Reproduction of long-term surface parameters and its application to regional climate change study in Paraguay

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1. Introduction

The Atlantic forest, covering much of Eastern Paraguay used to have dense forest cover until the 1970s but since then vast forested areas had been converted into large tracts of agricultural fields, and as consequence, Paraguay lost almost two thirds of its Atlantic forest between 1973 and 2000 1. Such landscape transformation is believed to influence regional climate because it changes the biophysical properties associated to a land-cover type and thus affects the surface-atmosphere interactions 2.

Modeling techniques are a common approach to study the effects of land-use changes over regional climate, in particular regional climate models with coupled land surface models, due to the enhanced ability of the latter to represent surface characteristics. Among the surface parameters needed to run land surface models, land-use information and Normalized Difference Vegetation Index (NDVI) are of major importance. Remote sensing have made possible to count with a variety of current high-resolution NDVI datasets and more accurate land-cover products but reliable past long-term data still remains an issue. In this regard, the AVHRR 8km resolution dataset has a great potential for land-cover change studies due to its extended record time, spanning 25 years of observations (1981-2006). Nonetheless, the quality of this data is subject of several errors, like those related to sampling processes that could reduce the utility of this information.

Thus, the purpose of this study is to reproduce past surface parameters for November to improve the representation of the surface characteristics for past epochs, and to show its application by performing a regional climate change study in Paraguay to provide a first overview of the impacts of land use change in the patterns of precipitation and the mechanisms that may lead to these changes.

2. Methodology

The methodology is divided in two parts, as it is detailed bellow.

2.1. Long-Term NDVI Adjustment

Normalized Difference Vegetation Index (NDVI) from SPOT Vegetation 1km resolution and monthly composite data was firstly resorted into forest and non-forest on a yearly basis using typical phenology characteristics of forest to construct NDVI characteristics curves based on the histogram method 3 and thus analyze the variation tendency of each 1km pixel pre-classified as forest. Using this tendency information, a decision tree classification method is applied to estimate the forest distribution at 1km resolution and to calculate forest ratio at several resolutions. Following, correlation analysis between AVHRR 8km 1-month composite and SPOT Vegetation 8km 1-month composite is performed for different ranges of forest ratio during the period both dataset overlap (Figure 1). The relationships encountered in the analysis are finally used to adjust the AVHRR NDVI data to the SPOT Vegetation for November during 1981-2006.

![Figure 1. Schematic representation of the NDVI adjustment process.](image)

2.2. Regional Climate Change Study for Paraguay.

The meso-scale numerical weather prediction model CReSiBUC 4 was applied to provide a first overview of the potential regional impacts of land cover change on the precipitation of November and to analyze the mechanisms that may lead to variations in regional climate.

<table>
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<th>Table 1. Simulation settings for each experiment</th>
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<td><strong>Simulation set</strong></td>
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For this, two sets of simulations, called Present and Past respectively, were conducted for November 2006-2011, each using different vegetation scenarios and NDVI data, as it is detailed in Table 1. The land-use scenarios for the 1990s and 2000s were obtained by combining USGS’ Global Land Cover Characterization data with the Paraguay Forest Change product (GLCF) 5. Additionally, a third set of simulation, named Original, was carried...
out using the original AVHRR product for November 2006-2007 (Table 1) to conduct a sensitivity analysis by comparing outcomes from this simulation with those obtained from the past ensemble.

3. Results and Discussion

3.1. Long-Term NDVI Adjustment

The 1km forest distribution map produced for the year 2000 has an overall accuracy of 0.957 when compared with Paraguay Forest Change product. NDVI correlations at 8km resolution between datasets presented a clear tendency that is dependent upon the forest ratio of each pixel. In general, correlation tended to increase as the pixel heterogeneity decreases, with higher values in pure pixels such as those with forest ratio of either 0 or 1, and lower values in pixels in which the forest presence is about half. A similar bias trend was observed, in which the slopes of the regression line equations, for different forest ratios, decrease as the pixel heterogeneity increases. Figure 2 shows the comparison between original AVHRR and adjusted dataset with SPOT Vegetation data (black dots and red marks, respectively), for the year 2003. From this figure it can be observed that, even though the correlation values are almost the same for both cases, the bias present in the data was reduced since the regression line of SPOT-adjusted NDVI is closer to the 1:1 line than that of SPOT-AVHRR.

![Figure 2. Comparison between SPOT Vegetation and AVHRR, and SPOT Vegetation and adjusted NDVI data; and difference between original and fitted AVHRR for Paraguay.](image)

3.2. Regional Climate Change Study for Paraguay

The land-cover change in Paraguay during the epochs 1990s and 2000s had somehow different impacts depending on the region where it was produced and the type of vegetation that was changed. For Eastern Paraguay, where forest was shifted to farmland, the impacts included higher albedo, which can be correlated to the decrease observed in NDVI that lead to a diminution of the latent heat and to an increment of the sensible flux; higher root zone soil wetness, and lower temperature range. For Western Paraguay however, the potential impacts, in the area where grassland was changed to farmland, correspond to a reduction of the latent heat and thus a decrement in the sensible heat fluxes, higher surface soil wetness and root zone wetness.

These changes in the energy balance could have driven changes in the pressure fields that in turn altered the magnitude and direction of wind, and thus produced the changes in the precipitation patterns observed in Figure 3, which shows a displacement of the precipitation nucleus in Eastern Paraguay to the southeast direction, as well as modifications in the distribution of rainfall in the western part of the country. Moreover, despite of the fact that the land use changes represented in this study were confined inside the borders of the country, the impacts also extended outside the limits of Paraguay suggesting that this kind of alterations can also affect regions where no transformation occurred.

Regarding the sensitivity analysis, the outcomes showed that precipitation was the variable that presented the highest level of sensitivity. According to Figure 4, the usage of the fitted NDVI leads to a drop in precipitation in the southwest corner when compared to the Original scenario. Furthermore, the fitted dataset produces a significant increase in precipitation in the center of the Eastern Region where the impacts of land-use change suggest a decrement. Additionally, the outcomes of Eastern Paraguay are more sensitive to the changes in NDVI than those of the Western Region.

![Figure 3. Six-month averaged rainfall for November for the Present, and the difference between Present and Past.](image)

![Figure 4. Rainfall outcome of the Original, and the difference between Original and Past.](image)

References


Key Words: NDVI, land cover change, regional climate modeling, Paraguay.