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# Land Cover Change Detection in Southern Brazil Through Orbital Imagery Classification Methods

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## 1. Introduction

Remote sensing has been considered a promising technology as support for agriculture since its beginnings, due to its contribution for a climatic perspective or for understanding of processes related to land. However, significant applications occurred only in the late twentieth century, as result of the creation of best orbital systems, with higher spatial resolution, more bands and stereoscopic capture. Several orbital platforms, as AQUA/TERRA, Quickbird and Ikonos are examples in that sense (Moreira, 2005; Embrapa, 2009).

Engineering innovations, new sensors and methods of digital image processing must be performed simultaneously so that the advances in remote sensing will be achieved. Anyway, the incorporation of orbital images on geographic information systems (GIS) and their post-processing appear as significant application since a daily life perspective, specially when classification methods are involved, because of their relation to land use, land cover and easy interpretation.

This chapter considers classification methods applied on orbital imagery in Southern Brazil, in the coastal plain of Rio Grande do Sul state (Fig. 1), where a sequence of lagoons and lakes of different sizes occurs in the context of subtropical to temperate climate with cold winters and hot summers, being organized according to the following four sections:

- About classification methods.
- Evaluation of rice planting area in the vicinity of Caiuba lagoon (1981 – 2009).
- Analysis of land cover evolution in the municipality of Montenegro (1993 – 2008).
- Comparison and evaluation of errors.

All the exposed data are related to research projects of the Embrapa Temperate Climate Research Center, Pelotas, Rio Grande do Sul state, one of the 45 research centers of the Brazilian Agricultural Research Corporation (Embrapa) spread on the national territory.

## 2. About classification methods

Classification methods were created in the statistical context, when a collection of objects or samples could be characterized and separated in different classes (Davis, 1986). The method
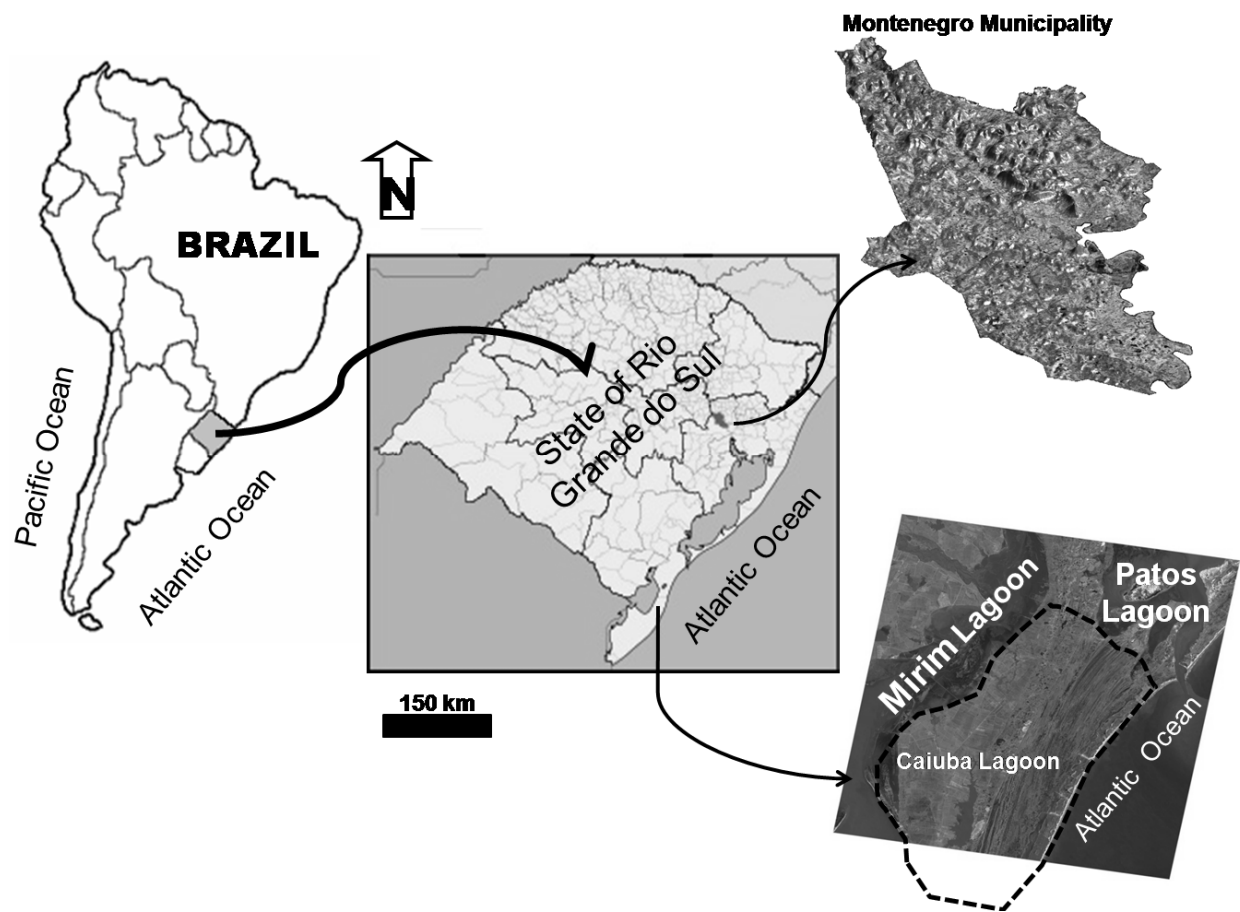
Fig. 1. Location of the areas of study in the context of South America, Brazil and the State of Rio Grande do Sul. Montenegro municipality as gray levels composite of the bands 1, 4 and 5 TM/Landsat 5 (Miranda, 2002, 2005) and Caiuba lagoon in gray levels composite of the bands 3, 2 and 1 ASTER (NASA, 2004) on september 26th, 2000.

was extended for processing of digital images considering the pixels as objects to be classified (Crosta, 1993, Lillesand & Kiefer, 1994, Jensen, 1996). The application of the classification methods on satelite imagery is affected by two main factors:

i.   Intervention of user.
ii.  Criteria of definition for the groups.

The "supervised classification" is included in topic (i), when the user defines the groups through digitalization of uniform spectral answer. Statistics are calculated for each group, so the classification is performed for all the image (pixel by pixel). The unsupervised classification eliminates the intervention of the user; then, the software defines the groups by means of scattergrams "band versus band", where isolines related to distribution density of the pixels are analysed (Crosta, 1993).

Different options for case (ii) are posible, by instance, criteria can use the standard deviation for the parallelepiped method or a minimum distance when an eliptical form is defined for each group or a combination of the later with statistical probability, that is, the maximum likelihood method. Jensen (1996) presented other criteria of classification, as Isodata method and the Fuzzy method.

Spectrometric methods measure the response of target materials in the laboratory or field. Then the spectral patterns are simulated for a specific sensor through a specialized software, so that a sequence of orbital images is classified according to the pattern generated by that software (Lillesand & Kiefer, 1994; Pontara, 1998; Moreira, 2005).

Classification of remote sensing images appear as useful tool in terms of land use, whether in local scale or in regional scale. Filippini-Alba and Siqueira (1999) classified land use in the municipality of Pelotas, Rio Grande do Sul state, Brazil, according to nine classes: agriculture, clay soils, forestry, natural forest, pastures, soil without vegetal cover, urban, water and wetlands. Natural forest and pastures occupied 23% and 30% of the territory respectively, with intense interference between the classes "urban" and "soil without vegetal cover". Similar classes were considered by Bolfe et al. (2009) for land use in Rio Grande do Sul state, but with different results. Agriculture and pastures occurred 32% and 50% of the territory respectively with only 3% for natural forest. The differences between both studies are easy explained in term of scale, because in the two occasions Landsat images were used and a municipality was considered at the former and a state at the latter, with territory difference of 1 to 155 times in size.

Lu et al. (2004) discriminated seven categories of change detection techniques: (i) algebra; (ii) transformation; (iii) classification; (iv) advanced models; (v) Strategies with geographic information systems (GIS); (vi) visual analysis and (vii) miscellanea. The classification methods are detached, with six different modalities. One of them, the "Post-classification comparison", is predominantly used in this chapter. That is, multi-temporal images are classified separately into thematic maps, then the classified images are compared pixel by pixel. The "Post-classification comparison" minimizes the atmospheric impacts, the environmental differences among multi-temporal imagery, as well as differences related to the sensor kind, providing a complete matrix of change information. However, some disadvantages can be appointed, because a great amount of time and expertise is required and, by other side, the final accuracy depends on the quality of the classified image due to the weather condition on that date.

Guild et al. (2004) quantified the areas of deforestation in the Amazonian forest, state of Rondonia, Brazil. The tasselled cup transformation (Crist & Kauth, 1986) was applied with the Landsat imagery from the years 1984, 1986 and 1992. The variables brightness, greenness and wetness were evaluated for each year, then, a file integrated the nine levels of information (three variables by three years). These data were processed through principal components and classification methods with overall accuracy of 79.3, 68.4% and 71.4%, for tasselled cap land cover change classification, tasselled cap with principal components land cover change classification and tasselled cap image differencing, respectivelly. Final classes were a combination between land cover and time, so change detection was quantified.

The two applications present in this chapter consider the Supervised classification method with maximum likelihood as criteria for definition of the classes. The proximity of the study areas and knowledge of the territory justify this option to take advantage of available information. Unsupervised classification is a fast proccess, good for unknown or outlying areas, when truth of field is unavailable and most time-consuming after processing, due to the need of class identification. Maximum likelihood criteira is restricted by software and time-consuming but it represents a improvement in relation simple criteria as the parallelepiped or the minimum distance.

Acording to Lu et al. (2004), methods (iii) and (v) were considered in this chapter. Classification (iii) was applied in both conditions, Caiuba lagoon and Montenegro municipality. The extraction of the poligon corresponding to the "potential area for agriculture" in the vicinity of Caiuba lagoon represents a tipical strategy of GIS (v). Softwares of digital images processing and GIS are very similar. Both can execute multilayer processing, including raster/vector files and logic/mathematical algorithms, but digital images processing is more specific for raster format and GIS for vector format.

## 3. Evaluation of rice planting area in the vicinity of Caiuba lagoon (1981-2009)

The Caiuba lagoon is part of the litoral lacunar complex of Rio Grande do Sul state, southern Brazil and it extends by 3300 hectares, in the municipality of Rio Grande, 15 kilometers to north extreme from the Taim Ecological Reserve and 45 kilometers to south from Patos lagoon (Fig. 1). This significant source of water is used mainly for irrigation of rice, specially when the Merin lagoon is further. Accordingly, the Foundation for Research Support in State of Rio Grande do Sul (FAPERGS) funded a research project leadered by the Federal University of Rio Grande (FURG) attempting to study the sustainability of the productive system, as well as the effects on local biodiversity. The Embrapa Temperate Climate  Research Center collaborated to  the evaluation of the agricultural area in the period 1973 to 2009 by satellite images. Imagery of Landsat satellite of different years was considered for similar times (Table 1), for the scenes corresponding to orbit 237 points 82 and 83 of the worldwide reference system 1 (MSS sensor) and for the scenes corresponding to orbit 221 points 82 and 83 of the worldwide reference system 2 (TM sensor). Thus, the atmospheric conditions were more or less equivalent, deriving in comparable image quality. Each image was evaluated for the various land uses and the areas occupied for the different classes were calculated in order to study the historical evolution of the process during the above period.

The first satellite of Landsat series was launched in 1972 with the multispectral scanner (MSS), with four bands in visible - near infrared and one in thermal infrared and

| Sensor | Date | Range of wavelengh and IFOV |
|--------|------|------------------------------|
| MSS | Sep. 6th, 1973 | 500 – 600nm, 600 – 700nm and 700 - 800nm, IFOV = 79m |
| MSS | Mar. 13th, 1981 | |
| TM | Jan. 22nd, 1991 | 630 – 690nm, 760 – 900nm and 1550 – 1750nm, IFOV = 30m |
| TM | Dec. 21st, 1996 | |
| TM | Dec. 19th, 2001 | |
| TM | Jan. 20th, 2002 | |
| TM | Jan. 28th, 2005 | |
| TM | Jan. 2nd, 2007 | |
| TM | Jan. 7th, 2009 | |

Table 1. Description of basical parameters of the images of Landsat series used for evaluation of the planting area of rice in the vicinity of tha Caiuba lagoon.
IFOV = instantaneous field of view. Source: INPE, 2010b.

instantaneous field of vision (IFOV) of 79 meters and 240 meters respectively. Improvements of the system included more bands (short-medium infrared) and reduction of IFOV to 30 meters and 120 meters respectively, for the thematic mapper (TM) in 1982 (Jensen, 1996). A panchromatic band was developed for the Landsat 7 satellite, with the TM plus sensor, but, the series reached to the end. The Landsat 5 satellite was an engineering success, the platform was launched in 1984 and is still on orbit. Anyway, the Landsat series represents the greatest collection of terrestrial images for environmental applications, specially, since a historical point of view.

Composites of three bands were used, with green band (500 – 600 nm), red band (600 – 700 nm) and near infrared band (700 - 800 nm) for the MSS sensor and the red band (630 – 690 nm), the nearinfrared band (760 – 900 nm) and the shortmedium infrared band (1550 – 1750 nm) for TM sensor. These games of bands are not equivalent, then similar patterns of colour were adjusted by visual observation.

Digital imagery was registered for the Universal Transverse of Mercator projection(UTM), zone 22 South with the datum WGS84, after that, a mosaic of pairs of scenes was composed, by instance, scene 237/82 and 237/83 for MSS sensor. So the mosaic was cutted evolving the study area and a file with the mentioned three bands was created for each date. Initially, data were processed by the supervised classification according to the maximum likelyhood criteria. Eigth poligons of homogeneous features were digitalized with the software ER-Mapper (1995), deriving in the test areas, then each pixel of the corresponding image was classified according to its similarity with the parameters of each test area (beach/dunes, forestry, rice crops, pastures, sandy fields, soil without vegetal cover, water and wetlands). A second strategy was developed to improve results, so the "potential area for agriculture", that is rice crops, pastures and soil without vegetal cover, was isolated and classified by similar way.

Results of the preliminar process of classification considered a rectangle of 30 km wide and 65 km long for the images of 2001, 2002 and 2005 (Fig. 2). The "potential zone for agriculture" is represented by a "central zone" in direction south - north to the East of Merin Lagoon, where agricultural areas are discriminated. A confusion between rice crop class and wetlands class is observed in the west - north sector of the study area. Sandy fields are long structures related to old movements of the sea (Atlantic Ocean), where a low charge of livestock is a common use and forestry is developed eventually, as observed in the images. The area occupied by water bodies was almost constant, that is 19 - 21% (Table 2), but, the wetlands were reduced in area in 2005, a year of drought probably, then, there was an increment in the area occupied by the class "Soil without vegetal cover" and a reduction of the area occupied by the class "Pastures".

When the "potential zone for agriculture" was isolated, the precison of evaluation of the area occupied by pastures, rice crops and soil without vegetal cover (SWVC) was improved. The kind of sensor, the date of the image and the meteorological conditions induced diferences among the imagery of different dates (Fig. 3). The images of 1973 and 1981 present a different characteristics due to captation with the MSS sensor. The first image corresponds to september, when the culture had not been implanted yet. Some agricultural areas showed different pattern in 2001 and 2002 (same harvest) related to waterlogged soils, probably, due to intense rain in that time. A differencial answer of the vegetation in the agricultural areas was observed since 2005, what suggests a evolution of the vegetal development of the rice
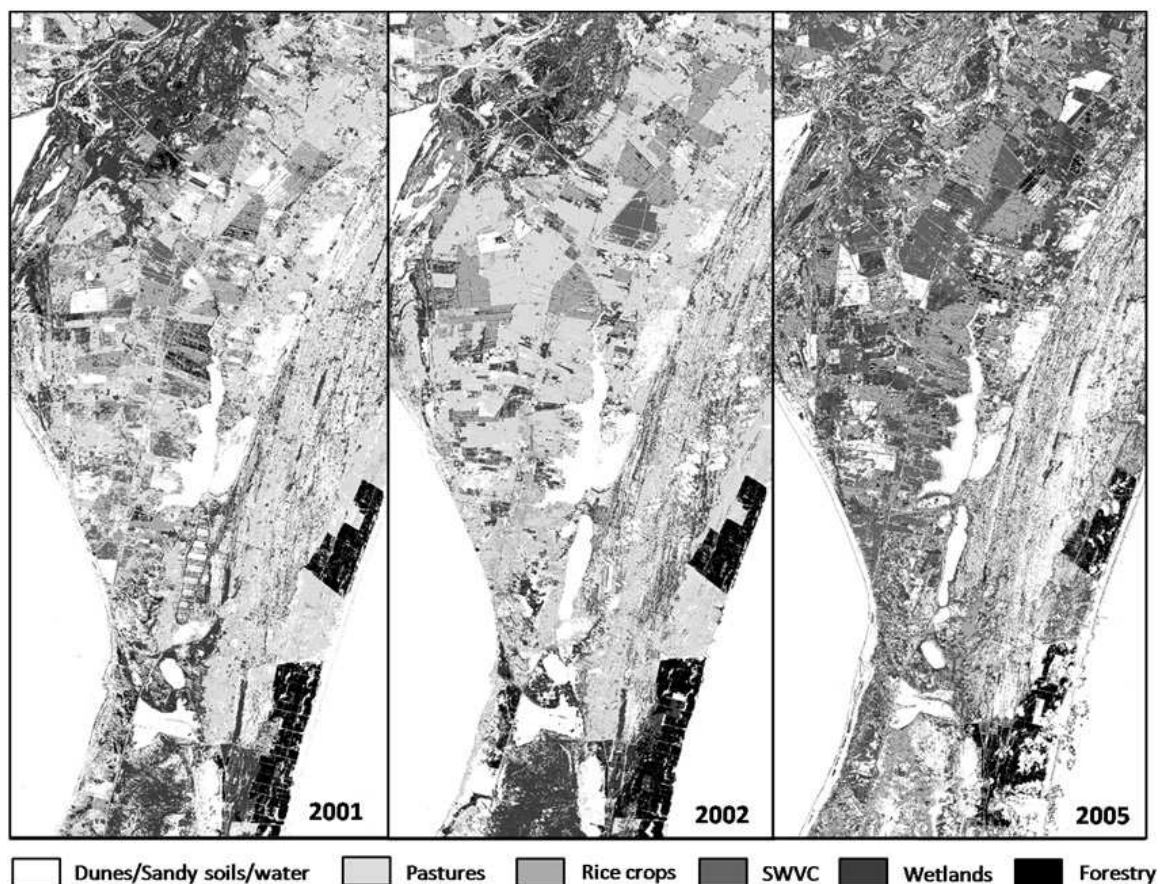
Fig. 2. Preliminary classification in the Caiuba region.

| Image date | Dec. 19th, 2001 | Jan. 20th, 2002 | Jan. 28th, 2005 |
|---|---|---|---|
| Water, % | 19.2 | 21.3 | 20.0 |
| Wetland, % | 17.8 | 18.5 | 11.3 |
| Pastures, % | 20.2 | 12.4 | 8.9 |
| Rice crops, % | 10.2 | 9.1 | 10.4 |
| Sandy fields, % | 17.7 | 13.6 | 15.1 |
| Beach/dunes, % | 6.7 | 6.3 | 10.5 |
| Florestry, % | 4.3 | 3.6 | 4.6 |
| Clouds, % | | 1.5 | |
| SWVC,% | 3.9 | 13.8 | 19.3 |
| Total area, ha | 202,777 | 204,088 | 208,907 |

Table 2. Preliminary areas of land cover calculated by classification methods in the vicinity of Caiubá region through Landsat-TM images in the period 2001 – 2005. SWVC = Soil without vegetal cover.

varieties or, perhaps, the introduction of a new crop. All the images show a intense rotation among pastures, rice and fallow lands, what lets a reduction of inputs, rest of the soil and improvement of productivity.
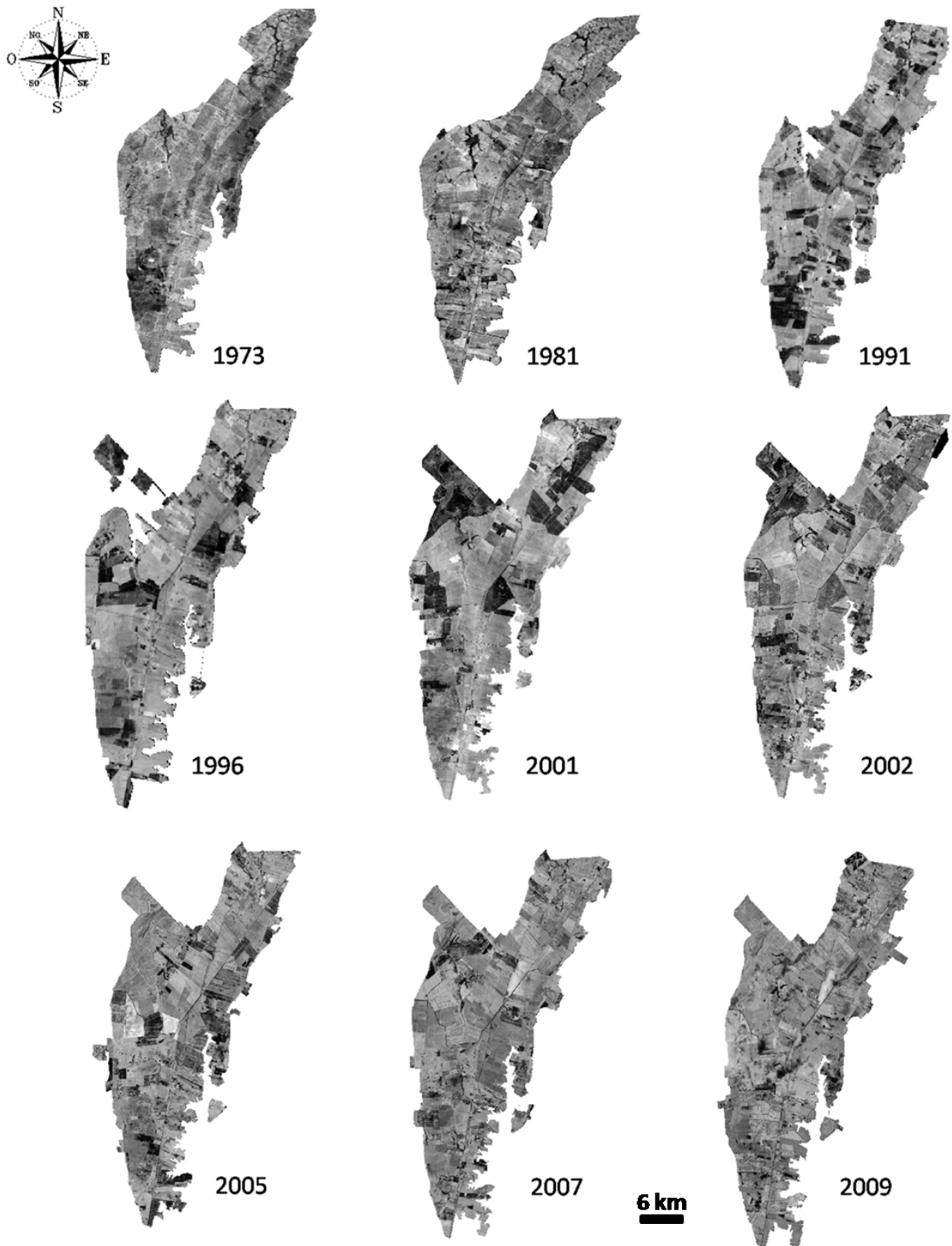
Fig. 3. Images Landsat corresponding to the "Potential zone for agriculture" for different dates.

The poligonal area was classified according to five classes: (1) Undefined; (2) Pastures; (3) Rice crops; (4) Soil without vegetal cover; (5) Water. The class "Undefined" represents rice crops or pastures depending on the year, thus it was incorporated to class "Pastures" in 1973, 1981 e 2001 and to class "Rice crops" in 1991, 1996, 2002, 2005, 2007 e 2009, accordingly the interpretation of the images. So, the classes "Pastures", "Rice crops", "SWVC" and "Water" were evaluated for occupied area (Fig. 4; Table 3).

The occurrence of water is almost insignificant inside the "potencial zone for agriculture", because the irrigation is performed through the water of the lagoons Caiuba and Mirim. The area occupied by the class "Rice crops" seems to depend on the vegetal developing, with restricted values when months previous to January are evolved. This fact was checked with the images of 2001 and 2002, corresponding to the same harvest, Dezember and January respectively.

By this reason, only the data corresponding to the months of january and march, when the vegetal developping of rice is reached, were consider in the graphic of "occupied area" as a function of time (Fig. 5).

| Year | Water | Pastures | Rice crops | SWVC | Total |
|---|---|---|---|---|---|
| 06/09/1973 | 173 | 19057 | 12856 | 13565 | 45652 |
| 13/03/1981 | 85 | 28593 | 13915 | 6592 | 49185 |
| 22/01/1991 | 52 | 17110 | 18751 | 15886 | 51798 |
| 21/12/1996 | 825 | 22534 | 12042 | 22534 | 57935 |
| 19/12/2001 | 56 | 30523 | 14404 | 8516 | 53498 |
| 20/01/2002 | 120 | 17579 | 20090 | 16299 | 54087 |
| 28/01/2005 | 49 | 13144 | 21963 | 20246 | 55402 |
| 02/01/2007 | 57 | 25062 | 21054 | 9467 | 55640 |
| 07/01/2009 | 80 | 5302 | 21029 | 31124 | 57535 |

Table 3. Area evaluation of land cover classes for the "potential zone for agriculture". The class "Undefined" was incorporated to the class "Pastures" or the class "Rice crops" according to the year. SWVC = Soils without vegetal cover. Data in hectares.

The area of the "Potential zone for agriculture" was delimited by digitalization, but a soft and constant increment is evident during the period 1981 to 2009. By other side, the area occupied by the class "Rice crops" was evaluated by classification methods; after a period of increment, the class reached a maximum in 2005 with 22 thousand hectares, then there was a stabilization in 2007 - 2009 with about 21 thousand hectares. The classes "Pastures" and "SWVC" showed oscillation in complementary way, because the sum of both classes was almost constant. As classes "Potential zone for agriculture" and "Rice crops" presented linear behavior in the graphic Area against time, thus, linear regression models were adjusted (Table 4).

The parameter $R^2$ is the correlation coefficient between the real variable and the adjusted variable by the model. So, a value near zero indicates bad adjust of the model and a value near one indicates a good adjust of the model. The parameter A indicates the annual growing rate for of the occupation area of the respective class. The area occupied by the
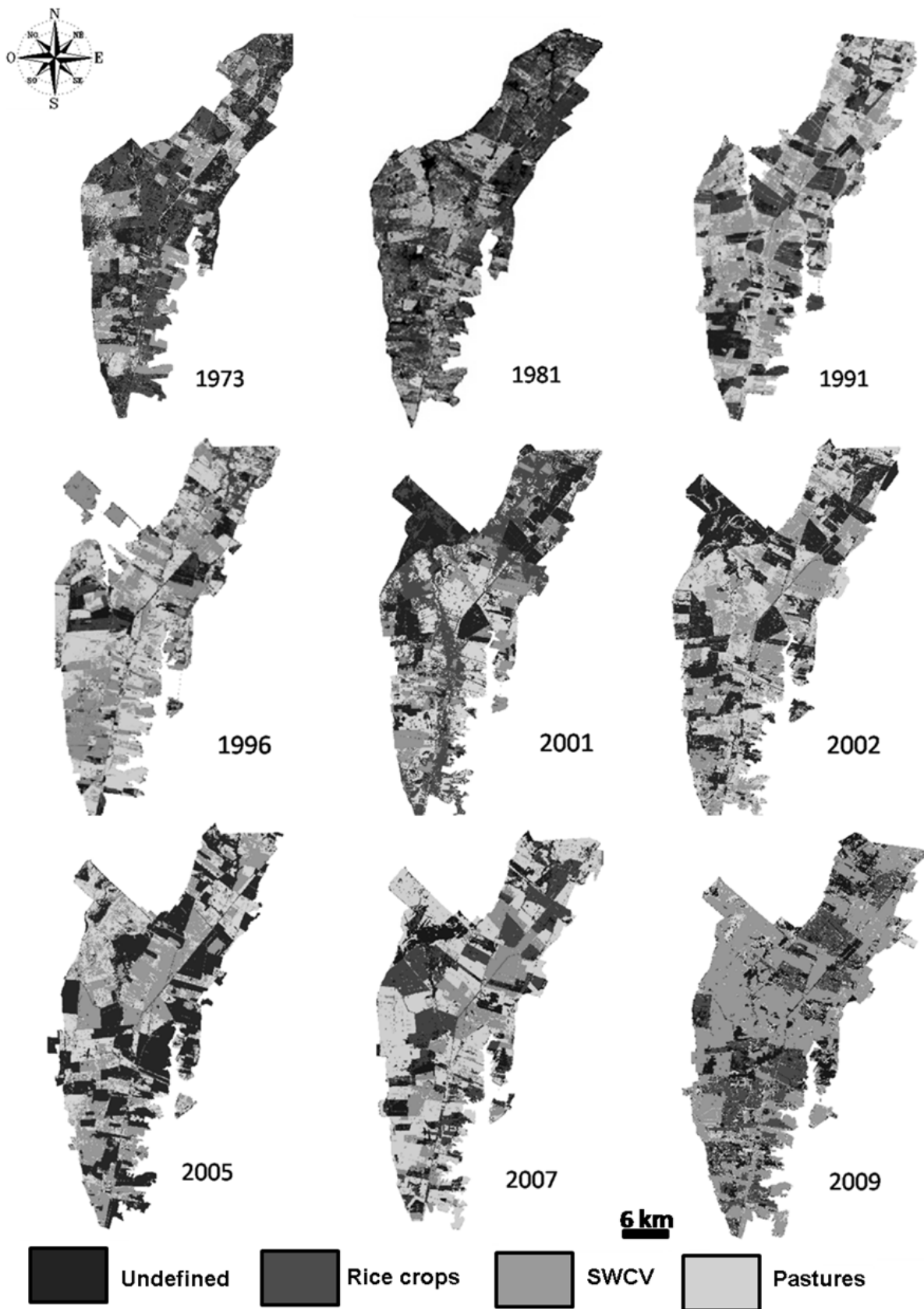
Fig. 4. Images Landsat post-classified corresponding to the "Potential zone for agriculture" for different dates.
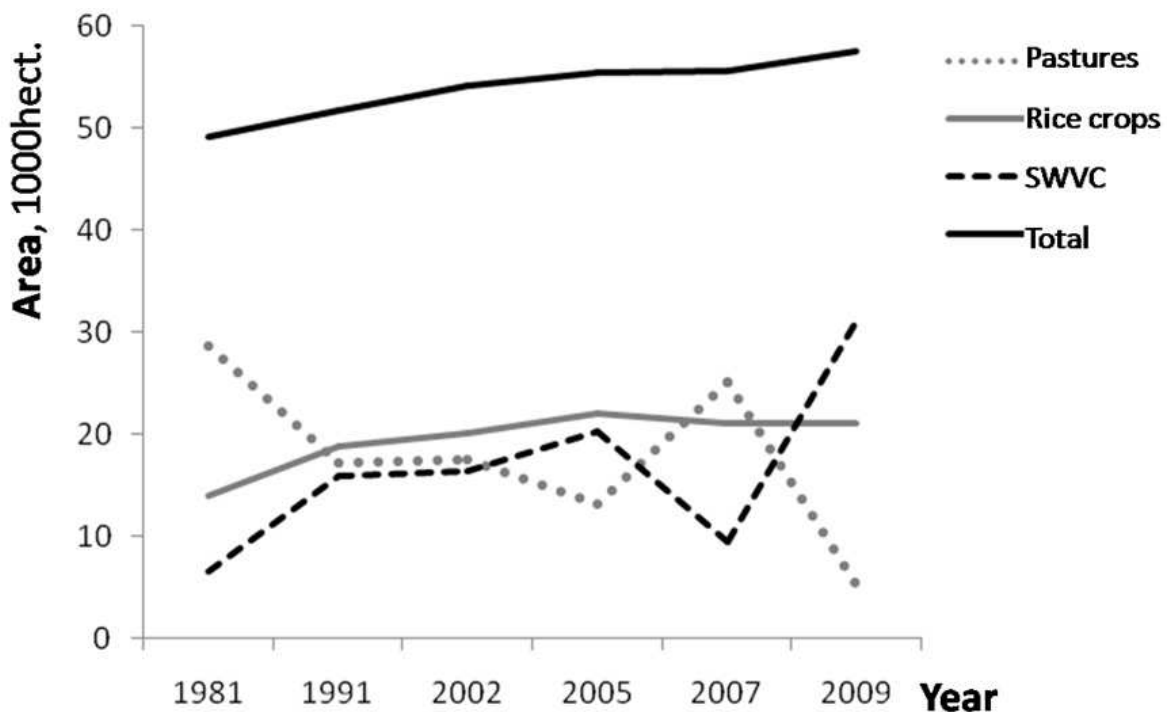
Fig. 5. Areas of land cover as function of the year in the "Potential area for agriculture" (Total), Caiuba region. SWVC = Soils without vegetal cover.

| Class of land cover | A | B | R² | Period |
|---|---|---|---|---|
| Potential zone for agriculture | 271 | 486996 | 0.97 | 1981 - 2009 |
| Rice crops | 302 | 584736 | 0.93 | 1981 - 2005 |

Table 4. Parameters of the linear regression models for the area of classes "Potential zone for agriculture" and "Rice crops" as a function of time (Area = A*year - B, in hectares).

"Potential area for agriculture" grew with a rate of 271 hectares by year, little inferior than the growing rate for the area occupied by the class "Rice crops", that is 302 hectares by year. Parameter B is the value of area in the year zero without real significance in this case.

Data of the municipality of Pelotas (Filippini Alba & Siqueira, 1999) and data for the state of Rio Grande do Sul (Bolfe et al., 2009) were compared to data presented here, after legend conversion. The correlation coefficient of the data discussed here was 0.54 with data of the first paper and 0.77 with data of the second one. Some classes showed significant differences, by instances Bolfe et al. (2009) evaluated 50% of area occupied by "pastures" in the state, but the value was about 30% for the other works. The area occupied by water was 19-20% in the Caiuba region, due to the occurrence of the lagoons. This value was 1% in the municipality context and 3% in the regional one.

## 4. Analisys of land cover evolution in the municipality of Montenegro, Estado do Rio Grande do Sul (1993-2008)

The municipality of Montenegro is located 55 kilometers South from Porto Alegre (state capital), with a territorial area of 420 square kilometers and population about 59,557 inhabitants. Thirty-three municipalities, including Montenegro, integrate the vegetal

carbon productive pole. The production of black acacia for the manufacture of tannin is an important activity for the economy of the municipality since 1948, when the first factory of tannin derived from the bark of acacia was installed (TANAC, 2010). Recently, the fruit production is becoming increasingly important in the context of local economy. The intense forest exploitation, the occurrence of new uses of land and a moderate urban occupation oriented the choice of the municipality of Montenegro for this research, focusing on the detection of temporal changes in the territorial organization, during the period 1993 to 2008, in the context of the project "Development and evaluation of products and co-products of the vegetal carbon productive chain in the State of Rio Grande do Sul, aiming for sustentability", with coordination of Embrapa Temperate Climate Reasearch Center.

The topography of the municipality is complex when compared to the previous case, while in the southeastern region occurs a flat terrain changing for slightly wavy; in the north sector occur a basalt plateau with a rugged relief.

Imagery of the Landsat 5 satellite were used, corresponding to the scene of orbit 221, points 80 and 81 for WRS-2 (INPE, 2010b), for three different dates: September 8th, 1993; August 8th, 1999 and October 3th, 2008. The initial data processing was performed with the software Marlin (INPE, 2010a), after that, the software ER-Mapper (1995) was used for classification according to isoclass likelyhood criteria. The images were registered with known ground control points, considering terrestrial features of easy identification, so that, the coordinates systems were uniformized and small errors eliminated. The projection used was the Universal Transector of Mercaptor (UTM), region 22 South, datum WGS 84.

Eigth classes were defined by the supervised classification process according to maximum likelihood criteria. The classes "Annual crops", "Perennial crops" and "Pastures/SWVC" were mapped together in gray tones (Fig. 6). The annual crops reached a maximum area of production in 1999 (Table 5) with poor production in previous and posterior times. By another hand, the perennial crops reached a maximum in 2008, after a significant increment in the previous years, as consequence of an important citrus production. Pastures and SWVC were mapped together due to the dinamic process of changes evolving both classes. A little reduction of the area occupied for both classes was observed.

| Class of land cover | 1993 | | 1999 | | 2008 | |
|---|---|---|---|---|---|---|
| Annual crops | 13.9 | 5835 | 21.2 | 8884 | 12.1 | 5084 |
| Forestry | 19.2 | 8076 | 5.5 | 2299 | 18.3 | 7686 |
| Native forest | 18.9 | 7948 | 23.0 | 9675 | 21.3 | 8957 |
| Pastures/SWVC | 27.0 | 11340 | 26.8 | 11246 | 23.2 | 9733 |
| Perennial crops | 8.9 | 3737 | 18.2 | 7655 | 19.6 | 8226 |
| Unevaluated | 3.3 | 1370 | 1.9 | 810 | 0.4 | 173 |
| Urban | 6.5 | 2729 | 2.1 | 878 | 3.3 | 1377 |
| Water | 2.3 | 968 | 1.3 | 554 | 1.8 | 767 |
| Units | % | hectares | % | hectares | % | hectares |

Table 5. Areas calculated with TM/Landsat 5 imagens for the period 1993 – 2008 through classification methods for Montenegro municipality (Schroder & Filippini-Alba, 2010a).
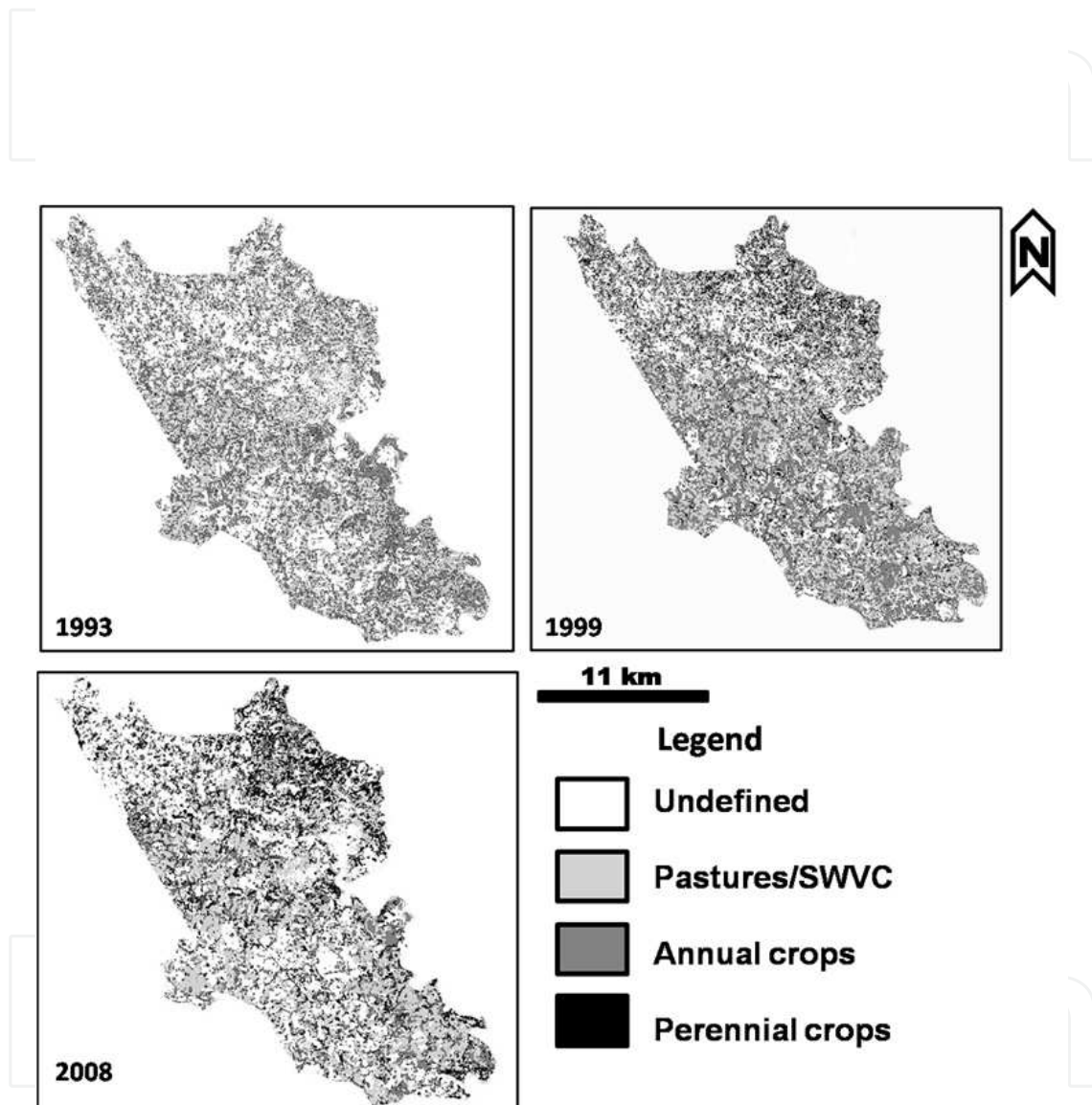
Fig. 6. Evolution of land cover related to agriculture and pastures/SWVC in the municipality of Montenegro based on Landsat 5 imagery (1993 – 2008).

The class "Forestry" showed a minimum of planting area in 1999, what is evident in the map of spatial distribution (Fig. 7.), but the class "Native forest" showed a maximum that year (Fig. 8). The class "Urban" includes other features besides the urban regions, by instance outcrops, which explains its high value in 1993. The density of the central spot in the image of 2008 suggest a real increment of urban population that year.
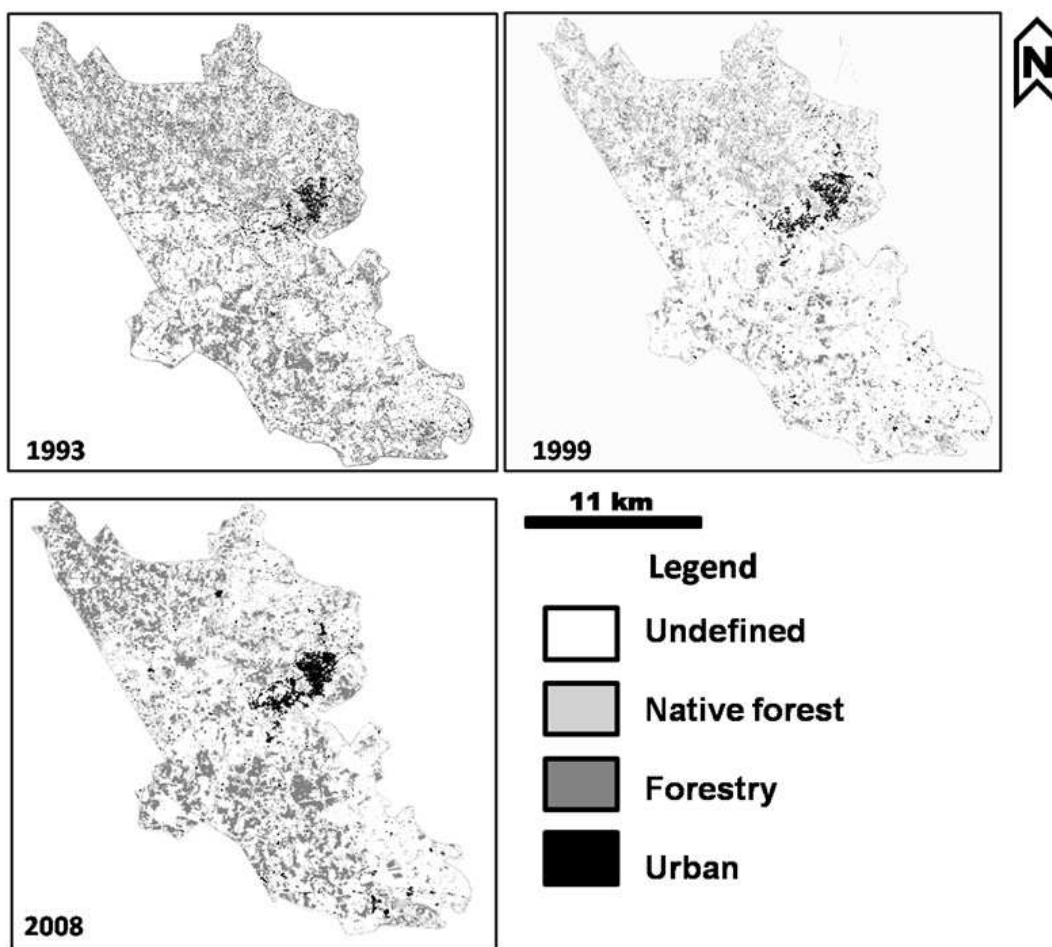


Fig. 7. Evolution of land cover related to the classes "Native forest", "Forestry" and "Urban" in the municipality of Montenegro based on Landsat 5 imagery (1993 – 2008).
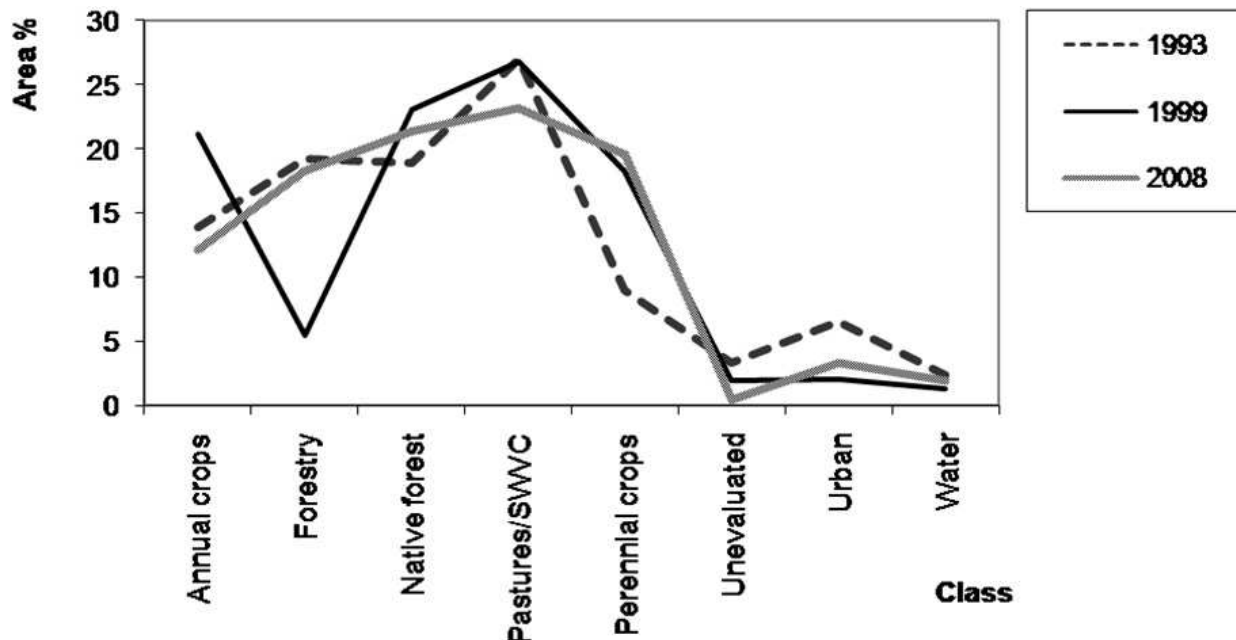
Fig. 8. Evolution of the land cover classes considered in this chapter in the municipality of Montenegro, Rio Grande do Sul state, Brazil.

## 5. Comparison and evaluation of errors

Two strategies were used to analize the errors of the classification methods: (a) Duplication of process with new test areas for the same classes in Caiuba region. (b) Confusion matrixs by truth of field for Montenegro municipality. Each strategy is related to a different error condition, that is, error of processing and error of the method respectively.

The maximum error for case (a) was for the class "Soils without vegetal cover", more or less 2% when the overall area was evaluated (Table 6). The interference of the clouds was of the same order (value insered with the class "Beach/dunes/clouds"). A confusion between dunes and water (sediments) occurred in the Caiuba region (central part of Fig. 9). Other sectors appear very similar for both images.

| Class | Image A | Image B |
|---|---|---|
| Water, % | 20.3 | 21.3 |
| Wetland, % | 18.9 | 18.5 |
| Pastures, % | 12.2 | 12.4 |
| Rice crops, % | 7.7 | 9.1 |
| Sandy fields, % | 13.4 | 13.6 |
| Beach/dunes/clouds, % | 8.4 | 7.8 |
| Forestry, % | 3.6 | 3.6 |
| SWVC,% | 15.6 | 13.8 |

Table 6. Errors derived from classification with new test areas in the Caiuba region for the image of Jan. 20th, 2002 in a total area of 204088 hectares. SWVC = Soil without vegetal cover.
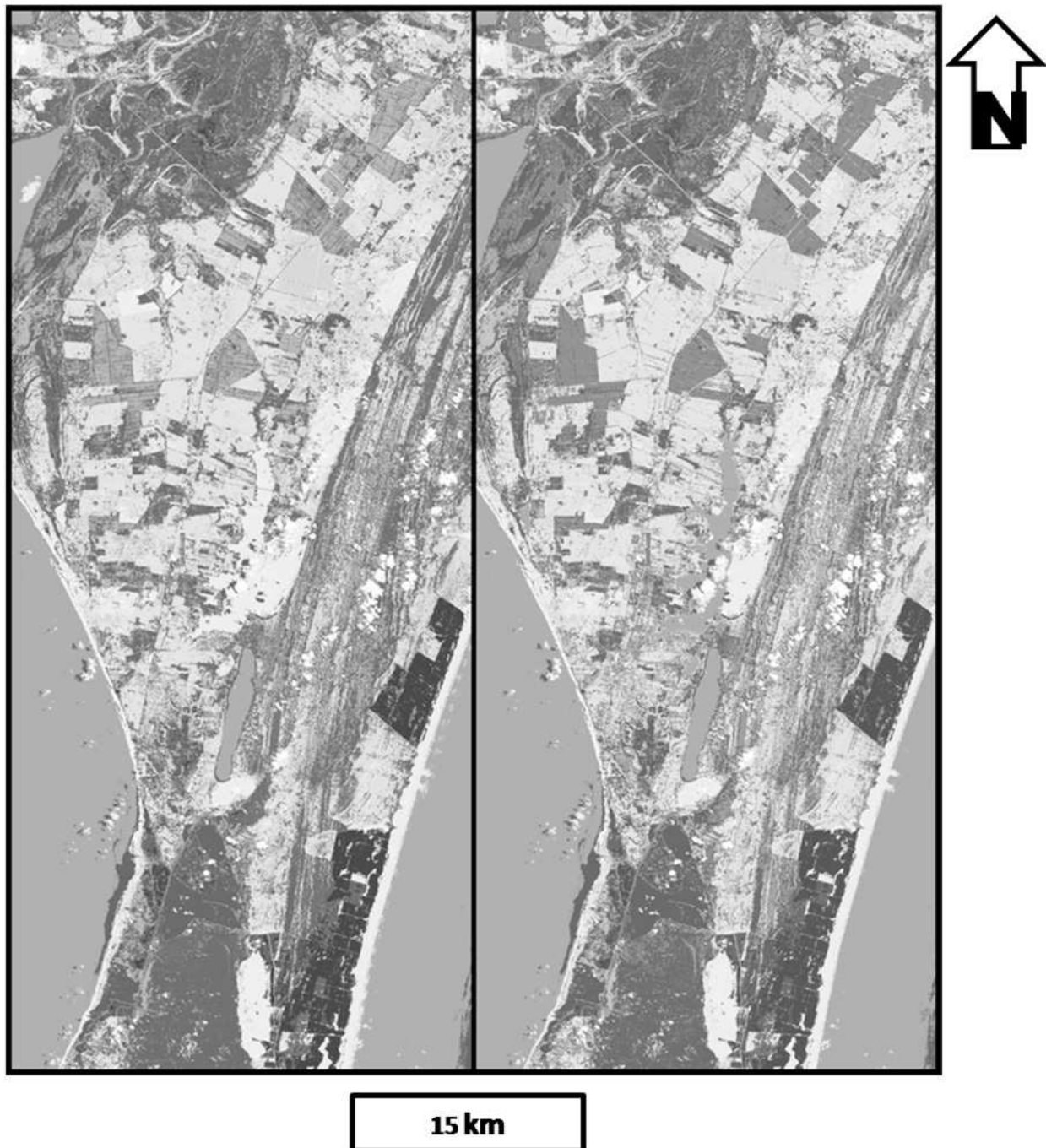
Fig. 9. Comparison of the classification in Caiuba region with Landsat image of 2002 for different test areas.

Data from Montenegro municipality considered the confusion matrix constructed with the truth of field for the Landsat 5 image of april 13, 2009. Thus, 48 control points were selected in the image, trying a "randomly - homogeneous" distribution on the territory of the municipality. Each point was verified at field in september-november 2009 and historical informations were collected with the local farmer when posible.

The accuracy of the method was moderate, that is, 42% for the full process (Table 7). Forestry, Pastures/SWVC, Perennial crops and Urban/outcrops showed the better results,

with values greater or equal than 50%. The rest of the classes presented low accuracy with values in the interval 0 – 25%. The correlation coefficient of the quantity of control points and the accuracy was 0.43, suggesting few dependence between both variables. Anyway, a critical case occurred with the class "Native forest" with 11 control points and only two hits. An explanation for the low accuracy of the classification process and some specific classes is the shadow derived from the steep topography, causing confusion among classes and inconsistent results. A improvement of the results is obtained when principal components are considerer before classification, with a potential increment of accuracy of 10% (Schroder & Filippini-Alba, 2010b).

|                 | Control points | SCC | Accuracy |
|-----------------|:--------------:|:---:|:--------:|
| Forestry        | 9              | 5   | 56%      |
| Pastures/SWVC   | 11             | 6   | 55%      |
| Water           | 2              | 0   | 0%       |
| Perennial crops | 7              | 4   | 57%      |
| Native forest   | 11             | 2   | 18%      |
| Urban/outcrops  | 4              | 2   | 50%      |
| Anual crops     | 4              | 1   | 25%      |
| **Total**       | **48**         | **20** | **42%** |

Table 7. Results of the confusion matrix for the process of classification in the municipality of Montenegro, Rio Grande do Sul state, Brazil (Schroder & Filippini-Alba, 2010b). SCC = samples correctly classified.

## 6. Conclusion

Two categories of change detection techniques (Lu et al., 2004) were considered in this chapter, all of them including classification methods: Post-classification comparison and strategy with GIS.

The strategy with GIS isolated the poligon corresponding to the "Potential area for agriculture", then, the interference between some pair of classes was eliminated, by instance, wetlands and rice crops. The post-classification comparison allowed a rapid approach about the region with minor accuracy (preliminary results). Definition of the method used depends on the ratio between cost and efficiency according to the designed objectives.

Errors associated to classification methods are mainly due to the spectral answer, by undefinition of classes or occurrence of pixels of transition, because the errors derived from digitalization were insignificant. Atmospheric conditions and the regional topography also influence the process of classification.

Land cover changes in a dynamic way, sometimes with significant transformation rates of one class to another, as the discussed cases confirm. Truth of field appears as an optimal method to improve results, but the cost of process, in time, financial and human resources is incremented.

## 7. Acknowledgments

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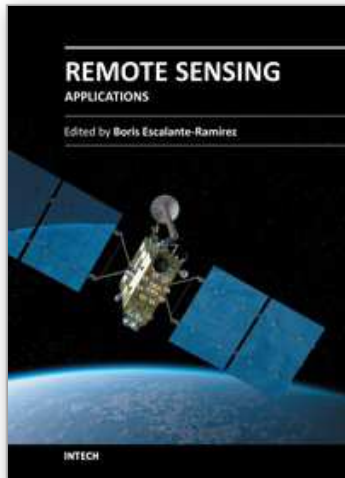
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Edited by Dr. Boris Escalante

Nowadays it is hard to find areas of human activity and development that have not profited from or contributed to remote sensing. Natural, physical and social activities find in remote sensing a common ground for interaction and development. This book intends to show the reader how remote sensing impacts other areas of science, technology, and human activity, by displaying a selected number of high quality contributions dealing with different remote sensing applications.

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