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SPATIOTEMPORAL PATTERNS OF DEFORESTATION IN RESPONSE TO THE BUILDING OF THE BELO MONTE HYDROELECTRIC PLANT IN THE AMAZON BASIN

ORLENO MARQUES DA SILVA JUNIOR, MARCO AURÉLIO DOS SANTOS and LEONARDO SOUSA DOS SANTOS

SUMMARY

The environmental impacts caused by the construction of hydroelectric projects are repeated throughout the literature. When poorly planned, these projects can stimulate activities that degrade the environment and can cause or stimulate deforestation around reservoirs. This paper analyzes deforestation around the Belo Monte hydroelectric plant, in the state of Pará, Brazil. The patterns found show that deforestation had a sudden increase in the year of construction of the plant (2011), presenting an increasing pattern between 2012 to 2015. It was observed that deforestation was concentrated near roads and outside areas of restricted use. The increase in deforestation demonstrates the need to adopt instruments to minimize this impact, with the creation of areas with legal protection among them.

One of the most controversial infrastructure projects in the history of the Brazilian Amazon is the Belo Monte Hydroelectric Complex. The process for implanting the Belo Monte Hydroelectric (HPP) started in the 1970s and after some adjustments and corrections in the viability studies, the Environmental Impact Statement and its respective report (EIS/RIMA), it was presented to the Brazilian Environmental Agency, IBAMA, in July 2009, and in February 2010 the project received its Preliminary License (n. 342/2010) (Fleury and Almeida, 2012; Fainguelernt, 2016).

In April 2010, the public tender occurred and was won by the consortium formed of various companies with the majority participation of Eletrobras (Brazilian Electric Power Plants) and its subsidiaries, which subsequently created Norte Energia, a special purpose entity.

Construction began in July 2011, when the installation permit was obtained. Flooding of the reservoir began in February 2016 and the first turbine went into operation in April of the same year.

The construction of infrastructure works of hydroelectric plants cause a series of environmental impacts. There is a large amount of literature demonstrating that activities that cause deforestation are stimulated in areas with hydroelectric dams (Fearnside, 1985; Ledec and Quintero, 2003; Havel *et al*., 2005; Chakravarty *et al*., 2012; Stickler *et al*., 2013; Athayde, 2014; Chen *et al*. 2015; Garcia *et al*., 2015).

The core issue, however, lies in the difficulty in separating the portion of this deforestation that indirectly derives from the project and that which has other explanations. In this case, it is important to work with quantifications of deforestation levels before

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and after the beginning of the project, in order to try to verify how much this factor may have influenced the increase in deforestation indices.

The aim of this article is to analyze the spatiotemporal patterns of deforestation around the Belo Monte HPP between 2005 and 2015, and thus verify how deforestation occurs in the area around the HPP, located in the Brazilian Amazon, in the state of Pará.

Methodology

Study area

In order to estimate the extension of the region neighboring the reservoir, a radius of analysis was used as defined by Barreto *et al.* (2011), who estimated in the case of the Tucuruí hydroelectric dam that the influence of the project's construction occurs more intensely within a radius of 150km from the HPP (Figure 1).

In this area the population increase was 50% greater than in the rest of the state of Pará between 1950 and 2000, the period before and eight years after the conclusion of the first stage of the project, in December 1992. Belo Monte presents similarities to Tucuruí, such as proximity to major highways and it being a region with expanding occupation.

Systematizations of georeferenced data

The treatment and analysis of the set of data and georeferenced information on the study area were conducted using the Geographic Information System QGIS Desktop 2.8.1 and digital databases of the Project for Satellite Monitoring of Deforestation in the Amazon, PRODES, available from the National Institute for Space Research (INPE, 2015), and cartographic databases of the Brazilian Institute of Geography and Statistics (IBGE, 2015).

Thematic mapping

The vector data (Polygon/Area) from PRODES covering 2005 to 2015 were analyzed using spatial statistics and visual interpretation, considering the attribute values of all of the deforested areas and those presented by the polygon features from PRODES. After obtaining the digital data from PRODES containing the information of interest, an information blueprint corresponding to the study area limit (mask) was outlined, thus generating a new thematic vector database.

Based on the vector data on deforestation, the centroids of the polygons from Prodes were generated, creating a new point type vector database, which inherited the attributes of the polygons from 2005 to 2015. After obtaining the deforestation polygons, their densities within the study area were estimated by applying the Kernel density estimator present in Q.Gis 2.8. The Kernel density estimator outlines the circular vicinity around each sample point corresponding to the sphere of influence, and then a mathematic radius function is applied, from 1 at the position of the point to 0 at the boundary of the vicinity. The value for the cell is the sum of the overlapping Kernel values, divided by the area of each study radius (Silverman, 1986).

Based on the Kernel density, deforestation maps were created classifying levels of density that vary according to color and tonality.

Main Socioenvironmental Impacts and Dynamics of Soil Use and Occupation

Altamira, the main population center affected by the project, is a city that originated with the Jesuit missions in the XVII century and consisted of a typical riverside city until the the opening of major highways and colonization projects encouraged by the Brazilian government in the 1970s.

The opening of the Transamazonian highway is a major icon in the region's occupation. In the wake of the highway came colonization projects such as the Integrated Colonization Project (PIC), implemented by the National Institute for Colonization and Agricultural Reform in Brazil (INCRA; Miranda, 1990).

Since the 1970s, the area around the city of Altamira has been the hotspot for the occupation of this region in the state of Pará.

The constuction of the HPP was concentrated in two municipalities, Altamira and Vitória do Xingu, where the hydroelectric dam's main powerhouse is located. Altamira is the biggest city in the region and in 2010 had a population of 99,075 people. Vitória do Xingu had 13,431 inhabitants at the time (IBGE, 2010).

At the advent of the project it was estimated that the immigrant population could reach 96,000 people (Norte Energia, 2011). In 2015 the population estimates from IBGE indicated that Altamira had already reached 110,000 inhabitants, an increase of 15% in only five years, which put pressure on public services such as healthcare, led to increased violence and caused other impacts that are common with abrupt increases of residents.

There are considerable historic levels of deforestation around the Belo Monte project, which very much predate the project and are mainly linked to agricultural activity and colonization projects. The deforestation index in the area analyzed in 2010, one year before the start of the HPP's construction, had already reached 19%, according to data from PRODES/INPE (2010).

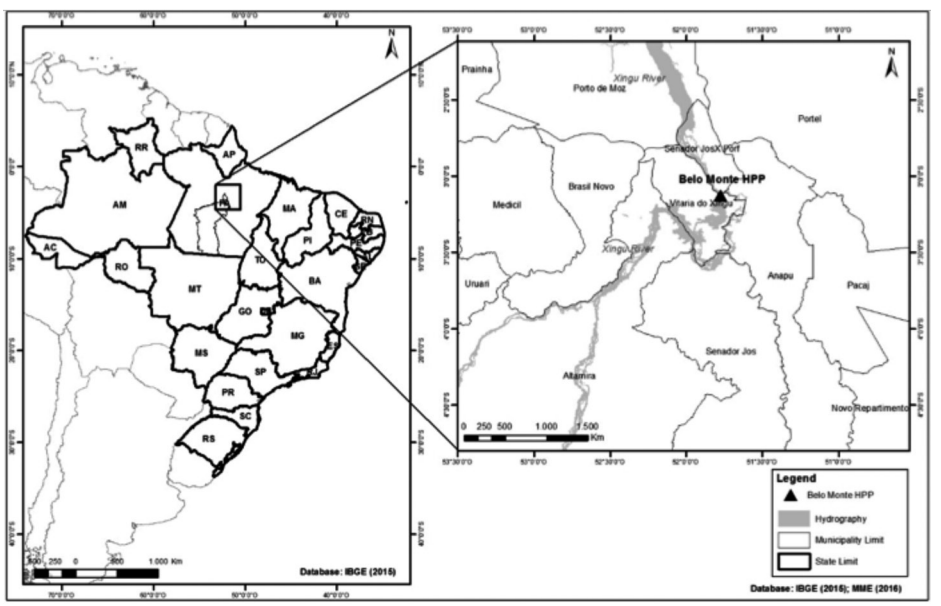

Figure 1. Study area.

Deforestation around Belo Monte between 2005 and 2015

By analyzing annual increases in deforestation between 2005 and 2015, it can be verified that in the period before the project (2005-2010) there was a variable tendency in deforestation, which started at a value close to 915km² in 2005 and reached a value of 343km² in 2009.

In 2005, the greatest areas of deforestation occurred along the Transamazonian highway between the cities of Anapu and Pacajá. This pattern varies between years but is always concentrated along the highways (Figure 2).

The deforestation rates rose again in 2010 (501km²) and reached a value close to 790km² in 2011, when construction of the HPP began. In this year, there is a greater concentration of points around the project, which spread out between 2012 and 2013, concentrating close to the HPP again in 2014 and 2015 (Figure 2).

Subsequently, a marked fall in deforestation is verified, but one which may not necessarily reflect reality, since according to the data from PRODES/INPE, in the period from 2012 to 2014 it was very difficult for the satellite images to detect deforestation in the Belo Monte region due to the considerable cloud cover that the satellites detected in this period.

In 2015, when the cloud cover was less intense, a 402km² increase in deforestation was detected. It is important to note that despite the intense cloud cover, the trend of deforestation around the HPP followed the pattern detected by INPE throughout the Brazilian Amazon, observing a growth in rates starting in 2012. These data are presented in Figure 3.

In 2010, the accumulated deforestation was 17,198.11km², with an increase of 1,771.55km² between 2011 and 2015, and total deforestation reaching almost 19,000km². Between 2011 and 2015 the increase in deforestation was a little greater than 10%, which results in an average increase of 2% a year.

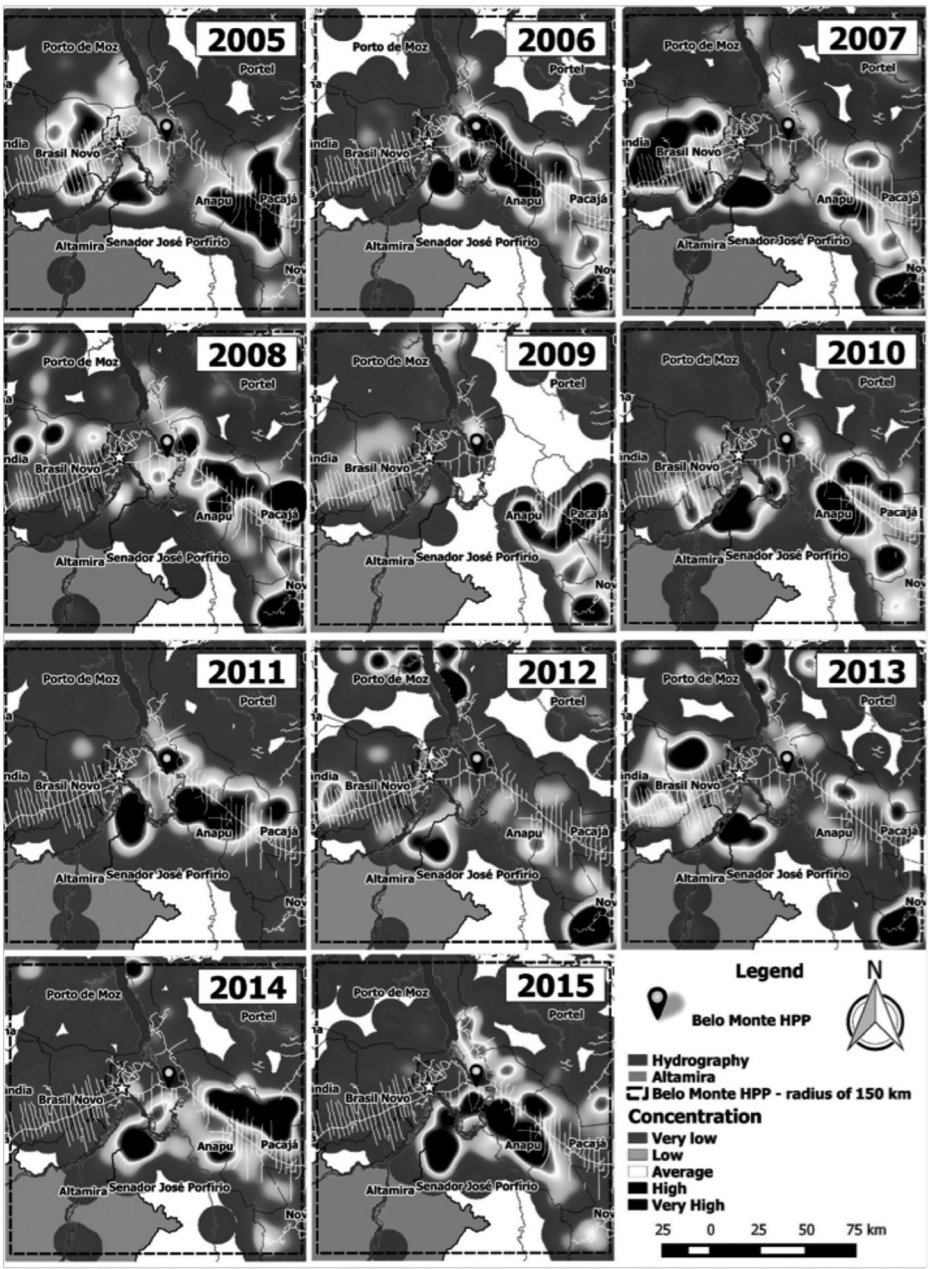

Figure 2. Spatial distribution of deforestation around the Belo Monte HPP (2005-2015).

Legal Instruments to Minimize Deforestation

One of the biggest concerns during the Belo Monte licensing process was the risk of deforestation, which could be exacerbated. Thus, in order to make viable the actions of the Basic Environmental Plan for the HPP, in 2010 Norte Energia commissioned a report, prepared by a team from the Institute for Man and Environment in the Amazon (Imazon), which aimed to meet the demands from IBAMA (the federal environmental licensing body) regarding the estimates of deforestation risks associated with the implantation of Belo Monte. One of the study's most urgent findings was the need to establish protected areas around the power station.

The creation of protected areas (PA) is an extremely positive measure, because they ensure, among other benefits, maintenance of germplasm and of water flow for human consumption (Medeiros *et al*., 2011), as well as natural resource conservation in general. In addition, the areas have been one of the pillars for deforestation reduction policy in the Amazon region (Ferreira *et al*., 2005; MMA, 2011; Veríssimo *et al*., 2011; Tabarelli *et al*., 2012; Nolte *et al*., 2013; Stickler *et al*., 2013; Cohn, 2014; Araújo

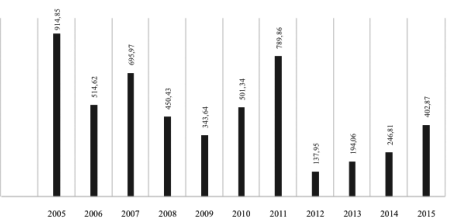

Figure 3. Evolution of annual deforestation around the Belo Monte HPP (km²).

and Barreto, 2015; Brandão Jr *et al*., 2015).

In 2010, the intense occupation of the region in which the hydroelectric plant was to be be constructed, and the absence of protected areas around it, were important factors considered in the licensing process. The lack of PAs around the plant aggravated the indirect deforestation caused by the project.

Thus, aware of the importance of protected areas in inhibiting deforestation, the Environmental Impact Statement of Belo Monte envisaged the implantation of PAs in two areas situated on the left bank of the Xingu river, enabling the formation of a continuous block of forests, with an area of ~1.6×10^6ha, close to the indigenous lands.

However, despite appearing in the Environmental Impact Statement and in the Basic Environmental Plan, up until the time the HPP came into operation in April 2016, none of the above mentioned PAs had yet been created.

There are around ten indigenous lands around the Xingu River, seven of which are affected in some way by the construction of the hydroelectric plant. According to the EIS/RIMA (IBAMA, 2016), the Paquiçamba and Arara da Volta Grande do Xingu indigenous lands are located in the area of direct influence and are affected by the reduction in the flow of the Xingu river.

The study by *Instituto Socioambiental* (ISA, 2015) shows the pressure exerted on indigenous land (IL) in the Xingu region. From 2011 to 2015, more than 633km of roads were built in order to illegally extract timber from the IL bordering Arara. The analysis showed that the roads are less than 20km from the Arara people's village.

Instead of protection and regularization, the data gathered by ISA indicate that the deforestation in the region is directly linked to the increase in immigration and illegal activities stimulated by the advent of the Belo Monte HPP.

The creation of restricted-use areas, such as IL and PA, is important as an aid to combat deforestation. However, in addition to the creation of these areas, it is important to give support to the already created areas that have resources for them to take care of their effective protection function.

Final Remarks and Recommendations

Evaluations must be made comparing activities carried out at the Belo Monte Hydroelectric Complex and the history of occupation around large hydroelectric dams constructed in the Amazon in the 1970s and 1980s.

The deforestation related to the Belo Monte HPP includes the opening of areas for the construction of the infrastructure of the project (roads, construction site, encampments, area for soil stocks, etc.) and for the reservoir. Another fact directly linked with deforestation is the increase of immigrants, which causes a rise in the demand for agricultural production and consequently stimulates the deforestation of new areas for food production.

For Belo Monte, it was shown that deforestation took place around the construction site, especially in areas without restricted use, and that this was facilitated by the absence of the state and lack of inspections.

The increase in deforestation in 2011 may be directly related to the start of construction of the hydroelectric plant, which shows the need for adopting instruments to minimize this impact.

The establishment of areas of restricted use, such as protected areas and indigenous lands, and/or inspection and monitoring in those already existing, are essential prerogatives for maintaining wild areas and restraining illicit and harmful activities.

Conservation and inspection work should be developed based on interaction between the company and IBAMA and the Institute for the Conservation of Biodiversity, ICMBio, improving discussions aimed at defining the priorities of actions both for selecting the space for Protected Areas to be created and implanted, and actions supporting and implanting existing PAs, which should receive investment in the form of environmental compensation.

Of the resources corresponding to environmental compensation for the project, in 2016 more than US$39 million was paid by Norte Energia, which should be invested primarily in PAs in the area of influence of the hydroelectric plant, both for implementation and for studies regarding the creation of new PAs.

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PATRÓN ESPACIO-TEMPORAL DE DESFORESTACIÓN EN RESPUESTA A LA CONSTRUCCIÓN DE LA PLANTA HIDROELÉCTRICA BELO MONTE EN LA CUENCA AMAZÓNICA

Orleno Marques da Silva Junior, Marco Aurélio dos Santos y Leonardo Sousa dos Santos

RESUMEN

Los impactos ambientales causados por la construcción de proyectos hidroeléctricos son recurrentes en la literatura. Estos proyectos, si están mal diseñados pueden conducir a la estimulación de actividades que degradan el medio ambiente y pueden causar o fomentar la deforestación alrededor de los embalses. En este artículo se hace un análisis de la deforestación que rodea la Planta Hidroeléctrica Belo Monte, en el estado de Pará, Brasil. Los patrones encontrados muestran que la deforestación tuvo un repentino aumento en el año de inicio de la construcción de la planta (2011), presentando un patrón ascendente entre 2012 y 2015. Se observó que la deforestación se concentró cerca de las carreteras y fuera de las zonas de uso restringido. El aumento de la deforestación demuestra la necesidad de adoptar instrumentos para minimizar este impacto, entre ellos la creación de áreas con protección legal.

PADRÃO ESPAÇO-TEMPORAL DE DESMATAMENTO EM RESPOSTA À CONSTRUÇÃO DA USINA HIDROELÉCTRICA BELO MONTE NA BACIA AMAZÔNICA

Orleno Marques da Silva Junior, Marco Aurélio dos Santos e Leonardo Sousa dos Santos

RESUMO

Os impactos ambientais provocados pela construção de empreendimentos hidroelétricos são recorrentes na literatura. Estes empreendimentos, quando mal projetados podem levar ao estímulo de atividades degradantes do meio ambiente e podem provocar ou estimular o desmatamento no entorno dos reservatórios. Este artigo fez uma análise do desmatamento no entorno da Usina Hidroeléctrica de Belo Monte, Estado do Pará, Brasil. Os padrões encontrados mostram que o desmatamento teve um aumento súbito no ano de início da construção da hidrelétrica (2011), apresentando um padrão ascendente entre 2012 a 2015. Observou-se que o desmatamento se concentrou próximos as rodovias e fora das áreas de uso restrito. O incremento no desmatamento mostra a necessidade de adoção de instrumentos para minimizar esse impacto, entre eles está criação de áreas com proteção legal.