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# Sustainability of aquaculture activity in the western region of Paraná, Brazil



[*Sustentabilidade da atividade aquícola na região oeste do Paraná, Brasil*]

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## ABSTRACT

The objective of this work was to evaluate the sustainability of aquaculture production systems in the western region of the state of Paraná through a set of indicators, making it possible to verify whether the activity is being managed within the concept of sustainable development for aquaculture. The study was conducted in the municipalities of Palotina and Maripá, in 50 aquaculture farms. A methodology of a set of sustainability indicators was used through the application of a questionnaire and interviews on the selected farms, which allowed them to be classified according to the three dimensions of sustainability (economic, social, and environmental), as well as to determine which indicators had more influence in each dimension. A group of farms that have an economic advantage over the others was observed; this gives them a relatively lower risk when it comes to the activity. Furthermore, environmental indicators have less influence on the formation of the gradient, indicating that environmental characteristics are similar between farms, regardless of the patterns observed for economic and social aspects.

Keywords: aquaculture. sustainable development. sustainability indicator

## RESUMO

*O objetivo deste trabalho constituiu em avaliar a sustentabilidade dos sistemas produtivos aquícolas na região oeste do estado do Paraná, por meio de um conjunto de indicadores, possibilitando averiguar se a atividade está sendo gerida dentro do conceito de desenvolvimento sustentável para aquicultura. O estudo foi conduzido nos municípios de Palotina e Maripá, em 50 propriedades aquícolas. A metodologia de conjunto de indicadores da sustentabilidade foi empregada por meio de aplicação de questionário e entrevistas nas propriedades selecionadas, o que permitiu ordenar as propriedades aquícolas de acordo com as três dimensões da sustentabilidade (econômica, social e ambiental), assim como determinar quais os indicadores de maior influência em cada dimensão. Pôde-se observar a formação de um grupo de propriedades que dispõe de vantagem econômica em relação aos demais, condição que lhes confere um risco relativamente menor em relação à atividade. Ademais, os indicadores ambientais apresentaram menor influência na formação do gradiente, resultado que aponta que as características ambientais são semelhantes entre as propriedades, independentemente dos padrões observados para os aspectos econômicos e sociais.*

*Palavras-chave: aquicultura. desenvolvimento sustentável, indicador de sustentabilidade*

## INTRODUCTION

Aquaculture is an emerging activity, expanding rapidly around the world in recent decades (The state…, 2022). However, this rapid expansion has increased social and environmental pressures. Even with possible positive impacts, such as food security, job creation, and reduced pressure on fish stocks (Siqueira, 2018), negative impacts can occur, such as the use of permanent preservation areas, the deposition of organic matter and sediments in water bodies, the introduction of non-native species into the natural aquatic environment, and the spread of pathogenic organisms (Ottinger *et al.*, 2016;

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Valenti *et al.*, 2018). All of this puts ecosystem services at risk, generating irreversible consequences for the environment and society.

The state of Paraná is currently the largest aquaculture producer in the country, and its production is concentrated in its western region (Anuário…, 2023). The intense growth and recent structural investments in the region, such as the installation of the largest fish slaughterhouse in Brazil, show the regional tendency of aquaculture expansion in the face of growing global demand. However, accelerated, and disorganized growth can lead to economic, social, and environmental problems. Producers need to be encouraged to adopt practices in line with the concept of sustainable development. This way, they can maximize production efficiency, and reduce losses, costs, and negative impacts, allowing the activity to be successful in the long run (Valenti *et al*., 2011).

Sustainability in aquaculture presents itself as a challenge in the face of the search for profitable production of aquatic organisms in an integrated, harmonious, and continuous manner with local ecosystems and communities (Valenti *et al*., 2011). To overcome this challenge, it is necessary to develop and apply effective methods to measure the systems' sustainability, which allows the assessment of the current situation and prospects for the various production systems, and assists in long-term political interventions (Moura *et al*., 2016). The joint assessment of indicators is a method with the main advantage of synthesizing a complex set of information, making phenomena of interest visible, and allowing the measurement and monitoring of sustainability in its various dimensions (Valenti *et al*., 2011). The set of indicators is an important tool for measuring sustainability in aquaculture systems (Moura *et al*., 2016; Valenti *et al*., 2018). It helps in decision-making, pointing out the existence of risks, potential, and trends in the development of the activity (Valenti *et al*., 2011).

Therefore, it is necessary to use tools to measure the sustainability of aquaculture production systems in the Western region of Paraná, to evaluate whether the activity is being conducted within the concept of sustainable development in aquaculture. A set of indicators was used to assess the economic, social, and environmental aspects of aquaculture farms in the region, in order to detect their strengths and weaknesses in terms of the sustainable development of the activity.

## MATERIALS AND METHODS

The study was conducted in the municipalities of Palotina and Maripá, in the western region of the state of Paraná, which includes the state's largest aquaculture center (Anuário…, 2023). In partnership with the Palotina Fish Association (APAQUI), and the Maripá Municipality Aquaculture Farmers Association (AQUIMAP), a survey of farms that carry out aquaculture activities in the region was conducted. A sample of 10% of the total number of identified aquaculture farms was chosen at random by drawing lots for on-site visits and data collection. The visits took place in 2018 and 2019, in an interview format, using semi-structured questionnaires (Valenti *et al*., 2018) and the indicator set methodology (Valenti *et al*., 2018) covering three dimensions of sustainability: economic, social, and environmental, totaling 24 indicators (Table 1).

To ordinate the farms according to the three dimensions of sustainability and determine which indicators have the greatest influence on each dimension, a similarity matrix formed by the Euclidean distances between them was obtained from a collected set of indicators. Principal Coordinates Analysis (PCoA) was used to summarize the indicators and ordinate the farms based on their similarities. As the ordination showed no outliers, the percentages of explanation of each axis were obtained for interpretation. The variables' influence levels on the axes retained for interpretation were measured using Pearson's correlation. The results were presented in bivariate graphs resulting from PCoA and Pearson correlations. All the analyses were carried out in the *R* software, using the *Vegan* and *Plotrix* packages. Due to the analyzed variables having different scales, they were relativized by each variable's maximum.

The interview's methodology was submitted to the Human Research Ethics Committee (CAAE; 95472218.4.0000.0102), ensuring the rights and protection of the research's participants.

Table 1**.** List of economic, social, and environmental sustainability indicators (Adapted from Valenti *et al*., 2018)

| Economic dimension | Social dimension | Environmental dimension |
|---|---|---|
| Gross Revenue (GR) | Proportional Cost of Work (PCW) | Use of Space (S) |
| Net Revenue (NR) | Remuneration of Work per unit of Production (RWUP) | Dependence on Water (W) |
| Net Income and Initial Investment Ratio (RII) | Required Work per Unit of Occupied Area (WA) | Use of Energy (E) |
| Payback (PB) | Required Work per Unity of Production (WP) | Proportion of Renewable Energy (PRE) |
| Risk Rate (RR) | Use of Local Workers (LW) | Use of Nitrogen (N) |
| | Revenue Fixation (RF) | Use of Phosphorus (P) |
| | Local Consumption of Production (LC) | Risk of Farmed Species (RFS) |
| | Schooling (SC) | Risk of the Production's Site (RPS) |
| | Racial Inclusion (RI) | |
| | Gender Inclusion (GI) | |
| | Age Inclusion (AI) | |

## RESULTS

The questionnaires were applied to 50 of the 480 (10.42%) identified farms. According to the questionnaires, 64% of the farms have been producing commercially for over five years. The oldest registered property has been in business for 30 years, and the most recent for one year. The annual production of the analyzed farms represents around 42.13% of all Palotina and Maripá's production during the research period.

The sampled farms cover 126 ha of water, distributed over 319 excavated tanks. Most have continuous flow systems with an average daily water renewal rate of 9% of the stored volume. Most systems use the terrain's characteristics to supply water to the tanks. Water pumping is used on only 26% of the farms. Production is focused on intensive tilapia farming (98%), using an average density of 7 ind/$m^2$, with a 2.2 to 10 ind/$m^2$ variation. Approximately 92% of the farms are small enterprises (<5 ha of water depth - Brasil, 2009). In 70% of the farms, aquaculture is presented as a complementary activity, with agriculture as the main one.

The workforce found among the owners interviewed is mostly family-based and is made up of white (86%) men (75.19%) between the ages of 22 and 40 (48.12%). The inputs' sale and consumption take place mostly locally (70% and 98% respectively), generating benefits for the local community.

Only 3.92% of the farms carried out an economic feasibility study before taking up the activity. Among the analyzed farms, 62.75% said they had a technical project, while the others started the activity through empirical knowledge. Although 94% of the farms said they had technical support, the visits' frequency was irregular in 54.16% of them. Among the studied farms, 58% are associated with cooperatives in the region.

According to the collected data, 78% of the farms said they had all the environmental authorizations to continue with the activity. The cultivation tanks of 68.63% of the farms are within the permanent preservation area defined by Federal Law No. 12,651 (Brasil, 2012). Regarding effluent control, 82% of the farms have settling tanks, but only 8% have monitored the effluent discharged into the receiving water body. The environmental sustainability indicators pointed to a low use of space (S) and use of energy (E). On the other hand, most of the farms showed high dependence on water (W), while only 2% used renewable energy systems. Most farms had a low use of nutrients fed into the systems. The risk of farmed species was high for 98.03% of the farms. The risk of the production's space was high as well for 68%,

demonstrating the high risk to biodiversity posed by the region's production systems.

The PCoA summarized 40% of the total variability in the first two ordination axes. A variation gradient was formed on the main diagonal, associated mainly with economic characteristics, such as gross revenue (GR), net revenue (NR), net income and initial investment ratio (RII), and social characteristics, such as local consumption of production (LC), as well as age inclusion (AI), and racial inclusion (RI). There were mostly people aged 22 to 40 (T) and 41 to 60 (MI), white (WH), and mixed-race (MR) (Fig. 1).
Two groups were also evident on the secondary diagonal, differentiated mainly by social characteristics related to gender inclusion (GI), use of local workers (LW), remuneration of work per unit of production (RWUP), and schooling (SC) (Fig. 1). Projecting these characteristics onto the main gradient of variation reveals that farms are made up mostly of men, mixed-race, between 22 and 40 years old, with a higher level of education, who use local labor and do not depend on the local placement of their produce, and have a great economic advantage over others, giving them a relatively lower risk regarding the activity.

The lesser influence of environmental indicators on the gradient formation indicates a similarity of environmental characteristics among farms, regardless of the patterns observed for economic and social aspects.

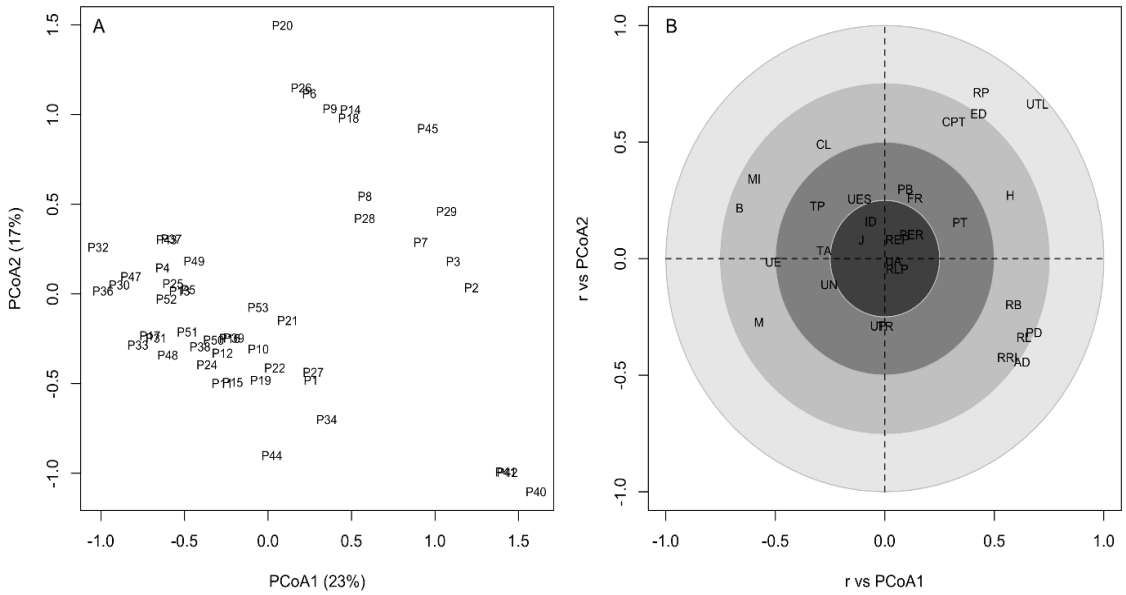


Figure 1. A) Ranking of aquaculture farms ($P_i$) on the first (PCoA1) and second (PCoA2) axes of the principal coordinates analysis on the Euclidean distances obtained from relativized characteristics relating to the economic, social, and environmental dimensions. Explanation percentages are shown next to the axes. B) Pearson correlations between PCoA axes and the variables summarized (GR, gross revenue; NR, net revenue; RII, net income and initial investment ratio; PB, payback; RR, risk rate; S, use of space; W, dependence on water; E, use of energy; PRE, proportion of renewable energy; P, use of phosphorus; N, use of nitrogen; RFS, risk of farmed species; RPS, risk of the production's site; PCW, proportional cost of work; RWUP, remuneration of work per unit of production; WA, required work per unit of occupied area; WP, required work per unity of production; LW, use of local workers; RF, revenue fixation; LC, local consumption of production; SC, schooling; GI, Gender Inclusion (M, men; W, women); RI, Racial Inclusion (WH, whites; B, blacks; MR, mixed-race); AI, Age Inclusion (Y, 14 to 21 years old; T, 22 to 40 years old; MI, 41 to 60 years old; E, > 60 years old). Gray scales separate the correlation intensities every 25%.

## DISCUSSION

The indicators highlighted the region's tendency for aquaculture development and its potential for expansion and productive growth with economic viability. Some farms have qualified technical assistance, especially those associated with regional cooperatives, and employ high stocking densities (from 6 to 10 ind/m²). Other enterprises use low stocking densities (2 to 3 ind/m²) and practice the activity without associations or technical assistance. It is possible to observe the formation of a farm group that has an economic advantage over the others, regarding their higher technical qualifications. The lack of technical qualifications has already been identified as one of the main obstacles to the development of the aquaculture production chain (Bueno *et al*., 2020). Farms with family labor and lower profitability become dependent on outsourced technical assistance, increasing costs, and consequently reducing the frequency of visits – which leads to major risks and potential damage to the farm and its production. It is important to encourage cooperativism and invest in training, qualifications, and innovations that seek predictability and uniformity in the production process, designed according to the producer's reality (Valenti *et al*., 2021). According to Valenti *et al*. (2021), most Brazilian aquaculture farms lack economic sustainability, especially due to the lack of appropriate management tools. This can be intensified by the fact that most farms have aquaculture as a secondary activity, increasing the risk of economic unsustainability going unnoticed by producers.

Despite the discrepancies in the economic dimension, it was not possible to assess whether the properties that are not economically sustainable are the ones with the lowest profitability. Valenti *et al*. (2011) cite that for small farms (<5 ha of water depth – Brasil, 2009) the activity must guarantee a profitability that can give the owner, as well as their family, an acceptable standard of living within the region in which they live. However, training, and technical qualifications are crucial to the financial success of aquaculture enterprises and to mitigate the impacts generated by the activity.

Given the aspects of social inclusion, it is possible to observe that the data found in the survey reflect the region's population – composed mainly of white people (72.9%), mostly between 20-40 years old (36.4%) (Características…, 2010). Gender inclusion is still low in aquaculture, which is considered predominantly male due to the physical demands involved (Oliveira and Florentino, 2018). Studies such as that by Santos *et al*. (2014) show that women associated with aquaculture organizations can develop successful aquaculture activities, challenging this trend. Female participation increased within the aquaculture production chain, accounting for 80% of the jobs generated in the meatpacking sector in the western region of Paraná (Rosalem and Nagata, 2018). Therefore, the growing participation of women can also expand to other areas of aquaculture, including production.

There were similarities in the indicators related to the environmental dimension of sustainability on all analyzed farms, regardless of their size and production time. Water body tanks that enter permanent preservation areas are common in the region and throughout the country (Nobile *et al*., 2019; Forneck *et al*., 2021), as is the use of large volumes of water, a lack of monitoring of effluent quality, and the escape of exotic species (Forneck *et al*., 2016).

Effective actions to control environmental impacts still rely on complying with legal requirements, which are often neglected due to a lack of inspection and monitoring. This can be seen by the significant proportion of properties with environmental authorizations (78%) but with production concentrated in permanent preservation areas (68%), with poor monitoring of effluent quality (8%), and a high risk to biodiversity due to the production of exotic species without control or monitoring of escapes (98%).

The lack of monitoring, the intensification of the systems, and the high use of water are worrisome, as they cause uncertainty about the quality of the effluent discharged and the risks to biodiversity. Even though the intensification of systems has led to less use of space, good management practices are important (Bueno *et al*., 2020) and allow an increase in yield per hectare, combined with the efficient use of natural resources.

Technologies that reduce these factors must be close to the producer's reality. It is necessary to encourage the training and qualification of the workforce to guarantee profitable production with efficient use of natural resources and nutrients. Investment in the environmental area cannot be held responsible for reducing the profitability of aquaculture enterprises. An economy that reduces pressure on the use of natural resources does not run counter to economic growth; it is in harmony with aquatic ecosystems, guaranteeing benefits for producers in the medium or long term, and allowing them to continue in the activity by reducing the risks caused by environmentally irresponsible actions (Siqueira, 2018).

## CONCLUSION

Aquaculture, such as other productive systems, has economic return as its main motivator, and the producer's permanence in the activity depends on this dimension. However, sustainability requires, in addition to concern for economic efficiency, consideration of the social and environmental dimensions. One dimension prevails to the detriment of the others. The indicators used pointed out the main strengths and weaknesses of the region's aquaculture activity. These aspects must be considered by the productive sector so that aquaculture can be developed in line with the concept of sustainable development.

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