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APPLICATION OF CBERS IMAGES AND MACHINE LEARNING IN THE SIZING AND LOCATION OF FISH FARMS

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Catuxo, V.T.S. [a]* - Ramos, J.F. [b] - Barros, F.A.L [c] - Cordeiro, C.A.M. [d]

(a) PhD Student in Animal Science.
ORCID: https://orcid.org/0009-0000-3360-0350. **LATTES:** http://lattes.cnpq.br/0487168661175170.
(b) MSc Student in Animal Science.
ORCID: https://orcid.org/0009-0004-6216-1499. **LATTES:** http://lattes.cnpq.br/2610656983249520.
(c) PhD in Animal Science.
ORCID: https://orcid.org/0000-0002-2392-6266. **LATTES:** http://lattes.cnpq.br/8413201747918962.
(d) PhD in Plant Production
ORCID: https://orcid.org/0000-0002-2698-6918. **LATTES:** http://lattes.cnpq.br/8413201747918962.

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(*) CORRESPONDING AUTHOR
Address: UFPA. Campus II - Castanhal, Institute of Veterinary Medicine, Zip Code: 68.740.970, Castanhal (PA), Brazil. Phone: (+55 91) 3267-0785
E-mail: victor.catuxo@castanhal.ufpa.br

Abstract

The use of tools based on artificial intelligence has significantly expanded the application of remote sensing, especially in the identification and monitoring of aquaculture parks. This study evaluated the applicability of the Segment Anything Model (SAM), integrated to SamGeo, in the automatic segmentation of fish farming areas in CBERS images with resolution of 2 meters, in the municipality of Conceição do Araguaia, Pará, Brazil. Two areas of interest were analyzed, and the processing of images was performed with natural language prompts, generating segmentation masks converted into vector format for analysis in GIS. The model performance was evaluated using IoU and F1-Score metrics, reaching values of 0.50 and 0.66, respectively. The methodology showed greater accuracy in tanks with regular shape, while smaller structures or narrow slopes presented limitations. The results demonstrate that the combination of CBERS images and advanced segmentation models allows efficient identification of fish farms, providing relevant support for monitoring and territorial management. However, improvements in image resolution and calibration of model parameters are recommended to increase precision in applications that require high spatial accuracy.

Keywords: Aquaculture, Segment Anything Model, Remote sensing, CBERS, Image Segmentation.

Resumo / Resumen

APLICAÇÃO DE IMAGENS CBERS E MACHINE LEARNING NO DIMENSIONAMENTO E LOCALIZAÇÃO DE FAZENDAS DE PEIXES

O uso de ferramentas baseadas em inteligência artificial tem ampliado significativamente a aplicação do sensoriamento remoto, especialmente na identificação e monitoramento de parques aquícolas. Este estudo avaliou a aplicabilidade do Segment Anything Model (SAM), integrado ao SamGeo, na segmentação automática de áreas de piscicultura em imagens CBERS com resolução de 2 metros, no município de Conceição do Araguaia, Pará, Brasil. Duas áreas de interesse foram analisadas, e o processamento das imagens foi realizado com prompts de linguagem natural, gerando máscaras de segmentação convertidas em formato vetorial para análise em SIG. O desempenho do modelo foi avaliado utilizando métricas de IoU e F1-Score, alcançando valores de 0,50 e 0,66, respectivamente. A metodologia apresentou maior acurácia em tanques com formato regular, enquanto estruturas menores ou com taludes estreitos apresentaram limitações. Os resultados demonstram que a combinação de imagens CBERS e modelos avançados de segmentação permite a identificação eficiente de pisciculturas, oferecendo suporte relevante para o monitoramento e gestão territorial. Entretanto, melhorias na resolução das imagens e calibração dos parâmetros do modelo são recomendadas para aumentar a precisão em aplicações que demandem alta exatidão espacial.

Palavras-chave: Aquicultura, Segment Anything Model, Sensoriamento remoto, CBERS, Segmentação de Imagens.

APLICACIÓN DE IMÁGENES CBERS Y APRENDIZAJE AUTOMÁTICO EN EL DIMENSIONAMIENTO Y LOCALIZACIÓN DE PISCIFACTORÍAS

El uso de herramientas basadas en inteligencia artificial ha ampliado significativamente la aplicación de sensores remotos, especialmente en la identificación y monitoreo de parques acuícolas. Este estudio evaluó la aplicabilidad del Segment Anything Model (SAM), integrado a SamGeo, en la segmentación automática de áreas de piscicultura en imágenes CBERS con resolución de 2 metros, en el municipio de Conceição do Araguaia, Pará, Brasil. Dos áreas de interés fueron analizadas, y el procesamiento de las imágenes fue realizado con prompts de lenguaje natural, generando máscaras de segmentación convertidas en formato vectorial para análisis en SIG. El desempeño del modelo fue evaluado utilizando métricas de IoU y F1-Score, alcanzando valores de 0,50 y 0,66, respectivamente. La metodología presentó mayor precisión en tanques con formato regular, mientras que estructuras más pequeñas o con taludes estrechos presentaron limitaciones. Los resultados demuestran que la combinación de imágenes CBERS y modelos avanzados de segmentación permite la identificación eficiente de piscifactorías, ofreciendo un soporte relevante para el monitoreo y gestión territorial. Sin embargo, se recomiendan mejoras en la resolución de las imágenes y calibración de los parámetros del modelo para aumentar la precisión en aplicaciones que demandan alta precisión espacial.

Palabras-clave: Acuicultura, Segment Anything Model, Sensor remoto, CBERS, Segmentación de Imágenes.

INTRODUCTION

The advancement of tools based on artificial intelligence has significantly expanded the possibilities of application in various areas of knowledge. Among them, remote sensing stands out, which has been benefiting from these technologies to perform faster, more accurate and large-scale analyses. In agriculture, the integration of aerial and satellite images with artificial intelligence methods has been consolidated as a strategic resource for crop and land use monitoring, offering greater predictive capacity and support to productive management (Fuentes-Peñailillo et al., 2024).

In the context of aquaculture, these tools have been particularly relevant in the identification and monitoring of aquaculture parks, contributing decisively to territorial management and monitoring of aquatic environments (Catuxo; Costa; Silva, 2021; Dong et al., 2024; Silva et al., 2024; Taskov et al., 2021). However, the identification of water bodies through images still faces technical challenges, such as wavy reflections, chromatic aberrations, motion blur and gaussian noise, which make it difficult to differentiate subtle color variations. These factors become especially critical in aquaculture, as the characteristic greenish tones of water can be confused with vegetation areas, compromising the accuracy of detection and monitoring of aquaculture structures (Wang; Zhao; Petzold, 2024).

Another distinctive aspect refers to the shape of aquaculture tanks, which usually have regular contours, close to the rectangular. This geometric configuration creates a striking visual pattern, favoring its differentiation from other structures. However, limitations due to the spatial resolution of satellite images can compromise the identification of these objects, reducing the precision in the delimitation of aquaculture areas (Silva et al., 2024; Xia; Guo; Chen, 2020).

In addition, several possibilities are presented for the identification of aquaculture tanks, especially when they follow the expected geometric pattern. These structures provide opportunities for public management and monitoring of the activity, ensuring greater transparency and efficiency in management. However, it should be noted that if not properly monitored, they can generate environmental and even social impacts, reinforcing the importance of developing effective monitoring and control tools (Catuxo; Costa; Silva, 2021; Duan et al., 2020; Silva et al., 2024).

In this context, the creation of robust identification methods becomes extremely relevant, and the use of segmentation techniques can decisively assist in this process, making it more precise, accessible and efficient. Thus, the present study aims to evaluate the applicability of the Segment Anything Model (SAM), integrated with SamGeo, in the detection and automatic segmentation of fish farming areas in CBERS satellite images in the municipality of Conceição do Araguaia, Pará, Brazil, using natural language as interface for interaction with the model.

MATERIAL E METHODS

STUDY AREA

The study was conducted in the city of Conceição do Araguaia, in the state of Pará. According to the Brazilian Institute of Geography and Statistics (IBGE), the municipality has distinguished itself in aquaculture, consolidating as the third largest producer of farmed fish in the state. In 2023, it reached a production of 1,146 tons, which reinforces its importance as an aquaculture pole and its significant contribution to the regional economy.

The main producers of the municipality are concentrated in the southern region, in extensive areas of rural settlements implemented by the federal government in the 1980s and 1990s (Catuxo; Costa; Silva, 2021).

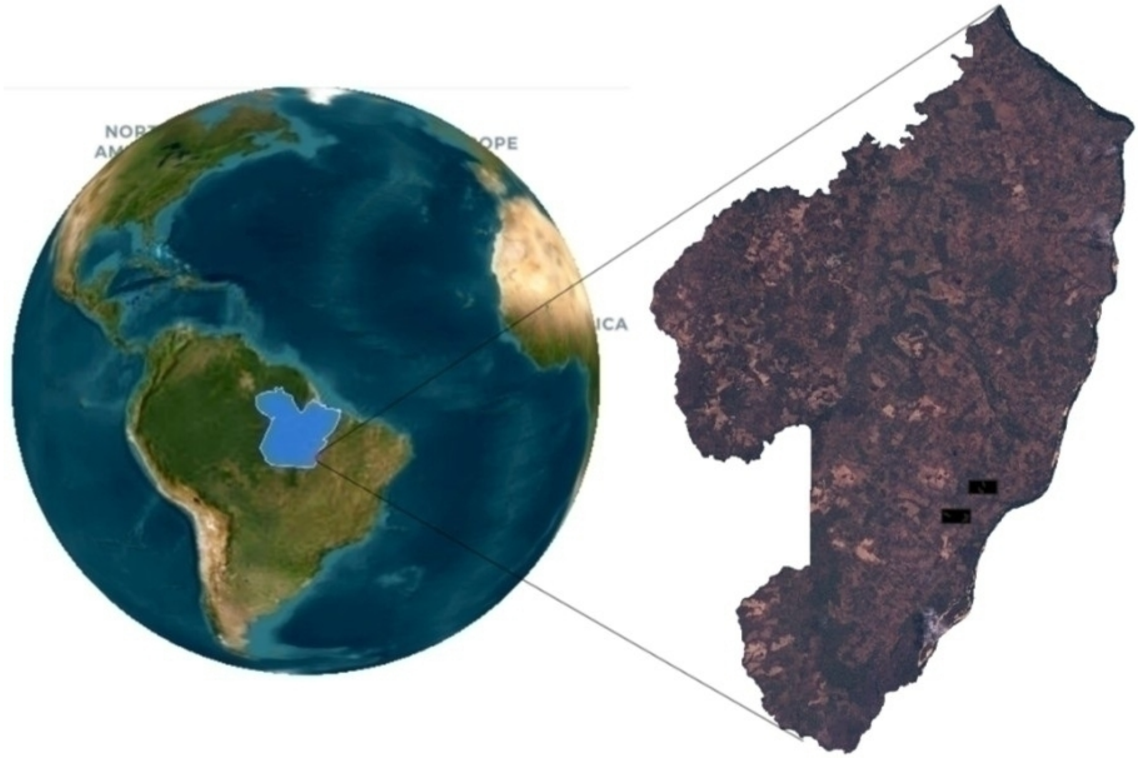


Figure 1 - Conceição do Araguaia, in the state of Pará - Brazil. Source: GEOAI, GEOBR, CBERS and Autors (2025)

IMAGES RGB

images used were obtained through the CBERS Explore plugin, integrated with the QGIS software. This plugin was developed to facilitate the search and download of products from the China-Brazil Earth Resources Satellite (CBERS) program. The selected image corresponds to an RGB composition with a spatial resolution of 2 meters, generated from the technique of fusion by Principal Components (PCA - Main Components Analysis).

For the selection of the image, preference was given to the drought period, coinciding with the month of August (28/08/2025), which favored obtaining a scene with low cloud cover. The image chosen for the fish farming areas was identified as CBERS4A_WPM_PCA_RGB321_20250828_210_124.

In this study, two areas of interest located in the southern region of the analyzed municipality were selected, as shown in the CBERS4A image (Figure 2).

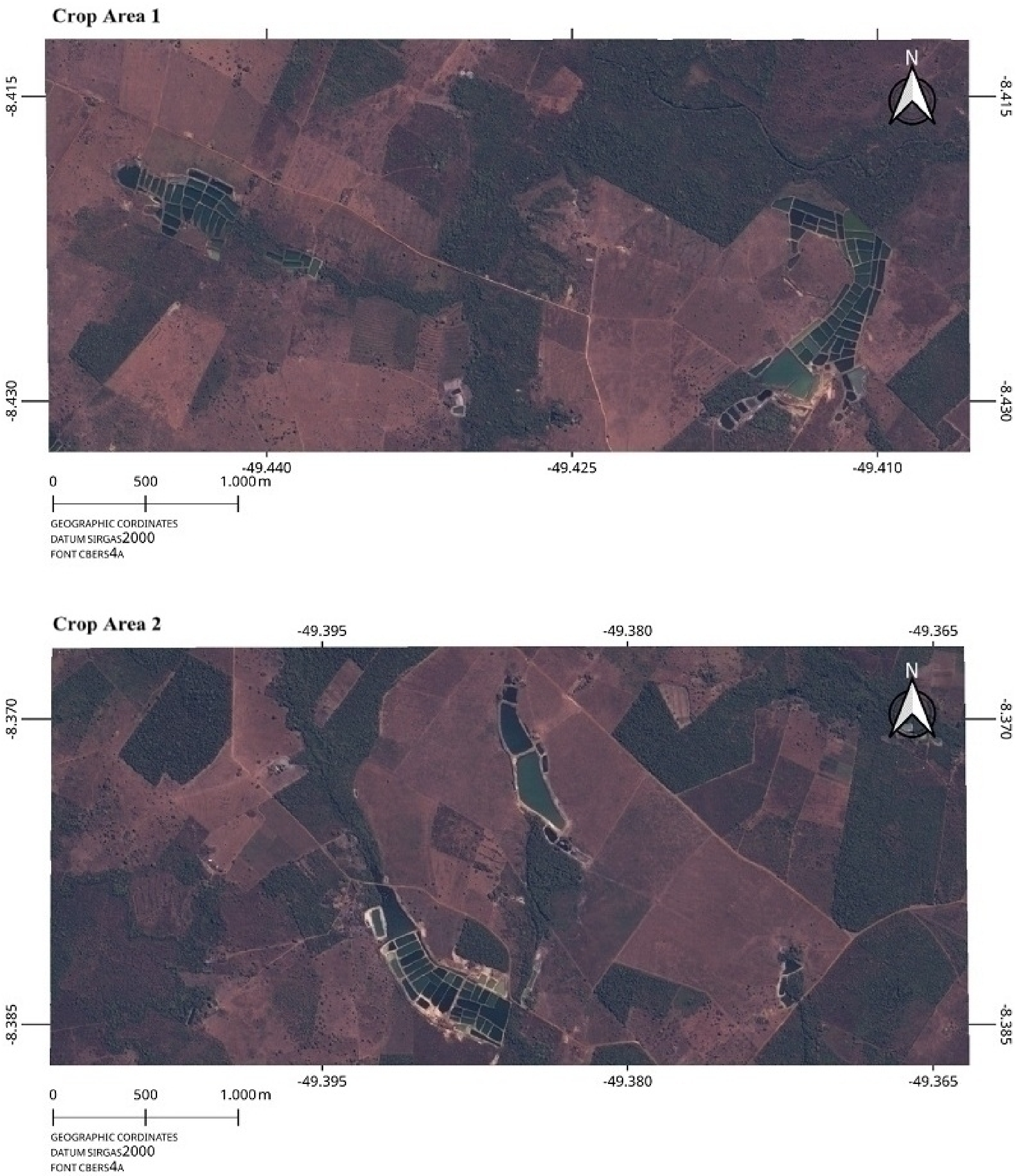


Figure 2 - Áreas (1 and 2) selected for the study, located south of the city of Conceição do Araguaia, in the state of Pará. Source: CBERS4A_WPM_PCA_RGB321_20250828_210_124. e Autores (2025)

DATA PROCESSING

The data processing was carried out with python language and the use of the tool Segment Anything Model (SAM), developed by Meta AI and recognized as one of the most advanced tools for image segmentation. The version used was the ViT-H (Vision Transformer Huge), the most robust available, with the ability to process 636 million parameters, which ensures high accuracy in object identification.

The execution of the model occurred by means of a command line (prompt), from which an instance of the SamGeo library was generated (Osco et al., 2023; Wu; Osco, 2023), which integrates SAM to geospatial applications. This procedure resulted in the creation of a segmentation mask of the original image, in which each object identified in the foreground was delineated and received a single pixel value, allowing the distinction between different features of the scene.

Additionally, DINO Grounding was incorporated, a model capable of performing zero-shot object detection, achieving high performance even without specific training. The joint application of the techniques made possible the isolation and automatic extraction of multiple geospatial features of interest. The generated product corresponds to an unclassified segmentation, in which segments are only identified but not yet labeled. Subsequently, these results could be converted into vector format, enabling additional analysis in Geographic Information Systems (GIS).

During the process of searching for objects, it was verified the need that the images contain the desired target. After initial identification, a search loop was implemented, which increased the probability of detection in the scene. Then the method generated a new mask, removed the already identified object and proceeded to search for other targets.

In the active search, adjustment parameters (between 0 and 1) defined by trial and error were considered, among which stand out: Box Threshold: used to detect objects in images. Higher values increase model selectivity by isolating only instances recognized with high confidence. Lower values extend the tolerance, favoring general detections but at risk of including less accurate results.
Text Threshold: used to associate detected objects with the provided text prompts. High values require strong correspondence between object and text, ensuring accuracy but restricting associations. Lower values allow wider associations, increasing coverage, but with possible loss of accuracy.

These parameters have the function of balancing accuracy and recovery. It should be noted that the ideal values vary according to the nature and quality of the images, as well as depending on the prompt used, so experimentation is necessary for its calibration.

This procedure shows the feasibility of a new paradigm of geospatial analysis, in which natural language acts as primary interface for interaction with advanced segmentation models, favoring the precise extraction of features in images (OSCO et al., 2023). The images were processed using segment-geospatial libraries, groundingdino-py and with the support of Leafmap (Wu, 2021).

The prompt adopted was "piscicultura" (in Portuguese), noting that the use of different languages can generate variations in results. The values defined for the threshold parameters were: 0.24 both for the box threshold (box threshold) and for the text threshold (text threshold).

AVALIATION OF MODEL

After the definition of the two areas of interest, the quantification of fish farms was carried out, taking into account the size of the production areas. The results obtained were then compared with the information provided by the SamGeo library.

In a simplistic way, a confusion matrix was used to analyze the classification model:

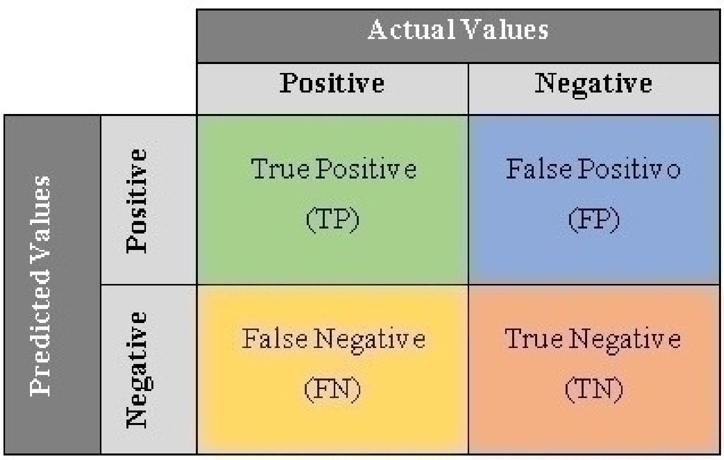


Figure 3 - Confusion Matrix.

To quantify the performance of the proposed segmentation model, four consolidated metrics in the literature were used: Union Intersection (IoU), and the F1-Score.

a) Intersection on Union (IoU): Also known as Jaccard's Coefficient, this metric evaluates the spatial overlap between the mask predicted by the model and the field truth mask. It is calculated by the ratio between the area of intersection and the area of union of the two regions. IoU values range from 0 to 1, where 1 indicates a perfect overlap. The equation defines IoU as:

Equation 1 – Intersection Analysis on the Union

$$IoU = \frac{TP}{TP + FP + FN}$$

b) F1 Score: Represents the harmonic mean between Precision and Recall. This metric is particularly useful when seeking a balance between the two, especially in scenarios with asymmetric class distribution. The F1-Score synthesizes the performance of the model in a single metric. For this index >9, they are considered optimal; 0.8 - 0.9, they are considered good; 0.5-0.8, they are acceptable and below 0.5, they are not acceptable.

Equation 2 - F1-Score Analysis

$$F1 = 2 \times \frac{precision \times recall}{precision + recall}$$

For the calculation of F1-Score were used:

a) Precision: Refers to the accuracy of positive predictions. It measures the proportion of pixels classified as positive that are in fact positive. A high precision indicates few false positives.

Equation 3 – Precision Analysis

$$precision = \frac{TP}{TP + FP}$$

Recall or Sensitivity: Refers to the ability of the model to find all relevant (positive) pixels in the image. It measures the proportion of actual positive pixels that have been correctly identified. A high sensitivity indicates few false negatives.

Equation 4 – Recall Analysis

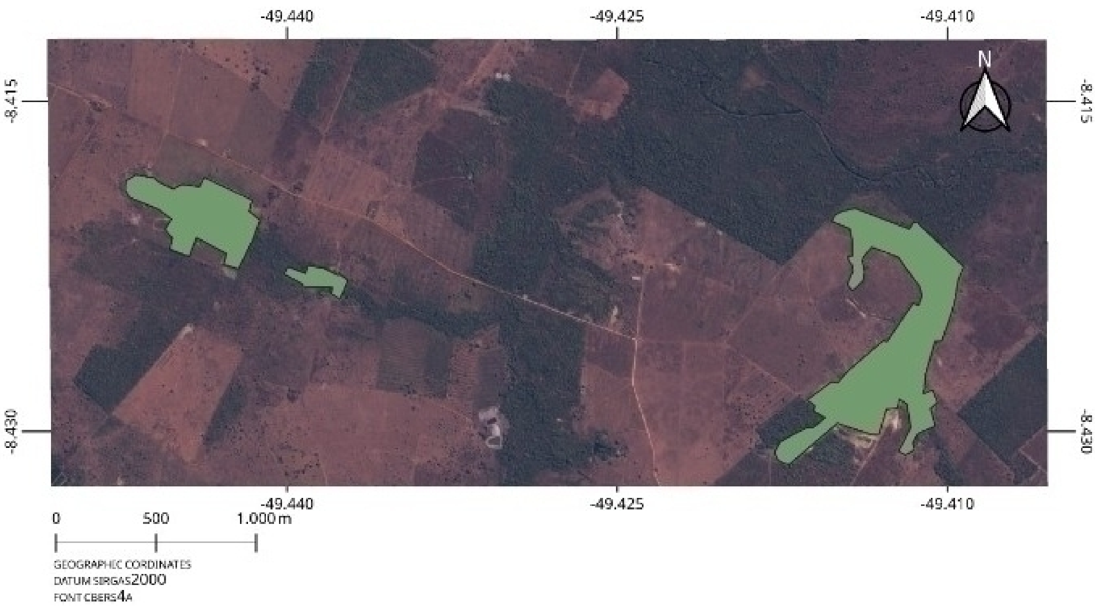
$$recall = \frac{TP}{TP + FN}$$

These comparisons were used to evaluate the accuracy of the adopted language model.

RESULTS

The results indicate that, with the use of the program and the cut-off areas, it was possible to identify 43,315 hectares in cut-off area 1 and 43,985 hectares in cut-off area 2, including both the water table and the slope. In comparison, the manual survey carried out reached 60,532 hectares for area 1 and 43,853 hectares for area 2.

It is noteworthy that, in the analysis of the second area, the program presented difficulty in correctly delimiting the region by means of a box, selecting all the available area. However, it is important to note that, in relation to the measurement of size, the program demonstrated greater accuracy.



Crop Area 1b

Figure 4.1 - Crop Area 1a - In the CBERS image, in the first and third frame; and identification of fish area with SAMGEO, in the second and fourth raised frame. Source: CBERS4A_WPM_PCA_RGB321_20250828_210_124. e Autores (2025)

Crop Area 2a

Figure 4.2 - Crop Area 1b - In the CBERS image, in the first and third frame; and identification of fish area with SAMGEO, in the second and fourth raised frame. Source: CBERS4A_WPM_PCA_RGB321_20250828_210_124. e Autores (2025)

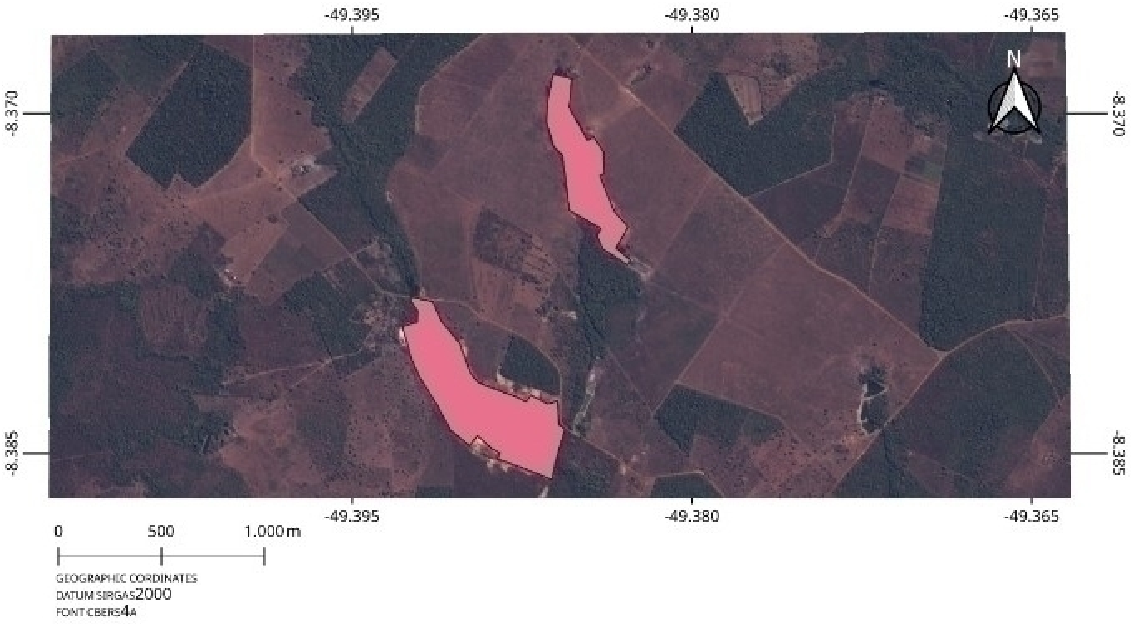


Figure 4.3 - Crop Area 2a - In the CBERS image, in the first and third frame; and identification of fish area with SAMGEO, in the second and fourth raised frame. Source: CBERS4A_WPM_PCA_RGB321_20250828_210_124. e Autores (2025)

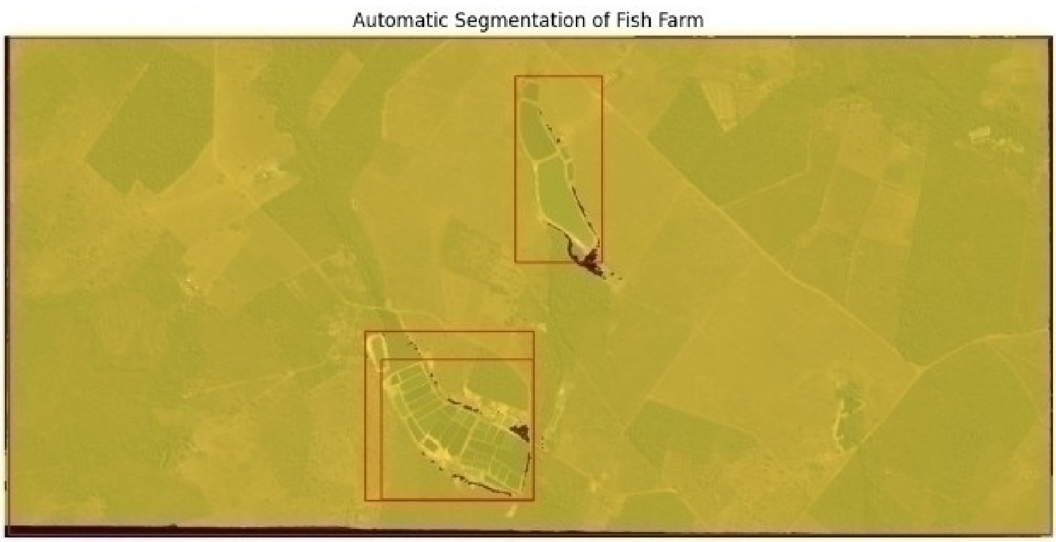


Figure 4.4 - Crop Area 2b - In the CBERS image, in the first and third frame; and identification of fish area with SAMGEO, in the second and fourth raised frame. Source: CBERS4A_WPM_PCA_RGB321_20250828_210_124. e Autores (2025)

It is noteworthy that, in the first area, the segmentation did not identify the set of fish farms located further to the center-west. This limitation resulted in a percentage difference of 28.75% between the methods, showing a significant discrepancy compared to the manual survey. In contrast, in area 2, the difference was only 0.30%, demonstrating high consistency between the two procedures.

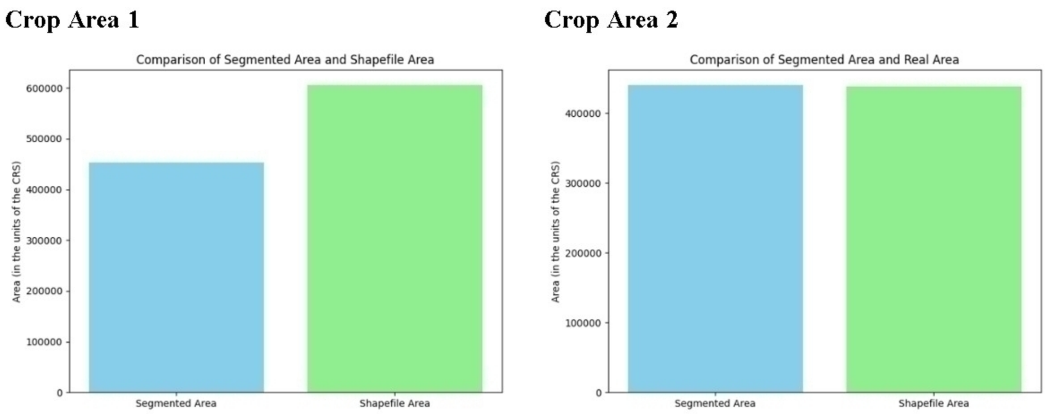


Figure 5 - Comparison of the survey through segmentation and manual, for both areas. Source: Autors (2025)

The quantitative results, represented by an IoU of 0.5 and a F1-Score of 0.66, provide a robust measure of model performance. A 0.5 IoU suggests that, on average, 50% of the area predicted by the model corresponds correctly to the field truth area, while the other 50% represent over- or under-estimation errors. The F1-Score, which is the harmonic mean between precision and recall, has a higher value (0.66), indicating that the model achieves a better balance between avoiding false positives and false negatives than the IoU metric alone could suggest. This level of performance is considered a solid starting point for complex segmentation tasks, but highlights the need for future optimizations for applications that demand high spatial precision.

DISCUSSION

The identified area was classified as pisciculture because it is located in the continental region of the state and, according to data from the Brazilian Institute of Geography and Statistics - IBGE, the main production of the municipality, is fish farming, with no record of another activity that uses the same structure.

The study demonstrated that the use of CBERS images, with spatial resolution of 2 meters, was suitable for the identification of larger fish farms, in detriment to smaller ones. It was found, however, that the application of SAM technology in satellite images presents limitations in object identification, due to the restricted resolution and high volume of information to be processed (Wang; Zhao; Petzold, 2024).

In the continental fish farms observed, the slopes that separate the tanks can reach up to 2 meters wide, which makes it difficult to detect them in images with a spatial resolution higher than this value. On the other hand, in areas of large agricultural crops, analyzed from medium resolution images, such as those of Sentinel-2 and Landsat-8, with pixels of about 10 meters, the results have been satisfactory (SUN et al., 2024). In addition, the boundaries formed by the slopes of the nurseries create well-defined edges, which favors the identification of objects related to aquaculture (He et al., 2024).

It should be noted that studies carried out with 4.77 m resolution images, pixel-oriented and based on spectral indices, applied on a large scale and with rapid execution, demonstrated potential for the extraction of aquaculture ponds in inland continental areas (Silva et al., 2024). This approach, based on the analysis of the form, proved to be very promising.

The values of IoU (0.50) and F1-Score (0.66) obtained in this study demonstrate performance compatible with the state of the art in detecting water bodies from low resolution satellite images, considering that benchmarks reported in the literature have metrics close to 0,47 and 0.62, respectively (Wang; Zhao; Petzold, 2024).

Therefore, there is a slight superiority of the approach described here, especially in the F1-Score, which shows better balance between precision and recall. This proximity to the reference results reinforces the robustness of the proposed methodology and highlights the complexity inherent in the segmentation of water bodies, whose irregular morphology contrasts with the more standardized configuration of fish farming tanks.

In the identification of offshore structures for aquaculture, an F1-Score of 0.50 was observed (Dong et al., 2024). This result, although lower than that obtained for continental water bodies, indicates the potential of the approach even in scenarios of greater complexity.

On the other hand, studies conducted with higher spatial resolution images, such as those of Landsat 8 OLI and very high resolution sensors, demonstrate that it is possible to achieve significantly higher metrics, reaching IoU and F1-Score values of 94.91 and 96.97, respectively (Ozdemir et al., 2024). These results show the direct impact of image resolution on the accuracy of detection and point out promising ways to improve the methodology proposed here, especially through the use of more advanced sensors and complementary pre-processing techniques.

CONCLUSION

The present study demonstrated the applicability of the Segment Anything Model (SAM), integrated to SamGeo, in the identification of fish farms in the municipality of Conceição do Araguaia (PA), using CBERS images of 2 meters of spatial resolution. The results showed that, although automatic segmentation presented limitations in the detection of smaller structures and areas with narrow slopes, the overall performance of the model was consistent, reaching IoU values of 0.50 and F1-Score of 0.66, compatible with benchmarks reported in the literature.

The comparison between the analyzed areas indicated that the methodology is more effective in cuttings where the tanks have regular and well-defined shapes, reducing discrepancies compared to manual survey. In addition, the proximity of the results obtained with the state of the art reinforces the robustness of the natural language prompts-based approach, highlighting its potential as an innovative tool for geospatial applications.

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Thus, it is concluded that the integration between CBERS images and advanced segmentation models based on artificial intelligence represents a relevant methodological advance for the monitoring of continental aquaculture. However, improvements related to image resolution and calibration of model parameters are essential to increase precision, consolidating this approach as a strategic tool for the management and planning of the aquaculture sector in Brazil.

DATA AVAILABILITY

Not applicable.

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Author's Affiliation

Catuxo, V.T.S. - Federal University of Pará, Castanhal (PA), Brazil.
Ramos, J.F. - Federal University of Pará, Castanhal (PA), Brazil.
Barros, F.A.L - Federal University of Pará, Castanhal (PA), Brazil.
Cordeiro, C.A.M. - Professor at Federal University of Pará, Bragança (PA), Brazil.

Authors' Contribution

Catuxo, V.T.S. - The author contributed to the elaboration, realization and manipulation of the data and writing
Ramos, J.F. - The author contributed to the elaboration, realization and manipulation of the data.
Barros, F.A.L - The author contributed to the elaboration, realization and manipulation of the data and writing
Cordeiro, C.A.M. - The author contributed to the elaboration, realization and manipulation of the data and writing

Editors in Charge

Alexandra Maria Oliveira
Alexandre Queiroz Pereira
Eduardo Von Dentz