Early Warning System for Drought and Desertification

Rita Marcia da Silva Pinto Vieira[1], Javier Tomasella[2], Regina Célia dos Santos Alvalá[2], Marcelo Francisco Sestini[1], Adriana Gomes Affonso[3], Marcos Santana[4], Francisco Campello[4]

[1]*Center for Earth System Science, São José dos Campos, Brazil.*
E-mail: {rita.marcia; marcelof.sestini}@inpe.br

[2]Center for Natural Disaster Monitoring and Alert, *Cachoeira Paulista, Brazil*
E-mail: {javier.tomasella; regina.alvalá} @cemaden.gov.br

[3]*Earth Observation Division, São José dos Campos, Brazil*
E-mail: affonso@dsr.inpe.br

[4]*Ministry of the Environment, Brasília, Brazil*
E-mail: {marcos-oliveira.santana; francisco.campello} @mma.gov.br

ABSTRACT: It is well known that most natural disasters, such as landslides, floods and droughts, are directly related to climate variability and particularly to its extremes. Several climate change scenarios indicate that the Semiarid of Brazil is very vulnerable. Land use and land cover changes in the semiarid region have been accelerated in the last decades due to both climatic and human factors. Due to more than 5 centuries of disorderly occupation and the fragility of the ecosystem, soil fertility and biological productivity in the semiarid Northeast of Brazil have been severely affected. Therefore it is essential to elaborate climate change mitigation plans and adaptation actions. To understand landscape changes is challenging because ecosystem drivers takes place at a wide spatial and temporal scales. This work will discuss conceptual and methodological bases for an early detection system of drought and desertification. For this purpose, a geographical database (scale 1:500.000) with physical, environmental and socio-economic information are being developed, allowing the interaction of drought and desertification indicators. The early warning system will integrate remote sensing data and weather forecasts that will enable a continuous assessment of the most susceptible areas, improving the understanding of the combined effects of drought and desertification.

***Keywords*: desertification, landscape changes, Gis.**

1. INTRODUCTION

Dryland ecosystems are fragile, highly vulnerable to climatic changes, and susceptible to desertification. These dryland regions comprise 41% of the global land area and are present in every continent putting at risk more than 1 billion people who are dependent on these lands for survival (ONU, 1997, Santini, 2005).

Degradation of these ecosystems refers to a combination of excessive human exploitation (overexploitation) and land-management, which goes beyond the land natural capacity, affecting soil, water resources and vegetation, and consequently worsening the quality and the availability of these fundamental resources for human life. Ecosystem degradation impacts not only human population and their livelihood, but also insect and bird populations and biodiversity as a whole. Among the most serious consequences of desertification process are: 1) elimination of original vegetation due to an invasive cover presence, with consequent biodiversity reduction; 2) partial or total soil loss due to physical (erosion) or chemical (salinity) phenomena; 3) decrease of water resources quantity and quality, primarily affecting runoff; and 4) decrease of soil fertility and productivity (ONU, 1997).

Nowadays, issues of change in patterns and land cover are of great interest due to the accelerated process of change that has occurred in recent decades (Aguiar, 2006). The understanding of the causes, feedback mechanisms and land use dynamic are crucial for appropriate policy interventions.

According to Geist and Lambin (2004), desertification is driven by a limited set of variables, being the most important climatic factors, economic and population growth. These factors stimulate the expansion of cropland and overgrazing.

Most of the methodologies for assessment of desertification are based on identifying indicators of different scales. These indicators should be based in satellite images, topographic data, climate, soils and geological data. However, those data are usually in different geographical projections and scales, hindering the information crossing.

Thus, the aim of this work is to develop a geographic database that will enable the integration and assimilation of bio-geophysical data, and will permit the identification of the desertification process in risk areas.

In this context, this paper will discuss the conceptual and methodological bases for an early detection system of drought and desertification. For this purpose, a geographical database (scale 1:500.000) with physical, environmental and socio-economic information are being developed. The early warning system will integrate remote sensing data and weather forecasts on software to integrate this information that will possible a continuous assessment of most susceptible areas, improving the understanding of the combined effects of drought and desertification.

2. METHODS

2.1 Study area

The study area is located in the equatorial zone (1-21ºS, 32-49ºW), covering an area of 1,797,123 km^2 and representing approximately 20% of the Brazilian territory (Figure 1). The study area limits were defined by the "Superintendência de Desenvolvimento do Nordeste" (SUDENE).

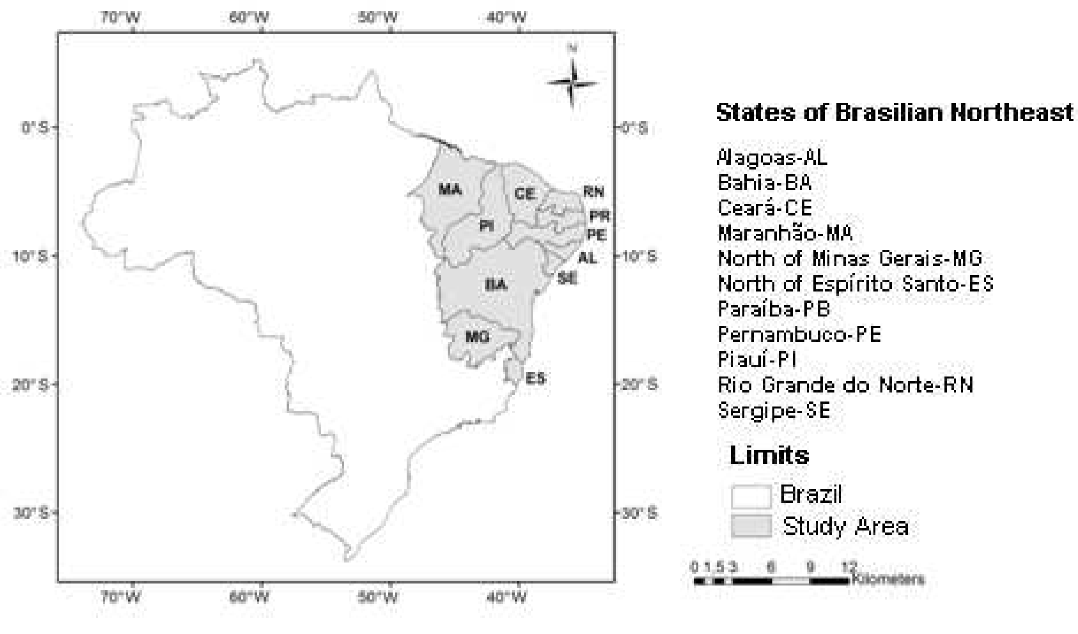

Fig.1: Study area

For all the GIS applications we used the SPRING – Georeferenced Information Processing System (Câmara et al., 1996). SPRING is a free GIS software and is a product of Brazil's National Institute for Space Research (INPE/DPI (Image Processing Division) and is a satellite image processing system with an object-oriented data model which provides for the integration of raster and vector data representations in a single environment.

2.2 Geology, Geomorphology and Pedology Maps

Geology and geomorphology maps from RADAM Project (Projeto Radam, 1973-1987) are being refined from the topographic breakline. The breaklines were created using Digital Terrain Model (DTM) derived from SRTM, at 90 meters of resolution. Soil maps from EMBRAPA (Jacomin et al., 2005) also are being refined using DTM but also taking into consideration information of slope. Both maps are being adjusted on the scale of 1:500.000.

2.3 Land Use and Land Cover Maps

Ninety Landsat-TM images (30 m resolution) of the dry period (July to September) from 2010 and 2011 were selected and geocoded based on GEOCOVER images (NASA). These images were used to update the base map from ProVeg Project (Vieira et al., 2010) which was based on Landsat images from 2000. Besides that, the PROBIO Project maps from the Ministry of Environment (MMA, 2007) and the high-resolution images from Google Earth were used as auxiliary data. The map scale is 1: 500:000.

2.4 Sensitivity criteria setting

The purpose of this stage is to assess the nature and the relative influence of desertification factors and to detect the most critical areas (hotspots). Thus, due the complex desertification phenomenon and with base in the European projects MEDALUS (Mediterranean Desertification And Land Use), each of these parameters will be grouped into various uniform classes and for each class is assigned a weight: 1 (no predisposition) and 2 (predisposition). The MEDALUS methodology can be adapted to different climate, environmental and social conditions, at different scales. The following four qualities are evaluated: soil quality; climatic quality; vegetation quality and management quality (Figure 2) where:

a) CQI = Climatic Quality Index = Aridity Index : is assessed using parameters related the aridity index I = [(P - PET) / PET] * 100 where: P = average annual precipitation (mm) and PET = average annual potential evapotranspiration (mm), deriving from the sum of the 12 values of average monthly PET.

b) SQI = Soil Quality Index: is defined using parameters such soil texture, parent material, depth and slope obtained in the geologic, geomorphologic and soil maps.

c) VQI = Vegetation Quality Index: this parameter will be calculated with vegetation characteristics related to fire risk, vegetation cover, drought resistance and erosion protection.

d) MQI = Management Quality Index: will be considered the intensity of land use and policy enforcement.

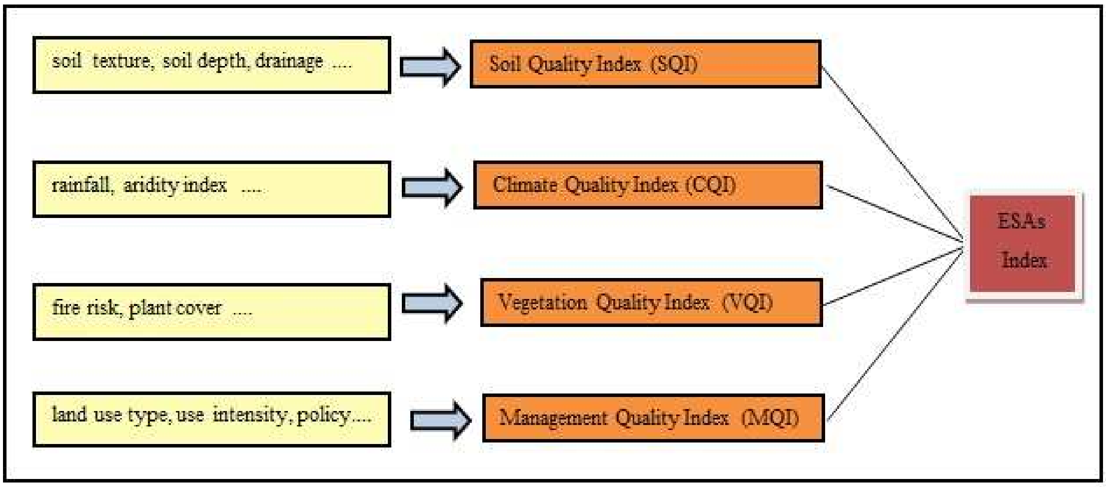

Fig.2 - Parameters used for the definition and mapping of the ESAs
Font: Adapted from Santini (2005)

The final step is the combination of the four indices which will determine the Environmentally Sensitive Areas (ESA) index as follow:

$$\mathbf{ESA = (SQI^* \, CQI^* \, VQI^* \, MQI)^{1/4}}$$

ESAs is defined on a two point scale, ranging from 1 (lower sensitivity) to 2 (high sensitivity) in Table 1.

Table 1. ESAs and corresponding ranges of indices

Type	Range
Low sensitivity	1 – 1.33
Medium sensitivity	1.34 – 1.66
High sensitivity	1.67 – 2

3. EXPECTED RESULTS

Because desertification/degradation in Brazil reaches almost all Northeast states, it is necessary to understand the factors that increase desertification in the study area.

There are many causes for desertification: climate changes, interdecadal and interannual hydrological changes, urbanization, population growth, agriculture (deforestation, burning, improper practices), and soil erosion.

It is expected that an alert system should include and consider all these aspects to identify the susceptible areas to desertification by adopting methodologies that could be applied in a large geographic context. Besides that it should provide tools for prevention, mitigation and monitoring of drought phenomena, and also information for sustainable planning to decision makers.

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