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Temporal analysis and evolution of fish farming in Alto Paraíso municipality, RO, Western Amazon, Brazil

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ABSTRACT: The aimed of the study was to identify the characteristics of fish farms and the progress of the enterprises that practice the activity during the time span of 13 years (2008 to 2021) in Alto Paraíso municipality (RO, Western Amazon), aiming to know the general aspects and verify the number of enterprises, spatialization in the municipality and size. The study was carried out using remote sensing tools, analyzing the occupation in the municipality with fish farming, through the processing of images from the SPOT-5 satellite (for 2008) and CBERS-4A satellite (for 2021), made available by SEDAM and INPE Agencies, respectively. Image processing was performed using the GIS QGis 3.20.2 (Odense) and allowed the creation of image maps of fish farming in the study area. In addition, the vectorization of fish farms was carried out, where the water surface area was analyzed for the composition of heat maps that allowed a geographic analysis of the behavior of patterns. The results obtained shown that in the municipality there are small, medium and large fish farms, the evolution of fish farms in the municipality was in the order of 200% for the number of enterprises and 874% for the amount of water surface.

Key words: fish production; ODS 2; ODS 12; production systems

Análise temporal e evolução da piscicultura no município de Alto Paraíso, RO, Amazônia Ocidental, Brasil

RESUMO: Este estudo buscou identificar as características das pisciculturas e o avanço dos empreendimentos que praticam a atividade durante o espaço temporal de 13 anos (2008 a 2021) no município de Alto Paraíso (RO, Amazônia Ocidental) visando conhecer os aspectos gerais e constatar a quantidade de empreendimentos, a espacialização no município e o tamanho. O estudo foi realizado por meio de ferramentas de sensoriamento remoto, analisando-se a ocupação no município com a piscicultura, através do processamento de imagens do satélite SPOT-5 (para 2008) e satélite CBERS-4A (para 2021), disponibilizadas pela SEDAM e INPE, respectivamente. O processamento das imagens foi realizado por meio do SIG QGis 3.20.2 (Odense) e permitiu a criação de cartas-imagem das pisciculturas na área de estudo. Além disso, foi realizada a vetorização das pisciculturas, onde analisou-se a área de espelho d'água para a composição de mapas de calor que permitiram uma análise geográfica de comportamento de padrões. Os resultados obtidos demonstram que no município existem pisciculturas, pequenas, médias e grandes. A evolução das pisciculturas no município se apresentou na ordem de 200% para o número de empreendimentos e de 874% para o quantitativo de espelho d'água.

Palavras-chave: produção de peixes; ODS 2; ODS 12; sistemas produtivos

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Introduction

The improvement of human well-being and more favorable conditions for survival are linked not only to the efficiency of economic activities, although also social and environmental aspects must prioritized (Brabo et al., 2015). The promotion of an improvement in the quality of life of a population is guided by good practices in health, citizenship, education, housing and a balanced diet, the latter being considered the great challenge of the millennium: to provide quality food to the world population, meeting their basic survival needs in a sustainable way (Passarinho, 2011). In this sense, aquaculture is considered the largest agribusiness on the planet, as it moves 144.4 billion dollars U$ annually and for the future the trend is for growth, due to the increase in demand given the growth of the world population, income evolution, urbanization and for providing diversified foods of nutritional quality (Dantas Filho et al., 2022).

Brazilian fish farming is an offshoot of aquaculture, has been growing over the years, given the jump in production 578,800 tons in year 2014 to 802,930 tons in year 2020, with revenue of around 8 billion R$ BRL (Peixe BR, 2021). Fish farming generates about 1 million direct and indirect jobs in Brazil, which is the world's fourth largest producer of *Oreochromis niloticus* (Nile tilapia), a species that represents 60% of the country's production. Native fish, led by *Colossoma macropomum* (tambaqui), participate with 35% and other species with 5% (Peixe BR, 2022). In Rondônia state, according to SEAGRI Agency (2020), the fish farming practiced for five years has provided the Rondônia state with leadership as the largest producer of native fish in Brazil, where tambaqui is the main species produced in captivity. About 50,600 tons of fish were produced in Rondônia state in year 2021 (Peixe BR, 2022).

In Alto Paraíso municipality for example, fish farming has been expanding more and more and is already seen as the main activity in some rural properties, being the only object of agricultural investment. According to data from the IDARON Agency, the Alto Paraíso municipality has 136,200 hectares of water sourface distributed in 10 properties, although it is known that this amount is higher, although it is not yet registered and accounted for by the Agency (Meante & Dória, 2017). However, SEDAM Agency (2021a) showes in its database the existence of 16 fish farms in Alto Paraíso municipality, which together add up to 174,581 hectares of wetlands (tanks) and environmentally licensed for fish farming.

The economic attractiveness and expansion of fish farming have put pressure on water surfaces, mainly due to the demand for volumes of water, its main input (Lopes, 2017). It is a fact that fish farming is a water-intensive activity that consumes more per unit of area than irrigated agriculture (Boyd & Gross, 2000). However, technical, scientific and representative currents of Brazilian fish farming have argued that fish farming does not consume, although rather uses water (Macedo & Sipaúba-Tavares, 2010). The fact is that when it comes to the intense use of a renewable natural resource, although with a limited source such as water, there are conflicts over the use of water resources, whether for quantity or quality (Bordalo, 2019).

Therefore, the current study identified problems that may occurring regarding the use of water resources by fish farms in Alto Paraíso municipality, Rondônia state, Western Amazon. In view of this, the aimed was to identify the spatial evolution of fish farms and characterize them in production system terms, size and management of fish farms, nor in relation to the lower environmental impact.

Material and methods

Study area

The study was carried out in Alto Paraíso municipality, in Rondônia state (Figure 1), inserted entirely in the Jamari river basin, which has 29,067 km² (Nóbrega et al., 2008). Alto Paraíso is located in the Rondônia state Center-North region, covers an area 2,651,822 km² and has an estimated population 21,847 inhabitants for year 2020 (IBGE, 2012). It is located at latitude: 09° 42' 47" south and longitude: 63° 19' 15" west, at an altitude 127 m. Its average annual rainfall is 2,302 mm and has a climate classification Am - humid or sub-humid tropical climate, according to Köppen, with annual average air temperature around 24 and 26° C, with a maximum temperature between 30 and 34° C, and a minimum between 17 and 23° C (Silva et al., 2017).

Survey of fish farms

With the aim of speeding up the process of identifying existing fish farms in Alto Paraíso municipality, a survey was carried out with the Agência de Defesa Sanitária Agrossilvipastoril do Estado de Rondônia (IDARON), a survey on the fish farms registered for the issuance of Animal Transport Guide (GTA). A similar survey was carried out at the Entidade Municipal de Assistência Técnica e Extensão Rural do Estado de Rondônia (EMATER-RO), because the entity provides technical assistance on some fish farms in the municipality. And, in a complementary way, another information survey was carried out with the Secretaria Estadual de Desenvolvimento Ambiental (SEDAM), in order to obtain documentary data of environmental licenses issued for fish farms in the municipality. In the surveys carried out, it was possible to obtain data on the number of enterprises, number of licensed enterprises, amount of area occupied with water surfaces and cultivated species.

Characterization of fish farms

The characterization of fish farms was carried out through on-site visits and application of a questionnaire to fish farmers based on the methodology of Rotta (2003), a research project approved by the Ethics Committee 4,752,736 – Universidade Federal de Rondônia (UNIR), CAAE no. 45832421.6.0000.5300. The questionnaire was applied in order to complement the data previously collected from government Agencies and to

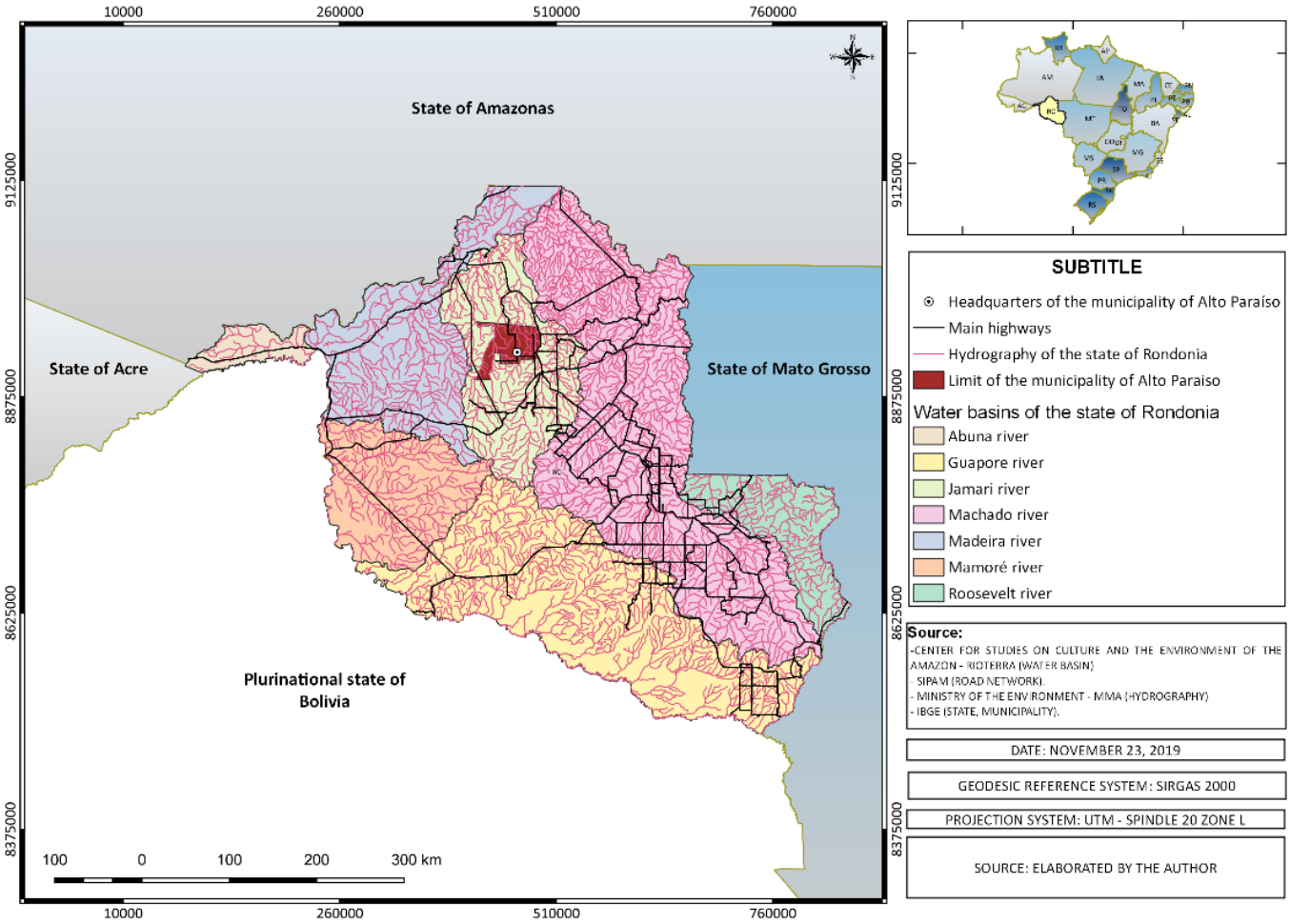

Figure 1. Hydrographic basins delimitation from Rondônia state, municipality of Alto Paraíso and location of its headquarters highlighted.

identify the profile of fish farmers and their fish farms. The aim was to characterize the enterprises in terms of their general aspects, number of enterprises, spatialization in Alto Paraíso municipality and commercial size.

Classification of fish farms according to commercial size

The classification of enterprises in terms of commercial size was carried out, based on CONAMA Resolution no. 413/2009 (Brasil, 2009) which governs the relationship of the aquaculture enterprise size and in accordance with state law of Rondônia no. 3,437/2014 (Rondônia, 2014) which deals with aquaculture in Rondônia state (Table 1).

Table 1. Size and characterization of fish farms according to legal instruments in Rondônia state.

Legal instrument	Commercial size (hectares)		
	Small	Medium	Large
CONAMA no. 413/2009 (Brasil, 2009)	< 5	5 to 50	> 50
Law no. 3437/2014 (Rondônia, 2014)	< 5	< 10	> 10

*Conselho Nacional do Meio Ambiente.

Identification of occupation, advancement and temporal evolution of fish farms

First, the database of the Instituto Brasileiro de Geografia e Estatística (IBGE) was accessed from where the shape file of the polygon vector layer of Alto Paraíso municipality was imported, which is the study area of this research. After that, for temporal analysis, remote sensing procedures and image geoprocessing were used, using images from the SPOT-5 satellite, panchromatic and multispectral band (B1, B2 and B3) from the HRG (High Resolution Geometric) sensor for year 2008, made available by the SEDAM Agency and for year 2021, images from the CBERS-4A satellite, panchromatic band of the WPM sensor (Multispectral and Panchromatic Wide Scanning Camera) from the catalog of images from the Instituto Nacional de Pesquisas Espaciais (INPE).

With the images obtained, the analysis, processing and cutting of the images began, using the Geographic Information System (GIS) QGis version 3.20.2. (Odense), with the aim of identifying all the fish farms in the perimeter of the Alto Paraíso municipality (Image Chart). The vectorization of fish farms was performed manually (each of the fish farms) in the form of polygons, using as reference the images from the SPOT-5 satellites with a resolution of 2.5 meters and CBERS-4A with a resolution of 2.5 meters to 0 (zero) meters. Still using QGis version 3.20.2, the polygons of the tanks referring to each fish farm were merged using the "Dissolver" algorithm, which grouped all the tanks of each fish farm and generated a unique feature from which the centroid containing the

preserved form was extracted the attribute table, specifically the attribute "water surface area" in hectares, which composes the database necessary for the heat map composition.

For this study, the aim was to compose heat maps (Kernel) or Kernel maps. Translating the word Kernel from English to Portuguese, Kernel means Nucleus and it is a good alternative for geographical analysis of patterns behavior that is carried out by interpolation methods resulting in punctual intensities of certain phenomena throughout the study region. The methodology used to compose the maps was based on the proposal by Rizzatti et al. (2020), who demonstrated through Kernel Density a map with the incidence of COVID-19 for the urban area of the Santa Maria, municipality, Rio Grande do Sul state, Brazil.

Therefore, in current study, first the definition of the radius (R) of distance was carried out, which was estimated from the subtraction and addition of the average to average distance (X) of points each with the average of the average standard deviation (X), in the in order to obtain a number that is adequate for the composition (Equation 1).

$$R = \overline{X} \pm \overline{X\delta} \quad (1)$$

In which: R = radius of influence; $\overline{X}$= average to average distance; and, $\overline{X\delta}$= average standard deviation.

The "Distance Matrix" algorithm was used to define the radius (R) (it has the function of creating a table containing a distance matrix, with the distances between all points in a layer of points) of the GIS QGis version 3.20 .2, selecting as the output matrix type: "Distance matrix summary (average, standard deviation, minimum and maximum)". Following the aforementioned methodology and using the vector layer of fish farming points previously processed, it was identified that the value of "R" that provided the better results for maps compositions was from the average subtraction of the average distance by the standard deviation average, therefore, R = 10,000 meters, allowed the generation of heat maps with better finishing, without exaggeration and with less possibility of wrong interpretations.

After defining R, still using the GIS QGis version 3.20.2, the Heatmap function (Kernel Density Estimation algorithm) was activated, selecting the Quartic function that weights with greater weight the closer points than more distant points, attributing a gradual decrease, which resulted in raster layers that were classified into 4 classes for the geographic distribution analysis of fish farms and 6 classes for the geographic distribution analysis according to water surface, and the analyzes were carried out for the years 2008 and 2021. Aiming at better understanding, Figure 2 shows a flowchart of the methodology adopted in current study.

Results

From the questionnaires application *in loco* and the vectorization carried out remotely through the handling of satellite images and geographic information system (GIS), it was possible to identify a number of 126 fish farms within the Alto Paraíso municipality perimeter, corresponding to a total of 331 hectares of water surface exclusively occupied with the activity. In Figure 3, the fish farms geographic locations visited for the questionnaires application can observed, as well as the fish farms location vectored through remote sensing tools.

It is noted that the fish farms are well dispersed throughout the entire municipal border area, being mainly located near the seat of the Alto Paraíso municipality. The identified characteristics of location point to small-scale fish farms practiced by family farmers, who have small land properties, seek diversity in production, proximity to consumers and economy with transport when purchasing inputs and selling production (Figure 3).

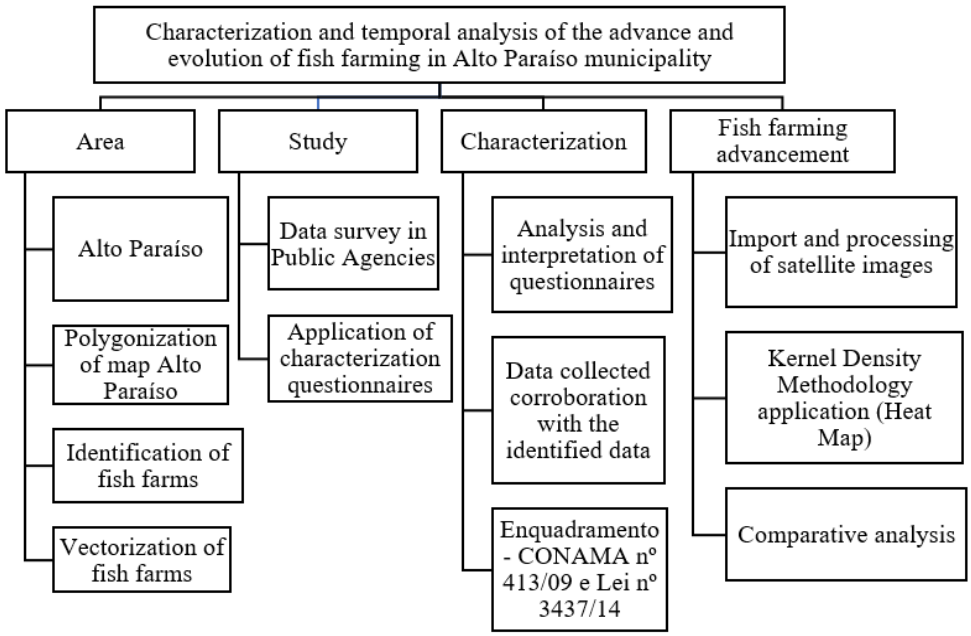

Figure 2. Methodology applied flowchart of the in current study.

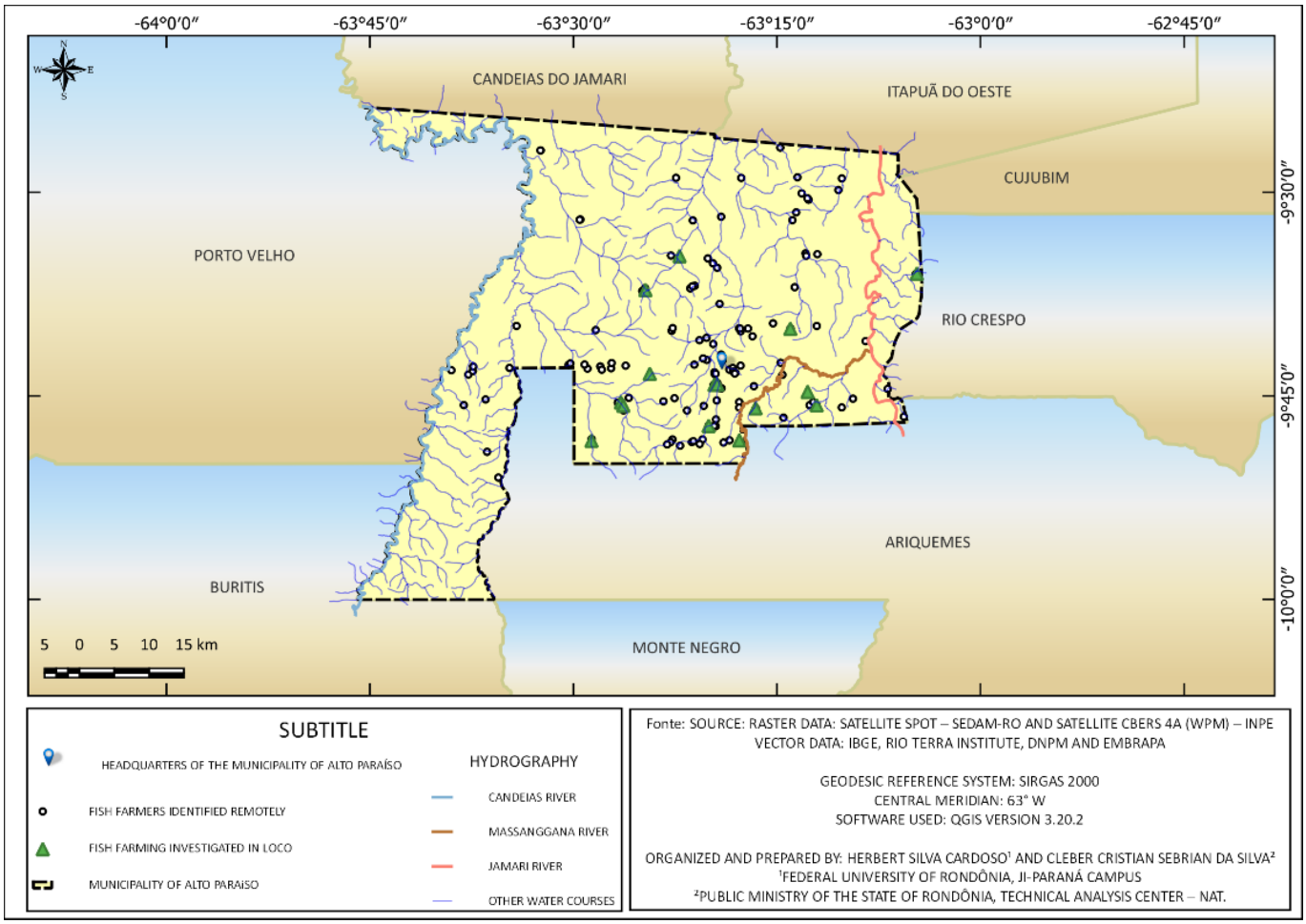

Figure 3. Alto Paraíso municipality geographic location polygon and of its fish farms, in Rondônia state, Western Amazon.

It is also noted that fish farms are not concentrated in the vicinity of the two largest rivers in the region, with the Jamari river at the east end and the Candeias river at the west end, classified as 3rd (third) order rivers, as they are the main rivers of their basins, that is, fish farms have, directly or indirectly, 1st (first) and 2nd (second) order rivers and streams that are tributaries of larger rivers as sources of water (Figure 3).

The classes of rocks that give rise to the soils of Alto Paraíso municipality, with granite and enderbite rocks being the most predominant, which account for most of the soil genesis and are the basis of its source materials (Figure 4A). According to Celino & Botelho (2005), the rocks in the region are rich in SiO_2 (Silica), Al_2O_3 (Aluminum oxide), K_2O (Potassium oxide) and Na_2O (Sodium oxide). And these form soils with a sandy-clay texture, light, friable, with high susceptibility to erosion, to groundwater contamination and water deficiency for cultivation in nurseries by derivation (Donagemma et al., 2016). Due to the soils characteristics of Alto Paraíso, fish farms are obliged to carry out puddling and soil compaction, in order to avoid infiltration of the water available to fill the supply ponds.

As they represent the vast majority of the lithological composition, granitic and enderbitic rocks mainly formed two soil classes in Alto Paraíso, Dystrophic Yellow Latosols and Dystrophic Red-Yellow Latosols (Figure 4B). According to Embrapa (2006), they are characteristic of Dystrophic Yellow Latosols and Dystrophic Red-Yellow Latosols, being shown in flat or gently undulating reliefs, occurring in well-drained and deep environments, and allowing agricultural development. However, they showes chemical limitations, being these soils of low natural fertility. The characteristics of the soils in Alto Paraíso municipality do not allow the cultivation of pastures and annual or perennial crops without taking corrective actions to improve fertility (Embrapa, 2011), that is, they require financial investments to achieve good productivity, making agriculture and livestock activities not so advantageous and allowing them to replaced by others, such as fish farming.

The existing fish farms in Alto Paraíso and the resulting interpolation of Kernel Density. A significant increase in the number of fish farms within the established 10 km radius can observed in this region studied (Figure 5). Comparing the figures, it is observed that for the year 2008 the number of existing fish farms within a radius of 10 km had its value increased for year 2021, causing the densities that represent smaller amounts to decrease in size and, consequently, the respective densities representing larger amounts increased significantly in the analyzed perimeter.

We can see the growth of fish farms occurring mainly around the municipal seat of Alto Paraíso, shown in Figure 5, by the 900% increase in the density of 5 to 10 fish farms per

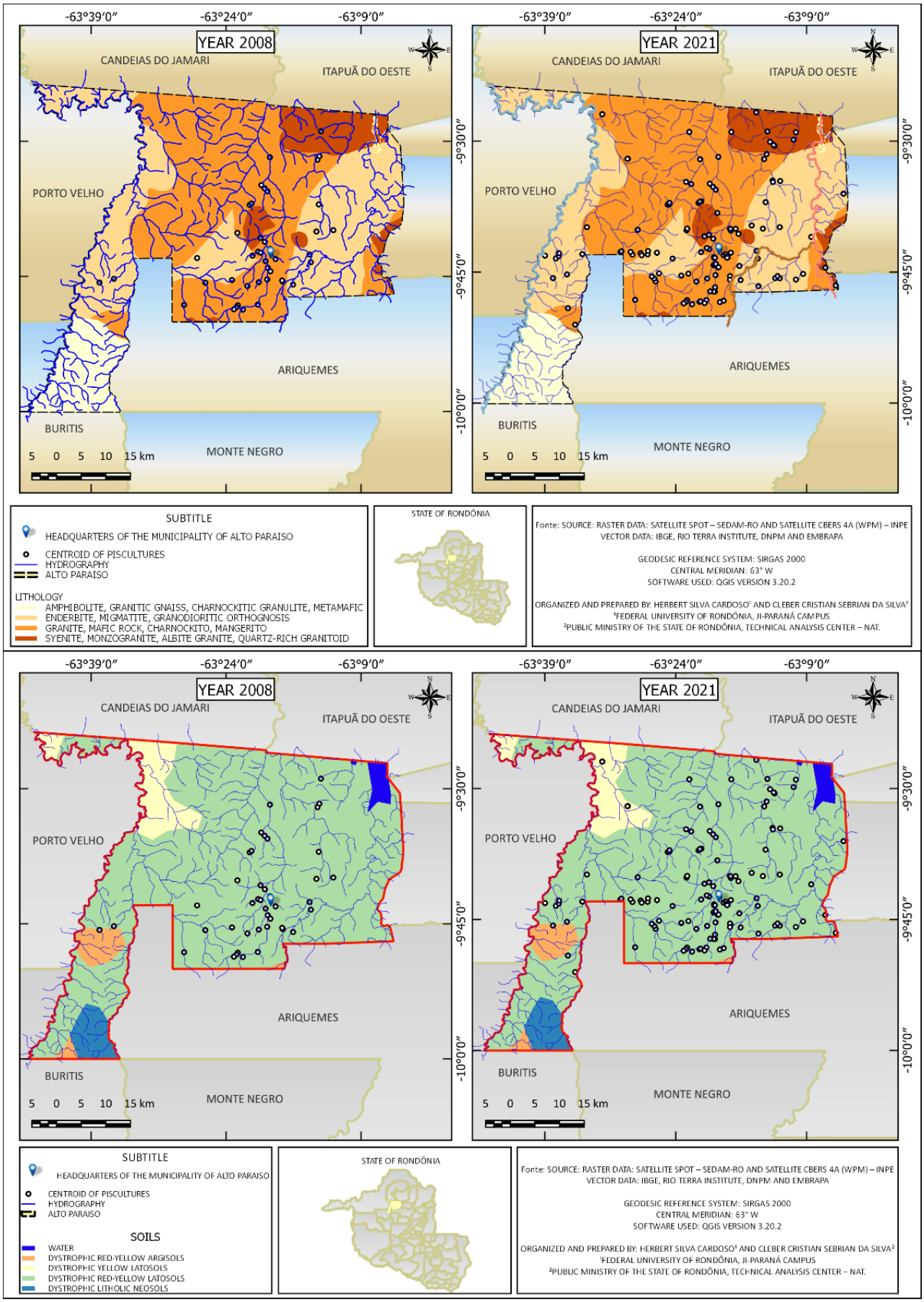

Figure 4. Location of fish farms and lithological geographic distribution (A) of soil classes (B) in Alto Paraíso municipality, in Rondônia state, Western Amazon.

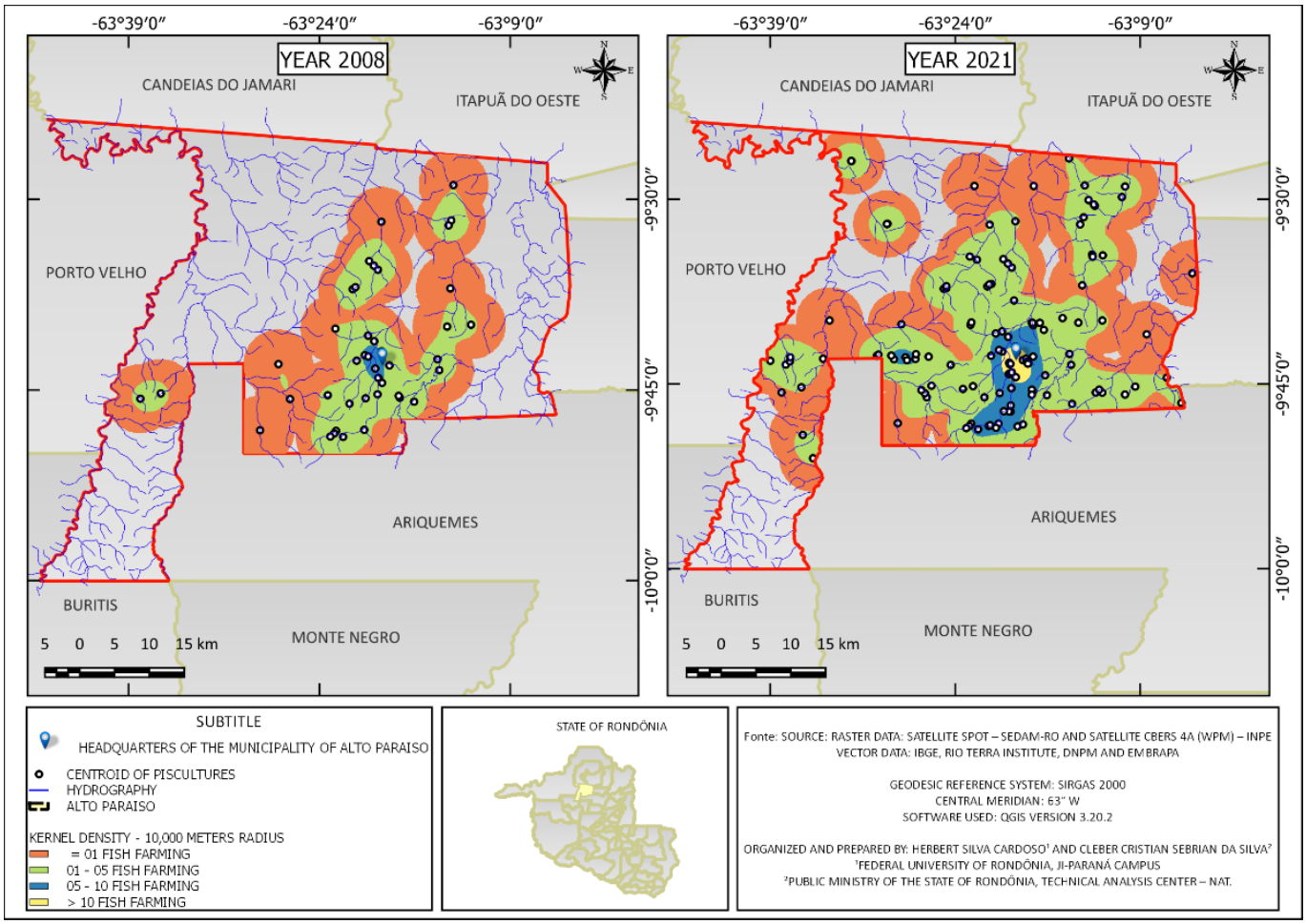

Figure 5. Location distribution heat map (Kernel) of fish farms in Alto Paraíso municipality, in Rondônia state, Western Amazon.

10 km radius and also by the emergence in the same area in year 2021, the situation of more than 10 fish farms located in the same range.

In Table 2, the number evolution of fish farms in Alto Paraíso is showed in more detail. These are the numbers of enterprises surveyed in loco on a database of entities with inherent and quantitative activities remotely vectored through GIS and its tools.

The properties in surroundings of the Alto Paraíso are the oldest rural properties and, consequently, tend to the first modified by human action. They were demarcated by Instituto Nacional de Colonização e Reforma Agrária (INCRA) in 1975s, through the PAD (Settlement Project) Marechal Dutra, which divided plots of 100 hectares and settled low-income, low-educational settlers and a greater number of families (Auzier Neto, 2011).

Observing in a comparative map between the years 2008 and 2021, which can better illustrate the amount of water surface of all existing fish farms in Alto Paraíso and the resulting interpolation of Kernel Density for the occurrence of 6 groups of different sizes of flooded area for the activity (Figure 6). The map shows an evolution in projects number of the different size classes between the years analyzed, where it can seen that only in year 2021 projects were identified that, in a radius of 10 km, added to their areas, occupy water surface sizes superior to 10 hectares, reaching up to areas larger than 50 hectares.

It can also seen in Figure 6 that there was an increase in larger fish farms and that they were distributed along the perimeter Alto Paraíso municipality area. However, it is noted that the feature (Kernel Density) that still occupies the largest size in Alto Paraíso is the one that represents fish farms smaller

Table 2. Fish farms identification (per unit) in Alto Paraíso municipality, according to data collected from government agencies and manual vectoring, for the years 2006 to 2021.

Government agencies	Years									
	2006	2008	2011	2012	2013	2015	2016	2019	2020	2021
IDARON*	-	-	-	-	-	-	-	2	9	10
SEDAM**	1	2	5	11	13	14	15	16	16	16
EMATER***	-	-	-	8	8	9	10	10	10	10
Vectorization	-	42	-	-	-	-	-	-	-	126

*Agência de Defesa Sanitária Agrosilvopastoril do estado de Rondônia; **Secretaria de Estado de Desenvolvimento Ambiental; ***Assistência Técnica e Extensão Rural.

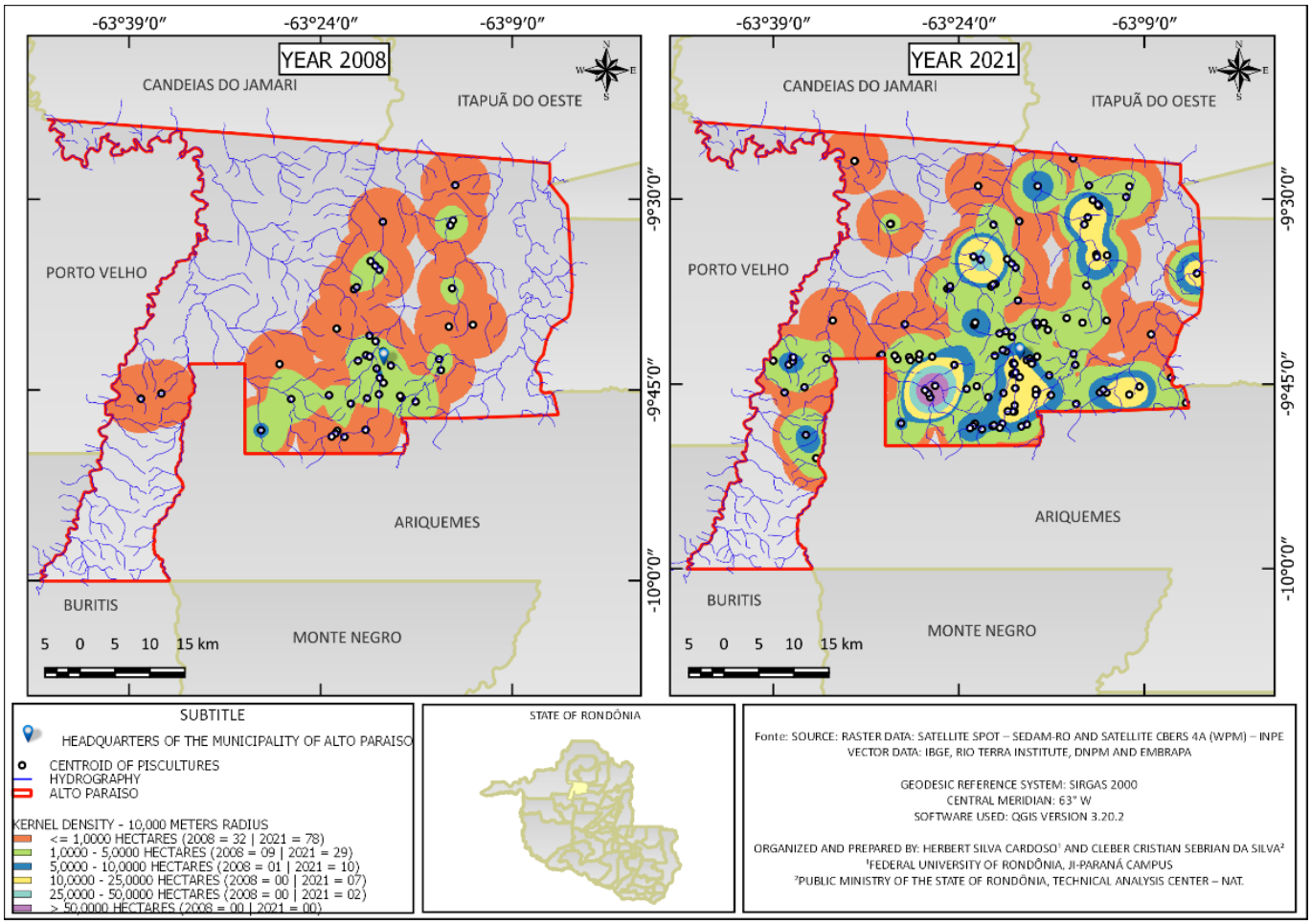

Figure 6. Water surface size heat map (Kernel) of fish farms in Alto Paraíso municipality, in Rondônia state, Western Amazon.

than one hectare. Nonetheless, it is axiomatic the growth of features that represent fish farms with water surfaces greater than one hectare to up to 5 hectares and greater than 5 hectares to up to 10 hectares, with greater expressiveness for the former.

In Table 3, the evolution of the water surface amount occupied by fish farms in Alto Paraíso municipality is showed in more detail. These are the numbers collected *in loco* from a database of entities with inherent and quantitative activities remotely vectored through GIS and its tools. It is evident that the data provided in Table 3 accompany the registration data of the fish farms (Table 2), demonstrating and confirming the disparity of data existing between the governmental Agencies of sanitary defense, inspection and technical assistance in Alto Paraíso municipality.

The IDARON Agency, showed in the year it started its registration of fish farms, a total of 35 hectares of water surface, evolving to 136 hectares in year 2021, a growth of 289%. While in the survey with EMATER-RO Agency, an amount of 27 hectares of water surface was identified in its records in year 2012, which increased to 35 hectares in year 2021, representing a growth of 30%. However, SEDAM Agency, which licensed the first fish farm in Alto Paraíso in year 2006, with a 6 hectares flooded area, also registered the growth of fish farms over the years, resulting in year 2021, at the 175 hectares mark, a significant evolution of 2,817%.

Finally, the vectorizations carried out using remote sensing showed for the year 2008, an amount of water surface occupied by the fish farming activity, equivalent to 34 hectares and for the year 2021 a total of 331 hectares, an advance of 874% in relation to the first year analyzed.

In Table 4 it is shown in an organized way, according to the two legal instruments that provide for the classification and size framing of fish farms. On the other hand, State Law

Table 3. Water surface (hectares) of fish farms in Alto Paraíso municipality, for the years 2006 to 2021.

Government agencies	Years									
	2006	2008	2011	2012	2013	2015	2016	2019	2020	2021
IDARON*	-	-	-	-	-	-	-	35	112	136
SEDAM**	6	13	37	103	123	124	136	140	162	175
EMATER***	-	-	-	27	27	30	32	35	35	35
Vectorization	-	34	-	-	-	-	-	-	-	331

*Agência de Defesa Sanitária Agrosilvopastoril do estado de Rondônia; **Secretaria de Estado de Desenvolvimento Ambiental; ***Assistência Técnica e Extensão Rural.

Table 4. Quantitative and classification by size according to legal instruments of fish farms located in Alto Paraíso municipality, in Rondônia state, Western Amazon.

Legal instrument	Commercial size (hectares)		
	Small	Medium	Large
CONAMA no. 413/2009 (Brasil, 2009)	107	19	0
Law no. 3437/2014 (Rondônia, 2014)	107	10	9

*Conselho Nacional do Meio Ambiente.

no. 3437/2014 (Rondônia, 2014) also classifies 85% of fish farms as small, although differs from CONAMA Resolution no. 413/2009 (Brasil, 2009) by classifying 8% of fish farms as being medium-sized and 7% as being large. According to CONAMA Resolution no. 413/2009 (Brasil, 2009), 85% of the fish farms in Alto Paraíso municipality are considered small and 15% are considered medium-sized, with no large-sized fish farms, according to the resolution cited.

Discussion

The greater number of smaller fish farms has positive points and is a global trend, mainly caused by the increase in fuel and transport costs, which influences the emergence of industrial conglomerates and the regionalization of food and input production enterprises (Sousa et al., 2019). It is also worth noting the increase in the number of consumers who are aware of environmental issues, who choose local products or products produced a short distance from where they live, in order to contribute to local development and to reduce the depletion of natural resources and the emission of polluting gases on the planet (Sousa et al., 2019).

Taking into account the geographic location of the fish farms studied, it is noted that the closest river to the production projects is the Massangana river, a 2nd order river that drains 852 km² and is also the river that the Alto Paraíso captures water from for urban supply. In the Plano Estadual de Recursos Hídricos de Rondônia and Ministério do Meio Ambiente (2018) prepared a report of daily and monthly averages of flow for the fluviometric station located on the Massangana river (code number: 15432000). During the entire time it was active, that is, from years 1981 to 2014, in this period, the report pointed to a Q95% daily flow rate equal to 1.15 m³. s^{-1} and a monthly flow of 1.41 m³ s^{-1}.

According to SEDAM Agency (2021b), during the years 2011 to 2016, ocurred 17 processes for granting water surface capture took place in Alto Paraíso municipality, totaling 9.15 m^3 s^{-1}. The value is six and a half times higher than the minimum permanence flow (of the Massangana river) used as a basis for granting processes by water resource management bodies. The data compared shown the fragility of water resources in Alto Paraíso, identify that the fish farms granted are not taking water directly from the Massangana river, or are not located upstream of the analyzed station. However, taking into account the geographical proximity and the projects insertion in the Massangana river sub-basin, there is an imminent risk of conflicts in the use of water resources by agricultural demand and urban use.

Studying methods and techniques for recovering altered areas in the Brazilian Amazon, Vieira et al. (2007) identified agroforestry systems and also fish farming (Ferreira, 2016) as activities that help to recover the productive capacity of altered areas, providing good yields per area. This situation is evident in Alto Paraíso municipality, since the soils of the Alto Paraíso are naturally infertile and in several areas, they are in conditions or process of degradation (Auzier Neto, 2011).

Most of the fish farms in Vale do Paraíso municipality are small properties that have been dismembered over the years, configuring themselves in small properties with degraded soil, an adverse situation for obtaining income in rural areas. Faced with this reality, it is evident that the activity of fish farming is growing in these properties as a practice that diversifies production and enables economic returns with good incomes occupying few areas of land, which can be the main activity or a secondary activity. A similar situation was found by Cota (2020) in the Rio Branco and Colorado rivers Basin, located and occupying part of the Alta Floresta D'Oeste, Alto Alegre dos Parecis, São Miguel do Guaporé, São Francisco do Guaporé, Parecis, Santa Luzia D 'Oeste, Novo Horizonte do Oeste and Nova Brasilândia D'Oeste municipalities, all in the state of Rondônia, where he identified the highest concentration of fish farms located in its northeast portion, a region very close to the headquarters of the various municipalities that make up this region, and with the highest rate of anthropization.

In a survey conducted out at IDARON Agency, it was identified that only from the year 2019 did this Agency start registering fish farms in the municipality, a necessary action to control the emissions of Animal Transport Guides (ATG), issued when fish is transported. During the period that IDARON Agency fed its database, there was a growth of around 400%, which represented an evolution from 2 fish farms in year 2019 to 10 fish farms in year 2021. A similar survey was carried out at EMATER and SEDAM Agencies, it was observed that the existing records at EMATER-RO Agency have evolved little from the time they started their assistance until now, going from 8 fisg farms (in year 2012) to 10 fish farms (in year 2021), representing a growth of 25%. The Governmental agency that has been carrying out the registration of fish farms in Alto Paraíso municipality for the longest time is SEDAM. This Agency has been registered since year 2006 (aone fish farm), and has been updating its records, resulting in a number of 16 fish farms in year 2021, an increase of 1,500%.

The IDARON Agency informed at the time of the visit (in current data survey) that it was not going to the field to update the fish farm records since year 2020, and has only been adding new records when it is sought after by the fish farmers themselves interested in issuing their ATGs. The reason for not updating their records, according to the Unidade de Gerenciamento Local de Sanidade Animal e Vegetal (ULSAV), is mainly due to the current pandemic situation caused by the Covid-19 virus, the isolation that was recommended by the health authorities and to the adoption by the Agency of work

form without face-to-face assistance to the population, using for this purpose distance communication tools and online systems for issuing documents.

The reasons given by EMATER-RO Agency about the small number of registrations are also related to the isolation recommended by health authorities for the prevention and control of the Covid-19 virus. However, the Manager of the Local Office of Alto Paraíso adds the need for more employees in the Agency. Nonetheless, SEDAM Agency stated that its registrations are carried out and updated as they arrive at its Escritórios Regionais de Gestão Ambiental (ERGA) through the requirements for the issuance of Environmental Licenses.

Finally, in current study there are the numbers that comprise the results of vectorization carried out on fish farms in Alto Paraíso. The vectorization was performed on two satellite images, one from year 2008 and another from year 2021, for comparison purposes. The result obtained was the identification of 42 existing fish farms in year 2008 and 126 fish farms in year 2021, a growth of 200%. Taking the data from SEDAM Agency as a reference, it is observed that in year 2008, operated 95% of fish farms in Alto Paraíso municipality without any type of Environmental License. And study current (in year 2021), the value has decreased, although, it remains high, reaching 87%.

In Figure 6, it can seen that by the year 2021, in the southern part of Alto Paraíso municipality, projects have emerged that represent the concentration of fish farms (within a radius of 10 km) occupying more than 50 hectares of water surface. The evolution of fish farms in Alto Paraíso municipality followed the trend of evolution that occurred in Rondônia state, which in year 2020, for the third year in a row, remained the largest producer of native fish in the country, with production of 65.5 thousand tons, 16 thousand hectares of water surface exclusively for fish farming and more than 4 thousand registered fish farmers (SEDAM, 2021b).

It was possible to identify in current study that the fish farms in Alto Paraíso are mostly small fish farms, a reality that remains even in municipalities that are in the region called Vale do Jamari. According to data from the IDARON Agency, the Vale do Jamari region concentrates the largest fish farms, including where three of the largest fish processing industries in Rondônia state are installed (Meante & Dória, 2017). However, Meante & Dória (2017) identified that although the Vale do Jamari region contains the largest fish farms in Rondônia state, the enterprises that represent the largest number are small fish farms, with undoubted participation of family farming in the activity. This overview is similar to that found in current study.

The fish farms in Rondônia state were not established along important water courses (rivers and streams). In reality they are concentrated near the main highways. In order to support the flow of production (Rocha, 2015). Nonetheless, there are some exceptions of agglomerations of fish farms implemented according to water resources, especially in Central-East region of Rondônia state along the Machado river (Krusche et al., 2005; Figueiredo et al., 2018; Hurtado et al., 2018; Pontuschka et al., 2021). As well as fish farms and small fishing ports, in Vale do Guaporé region (is also located in Rondônia state) along the Guaporé river (Adami, 2013; Freitas et al., 2016).

In prospecting the production chain organization in Rondônia state and evaluating the organizational infrastructure of fish farming, Xavier (2013), Feitoza (2018) and Monteiro (2021) found that there are several organizations that act separately in offering support in the production chain of fish farming. There is an institutional environment favorable to the production of native fish, with the intention of promoting policies to encourage production and to address the bottlenecks in the production chain, such as the industrialization and commercialization of production. However, these policies should more effective with all the improvement intentions put into practice so that the fish farming production chain can develop in a sustainable and perennial way.

Conclusions

The results found in the in loco study, as well as the remote research on the temporal space from years 2008 to 2021, in Alto Paraíso municipality, revealed that there are currently 126 fish farms that correspond to a total of 331 hectares of water surface, an evolution of 200% on projects and 973% on the total water surface during the period studied. In addition, it was identified that the projects are located along the entire municipal perimeter. And, the vast majority of fish farms are classified as small commercially, with a minimum quantity for medium-sized enterprises.

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Literature Cited

Adami, A.F. Gestão agrícola em propriedades rurais familiares do Vale do Guaporé – RO. Araras: Universidade Federal de São Carlos, 2013. 87p. Master's Dissertation. https://repositorio.ufscar.br/handle/ufscar/13826. 17 Feb. 2022.

Associação Brasileira da Piscicultura - Peixe BR. Anuário 2021: Peixe BR da Piscicultura. São Paulo: Peixe BR, 2021. 71p

Associação Brasileira da Piscicultura - Peixe BR. Anuário 2022: Peixe BR da Piscicultura. São Paulo: Peixe BR, 2022. 79p.

Auzier Neto, J.V. Desenvolvimento rural em Alto Paraíso - Rondônia: condições, viabilidade e desafios da agroecologia. Porto Velho: Universidade Federal de Rondônia, 2011. 123p. Master's Dissertation. https://ri.unir.br/jspui/handle/123456789/844. 17 Feb. 2022.

Bordalo, C.A. Os conflitos socioambientais pelo uso da água no Brasil na perspectiva da Ecologia Política. Revista de Geografia e Ecologia Política, v.1, n.2, p.78-110, 2019. https://doi.org/10.48075/amb.v1i2.23237.

Boyd, C.E.; Gross, A. Water use and conservation for inland aquaculture pond. Fisherles Mangement and Ecology, v.7, n.1-2, p.55-63, 2000. https://doi.org/10.1046/j.1365-2400.2000.00181.x.

Brabo, M.F.; Ferreira, L.A.; Veras, G.C.; Cintra, I.H.A.; Paiva, R.S.; Fujimoto, R.Y. Proposta de indicadores de sustentabilidade para parques aquícolas continentais: avaliação de um empreendimento na Amazônia. Revista Brasileira de Ciências Agrárias, v.10, n.2, p.315-321, 2015. https://doi.org/10.5039/agraria.v10i2a5309.

Brasil. Ministério do Meio Ambiente. Conselho Nacional de Meio Ambiente - CONAMA. Resolução n°413 de 26 de junho de 2009. Dispõe sobre o licenciamento ambiental da aquicultura, e dá outras providências. Diário Oficial da União, v.146, n.187, seção 1, p.126-129, 2009. https://www.icmbio.gov.br/cepsul/images/stories/legislacao/Resolucao/2009/RES_CONAMA_N413_2009.pdf. 18 Jan. 2022.

Celino, J. J.; Botelho, N. F. Evolução Geoquímica e Petrogênese de Charnockitos Ígneos no Cinturão Móvel Costeiro do Brasil. Boletim Paranaense de Geociências, n.57, p.25-47, 2005. https://doi.org/10.5380/geo.v57i0.6045.

Cota, T.S. Indicadores socioambientais da piscicultura como instrumento de gestão para Bacia Hidrográfica dos rios Branco e Colorado - Rondônia. Ji-Paraná: Universidade Federal de Rondônia, 2020. 164p. Master's Dissertation. https://ri.unir.br/jspui/handle/123456789/3070. 19 Mar. 2022.

Dantas Filho, J.V.; Pontuschka, R.B.; Rosa, B.L.; Gasparotto, P.H.G.; Marmentini, R.P.; Cavali, J. Mineral composition in commercial cuts of Colossoma macropomum (Cuvier, 1818) and Arapaima gigas (Schinz, 1822) in ideal weight class for commercialization. Acta Veterinaria Brasilica, v.16, n.2, p.172-179, 2022. https://doi.org/10.21708/avb.2022.16.2.10851.

Donagemma, G.K.; Freitas, P.L.; Balieira, F.C.; Fontana, A.; Spera, S.T.; Viana, J.H.M. et al. Characterization, agricultural potential, and perspectives for the management of light soils in Brazil. Pesquisa Agropecuária Brasileira, v.51, n.9, p.1003-1020, 2016. https://doi.org/10.1590/S0100-204X2016000900001.

Empresa Brasileira de Pesquisa Agropecuária - Embrapa. Sistema brasileiro de classificação de solos. 2.ed. Rio de Janeiro: Embrapa, 2006. 306p. http://www.infoteca.cnptia.embrapa.br/infoteca/handle/doc/338818. 19 Mar. 2022.

Empresa Brasileira de Pesquisa Agropecuária - Embrapa. Zoneamento de áreas aptas ao sistema plantio direto em Rondônia através do sistema de informações geográficas. 1.ed. Porto Velho: Embrapa Rondônia, 2011. 4p. (Embrapa Rondônia. Comunicado Técnico, 369). https://ainfo.cnptia.embrapa.br/digital/bitstream/item/59745/1/cot369-sistemaplantiodireto.pdf. 17 Feb. 2022.

Feitoza, D.L.S. Análise do risco da rentabilidade em pisciculturas de tambaqui nos estados do Amazonas, Rondônia e Roraima, para o mercado consumidor de Manaus-AM. Manaus: Universidade Federal do Amazonas, 2018. 91p. Master's Dissertation. https://tede.ufam.edu.br/handle/tede/6396. 29 Mar. 2022.

Ferreira, M.V. O homem, o rio e o viveiro: as relações de poder que entrelaçam o trabalho da piscicultura em Benjamin Constant, no Amazonas. Manaus: Universidade Federal do Amazonas, 2016. 260p. Doctoral Dissertation. https://tede.ufam.edu.br/handle/tede/5594. 29 Mar. 2022.

Figueiredo, F.M.; Bomfim, S.C.; Lima, R.A; Pontes, W.P.; Pontuschka, R.B.; Hurtado, F.B. Exploratory study of limnological parameters during the cycle of tambaqui finguerlings. Revista Eletrônica em Gestão, Educação e Tecnologia Ambiental, v. 22, e11, 2018. https://doi.org/10.5902/2236117034580.

Freitas, C.O.; Bertão, A.P.S.; Leite, E.S.; Silva, J.S.; Lima, T.O. Desafios dos pescadores artesanais amazônicos do Guaporé, Rondônia – RO, Brasil. Revista de Administração e Negócios da Amazônia, v.8, n.2, p.144-161, 2016. https://doi.org/10.18361/2176b-8366/rara.v8n2p144-161.

Hurtado, F.B.; Figueiredo, F.M.; Costa, R.L.C.; Bomfim, S.C; Queiroz, C.B.; Pontes, W.P. Parâmetros limnológicos em viveiros de piscicultura semi-intensiva de tambaqui com abastecimento em disposição sequencial. RAMA: Revista em Agronegócio e Meio Ambiente, v. 11, n.1, p. 9-30, 2018. https://doi.org/10.17765/2176-9168.2018v11n1p9-30.

Instituto Brasileiro de Geografia e Estatística - IBGE. Censo demográfico do Brasil de 2010 – Municípios do estado de Rondônia. Rio de Janeiro: IBGE, 2012.

Krusche, A.V.; Ballester, M.V.R.; Victoria, R.L.; Bernardes, M.C.; Leite, N.K.; Hanada, L. et al. Effects of land use changes in the biogeochemistry of fluvial systems of the Ji-Paraná river basin, Rondônia. Acta Amazonica, v.35, n.2, p.197-205, 2005. https://doi.org/10.1590/S0044-59672005000200009.

Lopes, F.S.C. A piscicultura e o processo de ocupação rural em Mirante da Serra - RO entre os anos de 1986 e 2016. Rolim de Moura: Universidade Federal de Rondônia, 2017. 66p. Master's Dissertation. https://sucupira.capes.gov.br/sucupira/public/consultas/coleta/trabalhoConclusao/viewTrabalhoConclusao.jsf?popup=true&id_trabalho=5049044#. 17 Feb. 2022.

Macedo, C.F.; Sipaúba-Tavares, L.H. Eutrophication and water quality in pisciculture: consequences and recommendations. Boletim do Instituto de Pesca, v.36, n.2, p.149-163, 2010. https://institutodepesca.org/index.php/bip/article/view/911. 29 Mar. 2022.

Meante, R.E.X.; Dória, C.R.C. Caracterização da cadeia produtiva da piscicultura no estado de Rondônia: desenvolvimento e fatores limitantes. Revista de Administração e Negócios da Amazônia, v.9, n.4, p.164-181, 2017. https://doi.org/10.18361/2176-8366/rara.v9n4p164-181.

Monteiro, V.S.B. Gestão colaborativa e os processos de negócios na cadeia de suprimentos da piscicultura do vale do Jamari-RO na região Amazônica. São Paulo: Universidade Paulista, 2021. 89p. Master's Dissertation. https://repositorio.unip.br/wp-content/uploads/tainacan-items/85/85638/VANESSA-DA-SILVA-BRESSAN-MONTEIRO.pdf. 18 Jan. 2022.

Nóbrega, R.S.; Souza, E.P.; Galvíncio, J.D. Análise da estimativa de precipitação do TRMM em uma sub-baciada Amazônia Ocidental. Revista de Geografia, v.25, n.1, p.6-20, 2008. https://periodicos.ufpe.br/revistas/revistageografia/article/view/228747. 19 Mar. 2022.

Passarinho, W. A. Impactos socioeconômicos e ambientais da aquicultura na região da Serra da Mesa – Goiás: A experiência de Uruaçu. Goiânia: Pontifícia Universidade Católica de Goiás, 2011. 71p. Academic Master's Thesis. http://tede2.pucgoias.edu.br:8080/handle/tede/2142. 29 Mar. 2022.

Pontuschka, R.B.; Rocha, V.G.; Santos, S.M.; Alonso, N.B.; Dantas Filho, J.V.; Lopes, V.M. et al. Limnological and microbiological parameters of Machado river and afluents near the city of Presidente Médici, Rondônia, Brazil. Revista Ibero-Americana de Ciências Ambientais, v.12, n.5, p.387-408, 2021. https://doi.org/10.6008/CBPC2179-6858.2021.005.0032.

Rizzatti, M.; Batista, N.L.; Spode, P.L.C.; Erthal, D.B.; Faria, R.M.; Scotti, A.A.V. et al. Mapeamento da COVID-19 por meio da densidade de Kernel. Revista Metodologias e Aprendizado, v.3, p.8-13, 2020. https://doi.org/10.21166/metapre.v3i0.1312.

Rocha, D.O. Geotecnologias aplicadas à estruturação de um sistema de informação geográfica da piscicultura no estado de Rondônia. Presidente Médici – RO: Curso de Engenharia de Pesca, Universidade Federal de Rondônia, 2015. 51p. Undergraduate Thesis. https://ri.unir.br/jspui/handle/123456789/984.

Rondônia. Lei nº 3437/2014, de 09 de setembro de 2014. Dispõe sobre a Aquicultura no Estado de Rondônia e dá outras providências. Diário Oficial do Estado de Rondônia, v.29, n.2538, p.9-13, 2014. https://diof.ro.gov.br/data/uploads/2014/09/Doe-09-09-2014.pdf. 19 Mar. 2022.

Rondônia; Ministério do Meio Ambiente - MMA. Plano estadual de recursos hídricos do estado de Rondônia – relatório final. Curitiba: RHA, 2018. 577p. http://coreh.sedam.ro.gov.br/wp-content/uploads/2019/08/RELATORIO-FINAL.pdf. 29 Mar. 2022.

Rotta, M. A. Diagnóstico da piscicultura na Bacia do Alto Taquari - MS. Corumbá: Embrapa Pantanal, 2003. 31p. (Embrapa Pantanal. Boletim de Pesquisa e Desenvolvimento, 40). https://ainfo.cnptia.embrapa.br/digital/bitstream/item/37412/1/BP40.pdf. 03 Mar. 2022.

Secretaria de Estado da Agricultura - SEAGRI. Governo de Rondônia fortalece setor da piscicultura com ações estratégicas em 2020. Porto Velho: SEAGRI, 2020. http://www.rondonia.ro.gov.br/governo-de-rondonia-fortalece-setor-da-piscicultura-com-acoes-estrategicas-em-2020/. 18 Jan. 2022

Secretaria de Estado de Desenvolvimento Ambiental - SEDAM. Coordenadoria de Licenciamento e Monitoramento Ambiental - COLMAM. Evolução das áreas de operação da piscicultura no estado de Rondônia. Porto Velho: SEDAM, 2021a.

Secretaria de Estado de Desenvolvimento Ambiental - SEDAM. Piscicultura tem grande desenvolvimento e criação de tambaqui é destaque em Rondônia. Porto Velho: SEDAM, 2021b. https://www.sedam.ro.gov.br/pisicultura-tem-grande-desenvolvimento-e-criacao-de-tambaqui-e-destaque-em-rondonia/. 18 Jan. 2022.

Silva, M.J.G.; Querino, C.A.S.; Santos Neto, L.A.; Silva, D.C.; Saraiva, F.A.M. Trend in the meteorological variables of Porto Velho-Rondônia. Journal of Environmental Analysis and Progress, v.2, n.4, p.474–481, 2017. https://doi.org/10.24221/jeap.2.4.2017.1478.474-481.

Sousa, R.G.C.; Assis, J.L.; Cozer, M.V.; Oliveira, C.M. Perfil socioeconômico da piscicultura em Presidente Médici (Rondônia – Brasil). Biota Amazonia, v.9, n.1, p.51-55, 2019. https://doi.org/10.18561/2179-5746/biotaamazonia.v9n1p51-55.

Vieira, T.A.; Rosa, L.S.; Vasconcelos, P.C.S.; Santos, M.M.; Modesto, R.S. Adoção de sistemas agroflorestais na agricultura familiar, em Igarapé-Açu, Pará, Brasil. Revista de Ciências Agrárias, v.47, n.1, p.9-22, 2007. https://ajaes.ufra.edu.br/index.php/ajaes/article/view/191. 19 Mar. 2022.

Xavier, R.E. Caracterização e prospecção da cadeia produtiva da psicultura no Estado de Rondônia. Porto Velho: Universidade Federal de Rondônia, 2013. 103p. Master's Dissertation. https://ri.unir.br/jspui/handle/123456789/2081. 17 Feb. 2022.