Dynamic Modeling for Changes Simulations in the Forest Cover in Rio Grande do Sul State, Brazil

Rudiney Soares PEREIRA, Ana Caroline Paim BENEDETTI and Claudia Maria de ALMEIDA, Brazil

Key words: Remote Sensing, NDVI, dynamic modeling, transition matrix

SUMMARY

Significative processes of conversion in the land use patterns have been verified in the State of Rio Grande do Sul due to the incorporation of forest areas during the last years. In this conception, this work aims to establish the methodological guidelines to analyze the dynamics of these patterns in the Serras do Sudeste and Campanha Meridional, which are micro regions located in the southern part of the State. Thematic maps from the years 2000, 2004 and 2008 were elaborate through the product NDVI (Normalized Difference Vegetation Index) from the MODIS sensor in a way to relate this index to the land use classes. The maps that we elaborated were used to drive a dynamic model, which made it possible to quantify, through the use of Markov model, the conversion rates between classes. The simulation designed using the probabilistic method weighs-of-evidence, and allowed to assess the role of influential variables in the forest cover changes of both micro regions. The main results are simulations based on the paradigm of Cellular Automata (CA), in which the forest areas are quantified and spatially distributed until the year 2016. The predictions modeled, based on the considered variables, indicate that the forest will expand over spaces previously allocated to agricultural activities and to extensive grazing of cattle, either with the introduction of exotic species or by means of regeneration. The forest cover in Serras do Sudeste will increase from 8,6% to 16,2% by the end of the period. In Campanha Meridional the increase will be from 11,1% to 12,5% and, in both micro regions, the expansion will tend to stabilize within the observed period.

RESUMO

Processos significativos de conversão nos padrões de uso da terra têm sido verificados no Estado do Rio Grande do Sul, devido à incorporação de áreas florestais nos últimos anos. Nessa concepção, este trabalho teve como objetivo analisar a dinâmica desses padrões nas Serras do Sudeste e Campanha Meridional, microrregiões pertencentes à Metade Sul do Estado. Mapas temáticos dos anos de 2000, 2004 e 2008 foram elaborados a partir do produto NDVI (Índice de Vegetação por Diferença Normalizada) do sensor MODIS. Os mapas elaborados serviram para alimentar um modelo dinâmico o qual possibilitou quantificar, através de matrizes Markovianas, as taxas de conversão entre as classes de uso da terra. A simulação foi concebida através do método probabilístico pesos de evidência, permitindo inferir sobre a contribuição das variáveis influentes nas mudanças na cobertura florestal das duas microrregiões. Os principais resultados constituem simulações baseadas no paradigma de Autômatos Celulares (AC), nas quais são quantificadas e distribuídas espacialmente as áreas florestais até o ano de 2016. Os prognósticos modelados, com base nas variáveis analisadas, indicaram que a floresta deverá ocupar espaços anteriormente destinados às atividades agrícolas e ao pastoreio extensivo do gado, tanto pela introdução de espécies exóticas como pelo estabelecimento da regeneração. A cobertura florestal na microrregião Serras do Sudeste passará de 8,6% para 16,2% ao fim do período. Na Campanha Meridional o acréscimo será de 11,1% para 12,5%, sendo observadas nas duas microrregiões, tendências à estabilidade dessa expansão florestal.

Dynamic Modeling for Changes Simulations in the Forest Cover in Rio Grande do Sul State, Brazil

Rudiney Soares PEREIRA, Ana Caroline Paim BENEDETTI and Claudia Maria de ALMEIDA, Brazil

1. INTRODUCTION

Historically, the southern half of the state of Rio Grande do Sul is a region essentially agrarian with economy is consolidated in cattle raising and rice growing. Over the time, the unproductive of the estates and insignificant contribution of industrial sectors have above all contribute to low levels of regional development taking place since the 1930s.

The cultural and economic poverty of the southern half has its origins in the way that the territory was distribute that was adopted by the Empire, in which were granted greatest of land, called allotments, to a few owners known as "ranchers."

The cattle, considered the groundwork of the southern half, has long been reducing its rate of expansion and slowing the growth in the region. Added to this, the lack of entrepreneurship and technological innovation. The urban structure of most municipalities in the southern half is consisted of a population with low power purchasing, made up of descendants of slaves and old pawns of farms.

In the year 2003, was released by the government of the Rio Grande do Sul State a Forestry Program which, among other objectives, provided foster commercial afforestation in cities of the southern half through the implementation of 40.000 hectares of forests, which can generate up 2014, a gross revenues of U$ 100 million dolars to growers.

The expansion of forestry involves the environmental situation of a large area of the state territory, the Pampa Biome. In this approach, one of the issues lies in how to evaluate the dynamics of this landscape ? And yet, how to monitor the transition process between the original biome field and forest cover?

Until recently, scientific researches have been realized out aimed to build a model of space suitable to represent the geographical reality, since that most computer systems is just of a static and unchanging reproduction of the phenomena inherently dynamic that ignores, for example, changes in the landscape.

In this case, the purpose of the dynamic modeling was to simulate changes in spacial and temporal attributes of the environment in a geographic territory. Its design allows the understanding of the mechanisms that determines the influential change function and thus, evaluate how a system evolves on a set of circumstances defined by the modeler.

The statement of Burrough and McDonnell (1998), which defines a dynamic spacial model as "a mathematical representation the real-world process in which a location on Earth's surface changes in response to variations in driving forces " summarizes the overcoming of modeling in relation to the limitations of current tools of GIS science.

When used for the phenomena study and the transition of classes of the landscape, the dynamic modeling becomes a useful tool for planning, because it allows the simulation of future scenarios.

In Brazil, researches of important relevance in the phenomena scientific deal with the modeling of deforestation, manly in the Amazon region, highlighting works by Soares-Filho et al. (2002) and Aguiar (2006). On the dynamics of urban areas, we highlight the work of Almeida (2003). Hendges (2007) developed a model suitable to represent the dynamic forestry in Rio Grande do Sul State, designing the expansion of forest areas for the year 2020.

As an example of that, are the products of the MODIS sensor, that in contrast to the low spacial resolution, where is available temporal high-frequency on global scale information. Is increasing the use of this tool to map attributes of the environment periodically, with notable emphasis on the monitoring of vegetation cover.

The MODIS sensor has characteristics that provides superior description capabilities of the spectral behavior of vegetation (Rudorff et al., 2007) and among the techniques used for this assessment, the study of vegetation indices (VI) shows up as one of the most efficient. The greatest benefit to the analyst of images of the MODIS sensor is the availability of infra-red recorded directly into a digital image, which allows an inference of the vegetation conditions.

Based on this information, it is intended in this study, using the product MOD13Q1 MODIS, to produce maps that describes the temporal behavior of spectral vegetation from the normalized difference vegetation index (NDVI) and based on this infra-red, discriminating the types: forest regeneration, field and soil without vegetation, so that information can be useful to serve as background for the implementation of dynamic spatial model.

The aim of this research is on the application of a tool for modeling the vegetation dynamics, with a view to the forest cover in two micro regions of the southern half of Rio Grande do Sul State, in the period from 2000 to 2008, based on this model, making the projection of future scenarios.

This research is postulated by the assumptions described below: It is feasible to use images from low spacial resolution (250 meters) for the extraction of thematic information about the landscape, thus allowing the monitoring of their spatiotemporal dynamics?
If the first hypothesis is confirmed, is it possible to establish a direct relationship between the themes of landscape and vegetation index provided by MOD13Q1 product and thus compensate for their low spatial resolution and support its high frequency and coverage on a global scale?

If the previous hypotheses are plausibles, then it is possible that you can feed a stochastic simulation model with the maps "vegetation index", for then obtain scenarios that describes the change process and rates transition observed in the vegetation during the period?

2. BACKGROUND

The following descriptions were taken from Rudorff et al. (2007), work in which numerous applications are dealt with MODIS. According to the authors, it is attributed to this instrument the generation of high-quality products, now with fixes atmospheric, radiometric and geometric.

The MODIS is consisted in the main sensor onboard the Terra and Aqua satellites, designed to provide global observations of land surface, ocean and atmosphere in the regions between 0.4 and 14.4 nm of the electromagnetic spectrum. Having a spacial resolution ranging from 250 m to 1 km and subdivision in 36 spectral bands, destinated to different applications, divided into 44 products (for more information see Rudorff et al., 2007, p. 15).

The product MOD13 contain the indices of vegetation NDVI (Normalized Difference Vegetation Index) and EVI (Enhanced Vegetation Index) produced in global escale in resolutions 1 km, 500 m and 250 m in the images color compositions or mosaics of 16 days.

The indices produced by the MOD13 allow studies, both over time like in space, on the conditions of cover vegetation, describing and reconstructing datas discriminating interannual variations on the vegetation in global and regional scales (Rudorff et al., 2007).

The images indices of vegetation are derivated from the spectral answers from the earth surface, and the reflectance of the vegetal cover depends of structural and optics propertys of the vegetation and the soil. The reflectance in the red track (0,55 – 0,70μm) reduce with a increasing in the foliar area index, while in the next infra-red track (0,70 – 1,30 μm) is verified that the reflectance is directly proportional to the increasing of foliar area index (MATSUMOTO E BITTENCOURT, 2001).

The Vegetation for Diference Normilized index (VDNI) is more sensitive in the presence of chlorophyll and others pigments that are responsable for the absorption of solar radiation in the band of the red, while that EVI is more sensitive to the variation in the structure of the canopy, including the LAI (Leaf Area Index), the physiognomy of the plant e the archtecture of the canopy (HUETE et al., 2002).

The NDVI in a relation betwen the reflectance (p) of the bands of the near infra-red (ivp) and of the red (R), that aims eliminate the seasonal diferences of the elevation solar angle and minimize the efects of the atmospheric atenuation in multitemporal images. It is the most used in several studies about vegetation that envolves the use of datas of Remote Sensing(MOREIRA, 2005).

It is expressed by the ratio between the difference in the reflectance (ρ) channels in the near infrared (0.70 to 1.30 mm) and red (0.55 to 0.70 mM) and the sum of these channels (ROUSE et al ., 1974), namely:

NDVI = (ρIVP – ρV) / (ρIVP + Pv).

Where:
ρIVP corresponds to the spectral response of the pixel in the near infrared band, and ρV corresponds to the spectral response of the pixel in the red visible band.

The value of this IV can vary on a scale from -1 to +1 (as nearest to 1, the higher is the density of vegetation), and 0 represents the approximate value for the lack of vegetation.

The NDVI has shown quite useful in an estimating of biophysical parameters of the vegetation, and its strong point is the concept of ratio which reduces various forms of multiplicative noise, as differences in lighting, shadows of clouds, atmospheric attenuation, certain topographical variations (Silva 2004).

The enhanced vegetation index (EVI) was developed to optimize the signal response of vegetation, enhancing the sensitivity in regions with higher densities of biomass, besides providing the vegetation monitoring through a connection of the canopy background signal and the atmospheric influences reduction. The EVI can be calculated using the following equation (JUSTICE et al., 1998):

EVI = G. (NIR-RED)/(L+IVP+C1.RED-C2.BLUE).

Where:
NIR is Nearest Infrared;
RED is red channel; BLUE is blue channel;
L is the adjustment factor for soil;
C1 and C2 are the coefficients of adjustment for the effect of aerosols in the atmosphere and G is the gain factor.
According to Huete et al. (1997), Justice et al. (1998), the coefficient values used by the EVI algorithm are: L = 1, C1 = 6, C2 = 7.5 and G = 2.5.

2.1 Spatial Dynamic Modeling

The advance of geotecnologies emphasized the representation of spatial phenomena in the computer as static form, as their main form of abstraction is on the map.

However, most of the phenomena, such as urban planning, runoff rainwater, seed dispersal, evolution of land use, are inherently dynamic and the statics representations commonly used in GIS not capture the space adequately .

More recently, the study of landscape change has been developed through the application of modeling techniques and the creation of modelings. Soares-Filho (1998) refers to the model term as:

"... research process that leads to the generation of model (representation) of a system. This process develops, then, by defining a set of hypotheses or predictions, which may be compared with measurements of the real world."

Depending on the agreement between the observed and the generated results, the model will be accepted, rejected or modified in some way, to be tested again. (Soares-Filho, 1998. P.55)

According to Wegener et al. (1986) apud Almeida (2003) a model is called dynamic, if it has an explicit time dimension, if the inputs and outputs vary over time, and if their states depends on previous states.

Goodchild et al. (1993) classifies the dynamic models into three broad groups: scale model, conceptual model and mathematical model.

The scale model is, in general, a model that reproduces a simplistic reduction of the original system; the conceptual model describes the process by building flowcharts showing the main system and the process and interrelationships among the subsystems of trainers; and the mathematical model used to systems of equations in its construction, can be classified into two groups: deterministic and stochastic-probabilistic.

The stochastic modeling is the simulation method used in this study. The rules of this process are: the weights of evidence method for the determination of transition probabilities between the classes analyzed (Bayes theorem); modeling by Cellular Automata; prognosis methods using Markov chains.

The Bayesian probability is related to two concepts: a priori probability P (D) and posterior probability P (D │ B) (Bonham-Carter, 1994; ALMEIDA, 2003; ALMEIDA et al. 2007; SILVA, 2003).

2.2 Modeling by Cellular Automata

The model of Cellular Automata (CA), originally conceived by von Neumann, in the 1960s (Rocha et al. 2001; GREMONINI and VICENTINI, 2008), aimed the simulation of artificial systems endowed with the faculty of self reproduction.

This model consists of an infinite and two-dimensional lattice of cells possessing equivalent discrete states, and each cell is connected to their immediate surroundings. The transition rules are exactly the same for each cell, and the cell structure is functionally homogeneous.
In the model based in Cellular Automata, the state of each cell depends on its previous state and a set of transition rules, that according to the specific arrangement of a certain neighborhood, being all the cells updated simultaneously in discrete time steps (Soares-Filho et al., 2002, Burrough and McDonnell, 1998).

Wolfram (1986) presents a formal description for the automata of von Neumann. According to the author, CA are mathematical idealizations of physical systems where space and time are discrete attributes, and the attributes also assume a set of discrete values equally; the state of a Cellular Automata is completely specified by the values of variables in each cell; a CA evolves in discrete time steps, with the variable value in one cell being affected by the values of the variables in the neighbors cells found in the previous time step, and th neighborhood of a cell is typically formed by the cell itself into account and all other cells located in their adjacencies.

The Cellular Automata are systems inherently dynamic and, currently, its use in the spacial simulation has become common, being sometimes included in GIS because of its easy implementation and ability to reproduce spacial phenomena, like the works of forest dynamics (LETT, et al., 1999), uses dynamics and land cover (ROCHA et al., 2001, Soares-Filho et al., 2002) and dynamics of urban land (ALMEIDA, 2003).

The software Dinamica, applicative used in this study, is an example of spacial simulation model of the type Cellular Automata (Soares-Filho et al., 2002). As local rules, uses a device allocation changes, starting with the premise that a landscape is composed of a variety of arrangements of elements (classes) superimposed on a matrix, which constitutes the input data in the process.

2.3 Prognosis methods by using Markov chains

A transition matrix is stochastic, composed of elements that represent the probability of a change of a use class to another (Haykin, 2000). Baca et al. (2007) report that the transition matrix comprises a mathematical representation of Markov chains, being the formalization of the modeling systems.

This model can be expressed by the matrix notation as noted by Baker (1989):

$\prod (t+1) = Pn \cdot \prod (t)$.

Where:
Π (t) is the system state at time t;
Π (t +1) is the system state at time t +1 and
Pn are the changes that may happend, which are represented in a probability transition matrix decomposed into a time step.

These transition matrices represent the probability of a determinated state i stay the same or move to the state j during time t -> t +1.
The Markov matrix simulates changes between use classes and covering in a multidirectional way, it means, portions of a class can theoretically change from one category to another mutually exclusive in any one time.

For Soares-Filho (1998), the transition probabilities are usually derived from relatives samples for a certain time. The model assumes that the future state of the system depends only on its present state and possibilities of transition, being independent of the path that led him to that state (state at time t-1). This model assumes that all information in the past has concentrated on the present state of the system (JRC and ESA, 1994).

For the estimate of the probabilities of transition, JRC and ESA (1994), the Markov chain requires an establishment only of a finite number of states and that the transition probabilities are known, but although there are simplicity in the process, several limitations are associated to the employment of this model to simulate changes in land use.

A limitation resides in the assumption that the probability of a particular set of outputs depends only on the current distribution among the states and probabilities of transitions (JRC and ESA, 1994).

The Markov chain has a finite number of states, their dynamics are non-periodic and it has no absorbing states, where Pij = 1.

In this case, Bell and Hinojosa (1977) proposes the calculation of an hypothetical system in equilibrium, through the method of principal components given by:

P = H. V. H-1 ,

where H is the matrix of eigenvectors, H-1 is the transpose matrix of eigenvectors and V is the matrix of eigenvalues.

According to Almeida (2003), this method applied to the Markov chain is useful to allow the decomposition of the matrix of transition probabilities, which are then, estimated for shorter time intervals, eg steps in a year. This method is used in the simulations to generate maps of land use per year, throughout the time series evaluated in this study.

Markov chains, the transition probabilities do not change with the time but, according to Baker (1989), if the probabilities of transitions are non-stationary, in fact, they can be inserted through adjustments in the matrix of transition probabilities, being extremely useful in the simulation of scenarios, since it can be adjusted to incorporate effects such as the influence of endogenous and exogenous variables to the model, overcoming the stationarity.

2.4 Computational models The Dinamica EGO Simulator

One of the computational models desenvolved to simulate the dynamics of landscapes is - Landscape Dynamic System. This is a freeware software created and maintained by the Remote Sensing Center (CSR), belonging to the Institute of Geosciences of the Federal University of Minas Gerais.

The application is based on discrete simulation and Cellular Automata, using as input parameters thematic maps of the landscape (usually derived from remote sensing data), represented by a matrix. In the modeling process implemented in this application, spacial variables are considered and classified into dynamic and static.

Also, other parameters are considered necessary to compose the input data: the annual rates of transition, minimum residence time in each state, the percentages allocated to each of the algorithms developed transition, among others. As output, the application produces thematic maps of the landscapeand and maps of the transition probability for each step of simulated time (Soares-Filho, 2001).

Soares-Filho (1998) describes the static variables and dynamics. The firsts refers to the maps with the characteristics usually associated with human and physical landscape, and dynamic variables refer, in most cases, to the maps of away, to certain types of use and land cover.

These, in turn, shift and are updated continually, so as to influence the calculation of transition probabilities at each iteration of the program, there have been changes in the state (lands uses) of the cells, thereby altering the distribution of uses, that again, are recalculated for the next phases of the simulation.

The algorithms expander and patcher are responsable for the spacial characteristics of transitions in land use on the Dynamics. The expander function is responsable for the expansion of previously existing patches of a class of a land use, and the function patcher, it means, intended to generate new patches through a mechanism of formation of seeds, in other words, the expander function performs transitions from one state i to a state j only in the vicinity of adjacent cells with jea function patcher performs state transitions from one state i to state j only in the neighborhood of adjacent cells with different state of j (Soares-Filho et al. 2007). Soares Filho et al. (2002, 2007) points out that both algorithms transitional dynamics of the application to adopt a stochastic selection mechanism.

The algorithm applied consists in scanning the map of original land use to identify cells with the highest probability values, and arrange them in an array of data. Following this procedure, the cells of this vector are randomly selected downward (the stochastic mechanism of internal selection can be mitigated or enhanced, depending on the desired degree of randomness). In the end, the land use map is again scanned to execute the selected transitions.

3. RESULTS AND DISCUSSION

3.1 NDVI maps

When compared directly to the vegetation index maps, we must consider that in this step was allocated to the theme class - "water", which was subsequently incorporated into the class "bare soil" for subsequent extraction of informations based on NDVI product. The tables 1 and 2 quantify the results obtained by the digital classification process.

Table 1 – Results of classification obtained for the region of Southeast Campaning

Land Use Class NDVI	Year 2000 Area (ha)	Difference Area(ha)	Year 2004 Area(ha)	Difference Area(ha)	Year 2008 Area(ha)	Difference Area(ha)
Soil without vegetation	276,643.75	-450.00	256,781.25	675.00	249,631.25	600.00
Field	1,180,112.5	-925.00	1,083,706.30	500.00	991,193.75	-825.00
Regeneration	53,193.75	725.00	120,625.00	-325.00	174,593.75	-550.00
Forest	142,331.25	650.00	191,168.75	-850.00	236,862.50	775.00
Total	1,652,281.25		1,652,281.25		1,652,281.25	

Table 2 - Results of classification obtained for the region of Southern Campaing

Land Use Class NDVI	Year 2000 Area (ha)	Difference Area(ha)	Year 2004 Area(ha)	Difference Area(ha)	Year 2008 Area(ha)	Difference Area(ha)
Soil without vegetation	550,875.00	775.00	377,150.00	475.00	349,237.50	-550.00
Field	586,075.00	-825.00	724,906.25	-625.00	708,250.00	725.00
Regeneration	130,618.75	675.00	164,150.00	-650.00	203,962,50	475.00
Forest	158,537.50	725.00	159,900,00	800.00	164,656.25	-650.00
Total	1,426,106.25		1,426,106.25		1,426,106.25	

The Figure 1 presents the thematic maps of the NDVI classes in the years 2000, 2004 and 2008 to the southeast and southern campaign.

3.2 Dynamic modeling and annual simulations

The simulation result in Dinamica EGO is determined by the algorithms of transition expander and patcher. The first is responsible for expanding and contraction of patches of cells in a given class, while the second is responsable for the appearance of new spots.

The table 3 presents the "single step transition matrix" for two simulation intervals, from 2000 to 2004 and from 2004 to 2008, both to Southeast Sierras as for Southern Campaign. In this matrix, are shown percentage rates throughout the simulation period (Soares-Filho et al.,2009) corresponding, in this study, in four years.

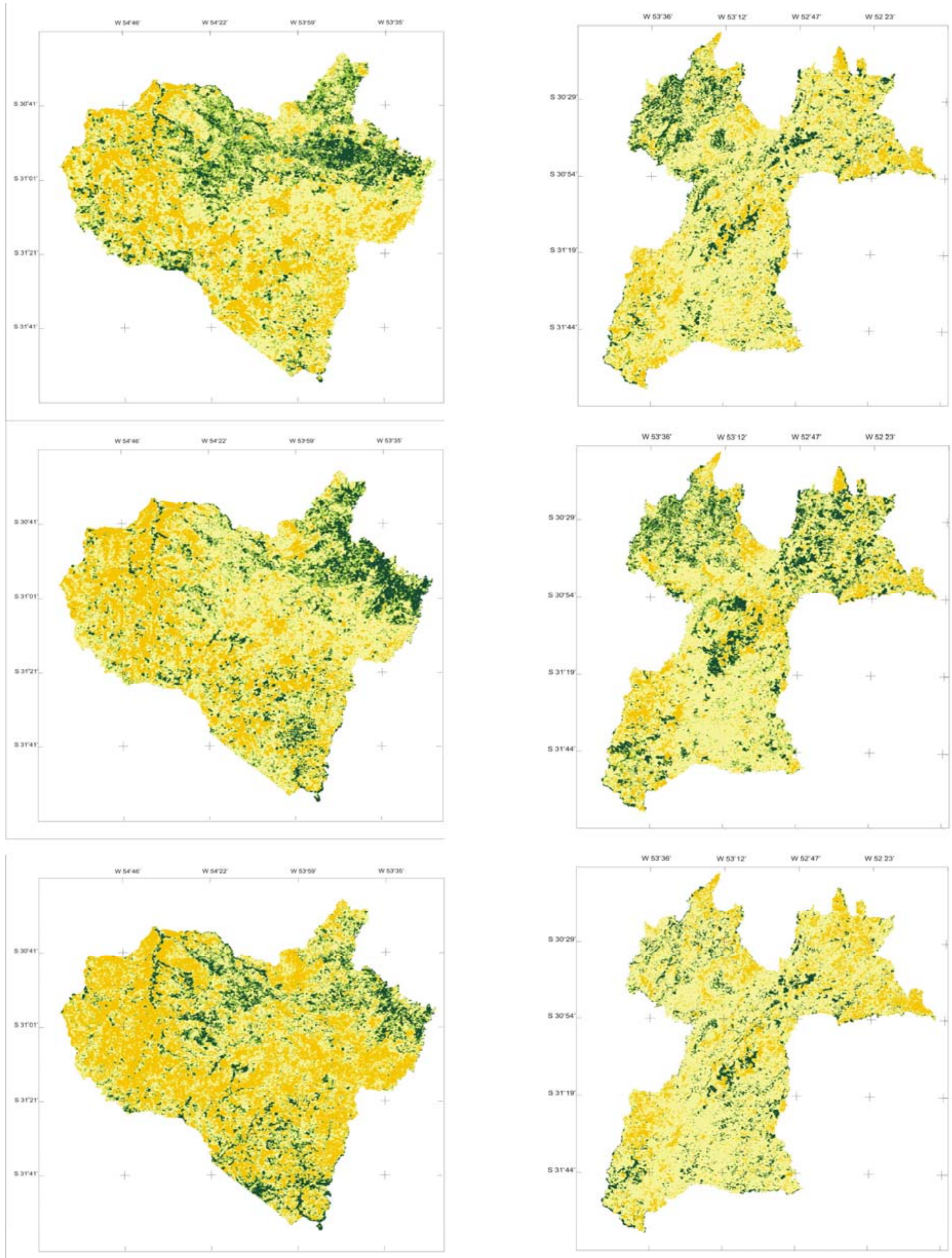

Figure 1 presents the thematic maps of the NDVI classes in the years 2000, 2004 and 2008 to the southeast and southern campaign.

According to the table 3, you can see in the micro region Sierras Southeast the following rates of net forest growth: 2.5%, 6.9% and 31.1% between 2000 and 2004 and 8.5%, 9.5% and 19.3% between 2004 and 2008. In micro Southern campaign, the rates of forest expansion correspond to 2.7%, 7.4% and 23.6% between 2000 and 2004, 3.1%, 8.6% and 22% between 2004 and 2008. These percentages are respectively referent to conversions of soil, field and forest to regenerate.

TABLE 3 Single step transition matrix to Southeast Montain Microregion

Years 2000 - 2004				
From / To	Soil	Field	Regeneration	Forest
Soil	-	0.475	0.012	0.025
Field	0.099	-	0.175	0.069
Regeneration	0.026	0.481	-	0.311
Forest	0.028	0.243	0.131	-
Years 2004 - 2008				
From / To	Soil	Field	Regeneration	Forest
Soil	-	0.419	0.038	0.085
Field	0.112	-	0.085	0.095
Regeneration	0.032	0.539	-	0.193
Forest	0.031	0.275	0.231	-

3.3 Simulation of future scenarios

In this study, were simulate forecasts for both micro and based on the time resolution chosen, which comprised a total range of eight years, it is possible to make reliable projections until the year 2016, taking, therefore like map of initial use, the “real” maps of 2008.

Figures 2 and 3 show respectively the classified maps of the simulation process for the period 2008 to 2016 for the Serra do Sudeste and Campanha Merdional, being the first map displayed corresponds to the "real" map of 2008, used as input into the model.

Tables 4 e 5 presents the outcomes of conversion of land use classes, such transitions, obtained from modeling the dynamics of use and forest cover for the period of eight years from 2008. We considered intervals of four years for the Serra do Sudeste and Campanha Merdional.

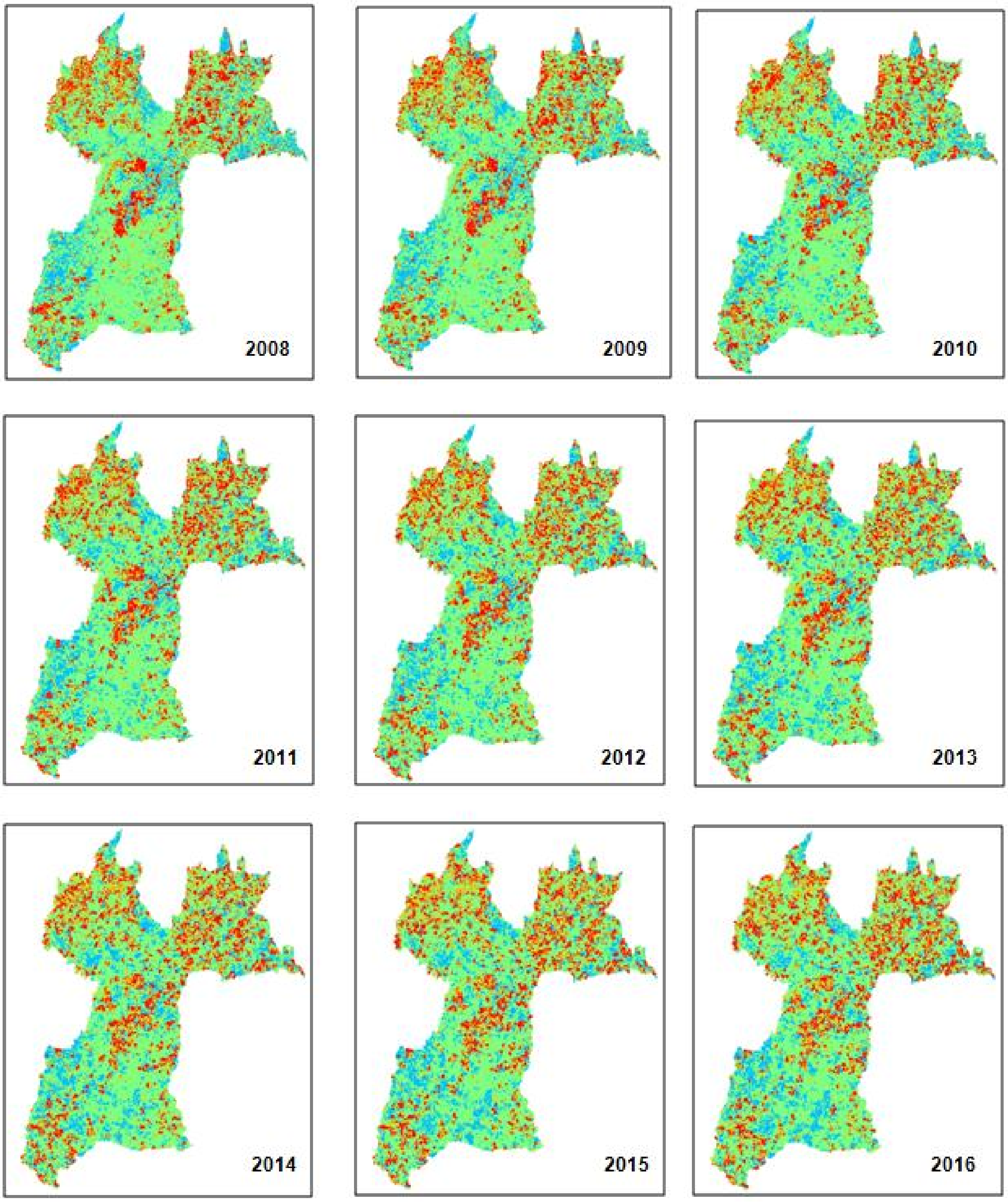

Figure 2 - Classified maps of the simulation process for the period 2008 to 2016 for the Serra do Sudeste.

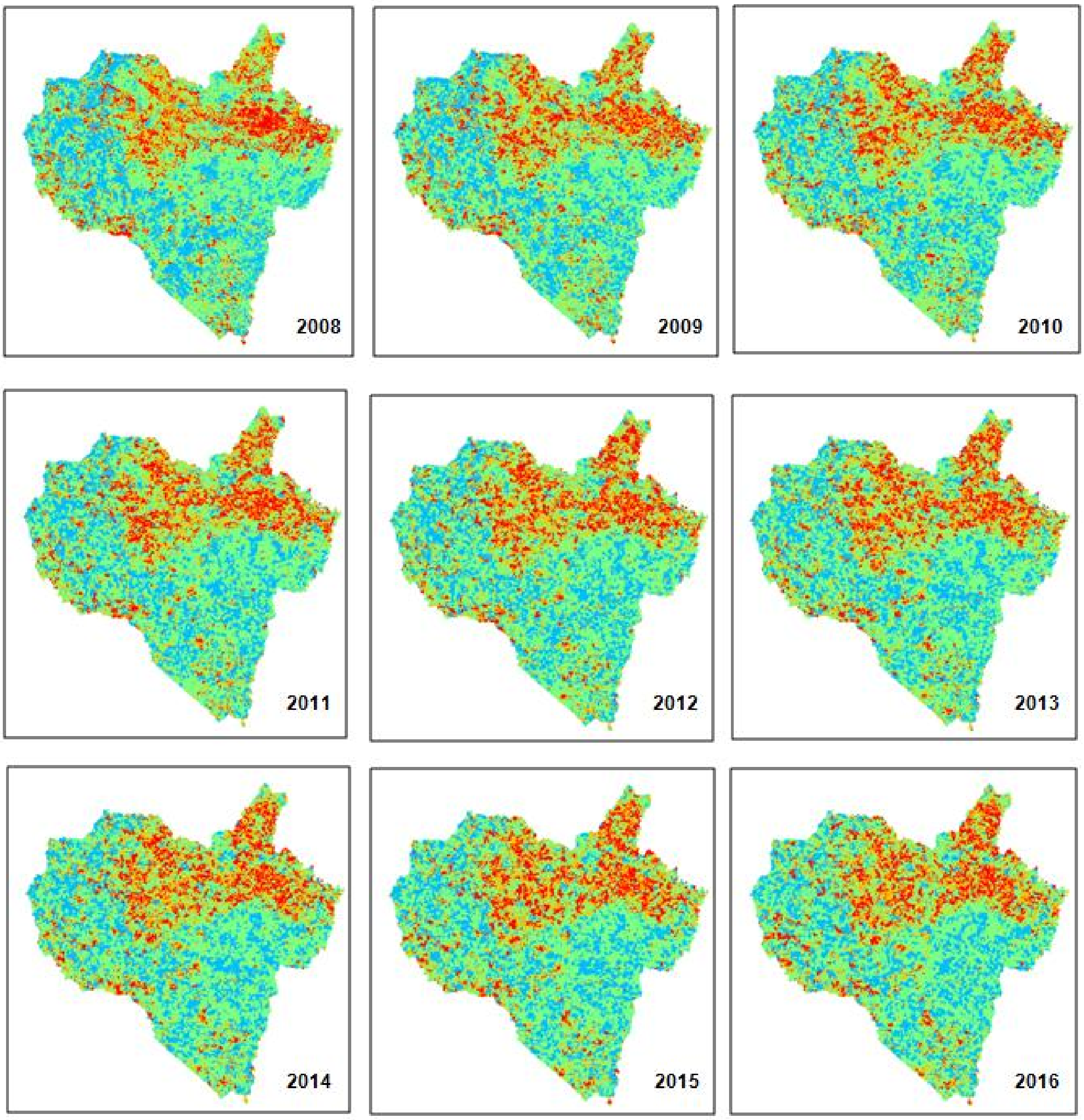

Figure 3 Classified maps of the simulation process for the period 2008 to 2016 for the Campanha Meridional.

Table 4 – Conversion process between vegetation classes in Serra do Sudeste between 2008 and 2016, values of area in hectares.

Class	Serras do Sudeste			
	Area (ha) 2012	Transition (ha) 2008-2012	Area(ha)	Transition (ha) 2008-2012
Soil	245,018.75	-4,612.50	241,056.25	-3,962.50
Field	963,731.25	-27,462.50	953,956.25	-9,775.00
Regeneration	185,106.25	10,512.50	189,856.25	4,750.00
Forest	258,425.00	21,562.50	267,412.50	8,987.50
Total	1,652,281.25	-	1,652,281.25	-

Table 5 – Conversion process between vegetation classes in Campanha Meridional between 2008 and 2016, values of area in hectares.

Class	Camapanha Meridional			
	Area (ha) 2012	Transition (ha) 2008-2012	Area(ha)	Transition (ha) 2008-2012
Soil	330,637.50	-18,600.00	322,025.00	-8,612.50
Field	708,950.00	700.00	709,587.50	637.50
Regeneration	212,950.00	8,987,50	216,487.50	3,537.50
Forest	173,568.75	8,912.50	178,006.30	4,437.50
Total	1,426,106.25	-	1,426,106.25	

4. CONCLUSIONS

The methodology allowed to use images from the MODIS product MOD13Q1 to obtain vegetation maps relating to the micro region of study. Thus, monitoring of NDVI in the series, allowed their membership to make use classes and land cover, and can distinguish the thresholds for forest regeneration field and soil without vegetation. In this way, it is clear that the reference values on the NDVI can be used to distinguish subjects or classes of land cover and use of images of low spacial resolution (250 m), however, it is necessary to adopt values separate and independent with respect to time bases. The thematic maps of vegetation, produced under this method could be used as a bases for modeling spacial dynamics, since in them were properly allocated the transition processes (reduction and expansion) of the forest cover and the other classes adopted. Regarding the changes in forest cover, the maps produced indicated that the forest cover increased from 8.6% to 11.6% and 14.3% compared to the total area of the microregion Sierras Southeast, respectively in the years 2000, 2004 and 2008 . In the Southern Campaign, the rates of expansion of forest cover were quantified in 11.1%, 11.2% and 11.5% compared to the total area of micro in the years of 2000, 2004 and

2008. Although the representation of forest cover in the thematic maps have been widespread forest expansion is given in two ways. Considering the scenario simulations, dynamic models have proven to be an efficient tool to track conversion processes of vegetation classes established by the parameters provided in the transition matrices that compose the model. The methodology adopted to simulate possible scenarios predictions, explained the intensity and location of changes in forest cover by the year 2016, through outputs (maps) annually. The results expecteds indicate that the forest cover in the Serras do Sudeste will from 15,6% in the year of 2012 to 16,8% of the total area of this micro region in the year of 2016. Southern Campaign in the micro region, the expansion is less pronounced, from 12.2% in 2012 to 12.5% in 2016. These values suggests, in the relation with the two micro-regions, the stability of the forest expansion. However, for this analysis, is necessarie to consider that the model trends are good only if they are kept the same conditions regarding the variables investigated. In this sense, it is suggested, for further studies, the evaluation of not only physical variables but also socioeconomic and even policies inherent in the study region.

REFERENCES

AGUIAR, A. P. D. Modelagem de Mudanças de Uso e Cobertura do Solo na Amazônia: Questões Gerais. In: INSTITUTO NACIONAL DE PESQUISAS ESPACIAIS. São José dos Campos:INPE,2006.Disponívelem:<http://www.dpi.inpe.br/cursos/tutoriais/modelagem/cap4modelosLUCC.pdf>. Acesso em: 20 out. 2008.

ALMEIDA, C. M. de. Modelagem da dinâmica espacial como uma ferramenta auxiliar ao planejamento: simulação de mudanças de uso da terra em áreas urbanas para as cidades de Bauru e Piracicaba (SP). 2003. 351f. Tese (Doutorado em Sensoriamento Remoto) Instituto Nacional de Pesquisas Espaciais. São José dos Campos, 2003.

Baca, J.F.M.; Netto, A.L.C.; Menezes, P.M.L. Modelagem da Dinâmica da Paisagem com Processos de Markov.(In): Meirelles, M.S.P.; Câmara, G.; Almeida, C.M. Geomática: modelos e aplicações ambientais. Embrapa Informação Tecnológica. Brasília, DF. 2007.

BAKER, W. L. A review of models of landscape change. Landscape Ecology, Amsterdã v. 2, n. 2, p. 111-133, 1989.

BELL, E. J.; HINOJOSA, R. C. Markov analysis of land use change: continuous time and stationary processes. Socio-Economic Planning Science. New York, v. 11, p. 13-17, 1977.

BURROUGH, P. A.; McDONNEL, R. A. Principles of Geographical Information Systems. Oxford: Clarendon Press, 1998. 333p.

GOODCHILD, M. F.; PARKS, B. O.; STEYAERT, L.T. Environmental Modeling with GIS. New York: Oxford University Press, 1993. 488p.

GREMONINI, L.; VICENTINI, E. Autômatos Celulares: Revisão Bibliográfica e Exemplos de Implementações. Curitiba: UNICENTRO, 2008. Revista Eletrônica. Disponível em:

http://web03.unicentro.br/especializacao/Revista_Pos/CE-Autom.pdf. Acesso em 02 ago. 2009.

HAYKIN, S. Redes Neurais: princípios e práticas. Porto Alegre: Bookman, 2000. 900 p.

HENDGES, E. R. Modelos estocásticos da dinâmica da paisagem florestal e simulação de cenários para o Estado do Rio Grande do Sul no período de 1988 a 2020. 2007. 233 f. Tese (Doutorado em Engenharia Florestal) – Universidade Federal de Santa Maria, Santa Maria, 2007.

HUETE, A.; DIDAN, K.; MIURA, T.; RODRIGUEZ, E.; GAO, X.; FERREIRA, L.Overview of the radiometric and biophysical performance of the MODIS vegetation indices. Remote Sensing of Environment. Maryland Heights, v. 83, p. 195-213, 2002.

JRC - Joint Research Centre – European Commission/Institute for Remote Sensing Applications. ESA - European Space Agency/ESRIN – Earthnet Programme Office. Modelling Deforestation Processes – A Review. Trees Series B: Research Report n° 1. Luxembourg: ECSC-EC-EAEC, 1994.

JUSTICE, C.O.; et al. The Moderate Resolution Imaging Spectroradiometer (MODIS): land remote sensing for global change research. IEEE Transactions on Geoscience and Remote Sensing, Ann Arbor, v. 36, n. 4, p.1228-1247, 1998.

LETT, C.; SILBER, C.; BARRET, N. Comparison of a cellular automata network and an individual-based model for the simulation of forest dynamics. Ecological Modelling. New York, v.121, n.2-3, p.277-293, 1999.

MATSUMOTO, M. H.; BITTENCOURT, M. D. Correlação entre Algumas Fisionomias de Cerrado, no Vale do Paraíba e Classes de Índices de Vegetação Obtidos Espectralmente. In: Simpósio Brasileiro de Sensoriamento Remoto,10, 2001, Foz do Iguaçu. Anais.... Foz do Iguaçu: INPE, 2001. p 1665 – 1672.

MOREIRA, M. A. Fundamentos do Sensoriamento Remoto e metodologias de aplicação. 3. ed. rev. e ampl. Viçosa: UFV, 2005. 307p.

ROCHA, J.; SOUSA, P. M; TENEDÓRIO, J. A. Geosimulação e Análise Espacial: Redes Neuronais e Autômatos Celulares na Previsão de Alterações nos Padrões de Uso e Ocupação do Solo. Inforgeo, Lisboa, v. 16, n. 17, p.123-137, 2001.

RUDORFF, B.F.T.; SHIMABUKURO, Y. E.; CEBALLOS, J.C. O Sensor MODIS e Suas Aplicações Ambientais no Brasil. São José dos Campos: Parêntese, 2007.
423 p.

SILVA, A. de B. Sistemas de Informações Geo-referenciadas: Conceitos e fundamentos. Campinas: UNICAMP, 2003. 236 p.

SILVA, E. T. J. B. Utilização dos índices de Vegetação do Sensor MODIS para Detecção de Desmatamentos no Cerrado: Investigação de Parâmetros e Estratégias. 2004, 146 f. Dissertação (Mestrado em Geologia) – Universidade de Brasília, Brasília, 2004.

SOARES FILHO, B. S. Modelagem dinâmica de paisagem de uma região de fronteira de colonização amazônica. 1998. 299 f. Tese (Doutorado Engenharia Civil). Escola Politécnica, Universidade de São Paulo, São Paulo, 1998.

SOARES FILHO, B. S. DINAMICA – Um software para simulação de dinâmica de paisagens. Anais do II Workshop em Tratamento de Imagens, NPDI/DCC/UFMG,2001.

SOARES-FILHO, B.S., PENNACHIN, C.; CERQUEIRA, G. DINAMICA – a stochastic cellular automata model designed to simulate the landscape dynamics in Amazonian colonization frontier. Ecological Modelling, v.154, p. 217-234, 2002.

SOARES-FILHO, B. S.; CERQUEIRA, G. C.; ARAÚJO, W. L.; VOLL E. Modelagem de Dinâmica de Paisagem: Concepção e Potencial de Aplicação de Modelos de Simulação Baseados em Autômato Celular. Megadiversidade. Belo Horizonte, v. 3, n. 1-2, p. 1-16, 2007.

SOARES-FILHO, B. S; RODRIGUES, H.; LELLES, W. Modeling Environmental Dynamics with Dinamica EGO. 1. ed. Belo Horizonte: CSR, 2009. v. 1. 115 p.

WOLFRAM, S. Theory and Applications of Cellular Automata: Including. New York: Selected Papers,1986.

CONTACTS

Rudiney Soares Pereira
Federal University of Santa Maria
Av. Roraima, N. 1000
CEP 97.105-900 Santa Maria RS
BRASIL
Tel. +55 55 3220-9468
Fax + 55 55 3220-8261
Email:rudiney.s.pereira@ufsm.br
Web site: http://www.ufsm.br/geosere

Ana Caroline Paim Benedetti
Federal University of Pampa
Av. Antônio Trilha, 1847
CEP 97.300-000 - São Gabriel - RS
BRASIL
Tel. +55 55 3232 6075
Email: anabenedetti@unipampa.edu.br
Web site: http://porteiras.unipampa.edu.br/saogabriel

Claudia Maria de Almeida
INPE – National Institute of Space Research
Av. dos Astronautas, 1758 – Jardim da Granja
CEP: 12.227-010 São José dos Campos SP
BRASIL
Tel.: +55 12 3945 6428
Email: almeida@dsr.inpe.br
Web site.: http://www.dsr.inpe.br/dsr/