Application of geophysical tools for evaluation of adequate ponds for Aquaculture

Introduction

Aquaculture is a process of controlled culture of freshwater or saltwater organisms and one of the most developed activities in the world (Calixto et al., 2020). Appropriate site selection is the first step important for the success and sustainability of any aquaculture development (Hadipour et al., 2014).

Adisukresno (1982), Hechanova (1982) and Jamandre and Rabanal (1975) defined the principal guidelines for the selection of a suitable site for coastal fish ponds: (i) soil quality; (ii) topography and tidal characteristics; (iii) vegetation; (iv) water supply and quality; (v) accessibility and (vi) availability of manpower for construction and operation. Extensive ponds are considered to be the most cost-effective option for traditional, semi-intensive freshwater fish farming operations, although the success of this approach will depend on the quality of the soil. Soils must be impervious (> 20% clay) to ensure a minimal loss of water through seepage, and clay or clay-loam soils are ideal (Basudha et al., 2019).

Geophysics provides important data on the subsurface of a site, including its lithology, stratigraphy, the detection of its water table, depth of the bedrock, the presence of depressions, the identification of faults, fractures, and other potentially important geological features (Souza and Gandolfo, 2018).

Pena and Oliva (2019) obtained satisfactory results using Ground Penetrating Radar (GPR) and Electromagnetic (EM34-3) geophysical tools to evaluate and compare sites earmarked for aquaculture installations in the municipalities of Bragança and Tracuateua, in the Brazilian state of Pará.

The present study employed geophysical tools (GPR and EM34-3) supported by Unmanned Aerial Vehicles (UAVs) to collect data on a terrain in the aquaculture production zone of Montenegro, in the municipality of Bragança. Given the paucity of data of this type, the study aimed to provide essential data on the adequacy of local terrains for the excavation of fish-rearing ponds for the development of future aquaculture installations in the region.

Material and methods

Study area

The study area is located in aquaculture production zone number 3 in the district of Montenegro (Figure 1), in the municipality of Bragança, in the northeastern extreme of the Brazilian state of Pará. The fish farm selected for the present study was an existing installation located on a smallholding (1º19'24.37" S, 46º50’57.81” W), which was undergoing expansion, with the excavation of a new pond, at the time of the study.

Data acquisition

The data were collected using a GSSI SIR 3000 Ground-Penetrating Radar (GPR), with 200 MHz and 400 MHz antennas, and time windows of 100 ns and 300 ns, respectively. Three profiles were surveyed at this site, with pulses being marked at 5-m intervals (Figure 1). The EM data were obtained using a Geonic Ltd. electrical conductivity meter (EM34-3). The apparent conductivity data was measured in mSm/m. As the existing ponds at the study site are 1–2 m in depth, thus, according to McNeill (1980), we prioritized in the interpretation of the results only the measurements collected with the coils of the Horizontal Dipole (HD) for the spacing between the coils for the 10 m cable because its depth of investigation is approximately 7.5 m. We also considered the same directions of the GPR profiles surveyed.
Results and Discussion

Profile L1 of the fish farm located on the smallholding (Figure 2) identified a chaotic zone between the starting point and the 80 m mark, in which reflectors in the form of hyperboles of energy dispersal may represent the presence of underground pipes or tubes that are part of the installation of the fish ponds, and the presence of small faults along almost the whole of the profile. During the survey, an electric fence, approximately 140 m in length was observed on the surface near the profile. A strong horizontal reflector was detected at a depth of 4.48–4.62 m.

A chaotic zone was also detected in profile L2 (Figure 3), which was approximately perpendicular to profile 1. This zone was located between the 40 and 160 m marks in which the hyperbole of energy dispersal and small faults were detected. As in the previous profile, a strong horizontal reflector was detected at a depth of 4.48–4.62 m.

In profile 3 (Figure 4), which is almost perpendicular to profile L2 (Figure 3), a 35-m long depression was detected, with a depth of 2.8 m. Hyperboles of energy dispersal were also detected, which may be associated with the presence of underground pipes or tubes associated with the installation of the fish ponds. The intrusion of a rocky body was detected between the 46 m and 50 m marks of the survey, which reached the layers near the surface, and may have caused faults in these layers. A strong horizontal reflector was also recorded at the same depth as the previous profiles.
Figure 3 Profile L2, with a 250 ns time window and a 200 MHz antenna. Dry season (October 2020).

Figure 4 Profile L3, with a time window of 200 ns and a 200 MHz antenna. Dry season (October 2020).

Figure 5 Pseudo-Sections of apparent conductivity: profiles L1 (A) and L2 (B) surveyed during the rainy season (March 2021).

The pseudo-sections of apparent conductivity for each survey are shown below, in Figures 5. The profile L3 was not performed due to the construction of a new electric fence. Three distinct areas of intense anomaly can be observed in the pseudo-section of profile 1 (Figure 5A), one between the 1st and 14th stations (dark red), the second between the 15th and 18th stations (dark red), and a third between the 21st and the 39th stations (red, dark red and orange). Three areas of intense anomaly were also found in profile 2 (Figure 5B), which are numbered 1–3 in the plot. Area 1 was observed at stations 5–11 and 17–29, with tones of red and orange in the central portion. Area 2, between stations 19–21 and 22–29, appears in dark red, while area 3 appears throughout the profile in relatively dark red. The apparent conductivity ranged from 1030-1523 mS/m in profile 1, and 900-1430 mS/m in profile 2. These conductivity values (according to the color scale) were recorded theoretically at a depth of 7.5 m, and
indicates the possible presence of soils derived from sandstone or with a high clay content (Davis and Annan, 1989). The results of the present study indicate that the soils at the site present adequate conditions for the implantation of aquaculture ponds. This confirms the adequacy of the existing ponds and the ongoing construction work, initiated in November 2020, for the implantation of a new pond.

Conclusions

At the fish farm in the aquaculture zone of Montenegro in the municipality of Bragança, Pará (Brazil), Ground Penetrating Radar identified a chaotic zone throughout much of the profiles surveyed, with the presence of reflectors in the form of hyperboles of energy dispersal that may be associated with the tubes and pipes used in the aquaculture installations and the presence of small faults throughout most of the profile. A strong horizontal reflector was detected at a depth of between 4.48 m and 4.62 m. At the site of the new pond, the presence of a 35-m long depression was identified, at a depth of 2.8 m. The intrusion of a rocky body was also detected at this site, reaching the layers near the surface, and causing faults in these layers.

The measurements of apparent conductivity obtained from the study site permitted the identification of soils with clayey and/or sandstone characteristics. Given this, it was important to have evaluated the terrain during the rainy season, given that the geophysical tools identified the terrain as being predominantly clayey (that is, soils with good plasticity, low permeability, low density, and high-water retention capacity), which is consistent with the recommendations of Basudha et al. (2019) for the implantation of aquaculture ponds.

Overall, the results of the geophysical prospecting conducted during the present study, together with the analysis of the existing excavations, confirmed the adequacy of the terrain for the implantation of new ponds. The study also confirmed the good performance of the geophysical tools as a method for the characterization of terrains destined for aquaculture installations.

References


Google Earth [2018] <https://www.google.com/earth/>


