

Land Cover Change Analysis from Remote Sensing Images and Statistical data: Case Study Itaipú region, Border Paraguay/Brazil.

Mauro Alixandrini¹, Hans-Peter Bähr²

¹ UFBA, Salvador/Brazil
Mauro.Alixandrinni@ufba.br

² KIT, Karlsruhe /Germany
hans-peter.baehr@ipf.uni-karlsruhe.de

Abstract

The historical context of the region was compared to the results obtained from the set of adopted images. Based on the analyzed documents we can define the main anthropogenic phenomena responsible for the changes in the vegetation cover in the region. We identified the Paraguayan agricultural expansionism and the predominantly agricultural Brazilian migratory movements to the border region between Brazil and Paraguay. The results show that the systematic process of deforestation had already been established before the beginning of the construction of Itaipú. Migratory processes associated with previous factors to the construction of hydroelectric show mainly correlations with the deforestation observed in the region. Furthermore, the analysis verifies the incoherent documentation about the current situation in the protected areas. The conclusions prove the characteristics of the employed method showing that its use is valid in a context of the analysis of the regional development.

Keywords: Land Cover Change, Thematic Map comparison, Itaipú.

1. Introduction

Firstly, the function of remote sensing images in this methodology should be explained. In Brazil, as in other South American countries, the availability of territorial information is very restricted. Territorial planning began to gain importance only in the seventies with the urbanization of the population. Until the present day, regional questions have been omitted or subjected to questions of the national development. Studies dealing with the history of the regional development especially suffer from a lack of data that prove one or another hypothesis.

Remote sensing data thus provide support for studies on physical territory realignment. In Brazil, images of average resolution derived from Landsat and CBERS are the most widely available free of cost data offered by The National Institute for Space Research (INPE) for research purposes. Another important characteristic of

the Landsat data is that it presents a historical record in orbital images for a period of over 30 years.

There exists a continuous set of Landsat data from mid-1972 until 2003¹, which provides an indispensable history of the state of the land surface. Data at these spatial resolutions can provide high potential mapping accuracy for natural vegetation and alterations.

Its images are used in deforestation and fire control in the Amazon Region, water resource monitoring, urban growth, soil occupation and education. It is also fundamental for large national and strategic projects like PRODES - the real-time evaluation of Amazon deforestation, CANASAT - the monitoring of sugar-cane areas, and DETER - real-time detection of Amazon deforestation, among others (INPE,2009).

2. Methodology

This study examines the validity of these assumptions regarding the accurate assessment of land-use maps derived from satellites images. The methodology was arranged according to the flow chart in Figure 2.1 and was started with the image data set. Then this data set was classified using an evaluation methodology based on random reference separation and validation. The result thematic maps were analyzed and compared with statistical data and historical sources.

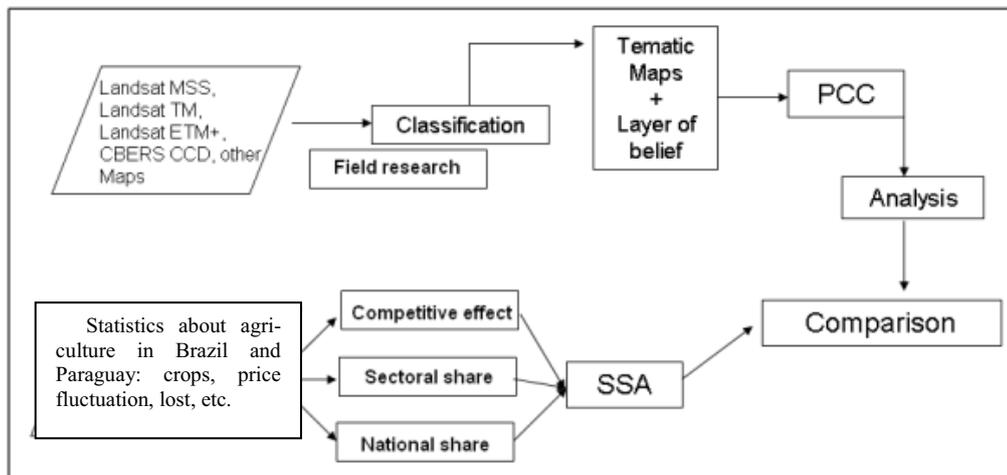


Figure 2.1: Arrangement of methodological steps.

The initial data are the result of a large survey on the history and development of the region where the Itaipú Dam was erected and the Itaipú reservoir is located. Research on this region was carried out to allow for both the selection and homogeneity of relevant information. This means that some sources were unreliable and others were incomplete.

The image data set required a separate research endeavor about technical aspects and sensor characteristics, since sensor imagery such as the multispectral scanner requires specific pre-processing, comparable to an ETM sensor.

¹ still functioning, but with faulty scan line corrector.

3. Results: Thematic Map comparison

The results were analyzed in three ways: first, the initial and final conditions of the region were compared; second, the progression of modifications each 10 years was studied, narrowing the list of probable change agents; third, using the section classification described in chapter five, precise issues that exemplify regional dynamics were identified.

The left and right sides of Figure 3.1 show the initial and present conditions of the region. In the Brazilian part of the region, east of the Iguaçu River, it can be observed that the process of agricultural expansion is in its advanced stage. Few regions remain unexploited; one of these is 100 km north of Foz do Iguaçu and another is a part of the Iguaçu National Park, near the southern edge of the region.

In Paraguay, west of the Paraná River, there is dense forest cover mainly in the districts north of Hernandarias. The areas used for agriculture are concentrated in Hernandarias and Ciudad del Este. These areas form an axis starting in Hernandarias that passes through the districts of Mbaracayú and San Alberto. This axis corresponds to the highway that connects the region to the north of the Department and the district of Salto del Guairá.

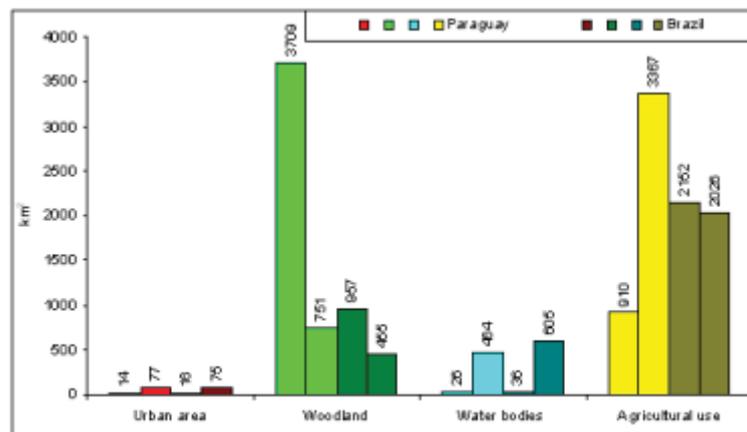


Figure 3.1: Results for 23.Feb.1973 and from 29.Mar.2009.

The first map from 1973 corresponds to a stage at which the feasibility study had already been completed and the site for the Itaipú dam had been chosen by the governments of Brazil and Paraguay. Construction was officially started in 1974. At that time there was a dense forest on the Paraguayan side of the Paraná River. Deforestation began in the south at the Paraná River along the road that links Hernandarias and Salto del Guairá.

On the Brazilian side, in the extreme west of Paraná, aggressive policies of agricultural expansion have been implemented since the 1950s. Little remains of the original forest apart from two large wooded areas: one southwest of Foz do Iguaçu in the Iguaçu National Park and another about 100 km north of Foz do Iguaçu in the border region near the Paraná River.

The changes seem to relate more to national agricultural policies and the construction of Itaipú. Itaipú catalyzed Brazilian migration into Paraguay and has ineffectively handled its Environmental Protection Zone.

Figure 3.1 shows the class development since 1973 for the two sides. The first class, urban area, presents similar growth on both sides. The same is true for the total area of bodies of water, which increased due to the formation of the reservoir

as well as to seasonal variations in the preconstruction period. The graph demonstrates a great difference in woodland area between the Brazilian and Paraguayan sides; however, Paraguay systematically lost its wooded cover in the region whereas the Brazilian side varied during the period.

Figure 3.1: Results from 23.Feb.1973 to 29.Mar.2009 .

When the class areas are compared, the difference is obvious. Figure 3.1 shows the progressive reduction in Paraguayan forest. On the Brazilian side, all areas remained at the same level except for the urban area.

4. Conclusion

The development of a research methodology that uses remote sensing data to quantify the changes observed in soil coverage due to the construction of a large hydroelectric plant should first analyze the limitations of the technique. It is only possible to map the features and phenomena that can be spatially characterized by their image properties. To verify the validity of the method, the spectral responses linked to variation in forest cover in the image were evaluated. The methodology was designed to show the evolution of deforestation in the study region. In a bi-temporal analysis, it is difficult to define which factors and processes are involved in the observed changes. However, in a multiple observation analysis, the speed of changes can be specified and we were able to verify that the speed of the changes in this region was correlated with the construction of Itaipú, which is an important finding of this study. The changes, nevertheless, were more closely related to the migration of Brazilians to the border region of Paraguay than to the formation of the reservoir.

The central objective of this study was to analyze the development of a region that was physically and economically modified by the installation of a large engineering project. Such anthropogenic changes produce, as can be imagined, both short and long-term effects. The short-term effects can include changes resulting from the formation of the reservoir and the labor used in the construction of the dam. The long-term effects are mostly related to the rural real estate market and the environmental projects developed by the company. The point is to define which effects are due to the changes and which are associated with other local processes. In general, such questions can only be discussed in a theoretical manner, since they depend on the systematic monitoring of the region for a long period prior to the installation of a power plant. The case studied here is no different; the available

information is very limited for an analysis of a broader scope. But that is always an inherent problem when studying historical facts.

The chief aspects that define the influence of Itaipú and its reservoir on the region are poor planning regarding reservoir-area occupant resettlement concomitant with the appreciation of the properties in the reservoir area. Since the Brazilian side had been developed with the necessary agricultural infrastructure for grain production, its value was much higher than the lands still covered by native vegetation in Paraguay. The flooding of cultivatable areas by the reservoir further propelled the migration of Brazilian farmers into Paraguay.

As the scenario evolved, forests were increasingly restricted to park areas (The National Park of Iguaçu, Biological Reserves and Refuges) due to progressive fragmentation. From the images it is possible to identify the forest regions that were not properly removed before the formation of the reservoir, which are in Paraguay north of Hernandarias. There has been a substantial recovery in riparian forest since the 90s, although it still remains fragmented; as can be seen Alixandrini(2010), as well as in the field observations carried out in 2008. This contradicts Itaipú's official reports that 100% of the region's riparian forest is restored and protected.

Regarding the results of the thematic mapping, compatibility was determined by re-sampling the thematic maps for smaller-scale comparison, i.e., generalizing the thematic matrix maps by analyzing the majority and the minority classes elements on an identical scale to the initial image of comparison. For instance, the scale always mentioned the thematic maps of 1980 derived from the MSS when making a comparison with a thematic map in 2000 derived from the ETM.

However, the analyzed region contains several specific characteristics that influenced many of the hypotheses generated during the study. The region is in a border zone between two countries with different politics and structures, each presenting a series of unique problems in the development of the region. During the bibliographical research, it was verified that a series of socio-economical processes directly influenced the physical appearance of the area in question, including the change in production from coffee to soybean and Brazilian migration to the Paraguayan border region. These migrants are called *Brasiguaios* in reference to their bi-national character, which can be seen in their family and commercial ties with Brazil. For this reason, we attempted to identify the human aspects related to the involved processes.

Further commentary can be made about the political aspects of the processes. For future regional initiatives, the political changes involved should be examined. Currently, there is pressure from both Brazil and Paraguay to revise the Itaipú contract. The contract, which was signed during the dictatorial period in both countries, allows a series of advantages for Brazil. An analysis of those advantages without the necessary historical context would be quite tedious, because the Brazilian and the Paraguayan governments have been disputing the issue for over 20 years now. Political advantages were considered during the original negotiations that are no longer taken into account when analyzing the international contract.

In Brazil and in Paraguay, most studies of this kind are bi-temporal and can distort the facts because they do not evaluate the dynamic phenomena occurring in the studied region. Our research was limited to the free data available in both countries, which shows a viable alternative for this type of study.

The study also observed that the infrastructure of data in Brazil and Paraguay is still in its initial phase. There is not as yet a clear organization of the various sources of spatial information like that which can be found in Europe, for example. There are movements in Brazil leading in this direction, but they are still cautious.

This study was important for its impartial depiction of the impact of Itaipú's construction on the forests of the Brazil-Paraguay border. It was also important to employ mappings and data available to any South American researcher for studying changes in soil coverage and use.

The thematic uncertainty was evaluated by analyzing the results of the "layer of belief" histograms, which showed the distribution of function through the contingency relationship of the pixels toward one or another class in the charts. These histograms are used to evaluate the uncertain on mistakes matrix considered.

The conclusions of the scenario analysis can be used as an example for other studies. The use of seasonal images for mapping and monitoring is recommended for several types of regional agriculture. Cross-referencing census information with that of agricultural and environmental institutions is also recommended to define the ecological fragility of the region.

The agricultural census in Brazil and Paraguay could use research linked to spatial distribution of the information for the following contrast with the responses and the employed models for the monitoring of harvests. The use of additional active sensors for the evaluations proved to be useful. There was a certain incompatibility between our results and those of the census due to different class definitions by the sensing equipment and different census statistics. The farming census is estimated by interviews with farmers, which makes its consistency suspect. In Brazil these data are currently crossed-referenced with models that follow the official harvest figures. Auxiliary data from the thematic mapping could improve the quality of such validation models.

In the present case, the employed methodology reached the expected result. It facilitated the study by either proving or ruling out related hypotheses, thus guiding the flow of the argument.

Future efforts must concentrate on the analysis of a larger number of classes and try to determine the rate of expansion of extensively-planted crops such as wheat and soy. Thus, the initial set of data is decisive for obtaining relevant results because the determination of classes related to the studied problems depends on it.

References

- Alixandrini, M. J. Jr. (2010), *Land cover change study with historical remote sensing Data set: case study Itaipu*. PhD thesis, Karlsruhe Institut of Technology-Karlsruhe, Germany.
- Bähr, H.-P. (1992) Adequate Decentral Management for Environmental Monitoring of Very Large Areas. Internationale Gesellschaft für Photogrammetrie und Fernerkundung.
- Bähr, H.-P. (2005) *Digitale Bildverarbeitung : Anwendungen in Photogrammetrie, Fernerkundung und GIS. 4., völlig neu bearb. Aufl. edn.* Heidelberg: Wichmann.
- INPE- National Institut for Spatial Resarchs.(2009). *Engenharia de Satélites*. São José dos Campos, Brazil.
- ITAIPU, (1994). *Itaipu: Hidroelectric Project*. Tech. rept. Itaipu.Foz do Iguaçu, Brazil.
- Foody, G.M., & Atkinson, P.M. (2002). *Uncertainty in remote sensing and GIS*. Wile & Sons.
- Goodchild, M. F., & Gopal, S. (1994), *The Accuracy Of Spatial Databases*. Taylor & Fancis.