Assessment of Environmental Vulnerability to Desertification Processes in the Hydrographic Sub-Basin of the Médio Jaguaribe – Ceará

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ABSTRACT. The process of desertification is the focus of many studies, but the association of social aspects in this analysis is still underutilized. The objective of this study is to evaluate the environmental vulnerability to desertification processes in the Hydrographic Sub-basin of the Médio Jaguaribe - Ceará. Therefore, data were collected from different sources, processed and manipulated to provide the composition of indices (index of vulnerability - social and natural aspects; environmental vulnerability index). It was found that the distribution of vulnerability in the study area ranged mostly from very low to low, where the social aspects were influential. Assume, then, that these aspects are important and determining when analyzing the level of environmental vulnerability to desertification processes. Thus, further study of each indicator used as well as the inclusion of other social factors, is needed.

Keywords: social aspects, indexes, cells

1. INTRODUCTION

We live today, according to Araújo; Freire (2008), surrounded by environmental problems, with regard to the use, occupancy and preservation of natural resources. These problems emerged due to the use of predatory nature by man. The cited authors add that the levels of degradation that natural resources have suffered over the recent times are of human responsibility.

Other studies (LEITE *et al.*, 1993; FERREIRA *et al.*, 1994) demonstrated that, in the State of Ceará, extensive areas have problems of environmental degradation and desertification relating them to the aridity index[1], ie, linked to aspects natural/weather.

The complexity in establishing a concept for desertification ultimately also affect the actual research methods and the ways in which such a process is studied. This fact can be justified in most cases because the concept of transdisciplinarity, which therefore requires a stake together from different areas and disciplines (WERTHEIN, 2001 *apud* MATALLO JR, 2001).

The United Nations (UN) defines desertification as land degradation in arid, semi-arid and dry sub-humid zones, resulting from various factors including climatic variations and human activities.

Assuming that the study of vulnerability to desertification processes, takes into account the limitations imposed on the environment through natural and anthropogenic components, the objective of this study was to evaluate the environmental vulnerability to desertification processes in the Hydrographic Sub-Basin of the Médio Jaguaribe - Ceará.

2. METHODOLOGICAL ASPECTS

2.1 Characterization of the Study Area

The Sub-basin Jaguaribe (Figure 1), the object of this research study, located in the eastern portion of the State of Ceará and is limited in its eastern portion, with the State of Rio Grande do Norte. This Sub-Basin drains fully nine municipalities: Alto Santo, Deputado Irapuan Pinheiro, Ererê, Iracema, Jaguaribe, Pereiro, Potiretama, São João do Jaguaribe, Solonópole besides drain, however partially, the cities of Icó (40.15%), Jaguaribara (91.79%), Jaguaretama (58.12%), Limoeiro do Norte (1.15%), Milhã (56.44%), Orós (7.31%) and Tabuleiro do Norte (21.47%) (CEARÁ, 2009).

In this research area, the predominant vegetation types are: open shrub caatinga, dense shrub caatinga and riparian forest, highly degraded, which borders part of the bed of the Rio Jaguaribe (op cit.). With annual rainfall around 742.6 mm and with a hot semi-arid climate, it appears that this region is prone to serious problems of degradation of natural resources (soil, vegetation, water, air etc.) that are enhanced by the action anthropic inconsequential, becoming brittle and poor areas, in areas prone to desertification causing consequently, social and economic problems.

[1] The aridity index, prepared by Thornthwaite (1948) and subsequently adjusted by Penman (1953), calculates the difference between the amount of rain and water loss of the system, ie, evapotranspiration (Barros, 2010).

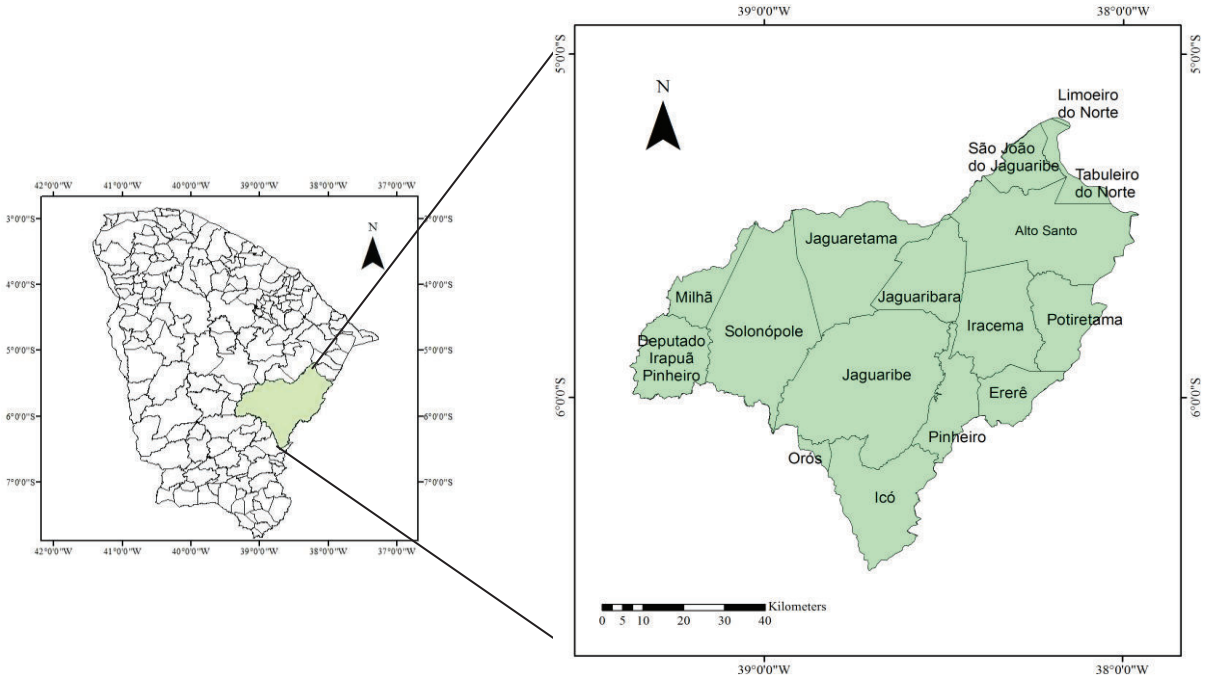


Figure 1: Location of Sub-basin of Médio Jaguaribe.

2.2 Selection of Indicators and Data Source

With the aim of obtaining a better assessment of environmental vulnerability, focusing on the processes of desertification, indicators[2] were adopted distributed according respects the following groups:

- Social (socioeconomic aspects);
- Natural (physical and climatic aspects).

In the present study will be generated three maps: 1 - Map of Natural Vulnerability, 2 - Map of Social Vulnerability and 3 - Map of Environmental Vulnerability (crossing data from the two maps above).

The variables used (Table 1) were selected by means of a literature which identified as relevant to the study of vulnerability to desertification processes.

Table 1: Classification of indicators as to their category, source data collection and timescale.

Category	Variable	Source of data	Period Analysis	
			Initiation	End
Social Aspects	Proportion of households with water supply (%)	IBGE (Census)	2010	
	Proportion of households with sanitation (%)	IBGE (Census)	2010	
	Proportion of households with garbage collected (%)	IBGE (Census)	2010	
	Proportion of households with electricity (%)	IBGE (Census)	2010	
	Illiteracy rate (%)	IBGE (Census)	2010	
	Proportion of people below the poverty line (%)	IBGE (Census)	2010	
Natural Aspects	Hydrography	MMA (Environmental Governance - Geoprocessing)	-	
	Types of Soil	LEÃO, 2010	-	
	Slope	NASA (*Shuttle Radar Topography Mission - SRTM*)	-	
	Precipitation	FUNCEME	1974	2010
	Use and Land cover	INPE (Landsat 5 Images)	2011	

[2] Single variable used in conjunction with one or more different variables to form a composite measure or a multiple scale (Hair et al. 2005).

2.3 Methodology

2.3.1 Techniques of Geoprocessing

Initially, it was necessary to apply different GIS techniques, not only for processing data, but also to leave them arranged so that it was possible to perform statistical analyzes.

The data type of *shapefile* and *raster* were processed so that their coordinates systems were standardized (UTM - SAD 1969, 24 South Zone).

The data from the Instituto Brasileiro de Geografia e Estatística (IBGE) were manipulated and reallocated by each census tract contained in Mesh Digital Census 2010 (provided by that instituition).

The main application of Terraview 4.2 was using the plugin Fill Cells. This plugin allows to calculate values (metrics) for attributes of table associated with information layers of cell type. The goal was to aggregate different data in the same space-time basis. We chose to use cells 10,000m x 10,000m, having encompassed more adequately census tracts.

2.3.2 Construction of the Environmental Vulnerability Desertification Processes Index (IVA)

Once established, each indicator has undergone two stages: the standardization of the selected variables and the calculation of this indicator itself. The standardization of variables aimed enable comparison and aggregation of them (they are expressed in varying magnitudes) and determine the classification of the cells studied, since it assumes values between 0 and 1, representing, respectively, the best and worst situation, ie, the higher the value, the greater its vulnerability (adapted from LIMA *et al*., 2008). We adopted, therefore, the expression:

$$IP_{ji} = \frac{I_{ji} - I_{jr}}{I_{jm} - I_{jr}} \quad (1)$$

Where:

IP*ji* = Value standardized indicator *j* in the *ith* cell or partial index of category *j* in the *ith* cell, being:
I*ji* = Value of indicator *j* in the *ith* cell
I*jr* = Value of the indicator *j* in the cell in worse situation
I*jm* = Value of indicator *j* in the cell in better situation

The partial indexes were obtained by the arithmetic average of the standardized values of each variable. Like this:

IVS*i* = Index of Vulnerability to Desertification – Social Aspects related to the ith cell
IVN*i* = Index of Vulnerability to Desertification – Natural aspects related to the ith cell

The Environmental Vulnerability Index (IVA) was the arithmetic average of the partial indicators:

$$IVA = \frac{1}{m}\sum_{j=1}^{n} IP_{ji} \quad (2)$$

Where:

IVA*i* = Environmental Vulnerability Index
i = Indicators/categories analyzed = (1,..., m)
j = Variables analyzed = (1,..., n)

For the analyzes were awarded the following classification:

Class Vulnerability	Interval between classes
1 ou very low	0,000 a 0,250
2 ou low	0,251 a 0,500
3 ou average	0,501 a 0,750
4 ou high	0,751 a 1,000

3. RESULTS AND DISCUSSION

3.1 Partial Indexes - Social Aspects (IVS) e Natural Aspects (IVN)

The Figure 2 shows the spatial distribution of the values obtained by partial indexes. Analyzing, a priori, partial index linked to social aspects (IVS), it appears that its majority classification was 2nd class characterized as low vulnerability. We can infer, then, that public policies related to the analyzed aspects (education, income and infrastructure) are expressing their efficiency and effectiveness as to their goals. Furthermore, we assume that the social aspects are not, alone, the determinants of desertification process found in some studies (for example: BARROS, 2010).

The above chart shows an area (cell) where the rating was high, ie greater vulnerability. This is located in the municipality of Jaguaribe which has lower levels of water supply, garbage collection, electricity distribution, and median values of sewage and people below the poverty line. The association of these values worsens, directly or indirectly, to misuse of natural resources.

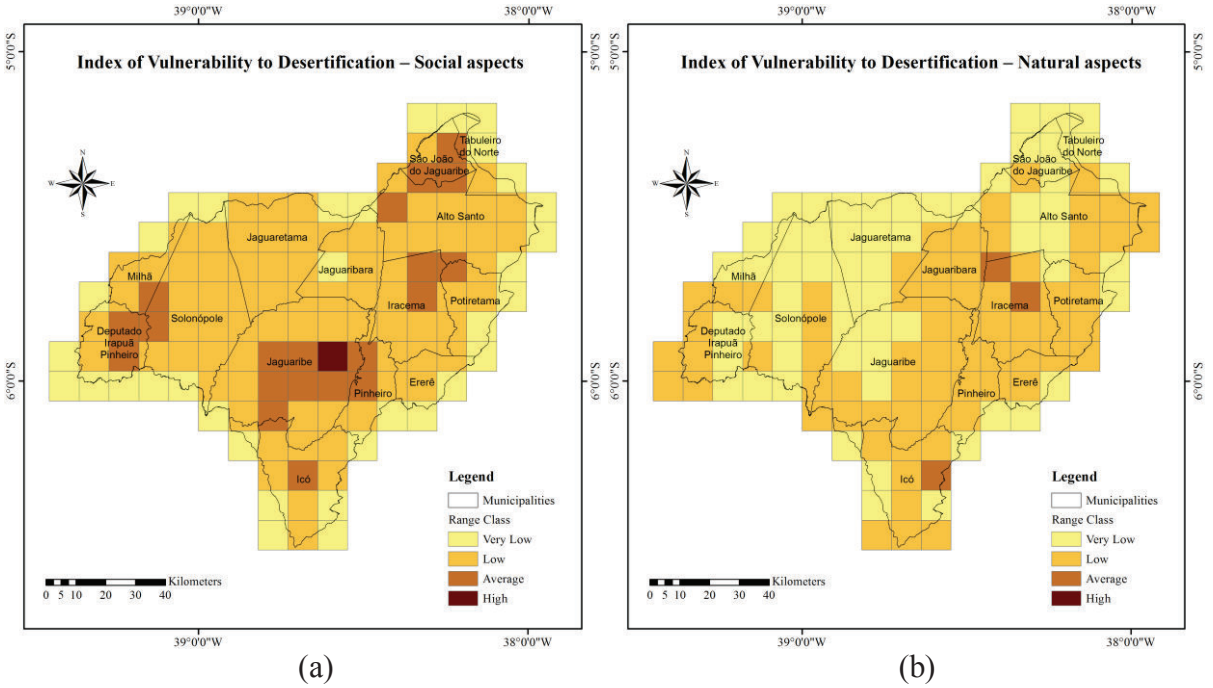


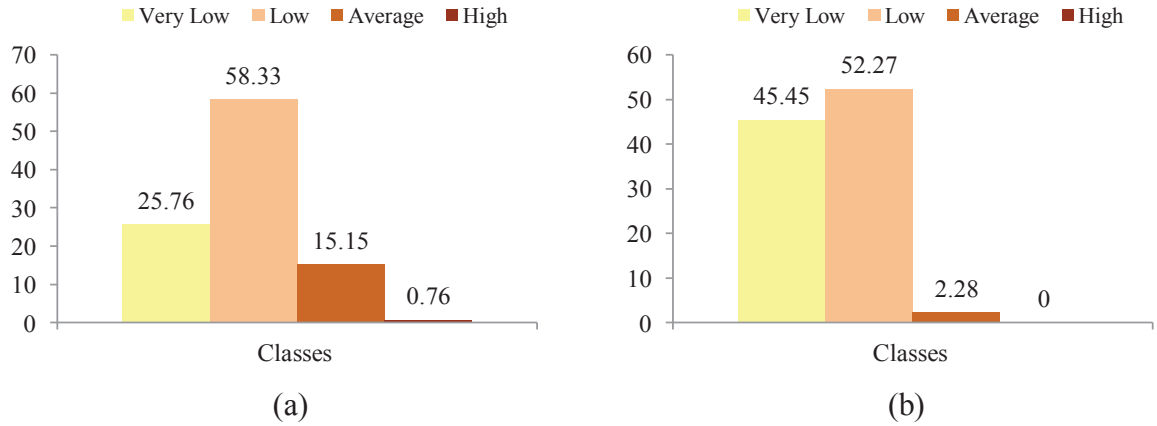
Figure 2: Spatialization Partial Indexes: (a) Index of Vulnerability to Desertification - Social Aspects, (b) Index of Vulnerability to Desertification - Natural Aspects.

Regarding the natural aspects, it was observed that the classification was varied by focusing between very low and low classes, the former being more concentrated in the upper portion and the second in the lower.

Among those framed in class 1 (very low), the determinants were mainly average annual rainfall ranging from 400 to 860 mm, use and land cover composed, mostly, by vegetation and water, and presents soils with physical and chemical characteristics that confer reduced vulnerability to desertification processes (e.g., greater depth, fertility, easy infiltration of water, etc.).

In cells classified as low vulnerability (2nd class), aspects that were influenced, mainly, to higher levels of steepness (located in this area the Ererê Sierra and Pereiro Sierra).

In the chart below (Graph 1), we can check the percentage distribution of each class for each observed partial index.



Graph 1: Percentage distribution of Environmental Vulnerability Classes: (a) Index of Vulnerability to Desertification - Social Aspects, (b) Index of Vulnerability to Desertification - Natural Aspects.

3.2 Environmental Vulnerability Index (IVA)

The Figure 3 shows the map obtained through the spatial distribution of the values of IVA. Note, by the pattern of distribution of classes in the cells, which the social aspects strongly influenced this index. Mainly due to more uniform spatial distribution of the second class (low vulnerability). The darker cells (mean vulnerability) was through the association of the social aspects that stood out on individual assessment of IVS, along with the slope steeper.

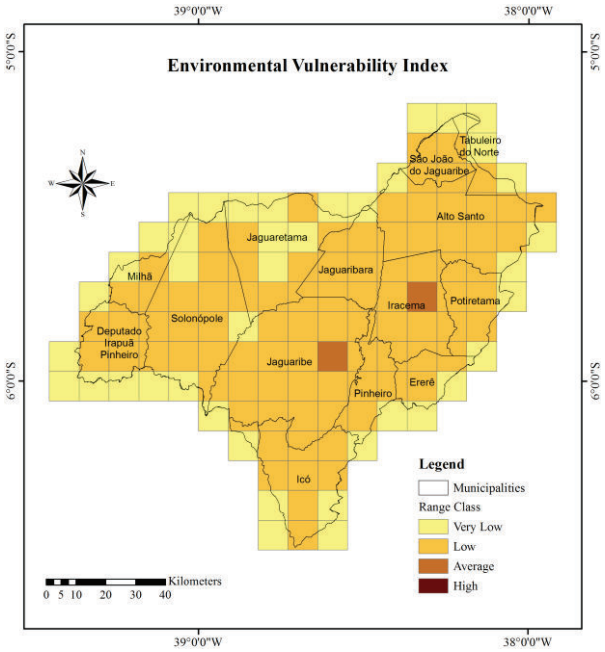
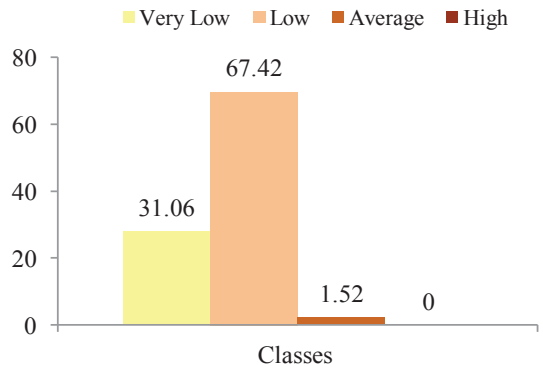


Figure 3: Spatialization of Environmental Vulnerability Index.

When we analyzed the percentage of each class in this index (Graph 2), we see clearly the dominance of the second class (low vulnerability).



Graph 2: Percentage distribution of classes of vulnerability observed in the Environmental Vulnerability Index.

4. POLICY ORIENTED RECOMMENDATIONS

The term "vulnerability" to be worked on the analysis perspective impacts natural and social adaptation, ie environmental vulnerability assessment should be generated in an inter-and trans. Also, knowing the history of the occupation process and economic development of the region helps to understand the local reality, however, fit this reality in regional and global context it is important to define future actions to combat desertification.

5. CONCLUSION AND SUGGESTION

The social aspects are important when analyzing and determining the level of Environmental Vulnerability to Desertification Processes. Thus, further study of each indicator used as well as the inclusion of other social factors, is needed.

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