# Land cover and land use in Brazil and the Environmental-Economic Accounts System

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## Abstract

*The objective of this work is to produce statistics that are going to show changes occurred in Brazil's ecosystems and these statistics are going to join the Environmental-Economic Accounts System – SEEA. It's based by a SEEA's methodology, diffused by United Nations - UN, which aims an approach between economic and environmental statistics, producing international comparability and conceptual uniformity to evaluate change process in land cover and land use that occurs in several countries. It's necessary to verifying the suitability of methodological procedures to Brazilian reality and the access to all information and files needed. The first step was analysing MODIS as orbital instrument on the purposed classification method. The choice of this sensor was made because of the product's quality and its capacity to generate images of a large area, though the challenge is to identify accurate Land usage's categories in images with a spatial resolution of approximately 250 meters. After the final classification, the next step is to make a quantification and comparison of data from these different years using a 1km² grids, as proposed in an already used methodology by The European Environment Agency. This procedure will allow evaluate and identify the process of changing in each grid of the land cover and land use, and provide historical series of the chosen years.*

**Keywords**: Remote Sensing. Land Use and Cover Change, Environmental Statistics, Geoprocessing.

## 1. Introduction

Among various metrics in the national accounts, GDP (Gross Domestic Product) is one of the most present in decision making (IBGE, 2008). However, GDP does not address adequately the social dimension and must incorporate environmental

assets and liabilities to become more satisfying (Turner, 1993; Cobb and Cobb, 1994; Daly and Cobb, 1994).

It is possible to measure environmental assets and liabilities through of mapping of land use and cover change - LUCC (Rapport and Friend, 1979; UN, 1993; Motta, 1995).

To map and measure LUCC processes is necessary to detect them. It is possible through many ways, for example, the map algebra (Bonham-Carter, 1994; Jensem, 1996). To perform map algebra, it is necessary two classifications at different times.

The aim of this article is to measure land use and land cover changes that occurred between 2000 and 2010, for Brazil. For this, it is necessary to consider the following specific objectives:

- Produce land use and land cover map for 2000 and 2010;
- Evaluate the land use and land cover map for 2000 and 2010;
- Detect and map the processes of changes that occurred between 2000 and 2010.

## 2. Methodology

### 2.1. Data Used

The data to be used are:

- MOD13Q Product, including NDVI and bands 1 (red), 2 (NiR) and 6 (SWiR) - images that will be classified to use on the mapping;
- TM5 Landsat Scenes - images that will be used as support;
- Google Earth Scenes - images that will be used as support;
- Digital Elevation Model by SRTM, interpolated by Topodata - support data
- Time series based on EVI MODIS - support data;
- Vegetation Map of Brazil (IBGE) - support mask;
- Deforestation Map of the Amazon, for 2000 and 2010 (PRODES) – support mask;
- Secondary Vegetation Map of the Amazon, for 2010 (TERRACLASS) - support mask;
- Biomes Map, for 2002 (MMA-PROBIO) - support mask;
- Remnant and Deforestation Map, for 2009 and 2010 (MMA-PROBIO II) - support mask;
- Land Use and Land Cover Map of Amapá, for 2000 (IBGE) - assessment and calculation of the Kappa Index;
- Land Use and Land Cover Map of Sergipe, for 2010 (IBGE) - assessment and calculation of the Kappa Index.

### 2.2. Procedures

The mapping will be published at 1:1,000,000 scale and will be done with unsupervised classification by region and matrix edition.

The segmentation adopted is the Region Growing. The criteria for Similarity and Area will be defined by biome, through empirical tests. The classification

adopted is the Isodata (unsupervised, by region). For more details about the segmentation and classification, see Camara et al., 1996.

After the classification, the association of classes is manually realized (on computer screen). In this association, many inputs are used to support, such as Digital Elevation Models, TM-5 Landsat Scenes, Google Earth and the EVI series. After the association, is performed a matrix edition. At this stage, is used several support vectors, such as vegetation maps (IBGE and PROBIO) and forest remaining and deforestation maps (PRODES, PROBIO II and TERRACLASS).

The Table 1 cites and describes the classes, according to IBGE (1992) and IBGE (2006).

**Table 1:** Description of classes.

| CLASSES | DESCRIPTION |
|---|---|
| Urbanized area | Includes areas of intensive, structured by buildings and road system, which dominate the non-agricultural artificial surfaces. |
| Forest vegetation | Considered as forest tree formations, including areas with dense forest (forest structure with continuous top cover), open forest (forest structure with varying degrees of discontinuity of the top cover), seasonal forest (forest structure with loss of the upper strata of the leaves during the unfavorable season - dry and cold) than the Araucaria forest (forest structure that comprises the area of natural distribution of *Araucaria angustifolia*, striking element in upper strata, which usually form continuous coverage). |
| Shrub vegetation | Considered as non- tree formations. Understood as grassland sites the different categories of physiognomic vegetation quite different from the forest, ie those which are characterized by a predominantly shrub layer, sparsely distributed over a carpet grassy-woody. Are included in this category the savannas, steppes, pioneer formations and ecological refuge. |
| Agricultural area | Broadly, agricultural land can be defined as land used for producing food, fiber and other commodities of agribusiness. Includes all cultivated land, characterized by the design of cultivated areas, or at rest, and may also comprise wetlands. May constitute heterogeneous agricultural areas or represent large areas of "plantations". They are in this category, temporary crops, permanent crops, pastures and forestry plantations. |
| Forest vegetation with agricultural activity | Considered the area that contains 50% to 75% of the polygon occupied by forest vegetation and the rest of the polygon with the agricultural area. |
| Shrub vegetation with agricultural activity | Considered the area that contains 50% to 75% of the polygon occupied by grassland and the remainder of the polygon with the agricultural area. |
| Agricultural area with forest remnants | Considered the area that contains 50% to 75% of the polygon occupied by farmland and the rest of the polygon with forest regeneration or remnants. |
| Other areas | Open areas or areas with sparse vegetation (to include sand, rocks and beaches). |
| Water bodies | Includes all classes of interior and coastal waters, such as water courses and channels (rivers, streams, canals and other linear water bodies), naturally enclosed bodies of water, no movement (regulated natural lakes) and artificial reservoirs (artificial water impoundments constructed for irrigation, flood control, water supply and electricity generation), and coastal lagoons or lagoons, estuaries and bays. |

The evaluation maps will be performed by two ways:

- Calculation of Kappa Index for two states with land use and land cover published map by IBGE and used as a reference, consistent with the image dates. These are the states of Amapá (2000) and Sergipe (2010);
- Overall rating for all entries through inputs for support and consultation to agencies from IBGE.

The change detection is performed by map algebra. To this, is be calculated a cross tabulation between the 2000 and 2010 classification (Hagen, 2002). The analysis of the processes of LUCC will be expressed through-the two types of outputs:

Non-spatialized (Tabular).

The outputs will be represented quantitatively using graphs and tables. Is possible to realize general changes, but can not verify the sites of occurrence of these changes. There´s changes that defines the regenerative processes (such as forestry and rural regeneration) and expansion processes (likewise as urban and agricultural expansion). There´s changes that defines the decrease processes (like as deforestation, reduction of grassland and agricultural decline). Some changes in the proportions of classes are characterized by qualitative changes (such as degradation and environmental suitability).

Urban shrinkage is not perceived in Brazil and it will not be considered on this change processes map, mainly due to inappropriate scale. In addition, changes in the classes "Other Areas" and "Water Bodies" are not objects of analysis in this work. So do not be mapped.

Spatialized.

It is possible to infer more precisely about the change processes through spatialized output. The LUCC processes to be checked are described on Table 2:

**Table 2:** Description of process.

| PROCESS | DESCRIPTION | |
|---|---|---|
| Deforestation | Reduction of the forest vegetation and replacement of the forest vegetation by agricultural area with forest remnants or agricultural area. | Environmental Liabilities |
| Reduction of Shrub Vegetation | Replacement of the shrub vegetation by urbanized area or agricultural area and replacement of the shrub vegetation with agricultural activity by agricultural area. | Environmental Liabilities |
| Degradation | Replacement of the shrub vegetation with agricultural activity by agricultural area with forest remnants and replacement of the forest vegetation with agricultural activity by shrub vegetation with agricultural activity or agricultural area with forest remnants. | Environmental Liabilities |
| Urban Expansion | Increase of urbanized area over all classes, except for forest vegetation and shrub vegetation. | Depends on the replaced class |
| Forest Regeneration | Increase of forest vegetation and replacement of the agricultural area with forest remnants by the forest vegetation with agricultural activity and replacement of shrub vegetation with agricultural activity by forest vegetation with agricultural activity. | Environmental Assets |
| Shrub regeneration | Replacement of the agricultural area or shrub vegetation with agricultural activity by shrub vegetation. | Environmental Assets |
| Environmental suitability | Replacement of the agricultural area by forest vegetation with agricultural activity or shrub vegetation with agricultural activity or agricultural area with forest remnants; replacement the agricultural area with forest remnants with the forest vegetation with agricultural activity. | Environmental Assets |

To generate an appropriate and consistent change map with the integration in the national accounts it was created transition rules (Table 3):

**Table 3**: Transition rules.

| CLASS | | PROCESS |
|---|---|---|
| 2000 | 2010 | |
| Urbanized Area | Any class | Urban shrinkage (UNLIKELY) |
| Forest vegetation | Urbanized area | Deforestation |
| Forest vegetation | Shrub vegetation | Deforestation |
| Forest vegetation | Agricultural area | Deforestation |
| Forest vegetation | Forest vegetation with agricultural activity | Deforestation |
| Forest vegetation | Shrub vegetation with agricultural activity | Deforestation |
| Forest vegetation | Agricultural area with forest remnants | Deforestation |
| Shrub vegetation | Urbanized area | Reduction of shrub vegetation |
| Shrub vegetation | Forest vegetation | Forest regeneration |
| Shrub vegetation | Agricultural area | Reduction of shrub vegetation |
| Shrub vegetation | Forest vegetation with agricultural activity | UNLIKELY |
| Shrub vegetation | Shrub vegetation with agricultural activity | Degradation |
| Shrub vegetation | Agricultural area with forest remnants | UNLIKELY |
| Agricultural area | Urbanized area | Urban expansion |
| Agricultural area | Forest vegetation | Forest regeneration |
| Agricultural area | Shrub vegetation | Shub regeneration |
| Agricultural area | Forest vegetation with agricultural activity | Environmental suitability |
| Agricultural area | Shrub vegetation with agricultural activity | Environmental suitability |
| Agricultural area | Agricultural area with forest remnants | Environmental suitability |
| Forest vegetation with agricultural activity | Urbanized area | Urban expansion |
| Forest vegetation with agricultural activity | Forest vegetation | Forest regeneration |
| Forest vegetation with agricultural activity | Shrub vegetation | UNLIKELY |
| Forest vegetation with agricultural activity | Agricultural area | Deforestation |
| Forest vegetation with agricultural activity | Shrub vegetation with agricultural activity | Degradation |
| Forest vegetation with agricultural activity | Agricultural area with forest remnants | Degradation |
| Shrub vegetation with agricultural activity | Urbanized area | Urban expansion |
| Shrub vegetation with agricultural activity | Forest vegetation | Forest regeneration |
| Shrub vegetation with agricultural activity | Shrub vegetation | Shrub regeneration |
| Shrub vegetation with agricultural activity | Agricultural area | Reduction of shrub vegetation |
| Shrub vegetation with agricultural activity | Forest vegetation with agricultural activity | Forest regeneration |
| Shrub vegetation with agricultural activity | Agricultural area with forest remnants | UNLIKELY |
| Agricultural area with forest remnants | Urbanized area | Urban expansion |
| Agricultural area with forest remnants | Forest vegetation | Forest regeneration |
| Agricultural area with forest remnants | Shrub vegetation | UNLIKELY |

| | | |
|---|---|---|
| Agricultural area with forest remnants | Agricultural area | Deforestation |
| Agricultural area with forest remnants | Forest vegetation with agricultural activity | Environmental suitability |
| Agricultural area with forest remnants | Shrub vegetation with agricultural activity | UNLIKELY |
| Other areas | Any class | Non-mappable |
| Water bodies | Any class | Non-mappable |

All data will be stored in 1km² grid to monitor the changes and to generate futures scenarios.

## 3. Expected Results

The expected results are related to the measurement of processes of change in land use and land cover. This quantification is a prerequisite for the evaluation and subsequent inclusion in the national accounts, enabling the calculation of GDP more realistic.

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