Ecosystem Services in Hydropower Planning in the Brazilian Amazon

The largest potential for Brazilian hydropower expansion is in the Amazon region. Its ecosystem services reveal the importance of the efforts to reduce the losses and disturbances in this biome. The hydropower planning would have to recognize the ecosystem services. In the hydropower sector, an integrated environmental assessment is carried out to support the planning of a set of hydropower projects in a watershed in order to discuss cumulative impacts. Cumulative impacts affect essential ecosystem services for traditional, indigenous and riparian populations in the Amazon. However, the ecosystem services approach is not included in this instrument. The objective is to analyze the ecosystem services affected by cumulative impacts of hydropower projects in the Teles Pires watershed. The main cumulative effects occur on aquatic ecosystems; they reduce vegetation cover and fragment terrestrial environments, besides altering the land structure. The main ecosystem services affected are food, water; habitat, besides ethical and cultural values. The impacts on such ecosystem services increase the vulnerability of the populations that are heavily dependent on these benefits for their livelihoods, worsening the socio-environmental problems. We recommend that the assessment of cumulative impacts on hydropower planning in the Amazon is also supported by the analysis of ecosystem services, whose approach allows including the perspective of vulnerabilities of local populations in decision-taking.

1. Introduction

The largest potential for expanding the electricity from hydropower plants in Brazil is situated in the Amazon frontier, where there are large areas of protected areas – conservation units, indigenous lands and lands occupied by traditional, indigenous and riparian peoples – with high value in terms of biodiversity and socioeconomic and socioenvironmental issues (Tolmasquim, 2016).

Biodiversity is indispensable for human well-being as a provider of environmental services. The ecosystem services provided by the great biodiversity of the Amazonian forests, coupled with the huge dependence of the Amazonian peoples on these services, are some of the several factors that lead to the need for engaging efforts to reduce the destruction of this biome (Fearnside, 2015).

According to MEA - Millennium Ecosystem Assessment (2005) changes in ecosystem services have a greater impact on the most vulnerable, poor and rural populations, leading to a worsening of socioeconomic issues and conflicts.

Hydroelectric dams have a central role in the provision of electric power in Brazil while causing numerous significant socio-environmental impacts beyond the area of the project covering the entire watershed. Thus, they cause cumulative and synergistic impacts that affect ecosystem services that are crucial to the Amazonian quality of life and biodiversity.

In the Brazilian hydropower sector, in addition to the traditional environmental impact assessment (EIA) for each hydroelectric plant, an instrument called Integrated Environmental Assessment (IEA) is also applied. IEA is a type of cumulative impact assessment that assesses the cumulative and synergistic impacts of a set of hydropower plants planned for the same hydrographic basin (Tucci and Mendes, 2006).

The advantages and limitations of the Brazilian IEA approach in the context of hydropower planning were discussed by Gallardo et al. (2017). However, the ecosystem services approach is not included in the IEA, or in other impact assessment instruments (Rosa & Sánchez, 2016).

In the Amazon region, the Teles Pires river basin covers an area of 141,278.62 km², located in the 3 states of Brazil (Mato Grosso, Amazonas and Pará), in an extension of 1,481 km from its source in Mato Grosso to The Teles Pires mainstreaming. The Tapajós river basin has the potential to generate 3,697 MW in six hydropower plants called Sinop, Colíder, Foz do Apiacás, Magessi, São Manuel and Teles Pires, as well as six small hydropower plants in operation and seven projected (EPE, 2009). The Teles Pires river and the Jurema river are the main tributaries of the Tapajós watershed, which has its river mouth in the Amazon river. For this reason, we choose the Teles Pires river basin for developing this research because the Tapajós watershed is the most threatened river considering the hydrophysical and ecological impacts caused by the hydropower planned projects (Latrubesse et al., 2017).

The objective of this research is to analyze the ecosystem services affected by cumulative impacts of hydropower projects in the Teles Pires watershed.

2. Methods

This research is supported by a qualitative, exploratory approach, through a case study, using documentary source and primary data collected in field work in the Teles Pires watershed in the hydropower region.

The documentary research object refers to the IEA of the Teles Pires watershed. The IEA follows the guidelines in Tucci and Mendes (2006) to evaluate the cumulative effects on the Teles Pires river basin, comprising three stages: (I) socioenvironmental characterization of the basin, with indication of the synthesis components; (II) the distributed environmental assessment, which aims at subdividing the basin, identifying environmental indicators, identifying weaknesses and potentialities, defining scenarios without the projects and with the projects, identifying and evaluating impacts and analyzing cumulative and synergistic impacts, besides identifying and analyzing the main conflicts; (III) integrated environmental assessment and proposal of guidelines and recommendations for future projects situated in the watershed.

The research was developed in two stages. The first was focused on the characterization of the basin and its hydropower projects and on the identification of the synthesis components that supported the identification of the environmental indicators that help to understand the fragilities and potentialities of the basin for defining the scenarios with the projects. The second step focused on identifying the main cumulative impacts described in the IEA, and on evaluating possible ecosystem services associated supported by the primary data obtained in the field with the beneficiaries of the services. This meant to identify the priority services among the set of services impacted by using the classification and methodology proposed by Landsberg et al. (2011; 2013).

3. Results and Discussion

The Teles Pires river basin was subdivided into three sub-basins: low, medium and high Teles Pires and four compartments, C1 (no project), C2 (Magessi, Sinop and Colíder hydropowers), C3 (Teles Pires and São Manuel hydropowers) and C4 (Foz do Apiacás hydropower), from physical aspects and physiognomy of large forest biomes, according to the synthesis components, which are (i) water resources and aquatic ecosystems, (ii) physical environment and terrestrial ecosystems and (iii) socioeconomics, thematically proposed and organized in the Term of Reference of the IEA.

The Teles Pires river presents great complexity along its mainstreaming, as well as physical aspects and physiognomy of the great forest biomes it comprises, such as the diversity of hydrogeological, ecosystems, geomorphology and soils, fauna and flora, demographic dynamics and the importance of its indigenous lands, for the maintenance of the ecosystem services essential for the Amazonian population and biodiversity (Cochrane et all, 2017, Fearnside, 2018).

Table 1 summarizes the results of the synthesis components, namely the nature of the impacts (positive or negative), the cumulative impacts and their indicators presented in the IEA of the Teles Pires watershed.

Table 1: The synthesis components and indicators of cumulative impacts of IEA of the Teles Pires watershed.

synthesis components	Cumulative impacts		Indicators of Cumulative Impacts
Water resources and aquatic ecosystems	Negative	Alteration of river regime	Flooded area
			Concentration of phosphorus per compartment
		Reservoir Eutrophication Potential	Possibility of thermal stratification of the designed reservoirs
		Habitat loss for icthyofauna	Flooded or affected areas of compartment
		Mercury contamination	Areas of irregular mining activity
Physical environment and terrestrial ecosystems	Negative	Loss of Areas with Potential Mineral	Flooded area
			Number of mining processes
		Reduced Vegetation Coverage and Fragmentation of Environments	Predominance of the Cerrado biome
			Predominance of the Amazonian biome
		Interference from Loss of Vegetation to Associated Wildlife	Filling the reservoir
			Area of the reservoir of the dams
			Roads and construction sites
			Workers and workforce in general engaged in works without adequate information
socioeconomics	Negative	Loss of Productive Areas	Anthropogenic rate
		Change of Structure Property	Number of affected establishments
		Pressure on health care	Number of hospitalizations / inhabitant
			Number of doctors / inhabitant
	Positive	Job Creation	Labor recruitment
		Growth of Municipal Collection	Tax collection and financial compensation

source: modified from IEA (EPE, 2009).

Table 2 presents three of the main cumulative impacts associated with the main ecosystem services affected, and their respective classes based on the classification and methodology of evaluation of ecosystem services of Landsberg et al. (2011; 2013), as well as the data from field interviews with the beneficiaries of the ecosystem services within the Teles Pires watershed.

Table 2: Summary of key cumulative impacts and affected ecosystem services in the Teles Pires watershed for hydropower planning.

Component-synthesis	**Cumulative Impacts**	**Ecosystem services**		
		Service	**Subcategory**	**Classification**
Water resources and aquatic ecosystems	Habitat loss for icthyofauna IC01	Food	Fishing in natural environemnts	provision
		Genetic resources		provision
		Habitat		Support
		Recreation and ecotourism		cultural
Physical environment and terrestrial ecosystems	Reduced Vegetation Coverage and Fragmentation of Environments IC02	Food	Wild food	provision
		Biological material	Wood	provision
			Fibers and resins	
			Ornamental resources	
		Biomass fuel		provision
		Genetic resources		provision
		Biochemicals and natural medicine		provision
		Air quality regulation		regulation
		Climate regulation	Global	regulation
			Regional and local	
		Regulation of water load and water flows		regulation
		Erosion control		regulation
		Regulation of diseases		regulation
		Regulation of natural disasters		regulation
		Recreation and ecotourism		cultural
		Ethnic and spiritual values		cultural
		Educational and Inspirational Values		cultural
		Habitat		support
		Nutrient cycling		support
		Primary production		support
Socioeconomics	Change of strucuture property IC03	Food	Agricultural products harvested for human or animal consumption	provision
			Animals raised for consumption	

According to the methodology proposed by Landsberg et al. (2011, 2013), tested in other studies such as Partidario & Gomes (2013), Rosa & Sánchez (2015; 2016), the impacts on relevant ecosystem services are evaluated from the perspective of the beneficiaries of these services. In this way, the initial primary data collected in the field from interviews with the key agents show that impacts IC01, IC02 and IC03 (according to the categorization of Table 1), have mainly impacted the ecosystem services “food”, in its subcategories "fishing in natural environment", "wild food" and "agricultural produce harvested for human or animal consumption", respectively. Services such as fish caught in the rivers are crucial for the subsistence of the traditional peoples of the region in great socioeconomic vulnerability, and who still often depend on these foods for their survival, aggravating the social problems of these families and of the region.

IC01 and IC02 have affected the "recreation and ecotourism" service, especially the recreational fishery that attracts a large number of tourists to the region. However, due to declining fish stocks, according to beneficiaries, the decline in tourism has had a major impact on the region trade and services activities.

The ecosystem services "regulation of water supply and water flows" and "ethnic and spiritual values" have been affected by the IC02 impact, with major changes in the population health. In the case of the first service, in which the population no longer had access to basic sanitation and quality water for consumption before the hydropower projects, this situation worsened after the projects due to the contamination of water with harmful substances, such as mercury. Regarding the second service, it has a great impact on the indigenous peoples of the region, such as the Munduruku.

4. Conclusions and Recommendations

Notwithstanding the analysis of cumulative impacts in the IEA, as its methodology does not contemplate the ecosystem services approach, the effectiveness of the instrument is considered not to be completely achieved. Twenty-six ecosystem services were identified in the four affected categories associated with the cumulative impacts, with seven being classified as priority by the beneficiaries. The main ecosystem services affected are food, water and habitat, besides ethical and cultural values.

Impacts on these ecosystem services have a major impact on local populations, as they affect access to food availability, the quality of water used by those populations that do not have access to water and sanitation and interfere with services regarding cultural values of indigenous communities that already suffer great pressure and threat on their way of life often leading to the disappearance of these cultures.

The impacts on the ecosystem services increase the vulnerability of populations who are heavily dependent on these benefits for their livelihoods, worsening the socio-environmental problems.

The lack of ecosystem services approach in the IEA of the Teles Pires watershed does not allow these cumulative impacts to be adequately considered and minimized in the decision-making process.

We recommend that the assessment of cumulative impacts on hydropower planning in the Amazon is also supported by the analysis of ecosystem services, whose approach allows including the perspective of vulnerabilities of local populations in decision-taking.

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