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Assessment of soil loss to vulnerability in the Boane District in Mozambique

Euclides Délio Matule [1]

Lucrêncio Silvestre Macarringue [1,2]

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Boane

Stability

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Abstract

The soil lost vulnerability study of the landscape units constitutes one of the mechanisms for the design of sustainable land use and cover and natural resources. Therefore, this research aimed to evaluate the soil loss vulnerability in the Boane district in 2018. The materials used included OLI Landsat 8 and ASTER GDTM V2 images, through which we generated land use and cover and slope maps respectively, soils, lithology, and precipitation databases available in CENACARTA. This data was processed in a GIS environment. The results showed that 53.3% of the district had median stability, 34.7% moderately vulnerable, 11.4% moderately stable, 0.6% stable and 0% vulnerable. These results indicate a favorable situation, but not comfortable at the short term, due to the accelerated rhythm of urbanization and its consequences to the environment that is seen in the last decades, joined to the lack or non-implementation of the main planning plans, that can change this situation in short term.

[1] Instituto de Formação em Administração de Terras e Cartografia, Matola, Moçambique. deliomatule@gmail.com

[2] Universidade Estadual de Campinas, São Paulo, Brasil. lucrencio.macarringue@gmail.com

INTRODUCTION

To analyse a landscape unit, it is necessary to know its genesis, physical constitution, form and stage of evolution, as well as the type of vegetation cover that develops on it. This information is provided by Geology, Geomorphology, Pedology and Phytogeography and needs to be integrated to have a faithful picture of each unit's behaviour towards the occupation. Finally, Climatology needs to help us to know some climatic characteristics of the region where the landscape unit is located, to predict its behaviour towards the changes imposed by the occupation (CREPANI et al., 2001).

The vulnerability to soil loss of landscape units is linked to the imbalance in the natural dynamics of the environment. Each component of the landscape, such as Geology, Geomorphology, Pedology, Vegetation, Climate and anthropic intervention, participates in this dynamic in an integrated way. These components, participate in this dynamic in an integrated way (DE LA ROSA et al., 2000; LU et al., 2004; CREPANI et al., 2008).

For Becker and Egler (1997) the vulnerability map to soil loss represents the analysis of the physical and biotic environment for the rational occupation and sustainable use of natural resources. Its association with data of social, economic and political potentiality offers subsidies to territorial management (LU et al., 2004). This vulnerability is analysed from the morphodynamic characterization of these units, based on methodologies developed by Crepani, et al. (1996).

The scale of the vulnerability of basic territorial units, from their morphodynamic characterization, is made according to criteria developed from the principles of Tricart's Ecodynamics (1977).

The criteria developed from these principles allow one to create a model where he can seek the assessment, relatively and empirically, of the stage of morphodynamic evolution of basic territorial units, assigning stability values to morphodynamic categories (CREPANI et al., 2001). From this first approximation, a greater variety of morphodynamic categories is sought, to construct a scale of vulnerability for situations that occur naturally (CREPANI, 2001).

In Mozambique, itinerant agriculture, wood exploitation, firewood and charcoal production and uncontrolled burning are considered the main factors for the reduction of vegetation cover and consequently soil erosion.

The population of Boane uses forest resources such as pegs, reeds and other material for house building and they take advantage of trees for firewood, wood and charcoal production, which are the fuels most used by the households. Because of this, the district presents serious problems of deforestation and soil erosion.

In ten years the district has had a population increase of almost 50%. This increase was due to the migration of the population from the cities of Maputo and Matola, causing the native vegetation cover to be removed for the construction of their houses. This fact precipitates, at first, the district vulnerability to soil loss.

Pereira and Pinto (2007) state that the speed and extent with which environmental problems have been occurring, resulting from the intense pressure generated by anthropic occupation, require the use of data collection techniques and systematic monitoring of the land surface, compatible with the speed of these changes.

In recent decades, empirical modelling techniques associated with geographic information systems and satellite imaging with moderate to high spatial and temporal resolution have facilitated the monitoring and quantification of the conditions of changes occurring on the earth's surface and their degradation (PONZONI et al., 2014; VIJITH; DODGE-WAN, 2017).

Thus, this article aims to assess vulnerability to soil loss in the Boane district in 2018. This analysis will serve as a basis or subsidy for the preparation of the different territorial planning instruments (at the district or municipality level), as well as the preparation of environmental planning, thus contributing to the production of conservation and preservation measures.

METHODOLOGY

Location and characterization of the study area

Boane District is located in the South of Maputo Province and borders in the North with Moamba District in the West and Southeast with Namaacha District, in the South and Southeast with Matutuine District and the East with Matola Municipality (Figure 1). It has an approximate surface area of 860 Km² and is home to a population of 210,498 inhabitants according to the 2017 Census (INE, 2017). It is a district with a dry tropical climate, with two well-defined seasons, the dry season (between April and September) and the rainy season (between October and March). The average annual temperature is 23.7ºC and the average annual precipitation is around 752 mm (MAE, 2005).

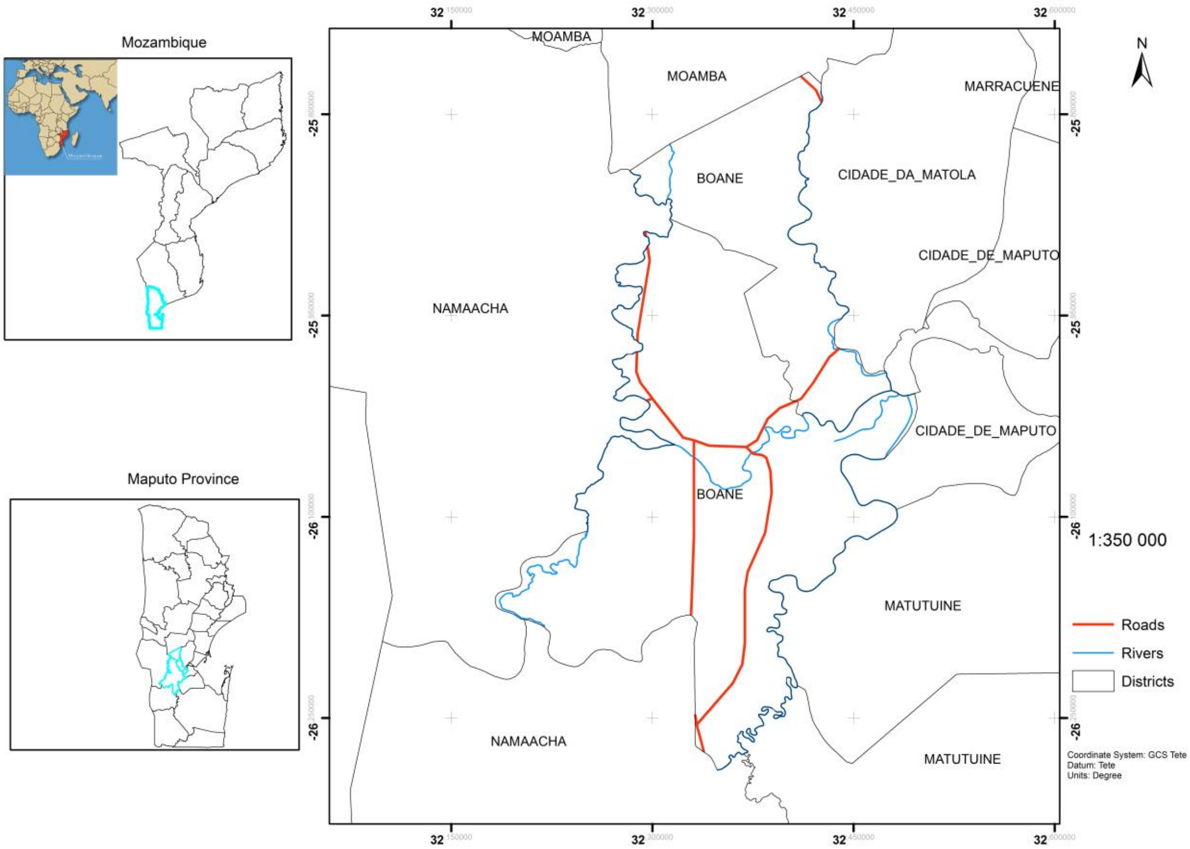
The district is crossed by the Umbeluzi, Tembe and Matola rivers belonging to the river basins of the same names, the Umbeluzi river being born in the neighbouring e-Swatini (former Swaziland) over a length of 70 km (MAE, 2005), most important, it is the main source of potable water for the cities of Maputo (capital of the country) and Matola besides being the main source of water for irrigated agriculture.

In the past, Boane was dominated by forests with high density of tree layer, thick trunk trees with wide treetops that rose to a height of 10 to 20m, which was degraded giving way to pasture and agricultural areas, with patches of secondary savannah and spontaneous or subspontaneous fruit trees (MUCHANGOS, 1999).

Boane consists of Jurassic-Cretaceous basalt material (Volcanic Karroo of the Upper Series), Mananga sediments, pebbles and alluvial sediments. The basalts are of Jurassic-Cretaceous age, belonging to the Karroo Super Group, formed during the last phase, which of the volcanic emanations called

Superior Stormberg or Superior Series. These basalts are part of the Libombos chain with a north-south direction and more than 450km long and 20-25km wide and inclined towards the east. On both banks of the Umbeluzi River, there are also quaternary coverings of sandy materials consisting of alluvial deposits or alluvial with gravel, quartz, rhyolites, some minerals and rocks (TIQUE; DYKSHOORN, 1993; VASCONCELOS, 2014).

Figure 1 Location of the study area.



Source: CENACARTA Database (1999).

The relief of the low course of the Umbeluzi River basin is characterized, in general, by a slightly undulating landscape without great differences in altitude. In the North, East and Southwest it presents a landscape with small differences of level, forming a true plain. The altitude varies from 0 to 300 meters (ALBINO, 2012).

According to Tique; Dykshoorn (1993), five main soil units can be found in most parts of the district: (i) derived from Basalts-Bv; (ii) from Mananga with sandy cover of less than 25cm-Ml; (iii) from Post-Mananga-P; (iv) on rolled Pebbles-S; and (v) alluvial from Umbeluzi-F river.

MATERIAL AND METHOD

Images from the OLI sensor of the Landsat satellite, Path/Row 167/78 WRS-2, UTM projection, Zone 36S and Datum WGS84 of June 15, 2018, were used; an ASTER GDTM V2 image, acquired through the following address: www.earthexplorer.usgs.gov.

The district/country digital cartographic database containing information on the following soil, geology and precipitation topics on a scale of 1: 1,000,000 was also used for the elaboration of the Soil Loss Vulnerability map.

The software ArcGIS 10 was used to process the information.

The work had several moments. The first was related to the image registration using the image/image method because a small displacement of the image was noticed and subsequently the OLI/ Landsat 8 colour (30m) and panchromatic (15m) images were merged to improve their quality, thus obtaining a colour image with 15m of spatial resolution.

The area of interest (Boane district) was then cut out. The false-colour composition 6R5G4B was used to facilitate the visualization and choice of samples for classification, and the supervised classification was chosen using the Maximum Likelihood (Maxver) method. In this process, three classes were created: (i) Vegetation Cover, (ii) Built Area and Exposed Soil (since the stability value is the same) and (iii) Water. Still at this moment, the slope map was generated with 6 classes according to Embrapa criteria: Class A, Flat (0-3%); Class B, Soft Wavy (3-8%); Class C, Moderately Wavy (8-13%); Class D, Wavy (13-20%); Class E, Strong Wavy (20-45%) and Class F, Mountainous or Escarpment (> 45%) (RAMALHO-FILHO; BEEK, 1995).

At the second moment, the analysis and generation of the thematic maps were made. In the case of the soil map, initially the nomenclature of soil types was changed (from the FAO classification to the Embrapa classification) to facilitate the identification of stability values of each soil type, following the classification presented by Crepani (2001) and then the elaboration of the rainfall intensity map, elaborated from the relation of the annual average rainfall map and the number of days with rain, transformed into months, that is, by dividing the annual average rainfall by the number of days with rain throughout the month.

The third moment was reserved for the conversion of the maps from the vector format to the matrix (reclassified with the values of the stabilities), as well as the arrangement of the database with all the information necessary for the analysis of the ecodynamics. The assigned stability values are shown in Table 1.

The analysis of Ecodynamics (last moment), served for the preparation of the map of Vulnerability to Soil Loss. The analysis was based on the methodology developed by Crepani et al. (1996) based on the concept of Tricart's Ecodynamics (1977) and the potential for integrated studies of satellite images, which allow a synoptic, repetitive and holistic view of the landscape, to subsidize Zoning (CREPANI et al., 2008).

Table 1. Stability Values of Types of Landscape Units.

Landscape Unity	Type	Stability
Geology	Sandstone	2,4
(Lithology)	Basic rocks (Gabro)	1,6
	Carbonated Rocks (Limestone/Dolimite)	2,9
	Acid Rocks (Riolites/Granite)	1,1
	Terraces (Unconsolidated Sediments)	3,0
Pluviometric	194,2 (600mm)	1,6
Intensity	226,5 (700mm)	1,8
Vegetation/Land	Water	1,0
Use	Exposed soils/inhabited area	3,0
	Vegetation (Forest Savannah, Mangrove)	1,5
Soils	Neossolo Litólico; Neossolo quatzarênico, Neossolo Flúvico	3,0
	Cambisssolos	2,5
	Argissolos/Nitossolos	2,0
Declivity (%)	< 2	1,0
	2 – 6	1,5
	6 – 20	2,0
	20 – 50	2,5
	> 50	3,0

Org.: By the Authors, 2018 from CREPANI et al. (2008).

Once values for all classes of all thematic maps were assigned, these maps were integrated using the map algebra technique, generating the Soil Loss Vulnerability Map, whose final value resulted from the arithmetic average of the individual values of each theme using the following equation:

$$V = \frac{G + R + S + Vg + C}{5}$$

Where:

V = Vulnerability of Landscape Unit

G = Vulnerability for Geology theme

R = Vulnerability for Geomorphology (Relief/declivity) theme

S = Vulnerability for the Soils theme

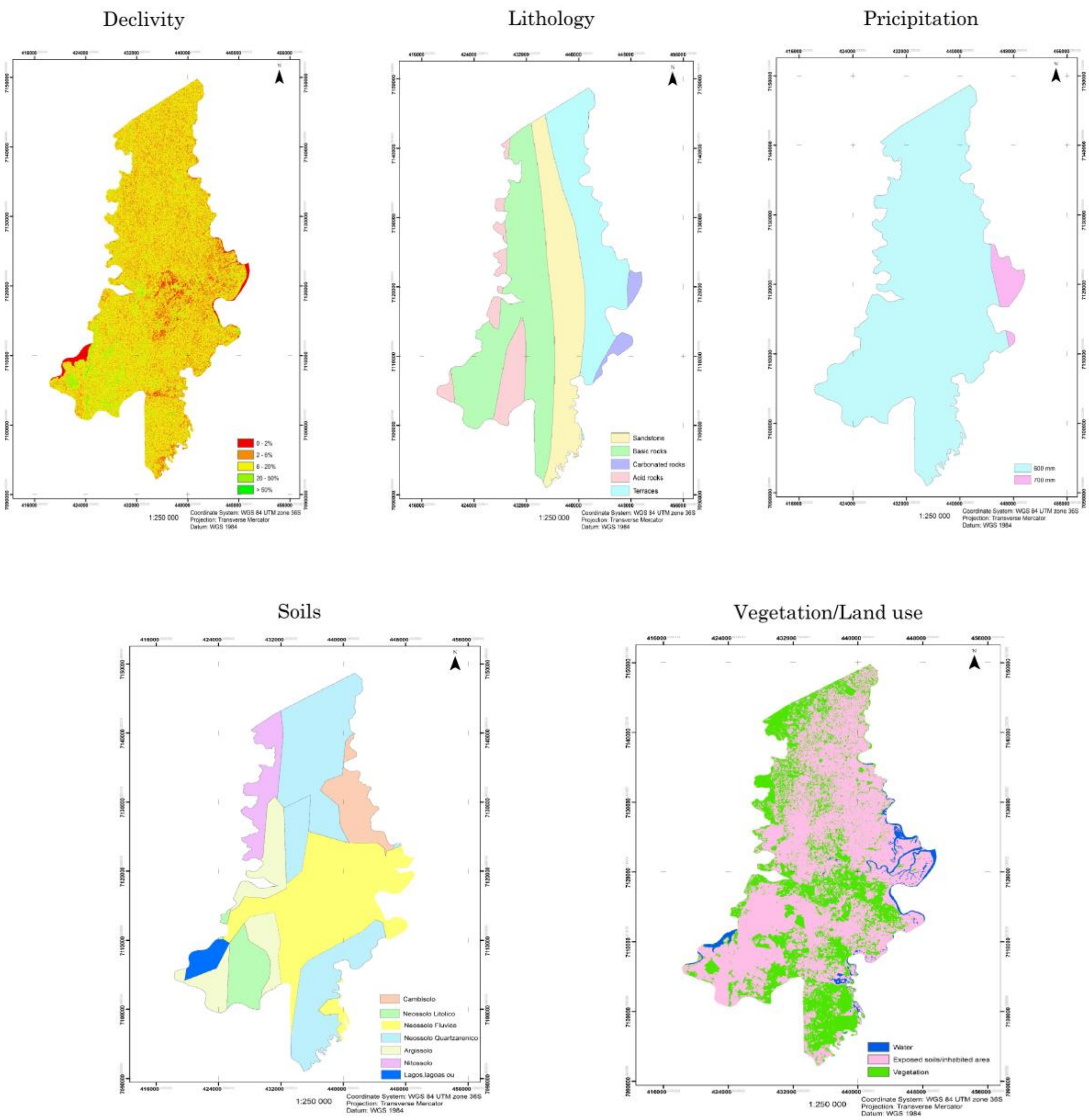
Vg = Vulnerability for the Vegetation/soil use theme

C = Vulnerability for Climate (Rainfall Intensity) theme

RESULTS AND DISCUSSION

Based on the data used in this research, it was possible to generate thematic maps of the following landscape components: lithology/geology, slope/geomorphology, pedology, land/vegetation cover and rainfall/climate index (Figure 2).

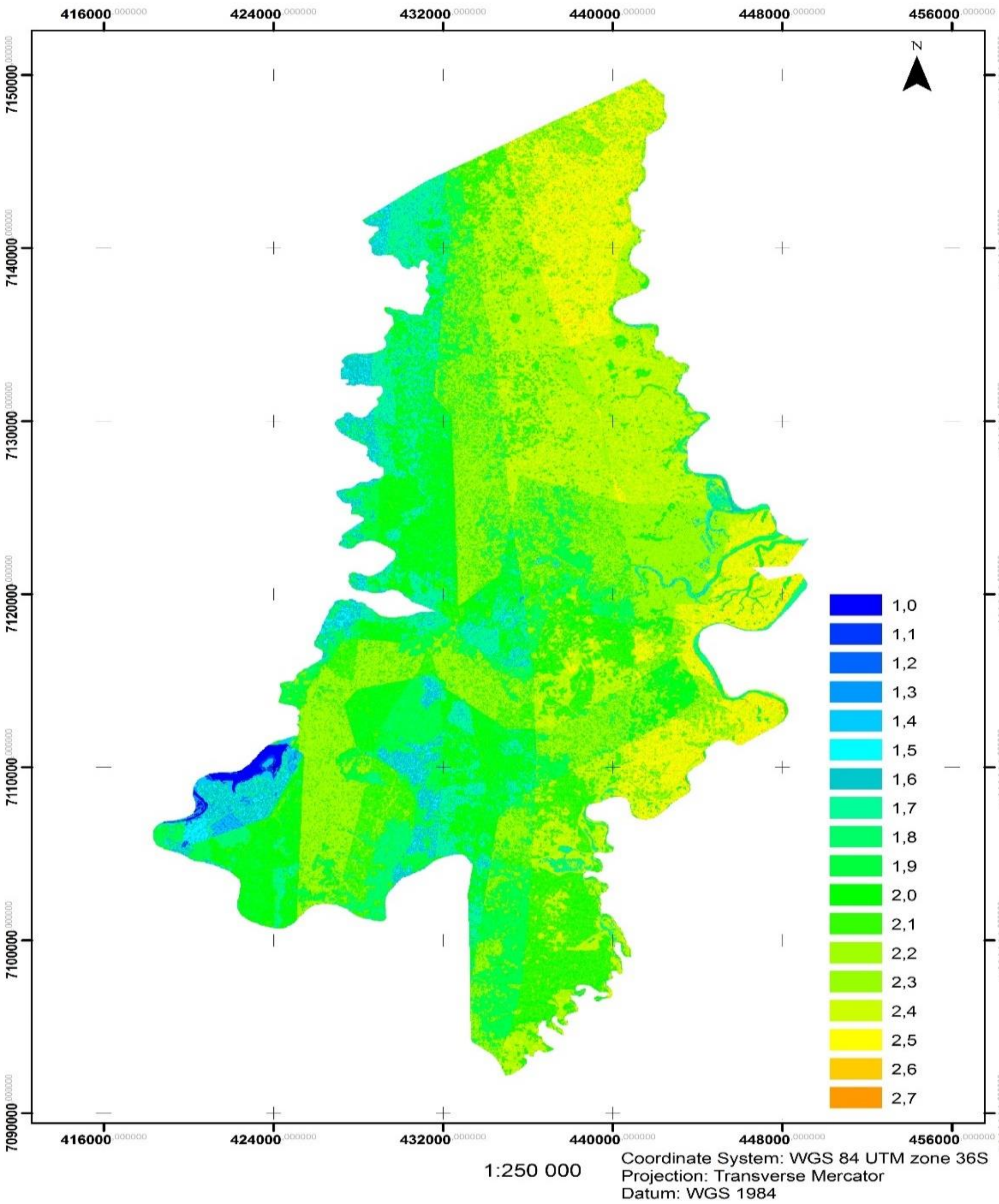
Figure 2. Classes of the landscape units.



Source: CENACARTA database (1999); OLI Landsat 8 (2018).

The map algebra process allowed us to calculate the average vulnerability value, obtaining 18 classes of Landscape Units (Figure 3), thus inferring that the district presents the stages of pedogenesis and morphogenesis.

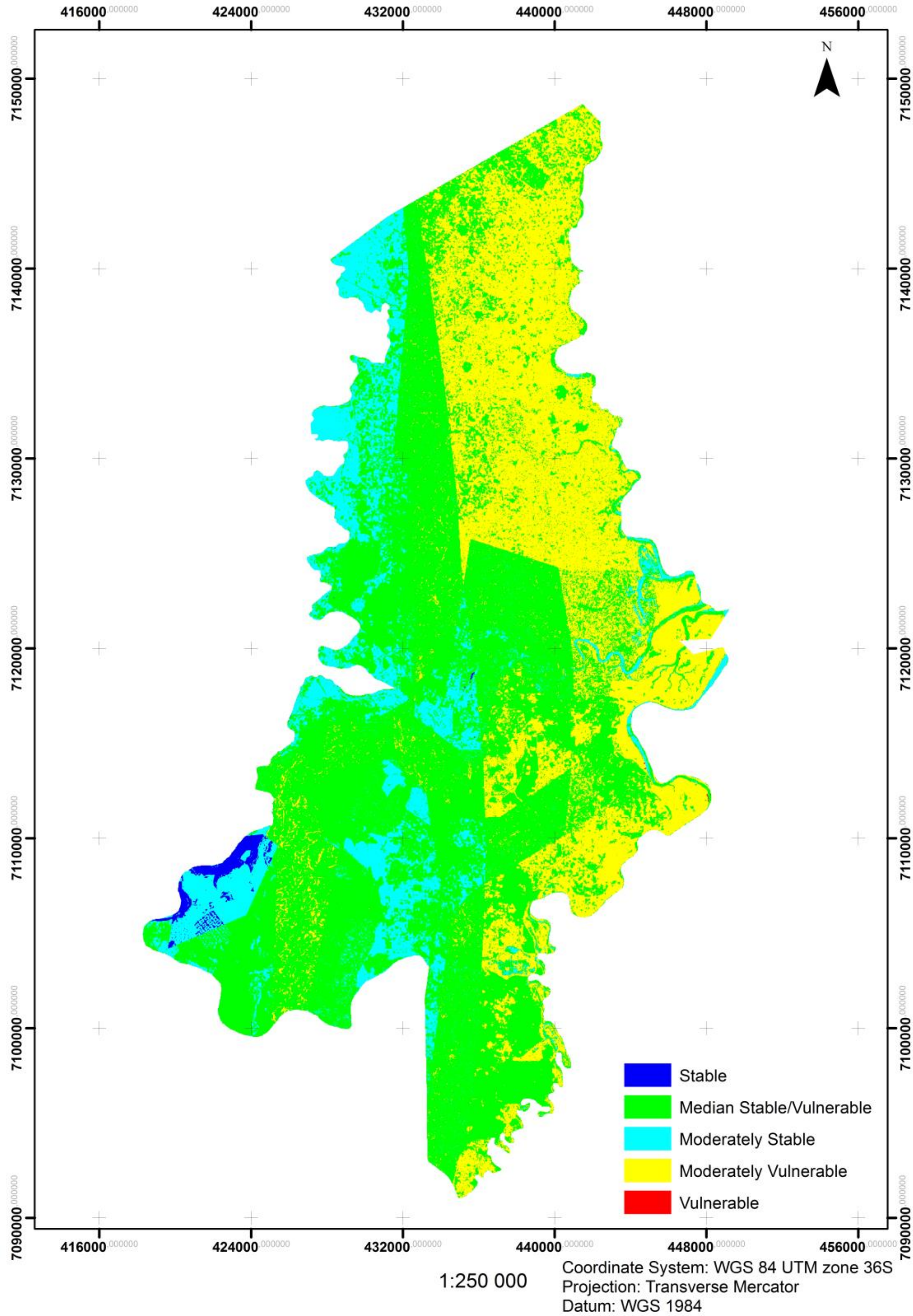
Figure 3. Average Vulnerability Values of Landscape Units.



Org.: By the Authors, 2018.

These average vulnerability values were divided as follows: values between 1 and 1.4 are considered stable, and those with values between 1.4 and 1.8 were defined as moderately stable. The degree between 1.8 to 2.2 represents the median stable/vulnerable class, the values between 2.2 to 2.6 refer to moderately vulnerable and the values between 2.6 to 3.0 define vulnerable areas (CREPANI, 2001). This allowed five categories of vulnerability to be obtained, namely: Stable, Median Stable/Vulnerable, Moderately Stable, Moderately Vulnerable and Vulnerable (Figure 4).

Figure 4. Boane District Soil Loss Vulnerability Map (2018).



Org.: By the Authors, 2018.

The district presents more than half of its area (53.3%) as Median Stable/Vulnerable and is distributed in almost the entire district (Table 2). This area is located in places where most of the vegetation cover exists and in clayey soils, with a structure that favours water retention, but that maintains good drainage and contains mineral salts in the amount necessary for soil fertility and plant growth.

Moderately Stable areas occupy 11.4% and are mostly located in areas with vegetation, acid rocks and nitossolos.

The Moderately Vulnerable area is 34.7% and is related to the existence of exposed soil due to the opening of new areas for habitation and cultivation, as well as the existence of Neossolos which are soils with high topographic factor values, thus constituting a considerable risk factor for soil loss (NEVES et al., 2011).

The stable areas are located along the rivers and in the small Libombos reservoir, constituting less than 1% of the district area, while the vulnerable areas are tiny, i.e., almost non-existent.

Table 2. Areas of each stability/vulnerability Type.

Types	Area (km²)	Percentage
Stable	5.00	0.6
Median Stable/Vulnerable	458.00	53.3
Moderately Stable	98.00	11.4
Moderately Vulnerable	298.00	34.7
Vulnerable	0.05	0.0
Total	859.05	100

Org.: By the Authors, 2018.

CONCLUSIONS

This article diagnosed the state of equilibrium and the natural dynamics of the district's environment, which constitutes a means for the design of sustainable practices of land use and occupation and natural resources.

The results showed the prevalence of a median stability (53.3% of the territory), a situation considered favourable, but we should not remain in a comfortable situation because with the pace of urbanisation in recent decades and its consequences on the environment in the absence of the implementation of planning, this situation can be put into question, also because there is a considerable area of moderate vulnerability.

The methodology applied has proved to be adequate as the results matched field observations. It is important to draw attention to the fact that this degree of stability must be maintained and to the intervention of researchers from the most diverse areas of knowledge to carry out more studies to guarantee an ecological balance in the district since there are few studies carried out in the country on this matter.

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