LUCC (Land Use and Cover Change) and the Environmental-Economic Accounts System in Brazil

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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 SEEA (Environmental-Economic Accounts System). It is based by a SEEA's methodology, diffused by UN (United Nations), 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 is 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 (Moderate Resolution Imaging Spectroradiometer) 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 m. After the final classification, the next step is to make a quantification and comparison of data from these different years using a 1 km² 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.

Key words: 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 [1]. However, GDP does not address adequately the social dimension and must incorporate environ-mental assets and liabilities to become more satisfying [2-4].

It is possible to measure environmental assets and liabilities through of mapping of LUCC (land use and cover change) [5-7].

To map and measure LUCC processes is necessary to detect them. It is possible through many ways, for example, the map algebra [8, 9]. To perform map

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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 (MODIS) 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 can refer to Ref. [10].

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. A matrix edition is performed, using several support maps, such as

vegetation maps (IBGE and PROBIO) and forest remaining and deforestation maps (PRODES, PROBIO II and TERRACLASS).

Table 1 cites and describes the classes, according to Refs. [11, 12].

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 (year 2000) and Sergipe (year 2010)

• Overall rating for all entries through inputs for support and consultation to agencies from IBGE.

The change detection is performed by cross tabulation between the 2000 and 2010 classification [13]. The analysis of the processes of LUCC will be expressed through the two types of outputs:

(1) Non-spatialized (Tabular)

The outputs will be represented quantitatively using graphs and tables. There are changes that define the regenerative processes (such as forestry and rural regeneration) and expansion processes (likewise as urban and agricultural expansion). There are 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 degrada-tion 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 has not been mapped.

(2) 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.

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

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, i.e. 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.

Table 2 **Description of processes.**

Processes	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

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

3. Preliminary Results

The measurement of LUCC processes is a prerequisite for the evaluation and subsequent inclusion in the national accounts, enabling the calculation of GDP more realistic.

The adoption of MODIS data, the choice of segmentation and classification techniques and the

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

definition of the transition rules are suitable for the measurement of environmental assets and liabilities inbiophysical units. The next step is the effective conversion to monetary units.

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