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A VEGETATION MAP OF THE NORTHEAST BRAZIL REGION FOR USE IN METEOROLOGICAL MODELING

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1. INTRODUCTION

Currently, the soil-vegetation-atmosphere transfer schemes (SVATs), which are coupled to the meteorological models, consider a detailed description of the interactions between the continental surface and the atmosphere. Thus, the inadequate or incomplete representation of the characteristics of the surface may have a negative impact in both long-term climate simulations and short-term weather forecasting applications. Due to the recognition of the role of the interactions, the parameterizations of the vegetation and the soil processes are progressively becoming more sophisticated, in order to treat the complexities of the physical system. So, efforts have been expended to obtain a more realistic representation of the vegetation (Wilson and Henderson-Sellers, 1985; Hall et al., 1995; Sud et al. 1996; DeFries et al., 1999; Champeaux et al., 2000), as well as to improve the knowledge of the regional details of the processes in the atmosphere and their interactions with the hydrological cycle.

Concerning the vegetation, the maps used in the surface models have been produced from compilations of some sources of data, such as Atlases, local maps and other registers (Defries and Townshend, 1994), in order to provide the boundary conditions for the climate models (Matthews, 1983; Wilson and Henderson-Sellers, 1985) and for the numerical weather predictions models. However, these data sets present several restrictions. First, the information comes from different sources, making it difficult to get classification compatible (Townshend et al., 1991); second, the maps cannot be updated frequently; and finally, the resolution of the conventional global maps usually is coarse to be used with the most advanced atmospheric models. In fact, for meteorological applications, a large range of resolutions is needed. According to Champeaux et al. (2000) the tendency is towards higher spatial resolutions models, and, in some cases, nested models or systems of extended coordinates, which demand detailed description of the surface. These considerations justify the use of alternative vegetation mapping techniques using observations from space, which, in principle, have the potential to fulfill the requirements in terms of homogeneity, time and space resolution.

With increasing frequency, remotely sensed data sets have been used to classify the global vegetation land cover. The primary goals in developing these products are to meet the needs of the modeling community and to attempt to better understand the role of human impacts on Earth systems through land cover conversions (Hansen et al., 2000). To classify regional, continental and global land covers multi-temporal remotely sensed data sets have been used to describe the vegetation dynamics, through the observation of the variation of the phenology along the course of a year (Verhoef et al., 1996). Thus, an increasing effort is being dedicated in different research centers for the production of land cover maps to be applied to climate models, in order to improve the simulations of the surface processes in such models adequately.

In this context, at the Center for Weather Forecasts and Climate Studies (CPTEC/INPE), an increasing effort is being dedicated for the elaboration of updated land cover maps of the Brazilian territory, to be applied in all its numerical models. For this reason, the available digital maps of vegetation have been used to determine the predominant type of vegetation in each grid of the models. Considering that different domains and grids with high resolution will be used for different purposes, it is necessary to have land cover maps including vegetation and land use changes. In a first effort, a land cover map for the Brazilian Legal Amazon Region was built through the compilation and the improvement of cartographic information on the vegetation cover and deforestation in the region.

The objective was to obtain a land cover map for use with a surface model for the simulation of the climate-atmosphere interaction, such as the Simplified Simple Biosphere Model (SsiB) coupled to the Eta regional model. The 1:5.000.000 IBGE Vegetation Map available for the region was aggregated in order to fit with the land cover types of the SSiB. Information on the spatial distribution of deforested areas obtained from the Brazilian Amazon Deforestation Monitoring Program was included to the data base. The result is an updated land cover map of the region suited to be used with the SSiB-ETA coupled models and sufficiently flexible to be adapted to more detailed surface-atmosphere interaction models (Sestini et al., 2002). Using the Eta model coupled with the SSiB Model, nested to the general circulation model from the Brazilian Center for Weather Forecasting and Climate Studies (GCM/CPTEC), Correia (2005) evaluated, using deforestation scenarios for the current and for potential future conditions, how the land cover changes in Amazônia would affect the regional climate. His results showed that the changes in the region's hydrological cycle, and the disruption of complex soil-plant-atmosphere relations, could be so profound that once the tropical forests were destroyed, they might not be able to reestablish themselves. The increase of the cloud cover and the precipitation over the deforested areas (with the scenarios mentioned above) is another indication that the mesoscale circulations affect the moisture and the heat transport in the atmosphere and, consequently, the climate.

As a continuation of the effort above mentioned, there is under construction a land cover map of the Northeast region of Brazil – NEB (1,550,940 Km^2 – 18.2% of the Brazilian territory), plus the northern part of Minas Gerais State (121,491 Km^2). This constitutes the area of actuation of the former SUDENE, now ADENE, totalizing 1,671,641 Km^2. It presents a great variability of geo-environmental conditions, especially of geomorphology, climate, soil and relief. Thus, it presents a great and complex number of scenarios and ecosystems, with their peculiarities and interrelations (Cavalcanti, 2003). This area is also known by the occurrence of strong and anomalous droughts (Hastenrath, 1990; Nimer, 1989), which have strong social and economic consequences. In the semiarid area of NEB (Figure 1), the annual precipitation is on average less than 800 mm; in addition, there is a broad region where it is less than 500 mm, which is susceptible to desertification. The rainy season extends from February to May, when the intertropical convergence zone (ITCZ) reaches its southernmost position (Oyama and Nobre, 2004). The NEB region is characterized for presenting high temperatures during the year, with a maximum thermal amplitude around 6°C. Moreover, more than 10% of the semiarid area of NEB has already undergone a very high degree of environmental degradation of soils, vegetation and hydrological resources (MMA, 2000), which is resultant from climatic variations and/or anthropogenic activities (Rodrigues et al., 1992). According to Souza et al. (2001), considering the strong social (the arid zone presents the lowest Index of Human Development of the country) and economic (great amounts of resources are needed to combat the droughts and floods) impacts, the sazonal forecast constitutes an important key for the governmental planning.

This work presents the land cover map of the States of Ceará, Rio Grande do Norte, Paraíba, Pernambuco, Alagoas and Sergipe (412,141.6 km^2), where most of the xeromorphic vegetation, known as *caatinga,* that characterizes the semi-arid region, is located. This map is already been been used with ETA-SSiB model to verify the impact of the improvement of the vegetation representation in the weather and climate predictions for the region.

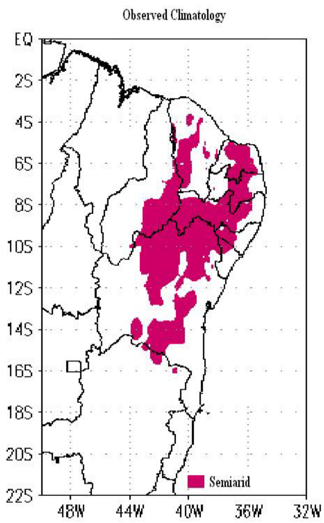

Figure 1. Northeast Semiarid Region (delimited by the isoieta of 800 mm).
Source: INMET (period 1961 -1990).

2. MATERIAL AND METHODS

The methodology used for the elaboration of the land cover map for the six states, followed the one of Sestini et al. (2002) for Legal Amazônia, with adaptations as summarized bellow.

A. Data and Basic Systems: The main products of remote sensing used were mosaics for each state composed with high resolution (30 m) Landsat Thematic Mapper TM data of the years of 1999 and 2000 with at most 5% of cloud covering. The mosaics were generated using the policonic projection, datum Sad/69. The mosaics were inserted in a database created with the SPRING software (Câmara et al., 1996).

B. Auxiliary Data: Due to the complexity of the study areas, which present different types of vegetation, but with similar spectral response, the 1:1,000,000 RADAMBRASIL vegetation maps available for the region, were used to help the interpretation of the images. These maps constitute the most extensive, detailed and up-to-date vegetation mapping effort for the Brazilian territory. To generate the maps, the RADAMBRASIL project used airbone, X-band (approximately 3 cm wavelength) radar images acquired in the early 1970s. Although these maps do not show the anthropogenic cover types since the 1970, they do represent the vegetation types of the Brazilian territory in detail.

C. Classes Compatibility: The compatibility among the RADAMBRASIL vegetation classes and those considered by the SSiB model was determined (Table 1). As there are less vegetation types in the SSiB model, especially for the *caatinga*, adaptations and/or aggregations of some of the RADAMBRASIL classes were made, despite that this is not always the best solution. On the other hand, the database includes the urban areas, which in the present map are considered as bare soil; rocky formations and sand dunes, which were not considered in the RADAMBRASIL maps, are classified as bare soil (biome 11 of SSiB model). The farming class (biome 12) includes crops (herbaceous, shrubs and tree types) in their different growth phases.

D. Adjustment of the polygons in the maps of RADAM 1:1.000.000: Due to the geo-referencing problems associated to the cartographic products (vegetation maps) of the RADAMBRASIL maps, distortions between the positioning of the spots of vegetation cover when overlapped with the Landsat mosaic of images were observed. To minimize these errors, the vectorial edition, implemented in the SPRING software, was used for the adjustment of the thematic polygons.

E. Select Image Subset: The mosaics were resized with the help of the RADAMBRASIL classes, which were grouped according to SSiB model types. This was done to improve the classification accuracy of the image processing.

F. Interpretation of the Landsat mosaic images and generation of the thematic and numerical maps: The resultant images were segmented using the thresholds of 8 for similarity and 30 for area. The ISOSEG, a non´ supervised classifier, was applied for the regions, with a 95% acceptance threshold, due to a more adequate separation of the targets analyzed. Thereafter, in the images, generic patterns (dense and open trees or shrubs, cropping areas, etc) were selected, thus creating an interpretation key for each of the different land cover classes. These keys are then used to identify the classes in the RADAMBRASIL maps; next, the corresponding SSiB classes are determined. Finally, the thematic updated land cover map for each state was re-sampled fwith the resolution of 1 km, and re-projected with the Lat/Long datum Sad/69, and then converted to a numerical grid, using a program written in the Geographical Space Language (LEGAL) of the SPRING software. The final land cover map may be incorporated in the SSiB model, which is coupled to the global and the regional models of CPTEC.

Tabela 1 – Correspondence between RADAMBRASIL and SSIB land cover classes.

PROVEG-NEB	RADAM	SSiB
1. Broadleaf-evergreen trees	Pioneer Formations (Pma, Pfm, Pmb, Pmh) and Broadleaf Evergreen (Foa Vsp)	**1.** Broadleaf-evergreen trees (rain forest)
2. Deciduous forest	Seasonal Semi-deciduous Forest (Fes, Vss e Vsp)	**2.** Broadleaf-deciduous trees
3. Savanna *Estepica* (*caatinga*)	Caa_eds, Caa_edp, Caa_eas, Caa_eap, Caa_epp e Eps).	**8.** Broadleaf shrubs with groundcover
4. Savanna (*cerrado*)	(Sd, Sas)	**6.** Broadleaf trees with groundcover
5. Farming	Agricultural activities (Ac)	**12.** Broadleaf-deciduous trees with crops
6. Bare soil	Not mapped	**11**. Bare soil
7. Urban areas	Not mapped	-
8. Water bodies	Not mapped	**13.** Water

3. RESULTS

The land cover map of the states of Ceará, Rio Grande do Norte, Paraíba, Pernambuco, Alagoas and Sergipe are shown on Figure 2. These states present extensive areas with farming activities. Parts of the agricultural areas are in a desertification process, and are already not cultivated, but were classified as farming. In addition, many areas of *caatinga* may have extensive pastures, which could be classified as farming; however, due to the difficulties of identification in the visual interpretation of the image, these areas were considered as native vegetation (*caatinga*). Moreover, despite the low cloud cover (5%), due to its concentration in some areas, it was not possible to identify their corresponding land cove; for these areas, the vegetation classification of the RADAMBRASIL maps was maintained.

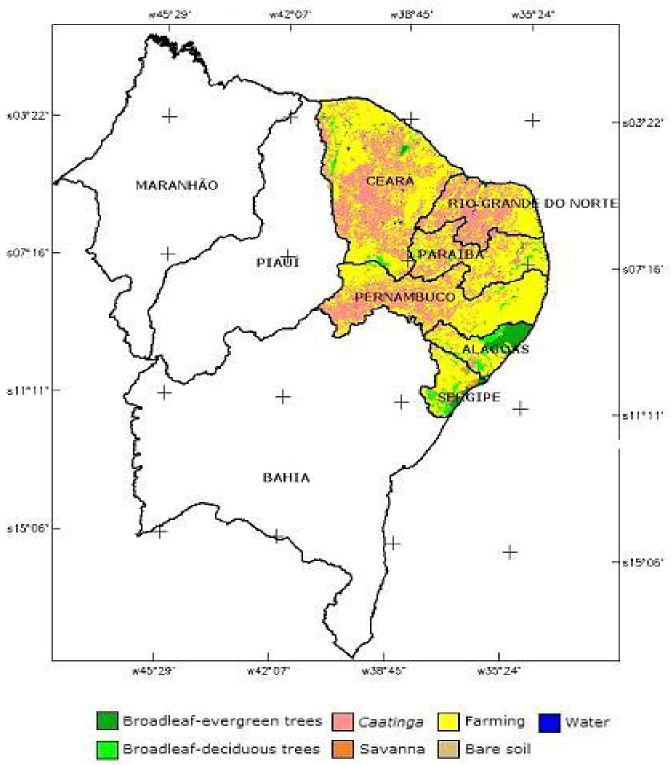

Figure 2. Land cover map for the six states.

On the other hand, the areas of contacts (ecological tension) or unresolved vegetation contact zones present in the RADAMBRASIL vegetation maps, which are defined as those that combine two or more types of vegetation cover, were classified by image segmentation followed by region classification. Then, they were edited to solve misclassifications and to obtain classes suited to SSiB model. Concerning to the bare soil .

areas and the water bodies, only the most significant ones were mapped; this, in some cases, excluded small spots or vegetation cover in its polygons. Figure 3 presents the land cover percentages for each of the six states, showing that farming predominates in all states, except in Rio Grande do Norte.

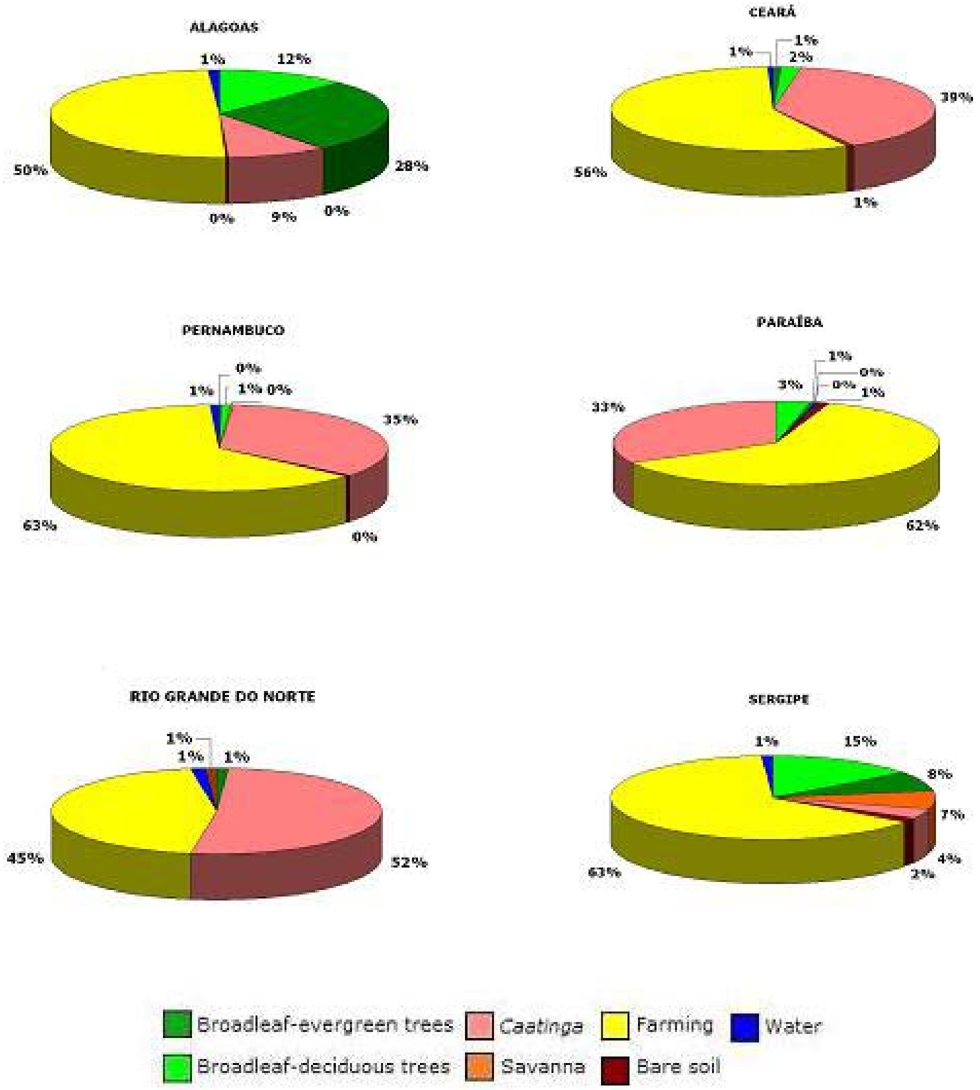

Figure 3. Land covers percentages for the six states.

4. CONCLUDING REMARKS

Simulations with the regional meteorological model ETA/SSiB, using the updated land cover maps generated by this study, both at local and the seasonal scales, showed significant impacts on the regional climate, when compared with the simulations using less detailed previous maps. Further, the set of the updated land cover maps for the six states of NEB, plus the map for Legal Amazon and the ones in elaboration for the remaining NEB States, will be very useful for the simulations with climate and weather numerical models, as well as for study of the dispersion of pollutants, among other purposes, once they represent more realistically the spatial variability of the land cover of two important Brazilian regions

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