividades humanas que provocan la degradación de la tierra se destacan: tala de árboles, quemas, prácticas agrícolas inadecuadas, entre otras. La investigación tuvo como objetivo desarrollar un mapa de riesgo y degradación de la tierra de la cuenca hidrográfica del río Lifidzi, utilizando geoprocesamiento en QGIS y ARGIS, con el análisis de los parámetros del entorno natural y cultural, buscando medir la ocurrencia de degradación de la tierra en el área de estudiar. La elección de esta cuenca hidrográfica se debió a sus peculiaridades edafológicas y climáticas y a su alta densidad de población. Como resultado, fue posible realizar un análisis cualitativo y cuantitativo de la influencia antropogénica en la degradación de las tierras de la cuenca.

Palabras clave: Angónia, potencial de erosión natural, riesgos de degradación ambiental, geoprocesamiento, teledetección.

Resumo

A degradação de terras é um dos maiores problemas ambientais globais que a humanidade enfrenta atualmente. Dentre atividades humanas que causam a degradação de terras destacam-se: corte de árvores, queimadas, práticas inadequadas na agricultura, entre outras. A pesquisa teve como objetivo elaborar um mapa de risco e degradação de terras da bacia hidrográfica do Rio Lifidzi, utilizando geoprocessamento em QGIS e ARGIS, com a análise dos parâmetros do meio natural e cultural, buscando medir a ocorrência da degradação de terras na área de estudo. A escolha desta bacia hidrográfica decorreu das suas peculiaridades pedológicas, climáticas e elevada densidade populacional . Como resultado, foi possível realizar uma análise qualitativa e quantitativa da influência antrópica na degradação de terras da bacia.

Palavras-chave: Angónia, potencial natural de erosão, riscos de degradação ambiental, geoprocessamento, sensoriamento remoto.

Introduction

Land degradation is defined as “reduction in soil quality due to human abuse” Lal; Stewart, (1990). Soil conservation can be understood as the treatment of soils according to their needs and use compatible with their current and future potential Lantieri et al., (1990). Pruski (2013) highlights that soil degradation results

in the loss of the productive capacity of soils to generate environmental goods and services due to degradative processes.

Tricart (1977) argues that, in tropical environments, vegetation plays a fundamental role in dissipating the energy of raindrops, protecting the soil from erosion. The presence of continuous and dense vegetation cover favors water infiltration and reduces the direct impact of rain. Pruski (2013) reinforces that vegetation protects the soil, increasing water infiltration and reducing surface runoff. Crepani et al. (2008) add that reducing surface runoff helps to minimize the erosive capacity of water. According to Kohnke and Franzmeier (1995) and Bertoni and Lombardi Neto (2012), the removal of vegetation results in the degradation of organic matter and microorganisms in the soil, aggravating the erosion process. The situation is more critical in developing countries, where factors such as population growth, hillside cultivation, deforestation and excessive grazing accelerate degradation (Pimentel (2006); IAO, (2009). In these countries, the intensified use of fragile lands aggravates the cycle of degradation, population growth and poverty (Vortman et al., (2003, 2015); IAO, (2009).

In Mozambique, erosion is a serious environmental problem, exacerbated by poverty and the inadequate use of natural resources (INE, (2011); Micoa (2007). The combination of inadequate agricultural practices, uncontrolled burning and the use of lands susceptible to erosion aggravates the situation (Micoa, (2007). The agricultural sector, a pillar of the Mozambican economy, suffers from low productivity, influenced by unsustainable practices and soil erosion Micoa, (2000; 2007); INE, (2011); Manjate, (2013).

This study seeks to contribute methodologically to the understanding of soil degradation processes in Mozambique, addressing the difficulties in data collection, the scarcity of cartographic materials and the importance of proficiency in local languages for conducting fieldwork. The research stands out for filling the gap in the production of data and analyses at the mesoscale in the Mozambican context.

Materials and methods

The cartographic base was prepared using topographic maps at scales of 1:50,000 and 1:250,000 covering the Angónia Plateau. The topographic maps were acquired from the National Center for Cartography and Remote Sensing (CENACARTA) and were scanned using an A0 scanner at a resolution of 300 dpi in TIF format, and the extension is compatible with ArcGis 10.5 software.

Then, in ArcGis 10.5 GIS, the Universal Transverse Mercator (UTM) projection system was configured – Central Meridian: 33° E of Greenwich, Clarke Ellipsoid, 1866, Tete horizontal datum, the same as that recorded on the scanned topographic maps. topographic maps were converted from the Tete horizontal datum to the MOZNET/ITRF94 datum, since it is compatible with the World Geodetic System (WGS 84) horizontal datum. The transformation to the MOZNET/ITRF94 Datum is a CENACARTA recommendation for all cartographic work in Mozambique.

After georeferencing the topographic maps, the layers such as: study area boundaries, contour lines (with 10 m equidistance), elevation points, drainage network, meteorological stations, settlements and access roads were vectorized using the ArcGis 10.5 drawing and editing module.

In order to ensure the accuracy and consistency of the database, the vectorized features were evaluated in terms of neighborhood relationships, connectivity, overlapping boundaries or the presence of empty spaces. The procedure for evaluating and correcting inconsistencies was carried out by applying pre-established topological rules. Specifically in ArcGis 10.5, these operations can be performed automatically by the Topology tool.

To prepare the land degradation map for the Angonia Plateau, the thematic maps of Geomorphology, Geology, Pedology, Land Use and Coverage (Florenzano, 2008, p. 122) were prepared and integrated using a GIS. These elements were treated in an integrated manner, enabling a diagnosis of the different hierarchical categories of fragility of natural environments to be obtained. The following steps were

followed to prepare the land degradation map for the Angonia Plateau in a GIS environment:

a) In the first stage, a table was prepared containing all the variables necessary for the analysis of land degradation, assigning values from 1 to 5, that is, from the most unstable to the least unstable according to Ross (1994);

b) In the second stage, all vector files (land use, geology and soils) were combined and transformed into Raster files using the ArcGIS 10.5 tool - Arctoolbox – conversion tools – to Raster. Hypsometry, terrain slope and water accumulation did not need to be transformed as they were already in Raster format. Afterwards, reclassification was performed using the Reclassify tool in ArcGIS 10.5 in Arctoolbox – Reclass – Reclassify according to the established weights;

c) In the third stage, multicriteria analysis was performed using the Raster tool. Subsequently, the "Project Raster" tool in the "Data Management Tools" of ArcGIS 10.5 was used to transform the projection system of the Arctoolbox Calculator maps into Spatial Analysis Tools – Map Algebra – Raster Calculator. The reclassified files generated using the formula presented were overlaid.

The formula used to obtain the Environmental Fragility Chart was: (Land use*35%) + (Geomorphology*25) +(Geology*13) + (Soil*12) + (Water accumulation*15%).

Results and discussion

The analysis of land degradation was based on a systemic approach, which took into account several parameters of the physical and cultural environment of the Angonia Plateau. In this way, the necessary data were collected to extract essential parameters for the integrated assessment of land degradation, such as: geology, geomorphology (topography, hypsometry and slope), pedology, thermo-pluviometric data, and land use, vegetation cover and soil management, which

underwent a process of class definition with several criteria related to the mappings and methodologies for assessing natural resources developed by Marques et al. (1971), Tricart (1977), Lepsch et al. (1983 and 1991), Ramalho Filho et al. (1978), Ramalho Filho and Beek (1995), Ross (1994), Becker and Egler (1996), and Crepani et al. (2008). Based on the degrees of influence described above, the land degradation risk map of the Angonia Plateau was produced. Table 1 summarizes the distribution of land degradation risk on the Angonia Plateau, classified into five risk levels.

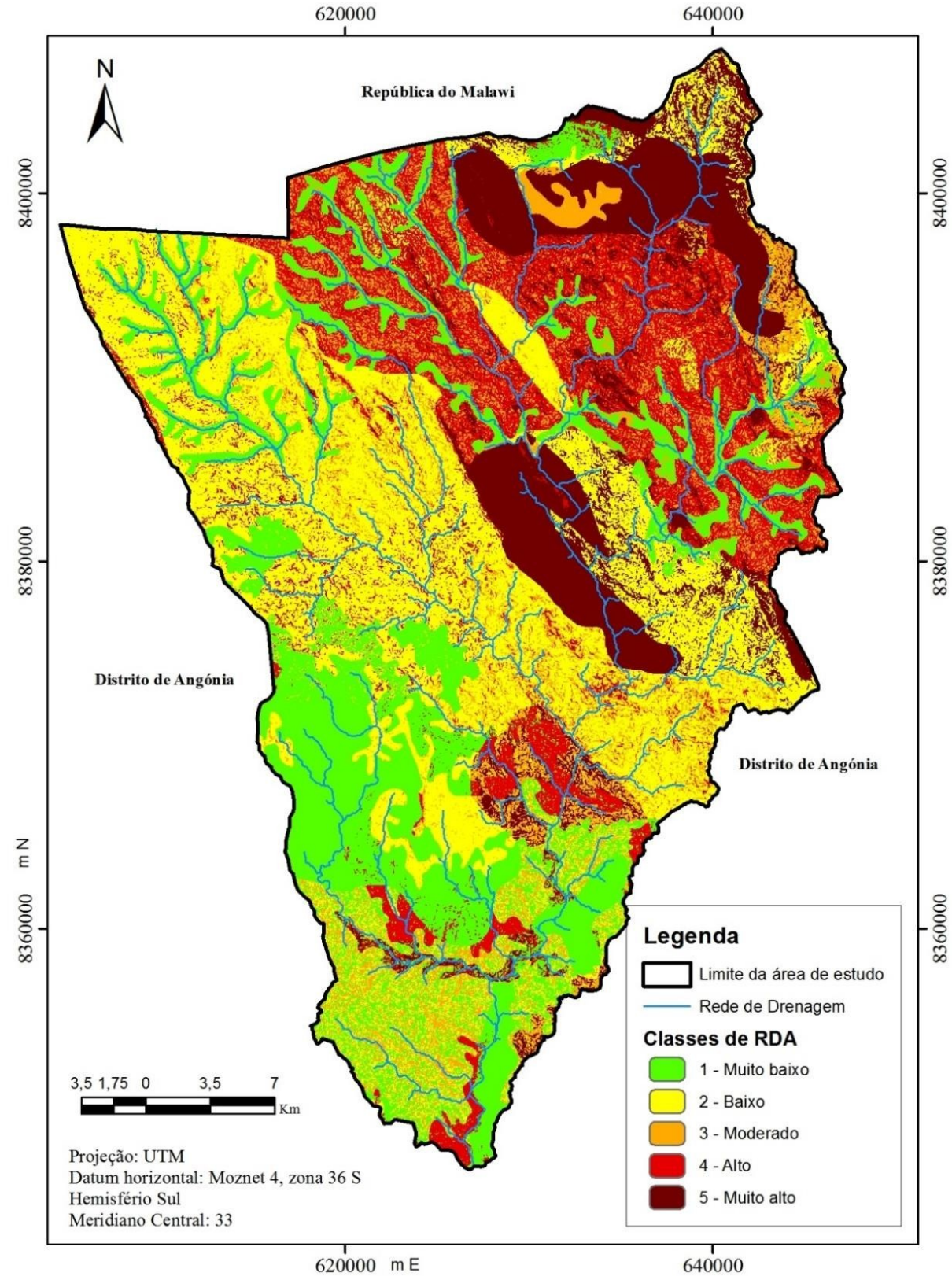
Table 1 – Risk of land degradation in the Planalto Angónia

PNE class	Risk	**area (km²)**	**area (%)**
Risk 1	Very low	331,61	23,17
Risk 2	Low	462,13	32,29
Risk 3	Moderate	176,68	12,35
Risk 4	High	234,34	16,37
Risk 5	Risk 4 High	226,38	15,82

Source: Mandala (2024)

The land degradation risk map (map 1) directly reflects the pressure that the population places on land resources, with the use of vegetation cover to satisfy basic needs such as housing construction, search for wood fuel for cooking, animal grazing, as well as the pressure exerted by traditional land management practices, such as opening up flowerbeds and using fire to clear crop fields (panels 1 and 3).

Map 1- Risk of environmental degradation due to water erosion Lifidzi River Basin.



Source: Mandala (2024)

Panel 1 - Areas of low potential for land degradation and their use

a) Partial view of a Dambo

b) Cattle grazing

c) The cattle herders

d) Vegetable production in Dambo

Source: Mandala August(2024)

Panel 2 - Areas of high potential for land degradation and their use

a) Rocky outcrop areas

b) Areas of very steep slopes

Source: Mandala August(2024)

Panel 3 – Activities that accelerate environmental degradation

a) Partial view of a Dambo with ravine	b) Ravine due to cattle
	
	
c) Cultivation in sloping areas	d) Signs of sheet erosion

Source: Mandala August(2024)

Final Considerations

Environmental diagnostic studies are important for planning and managing environmental situations appropriately, taking into account the characteristics and limitations that a given area may present. In this context, land degradation analysis can be considered a fundamental support for environmental diagnostics, since it provides relevant information about the environment, considering its possible weaknesses and potentialities, thus allowing decision-making bodies to seek possibilities for preventing and mitigating land degradation due to water erosion.

Based on the objectives, methodological procedures applied and results obtained in this study, the following conclusions are indicated:

• The methodology applied allowed for combining variables (analytical procedure) and preparing summary maps (integration procedures) for the quantitative-qualitative analysis of the natural erosion potential and indicating the environmental impact of human pressure on land use.

• The Land Degradation Risk Map, as a cartographic-summary document that resulted from the integration of the parameters of the physical and cultural environment, allowed for the identification of sectors within the study area with variations in the risk of land degradation.

• In general, soil management, through primitive family farming practices (with no conservation practices), has been shown to have a strong environmental impact in areas of subsistence family farming. The way in which farmers manage the soil influences erosion, even in areas with low slopes, since they completely remove the remains of previous cultivation associated with burning. In this context, when the first rains occur in November and December, especially those of a highly erosive nature, they find the soils completely unprotected, which increases the risk of environmental degradation due to water erosion of the soils (laminar and in furrows).

• The contributions of the use of Remote Sensing techniques for the extraction of primary environmental data and the Geographic Information System (GIS) were essential for the preparation of thematic cartographic documents and analyses. The images from the Sentinel-2 Sensor with 10 meters of spatial resolution were compatible, at the information level, for the extraction of thematic data in the context of the working scale (1:50,000). It is important to highlight that

the data acquired through Remote Sensing techniques were validated through observations carried out in field work.

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