





Assessment of fish farming environmental suitability scenarios in compliance with the Brazilian Forest Code

Bruna Roque Loureiro^{1*} , Marcus Vinícius de Andrada² , Eric Arthur Bastos Routledge³ ,
Fabiano Muller Silva⁴ , Nathalia Marchiori^{1,4} , Alex Pires de Oliveira Nuñez¹ 

¹ Universidade Federal de Santa Catarina , Departamento de Aquicultura, Laboratório de Biologia – Florianópolis (SC), Brazil.

² Universidade Federal de Santa Catarina , Centro de Filosofia e Ciências Humanas – Florianópolis (SC), Brazil.

³ Empresa Brasileira de Pesquisa Agropecuária  – Brasília (DF), Brazil.

⁴ Empresa de Pesquisa Agropecuária e Extensão Rural de Santa Catarina , Aquaculture and Fisheries Development Center – Florianópolis (SC), Brazil.

*Corresponding author: brunaroqueloureiro@gmail.com

ABSTRACT

This study aimed to evaluate environmental suitability scenarios for fish farms in Santa Catarina, Brazil, applying the rules regarding suitability and occupation in Permanent Preservation Areas (PPAs) of the current Forest Code. Rural properties (n=15) with commercial aquaculture were selected to verify the occupation scenarios in PPAs. The suitability analysis was based on the legal regulations that guide the activity's licensing process, later with the inclusion of public databases that make up this environmental policy. From the suitability maps per property in different scenarios, in the most restrictive rule, 93.3% of the properties analyzed presented environmental liabilities due to occupation in PPAs. Based on the least restrictive rule, 80% of the rural properties presented environmental liabilities. Considering the ideal scenario, in which PPA occupation is absent, 6% of the fish farms were identified; in the less restrictive scenario, 16%; and in the restrictive scenario, 78% of the fish farms. In conclusion, legal uncertainty surrounding the application of the NFC in the Atlantic Forest biome can be an obstacle to the regularization of environmental processes in fish farming. However, is possible and feasible in both scenarios, only for occupation profiles III and IV is it more particular to continue with the activity, considering the minimum recomposition rule.

Keywords: Aquaculture, Environmental assessment; Permanent preservation areas; Forest legislation; Rural environmental registry.

Cenários de adequação ambiental para pisciculturas com base no Código Florestal Brasileiro

RESUMO

Este estudo teve como objetivo avaliar cenários de adequação ambiental para pisciculturas em Santa Catarina, Brasil, aplicando as regras de adequação e ocupação em Áreas de Preservação Permanente (APPs) do Código Florestal vigente. Propriedades rurais (n=15) com aquicultura comercial foram selecionadas para projeção de cenários de ocupação em APPs. A análise de adequação foi baseada nas normas legais que norteiam o processo de licenciamento da atividade, posteriormente com a inclusão de bases de dados públicas que compõem essa política ambiental. A partir dos mapas de adequação por propriedade em diferentes cenários, na regra mais restritiva, 93,3% das propriedades analisadas apresentaram passivos ambientais devido à ocupação em APPs. Na regra menos restritiva, 80% das propriedades rurais apresentaram passivos ambientais. Considerando o cenário ideal, em que não há ocupação de APP, foram identificadas 6% das pisciculturas; no cenário menos restritivo, 16%; e no cenário restritivo, 78% das pisciculturas. Em conclusão, a insegurança jurídica quanto à aplicação do NFC no bioma Mata Atlântica pode ser um obstáculo à regularização dos processos ambientais na piscicultura. No entanto, é possível e viável em ambos os cenários, apenas para os perfis de ocupação III e IV é mais particular a análise para a continuidade da atividade, considerando a regra de recomposição mínima.

Palavras-chave: Aquicultura; Avaliação ambiental; Áreas de preservação permanente; Legislação florestal; Cadastro ambiental rural.

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INTRODUCTION

Aquaculture in Brazil started in the 17th century, but it gained professional status only in the 1970s. Therefore, industrial aquaculture is a relatively young activity in Brazil, with about half a century of existence. The bulk of production comes from small business owners and farms with pond areas of less than 2 ha, similarly to several important producing countries in Asia (Valenti et al., 2021).

Fish farming plays a pivotal role in Brazil's aquaculture landscape, contributing significantly to the nation's economy. In 2023 alone, the production of continental fish reached an impressive 887,029 tons, making a notable growth of 3.1% from the preceding year (PeixeBR, 2024). Among the states driving this thriving aquaculture sector, Santa Catarina state stands out as a key player, particularly in tilapia cultivation withing continental waters. With a production of 56,100 tons, Santa Catarina witnessed a growth of 3.3% compared to the previous year, securing its position as the fifth-largest contributor to national fish farming activities (PeixeBR, 2024).

Despite the optimistic outlook presented by the production statistics, the fish farming industry grapples with significant challenges and conflicts, particularly concerning the regulatory framework governing its operations. A considerable portion of fish farming activities, facilitated through nursery structures, operates within permanent preservation areas (PPAs). PPAs are protected areas with or without native vegetation, with the environmental function of preserving water resources, landscape, geological stability, and biodiversity; promoting the genetic flow of fauna and flora; protecting soil; and ensuring the well-being of populations (Brasil, 2012). The irregular occupation of these areas, analyzed from the legal point of view of the forest theme, is considered the main obstacle in the process of obtaining environmental licenses, a critical step towards regularization fish farming operations. Given the environmental regularization is a mandatory requirement for granting bank credit (Barroso et al., 2016), the consequences of this obstacle for the sector are evident.

Most fish farming sites in Santa Catarina are located either in PPAs or their boundaries, leading to environmental liabilities in these areas (Loureiro et al., 2019). Environmental liability occurs when an environmental asset is significantly damaged or when human activities pose potential risks to property. Consequently, this scenario imposes an obligation to implement measures aimed at controlling, preventing, and mitigating environmental impacts (Wakim and Wakim, 2012).

Rodrigues et al. (2011) recorded differences in the irregular occupation of PPAs between small and large agricultural units.

Their findings revealed that in small-scale agricultural units they are predominantly engaged in low-mechanized farming activities, often utilizing pastures and relying heavily on family labor. In contrast, large agricultural enterprises tend to adopt highly mechanized approaches, with specific wages and delineated tasks. Family farming, developed on small farms, plays a vital role in bolstering the sustainability of rural communities, fostering diverse production of healthy and safe food, and conserving natural resources and biodiversity (Santos et al., 2023).

The environmental suitability of fish farming activities developed in small production units, defined as those comprising up to four fiscal modules, must be treated differently in relation to environmental impacts. This differentiation is stipulated by the Brazilian legislation, which mandates compliance with minimum requirements for forest reconstitution and land use suitability. Moreover, the legislation prioritizes access to public policies for such operations (Brasil, 2012).

Over the past 25 years, agriculture, particularly in small farms, has experienced significant advancements in defining and understanding the characteristics and significance of the social group known as family farming (Grisa and Schneider, 2015; Grisa et al., 2017; Kageyama et al., 2013; Schneider and Cassol, 2014; Belik, 2000). Skoet and Raney (2016) utilized crowdsourcing and satellite imagery to show that farms smaller than 2 hectares produce about 30 percent of most food commodities in sub-Saharan Africa, Southeast Asia, and South Asia. Globally, farms smaller than 2 hectares account for the production of between 10 and 35 percent of food categories.

In Brazil, the classification of rural properties is contained in Law No. 8,629/1993 (Art. 4, II and III), in the definition of small property (property with an area between 1 and 4 fiscal modules) and medium property (rural property with an area greater than 4 and up to 15 fiscal modules), with the understanding that a small property is a rural property with an area less than 1 fiscal module, and a large property is one with an area greater than 15 fiscal modules. The fiscal module is a unit of measurement, in hectares, whose value is set by the National Institute of Colonization and Agrarian Reform (INCRA) for each Brazilian municipality.

In in the context of land use and conservation efforts, Santa Catarina state is entirely encompassed within the Atlantic Forest biome, with only 22.8% of the original vegetation remaining. Urgent actions are necessary to restore these areas while ensuring compatibility with existing activities. Consequently, production models for agricultural activities must be adapted to sustainable development principles. In 2020, the Ministry of Agriculture, Livestock, and Supply presented a document with guidelines

for the sustainable development of Brazilian agriculture. This document stresses that one of the main challenges for the sustainable development of Brazilian agriculture is the implementation of the New Forest Code (NFC) and instruments that help with the environmental regularization of rural properties.

The Federal Law No. 12,651/2012 (Brasil, 2012) was promulgated to protect native vegetation. In addition, this law created the concept of consolidated rural areas as areas defining them as regions of rural property with established human presence as of July 22nd, 2008, encompassing buildings, improvements, or agroforestry activities. Notably, it recognizes a distinct approach to occupation within PPAs, particularly emphasizing the differentiated treatment afforded to small rural properties (Article 61). Therefore, the implementation of NFC stands as a critical measure for the recovery and restoration of all Brazilian biomes. Also, it is important to highlight the Atlantic Forest, since this historically occupied biome (Morellato and Haddad, 2000) is highly fragmented and immersed in a large agricultural matrix, resulting in 11.7% of old secondary forest cover (i.e., > 30 years) (Rezende et al., 2015). In addition, this law establishes crucial public policy instruments for environmental protection and increases the efficiency of land use (MapBiomias, 2018).

Given the subject matter, the utilization of geoprocessing tools emerges as indispensable for facilitating enhanced planning practices, as highlighted by Souza Jr. et al. (2020). Spatially explicit data concerning the historical trajectories of land use in Brazil assumes paramount importance in informing effective planning endeavors and the sustainable management of natural resources, as well as in guiding policy formulation and various other social application.

Different studies have evaluated NFC compliance (Soares-Filho et al., 2014; Guidotti et al., 2017; Rajão et al., 2020), distribution of land categories in Brazil (Sparovek et al., 2019), and the degree of information in the Rural Environmental Registry (RER). The NFC institutes the RER, which allows the environmental passivity of rural properties (Pinto et al., 2018). However, according to Faria et al. (2021), updated and detailed analyses for implementing the NCF in the Atlantic Forest biome are lacking, particularly concerning environmental suitability programs.

The Atlantic Forest biome holds significant national importance and is afforded constitutional protection as a heritage site in Brazil. According to Article 225 of the Brazilian Constitution of 1988, any utilization of this biome “will be carried out, following the law, under conditions that ensure the preservation of the environment, including the use of natural resources”. Thus, the Atlantic Forest Law (AFL) (Brasil, 2006)

establishes that the conservation, protection, regeneration, and use of the Atlantic Forest biome must comply with the provisions of this law and environmental legislation.

In 2020, the Public Ministry of Santa Catarina state and the Federal Public Ministry obtained a favorable preliminary decision in a public civil action regarding the complete application of legislation protecting the Atlantic Forest biome. This legal action successfully halted the application of the NFC without considering the particularities provided in the AFL. Notably, this interpretation aligns with the stance adopted by both the Environment Institute of Santa Catarina and the Brazilian Institute of Environment and Renewable Natural Resources. Despite the conflict between these two laws, the Ministry of Environment showed no contradiction because the AFL would only apply to remnants of native vegetation and not to areas already occupied.

For the environmental regularization of fish farming, rural properties must comply with environmental requirements, including the RER. This registration is closely associated with the environmental adequacy of the property where fish farming is practiced, mainly in mapping existing environmental liabilities, such as the occupation in PPAs and the recognition of consolidated rural areas. After registering rural properties in the RER system, a series of advantages provided by the environmental regularization program will be available, comprising a set of actions developed to adapt and promote environmental regularization (Loureiro et al., 2019).

In this context, the objective of this study was to analyze the process of environmental adequacy among rural properties engaged in fish farming and to assess occupation and adequacy scenarios following the application of the NCF within the Atlantic Forest biome. This study was based on the assumption that the legal uncertainty surrounding the application of the NFC in the Atlantic Forest biome could be an obstacle to the regularization and adequation of environmental processes in fish farming. However, the study assessed the feasibility of two regularization scenarios, one applying the rule in article 61 and the other applying the general rule through article 4, stipulated in the NFC.

MATERIAL AND METHODS

Study area

The municipality of Grão-Pará (Santa Catarina, Brazil) was selected as the study area because of its importance in the production of tilapia (*Oreochromis niloticus*) and the configuration of the activity, which is mainly conducted

by family farming units, as in much of the state (EPAGRI, 2020). Land ownership of the municipality was structured by considering rural properties as small- or medium-sized units, characterizing them as representative fish farming practices in Santa Catarina.

Agricultural performance in Santa Catarina can be evaluated based on farmers' participation in the National Program for Strengthening Family Farming, a strategic government program facilitating access to rural credit. According to the Agricultural Research and Rural Extension Company of Santa Catarina (EPAGRI, 2021), the involvement of fish farmers was significant, reaching 13.42 and 14.04% of the total resources used in the country in 2019 and 2020, respectively. It is worth noticing that family farming has a strategic position in the state since it is responsible for a large part of the food production chain. The municipality includes 50 commercial fish farming units with an annual production of 1,035 tons, and tilapia is the main species, accounting for 99.9% of the total output (CEDAP, 2021).

For this study, 15 commercial fish farms in the municipality were selected. All these properties were classified as small rural properties by having up to four fiscal modules. Following the guidelines of the INCRA, a fiscal module in Grão-Pará is equivalent to 14 hectares. The total area of these properties and their corresponding equivalence in fiscal modules are documented in Table 1, while the geospatial distribution of the samples is represented in Fig. 1.

A bibliographic, documentary, and jurisprudential survey were conducted to elucidate the main points of conflict regarding the occupation of PPAs by production ponds and to evaluate which legal provisions should be considered for the adequacy of the environmental liabilities identified on the subject in question, within the scenarios of this study.

Eight legal provisions were listed after a documentary analysis that guided the licensing process of continental fish farming (Table 2), considering that the analysis focused on the environmental adequacy of rural properties.

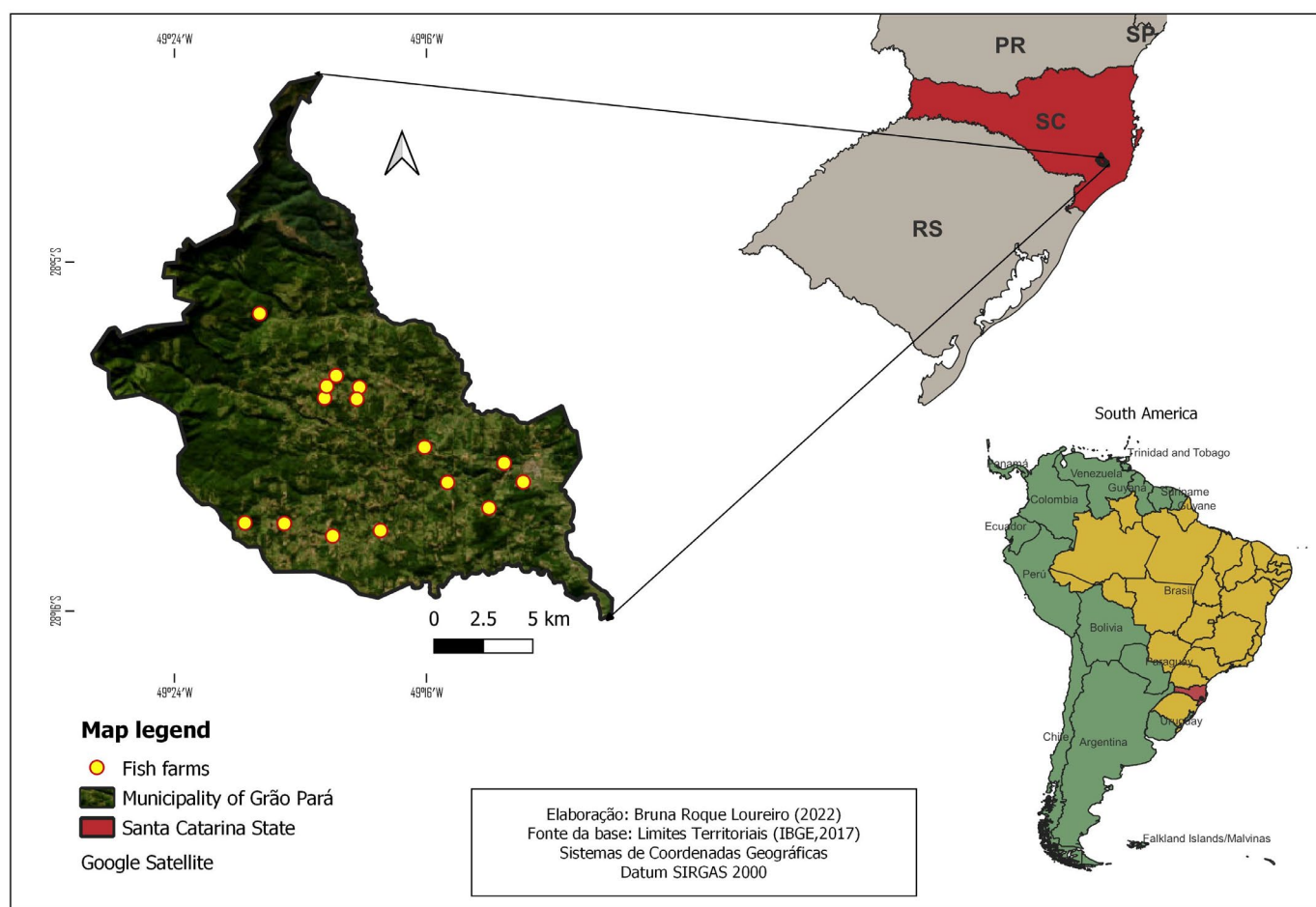


Figure 1. Spatial distribution of fish farmers analyzed in the municipality of Grão-Pará (SC), Brazil.

Table 1. Total area of the rural properties of the fish farms analyzed in Grão Pará (SC), and their equivalence in tax module.

Fish farming	Total area of the property (ha ²)	Tax module		
		0 a 1	≥ 1 a 2	≥ 2 a 4
P1	14.89		1.07	
P2	33.65			2.40
P3	21.82		1.56	
P4	17.04		1.22	
P5	22.54		1.61	
P6	33.56			2.40
P7	33.55			2.40
P8	21.03		1.50	
P9	16.69		1.19	
P10	8.28	0.59		
P11	19.47		1.39	
P12	10.82	0.77		
P13	42.05			3.00
P14	47.16			3.37
P15	13.38	0.96		

Legal base for environmental compliance in fish farms

Environmental analysis of fish farms

After analyzing the legal provisions, environmental adequacy projects were elaborated for each rural property. Using the data from the georeferenced fish farms, considering all fish farm production ponds, through mapping by the EPAGRI, it was possible to refine the cartographic data of the earthen ponds of the analyzed properties. Subsequently, data from the RER, available for public access through a federal platform (<http://www.car.gov.br/publico/imoveis/index>), were incorporated to compose the geographic information with data on the total perimeter of the properties. However, it is essential to consider that this registration is self-declaratory and aims at the environmental regularization of the property, not the land, and that the perimeter of the property used by the base was only to have a reference on the average fiscal module in which fish farming activity was located.

Water resources were the last layer incorporated in the environmental analysis, considering data from the streams and springs of the National Water Agency, and complemented with single and double streams available from the Brazilian Foundation for Sustainable Development (FBDS, 2023). However, to conceive the layers of PPAs, it was necessary to individually measure the width of the water courses from the

Table 2. Legal provisions at the federal and state levels analyzed in this study.

Legal Provision	Main subject matter
Article 225 Constitution of the Federative Republic of Brazil (1988)	Chapter VI - The Environment
Federal Law no. 11,428 (December 22, 2006)	Provides for the use and protection of native vegetation of the Atlantic Forest biome and other provisions (Atlantic Forest Law)
Federal Law 12,651 (May 25, 2012)	Provides for the protection of native vegetation and other provisions (New Forest Code)
Federal Law No. 12,727 (October 17, 2012)	Amends Law No. 12,651, of May 25, 2012, which provides for the protection of native vegetation and others
PR-DF-Manifestation -11687/2020*	Public Civil Action in the determination of suspension of Order no. 4,410/2020 issued by the Minister of the Environment, to avoid flagrant disrespect for the special protective legislation of the Atlantic Forest biome
Judgment of the DAU and DAC of the Forest Code (ADI: 4.937/2019 and ADC 42/2018)**	Judgment of Direct Actions of Unconstitutionality and the Declaratory Action of Constitutionality that discuss the terms of the Brazilian Forest Code
State Law No. 16,342 (January 21, 2014)	Establishes the state environmental Code of Santa Catarina.

*see at: https://climatecasechart.com/wp-content/uploads/non-us-case-documents/2020/20200506_ACP-no-1026950-48.2020.4.01.3400_petition.pdf;
**see at: <https://redir.stf.jus.br/paginadorpub/paginador.jsp?docTP=TP&docID=750595851&prcID=4355144>

satellite images and thus define the preservation strip around them to be adopted in each project.

For each rural property, an environmental situation project was prepared that shows the analysis of the occupation of the APPs by the relevant productive unit and the possible occupation patterns of the activity in these areas (Fig. 2). Digital image processing was performed using the QGIS Browser 2.18[®] software, with UTM projection, zone 22 S, and SIRGAS 2000 Datum. The RapidEye image (5 m) was the satellite base used for environmental analysis of the rural property, considering 2013 as a reference.

Two scenarios were simulated for the mapping of rural properties, one with the application of the rule of recomposition of PPAs (Table 3) provided for in the Forest Code (Articles 61-A and 61-B), considered as the least restrictive rule. For the application of the most restrictive rule, provided for in Article 4 of the same law, which water courses less than 10 meters in width shall have a minimum marginal protection strip width of 30 m for both sides.

To assess the impact of applying the general rule compared to the less restrictive rule, an environmental situation map was drawn up for each aquaculture unit to identify and quantify the occupation of fish production ponds in PPAs. When the intervention was identified, the conflict area occupied by the PPA was calculated, and a set of occupation profiles was created. In addition, we evaluated whether the production units were possible to be preserved or if they could be removed from the PPA.

In this study, four occupation profiles were established in the PPAs in the municipality studied, with the total size of the rural property, water courses present, fish earthen ponds, and the size of

Table 3. Mandatory bands for the recovery of permanent preservation areas, according to article 61 of the New Forest Code.

Property size	Recovery range (m)
0 to 1 TM	5
≥ 1 to 2 TM	8
≥ 2 to 4 TM	15

TM: tax module.

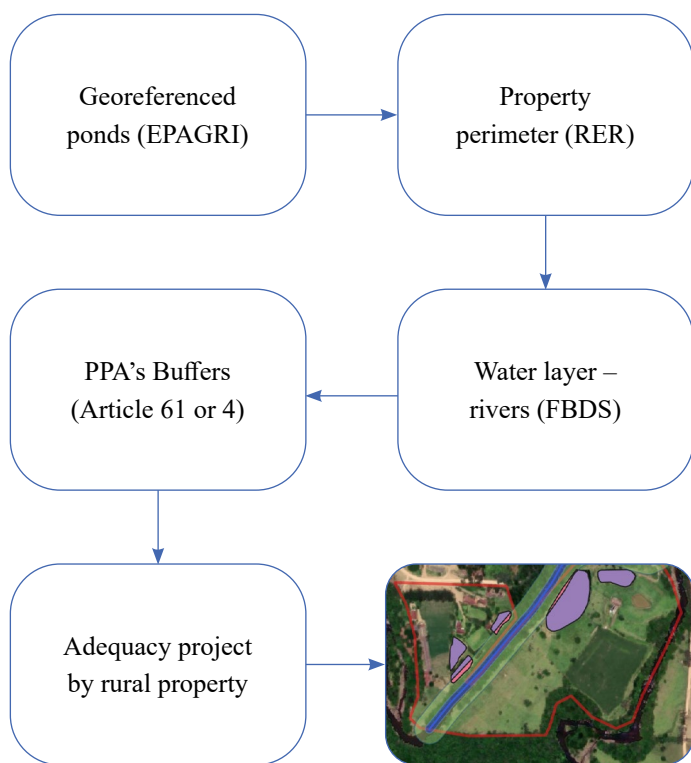
the marginal protection buffer strip required in the two scenarios analyzed as a reference. Profile I comprises fish farms with no environmental liabilities or restrictions on the environmental suitability process. Profile II represents fish farms with a small area of occupation, and only when the most restrictive rule is applied and offers a viable scenario for maintaining production units in the PPAs. For Profile III, occupation is considered moderate. However, the particularities of this occupation, such as the presence of a preserved marginal protection strip in the total area of the property, can contribute to obtaining authorization for an environmental license. Finally, in Profile IV, all fish earthen ponds are distributed in PPAs, a critical occupation that represents an obstacle to environmental suitability.

RESULTS

Legal base for environmental compliance in fish farms

From the analysis of the legal bases considered in this study, the conflicts are based on the understanding and questioning of the concept of consolidated use provided for by the NFC being applied to all Brazilian biomes, including the Atlantic Forest areas. However, according to environmental organizations and other representatives, they question whether this point is applicable to the Atlantic Forest biome, since it has a specific law, and some articles of that law already deal with the suppression of vegetation. As a result, the understanding is that the consolidated use implemented by the NFC has amnestied suppression in areas that were already regulated and could not have been suppressed.

This conflict is, therefore, one of the central points of contention that bring uncertainty about the application of the current Forest Code regarding consolidated PPAs within the Atlantic Forest biome. However, those who advocate for the full application of the Forest Code consider that this issue would not conflict with interpretation, if consolidated rural areas are recognized; land use from the reference date would be regularized and would still have its minimum required reforestation area.



EPAGRI: Agricultural Research and Rural Extension Company of Santa Catarina; RER: Rural Environmental Registry; PPA: permanent preservation area; FBDS: Brazilian Fund for Sustainable Development. Source: The authors.

Figure 2. Steps for the elaboration of the individual project of environmental analysis by rural property analyzed. In parentheses are the database sources used.

The NCF developed the concept of “consolidated rural areas”. The milestone date for occupations was July 22, 2008, and as a result, the continuity of agroforestry activities in the PPAs was authorized. However, the maintenance of activities and structures is conditioned to minimum recovery, with a smaller area than that established in the general rule. In other words, part of the irregularly suppressed PPAs will no longer be recovered if we consider Article 4’s rule compared with Article 61. However, the NFC allows for the maintenance of existing activities in consolidated areas, considering that they are previously licensed.

In this context, fish farming operations in Santa Catarina and other Brazilian states requiring environmental licenses must integrate environmental suitability assessments, particularly concerning the recovery of PPAs in the event of occupation. Consequently, addressing legal ambiguities to determine the areas for restoration and establish legal certainty between producers and environmental agencies poses a significant challenge.

This legal issue was established by applying the most restrictive rules in the restoration of PPAs. If understanding the concept of a consolidated rural area in the Atlantic Forest biome does not apply prevails, the areas in hectare to be recovered by fish farming occupation will be more expressive.

Occupation in areas of permanent preservation by fish farms

Among the fish farms analyzed in this study, 93.3% were found to have environmental liabilities due to the occupation of PPAs, under the most restrictive rule (Article 4), alternatively, 80% exhibited liabilities for occupying PPAs under the least restrictive rule (Article 61), as can be observed in Table 4. Overall, 60% of the fish farms analyzed would have an occupancy exceeding 50% in PPAs if the most restrictive rule were applied, with an average occupancy rate of 51.3%. However, if the least restrictive rule were applied, this rate would decrease to 20%, with an average occupancy rate of 25.7%.

By analyzing the individual maps, it was possible to determine in absolute numbers how much the occupations represented in terms of the total area of the rural property where the fish farms were located. Losses in production areas were significant when the general rule was applied. In the Article 61 scenario, the situation was viable, with only 20% of the units committed, compared to 90% in the first scenario. Under to the most restrictive rule (Article 4), fish farms P2, P5 and P15 have practically lost the total area of the fish farms (95.6, 98, and 95% of the total area of the earthen fishponds, respectively).

Table 4. Production units and the values of their occupation in the marginal protection strip (MPS), by the general rule and by the restrictive rule, and classification of nurseries by occupation profile described in the methodology.

Production unit	MPS Occupation		Occupation (%) Art. 61*	General Rule (%)		Occupation profile	Compromised fish earthen ponds (%)
	Art. 61 (m)	Art. 4 (m)		Art. 4*	Art. 61*		
P1	8	30	0.00	10.26	IV	60	
P2	15	30	62.04	95.62	III	100	
P3	8	30	44.44	63.70	III	100	
P4	8	30	21.21	65.15	III	100	
P5	8	30	42.5	98.00	I	100	
P6	15	30	5.83	25.56	IV	80	
P7	15	30	28.72	40.42	III	0	
P8	8	30	17.18	53.30	III	100	
P9	8	30	0.00	0.00	II	0	
P10	5	30	7.56	40.34	III	0	
P11	8	30	14.02	54.05	III	0	
P12	5	30	0.00	13.58	IV	50	
P13	15	30	35.90	57.69	III	50	
P14	15	30	51.68	83.49	I	60	
P15	5	30	55.00	95.00	I	50	

*Law no. 12.651/2012.



Environmental analysis of fish farms

According to the criteria related to the size and severity potential of the species, fish farming can be classified as a low-impact activity. This classification meets the provisions of the NCF that allow for the maintenance of production structures in PPAs for low-impact activities.

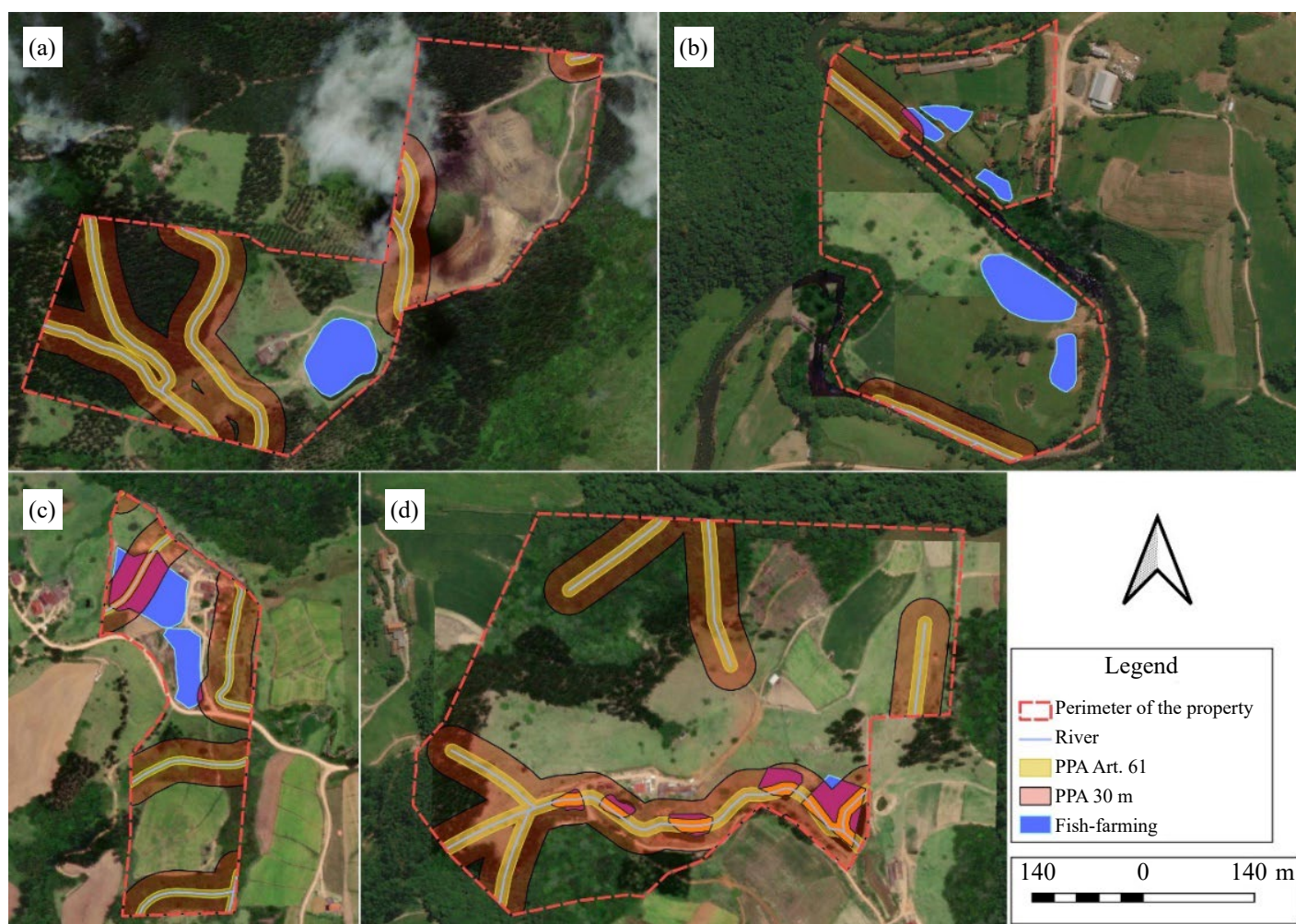
According to the legal bases, fish farms classified as low impact and small rural properties can have their rural area consolidated, respecting the minimum recovery requirement foreseen in the NCF (articles 61 and 61 B).

From the established occupation profiles, referring to the occupations in the PPAs (Fig. 3), it was possible to observe that in the scenario considered ideal, with total suitability for both scenarios, fish farming would have the viability of an unimpeded suitability process (Fig. 3a). Figure 3b depicts the production unit inserted into the PPA,

but with minimum occupation. However, although this occupation was small, the profile was unsuitable for applying the most restrictive rule, with 10.2% of occupations in this protected area. Figure 3c shows the occupancy profile of the fish earthen ponds in both scenarios, with moderate occupancy; however, when the most restrictive rule was applied, the occupancy rate was 41%, which dropped to 7.5% when the least restrictive rule was applied. Finally, in Fig. 3d, which represents the critical profile, it is observed that rural property occupies more than 50% of the marginal strip of watercourse protection for the most flexible scenario and more than 70% for the most restrictive scenario.

DISCUSSION

The NCF acknowledges the maintenance of agricultural activities and their associated structures in the PPAs through the concept of a consolidated rural area, according to the legal



Source: The authors.

Figure 3. Occupation profiles of fish earthen ponds in permanent areas in rural properties analyzed in the municipality of Grão-Pará, Santa Catarina, Brazil: (a) Profile I: ideal occupation; (b) Profile II: minimum occupancy; (c) Profile III: moderate occupation; (d) Profile IV: critical occupation.

framework of July 12th, 2008. However, this condition must respect the rules established not only by the provisions of the Forest Code, but also by specific laws such as the AFL. The need for minimum recomposition, as foreseen in Article 61 of the NFC, is mandatory for maintaining these activities and facilities. In the case of interventions that have irregularly eliminated native vegetation, the AFL needs to be followed, even if the NFC has provided amnesty for the suppression of vegetation, recognizing these areas as consolidated use.

The forest recovery of a deforested area must follow the provisions outlined in the specific laws, as there was already a previous regulation that guided the subject (Federal Decrees no. 99,547/1990 and followed by the AFL), and it will continue to be required. Therefore, owners may be required to cease their activities depending on the previous environmental liabilities of the property.

In this study, more than 80% of the fish farms analyzed, regardless of the standard applied, will have environmental regularization restrictions regarding the occupation of APPs. Therefore, these fish farms will have to comply with the rules not only of the new code, but also of the current provisions for suppressing vegetation. This is in line with a current discussion in the sector, since various productive sectors have been adapting to a policy that complies with the 2030 Agenda (UN, 2015) and the Sustainable Development Goals.

According to Faria et al. (2021), an analysis of the surpluses and deficits of native vegetation estimated in the implementation of the AFL showed that the states of Minas Gerais, São Paulo, Paraná, and Santa Catarina had the most significant deficits in vegetation in the PPAs, representing 28, 20, 11, and 11% of the biome, respectively. According to this study, in Rio de Janeiro, Espírito Santo, Goiás, São Paulo, Minas Gerais, and Santa Catarina, the deficit in native vegetation was estimated to be more than 60% in rural properties. However, a large portion (90%) of those classified as small presented an average rate of 14% of the total area deficit in the PPAs. However, large properties (> 15 MT), representing only 2% of the total, presented an area equivalent to 42% of the estimated deficit. In other words, adjusting only rural properties classified as large would reduce the deficit in the Atlantic Forest to be restored by 2 million hectares (42%). This number was more significant than the 14% deficit in properties classified as small.

Brazil is suitable for studying the value chain of fish produced in inland small-scale pond farms. This vast country has a growing inland fish culture sector that reached ~ 550,000 t in the year 2020 (FAO, 2022). In this context, differentiated treatments

applied to small rural properties should be highlighted, especially when activities framed as having low environmental impact are developed on these properties. All fish farms analyzed in this study fit the profile of low-impact activities according to the criteria established by the Brazilian Resolution of the National Environmental Council (Brasil, 2009), which provides for the environmental licensing of aquaculture.

When analyzing the occupation profiles proposed in this study, the fish farms classified as Profile I presented a positive scenario without restrictions, regardless of the rule applied, as they did not present environmental liabilities related to the occupation in the PPAs. Therefore, these properties demonstrate the feasibility of environmental adequacy without the use of compensation instruments. However, the fish farms classified in profiles II or III, which presented minimal or moderate occupations, were the majority in this study, with 73% of the production units. Despite their differences, both groups can maintain their production structures and obtain an environmental license by analyzing the legal provisions and instruments that allow compensation for this occupation, such as the term of adjustment of conduct or environmental compensation by area, for the environmental suitability of the activity. Profile IV, however, presents a critical occupation regardless the scenarios.

Profile I, the ideal scenario, was less representative (6%), and irregular occupations were present in 94% of the fish farms analyzed. Thus, discussing alternatives to an activity's environmental adequacy process is highly relevant, including environmental compensation.

Environmental compensation consists of reserving a site for conservation that must be equivalent in extent and ecological standards to the place to be compensated for and located in the same biome (Brasil, 2014). This can be understood as a mechanism of entrepreneurs' accountability for the damage they cause to the environment by suppressing the native vegetation. Profile IV represents a critical occupation regardless of the rule applied, and the property must be subjected to an integrated environmental assessment process. The cumulative impact of occupation in the preservation areas was analyzed.

Through Ordinance No. 43 (March 18th, 2021), the Institute of the Environment of the State of Santa Catarina established options of compensation for the use of PPAs in cases of public utility and social interest found in the State Environmental Code. Through this ordinance, Santa Catarina became one of the first Brazilian states to regulate the use of compensation in environmental licensing processes, thereby providing an alternative in this particular occupation scenario.

The environmental code of the state of Santa Catarina (Santa Catarina, 2014) provides activities classified as social interest, which follow the same guidelines listed in the forest code. In this sense, fish farming could be included in these activities, considering that using water resources is an integral and essential part of this activity, according to Articles 3 and IX of the NCF. In other words, within the scope of federal and state law, legal devices lead to the permission of some occupational situations in PPAs as long as the foreseen rules are respected.

Another point to be considered is that according to the AFL, which provides that vegetation can be suppressed in cases of social interest, as provided by the NFC, the situations of occupations and specific activities classified as low impact and of social interest can benefit from the framing of the concept of a consolidated area. Thus, the fish farms in this study fit the environmental suitability scenario because they met the legal provisions of the NCF and the AFL. However, despite allowing these structures to be maintained following legal requirements, it is essential to notice that it applies strictly to compensation for using PPAs and that compensation for suppressing vegetation must be analyzed in a specific administrative process based on the AFL.

In these legal interpretations, it is vital to bring into discussion that forest conservation and restoration actions are essential for recovering from environmental damage caused by deforestation. Moreover, efforts to make the environment and production more compatible should be encouraged. However, even with the priority of restoring PPAs, compensation for occupying PPAs in other areas can lead to positive gains when ecological restoration is effective. In this sense, permission to maintain a production unit in a PPA would need to be linked to the creation of mechanisms and technical reference indexes for compensation in priority areas, such as the formation or increase in ecological corridors.

Thus, proposing solutions that can result in the recovery of these liabilities through other mechanisms, depending on the occupation scenario, can allow the effective fulfillment of sustainability, in which environmental issues will be integrated with social and economic issues, considering the importance of this vital sector in food production and family farming characteristics.

Another point deserving investigation is the differentiated treatment of producers located on small properties, as they play an important role in food production in Brazil. According to a study conducted by Lowder et al. (2019), it was found that small properties are growing as a territorial configuration in Brazil.

In this study, one limitation was the information from the rural environmental registry, which has not advanced in the validation analysis in the state of Santa Catarina. Thus, the veracity of

the information declared by the rural landowners is only an estimate of the property size. Therefore, it is recommended that, when adopting the process of adequacy of a fish farm with the environmental agency, the producer considers the size of his/her property more accurately in the methodological model presented.

CONCLUSION

The analysis of the legal instruments shows that legal uncertainty regarding the application of the Forest Code in the Atlantic Forest biome reflects difficulties in the regularization process and environmental suitability of continental fish farms in the municipality of Grão-Pará.

The analysis of the occupation profile, when comparing the application of the general rule (Article 4), showed that, with its application, the maintenance of the nurseries becomes unfeasible from this point of view.

When analyzing the occupation of fish production facilities in PPAs, the relevance of understanding the process of land occupation by this activity and its economic and social aspects is highlighted. According to the Brazilian legislation, land profiles should be treated differently. In this study, most rural properties were classified as small; thus, the occupation process of these conservation areas showed a common scenario.

CONFLICT OF INTEREST

Nothing to declare.


DATA AVAILABILITY STATEMENT

Data will be available upon request.

AUTHORS' CONTRIBUTION

Conceptualization: Loureiro BR, Nuñez APO; **Formal analysis:** Loureiro BR, Andrada MV, Routledge EAB, Silva FM, Marchiori N, Nuñez APO; **Investigation:** Loureiro BR; **Methodology:** Loureiro BR, Nuñez APO; **Supervision:** Loureiro BR, Silva FM, Nuñez APO; **Resources:** Loureiro BR, Silva FM, Nuñez APO; **Writing – original draft:** Loureiro BR, Nuñez APO; **Writing – review and editing:** Loureiro BR, Routledge EAB, Silva FM, Nuñez APO; **Final approval:** Loureiro BR.

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