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ARTIFICIAL WATER RESERVOIRS: PERSPECTIVES ON THE BRAZILIAN LAW FOR THE PROTECTION OF NATIVE VEGETATION

RESERVATÓRIOS ARTIFICIAIS DE ÁGUA: PERSPECTIVAS DA LEI BRASILEIRA DE PROTEÇÃO DA VEGETAÇÃO NATIVA

EMBALSES ARTIFICIALES: PERSPECTIVAS SOBRE LA LEY BRASILEÑA PARA LA PROTECCIÓN DE LA VEGETACIÓN NATIVA

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ABSTRACT

The land surrounding artificial reservoirs is legally categorized as permanently protected areas (PPAs). However, updates to laws have led to uncertainties regarding such protection. To further clarify the effects of these changes, exploratory research was conducted and included a case study of the reservoirs in the Doce River Basin in the state of Minas Gerais, Brazil. Land use and land cover were analysed, and the vegetation cover within the PPA limits, as defined in the current and prior legislation, was quantified. At the study site, it is possible that approximately 87% of the area would no longer be classified as a PPA due to the less stringent protection limits for both hydroelectric power projects and public water supplies licensed after August 24, 2001. To minimize this loss, legal discussions are necessary, as well as new ecological studies to determine the impacts of the changes in the environmental legislation.

Keywords: Doce River Basin. Federal Law no. 12. 651/2012. New Brazilian Forest Code.

RESUMO

O entorno dos reservatórios artificiais é categorizado legalmente como Área de Preservação Permanente (APP). Porém, atualizações nos textos jurídicos trouxeram incertezas quanto a essa proteção. Buscando maior esclarecimento sobre os efeitos dessas mudanças, realizou-

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se pesquisa exploratória sobre a temática e estudo de caso em reservatórios da vertente mineira da bacia hidrográfica do rio Doce. Foram analisados uso e cobertura da terra e quantificada a cobertura vegetal nos limites de APP definidos na legislação atual e anterior. No local de estudo, cerca de 87% da área poderá deixar de ser enquadrada como APP devido à flexibilização nos limites de proteção de empreendimentos de aproveitamento de energia hidrelétrica e abastecimento público de água licenciados após 24 de agosto de 2001. Discussões em nível jurídico são necessárias para minimizar essa perda, bem como a realização de estudos ecológicos para comprovar os impactos que poderão ocorrer devido a alteração da legislação ambiental.

Palavras-chave: Bacia do Rio Doce. Lei Federal Nº 12. 651/2012. Novo Código Florestal.

RESUMEN
El territorio que rodea los embalses artificiales está legalmente categorizado como áreas permanentemente protegidas (APP). Sin embargo, las actualizaciones de las leyes han generado incertidumbres respecto a tal protección. Para aclarar aún más los efectos de estos cambios, se realizó una investigación exploratoria que incluyó un estudio de caso de los embalses de la cuenca del río Doce en el estado de Minas Gerais, Brasil. Se analizó el uso y la cobertura del territorio, y se cuantificó la cobertura vegetal dentro de los límites de APP, tal como se define en la legislación actual y anterior. En el sitio de estudio, es posible que aproximadamente el 87% del área ya no fuera clasificada como APP debido a los límites de protección menos rigurosos tanto para los proyectos hidroeléctricos como para los suministros públicos de agua autorizados después del 24 de agosto de 2001. Para minimizar esta pérdida, son necesarias discusiones legales, así como nuevos estudios ecológicos para determinar los impactos de los cambios en la legislación ambiental.

Palabras clave: Cuenca del Río Doce. Ley Federal No. 12.651/2012. Nuevo Código Forestal Brasileño.

1 INTRODUCTION

Artificial reservoirs are considered non-natural accumulations of water created by damming rivers for multiple uses. This damming enables volume accumulation and raising of the water level. Altering the character of a watercourse from lotic to lentic can lead to the erroneous conclusion that the banks of a reservoir do not require protection. However, as Müller notes (1995), the coastline formed by the creation of an artificial reservoir is established on a geologically and biologically unprepared surface, leading to erosive processes along the banks.

Erosion caused by wave action generated in an artificial reservoir (overlapping) causes the abrasion and rupture of bank slopes. The erosion processes involved then progress according to the geological and geotechnical characteristics of the banks. With respect to the cohesion of the soils, sandy soils with low cohesion are easily disaggregated, whereas young and more cohesive soils resist erosion. Similarly, the position of the water table can generate instabilities and trigger landslides on the slopes. The relief and the use of the banks (including the removal of vegetation, the establishment of allotments, construction and poorly designed drainage structures) is another influential factor (Dąbrowska *et al.*, 2016).

The environmental sensitivity of the areas around artificial reservoirs implies that, under the previous Brazilian Forest Code (Federal Law No. 4.771/1965), they were classified as permanently protected areas (PPAs). Thus, regardless of whether they were covered by native vegetation, these sites were under a special use regime. As such, land cover interventions or vegetation removal were only possible if such measures caused minimal environmental impact and served the public interest. This use regime was intended to preserve water resources, scenery, geological stability, biodiversity, the gene flow of fauna and flora, the protection of soil and to ensure human well-being (Brazil, 1965).

Although the environments around artificial reservoirs must be protected and access restricted, the Brazilian Forest Code of 1965 was replaced by the Law for the Protection of Native Vegetation (LPVN, in its Portuguese acronym) No. 12.651/2012. The latter allows for greater flexibility in the use of these areas. Thus, whether the new legal framework makes these areas more vulnerable is a pertinent matter of inquiry and the aim of this study. To determine this vulnerability, the Doce River Basin in the state of Minas Gerais was used as a case study. The relevant state level legislation was also considered (No. 20.922/2013).

2 MATERIALS AND METHODS

2.1 DESCRIPTION OF THE STUDY AREA

The Doce River Basin in Minas Gerais, Brazil was selected for scenario analysis. This basin is part of the Southeast Atlantic River Basin and is circumscribed by the latitudes 17°45' and 21°15' S and longitudes 39°55' and 43°45' W. It has a drainage area of approximately 86,715 km2 and, as it is in two states, Minas Gerais (86%) and Espírito Santo (14%), it is under federal jurisdiction.

The study area includes 229 municipalities (203 in Minas Gerais and 26 in Espírito Santo) with approximately 3.6 million inhabitants (IBGE, 2017). The primary economic activities are agriculture and agribusiness, especially the production of sugar and alcohol. The area includes a steel-manufacturing complex that is important for Latin America and is linked to mining and reforestation companies. There is great potential in the pulp, paper, dairy and trade sectors, as well as services related to industrial complexes, such as electricity generation (ANA, 2013).

Artificial water reservoirs used for power generation or public water supply were selected for the analysis. These reservoirs were subdivided as follows.

2.2 ANALYSIS OF ARTIFICIAL RESERVOIRS WITH LICENSES OR PERMISSION TO OPERATE GRANTED BEFORE AUGUST 24, 2001

Per Article 62 of the LPVN, the PPA for enterprises registered, licensed or granted permission to operate before Provisional Measure (MP, in its Portuguese acronym) No. 2.166-67 of August 24, 2001, is the distance between the normal maximum operating level and the maximum maximorum level (Brasil, 2012). All the artificial reservoirs in the Doce River Basin meeting these criteria were selected, to determine the impacts of the transitional provisions on these reservoirs through an analysis of the legislation and specialized technical literature.

2.3 ANALYSIS OF ARTIFICIAL RESERVOIRS WITH LICENSES OR PERMISSION TO OPERATE GRANTED AFTER AUGUST 24, 2001

According to Article 5 of the LPVN, building a reservoir for energy generation or public water supply requires the developer acquire, expropriate or obtain an easement for the PPA. The limits of the PPA should be established during environmental licensing, at a minimum of 30 m and maximum of 100 m in rural areas, and a minimum of 15 m and maximum of 30 m in urban areas (Brasil, 2012).

For this category, the selected case study was the artificial reservoir of the Baguari Hydroelectric Power Plant (HPP). This reservoir was selected because the environmental studies and processes of legal compliance were conducted in the period of transition between federal and state forest legislation. The following documents related to the licensing process were also consulted: Environmental Plan for the Conservation and Use of the Surrounding Areas Around Artificial Reservoirs (PACUERA, by its Portuguese acronym) and an Environmental Impact Assessment (EIA), both provided by the State Environment and Water Resources System (SISEMA, in its Portuguese acronym).

The Baguari HPP is located in the Doce River Basin in the state of Minas Gerais, 322.3 km upstream from the mouth of the river. The axis of the dam is located at the geographic coordinates 19º01'34" S and 42º07'32" W. It extends 22 km along the course of the Doce River and approximately 5 km along the Corrente Grande River. The artificial lake influences the municipalities of Governador Valadares, Periquito, Alpercata, Sobrália, Fernandes Tourinho and Iapu, all located in the state of Minas Gerais.

The Baguari HPP is a run-of-river structure and is part of the National Interconnected System of Brazil. The normal maximum operating level and maximum maximorum reservoir level is 185.00 m. The normal operating minimum is 184.50 m. The flooded area is approximately 16 km2, of which 8.3 km2 is the riverbed. In its upper middle section (upstream), the reservoir coincides with the river channel (Bios, 2014).

A comparative analysis was performed between Federal Law No. 4.771/1965 (including the National Environment Council Resolution – CONAMA – No. 302/2002 and State Law No. 14.309/2002) and the LPVN (including State Law No. 20.922/2013) to verify if changes had occurred in the PPAs of the artificial reservoirs of the Baguari HPP.

For the visual analysis of the data, RapidEye satellite images with a spatial resolution of 5 m were used. The data processing and analyses were performed using ArcGIS, version 10.1 software. Land use and cover data were extracted using a raster file created using an object-based supervised classification and the support vector machine (SVM) algorithm. The geoprocessing and analysis were performed by the Laboratory of Forest Management Studies and Projects of the Federal University of Lavras (LEMAF/UFLA, by its Portuguese acronym).

3 RESULTS AND DISCUSSION

3.1 BRIEF HISTORY OF THE PPAS OF ARTIFICIAL RESERVOIRS IN BRAZIL AND MINAS GERAIS

The previous Forest Code treated artificial reservoirs, lakes, ponds and natural water reservoirs in the same manner, establishing common protection limits. With the implementation of the LPVN, the term “reservoirs” was no longer applied to natural water bodies, being used only for artificial reservoirs, and natural lakes and ponds were treated separately (Article 4, Paragraph II). Thus, the protected area boundaries became defined by the project’s environmental license. For projects aimed at power generation or public water supply, a minimum distance of 30 metres was established for rural areas and 15 metres for urban areas, with a maximum of 100 metres in rural areas and 30 metres in urban areas (Brasil, 2012).

Under the new environmental protection regime, no minimum size was defined for reservoirs not used for energy generation (Article 4, Paragraph III). In addition to these changes, the LPVN: a) did not require a PPA for the areas around artificial water reservoirs that were not created by the damming or impoundment of natural watercourses; (b) eliminated PPAs for areas around natural or artificial water accumulations of less than one hectare in area; and c) determined, for projects “registered or with their licensing or permission to operate granted before MP No. 2.166-67/2001,” that the PPA be defined by the distance between the normal maximum operating level and the maximum maximorum (Brasil, 2012).

Regarding the leasing of artificial water reservoirs for power generation or public water supply, the new legislation maintained the project developer’s obligation to expropriate or obtain an administrative easement for the PPA around a reservoir. It also maintained the possibility of using up to 10% of the total PPA. This level was in accordance with the terms of reference issued by the competent institution of the National Environmental System, through the PACUERA. In special cases, in addition to this authorization to use 10% of the PPA, prior activities and businesses operating in these areas could continue to do so under the rubric of well-established anthropogenic use. Therefore, all entities and individuals who had conducted activities in the PPA until July 22, 2008, in violation of the previous legislation, obtained a license to continue these activities.

The 2002 Minas Gerais Law divided PPA metreage into the following categories: a) 15 m for electric power generation reservoirs up to 10 ha, with no compensation for

environmental losses; b) 30 m for a lagoon or reservoir located in a well-established urban area; c) 30 m for artificial water bodies, except tanks for aquaculture; and d) for natural water reservoirs located in rural areas, 50 m for those with an area of 20 ha or less and 100 m for those with an area over 20 ha (Minas Gerais, 2002).

In 2009, State Law No. 18.023 amended State Law 14.309/2002, which, in general, excluded the specification of PPAs for hydroelectric dams. This exclusion occurred because their delimitation would have already been defined in the river basin master plan (Article 10, Paragraph 2), which establishes PPAs with a width of 30 metres (Article 10, Paragraph 4). However, few watersheds actually had a master plan, thus transforming this exception into the rule in the state of Minas Gerais. This rule commonly began to be referred to as the "30-m law."

In 2013, the New Minas Gerais Law codified what was established in the LPVN, specifically in Article 4, §3 and Article 5, namely, that there was no longer any need for the protection of artificial water reservoirs that were not created by the damming or impoundment of natural watercourses. However, the Law of the State of Minas Gerais differed on the PPA parameters for artificial reservoirs with a surface area of up to 20 ha located in rural areas. According to Article 9, §3, the PPA must extend to a minimum of 15 metres measured from the maximum operating height, with a maximum range of 50 metres. Paragraph 4 specified that, unless it was in violation of municipal law, the PPA should be 15 metres in urban areas.

In addition to authorizing PPA use in special cases, the continuity of activities and businesses in these spaces was allowed under the rubric of established anthropogenic use. Thus, all those who had conducted activities in PPAs up to July 22, 2008, effectively obtained a license to continue these activities through the new LPVN (Laudares *et al.*, 2017).

3.2 ARTIFICIAL RESERVOIRS WITH LICENSES OR PERMISSION TO OPERATE GRANTED BEFORE PROVISIONAL MEASURE NO. 2.166-67 OF AUGUST 24, 2001

MP No. 2.166-67/2001 established an obligation of the project developer to expropriate or acquire the PPAs around the artificial reservoirs, and allocated decision making regarding the parameters and regime of use to CONAMA. These changes made it clear that, from that moment forwards, third parties could not be assigned responsibility for the PPAs. According to Article 62 of the LPVN, the date of August 24, 2001 was established as a marker for the stringent compliance with the new law as well as its new flexible implementation. It should be noted that the LPVN adds the ability to obtain an administrative easement for the

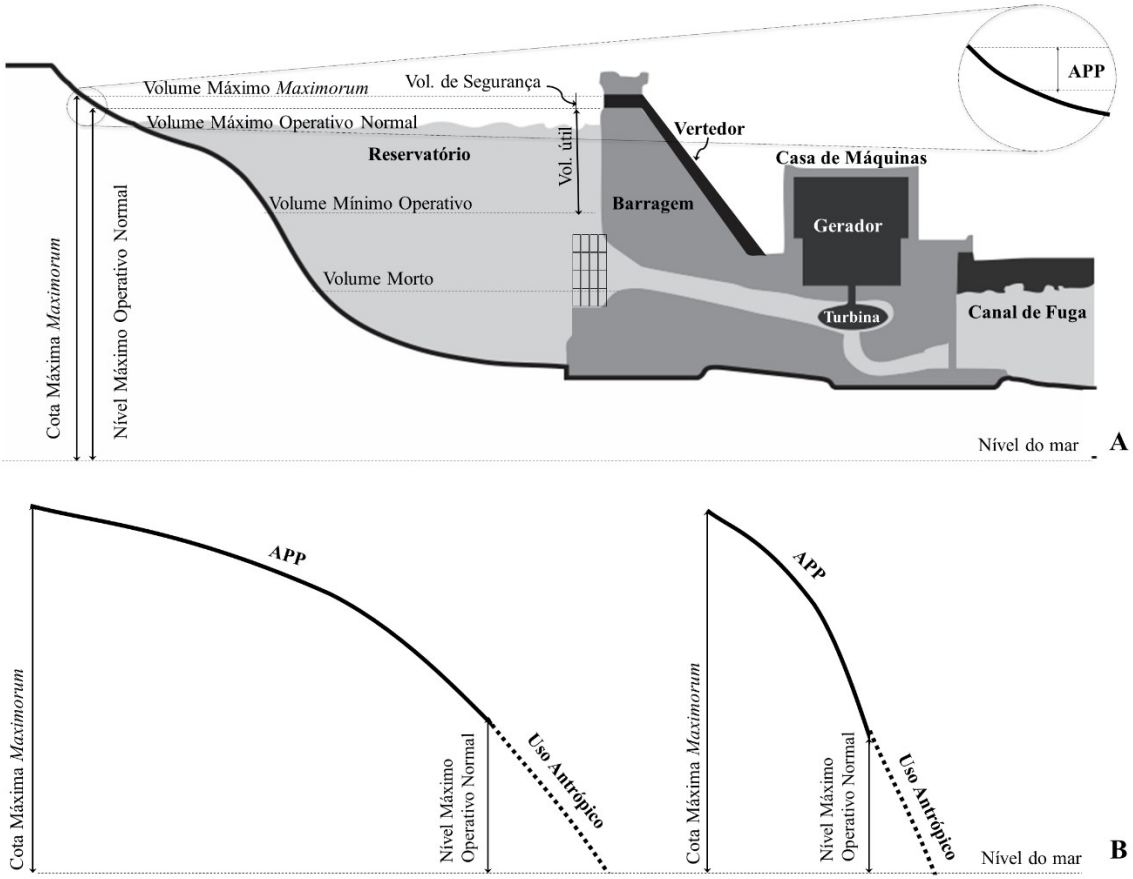
PPA in the surrounding area of the reservoir. Thus, it is possible for the State to intervene in private property for the public good, placing some restrictions on the owner's use and enjoyment of the property. This intervention enables a mandatory specific use of the land in exchange of the value of the easement (Rodrigues and Messias Júnior, 2013).

The weakening of the regulations, with respect to the variation between the maximum operational limit and the maximum maximorum, created inconsistencies regarding PPAs and the need for protection in areas where anthropogenic pressures had significantly modified the landscape (Oliveira *et al.*, 2018). Legally, PPAs should meet their norms as established in the law. However, a variation in the dimensions only provides safety from a range of probable floods. This safety was designed to protect not only the riverine population but also the project, more specifically, its infrastructure and, consequently, the life of the hydroelectric plant.

The term "head of water" in the hydroelectric dam context, refers to the vertical distance between the water level of the reservoir and the mean sea level. The "normal maximum" is the water level where the riverbed should be in normal operational activities. The "maximum maximorum" level is the maximum superelevation level in a possible flood episode (Figure 1A). Thus, the range of the PPA is dependent on the slope of the reservoir environment; the greater the slope, the smaller the range. Therefore, the range varies along the reservoir (Figure 1B).

Figure 1

A – Components of an artificial reservoir, showing the PPA and the maximum maximorum head of water and normal maximum operating level. B – Change in the area of the PPA depending upon slope, with the PPA decreasing as slope increases



Source: Prepared by the authors.

Analysing the primary reservoirs of the Doce River Basin that date to before MP 2.666-67/2001 (Table 1) reveals that Article 62 of the LPVN does not meet the requirements of a PPA. In other words, the small difference between the maximorum head of water and the normal maximum operating level is insufficient to maintain the ecological functions of a PPA.

Table 1

Primary artificial reservoirs of the Doce River in Minas Gerais

HPP	Normal maximum operating level (m)	Maximum *maximorum* height (m)	Difference	Licensing year
Guilman Amorim	495,00	498,50	3,50	1995
Sá Carvalho	372,93	373,03	0,10	1944
Salto Grande	356,12	356,12	0,00	1949
Porto Estrela	257,70	259,60	1,90	1997
Risoleta Neves	327,50	327,50	0,00	2000

(Candonga)				
Aimorés	90,00	92,00	2,00	1975

Source: ONS (2018).

The small differences between the heads of water also limit the use of geotechnologies, because the differences cannot be detected using the best spatial resolution available free of charge for geoprocessing analysis, such as the 30-m (1 arc-second) resolution Shuttle Radar Topography Mission (SRTM) digital elevation model. To ensure that PPAs are serving their purpose, a greater investment in technology and greater demand for a cadre of specialists are needed. However, the studies and demarcations of the boundaries of PPAs should be conducted in loco.

Article 62 of the LPVN did not result in technical or environmental benefits. It only facilitated the regularization of projects within PPAs through a modification of the previous legal framework. It is important to note that this article is included in the transitional provisions, Section II of Chapter XIII, and is therefore not meant to be a corrective action for circumstances already covered by the previous legislation. Caribé (2013) notes that the transitional provisions are intended to address outstanding issues, such as reservoirs that were granted operating licenses until August 24, 2001, pending environmental regulation.

3.3 ARTIFICIAL RESERVOIRS WITH LICENSES OR PERMISSION TO OPERATE GRANTED AFTER PROVISIONAL MEASURE NO. 2.166-67 OF AUGUST 24, 2001

The Baguari HPP is an artificial water reservoir used for energy generation. As such, Article 5 of the LPVN and Article 22 of the current mining legislation are relevant to its environmental licensing. Therefore, the project developer must acquire, expropriate or obtain an administrative easement for the PPAs around the reservoir.

The PACUERA of the Baguari HPP establishes a variable PPA around the reservoir. This variable PPA was already foreseen by CONAMA Resolution No. 302/2002, which regulated the implementation of the 1965 Brazilian Forest Code. As established in the environmental licensing and water resources of the basin where the reservoir is located, the CONAMA resolution allowed for the limits of the PPA to be increased or reduced, without being decreased beyond minimum levels. The legality was also bolstered by State Law No. 14.309/2002 (modified by State Law No. 18.023 /2009), regarding the establishment of the minimum range of 30 m in rural areas.

Given that under both CONAMA Resolution No. 302/2002 and State Law No. 14.309/2002, a variable PPA was an exception, a simulation of the possible losses resulting from the change in the Brazilian Forest Code conducted for Baguari HPP. Table 2 presents the results of this analysis, showing the reductions of the protected areas in the reservoir's surroundings for rural or urban zones.

Table 2

Soil use in the Baguari HPP

Soil use	PPA					
	Current laws			Revoked laws		
	Urban 15 m	Rural 30 m	Total	Urban 30 m	Rural 100 m	Total
	Area (ha)					
Remaining	0,01	96,63	96,64	0,09	175,01	175,10
Consolidated Area	1,34	194,05	195,39	2,3	585,28	587,60
Water	0,00	3,20	3,20	0,00	16,73	16,73
Urban Infrastructure	0,63	0,00	0,63	1,50	1,27	2,77
Total PPA	1,98	293,88	295,86	3,89	778,29	782,20

Source: Prepared by the authors.

The simulation revealed a loss of 87.16% of the PPA around the reservoir caused by the change in legislation. Regarding the native vegetation remnant in the PPA, 78.46 ha (10.03%) were no longer protected. In areas where native vegetation is still present, land use conversion may be permitted by the competent environmental agencies if the project developer claims public utility, social interest or that the planned activities are of minimal environmental impact. Due to the long-term nature of the activities in PPAs located in rural areas, 585.28 ha (74.83%) of the vegetation would no longer be restored. In well-established urban areas, should Article 2, Item III be cited, approximately 3.80 ha (97.75%) of the PPA would no longer be restored. This is because, when included in the municipal master plan and according to the expansion of projects approved by the municipality on July 22, 2018, under certain circumstances, this element of the law establishes alternative land uses in long-occupied areas. These include the occupation of areas with buildings, improvements or land subdivisions.

The Technical Assistance and Rural Extension Company of the state of Minas Gerais conducted a study to verify the effect of economic limits on the implementation of a PPA with variable widths (from 30 to 100 m) or a linear range (of 100 m), the latter being based on the PACUERA of the Baguari HPP. The economic productivity of the use of these lands was considered, as well as the total for each productive system. As a result, for the year 2001, the

monetary loss would have been R$ 2,996.77 for the variable PPA and R$ 530,776.07 for the linear PPA of 100 m. The report did not discuss the environmental advantages associated with the extension of the PPA; instead, it considered how the increase in the protected area would significantly impinge upon the way of life of local producers. Stating that there is no significant environmental improvement is questionable, given that the area includes an aquatic-terrestrial transition zone. This transition area is important with respect to the regulation of sediment transport, water and nutrients throughout the landscape. The area also facilitates the pollination of agricultural crops as well as climate regulation. It also contributes to maintaining the turbines of the hydroelectric plants, increasing the useful life of dams and their ability to generate energy (Meynendonckx *et al.*, 2006; Tambosi *et al.*, 2015; Ou *et al.*, 2016; Brancalion *et al.*, 2016). In defining this variable area for the protection of ecosystem services, the use of the soil and the relief of the area surrounding the reservoir (Maillard and Santos, 2008; Ou *et al.*, 2016, Brancalion *et al.*, 2016) should be considered.

Maillard and Santos (2008) indicated that the establishment of a 30-m buffer for water quality protection may be effective for pastures, but that it should be wider in areas where large amounts of nitrogen fertilizer are used. Ou *et al.* (2016) determined that, to mitigate the effects of fertilizer use, the buffer should be approximately 100 m wide to better ensure acceptable water quality.

According to Hansen *et al.* (2010), a review of 222 studies conducted in Australia indicated that the protective range for species of fauna and flora in riparian forests should vary according to the intensity of land use: 100 metres for high intensity, 70 metres for moderate intensity and 40 metres for low intensity. In the state of São Paulo, Valle *et al.* (2013) determined that, compared to wider bands (60 and 100 metres wide), there was a continuous decrease in the number of threatened species of aquatic macroinvertebrates in bands 30 metres wide. Metzger (2010) argued that a minimum of 100 metres of forested area for each margin of the streams in the Cerrado (tropical savannah) region would be necessary for the maintenance of local biodiversity. Ramos and Anjos (2014) noted that vegetation corridors need to be at least 50 metres wide for animals to be able to use them.

Therefore, for a variable range of PPAs to be feasible, there should be sufficient technical knowledge regarding the region where the project is located. This would allow the specification of a PPA oriented towards sustainable development.

4 CONCLUSIONS

The primary environmental issues related to artificial reservoirs stemming from the changes in the LPVN are as follows: I. The surrounding areas of artificial reservoirs smaller than one hectare in size are no longer classified as a PPA; II. The PPA limits for businesses with a license or permission to operate granted before MP No. 2.166-67/2001 are determined by the distance between the normal maximum operating level and the maximum maximorum head of water. The latter, which was included in the transitional measures, only considered the protection of businesses and riverine populations from eventual floods and ignored the ecological functions of the PPA. Thus, the laws assumed a purely regulatory function and ignored environmental considerations. This was also the case at the state level in Minas Gerais, following State Law No. 20.922/2013.

The use of a variable PPA for the surroundings of artificial reservoirs was considered viable for those PPAs that were legally established after MP No. 2.166-67/2001. However, this would require in-depth studies of the technical-environmental knowledge of a region that focused on the maximum conservation of the remnants of native vegetation. In the case of the Baguari HPP, a possible loss of 87.16% of PPA was determined; therefore, provided the current soil cover, 74.83% of the area will not need to be restored as its anthropogenic use is well established.

It is therefore necessary to consider new legal mechanisms to mitigate the losses mentioned, as well as to conduct ecological studies proving the effects of the flexibilization of the law on the essential functions of PPAs.

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