ISSN: 2177-3246

CASE STUDY: ENVIRONMENTAL ASSESSMENT OF BELO MONTE HYDROPOWER PLANT

ESTUDO DE CASO: AVALIAÇÃO AMBIENTAL DA USINA HIDRELÉTRICA DE BELO MONTE

ESTUDIO DE CASO: EVALUACIÓN AMBIENTAL DE LA CENTRAL HIDROELÉCTRICA DE BELO MONTE

10.56238/revgeov17n4-222

Yasmim Kubrusly Provenzano[1]

ABSTRACT
The expansion of large-scale hydropower projects in the Brazilian Amazon has raised significant scientific and environmental concerns due to their extensive socio-environmental impacts. This study presents an integrated assessment of the environmental impacts associated with the Belo Monte Hydropower Plant, located in the Xingu River basin, Pará State, Brazil. The analysis encompasses physical, biotic, and socioeconomic components, based on secondary data from official reports and peer-reviewed literature. Impact evaluation was conducted using criteria of spatial scale, temporal duration, and reversibility, supported by a structured environmental valuation framework. Results indicate that the most significant impacts are related to hydrological regime alteration, habitat loss, ecosystem fragmentation, and population displacement. The reduction of river flow in the Volta Grande do Xingu is identified as a critical driver of ecological degradation. Socioeconomic effects include unplanned urban growth, increased pressure on infrastructure, and disruption of traditional livelihoods. Overall, the findings reveal a predominance of high-magnitude, long-term, and largely irreversible negative impacts, highlighting the need for improved strategic environmental planning and more robust impact assessment approaches in large-scale infrastructure projects in ecologically sensitive regions.

Keywords: Hydropower. Environmental Impacts. Belo Monte. Xingu River. Habitat Loss. Ecosystem Fragmentation. Hydrological Alteration. Population Displacement. Environmental Assessment.

RESUMO
A expansão de projetos hidrelétricos de grande escala na Amazônia brasileira tem gerado preocupações científicas e ambientais significativas devido aos seus extensos impactos socioambientais; este estudo apresenta uma avaliação integrada dos impactos ambientais associados à Belo Monte Hydropower Plant, localizada na bacia do Xingu River, no estado do Pará, Brasil; a análise abrange componentes físicos, bióticos e socioeconômicos, com base em dados secundários provenientes de relatórios oficiais e literatura revisada por pares; a avaliação dos impactos foi conduzida utilizando critérios de escala espacial, duração

[1] Environmental Engineer. Master's candidate in Urban Engineering. Universidade Federal do Rio de Janeiro (UFRJ). E-mail: yasmim.kubrusly@poli.ufrj.br

temporal e reversibilidade, apoiada por um framework estruturado de valoração ambiental; os resultados indicam que os impactos mais significativos estão relacionados à alteração do regime hidrológico, perda de habitat, fragmentação de ecossistemas e deslocamento populacional; a redução da vazão do rio na Volta Grande do Xingu é identificada como um fator crítico de degradação ecológica; os efeitos socioeconômicos incluem crescimento urbano não planejado, aumento da pressão sobre a infraestrutura e interrupção de modos de vida tradicionais; de modo geral, os achados revelam a predominância de impactos negativos de alta magnitude, de longo prazo e, em grande parte, irreversíveis, destacando a necessidade de um planejamento ambiental estratégico mais eficaz e de abordagens mais robustas de avaliação de impactos em projetos de infraestrutura de grande escala em regiões ecologicamente sensíveis.

Palavras-chave: Hidrelétricas. Impactos Ambientais. Belo Monte. Rio Xingu. Perda de Habitat. Fragmentação de Ecossistemas. Alteração Hidrológica. Deslocamento Populacional. Avaliação Ambiental.

RESUMEN
La expansión de proyectos hidroeléctricos de gran escala en la Amazonía brasileña ha generado importantes preocupaciones científicas y ambientales debido a sus extensos impactos socioambientales; este estudio presenta una evaluación integrada de los impactos ambientales asociados a la Belo Monte Hydropower Plant, ubicada en la cuenca del Xingu River, en el estado de Pará, Brasil; el análisis abarca componentes físicos, bióticos y socioeconómicos, basado en datos secundarios provenientes de informes oficiales y literatura revisada por pares; la evaluación de impactos se llevó a cabo utilizando criterios de escala espacial, duración temporal y reversibilidad, apoyada por un marco estructurado de valoración ambiental; los resultados indican que los impactos más significativos están relacionados con la alteración del régimen hidrológico, la pérdida de hábitat, la fragmentación de ecosistemas y el desplazamiento de poblaciones; la reducción del caudal del río en la Volta Grande do Xingu se identifica como un factor crítico de degradación ecológica; los efectos socioeconómicos incluyen crecimiento urbano no planificado, aumento de la presión sobre la infraestructura y la interrupción de los medios de vida tradicionales; en general, los hallazgos revelan un predominio de impactos negativos de gran magnitud, de largo plazo y en gran medida irreversibles, lo que resalta la necesidad de una mejor planificación ambiental estratégica y de enfoques más sólidos de evaluación de impactos en proyectos de infraestructura a gran escala en regiones ecológicamente sensibles.

Palabras clave: Hidroelectricidad. Impactos Ambientales. Belo Monte. Río Xingu. Pérdida de Hábitat. Fragmentación de Ecosistemas. Alteración Hidrológica. Desplazamiento de Población. Evaluación Ambiental.

1 SCOPE AND APPROACH

The scope of this project is analysing the impacts of a hydroelectric power plant located in the state of Pará in the Northern region of Brazil, at the coordinates 3º7'34.7" to the South; 51º45’52.8’’ to the North. This plant was built in the Xingu river basin, close to the municipality of Altamira. The work is divided into activities from the project, baselines with detailed discussions about physical characteristics, biota, social and economic issues, effects caused by the project and the potential measures to mitigate these impacts.

The Feasibility Studies for this construction were concluded in 2002. The Brazilian National Congress authorized, in 2005, the Eletrobrás - Centrais Elétricas Brasileiras S/A - to complete and update these studies. The construction of a hydropower plant caused both negative and positive effects, and it was necessary to study the physical environment (climate, water quality, mineral resources mineral resources and geology, among others), the biotic environment (plants and animals), the socioeconomic environment (economic activities, historical and cultural heritage, health, education, among others) and the communities.

With the growth of the country, the energy demand has also increased, so it was necessary to develop projects to meet the demand for energy. The Belo Monte power plant project has a capacity of 11,233.1 MW. It will have a main reservoir on the Xingu River, about 40 kilometers downstream from the town of Altamira in the Pimental site. The water will be diverted from this reservoir by channels to Canals Reservoir, located 50 kilometers from Altamira city.

2 PROJECT AND ACTIVITIES

The Belo Monte hydropower plant began construction in 2011 on Xingu River in the Brazilian Amazon. It consists of a main barrage, 40 km downstream from the city of Altamira, at the Pimental site, a second barrage at Bela Vista, a main power house, situated in the Belo Monte community, two derivation canals and several dykes. The Belo Monte reservoir is planned to have 516 km2 of flooded area. It will require excavations of 150.7 million m3 and 50 million m3 of rock, requiring the use of 4.2 million m3 of concrete.

Once completed, it is estimated that Belo Monte will have the potential to produce up to 11,200 MW, making it the third largest hydroelectric power station in the world by installed capacity. Under the responsibility of the federal government's Ministry of Mines and Energy and executed by the Norte Energia consortium, Belo Monte has 18,000 workers on four construction sites.

Considering the complexity of the project and meeting the requirements of the environmental institutions, the construction effectively began in 2013, and in 2015 the operating license to fill the reservoirs was obtained. In 2016 the project was inaugurated and 2019 began full operation with all turbines. The turbine start-up also marked the official inauguration of the enterprise, which will be able to operate with a total capacity of 11,233.1 megawatts (MW) and an average power generation quantity of 4,571 MW.

3 LOCAL CHARACTERISTICS

3.1 SOIL

The basin includes a part of ten major relief units, which were differentiated based on data from the IBGE (1993) and the RADAMBRASIL Project (1981 and 1982). From upstream to downstream, it occurs: Guimarães Plateau / Alcantilados, Upper Araguaia Depression / Tocantins, Paranatinga Depression, Parecis Plateau / Upper Xingu, Southern Amazon Depression, Southern Amazon Residual Plateaus, Amazon Marginal Plateau, Amazon Depression, Amazon Fluvio-lagoon Plain and Fluvial Plains.

The Xingu River and its tributaries cut through crystalline basement rocks and Paleozoic, Mesozoic and Cenozoic sedimentary rocks, which constitute units of different ages. Conditioned by different rocks and reliefs, the Xingu River Basin has the following types of soils: Yellow Latosols, Red-Yellow Latosols, Red-Yellow Ultisols, Red Argisols, Litholic Neosols and Rocky Outcrops, Quartzarenic Neosols, Petric Plintosols and Gleysols.

3.2 HYDROLOGY

The Xingu River is born in the state of Mato Grosso, formed by the Culuene and Sete de Setembro rivers, which, in turn, are born in the Roncador mountain range at an altitude of about 800m and 500m, respectively, and flows into Porto de Moz, in Pará. Its total extension is about 1,815 km and its main tributaries are the Iriri, Curuá, Bacajá, Fresco, Suiá-Miçu, Liberdade, Ronuro, Manissauá-Miçu, Ferro, Cuvisevo and Comandante Fontoura. Its contribution basin has a total area of approximately 509,000 km² and has an elongated shape, with a maximum width of 550 km, developing in a south-north direction, from parallels 15º to 1º, until it flows into the Amazon River.

In addition to the Xingu River itself, another important river in this area is the Bacajá, which meets the Xingu in the Volta Grande section. From the Bacajá river until near the meeting with the Iriri river, the Xingu flows more slowly, with the formation of several islands and boulders: blocks of rock important for some animals, such as bats, and some types of fish, such as acaris.

In the dry season, the amount of water that flows in the river is much smaller than in the high season (on average it is less than 5 percent of the amount of water that normally flows through the Xingu River in the rainy season).

3.3 CLIMATE

According to the Köppen classification, the climates that predominate in the Xingu River basin consist of Am and Aw. The Am climate is hot and humid, with average annual precipitation between 1,800 and 2,500 mm, low annual thermal amplitude and average temperature of 25ºC. The Aw climate has an average annual rainfall of 2,000 mm, dry winter and maximum rainfall in summer, with an average annual temperature of 22ºC (CLIMATE-DATA). The following topics will further detail the temperature, humidity and precipitation aspects of the entire Xingu River basin.

3.4 TEMPERATURE

Due to its geographical position close to the Equator and its low altitudes, the basin is characterized by a warm climate, with the highest temperatures occurring from August to December. The maximums are not excessive, due to the strong relative humidity and the intense cloudiness. On the other hand, in the coldest months, June to July, the average temperature is hardly below 24 °C. In particular cases, when the continental polar air invades, the absolute minimums can reach 8 ºC. In the region of Altamira and Porto de Moz, the lower part of the basin, the average temperature during the year is between 25.4ºC and 27.3ºC, with minimums in February and maximums in October. As an indicator of the average stretch, there is the locality of São Félix do Xingu. In this one, in a more southern position and at a higher altitude than the lower section, the monthly averages are between 24.6ºC (minimum in July) and 25.4ºC (maximum in September). For the upper part of the basin, the average temperature is 25.2ºC, with the minimum occurring in May with values around 24.4ºC. Maximums usually occur from February with values between 27.0ºC and 28ºC.

3.5 HUMIDITY

In the lower part of the basin, both at the latitude of Porto de Moz and Altamira, the relative humidity curve grows from November to April-May, ranging from 83% to 89% and 79% to 88%, respectively. Between June and October it reduces up to 82% in Porto de Moz, and between May and October up to 78% in Altamira. Characterizing the middle section of the basin, São Félix do Xingu shows a slight change in the relative humidity curve in relation to the lower section, with maximum in January (89%) and minimum between July and August

(81%). In the upper section of the basin, the relative humidity is slightly below the average section, with maximums in January/February (80% and 83%) and minimums in August/September (60.7 and 64.5%).

3.6 PRECIPITATION

In the Xingu River basin, the precipitation increases in the direction of its development, from upstream to downstream, ranging from 1,500mm near the source to 2,600mm at the mouth. The average annual rainfall in the basin is around 1,800 mm.

Throughout the year, the basin presents a well-defined seasonality. The rainy season, from the headwaters of the river to the upper middle part of the basin, comprises the months from December to March; in the middle range of the basin to the lower course, the rainy season lasts from February to May. Thus, it is clearly noted that, between the headwaters and the lower course, the rainy season is delayed by about one or two months. This fact favors the occurrence of large outflows in the medium and low courses. The discharges that occur in these stretches, in the period from February to April, come from the surface runoff of the rains that reach the lower middle segment of the basin and from the runoff from the precipitations from one to two months before, in the upper and upper middle parts. It is also worth mentioning the large accumulation in the river channel itself and in the adjacent marginal lowlands, which has great effects on the dampening of the floods and their transit time along the main channel of the Xingu River.

3.7 BIOTA

The Xingu River basin is predominated by the Amazon biome and a small part by the Cerrado biome. Cerrado is structurally simpler than forest formations such as Amazon and it contains a flora largely endemic. In the study area, the hydrographic characteristics is an important intervening factor in diversity. Interfluvial environments on "terra firme" areas and flooded environments create humidity gradients to different species of plant and animal increasing the diversity among habitats (AMARAL, 1996 apud NELSON; OLIVEIRA, 2001).

Due to the high diversity of the area, in this work we will only indicate some of the species that can be found in the basin. In the basin were identified a list of endangered species, vegetations such as: pau-de-rosa, pau-amarelo, cravo-do-maranhão. Birds: ararajuba, andarilho, jacu-de-barriga- -castanha. Mammals: lobo-guará, cuxiú-preto, tamanduá-bandeira. Reptiles: Tropidurus, cágado.

There are about 440 species of birds and some are endangered: red arara, Ararajuba, etc. 259 species of mammals such as: Guariba, Prego and Cuxiú, and 174 species of reptiles and amphibians, such as frogs, lizards, tracajás, snakes and caimans. In the aquatic environment botos and peixes-boi are found in the final stretch of the Xingu River, below the site of the future main power house future powerhouse of the Belo Monte AHE. Amazon river zone is the region where the Amazon turtle lays its eggs. Pirarucu, Piramutaba and Dourada are species of fish that only occur in this zone.

3.8 SOCIOECONOMIC

3.8.1 Population

As the Xingu River is a river that encompasses 2 large states of Brazil (Mato Grosso and Pará), the amount of indigenous territories dependent on it is gigantic. Among the indigenous tribes existing from the head of the river to the mouth, 20 peoples can be mentioned, according to Table 1.

Table 1

Indigenous tribes existing on Xingu River

Indigenous tribes	
Capoto de Arinã	Suiá
Kayapó	Trumai
A'uwe	Ikpeng
Xavante	Panará
Mebêngôkre	Nafutkua
Yudjá	Tapayuna
Juruna	Yawalapiti
Kawaiwete	Waurá
Kaiabi	Mehinaku
Kisêdjê	

However, for the purpose of studying environmental impacts, only the indigenous reserves closest to the area of influence of the Hidropower were considered, among them are:

- Indigenous Land Paquiçamba
- Indigenous Land Arara da Volta Grande do Xingu
- Indigenous Land Juruna do km 17
- Indigenous Land Trincheira Bacajá
- Indigenous Land Arara

• Indigenous Land Cachoeira Seca
• Indigenous Land Kararaô
• Indigenous Land Koatinemo
• Indigenous Land Araweté/Igarapé Ipixuna
• Indigenous Land Apyterewa

In view of these territories of direct and indirect influence, the National Indian Foundation (Funai) pointed out the need for more detailed studies for the Paquiçamba and Arara Indigenous Lands of Volta Grande do Xingu, and for the Juruna Indigenous Area at km 17 because the Paquiçamba and Arara Indigenous Lands of Volta Grande do Xingu are in the Direct Influence Area (DIA), being affected by the reduction in the flow of the Xingu River. And because the Juruna Indigenous Area at km 17 is on the margins of Highway PA-415 and, therefore, should be influenced by the increase in traffic on this road. These Indigenous areas form what Funai called Group 1 for the studies of Belo Monte hidropower. Group 2 is formed by the other 7 ILs, which form a continuous block of indigenous lands.

In addition to these Indigenous Lands and Areas, there is also the population of the municipalities of Altamira and Vitória do Xingu who live on the banks of the river, in the stretch to be affected by the Belo Monte hidropower.

3.8.2 Agriculture and extraction

In IIA (Indirect Influenced Area), most of the economic activities is on to agriculture and extractivism vegetable. The sum of everything that is produced by the eleven municipalities, called the Internal Product Gross (GDP), corresponded to approximately 3 percent of everything that was produced in Pará in 2005.

It has large properties (with more than 10 thousand hectares), which occupy 30 percent of rural areas. The small and medium properties (between 100 and 500 hectares) occupy 70 percent of rural areas.

Family farming is the basis of the local economy and has its origin in riverside agriculture and in traditional extractive activities (rubber, Brazil nuts). In the 1970s and 1980s there was an increase in these activities because of the colonization projects of the federal government.

Besides that, cocoa is IIA's main culture. The municipality of Medicilância is the largest producer in the state of Pará and the second in Brazil. Coffee, pepper, banana and coconut are other crops found, in addition to cassava, rice, corn and beans, which form the food base of the region.

Livestock occupies a large part of the land, about four times more than the areas that are occupied by crops. The municipality of Altamira is the fourth largest cattle raiser in the State of Pará

Forest areas are also used for economic activity, such as plant extraction, which combines traditional activities, such as the extraction of Brazil nuts and açaí, with others with a great environmental impact, such as logging. About 10 percent of the extraction in the state of Pará is made in the IIA from Belo Monte plant, with high production of firewood and wood in logs.

3.8.3 Services and Industrial sector

The industrial activities are small. They are more linked to agricultural production (such as pulp separation, grain milling and animal slaughter) and, mainly, to companies dedicated to the transformation of wood into products that can be sold and to mineral extraction, mostly located in Altamira.

Commerce and the provision of services are formed by small businesses, many of which are family-owned. Retail trade (food, beverages and personal items), restaurants, pensions, bars and small hotels are in greater number in the region.

Services related to the extractive industry and agriculture and livestock are also present, such as trade and repair of machinery and equipment, sale of seeds and agricultural inputs.

Only Altamira has a more varied set of services, such as banks, colleges, hospitals and government representatives, such as INSS, Public Prosecutor's Office, State Departments and others.

Infrastructure, in general, is weak, as well as public education and health services. Getting around the region, or even getting to other places, is difficult, even on the Transamazonian, which is not paved.

During periods of rain, it is often not possible to go through the crossbars. For this reason, the Xingu River and its tributaries are very important to the population, as navigation on the river is the most used form of transport, including cargo transport.)

The distribution of electricity in IIA, as well as in the entire State of Pará, is carried out by “Centrais Elétricas do Pará S.A.” (Celpa). The transmission networks (lines) that depart from the Tucuruí HPP reach the IIA at the Altamira, Transamazônica and Rurópolis substations.

Connexion to the Network (Power, Water, and Wastewater)

In the municipalities of Gurupá and Porto Moz, distributed energy is produced on site, in isolated systems, as there are no network branches that allow the service to be connected to the SIN (National Interconnected System).

In the rural areas of IIA, the population uses wells, springs and rivers. Sewage is usually dumped into black pits. At municipal headquarters, water supply systems reach a very small number of homes.

About 23 percent of homes do not have sanitary facilities, only 13 percent have septic tanks, and only 1 percent of sewage is collected by sewerage or drainage.

3.8.4 Non-economic activities

The number of associations is also large: rural family home associations, community radios and various associations of farmers, workers and the defense of women's rights. At IIA there are also religious institutions, in addition to academic and legal entities

With regard to the cultural heritage of the IIA, one cannot fail to mention the archaeological sites, which are places or camps where ancient people left signs of their passage over time.

3.8.5 Evolution

If the project were not carried out, it is likely that the local characteristics would remain the same or at least similar over the years. However, some changes due to deforestation, climate change and cultural changes could happen. As such changes were not considered in the environmental impact report studied, the impacts assessed in the following section will be measured according to the original characteristics of the area.

4 IMPACT ASSESSMENT

The Belo Monte hydropower plant would provoke many environmental changes in the region of Xingu River and also in people's lives. There will be changes in the landscape, in the river water behavior, in the fauna and vegetation, in society and in economics. The Table 2 shows the identification of the major impacts and the project phases they will occur. Subsequently, these impacts will be further detailed below.

Table 2

Impacts identification

Environmental factors		Physical						Biodiversity			Socioeconomic												
Impacts to be assessed		Landscape change	Change in basin runoff	Change in water quality	Drainage change	Climate change	Affectation of geological resources	Vegetation destruction/affectation	Fauna destruction/affectation	Changing fish species and types of fishing	Generating expectations in the local population	Disorderly population growth	Changes in accesses	Job creation	Lack of fish for food	Lack of sanitation	Eviction with low compensation	Increase in energy production	Unsatisfactory performance	High electricity bill	Political conflicts	Cultural change	Damage to archaeological heritage
Project phase	Design										x												
	Construction	x	x	x	x	x	x	x	x	x			x	x	x	x	x			x	x	x	x
	Operation	x	x	x	x	x	x	x	x	x		x	x			x		x	x	x	x	x	x
	End of life	x	x	x	x	x	x	x	x	x			x			x				x	x	x	x

4.1 PHYSICAL IMPACTS

The physical impact most easily noticed is the landscape changes caused by the earth moving that occurs during the works and construction of the hydropower plant main structures. For this, it is necessary to use borrowing areas, quarries and sand deposits. In addition, the excavations generate a large amount of material that must be placed in appropriate places, often in areas close to the canals, further affecting the local landscape.

The large earth movements, combined with the removal of vegetation, can cause landslides and erosion, affecting the fertility and quality of the local soil. Where this happens, the land can be dragged to the nearest streams, causing silting and changing the quality of the waters, which will become darker and with more sediments. This could negatively affect aquatic species that are not resistant to changes in water quality, and even cause the death of fishes, which also affects local fishing activity.

Another expected impact is linked to the interruption of the streams of the Canals Reservoir, due to the construction of the dikes. The fish that live in these streams, and that depend on the plains that will be flooded, will suffer negative consequences, even the disappearance of species.

An impact linked to the loss of mineral resources in the region is the clay deposits existing in the floodplains and in the alluvium of the Ambé and Panelas creeks, in Altamira. They used to be exploited during the dry season (7 months of the year) and would be permanently flooded with the filling of the Xingu Reservoir.

With the formation of this reservoir, the water levels in the Altamira streams increase up to a height of 100 m, while the water velocity decreases. These changes, together with the amount of untreated sewage that is released into its waters, can cause a worsening in the water quality of the streams, and favor the growth of aquatic plants, harming fish and water use. In addition, the formation of this reservoir will take 16,420 people to be moved.

The water quality of the Canals Reservoir can also be harmed because the depth of the reservoir is large and because it will form some lateral areas of inundation where the water will be more still. In addition, existing vegetation could rot after being flooded, further affecting the water quality of the reservoir.

During the operation of the Belo Monte Hydropower Plant, the stretch of the Xingu River between the Sítio Pimental dam and the main powerhouse will suffer a reduction in the volume of water, especially in the years when it rains less. This is because part of the waters from the Xingu Reservoir will be diverted to generate energy in the main powerhouse. This stretch of the Xingu River is 100 km long along its central channel and has very important environments for fish and terrestrial fauna.

The interruption of some streams, construction of dikes and formation of reservoirs will affect the drainage of the basin as a whole, and may also influence the local climate. Decreasing the volume of runoff from the river will increase the scarcity of rain, which can even impair the efficiency of the plant.

4.2 BIODIVERSITY IMPACTS

The Amazon basin concentrates the largest aquatic biodiversity on the planet, with 16% of the planet's freshwater fish species. Just under half of the 2,411 species described are endemic, i.e. they do not exist anywhere else. The Xingu River is the largest supplier of clear water. Because of these particularities, the project is very complex and difficult as it has to deal with the various possible impacts on the fauna and flora.

Impacts related to the loss of vegetation and natural environments, increase of noise and dust with fauna disturbance, loss of extractive resources, among others mentioned throughout the work, can be expected from the project. At the beginning of the construction, studies estimated 27426 km2 of deforested area, and a total flooded area of 516 km² (França, F.G., 2016). Other authors believe that the dams would form a reservoir with a net surface area of 440 km2 (Reid et al, 2005).

The construction of hydropower plants interferes with ecosystems. When very intense, the loss and fragmentation of terrestrial habitats can cause population depletions of fauna and flora, with the possibility of local extinction of species including those species considered rare, endemic and/or threatened with extinction.

The study of the environmental impacts are divided into: the areas farthest from Belo Monte (Indirect Influence Area-IIA), the neighboring areas (Direct Influence Area-DIA) and the construction/reservoir areas (Directly Affected Area-DAA). A fauna and flora diagnosis of each small study area and possible species impacted by the project will then be carried out.

4.3 INDIRECT INFLUENCE AREA - IIA

It is considered IIA the mouth Xingu River, in the Amazon River, until Iriri river. This area corresponds to 5% of the hydrographic basin of the Xingu river. In IIA, flora and fauna due to geography, soil and local climate, are divided into: dryland forest, alluvial forest and vegetation associated with stones. These different ecosystems will be described below.

Dryland Forest: Forest with high biodiversity in trees, some with important economic value, such as mahogany, Brazil nut, Maçaranduba, ipê and Cedar, which can reach heights of over 50 meters. There are also palm trees and lianas, as well as plants with wide, long leaves, such as heliconias and wild banana trees. As they are located in areas of higher altitude they are not at risk of flooding. However, this ecosystem is the most affected by deforestation for subsistence farming and pasture.

Alluvial Forest: It is directly influenced by the rivers and floods, the duration of the flood (generally from March to June). The forest is popularly called Várzea Forest. The height of the trees ranges from 25 to 30 meters. In the Alluvial Forest may find samaúma, andiroba, munguba, ucuúba, among others.

Vegetation associated with rocky areas: this vegetation grows on the rocks of the river Xingu and Iriri rivers. Formed mostly with herbs and shrubs with fixed roots in the cracks and faults of the rocks. In these places there are various shrubs of camu-camu, acapurana and araçá. Also part of this vegetation are other plants typically known as water lettuce. Over the last few years, the native vegetation in the region has been removed due to deforestation and environmental degradation.

4.4 DIRECT INFLUENCE AREA - DIA AND DIRECTLY AFFECTED AREA - DAA

Vegetation of DIA and DAA are similar to IIA. Deforestation and hunting over the last 30 years has resulted in remaining small patches of forest and death of larger mammals such as tapirs, monkeys, and deer. Also there is a wide biodiversity in reptiles and amphibians and it suffers from trafficking for the trade of animal skins.

The group of animals present in DIA and DAA are typical of the south-eastern region of Amazon. Studies estimated 31 species of large and medium-sized mammals such as: tapirs and capybaras, 64 species of bats, total of 79 species live on “terra firme” forest and 22 in alluvial forests, such as: bico-de-brasa, pica-pau-anão, arapaçu-bicudo.

The flooded areas in DIA and DAA are important for frogs, toads and frogs and toads, which spend life in the water. In DIA there is also some species of alligators: jacaré-coroa and jacaré-tinga for example. All 3 areas have similar vegetation, Xingu River acts as a barrier for some birds, some reptiles and amphibians and some mammals, especially monkeys: cuxiú-de-nariz-branco.

Finally, the Amazon basin concentrates the largest aquatic biodiversity on the planet, with 16% of the planet's freshwater fish species. Just under half of the 2,411 species described are endemic, i.e. they do not exist anywhere else. The Xingu River is the largest supplier of clear water. Because of these particularities, the project is very complex and difficult as it has to deal with the various possible impacts on the fauna and flora.

Impacts related to the loss of vegetation and natural environments, increase of noise and dust with fauna disturbance, loss of extractive resources, among others mentioned throughout the work, can be expected from the project.

4.5 SOCIOECONOMIC IMPACTS

With 80% of the Xingu River diverted, the reduction of the flow of the River, especially in the section of the big turn, is one of the biggest concerns of the populations dependent on the River. The waters of the Xingu are used for several purposes, including fishing, agriculture, drinking water, recreational, among others. The most alarming consequences related to this decrease in river flow are the decrease in fish in the river. As reported by the local fishermen themselves, Rio has its own seasonality, with periods of flood and drought, and for each period there is a type of species of fish that develops best. With the installation of the Plant, the variation of the river's flow will be made much more abruptly, without allowing the fish to adapt to the river's new routine. In addition, with the reduction in the flow of the river in the Volta do Xingu, it is expected a great death of fish that are used to feed the local people. To meet this nutritional demand, some indigenous tribes have reported that hunting in the forest will need to be increased.

In addition to the food consequences, another factor of great local revolt was the need to evict residents close to Rio. More than 20,000 displaced people were registered, including 7,000 indigenous people from 12 ethnic groups. The company Norte Energia, responsible for the work, was obliged to compensate these people by offering them a new home. However, the riverine people reported that in addition to the compensation being much lower than the amount they considered fair, they were still removed to areas far from the river called collective urban resettlements (they spend about R$60 in transport to get to the river), impacting their entire Lifestyle. As for the indigenous people, many tribes broke up into smaller villages, as compensation was paid per village, which had an impact not only on their lifestyle, but also on their culture.

ISSN: 2177-3246

Another noticeable impact was the unsustainable growth of the city of Altamira. For the construction of the plant, a huge workforce was needed, which made a city of 77,000 inhabitants (IBGE, 2000) receive at least 20,000 new residents. The workers hired by Norte Energia, in addition to receiving a low salary, were also required to stay in the accommodation for 6 consecutive months, having the right to visit the family only once a year. In addition, the company's housing costs were extremely high. “To participate in the recreation area, you should pay R$30, to buy a coca cola you pay R$7, when outside the accommodation it is only R$4”. Because of so many variations in the region, local psychologists say mental health is a major concern. Another significant fact is related to the increase in violence rates since the beginning of the plant's construction project. In 2017 it was considered the most violent municipality in Brazil, when 10 years earlier it was not even on the list of the most violent cities. in its 4 sectors, water supply, sanitary sewage, urban drainage and solid waste collection. This promised change was not realized and there was an increase in flooded areas, stagnant water and diseases derived from these problems.

As if these negative points were not enough, another point of high questioning is related to the installed capacity of the plant. It says it has an installed capacity of 11,233MW, however, due to the drought regime, the annual average will be only 4,571MW. The firm energy of this mega enterprise will be lower than the Brazilian average. And its main destination will be electro-intensive industries (which employ few people). The local population pays one of the most expensive electricity bills in Brazil, despite having the plant in their territory.

Due to the large amount of socio-environmental consequences, the construction of the Belo Monte Plant generated several controversies, conflicts and popular demonstrations. There were so many provocations that the minister of mines and energy, Edison Lobão, even referred to the indigenous people as “demonic forces are preventing the construction of the plant”. Also through indigenous efforts, they managed to change the name of the plant, which was previously called kararaô (indigenous war cry), as they were against giving such a meaningful name to something that could be the end of their way of life.

5 ASSESSMENT

According to the identified and detailed impacts, evaluation criteria were created so that it was possible to identify the most relevant impacts. These criteria took into account the spatial scale, time scale and reversibility.

Spatially, a larger affected area leads to a greater significance of the considered activity. Thus, the construction works, mainly excavation, deforestation and flooding, are those that have the largest environmental impacts.

On the time scale, the duration of the impact is considered, which can range from days to decades. Thereby, the impacts caused by the plant's operating activity are the most extensive, since it has a useful life of at least 20 years.

In terms of reversibility, it is taken into account whether the impact is permanent or reversible. In this way, the impacts related to construction, which affect the physical environment and biodiversity permanently are those with the largest relevance.

In these three aspects, a scale was created that goes from -5 to +5, where -5 represents a high negative impact, capable of destroying a natural resource, and +5 represents a high positive impact, in which something very significant is created for the society. The Table 3 shows the values assigned to each project activity within this scale, considering the three aspects mentioned.

Table 3

Impacts assessment

Activities	**Environmental factors**										
	Physical				**Biodiversity**			**Socioeconomic**			
	Landscape	Hydrology	Climate	Geology	Vegetation	Fauna	Acoustic	Job creation	Cultural heritage	Energy	Soil use conflicts
Field studies and services								3			
Mobilization and hiring of manpower								4			
Properties acquisition											-5
Excavation and construction of roads and main structures	-3	-2	-1	-3	-3	-2	-2				
Demobilization of manpower								-4			
Deforestation and cleaning of reservoir	-3	-3	-3	-2	-5	-5	-2				

areas											
Flooding of areas for reservoir formation	-3	-5	-3	-3	-4	-4			-5		
Generation and transmission of energy								2		4	
Reduction in the water volume of Xingu River		-3	-2			-3					

Through Table 3, it can be seen that the activities that cause the biggest number of impacts and those with the largest relevance are “excavation and construction of roads and main structures”, “deforestation and cleaning of reservoir areas” and “flooding of areas for reservoir formation”. These three activities are closely linked to the construction phase and their stakeholders are mainly those responsible for the project and the population that will be affected by changes in physical and biodiversity aspects, such as hydrographic changes, impacts on fisheries and climatic changes. It is also worth mentioning the stakeholders of the “properties acquisition” activity, which affects the people who would need to be moved to build the dam, including the indigenous population.

6 CONCLUSION AND POTENTIAL MEASURES

In 2020, the Brazilian court recognized the construction of the Belo Monte hydroelectric plant as an ethnocide. The river flow decreased, some fish species are scarce in the region, there was a record of a disorderly population increase and therefore, without adequate infrastructure and basic sanitation, in addition to a great dissatisfaction of the local peoples. As the impacts of the Belo Monte hydroelectric plant can be observed at physical, biological and social levels, actions are needed to minimize its consequences. Even before these actions, a strategic environmental assessment should have been carried out, which would define the real need to build the plant, a better installed capacity, a smarter location that could further optimize the plant's potential, generating the least negative impact possible. As the idea of this work is to study the impacts of an existing project, only some potential measures that could be introduced throughout the phases of the plant's existence (construction, operation and end of life) will be mentioned to prevent major problems. A Plan for the conservation of aquatic systems, a Plan to assist the affected population, a Plan for the valorization of heritage, a Public Health Plan, an Integrated Management Plan for Volta

ISSN: 2177-3246

Grande do Xingu and a Basic Sanitation Plan, among others, are recommended and will be better explained in the next work.

REFERENCES

Brasil. Ministério de Minas e Energia. (2009). Avaliação ambiental integrada da bacia hidrográfica do Rio Xingu. Brasília.

Brasil. Ministério do Meio Ambiente. (2009). Relatório de Impacto Ambiental (RIMA): Aproveitamento Hidrelétrico Belo Monte. Brasília.

Climate-data.org. (n.d.). Clima: Belém, Pará, Brasil. https://pt.climate-data.org/america-do-sul/brasil/para/belem-4299/

Fearnside, P. M. (2016). Environmental and social impacts of hydroelectric dams in Brazilian Amazonia: Implications for the aluminum industry. World Development, 77, 48–65.

Fearnside, P. M. (2017). Belo Monte: Actors and arguments in the struggle over Brazil's most controversial Amazonian dam. Die Erde, 148(1), 14–26.

Fleury, L. C. (2013). Conflito ambiental e cosmopolíticas na Amazônia brasileira: A construção da Usina Hidrelétrica de Belo Monte em perspectiva [Tese de doutorado, Universidade Federal do Rio Grande do Sul].

França, G. F. (2016). Avaliação dos padrões de desmatamento na região de influência da UHE Belo Monte, Pará [Dissertação de mestrado, Universidade de Brasília].

Glasson, J., Therivel, R., & Chadwick, A. (2013). Introduction to environmental impact assessment (4. ed.). Routledge.

Lees, A. C., et al. (2016). Hydropower and the future of Amazonian biodiversity. Biodiversity and Conservation, 25, 451–466.

Magalhães, S. B., & Cunha, M. C. da (Orgs.). (2017). A expulsão de ribeirinhos em Belo Monte: Relatório da SBPC. SBPC.

Neto, J. Q. de, & Herrera, J. A. (2017). Expansão urbana recente em Altamira (PA): Novas tendências de crescimento a partir da instalação da UHE Belo Monte. Ateliê Geográfico, 11(3), 1–20.

Reid, J., et al. (2005). Análise dos custos e benefícios do complexo hidrelétrico Belo Monte. Conservation Strategy Fund.

Winemiller, K. O., et al. (2016). Balancing hydropower and biodiversity in the Amazon, Congo, and Mekong. Science, 351(6269), 128–129.