# Monitoring land use changes around the indigenous lands of the Xingu basin in Mato Grosso, Brazil

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# MONITORING LAND USE CHANGES AROUND THE INDIGENOUS LANDS OF THE XINGU BASIN IN MATO GROSSO, BRAZIL

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**ABSTRACT**

Indigenous lands represent an efficient way to protect indigenous communities and environment in Brazil. However, these lands are also highly affected y the land use changes occuring in its surroundings. We quantified the land use changes in the Xingu basin based on MODIS EVI data between 2000 and 2006. We estimated the deforested area inside and outside the indigenous lands, the crop expansion and intensification around the protected areas. Our results indicate that, even if indigenous lands are efficient to limit deforestation (97.5% of deforestation is outside the indigenous lands), crop expansion and intensification (double crop systems) are increasing rapidly, what may imply pollution of headwaters of the Xingu river which crosses the protected area.

***Index Terms***— MODIS EVI, Amazonia, indigenous land, land use changes, soybean

## 1. INTRODUCTION

The State of Mato Grosso (906000 km²), located in the southern region of the Brazilian Amazon, is composed of three main biomas (rainforest, savanna or "*cerrado*" and Pantanal), all considered for their biodiversity. However, Mato Grosso is suffering devastating land use changes. According to the INPE (Instituto Nacional de Pesquisas Espaciais), 40% of the Amazonian deforestation during the 1992-2005 years took place in the State of Mato Grosso, i. e. 104,076 km². These land use changes have been partly explained by the expansion of pasture and mechanized agriculture, primarily based on soybean crops [1]. In order to limit the deforestation in Amazonia and the *cerrado*, the Federal government created reserved areas like national parks and indigenous lands (about 31.1% of the Brazilian Amazonia, i. e. 1,318,329 km², are actually protected while this rate is only 2.2% in the *cerrado*). These lands may be considered to be protected areas for environmental conservation or for the preservation of traditional (mainly indigenous) communities. The main issue regarding the administrative situation of such protected areas consists in understanding how societies affect and are affected by land use changes inside and outside such areas. First, we need to determine if it is more efficient to protect the native vegetation by creating uninhabited areas or areas inhabited by "traditional" populations [2]. Second, we need to determine how land use changes observed outside protected areas may cause further difficulties for the traditional populations therein that suffer new constraints and limitations for sustaining themselves. Remote sensing techniques can bring new elements to bear on these issues. The objective of this paper is to study the evolution of land use changes on the surrounding areas of the indigenous lands of the Xingu basin, in Mato Grosso.

## 2. STUDY AREA, DATA USED AND METHOD

### 2.1. Study area

The Xingu basin (fig. 1) in Mato Grosso represents an area of 17,732,544 hectares where 14 indigenous lands have been established comprising a total area of 4,220,494 hectares, i. e. 23.8% of the basin's area. A population of 23,000 Amerindians inhabits these indigenous lands. This culturally diverse population speaks no less than 15 different indigenous languages.

The biggest indigenous area of the basin is the Xingu Indigenous Land (formerly the Xingu National Park, 2,648,126 ha), which was founded in 1961. This area is located on both sides of the Xingu River, a tributary of the Amazon River. However, all the headwaters of the Xingu River are located outside the indigenous lands and are now affected by the land use changes occurring in their surroundings. The progression of the agricultural frontier along the western and eastern borders of the Xingu indigenous land is affecting water quality in the basin. This is an important socio-environmental problem because of the presence of indigenous communities in the Upper Xingu whose diet is based mainly on fish consumption. Some indigenous villages in the borders of the Xingu Indigenous Land have systematically resorted to drinking water from wells because of the pollution of river waters by agro-toxic substances used in crops like soy. Another recent impact on the indigenous lands was the construction of dam outside the protected area in the Culuene River, one of the headwaters of the Xingu, which changed water levels and significantly reduced the river's fish population, according to the indigenous communities in the region. As a matter of fact, preservation of water quality in the basin is now one of the priorities of the ISA (Instituto Socio-Ambiental) and the EMBRAPA (Empresa Brasileira de Pesquisa Agropecuaria) through the Y Ikatu Xingu project.

### 2.2. Data used

Deforestation maps were provided by the INPE and the SEMA (Secretary of Environment of Mato Grosso) and were resampled to a 250m MODIS resolution. INPE data are annually and automatically provided for the Amazon forest bioma, but it does not include deforestation in the *cerrado*. On the contrary, SEMA data consider deforestation in the entire State of Mato Grosso, but it is not provided automatically. Based on these two sources of data, we created new combined deforestation maps in Mato Grosso for the period 2001-2006 [3]. Two successive classifications of MODIS TERRA/EVI time series were then carried out through the application of a five-step classification process described in [3][4]. The first classification (overall accuracy = 85.5% and Kappa = 0.8067) aimed at creating an agricultural mask used for the second classification (overall accuracy = 74% and Kappa = 0.675), which led us to distinguishing main agricultural management practices. It allowed us to detect the main commercial crops (soybean, corn and cotton) and production systems (single vs. double cropping systems) with sufficient user and producer accuracy (>70%). Single cropping systems correspond to soybean and cotton harvests. Double cropping systems correspond to a main harvest of soybean followed by a harvest of corn, cotton, millet or sorghum.

### 2.3. Method

Deforestation maps and land use classifications were used to analyze the evolution of land use changes in the Xingu basin in Mato Grosso through the computation of a few indices such as : (i) evolution of deforestation inside and outside protected areas and indigenous lands, (ii) evolution of the agricultural areas in the Xingu basin, (iii) evolution of the areas planted in soybean, corn and cotton within the basin and (iv) evolution of the area planted in double cropping systems within the basin.

## 3. RESULTS

The deforestation maps indicated that clearings increased by 38% during the study period 2000-2006. New clearings represented 1,686,125 ha so that the total deforested area in 2006 in the Xingu basin reached 6,110,228 ha, i. e. 34% of its total area. Actually, 97.5% of the deforested areas were detected outside the indigenous lands. Thus, those lands were quite well protected (only 3.5% of their areas were cleared until 2006), confirming the previous conclusions by authors [2] who claim their efficiency in protecting forests. Nevertheless, the land use changes observed outside the protected areas imply new environmental constraints. Mechanized agricultural areas increased from 243,768 ha in 2000 to 848,456 ha in 2006, i. e. a +248% growth. The maps (fig. 1) showed that the areas used for new crops are now reaching the border of the indigenous lands, putting great pressure on these protected areas. In addition, due to the expansion of agriculture, farmers have adopted new agricultural practices. In 2000, 24% of the cultivated areas were planted in double cropping systems. This rate grew to 49% in 2006. This evolution indicated that the producers were trying to make use of the soils during the entire rainy season, thus limiting soil erosion and water pollution. This

notwithstanding, by altering their practices, they were also intensifying production by planting commercial crops such as cotton and corn after the soybean harvest. Overall, corn areas increased drastically from 1,587 in 2000 to 85,300 ha in 2006. Cotton areas also increased significantly, from 9,281 to 15,218 ha. Such an expansion may have devastating environmental consequences because it implies the use of more chemicals that could potentially pollute water and soils in the Xingu basin.

## 4. CONCLUSION

Our results illustrate how the indigenous lands are the sole efficient means of limiting deforestation in Amazonia. However, some authors now question whether this fact will remain true on the long term. The demographic growth and the adoption of a "way of life" patterned after the Brazilian society are factors that may affect the ability of traditional populations to protect their territories [5]. Indeed, we should keep in mind that the contact between indigenous and Western populations in the Xingu basin remains recent (permanent contact with the indigenous communities in the area was established only in the 1940s by the Villas Bôas brothers). Will these populations be able to protect their forest in the long run? On the western part of Mato Grosso, the Parecis indigenous population, which was contacted more than 350 years ago, are now planting 18,000 hectares of soybean in cooperation with the farmers of the surrounding municipalities [5]. Does this process may be repeated in the Xingu basin? If the expansion of mechanized agriculture around the headwaters of the Xingu rivers goes on at this rate provoking such high levels of water pollution, the urgent need for indigenous communities to adopt the way of life now widespread in Mato Grosso may be accelerated and the forest will suffer its consequences.

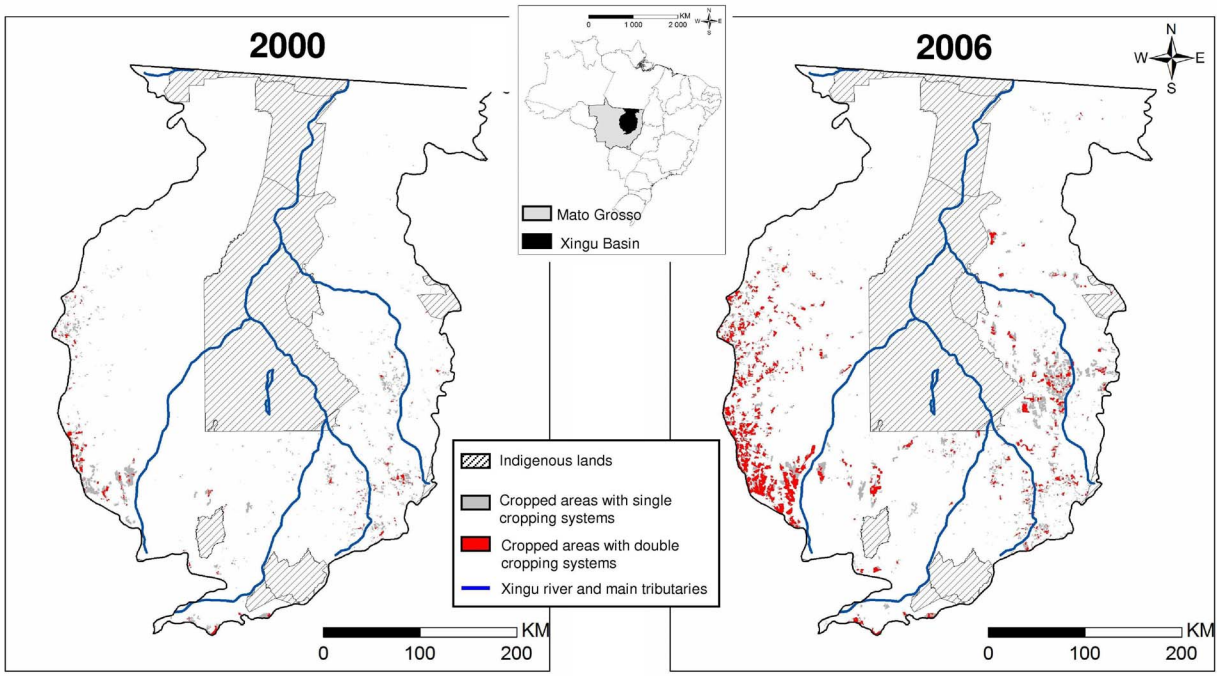


Figure 1 : Evolution of agriculture expansion and intensification in the Xingu basin between 2000 and 2006

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