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Improving policies and instruments to address cumulative impacts of small hydropower in the Amazon

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ABSTRACT

Small hydropower plants (SHPs) are rapidly sprawling, both globally and across the Amazon's free flowing rivers, threatening provision of ecosystem services, river connectivity, biodiversity conservation, and the livelihoods of indigenous and traditional communities. In Brazil, cumulative impacts of SHPs have been largely neglected in planning and policy instruments. In this perspective article, we highlight current policy challenges and options for assessing the impacts of small hydroelectric plants in the Amazon, which deserve more attention in both academic research and public policies. We review environmental licensing of seven small and one large dam in the Cupari river, a Tapajós tributary, which is being challenged in Federal Courts based on inadequate cumulative impact assessment. We argue for the need of adopting good practices in cross-scale environmental assessment when applying existing or new policy instruments, including: the adoption of Strategic Environmental Assessment in planning for hydropower expansion taking into consideration other plans, programs and policies at regional and Amazon-wide scales; developing integrated environmental assessments considering inventoried SHPs and large hydropower plants; using scientific evidence and technological tools in planning and siting of SHPs; complying with policies that protect human and environmental rights; and strengthening intersectoral dialogue and multi-stakeholder forums and committees.

1. Global and Amazonian expansion of small dams

Small hydropower plants (SHPs) are proliferating around the world, driven by policies and economic incentives for renewable energy production; by reaching a maximum limit of exploitation of the hydropower potential of larger rivers in many developed countries; and by the perception that smaller projects have fewer negative environmental impacts compared to large hydroelectric plants (Couto and Olden, 2018; Lange et al., 2018; Tullos et al., 2010). A recent survey identified 82,891 SHPs operating in 150 countries (Couto and Olden, 2018). In Brazil, incentives and policy regulations have contributed to a five-fold increase in the number of small dams in the last 20 years, with 87 currently operating and 256 inventoried in Amazonian rivers (ANEEL, 2018a; Couto and Olden, 2018).

In Brazil, the leakage of corruption scandals and the social, environmental and economic costs associated with the construction of the Madeira dams and the giant Belo Monte in the Xingu River has gained repercussion in the press and in scientific studies (de Sousa Júnior and Reid, 2010; Fearnside, 2014). In 2018, a former Executive Secretary of the Brazilian Ministry of Mines and Energy (MME) announced the need to review the mega-dam building policy for the Amazon, and to better calculate risks, costs and benefits of these projects (Branford, 2018). After conflicts and resistance by indigenous peoples and traditional communities, the construction of a complex of seven large hydropower plants (LHPs) has been temporarily suspended for the Tapajós basin (Athayde, 2014; Walker and Simmons, 2018; WWF, 2016).

While large dams are in standby, SHPs are on the rise, often associated with other economic activities and infrastructure development,

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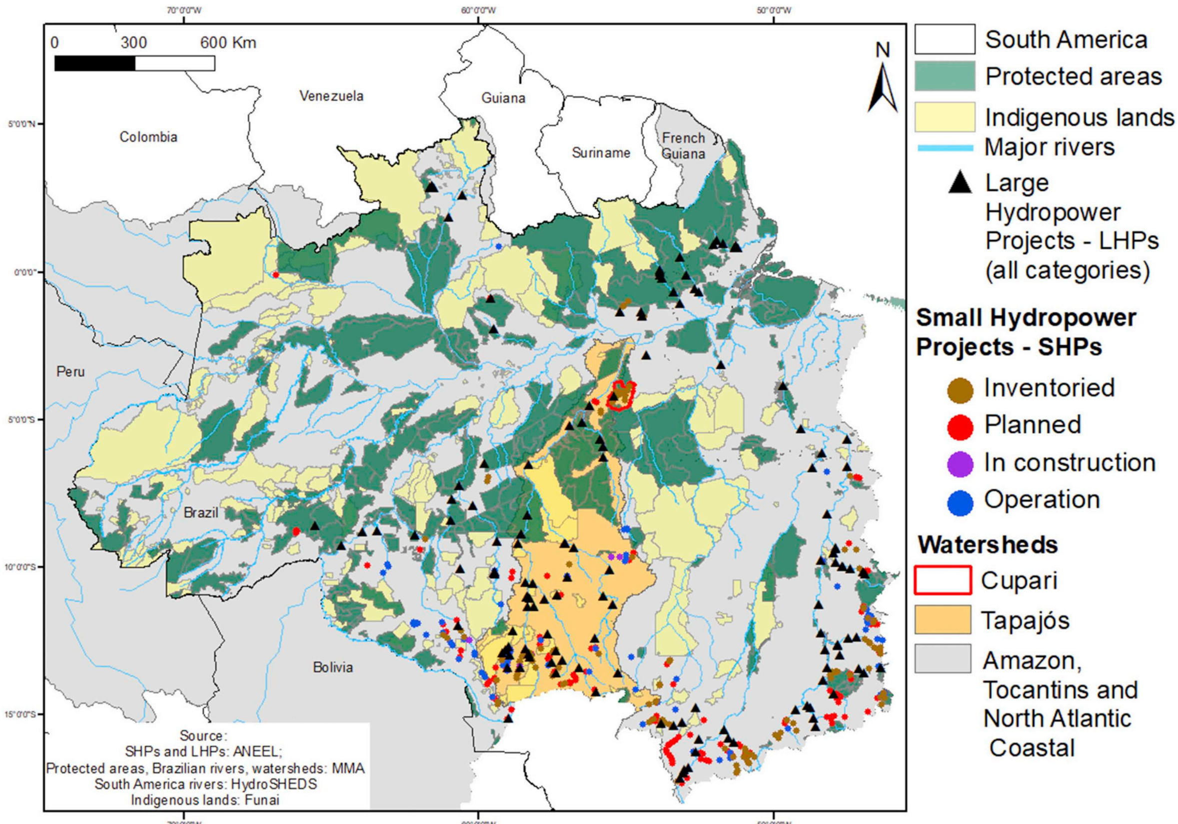

Fig. 1. Map of existing, planned and inventoried large (LHPs, >30 MW) and small (SHPs, 5-29.9 MW) hydropower plants (HPs) in Brazilian Amazon rivers. The Cupari sub-Basin of the Tapajós watershed is highlighted, where 29 inventoried HPs represent 65% of the total inventoried electricity potential of the Tapajós watershed (ANEEL, 2018a). Among these, eight are under a licensing process currently questioned by a lawsuit (MPF, 2018) filed by the Brazilian Federal Prosecution Service against the State Secretary of the Environment and Sustainability of the Pará State (SEMAS-PA) and the Brazilian Institute of the Environment and Natural Resources (IBAMA).

such as agribusiness, mining, waterways, transmission lines, roads and ports (Alarcon et al., 2016; Couto and Olden, 2018; Fearnside, 2015a). SHPs are not always planned to be built as single projects; often, they can be part of a cascade of plants along a river stem and its tributaries. Although smaller projects could cause less significant impacts, the Environmental and Social Impact Assessment (ESIA) experience emphasizes the environmental sensitiveness and the significance of the cumulative effects with other projects for an appropriate understanding of future decision-making consequences (Gallardo et al., 2017).

Currently, our understanding of existing and potential environmental and social impacts of the SHPs expansion, and the capacity to mitigate its negative consequences, is drastically limited by lack of rigorous cumulative impact assessment (CIA). Cumulative environmental impacts (or effects) are defined as changes to the environment caused by an action in combination with other past, present and future actions, resulting from different process of accumulation, which may be additive (sum of individual effects) or synergistic (when combined effects are greater than the sum of individual ones) (Hegmann et al., 1999; IFC, 2013; Seitz et al., 2011). Gaps in CIA for planning of small dams are associated with other problems mentioned in the literature, including the absence of effective integrated planning tools (Gallardo et al., 2017; Latrubesse et al., 2017; TCU, 2017); ineffective environmental licensing policies for SHPs (Couto and Olden, 2018; Fearnside, 2015b); data and research gaps (Kibler and Tullos, 2013; Latrubesse et al., 2017; Lange et al., 2018); and undue political interference in decision-making (Couto and Olden, 2018; Fearnside, 2015b; Gallardo et al., 2017; Millikan, 2016).

Recently, an inappropriate evaluation of cumulative impacts of a cascade of seven SHPs and one large hydropower plant in the Cupari river (a Tapajós tributary in the Amazon basin, see Fig. 1), grounded the Brazilian Federal Prosecution Service (MPF) to file a lawsuit against the Pará State Environmental Agency (Secretary of Environment and Sustainability of the State of Pará - SEMAS-PA) and the Federal Environmental Agency Brazilian Institute of the Environment and Natural Resources (IBAMA) requesting suspension of the environmental licensing process until an appropriate study is presented by the developing company (MPF, 2018). This case provides a window of opportunity to analyze existing policies and instruments used in hydropower (both small and large dams) and watershed planning towards the improvement of CIA policy and practice in Brazil.

This opinion article is based on secondary data and documentary analyses. Our examination of the Environmental Impact Assessment (EIA) for the Cupari river is based on the thorough and well-documented report prepared by officers and attorneys of the Federal Prosecution Service of Brazil (MPF, 2018), which was used in the lawsuit. We suggest that if the pattern of dam building proposed for the Cupari expands, hundreds of SHPs could be built in Amazon tributaries under deficient policy and planning instruments, alarmingly multiplying cumulative social and environmental impacts.

2. Definitions and policy implications of small hydropower

The definition of what constitutes a SHP is fairly arbitrary and differs among countries (Couto and Olden, 2018). Most international agencies define SHPs as those producing up to 10 MW of generating capacity. In Brazil, the definition and legal regulation of micro and small dams[1] have changed over the last two decades. The Resolution 673/2015 of the Brazilian Electricity Regulatory Agency (ANEEL), currently in place, defines small dams as those with generating potency above 5 MW and equal or inferior to 30 MW and featuring reservoirs up to 13 km^2, excluding the regular river bed (ANEEL, 2018b; ANEEL, 2018c). All dams over 30MW of generating potency are considered large hydropower plants[2] (LHPs), and concessions for dams over 50 MW are necessarily tied to public bidding processes. In some cases, hydroelectric dams with generating potency over 30MW but under 50MW can be authorized by ANEEL without the necessity to undergo public bidding, but they are still designated large dams (Brazil, 1995, 1996). Micro dams include plants with generating potency between 0 and 5 MW.

Globally, political and economic incentives have fueled the growth of SHPs, which currently represent an important component of future energy portfolios and strategies in both developed and developing countries, in contrast with a decrease of policy support and investments in LHPs in some cases (Couto and Olden, 2018; Kao et al., 2014). For example, renewable portfolio standards in the US reject LHPs but embrace electricity from SHPs, under the general assumption that they generate less social-ecological impacts in comparison to large plants (Kao et al., 2014). Additionally, policies regulating SHPs are more flexible in comparison to larger dams (Couto and Olden, 2018). In Brazil, only a simplified environmental impact report is required for projects up to 10 MW, whereas for those between 10 and 29.9 MW, developers normally need to submit an environmental and social impact assessment to the designated governmental agency, who will review the assessment and organize mandatory public hearings (ANEEL, 2018c).

Despite persistent knowledge gaps, scientists have challenged the assumption that SHPs are less ecologically harmful in comparison to larger dams, especially for projects built in cascade (Bakken et al., 2012; Gleick, 1992; Kibler and Tullos, 2013). Post-dam studies have shown that the ecological footprint of SHPs per megawatt of electricity produced may be much higher than those of large dams (Bakken et al., 2012; Kibler and Tullos, 2013; Lange et al., 2018; Ziv et al., 2012). Studies have also found significant cumulative impacts of cascades of small dams on river ecology including: loss and/or change in habitats (Kibler and Tullos, 2013); decrease on catchment and hydrologic connectivity at the sub-basin scale ("water-mediated transfer of matter, energy and/or organisms") (Fencl et al., 2015; Kibler and Tullos, 2013; Pringle, 2003); increased barriers for fish movement (Lange et al., 2018; Opperman, 2018) and consequent reduced genetic diversity, with diminished potential for adaptation to changing environmental conditions and increased local extinction risk (Lange et al., 2018). At the basin-scale, impacts produced by both large and small dams on the hydrophysical dynamics of Amazonian river systems (including sediment transport and morphodynamic changes), which are critical physical components supporting habitat diversification, biodiversity and associated human livelihoods, have been largely neglected in planning processes and instruments (Latrubesse et al., 2017).

3. The science and practice of cumulative impact assessment

The science and practice of CIA is evolving, and there is no single procedure accepted globally (Canter and Ross, 2010; IFC, 2013). CIA includes the analysis of impacts, risks and uncertainty of a given project on valued environmental and social components (VECs) within a regional planning process. VECs may include water, fisheries, soil, archaeological sites, aesthetic and/or cultural values (see Fig. 3) (Hegmann et al., 1999; IFC, 2013).

Good practices in CIA may include a combination of several steps, tools and procedures articulating scientific methods, policy instruments, public participation and stakeholder dialogue at appropriate time frames and spatial scales (Canter and Atkinson, 2010; Hegmann et al., 1999; IFC, 2013). Case-studies from CIA application in Europe, Canada and the US point to important lessons learned, including: the importance of conducting an early scoping process considering public input and stakeholder participation in the definition of VECs; using the best science and information available to build a baseline on the state of VECs; assessing the interaction of potential effects on VECs with other projects, plans and programs at larger scales; and making updated information publicly available (Canter and Atkinson, 2010; Canter and Ross, 2010). In the US, an adaptive management approach has been developed for operation of the Glen Canyon Dam in the Colorado river, enabling stakeholder dialogue and improved learning about cumulative impacts on the river system and its uncertainties, as well as implications of management decisions, despite persistent challenges (Melis et al., 2010).

To fully capture the social and environmental effects of a specific project, CIA needs to consider other relevant projects, programs and policies planned or in effect for a given region. This requires cross-scalar articulation in the planning process, which can take place both at the project scale (a SHP project could consider waterways, roads, regional development plans) and at regional and strategic scales (energy plans could also consider transportation plans, water conflicts, biodiversity conservation priorities and territorial policies). At the project scale, CIA can be part of the environmental and social impact assessment process, with in-depth studies being presented in the ESIA report, or as a separate study. At regional and strategic scales, CIA can be performed through the Strategic Environmental Assessment (SEA), which is applied to policies, plans e programs that can potentially cause social and environmental impacts. This instrument has been adopted in many countries, but it is not mandatory and has rarely been used in Brazil (Andrade and Santos, 2015; Sánchez, 2017).

Brazilian policies require assessment of cumulative effects during the ESIA process at the project scale, and through an Environmental Integrated Assessment (IEA) at the watershed scale (MME/CEPEL, 2010). Important pitfalls of this later instrument are two-fold: first, it only considers the effects of built and planned hydropower plants, which deeply reduces the understanding of cumulative impacts driven by other related actions (Gallardo et al., 2017); second, IEAs have often ignored small dams. A brief analysis of 15 IEAs concluded for Brazilian watersheds reveals that 60% were developed for Amazonian river basins, and 40% completely ignore SHPs (Table SI - 1).

4. The Cupari small dam complex in the Tapajós watershed

The Amazon basin represents 5% of land on Earth, with a mean annual discharge of nearly 210×103 m^3/s, contributing with 16%–20% of the annual global freshwater discharge (Park and Latrubesse, 2015). Its dynamics controls the complex diversity of the forest and associated ecosystems (Salo et al., 1986), which influences regional and global climate (Davidson et al., 2012; Shukla et al., 1990).

In a recent assessment of the environmental impact of planned dams on the whole Amazon basin, Latrubesse et al. (2017) identified the Tapajós as the most threatened Amazonian cratonic[3] river considering hydrophysical and ecological impacts. Tapajós specific hydrology and geomorphology characteristics entail disturbance regimes that result in high habitat diversity of the alluvial landscape, high biotic diversity,

[1] In Portuguese, micro dams are designated *Central Geradora Hidrelétrica* – CHG and small dams are commonly known as *Pequenas Centrais Hidrelétricas* – PCHs.

[2] In Portuguese, UHE (Usina Hidrelétrica), which includes all dams over 30MW of generating potency.

[3] Allen and Armitage (2012) define cratonic basins as sites of prolonged, broadly distributed but slow subsidence of the continental lithosphere, which are generally filled with shallow water and terrestrial sedimentary rocks.

and high levels of endemism of both aquatic and non-aquatic species (Latrubesse et al., 2017). The Tapajós basin is located on the border region of the deforestation arch of the Brazilian Amazon, in a still poorly known biodiversity hotspot. Around one third of the basin is under some form of protection either as protected areas or as indigenous territories, which cover 13.6% and 17.9% of the basin respectively (WWF, 2016). It is also considered one of the eight most important areas of the Amazon regarding diversity and endemism of fish and birds' species (WWF, 2016).

The Tapajós basin connectivity, hydrophysical dynamics, biodiversity and indigenous and traditional livelihoods are highly threatened by government plans to build several LHPs along the river main stem and on its tributaries, without considering small dams (Fearnside, 2015a,b; Latrubesse et al., 2017). According to the Integrated Environmental Assessment (IEA) of the Tapajós basin, the complex of LHPs include three dams proposed to be built in the main stem of the Tapajós, and another four in its major tributary Jamaxim river. In addition, the Brazilian Energy Research Company (EPE) has identified 44 sites for possible dam construction in the Basin (Ecology Brasil and Grupo de Estudos do Tapajós, 2014; WWF, 2016).

The Cupari river is a tributary of the Tapajós connected to indigenous lands, archaeological sites and protected areas, such as the Tapajós and the Trairão National Forests (FLONAs) and the Riozinho do Anfrísio Extractive Reserve (IBAMA/MMA, 2004; MPF, 2018). In the Cupari sub-basin, the predominant vegetation is Amazon forest, but with the construction of the Transamazonian highway in the 1970s, human settlements have spread according to the classical fishbone pattern triggered by deforestation and cattle ranching, followed by subsistence agriculture. The population is concentrated in rural and urban agglomerates with low demographic density (IBAMA/MMA, 2004).

The proposed SHP cascade in the Cupari basin is emblematic due to the lack of cumulative impact assessment considering the effects of SHPs added the other existing and planned hydropower projects. The CIA presented in the Integrated Environmental Assessment conducted for the Tapajós basin ignored the cumulative impacts of the SHPs – both present and future - hindering the understanding of long-term implications for Amazon-wide freshwater connectivity, hydrological processes, morphodynamics and sustainability (Anderson et al., 2018; Latrubesse et al., 2017; Timpe and Kaplan, 2017).

The Cupari complex includes a total of eight hydropower projects: four SHPs in the east arm, and three SHPs plus one large dam in its west arm. Two Environmental Impact Assessments (EIAs) were presented separately for the east and the west arm (CIENGE/AMBIENTARE, 2016a, 2016b), and were also individually discussed in the initial public hearings involving potentially affected local populations, including settlers, urban residents, indigenous communities and traditional riverine communities who occupy the Tapajós and the Trairão National Forests protected areas (IBAMA/MMA, 2004; MPF, 2018). The two complexes would flood an area of almost 20 km^2 to generate 157.5 MW, across three municipalities. If its hydropower potential is fully implemented, the 7,2 thousand km^2 Cupari watershed would host 28 small and one large dam, with one dam for every 42 km of river.

The two EIAs considered as directed affected areas those within 300 m from the impoundments, failing to analyze cumulative impacts on valued social and environmental components (see Fig. 3). Although the studies consider the potential for accumulation of environment effects, they only establish cumulative and synergism as qualitative attributes to evaluate the significance of the impacts (cumulative/non-cumulative and synergistic/non-synergistic), falling short to develop a CIA process based on good practice guidance (as discussed by Canter and Ross, 2010 and Hegmann et al., 1999), and neglecting cascade effects. Further, despite the EIAs indicate consequences for fish communities due to the changes in water flows and disruption of migratory fish habitats, they fail to report social consequences of impacts on fish stocks to traditional communities located downstream of the dam sites, claiming lack of information about these communities (CIENGE/AMBIENTARE, 2016b, 2016a). In addition, the EIA for the east complex did not consider potential impacts to the Tapajós National Forest, a federal protected area of 549.257 ha, which hosts a rich diversity of fish, mammal and birds, some of them endangered with extinction, and which is occupied by several traditional riverine communities (IBAMA/MMA, 2004).

The arrangements developed for the EIAs and accompanying licensing process contradicts Brazilian national policies, as well as international treaties for the defense of human rights of which the country is signatory, which require free prior and informed consultation for indigenous and traditional communities whose territories and livelihoods might be potentially affected by these types of projects (International Labor Organization - Indigenous and Tribal Peoples Convention no. 169 - ILO, 1989). Environmental policy in Brazil determines that, for sets of LHPs in a watershed, another study is necessary - the Integrated Environmental Assessment (IEA), but the inclusion of SHPs in these instruments is not mandatory (MME/CEPEL, 2010; Pires et al., 2008).

The Cupari sub-basin is part of the IEA of the Tapajós watershed. This document reports the impacts of seven large hydroelectric dams (above 30 MW), and it fails to consider the hydropower plant Águas Lindas, which is part of the Cupari west arm project (Ecology Brasil and Grupo de Estudos do Tapajós, 2014). Additionally, the 28 inventoried SHPs in the Cupari sub-basin were not addressed in the IEA (Fig. 2; Table SI - 2).

Although actions other than hydropower projects are not the specific focus of the IEA policy (Gallardo et al., 2017), the Tapajós IEA does not consider other development plans (at the local, regional and national scale) and projects (mining, waterways, roads, ports), as well as dozens of small dams inventoried in the basin, compromising its ability to be used as an effective planning and management instrument (Millikan, 2016).

5. Conclusion and policy implications

The current global boom of small dams call for a careful review of policies, investments and instruments used for assessing cumulative impacts around the world. In Brazil, there are two policy instruments which are supposed to address cumulative impacts at the project scale (ESIA) and basin scale (IEA), but both are ill-equipped to tackle the challenges related to the proliferation of both LHPs and SHPs in the Amazon basin. Improvements in CIA can take place in both instruments, as well as in the implementation of the Strategic Environmental Assessment for regional and basin-wide scale planning.

First, at the project level, procedural and methodological guidelines for CIA assessment for sets of SHPs need to be urgently developed. This is relevant because although CIA is internationally recommended at the project level (IFC, 2013), it is only superficially mentioned in Brazilian law, lacking specific regulations and guidelines to support the process (Duarte et al., 2017a). The guidelines could: (i) provide detailed information in Terms of Reference regarding the process for selection of affected VECs to be considered; (ii) develop guidelines to assist relevant tasks of CIA; (iii) promote shared decision-making processes and responsibility between projects proponents, governmental agencies and stakeholders; (iv) establish a regional database with data and information derived from monitoring projects (Dibo et al., 2018); and (v) develop multi-project environmental and social impact assessments (Vilardo and La Rovere, 2018).

Second, at the watershed scale, the IEA should consider SHPs in different planning stages. Currently, it considers only hydropower projects in advanced stages, and it is not updated periodically. This hinders an adequate inclusion of SHPs, which have shorter planning cycles, with simpler regulations in comparison to large dams. Ideally, those studies would include all the SHPs already inventoried in its CIA, to build a “full development scenario” respecting the precautionary

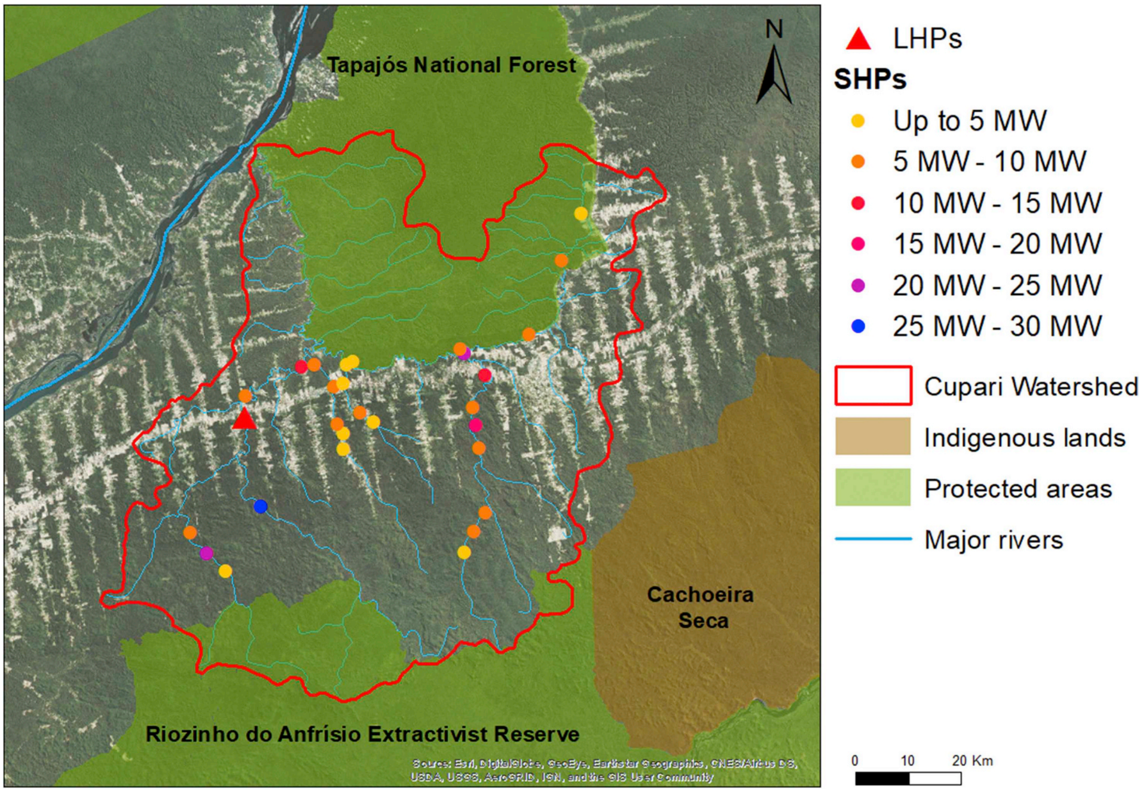

Fig. 2. Detailed map of the Cupari sub-basin, showing protected areas and indigenous lands, and evidencing the fish-bone pattern of deforestation accompanying the Transamazonian highway. The 28 small hydropower plants (SHPs) and one large hydropower plant (LHPs) are located and distinguished by electricity generation capacity in megawatts (MW).

principle. An adaptive management approach can also be implemented updating the IEA when new plants are inventoried or move to the construction phase.

Additionally, IEA could expand the scope to include other past, present and reasonably foreseeable future actions within a river basin, beyond the hydropower sector (Gallardo et al., 2017; Sánchez, 2017). In the Cupari case, the Tapajós IEA presents a CIA, but considers only seven large hydroelectric dams, failing to include SHPs, other infrastructure projects planned for the region, as well as one large dam being licensed in the west arm of the Cupari complex.

Whereas international good practices for CIA can provide a starting point for studying impacts of a set of dams, we must consider that the Amazon basin is the largest and most complex fluvial system on Earth, thus fragmented studies in tributary rivers would not provide answers capable of predicting changes throughout the basin (Latrubesse et al., 2017). Improvements in assessing cumulative impacts in sub-basins are relevant contributions, but broader instruments are also fundamental to explore the combined effect of human interventions on the Amazon basin. This will require international cooperation efforts to support the decision-making process, which could be assisted by an international panel of multidisciplinary experts and a participatory basin management committee with diverse socio-political actors (Latrubesse et al., 2017).

The improvements in the current instruments and the implementation of new multi-scalar instruments for watershed planning and management in the Amazon may occur through the establishment of strategic partnerships and collaborative learning between governmental agencies, private sector, academia and civil society, which remains challenging given the diversity of perspectives and interests at stake (Duarte et al., 2017a,b; Westin et al., 2014). It is also important to strengthen existing governance structures that would allow enhanced benefit-sharing and transparence; compliance with national and international policies for protection of human and environmental rights; and public participation in decision-making, such as multi-stakeholder watershed committees (Siegmund-Schultze et al., 2015).

Beyond instruments at the project and watershed scales, cumulative impacts should also be considered in strategic initiatives across scales. Regional development plans are poorly articulated in the Amazon basin (Westin et al., 2014), making the projection of results of interactions between impacts of policies, plans, programs and projects of a set of initiatives impossible. Energy and territorial planning in the Amazon could adopt the Strategic Environmental Assessment to provide a broader picture of existing drivers and potential impacts. It would be an integrative instrument, addressing CIA practice (Andrade and Santos, 2015). This might be an appropriate instrument to assist the decision-making process and improve consideration of implications of choices to reconcile long-term economic development and sustainability (Sánchez, 2017). The Tribunal de Contas da União (TCU, Federal Court of Auditors) of Brazil recently recommended the adoption of the SEA instrument for hydropower planning, after assessing lessons learned from large dam development across the Amazon (TCU, 2017).

The current mismatch between small dam implementation and environmental planning in Amazon free-flowing rivers is a threat not only to sustainability in this region, but also to other Brazilian biomes and countries facing the SHPs boom. The implementation of SHPs in the Tapajós basin based on deficient policies and planning instruments has been a neglected threat to the most vulnerable Amazonian river system (Latrubesse et al., 2017), which deserves special attention from government planners, scientists, private sector and civil society. Advancing policies and practices for integrated social and environmental cumulative impact assessment is essential to provide planners and society with enough information to support wiser decisions.

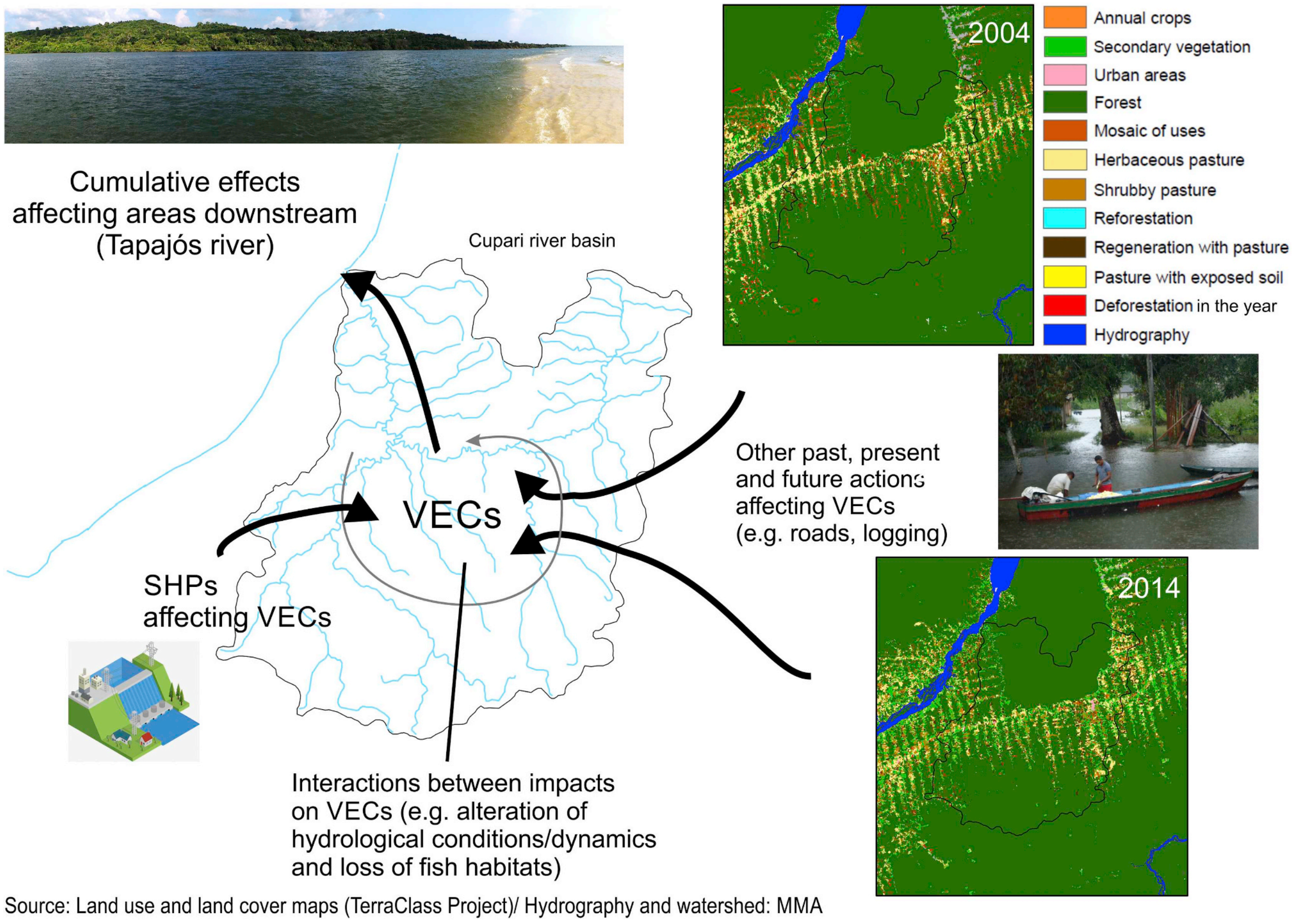

Fig. 3. Environmental quality and human livelihoods in the Cupari watershed will be affected by the proposed small and large hydropower plants and by other ongoing and future plans. Cumulative impacts are likely on diverse valued environmental and social components (VECs). The main driver of deforestation is the Transamazonian highway, built in the 1970s, visible in the center of the images. The satellite images show a progressive encroachment of human activities over the forest not only in the Cupari watershed, but also on the left margin of the Tapajós National Forest.

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Conflicts of interest

The authors declare no competing interests.

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Appendix A. Supplementary data

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