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SUSTAINABILITY ISSUES: RIPARIAN VEGETATION AND ITS IMPORTANCE IN THE HYDROLOGICAL CYCLE IN AMAZONIAN ECOSYSTEMS[1]

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Abstract. Deforestation and degradation of riparian forests have advanced significantly in the Amazon. This fact has drawn attention to its protection, especially since these forests are one of the fundamental components of the hydrogeochemical cycles and the hydrological cycle. The objective of this article is to analyze the importance of riparian vegetation in the protection of Amazonian water resources and to discuss the main changes/innovations of the New Forest Code related to PPAs. The new Brazilian Forest Code (Law 12.651, of May 25, 2012) defines the Permanent Preservation Area (PPA regions) as "protected area, covered or not by native vegetation, with the environmental function of preserving water resources, landscape, geological stability and biodiversity, as well as facilitating the gene flow of fauna and flora, protecting the soil and ensuring the well-being of human populations. "In the context of the New Forest Code, the main changes related to the Permanent Preservation Areas (PPAs), as well as the fragilities and threats to its integrity, and what is being done to mitigate the loss of vegetation cover in the Amazon.

Keywords: Sustainability Issues; Watershed Forests; Water Resources; Brazilian Forest Code; Amazon

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1. Introduction

The Amazon biome plays an important role in the national and international scenario regarding to climatic issues. This is mainly due to its territorial extension and the enormous diversity of environments, including wetlands and biodiversity, with 53 large ecosystems. These ecosystems can be grouped into forest areas; typical Andean environments (near the highest springs of the basin); varzeas (floodplain vegetation); areas of tropical savannas and steppes. Among these environments, the most extensive are the humid forests of southwestern Amazonia, the humid forests of the Madeira-Tapajós regions and the humid forests of the Guyanas (Sayres et al., 2008).

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The Amazonian wetlands biomes are covered with several flood vegetation typologies, very rich in species and highly adapted to prolonged and deep floods (Inau, 2017). Despite the efforts of the scientific community, wetlands are still considered of little economic, ecological and/or social value in Brazil. This is evident in the debate about the new Forest Code, which completely ignores the ecological and socioeconomic importance of Humid Areas (HA) (Souza Jr. et al. 2011; Piedade et al. 2012; Junk et al. 2012; Rocha et al. 2018; Cardoso et al. 2018; Muniz et al. 2018). The discussion highlights gaps concerning the importance of HA by decision makers, as well as the absence of legal mechanisms for their adequate protection / conservation.

Varzea forests and floodplains usually have less diversity than terra-firme forests. They hold animals and plants adapted to seasonal hydrological conditions. The smaller diversity of this type of vegetation occurs because there are few species that have morpho-physiological mechanisms that support the seasonal flooding rhythm (Ferreira & Stohlgren, 1999). Riparian forests and vegetation mosaics in hydrographic basins are one of the fundamental components of the hydro-geochemical and hydrological cycles (Tundisi and Tundisi, 2010). The removal of these forests has considerable impacts on water quality and on the environmental services of aquatic ecosystems (Tucci and Mendes, 2006).

The set of ecological processes supported by riparian forests has fundamental economic components, such as renewal of water quality; the control and recharge of aquifers; water replenished by evapotranspiration and in the control of sedimentation of aquatic ecosystems. All these factors reflect the processes of water volume preservation. In addition, they act in the supply of organic matter for fauna and stock keeping, diversity, and refuge of the fauna, besides being constituted in a breeding area (Tundisi and Tundisi, 2008). Deforestation and degradation of riparian forests have advanced significantly in the Amazon. This has raised awareness of their protection, especially as these forests protect water, a resource that is becoming scarce in the world. Large expanses of riparian forests are destroyed by the development of cities, deforestation for timber extraction, use in cutting-to-subsistence agriculture and ranching, due to the high fertility of their soil and easy access (Junk et al., 2000). In addition, anthropic activity in these areas leads to enormous socioeconomic and environmental damages (Zelarayán et al., 2015).

Concern over the conservation and restoration of riparian vegetation cover is relatively recent in Brazil and has been the subject of wide and frequent discussions. Current legislation addresses technical-scientific and conservationist issues. The importance of the forests along the rivers is based on the diverse benefits that this type of vegetation brings to the ecosystem, exerting a protective function on all the natural, biotic and abiotic resources. According to Tambosi et al. (2015), the presence of vegetation, particularly of riparian forests, supports a series of eco-hydrological functions, since this vegetation provides a suitable microclimate for the aquatic environment, reducing the incidence of increasing the thermal stability of the aquatic environment.

The functions of riparian vegetation also guarantee greater stability in different physicochemical parameters of water, besides reducing the risk of eutrophication. Therefore, it favors the maintenance of water quality and possible treatment costs for human use (Casatti, 2010; Tundisi & Tundisi, 2010; Tundisi, 2014; Rivza, Kruzmetra, 2017). In this context, this article aims to analyze the importance of riparian vegetation in the protection of Amazonian water resources, as well as to discuss the main changes/innovations of the new Forest Code related to PPAs. Considering that the same, among other determinations, began to demand the presence of vegetation on the banks of rivers, lakes and streams, and the recovery of degraded areas. In the section two it is discussed the importance of Permanent Preservation Areas in different biomes according to the different types of vegetation cover. Section three addresses the implications of the new forest codes to small holder and landowner of large proprieties. It is also discussed different points of view from environmentalists to landowners. Section four points out the fragility and threats the integrity of the permanent preservation areas. Finally, it is explained what the Ministry of Environment has done to mitigate the threats of these important protected areas through the PLANAVEG (project to restore deforested areas in all Brazilian biomes).

2. Permanent Preservation Areas (PPAs) and their importance.

The new Brazilian Forest Code (Law 12.651, dated May 25th, 2012) defines a Permanent Preservation Area (PPA) as "protected area, covered or not by native vegetation, with the environmental function of preserving water resources, landscape, geological stability and biodiversity, as well as facilitating the gene flow of fauna and flora, protecting the soil and ensuring the well-being of human populations. PPAs are identified in rural and urban areas as sensitive land areas, such as the marginal ranges of any perennial and intermittent natural watercourse; areas around lakes and natural lagoons; the areas surrounding artificial water reservoirs resulting from the damming or dykes of natural water courses; the areas around the springs and perennial water springs, whatever their topographical situation; the tops of hills; slopes with slopes greater than 45 °; the seashore creeping vegetation ("*restingas*") and dunes, the mangroves and the borders of plateau and sandbanks in a river (Federal Law no. 12.651 - Brazilian Forest Code). PPAs are essential for the maintenance of water resources. The presence of vegetation, and in particular of forests in these riparian areas, provides a series of eco-hydrological functions, directly influencing the physical-chemical and biological parameters of water bodies (Tambosi et al., 2015). Despite this, PPAs are currently subject to large extensions of degradation due to the intensification of anthropogenic pressures on the environment. As a result, there is a process of replacing natural landscapes with other uses and land occupations and the conversion of forest cover areas into forest fragments, compromising the environment and, in many cases, affecting the availability of important natural resources to life (Moreira et al., 2015).

3. What does the Law say about Permanent Preservation Areas (PPAs)?

In order to strengthen the protection of water resources, the Brazilian Forestry Law establishes the need for the presence of Permanent Preservation Areas, as well as their recovery and conservation. However, over the years, Brazilian Environmental Legislation has undergone changes, the main one being the creation of Law 12.651 of May 25, 2012, which became known as the "New Brazilian Forest Code", replacing the "1965 Forest Code. The "New Forest Code" has been harshly criticized by environmentalists, especially regarding changes in the preservation and recovery of APPS.

One of the main changes that occurred was the reduction of protected areas. The new law includes the areas of PPAs in the calculation of the Legal Reserve of rural properties (80% of the territory must be covered by forest in Amazon region). This measure made the calculation of the PPAs size more flexible with respect to the starting point for the delimitation of the marginal strip to the watercourses. In the 1965 code, the extent of the area to be preserved (APP) was delimited from the highest level of the rivers (highest seasonal bed), including flood areas at times of floods, varying according to the width of the water course. With the creation of the new forest code, PPA was delimited by the regular river bed and the recovery of riparian vegetation or riparian forests in small properties (up to four fiscal modules) began to vary according to the size of the property. The range to be recomposed ranges from 5 to 15 m. Properties with more than four fiscal modules, the range to be preserved ranges from 30 to 500 m. For Tambosi et al. (2015), this change has a double effect: (i) it reduces the width of the river (which formerly included the annual floodplain), so that the width of the protection range can be reduced; and ii) it reduces the protection of floodplain forest areas, especially in rivers with broad floodplains (as is the case with several rivers and in the Amazon). The authors also point out that with the new Forest Code riparian PPAs will protect only part of the floodplain areas, which is particularly serious since floodplains play important ecosystem and hydrological functions. In addition to attenuating the erosive forces of surface runoff of rainwater, floodplains help control floods and water quality, are fundamental in aquifer recharge, and still exert an ecological function - they are systems of transition between terrestrial and aquatic ecosystems, among others (Tundisi and Tundisi, 2010; Silva et al., 2012).

Protection of springs is another important difference between the "Old" and the "New" Forest Code. The 2012 Forest Code only covers perennial springs. The protection of intermittent springs and the marginal ranges of ephemeral watercourses were excluded. According to Tambosi et al. (2015), this threatens several springs and watercourses and, consequently, jeopardizes the protection of water resources, particularly in more susceptible areas where the climate is drier.

One of the points criticized in the new code is the amnesty of fines for producers who have deforested their protected areas (PPAs and Legal Reserve) until July 22, 2008 (date of the decree that regulates the Environmental Crimes Law - Law 9,605 of December 12, 2008). February 1998). For some environmentalists, this amnesty creates a legal precedent and insecurity that encourages deforestation. Those who commit environmental crimes may be forgiven of their penalties (Orenstein, 2017). In addition, in the 1965 forest code, all areas of PPA (Riparian forests) occupied by anthropic activity should be restored / recovered with native vegetation. In the "New Forest Code", the PPAs with use already consolidated until July 22, 2008 have to be recovered, but not in their entirety. The extent of the PPA to be recovered varies according to the size of the property in fiscal modules, the type of PPA and the width of the water bodies. As established in the new code, areas to be restored along the banks of rivers, lakes, ponds and footpaths diminish as the size of the property decreases. There is also a maximum value of 10% for properties less than two fiscal modules and 20% between two and four fiscal modules (Federal Law 12.651 / 2012). This reduction of the areas to be restored, together with the non-requirement of restoration of the hilltop and hillside PPAs, may reduce the potential of these areas to provide all eco-hydrological services. They are essential for both the provision and the quality of water for human use (Tambosi et al., 2015).

One of the positive aspects of the "New Forest Code" was the creation of the Rural Environmental Registry (CAR-Acronym in Portuguese language). It is mandatory for all rural properties in Brazil, being the first step in the process of environmental regularization of private lands. The CAR includes all environmental information of rural properties and appropriations, such as PPAs and Legal Reserve areas, with geo-referenced data and landowner information. The owner who does not register his rural property loses the opportunity of environmental regularization under the conditions and terms offered by Law 12.651. They will lose the opportunity of the suspension of the notices and fines received before July 22, 2008. The same will be prevented from receiving agricultural credit from financial institutions, as well as from marketing its land. In the process of buying and selling rural properties, the environmental liability must be legalized. Since the enactment of the New Forest Code, CAR is the most concrete result of the law. As of April 30, 2017, 4.1 million rural properties had been registered in the CAR, representing a total of 408 million hectares (Orenstein, 2017).

Farmers who join the CAR are well-regarded both in the agricultural sector of the economy and as well by environmentalists. Rural properties registered in the CAR with environmental liabilities - PPAs and altered / deforested legal reserves may join the PRA (Environmental Regularization Program). The PRA allows the states to guide and accompany the rural producers in the elaboration and implementation of the actions necessary for the recovery of areas with environmental liabilities. However, as it depends on the investment of each state of the Brazilian Federation, the PRA is not yet fully established in all regions of Brazil. One of the most expected by agrarian sectors and environmentalists, but still far from working in practice is the CRA (Environmental Reserve Quota). It is a title that can be issued to anyone who has a Legal Reserve area surplus. The landowner can negotiate this forest asset with another producer who has insufficient reserves. These shares would be traded on the Stock Exchange (Orenstein, 2017). This share is interesting from the point of view of the preservation of biodiversity, since water resources are inefficient. This policy does not take into account river basins. This may in the future mean some basins with a percentage of vegetation cover lower than that recommended for the maintenance of water resources. Otherwise, other basins would receive more quotas, and would have a greater integrality of the vegetal resources. There would therefore be an imbalance in the uniformity of landscapes.

Due to these major changes, the debate on the new Forest Code has intensified. However, one does not believe in a setback, but in a new way. Since the new Forest Code does not only consider environmental issues, but also economic and social aspects. The new code allows the continuity of economic activities in part of the PPAs already consolidated until 07/22/2008. Thus, the restoration of the vegetation in the legal reserve areas will be possible to intercalate native species with fruit trees in an agroforestry system. This allows a change of attitude of farmers and rancher as it can be an incentive to recover their degraded areas. It combines ecological balance and a future economic return. In this way, the country could reach a sustainable development in balance of environment conservation policies (Stjepanović et al. 2017).

4. Fragility and threats to the integrity of PPAs

Anthropogenic activities of various types have increased in the last fifty years in the Amazon Basin. Large areas of lowland and terra-firme forests have already been deforested for forest exploitation, agricultural and livestock use an extension of PPAs. Another important factor to be considered is the mining of gold, iron, tin, china clay and bauxite that has resulted in deforestation of significant areas. The oil industry does not require large deforested areas. However, all these mining developments must be well planned to avoid increasing the risk of contamination of the river system. The elimination of the original vegetation has resulted in the increase of the erosion rates and the sedimentation of the river system. It can also result in a change in the regional climate, due to its importance in the regional hydrological cycle and its contribution to the atmospheric balance of CO2 and H2O, causing a consequent influence on the global climate. Some research indicates that rainfall in the Amazon Basin will decrease in the coming decades due to changes in global climate, and this may significantly alter the geological and biogeochemical characteristics of river systems.

5. What is being done to mitigate the loss of vegetation cover in the Amazon?

The Ministry of Environment (MMA) concerned with the implementation of Law 12.651, May 25th, 2012, proposed the National Plan for the Recovery of Native Vegetation - PLANAVEG. The elaboration of this plan was a huge challenge for the technicians and its implementation has been discussed among various sectors of society, academic, political and business. It was based on experiences and success actions both in Brazil and abroad. PLANAVEG was designed to meet these demands. It also aimed to expand and strengthen public policies, financial incentives, private markets, agricultural practices, and other measures. This will allow the recovery of native vegetation to a minimum of 12.5 million hectares over the next 20 years. The measures foreseen in the Plan will determine the basis for achieving recovery on a larger scale, with the possibility of adding additional areas to those required by Law 12,651 / 2012. PLANAVEG is based on eight strategic initiatives designed to motivate, facilitate and implement the recovery of native vegetation (MMA) with national, every state and municipalities coverage:

Awareness: to launch a communication movement focused on farmers, agribusiness, urban citizens, opinion leaders and decision makers. This is to promote awareness of what is the recovery of native vegetation, what benefits it brings, and how to get involved and support this process.

Seeds & seedlings: promote the productive chain of native vegetation recovery by increasing the capacity of nurseries and other structures to produce native species, and rationalize policies to improve the quantity, quality, and accessibility of seed and seedlings of native species.

Markets: to foster markets from which landowners can generate revenues through the sale of timber, non-timber products, protection of watersheds, among other services and products generated by the recovery of native vegetation.

Institutions: to define roles and responsibilities among government bodies, companies, and civil society, and align and integrate existing and new public policies for the recovery of native vegetation.

Financial mechanisms: to develop innovative financial mechanisms to encourage the recovery of native vegetation, including preferential bank loans, grants, environmental compensation, specific tax exemptions and forest titles.

Rural extension: to expand the rural extension service (public and private) to contribute to the training of landowners, with emphasis on low-cost recovery methods.

Spatial planning & monitoring: to implement a national spatial planning and monitoring system to support the decision-making process for the recovery of native vegetation.

Research & Development: to increase the scale and focus of research and development and innovation investment to reduce cost, improve quality and increase the efficiency of native vegetation recovery, taking into account environmental, social and economic factors (Miriam & Randoslav, 2017).

The ecological restoration science is still relatively recent; there is a huge challenge to find new knowledge and techniques of species suitable for restoration. Simple phenological information of the species is often scarce. Forestry science has focused on the knowledge of species of economic interest, but with species of ecological interest are few examples that we have with Amazonian species. The CT-PETRO-Amazonia network over 10 years of research on ecological restoration in the state of Amazonas has accumulated reasonable information about the important species in projects for the recovery of degraded areas or ecological restoration (Melo et al, 2014; Amaral et al. al. 2014). There have also been advances in bioengineering, forestry, and ecological studies, as well as comparative monitoring of restored areas compared to the matrix ecosystem.

6. Conclusions

The new forest code presented advances in the Brazilian environmental legislation but has some constraint in humid areas in the Amazon region. This can be explained by the huge forested areas that annually have been flooded. The current legislation still is focused on river channel width. This type of vegetation is still vulnerable to illegal logging or subsistence agriculture. The Rural Environmental Registry (CAR) is an excellent tool to monitor rural properties in terms of good environmental practices and deforestation control. However, the implementation and control are still to be boosted in some northern States. Local politicians have pressed the government to postpone the effective application of this important environmental law. The National Plan for the Recovery of Native Vegetation (PLANAVEG) is promising policy to restore deforested area in the Amazon region. Despite the huge involvement of researchers, NGOs, environment ministry officials, as well as state secretariats, the start of efforts to restore the vegetation has been hampered by the country's severe political and economic crisis (Iorio et al, 2018).

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