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APPRAISING SERVICES TO THE ECOSYSTEM: AN ANALYSIS OF ITAIPU POWER PLANT´S WATER SUPPLY IN ENERGY GENERATION

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INTRODUCTION

In sustainability studies, we see an increasing number of technical analyses on the socio-environmental impacts caused by major corporations in the area of power generation (Morimoto, 2013; Liu et al., 2013; Jiang, Quiang and Lin, 2016). Moreira *et al.* (2015) and Jiang, Quiang and Lin (2016) observed that the themes related with the issues hydroelectric plants face – among which those on environment management and sustainability – have become more attractive than the transformation technology itself, and that there is an interdisciplinary trend in research.

Due to the size of these projects and their impact on the environments where they are installed, hydroelectric actions related to sustainability are often discussed. From these, Jabbour *et al.* (2012) highlight the actions of a reactive nature, resulting from judicial demands, the pressure of stakeholders and surrounding communities; actions of a preventive nature, resulting from decisions to monitor environmental issues sensitive to the project (vegetation edges along the reservoir, water quality, *etc*); and actions of a proactive nature, resulting from the strategic orientation of the corporations involved.

Still in regards to sustainability and hydroelectric dams, most studies contemplate economic, social and environmental assessments (LIU *et al*., 2013; KUMAR; KATOCH, 2016). Local impact, the constraints these ventures can generate in ecosystems and nearby communities, changes in the dynamics of the aquatic and terrestrial habitat, the deposition of sediments in riverbeds, and others are also considered (YUKSEL, 2010; ZAO *et al*., 2012).

It is recognized that corporations cause impact in the surroundings of their operation, and that cautionary attention to these impacts becomes absolutely necessary, particularly in the social, economic, and environmental spheres. In this context, much has been discussed about the need for corporations to address the subject of sustainability, not only as an accessory matter, but incorporating it on strategic decision-making processes (Engert, Rauter and Baumgartner 2016; Moreira et al., 2015). It is in this scenario that many hydroelectric plants develop their sustainability programs, oriented by socio-environmental and economic issues. However, the definition of how to prioritize investments in these programs, as well as the magnitude of these investments still represents a challenge, so that one of the alternatives for this endeavor consists in the assessment of the ecosystem utility services (Garcia; Romeiro, 2015). By evaluating the utility services provided by the environment economically, governments and businesses can establish references for their expenditure with preservation, support actions to mitigate the degradation of natural resources, and in the case of need for payments for environmental utility services (Motta, 2001).

In face of the above, the objective of this study is to analyze the geographic reach and distribution of Itaipu power plant´s investments in environmental programs, among which their following actions: (i) sediment monitoring; (ii) micro-pollutants; (iii) water quality; (iv) vegetation management of the reservoir protection range; and (v) management of river basins, considering the area of influence and the water contributions of the municipalities upstream of its reservoir.

This subject constitutes a research opportunity, since in preliminary literature review attempts to evaluate the ecosystem services of the reservoirs of the Brazilian hydroelectric plants were not identified, despite the fact that this type of plants represents the main source of energy in the country (MME, 2017). In addition, the information generated through the evaluation can be useful for licensing processes, negotiation of the conditions for installation and operation, and environmental compensations. The article begins with the theoretical reference, and in sequence, the methodological procedures and findings are presented. Finally, the final considerations are discussed.

THEORETICAL REFERENCES

Evaluating Ecosystem Utility Services

It is argued that part of poverty and social inequalities is due to the lack of preservation of ecosystems, or their use in an unsustainable way, especially when looking for the needs of future generations (MEA, 2005). In this sense, attention has been focused on the economic benefits of maintaining biodiversity (TEEB, 2010). Given its relevance, in the academic and business circles, the economic evaluation of the benefits these ecosystems bring to society is what has been sought. Environmental evaluation consists of the process by which one seeks to estimate the economic value of natural resources by determining the equivalence of other available resources in the economy (Ojea et al., 2012).

The following table presents the definition of ecosystem utility services.

Concept of ecosystem utility services	**Author**
Conditions and processes by which natural ecosystems provide support to human wellbeing	Daily (1997)
Benefits human populations directly or indirectly obtain from ecosystem functions	Costanza (1997)
Components of nature directly harnessed to maintain human wellbeing	Boud; Banzhaf (2007)
Benefits people obtain from ecosystems	Wallace (2007)
Aspects of ecosystems used (directly or indirectly) for maintenance of human wellbeing	Fisher et al.(2009)
Benefits people obtain from ecosystems	MA (2005)

Table 1- Definition of ecosystem utility services
Source: Prepared based on the literature review

Recognizing the consensus about the concept, the challenge is to verify how to measure it from an economic perspective. In this context, Turner, Adger and Brouwer (1998), and Motta (2001) defend that although there are limits to economic calculation, recognizing that not everything is subject to significant monetary valuation, measurement can play a significant role in the process of environmental policy evaluation. In a study by Groot *et al.* (2002), the understanding about the quantification of ecosystem utility services was still identified as a problem with no definitive answer, besides the different interpretations of the implications of these calculations for the academic and business perspective (Spangenberg; Settele, 2010; Turner et al., 2010).

Turner and Daily (2007) point out the main challenges of defining a structure to evaluate ecosystem utility services, focusing on detailing information at relevant decision-making scales; practical *know-how* in the process of institutional design and implementation; and the presentation of compelling models of success in which economic incentives are aligned with preservation. In the words of these authors:

> Despite growing general awareness of conserved ecosystem benefits, detailed information at scales useful for decision makers on how people benefit from specific services remains deficient.

> This "information failure" is one reason why conservation investment finance is still too low and sometimes ineffective (Turner; Daily, 2007, p.27).

Among other shortcomings identified by Turner and Daily (2007), we can mention (i) "*institutional failure*s", in the sense that the beneficiaries of ecosystem utility services are often different and distant from those that gain with the transformation of the ecosystem. Local socio-ecological contexts, including property rights and institutions, often overlooked conservation programs; (ii) the "*market failures*" that derive from public characteristics of many benefits and their lack of prices. Markets typically reward short-term values of natural resources (overvaluing preservation opportunity costs) in detriment of long-term ecological health.

The arguments that support the evaluation exercise are based on the following points:

i. With the absence of market prices and definitions of property rights over particular natural resources, the evaluation of ecosystem utility services is sometimes not considered (Turner et al., 2010);
ii. However, the evaluation has opened new spaces for the debate on environmental policies, including in areas where dialogue on modes of preservation occurred in an abstract and imprecise way (Turner et al., 2010);
iii. In addition, proving how valuable an ecosystem utility service is can help in the projections for the economic development of countries (Motta, 2001);
iv. Evaluation can help prioritize organizations´ investments in environmental preservation (Fu *et al.*, 2014) e;
v. It can help in the construction of policies aimed at paying for environmental utility services in a precise way (Fu *et al.*, 2014);

As an exception to the exercise of the evaluation of ecosystem utility services, it is argued that the aggregation between the different functions provided by a given ecosystem should be restricted, due to the double counting risks. It is necessary to address possible incompatibilities between different evaluation measures (such as opportunity costs, consumer surplus, and market prices) (Turner; Adger; Brouwer, 1998), and the risk of problems related to the overlapping of ecosystem utility services and ambiguities in the interpretation of these services (Ojea; Ortega; Chiabai, 2012). Finally, the problem of lack of consensus on the commonly used methodologies, with respect to their efficiency to fulfil the intended purpose should be looked at (Nogueira *et al.*, 2000; Falco *et al.*, 2013). Discussing the challenges of defining the value of the ecosystem utility service of water supply, Garcia and Romero (2015, p.73-74) state that:

> "pricing" water is not a trivial task. Firstly, because there may not be sufficient information to allow an adequate valuation; secondly, because it is possible that situations occur where the adequate price cannot be fully charged to end-users [...] Adequate pricing must be understood as allowing for the maintenance of the "production" conditions, in terms of quantity and quality of the water resource.

Interfaces with Hydroelectric Plants

Among the evaluation models, we highlight the pioneering work of Costanza *et al.* (1997), which seeks to connect the processes and functions of the ecosystem with results of goods and services to which one can then assign economical value. Bryan *et al* (2010) sought to design an evaluation model in which it will be possible for decision-makers to establish investment priorities. Keller *et al.*(2012), in turn, present a model of evaluation of ecosystem services of regulation of water quality considering cause-effect relationships, concomitantly identifying the ecological pathways.

In an attempt to evaluate ecosystem utility services derived from the construction of reservoirs, Fu *et al.* (2014) argue that dams cannot completely replace the water conservation function of the ecosystem reservoir, and present high economic and environmental costs which must be paid. Compensation for water conservation services should become a basis for the ecological compensation owed by the hydroelectric plant. It is from this perspective that many of the initiatives materialized in sustainability programs developed by hydroelectric plants, and in payment programs for environmental services are justified. The former envisage preserving the environment affected by the hydroelectric plant, by acting in socio-environmental and economic initiatives, while the second consists in the remuneration of the agents that ensure the preservation of the environment. In both cases, understanding ecosystem utility services and their corresponding manner of assessment helps to define values, establish priorities, and evaluate results. Still according to these authors:

> Hydropower development is an important way to solve the energy demand in developing countries. In the global context of climate change, its importance is more prominent. But unscientific hydropower development causes great negative impact on the environment, thereby affecting the region's sustainable development. This requires stakeholders of hydropower development to correctly understand the relationship between protection and development, to fully consider the influence of ecosystem services on hydropower benefits, and to change the performance from passive compensation for environmental damage to active participation in watershed protection, so as to reduce the impact on the environment (FU et al., 2014, p.345).

Jager and Smith (2008), and Brauman *et al.* (2007) affirm that the reservoirs of large hydroelectric plants operate in systems that seek to maximize revenue based on the sale of energy, respecting some permits for use of the reservoir. Notwithstanding, these optimization systems do not usually consider the health of the aquatic ecosystem. To these authors, both situations must be reconciled, discarding a *trade-off* between the maximization of generation revenue and the preservation of the reservoir, so that harmonizing generation efficiency with environmental preservation becomes more plausible, based on the valuation of water supply.

In this way, in addition to deepening the debate on potential mitigating actions of risks of environmental degradation, as well as initiatives for preservation, it is still possible to remunerate agents – by paying for environmental services – who participate in initiatives of this nature, either by mitigating environmental impacts (Chan et al., 2006), soil erosion reduction (Lu*;* Li, 2006), or the cost of opportunities resulting from the fact that local residents give up their crops to preserve river springs (Brinkman, 2001).

In Brazil, approximately 65% of energy generation comes from hydroelectric plants, representing the main power source, followed by thermoelectric plants (coal, natural gas, and biomass) with 15%, wind power (4%), nuclear (3%), and other sources with 13% (MME, 2017). Considering the relevance of this source to energy supply, the main ecosystem services and their potential interfaces with hydroelectric plants are presented below.

Ecosystem utility services	**Concept**	**Relation with hydroelectric plants**
General provision	Production of tangible goods (food or inputs) that generate wellbeing.	Fish supply/monitoring
Water supply	Contribution in terms of quantity of water	Dependence for generation/impact on downstream users
Water quality regulation	Water quality control	Influence turbine operation
Regulation of assimilation of liquid effluents	Capacity of the ecosystems to dilute a pollutant load	Upstream third-part effluents may influence the plant
Regulation of global climate	Influence on emissions of relevant greenhouse gases	Maintenance and restauration of surrounding areas
Regulation of soil erosion	Role of ecosystems in the control of soil erosion processes	Control and monitoring, depending on the impact on the life of the reservoir
Leisure and tourism	Role of ecosystems in relaxation and leisure	Influence in touristic activities
Cultural services	Natural benefits	Modification of landscapes and interaction with ecosystems

Table 2: Main ecosystem services and interfaces with hydroelectric plants
Source: Adapted from TeSE –GV'ces (2017).

In this research, we considered the ecosystem utility service that is water supply as a priority, once it represents the input for generation, both for the total quantity provisioned and for the change in flow patterns. The existence of the enterprise, in turn, can also affect the availability of this ecosystem utility service to third parties. Besides, it is understood that the different uses of the soil in the basin, with the presence of greater or lesser degree of vegetation, potentially affects the availability of water for the generation system (GVces, 2018).

METHODOLOGICAL PROCEDURES

The proposal for the integration of the themes is illustrated here in the form of Itaipu hydroelectric plant and its particular *Sustainability Program*. The choice was intentional, once the corporation is considered the largest power generating hydroelectric plant in the world, with its sustainability program in force for over a decade, being internationally recognized for its contribution to the socio-economic development of the western region of Parana state, for its participation in the supply of energy to Brazil (approx. 18% of the country), and for its water management and conservation practices. The operation of this plant began in 1984. Its reservoir is 170km long, and 20 power units generating 700MW each were installed.

In addition, it is a company whose sustainability is supported by strategic planning, and whose vision shows. "Until 2020, ITAIPU Binational will consolidate as the best performance generator of clean and renewable power, with the best operative performance and best practices of sustainability in the world, impelling the sustainable development and regional integration" (ITAIPU, 2018).

The research was conducted assessing documents such as the *Ten-Year Energy Plan* (Brazil, 2017), the plant´s annual sustainability reports, other documents such as technical reports, and energy auction notices. The purpose of this stage of data collection was to obtain information about the actions contemplated by the sustainability program of this plant, as well as the localities benefited, and the data related to water consumption, energy generation, and revenues. Subsequently, we performed the valuation exercise for the water supply utility service using both the reposition cost and market prices methods (FU *et al*., 2014; GVces, 2018). With this information, we analyzed:

i. The expenses with environmental actions (in the period of 2010-2017) that may contribute for the maintenance of said ecosystem utility service;
ii. The history of energy generation, water consumption, and revenues obtained (in the same period: 2010-2017);
iii. The costs of replacing this source, in the eventuality of interruption of water supply;
iv. The localities where such investments were made, considering the map of the water contributions for the generation of energy.

Finally, the data obtained was presented to the managers of the environmental actions analyzed, and to the Itaipu power plant´s superintendent of environmental management, in order to obtain validation in face of the results.

PRESENTING THE FINDINGS

The following table presents the environmental actions considered in this evaluation, taking in consideration its objectives, the justification for the development and the disbursement made during the period considered: 2010 to 2017.

The environmental programs selected were the following:

Environmental action	Objective	Justification	Investments between 2010-2017
Sediment monitoring	Determine solid discharges and estimate the production of sediment in the water contribution basin, in order to estimate the sedimentation and guide the conservation actions. Operate the sedimentation measurement stations to estimate the life of the reservoir.	Accelerated erosion that has been occurring in the soil, particularly in agricultural areas, has become increasingly critical and difficult to be contained. The lack of erosion control practices – called conservation practices – generates serious social, environmental, and economic impacts such as impoverishment of soil fertility, deposition of sediment in reservoirs (diminishing life), compromising their multiple uses.	US$ 378,000.00
Water quality monitoring	Monitor the quality of the water in the reservoir, affluent streams, micro-basins, and groundwater. Provide technical subsidies for the management of the hydrous body.	Artificial eutrophication of reservoirs occurs due to the release of nutrients from different origins, such as: domestic, industrial, and/or agricultural effluents. This type of eutrophication is responsible for the "premature aging" of the aquatic ecosystem, where deep physical, chemical, and biological mutations then occur. This phenomenon can compromise water supply and generation of energy due to the proliferation of (macrophyte) aquatic plants. This monitoring allows also for the recommendation of preventive and/or corrective sanitation measures that eventually can be adopted to improve the water quality for different uses.	US$ 1,670,430
Micro-pollutants monitoring	Know the technical factors that can limit the commitment of the productive and edaphic environment to establish rational programs of	Monitoring agrotoxics and their metabolites in different matrices, and understanding their dynamics and influence in relation to biodiversity	US$ 202,680.00

	management and recommendation, whose more efficient use promotes the increase of harvests and reduces the costs and risks of environmental damage. Identify, quantify, and evaluate the main micro-pollutants in the cross-border region (BR-PY), in diverse matrices of environmental relevance (water, soil, nourishment and living organisms), seeking to understand the spread of these dynamics in the environment, and their relation with biodiversity.	is a necessity of the region belonging to the area of influence of the Itaipu power plant. This type of study contributes to the development of a region in various aspects, such as the development of management activities aimed at increasing productivity, and reducing environmental impacts.	
Management of vegetation in the protected area	Preserve and recover the protected areas belonging to the Itaipu power plant, guaranteeing their biological integrity and compliance with legal precepts, contributing to the preservation of regional biodiversity.	Itaipu protected areas, comprising the reservoir protection strip, reserves, and biological refuges require recovery actions, forest maintenance and monitoring, as well as legal regulations for their allowed multiple uses within sustainability criteria. The production of forest seedlings, foreseen in this action, aims to attend the reforestation programs for the areas belonging to the corporation, and the recovery of the permanent preservation areas in the micro-basins.	US$ 1,000,128.00
Management of river basins	Implement a set of water and soil management activities for environmental monitoring of the micro-basins affected by the Itaipu reservoir.	Reduce the contribution of sediments to the reservoir so that water is available with quality and quantity sufficient for energy production, and other uses.	US$ 6,034,300.00

Table 3: Distribution of investments in environmental actions
Source: Elaborated by the authors based on collection of secondary data

Regarding the history of energy generation and consumption, the following table presents the information that denotes dependency of water as an input, once its decline causes a decrease in generation. In this case, it is suggested that the economic evaluation reflects the loss of equivalent billing (GVces, 2018).

Table 4: History of water generation and consumption

Year	Generation (m³)	Cooling (m³)	Total (m³)	Total (GWh)	Revenue (US$)	m³/US$
2010	302.097.254.400	365.868.058	302.463.122.458	85.303	3.450.500.000	87.65
2011	325.706.832.000	365.868.058	326.072.700.058	91.523	3.384.400.000	96.34
2012	344.470.233.600	365.868.058	344.836.101.658	97.533	3.703.500.000	93.11
2013	349.168.579.200	365.868.058	349.534.447.258	97.878	3.760.100.000	92.95
2014	308.814.940.800	365.868.058	309.180.808.858	87.165	3.680.400.000	84.00
2015	314.462.476.800	365.868.058	314.828.344.858	88.575	3.680.800.000	85.53
2016	369.632.851.200	365.868.058	369.998.719.258	102.335	3.811.500.000	97.07
2017	336.110.688.000	365.868.058	336.476.556.058	95.682	3.729.703.000	90.21

Source: Based on secondary data

For the evaluation of the costs of replacing the energy source, the disbursement of replacing water was not examined, as it did not apply to the scenario. As an alternative (GVces, 2018), the replacement costs were used to deliver the same amount of energy to the Brazilian electric system. For this analysis, the lowest and the highest price of the energy auctions for an alternative source, thermal energy, from the last auctions of the chamber of commercialization of electric energy were considered (CCEE, 2017). In this scenario, it was verified that the disbursement for replacement of water would transit in a spectrum of 69% to 151% superior to Itaipu´s revenue.

Table 5: Comparatives by source of energy (lowest and highest rate)

YEAR	Production MWh	Itaipu revenue	Thermal min. price (US$ 67.12/MWh)	Thermal max. price (US$ 92.96/MWh)	(Itaipu - P. min) (Itaipu - P.max)
2010	85.303.000,00	3.450.500.000,00	5.771.134.259,26	7.992.025.925,93	67% - 132%
2011	91.523.000,00	3.384.400.000,00	6.143.905.092,59	8.508.249.259,26	82% - 151%
2012	97.533.000,00	3.703.500.000,00	6.547.354.166,67	9.066.956.666,67	77% - 145%

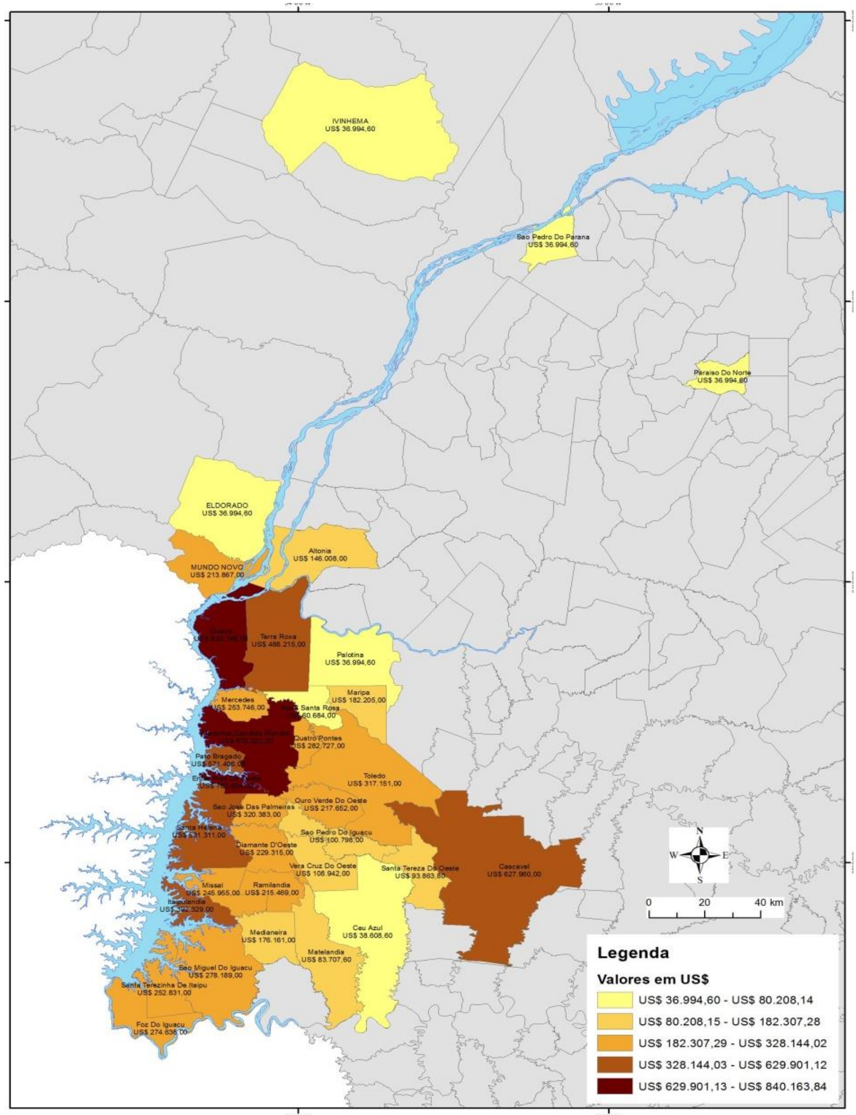
2013	97.878.000,00	3.760.100.000,00	6.570.513.888,89	9.099.028.888,89	74% - 142%
2014	87.165.000,00	3.680.400.000,00	5.851.354.166,67	8.103.116.666,67	59% - 120%
2015	88.575.000,00	3.680.800.000,00	5.946.006.944,44	8.234.194.444,44	61% - 124%
2016	102.335.000,00	3.811.500.000,00	6.869.710.648,15	9.513.364.814,81	80% - 150%
2017	95.682.000,00	3.729.703.000,00	6.422.175.840,00	8.894.598.720,00	72% - 138%

Source: Based on secondary data

For the conditions described in the first table above, the water supply services would be estimated by the market price method in approx. US$ 29 trillion dollars. For the conditions on the second table, using the method of costing replacement of water supply for power generation, the valuation would be in a minimum US$ 50 trillion dollars.

Recognizing this gradient as an estimate for the valuation of water supply, there is a strong possibility the analyzed power plant should expand its investments to include costs for ecologic compensation and environmental preservation (Fu *et al.*, 2014) in order to ensure continuity in water supply for power generation. It is recognized, however, that the application of more than one method for the evaluation suggests a significant breadth of values, representing still a challenge (Turner; Daily, 2007), as much as the impossibility of charging end-users an adequate value (Garcia; Romero, 2015), either because of resource constraints or because of the absence of clear public policies to support these evaluations.

From the aspect of environmental sustainability (Motta, 2001), this exercise would support actions to protect natural resources, such as water and micro-pollutants monitoring, besides management of the vegetation at the edge of the reservoir – and actions to mitigate degradation, such as those acting on water and soil, with the objective of reducing the ingress of sediments in the reservoir. Finally, we evaluated the localities where investments in environmental actions were carried out, considering the map of water contributions for the generation of energy, according to the following figure: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Paraiso Do Norte
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ELDORADO
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MUNDO NOVO
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Altonia
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Terra Roxa
US$ 486.215,00
Palotina
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Mercedes
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Maripa
US$ 182.205,00
Santa Rosa
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Quatro Pontes
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Toledo
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Ouro Verde Do Oeste
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Santa Helena
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Missal
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Ramilandia
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Foz Do Iguacu
US$ 274.636,00
54°0'0"W
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20
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Legenda
Valores em US$
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US$ 80.208,15 - US$ 182.307,28
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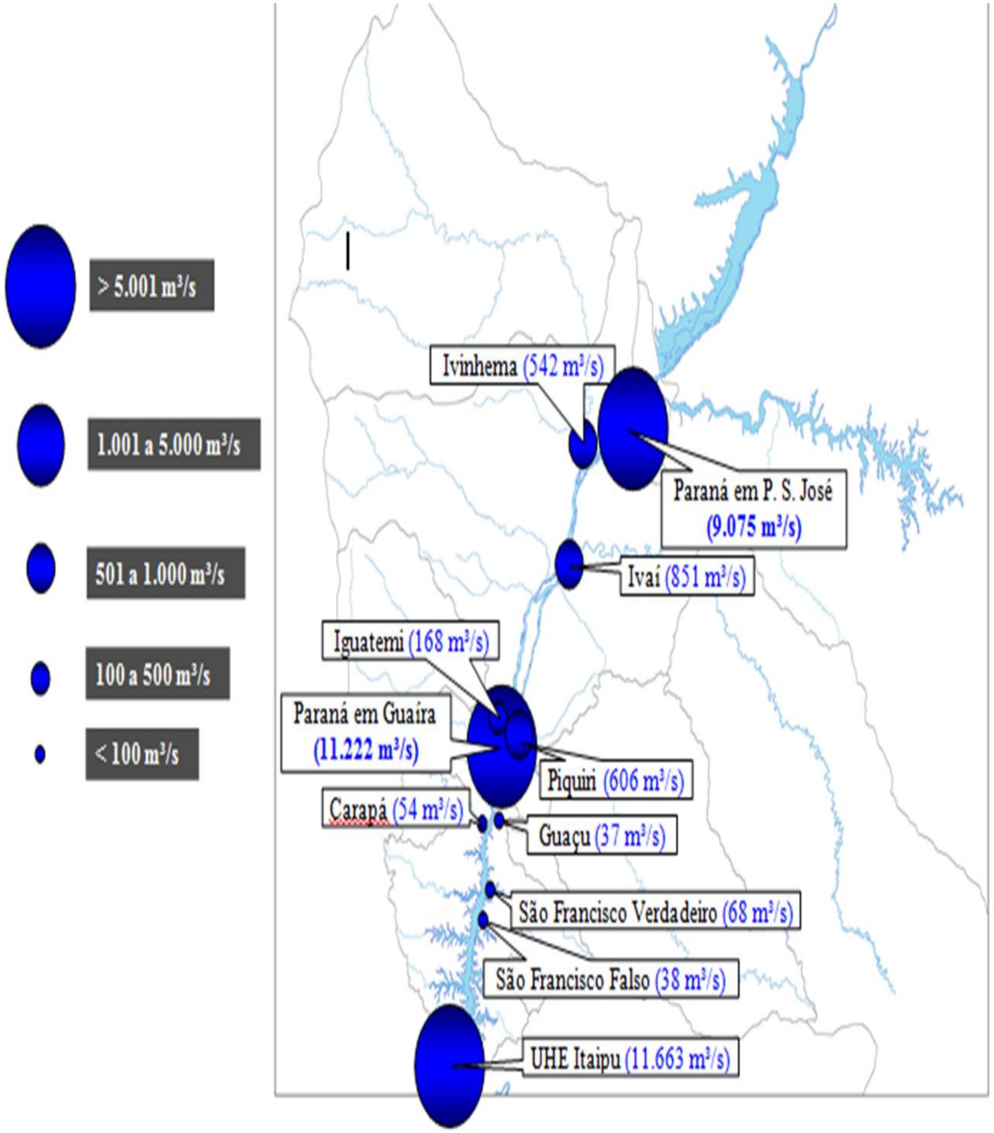
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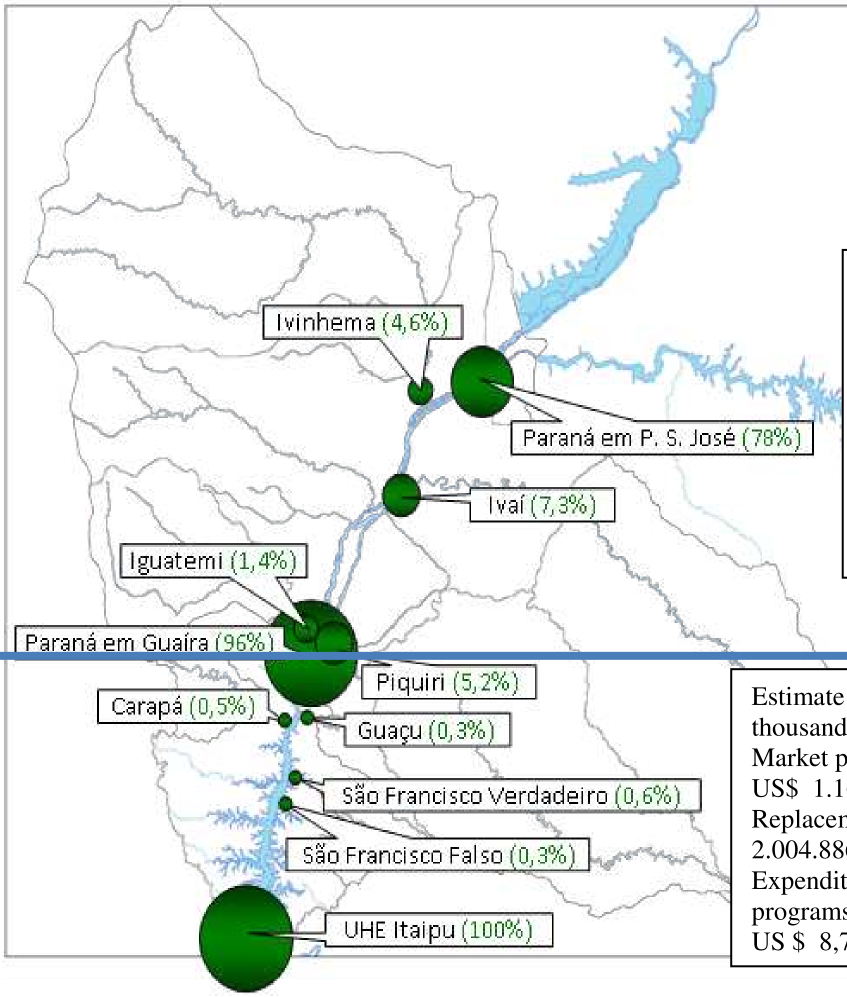
1.001 a 5.000 m³/s
501 a 1.000 m³/s
100 a 500 m³/s
< 100 m³/s
Ivinhema (542 m³/s)
Paraná em P. S. José (9.075 m³/s)
Ivaí (851 m³/s)
Iguatemi (168 m³/s)
Paraná em Guaíra (11.222 m³/s)
Piquiri (606 m³/s)
Carapá (54 m³/s)
Guaçu (37 m³/s)
São Francisco Verdadeiro (68 m³/s)
São Francisco Falso (38 m³/s)
UHE Itaipu (11.663 m³/s)

Figure 1: Spatial distribution of the investments X water supply valuation.
Source: Elaborated by the authors.

With the information on the evaluation of the ecosystem utility services of water supply for the Itaipu hydroelectric power plant, the water contributions for its reservoir, the spatial distribution of the investments in environmental actions aiming to maintain useful life in the reservoir, we next examined the following questions: (i) *Do the current investments spatially contemplate the regions that most contribute to the supply of water for power generation, i.e., the regions that provide the ecosystem service of water supply*? (ii) *What is the value of water provision for power generation*? The following map, validated by the representatives of the management board of the power plant in question, illustrates the questionings.



Estimate of water supply valuation (in thousands of dollars):
Market prices method: US$ 28,032,086.880
Replacement cost method: US$ 48,117,268.80640
Expenditure on environmental programs in the region:
US $ 507,8534

Estimate of water supply valuation (in thousands of dollars):
Market prices method:
US$ 1.168.036.120,00
Replacement cost method: US$ 2.004.886.200,27
Expenditure on environmental programs in the region:
US $ 8,777,684.6

Figure 2: Spatial distribution of the investments considering water supply valuation.
Source: Elaborated by the authors.

From the analysis of figure 2, it can be affirmed that the region that receives more investment in environmental preservation, through actions directed to sediments monitoring, micro-pollutants monitoring, water quality monitoring, management of vegetation in the reservoir´s protective edge, and micro-basins management represents, from the perspective of evaluating ecosystem utility water supply services, the one that contributes with only 4% to the water resources used for power generation. Almost all of the input for power generation is in fact provided by the most upstream region.

CONCLUSIONS

The objective of this work was to analyze the geographic reach and distribution of Itaipu hydroelectric power plant´s investments in environmental programs, among which their following actions: (i) sediment monitoring; (ii) micro-pollutants; (iii) water quality; (iv) vegetation management of the reservoir protection edge; and (v) management of river basins, considering the area of influence and the water contributions of the municipalities upstream of its reservoir. Information on water consumption was used to assess the provision of this input used in power generation, and concurrently the spatial distribution of investments was also observed.

It was found that approximately 5,4% of the investments in environmental preservation is concentrated in the region that contributes with approximately 96% of the water used for power generation, whereas that 94,6% of the investments are made in the region that contributes with only 4% of the water used. This evaluation exercise proves the relevance of environmental preservation actions, and provides support to the power plant under analysis, for the increase of investments to be made on the field of sustainability and the flow of these to specific regions. The evaluation exercise can also support new proactive and precautionary initiatives (Jabbour *et al.* 2012) turned to the preservation of the reservoir.

It should be noted that the power plant under analysis carries out innumerable other environmental actions which, due to their scope, were not considered in the current analysis, although they all are immensely relevant for the preservation of aquatic and terrestrial biodiversity. It should also be noted that, from a technical point of view, there are other factors that also contribute for energy generation, such as upstream and downstream water levels, availability of other generating units, and market demand for energy and streaming.

As a limitation of this research, we should mention the difficulties stemming from the non-replicability of some of the valuation, given the unique characteristics of the power plant under analysis, the fragmentation of the information required for the evaluation, the limited time perspective utilized (only 8 years), and the absence of comparatives, which could corroborate the analyzes performed in this research. Lastly, future research is suggested, undertaking similar studies in other large-scale hydroelectric power plants, and the re-evaluation of other environmental programs, from the perspective of their contributions to other localities supplying water for energy generation.

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