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Sustainable Seridó: Integrated Assessment of Water, Soil, and Vegetation Using the GLOBE/NASA Program

Salma Sophia Felix dos Santos
Escola Estadual Professora Calpúrnia Caldas de Amorim - EECCAM
Rua Manoel Gonçalves de Melo, 42; Caicó-RN
salmasophiasantos@gmail.com

Fernanda Sofia Soares Santos
Escola Estadual Professora Calpúrnia Caldas de Amorim - EECCAM
Rua Manoel Gonçalves de Melo, 42; Caicó-RN
fernandasofia193@gmail.com

Emilly Talita da Silva Xavier
Escola Estadual Professora Calpúrnia Caldas de Amorim - EECCAM
Rua Manoel Gonçalves de Melo, 42; Caicó-RN
emillyinfojimin@gmail.com

Janniely Lívia dos Santos Medeiros
Escola Estadual Professora Calpúrnia Caldas de Amorim - EECCAM
Rua Manoel Gonçalves de Melo, 42; Caicó-RN
jannielyinfo@gmail.com

Thaynara Mayane Fernandes de Souza
Escola Estadual Professora Calpúrnia Caldas de Amorim - EECCAM
Rua Manoel Gonçalves de Melo, 42; Caicó-RN
Thaynaramayane@gmail.com

Alaine Maria dos Santos Silva
Escola Estadual Professora Calpúrnia Caldas de Amorim - EECCAM
Rua Manoel Gonçalves de Melo, 42; Caicó-RN
alainemss@gmail.com

ABSTRACT

This study investigated the interactions among soil, vegetation, and water resources in semi-arid ecosystems of northeastern Brazil, integrating empirical observation, digital technology, and citizen science. The research was carried out at *Escola Estadual Professora Calpúrnia Caldas de Amorim*, in Caicó-RN, and was based on the application of GLOBE/NASA scientific protocols in the spheres of the pedosphere, biosphere, and hydrosphere. The analyses included physicochemical parameters of water (pH, turbidity, nitrite, and temperature), as well as soil characteristics (texture, moisture, and infiltration) and vegetation attributes (tree height and diameter). Measurements were conducted using Merck pH test strips, a KP AA0008 (Knup) conductivity meter, and a Secchi disk built by the research team, along with the GLOBE Observer app for georeferencing and data submission to the program's international database. Results showed significant differences between areas near the school and the margins of the Barra Nova River, particularly in terms of soil moisture and water turbidity, highlighting the influence of vegetation cover and anthropogenic impacts on environmental quality. The study demonstrates the potential of GLOBE protocols as pedagogical tools for Science Education and for strengthening critical environmental education,

contributing to the development of student protagonism and commitment to sustainability and the Sustainable Development Goals (SDGs 4, 13, and 15).

KEYWORDS. citizen science; science education, GLOBE Observer, semi-arid region, sustainability.

1. RESEARCH QUESTIONS

The contemporary environmental crisis poses to science the challenge of understanding the interrelationships among soil, vegetation, and water, particularly in fragile and vulnerable ecosystems such as those found in Brazil's northeastern semi-arid region. In this context, the present study aims to investigate the interactions between soil properties, vegetation cover, and water quality in the Seridó region of Rio Grande do Norte, Brazil, using the scientific protocols of the GLOBE/NASA Program and the application of the ecofilter as a low-cost ecological technology.

From this perspective, the following research question is proposed: How do soil characteristics and vegetation cover influence water quality in semi-arid ecosystems of Rio Grande do Norte, and how can the use of the ecofilter contribute to improving the physicochemical parameters of this water?

The central problem of this investigation arises from the need to understand how soil management practices and vegetation conservation impact water resources in semi-arid regions, which are often marked by scarcity and environmental degradation. Recent studies highlight that the correlation among these factors is decisive for ecosystem sustainability and for the quality of water available to local populations (Silva & Almeida, 2022; NASA GLOBE, 2024; Brazil, 2021).

The Seridó region of Rio Grande do Norte, characterized by shallow soils, Caatinga vegetation, and an irregular rainfall regime, constitutes a privileged setting for the development of investigative practices that combine scientific education and sustainability. In this context, the use of GLOBE protocols within the hydrosphere, pedosphere, and biosphere domains represents an opportunity to integrate empirical observation with the analysis of real environmental data, fostering an understanding of the Earth as a dynamic and interdependent system.

2. INTRODUCTION AND REVIEW OF LITERATURE

Global environmental transformations and the intensification of climate change have increased the need for research that connects scientific knowledge to the socio-environmental realities of specific territories, particularly in vulnerable regions such as Brazil's semi-arid zone. In this context, water scarcity, soil degradation, and the loss of vegetation cover compromise ecological balance and the well-being of populations that directly depend on these natural resources (Carvalho, 2021; United Nations, 2015).

The Seridó region of Rio Grande do Norte, located in the interior of northeastern Brazil, clearly reflects these challenges, presenting shallow and erosion-prone soils, Caatinga vegetation, and an irregular rainfall regime. This reality demands innovative strategies for environmental monitoring and sustainable management that integrate science, technology, and social participation (Santos & Lima, 2023).

The literature indicates that the interrelationship among soil, vegetation, and water constitutes a central element for the sustainability of semi-arid ecosystems. Soil infiltration and water storage capacity, combined with vegetation cover, directly influence hydrological processes and the physicochemical parameters of water. Degraded soils and vegetation removal tend to intensify surface runoff, erosion, and sedimentation, negatively affecting water quality and aquatic biodiversity (Costa et al., 2020; Brazil, 2021; Oliveira & Nascimento, 2022).

Within this framework, the GLOBE/NASA Program (Global Learning and Observations to Benefit the Environment) stands out as a scientific and educational initiative grounded in the principles of citizen science. Established in 1995, the program promotes the engagement of students, teachers, and communities in the collection and analysis of environmental data through standardized, internationally recognized protocols covering the hydrosphere, pedosphere, and

biosphere (NASA GLOBE, 2024). The application of these protocols enables an integrated assessment of environmental systems, fostering an understanding of the Earth as a dynamic and interdependent system while supporting participatory environmental monitoring.

Complementing this approach, the use of sustainable ecological technologies such as the ecofilter represents a viable strategy for improving water quality in semi-arid regions. Based on natural, low-cost materials, the ecofilter has demonstrated potential to reduce turbidity, sediments, and contaminants, while also serving as an educational and mobilizing tool that promotes rational water use and community autonomy (Silva et al., 2021; Ferreira & Lopes, 2022).

The integration of critical environmental education, citizen science, scientific protocols, and sustainable technologies strengthens social engagement and scientific literacy in the Seridó territory. Aligned with the Sustainable Development Goals of the 2030 Agenda—particularly SDG 6 (Clean Water and Sanitation), SDG 13 (Climate Action), and SDG 15 (Life on Land)—this research reaffirms the role of applied science and educational institutions as agents of socio-environmental transformation in addressing the challenges of semi-arid regions.

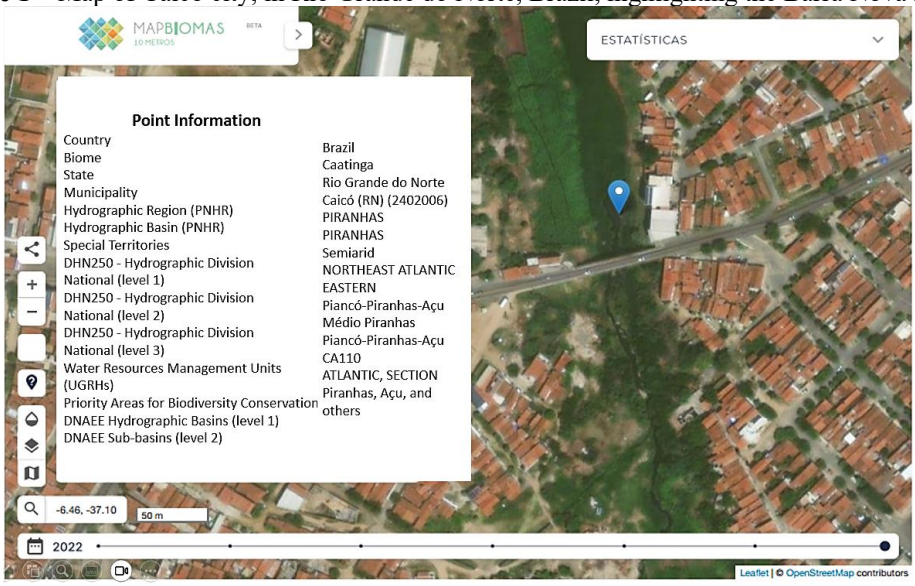
3. RESEACH METHOS

The present study is characterized as applied research of a qualitative nature with an exploratory–descriptive approach, grounded in the principles of scientific education and participatory citizen science.

3.1 Study Area

The study was conducted with high school students from the Escola Estadual Professora Calpúrnia Caldas de Amorim, located in the municipality of Caicó, Rio Grande do Norte (Figure 1), within the Seridó region. The adopted methodology combined empirical observation, the use of digital technologies, and scientific experimentation, integrating environmental protocols from the GLOBE/NASA Program with pedagogical modeling practices using three-dimensional scale models, with an emphasis on the investigation and representation of local environmental phenomena.

Figure 1 – Map of Caicó city, in Rio Grande do Norte, Brazil, highlighting the Barra Nova River.



Source: https://plataforma.brasil.mapbiomas.org/agua/caico

The research was carried out in the surroundings of the Barra Nova River, an area adjacent to the school and considered of ecological relevance to the municipality of Caicó. This region is characterized by a semi-arid climate, high average annual temperatures, and water scarcity—conditions that directly influence infiltration processes, evaporation rates, and surface water quality.

The central objective of the research was to evaluate the influence of environmental variables—such as soil type, vegetation cover, and atmospheric conditions—on water quality, as well as to test the efficiency of an ecological ecofilter proposed as a low-cost sustainable technology for water purification and the promotion of environmental education among students.

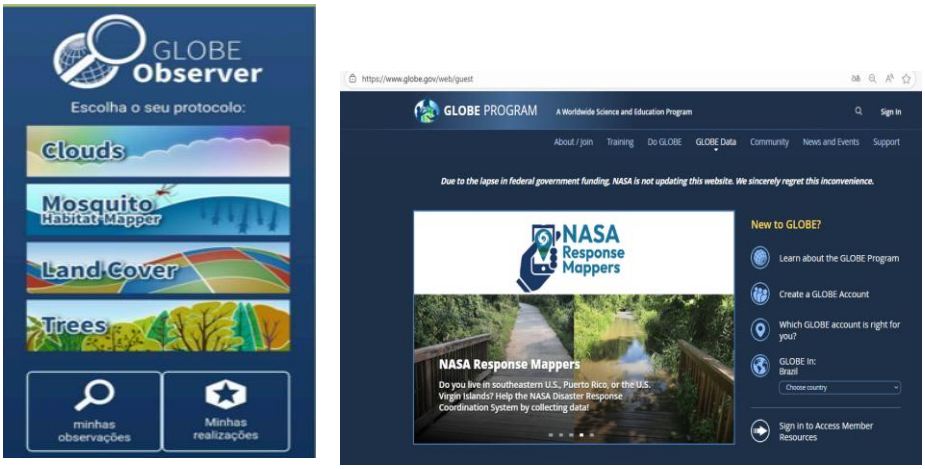
3.2 Environmental Data Collection Using GLOBE Protocols and the GLOBE Observer Application

The methodology combined empirical observation, digital technology, and scientific modeling through three-dimensional scale models, integrating investigative practices into the teaching–learning process. The study involved high school students, including students from special education programs, in order to promote an inclusive and participatory approach to understanding local environmental phenomena.

Activities were developed based on the official protocols of the GLOBE/NASA Program, encompassing different components of the Earth system. Within the atmosphere protocol, cloud observation and classification by type and coverage were conducted using the GLOBE Observer – Clouds application. Regarding the pedosphere, analyses of soil texture, color, moisture, and infiltration were performed in the school surroundings. In the biosphere domain, activities focused on measuring tree height and diameter to estimate local biodiversity. Finally, within the hydrosphere domain, physicochemical water quality parameters were collected and measured, including pH, conductivity, turbidity, nitrite, and temperature.

Figure 2 presents the home screen of the GLOBE Observer application and the GLOBE Program webpage, respectively.

Figure 2. Representation of the GLOBE Observer application home screen and the GLOBE Program webpage.



Source: research data (2025).

All collected data were recorded in the GLOBE Observer application and subsequently exported for statistical analysis. Turbidity, pH, conductivity, nitrates, and microbiological load were considered dependent variables, while filter composition and local environmental conditions were treated as independent variables.

3.3 Construction and Application of the Experimental Ecofilter

The experimental ecofilter was developed based on principles of sustainability, accessibility, and material reuse, aiming to integrate low cost, functional efficiency, and environmental responsibility. The main structure was constructed from a 1.5-liter PET bottle, and the filtering layers consisted of a metal sieve, gauze, and cotton, responsible for retaining fine particles and solid impurities. Activated carbon and dehydrated coconut husk were used as active filtering media, due to their recognized capacity for adsorbing organic and inorganic compounds. The ecofilter prototype is illustrated in Figure 3.

Figure 3. Representation of the ecofilter prototype.

Source: research data (2025).

Water samples were initially collected from the Barra Nova River in Caicó and subsequently expanded to other water bodies in the Seridó region in order to assess the reproducibility and applicability of the system under different environmental conditions. Unfiltered samples were used as experimental controls, enabling direct comparison with treated samples.

3.4 Physicochemical and Microbiological Analyses

The following physicochemical and microbiological analyses were performed to evaluate water quality before and after application of the ecofilter.

3.4.1 Physicochemical Parameters

Physicochemical analyses included the determination of pH, electrical conductivity, turbidity, temperature, and nitrates, in accordance with the Hydrosphere protocols of the GLOBE/NASA Program, ensuring standardization and international comparability of the data.

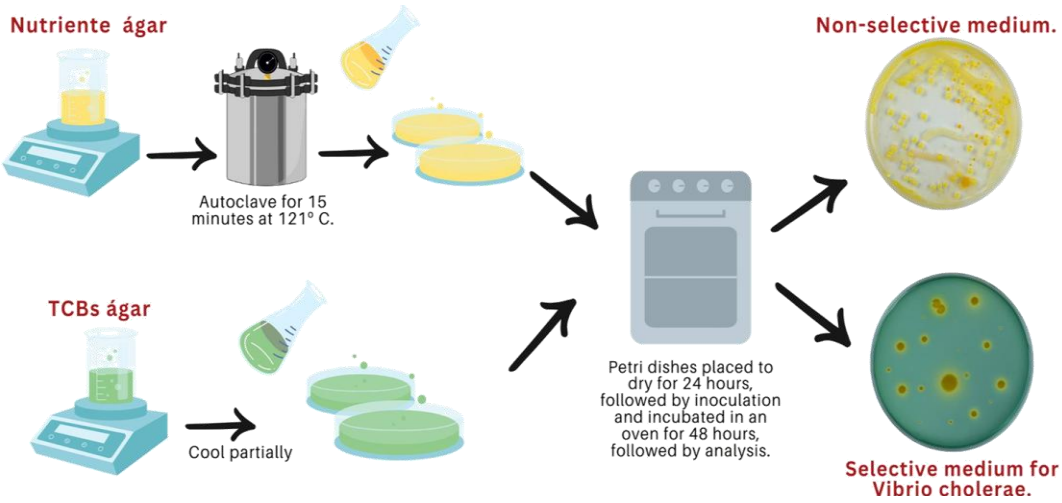
For water quality monitoring, a KP AA0008 electrical conductivity meter (Knup), Merck pH strips, and a Secchi disk were used to assess turbidity. The integrated evaluation of water quality was conducted using the Water Quality Index (WQI), adapted from House (1989) and Cymes & Glińska-Lewczuk (2016), with the aim of quantifying the impact of the filtration process on the evaluated environmental parameters.

3.4.2 Microbiological Assays

Microbiological analyses were carried out using Nutrient Agar and TCBS Agar (Thiosulfate-Citrate-Bile Salts-Sucrose Agar) (Himedia) to identify total coliforms, thermotolerant coliforms, and Vibrio species, which are recognized indicators of fecal contamination and organic pollution. Culture media were prepared according to the manufacturer's specifications, sterilized, and inoculated with water samples collected before and after filtration, followed by incubation at 37 °C for 48 hours (Figure 4).

After the incubation period, formed colonies were visually quantified and compared between control and filtered groups, allowing evaluation of the microbiological efficiency of the ecofilter and correlation of the results with the physicochemical variables of the water.

Figure 4. Schematic representation of the preparation of Nutrient Agar and TCBS Agar culture media.



Source: authors' elaboration (2025).

3.5 Data Integration and Analysis

Data obtained through the GLOBE Observer application were integrated with physicochemical, microbiological, and Water Quality Index (WQI) results, enabling a comprehensive analysis of the factors influencing water quality. This integration allowed for the assessment of the influence of environmental variables—such as soil, vegetation, and atmosphere—on water conditions, the determination of ecofilter efficiency in reducing turbidity, electrical conductivity, and microbiological load, and the identification of regional environmental patterns associated with water sustainability in semi-arid ecosystems.

Statistical analysis was performed based on measures of central tendency, dispersion, and correlation ($p \geq 0.05$), ensuring the robustness and experimental reliability of the obtained results.

The adopted methodology articulated citizen science, environmental education, and sustainable technology, favoring its replicability in different school and community contexts. The integration of GLOBE/NASA protocols and the GLOBE Observer application with the development of a low-cost ecological ecofilter constitutes a methodological innovation aimed at participatory diagnosis and mitigation of water pollution in semi-arid regions, with potential for expansion to other rivers, reservoirs, and water bodies in the Seridó region.

4. RESULTS

4.1 Atmospheric Observations (Cloud Protocol)

Observations conducted using the *GLOBE Observer – Clouds* application provided detailed data on cloud types, land cover, and soil characteristics in the sampling areas along the Barra Nova River, in Caicó, Rio Grande do Norte, Brazil (NASA, 2023). Images captured in multiple directions revealed a predominance of cumulus clouds (38%) and cirrus clouds (27%), with occasional occurrences of stratocumulus (21%) and nimbostratus (8%). Days with no significant cloud cover accounted for 6% of the observations (Table 1).

Table 1. *Frequency of observed cloud types (n = 12 days)*

Cloud type	Frequency (%)
Cumulus	38
Cirrus	27
Stratocumulus	21
Nimbostratus	8
No cloud cover	6

Source: GLOBE Observer App data collected by the researchers (2025).

Cumulus and cirrus clouds were predominantly observed during periods of higher solar radiation and lower relative humidity, whereas stratocumulus and nimbostratus clouds occurred mainly during thermal transition days associated with increased atmospheric moisture.

4.2 Pedosphere (Soil Analysis)

Soil samples were collected from two distinct environments: the school surroundings and the margins of the Barra Nova River. Analyses followed the physical and chemical characterization parameters established by the GLOBE/NASA Pedosphere Protocol.

The results indicated predominantly sandy to sandy-loam textures, slightly acidic pH values, and low water retention in the more exposed areas. In contrast, soils collected along the riverbanks showed darker coloration, higher moisture content, and improved infiltration rates, likely influenced by denser vegetation cover.

Table 2. *Average soil parameters analyzed*

Sampling site	Dominant texture	Moisture (%)	Infiltration (mL/min)	pH
School surroundings	Sandy	7.2	8.5	6.4
Barra Nova River margin	Sandy-loam	11.5	6.2	6.7

Source: Research data (2025).

4.3 Biosphere (Tree Measurements)

Within the Biosphere Protocol, height and diameter at breast height (DBH) measurements were performed on ten trees located in the school surroundings using measuring tape and the *GLOBE Observer* application (NASA, 2023). The identified species included *Ziziphus joazeiro*, *Prosopis juliflora*, and *Spondias tuberosa*, all characteristic of the Caatinga biome.

The results indicated an average tree height of 4.8 m and an average DBH of 0.23 m, values consistent with medium-sized, drought-resilient species typical of semi-arid environments.

4.4 Hydrosphere (Water Collection and Analysis)

Water samples were collected from three sources: distilled water, unfiltered river water, and filtered river water. The physicochemical parameters analyzed included pH, turbidity, electrical conductivity, nitrite concentration, and temperature, following official GLOBE Hydrosphere Protocols.

Before filtration, river water samples showed elevated turbidity, electrical conductivity above recommended levels, detectable nitrite concentrations, and slightly acidic pH values. After ecofilter application, significant reductions in turbidity, conductivity, and nitrite levels were observed, along with partial pH neutralization (Table 3).

Table 3. *Physicochemical characterization of Barra Nova River water before and after filtration*

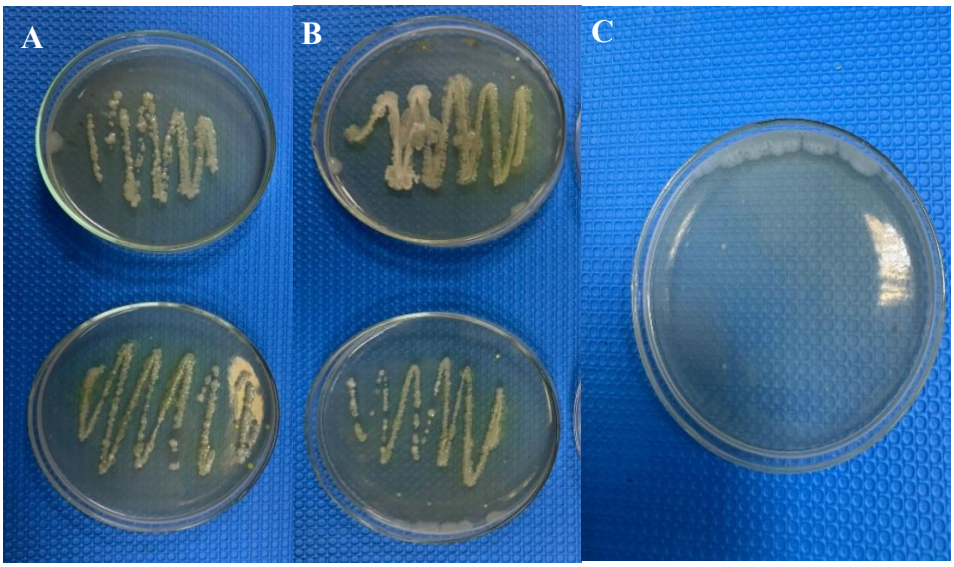
Parameter	Distilled water	River water (unfiltered)	River water (filtered)
Temperature (°C)	23.0 ± 0.09	24.0 ± 0.07	24.0 ± 0.06
Transparency	Transparent	Turbid	Translucent
pH	6.5 ± 0.2	5.5 ± 0.2	6.0 ± 0.2
Electrical conductivity (µS/cm)	0.264 ± 0.02	0.345 ± 0.20	0.219 ± 0.03
Nitrite (mg/L)	Absent	0.12 ± 0.01	0.03 ± 0.01

Source: Research data (2025).

4.5 Microbiological Analysis

Microbiological analyses were performed in duplicate using Nutrient Agar and TCBS Agar. On Nutrient Agar, similar microbial growth was observed in filtered and unfiltered samples. This result is shown in Figure 5.

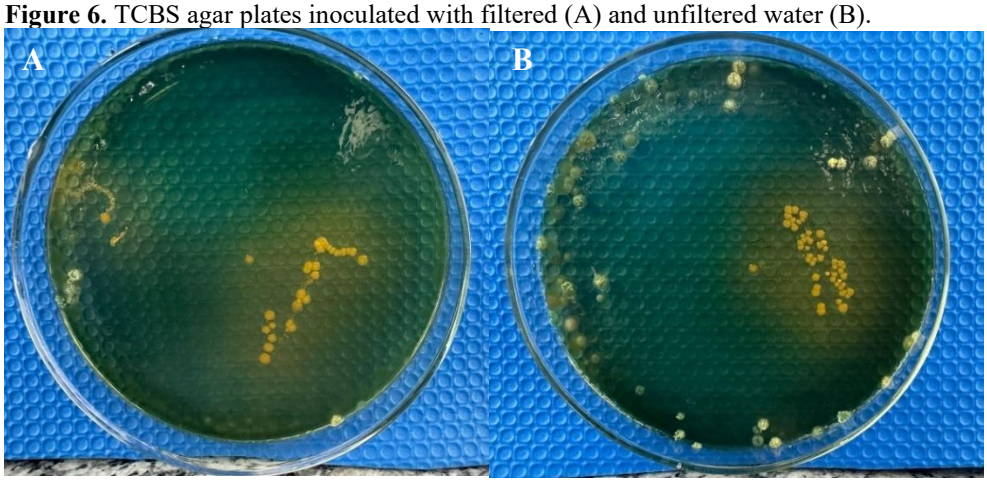
Figure 5. Nutrient agar plates inoculated with filtered river water (A), unfiltered water (B), and the control plate (C).



Source: Author's own data

The TCBS Agar test, used to detect pathogenic microorganisms, revealed that the filtered water had fewer bacterial colonies, particularly the yellow colonies characteristic of *Vibrio cholerae*, a pathogen associated with fecal contamination. This result is illustrated in Figure 6. The unfiltered water plates, however, showed both yellow and whitish colonies, suggesting the presence of additional pathogenic microorganisms, such as other *Vibrio* species or *Escherichia coli*.

Figure 6. TCBS agar plates inoculated with filtered (A) and unfiltered water (B).



Source: Author's own data

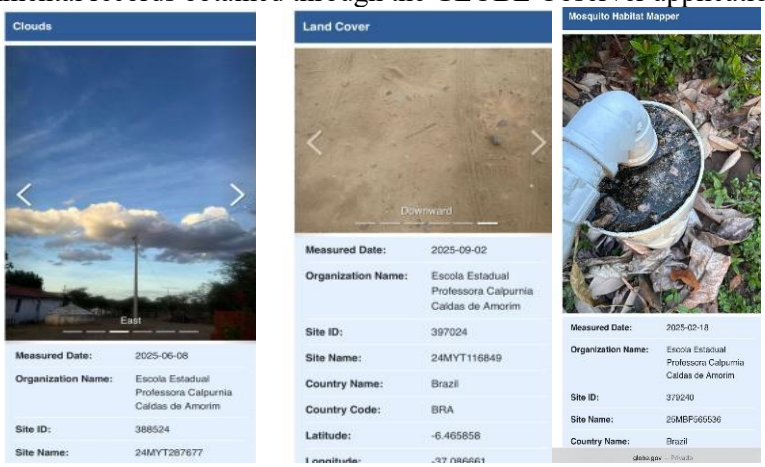
However, TCBS Agar analyses revealed a reduction in colonies suggestive of *Vibrio cholerae* in filtered samples, while unfiltered samples showed a higher diversity of potentially pathogenic colonies.

4.6 Integration of Environmental Data via GLOBE Observer

The data recorded through the GLOBE Observer application were integrated into NASA's global platform and are monitored in Brazil by the Brazilian Space Agency (AEB), demonstrating

how local citizen science contributes to international databases and continuous environmental monitoring.

Figure 6. Environmental records obtained through the GLOBE Observer application**.**



Source: Research data (2025).

These records are particularly relevant because satellite remote sensing does not always capture small-scale local variations in soil, vegetation, and cloud cover with sufficient accuracy, making the use of the application essential for complementing environmental monitoring data. The collected information allows the correlation of environmental characteristics with the physicochemical parameters of water, demonstrating the direct influence of environmental conditions on water quality (Tozzi, 2004; Silva & Moura, 2019).

Overall, the correlation between environmental data collected via GLOBE Observer and the physicochemical and microbiological results showed that areas with greater vegetation cover and more permeable soils exhibited better water quality indicators. These findings reinforce the hypothesis that environmental variables directly influence water quality and the efficiency of water treatment processes.

5. DISCUSSION

The predominance of cumulus and cirrus clouds reflects the typical atmospheric behavior of the semi-arid climate of the Seridó region, characterized by high solar radiation, low relative humidity, and marked thermal amplitudes (World Meteorological Organization [WMO], 2017; Medeiros et al., 2019). These atmospheric conditions directly influence evapotranspiration rates and local hydrological dynamics.

Soil analyses demonstrated the influence of vegetation cover on moisture retention and infiltration capacity. Sandy and sandy-loam textures with low organic matter content were associated with reduced water retention, consistent with findings reported for semi-arid soils (Silva & Nóbrega, 2020). In contrast, riverbank soils exhibited improved physical properties, highlighting the role of riparian vegetation in soil conservation.

The biosphere data corroborate previous studies indicating that Caatinga species exhibit adaptive traits that promote resilience to water stress and contribute to soil stability and microclimatic regulation (Almeida et al., 2019; Medeiros et al., 2019).

Regarding water quality, the ecofilter proved effective in improving key physicochemical parameters, particularly turbidity, conductivity, and nitrite concentration. The reduction in nitrite levels is especially relevant due to its potential risks to human health and aquatic biota (Brasil, 2017). Although the ecofilter did not completely eliminate microbial presence, the observed reduction of Vibrio-like colonies represents a meaningful improvement in sanitary safety, consistent with previous studies (Tille, 2017; Tropea, 2022).

The integration of atmospheric, pedospheric, biospheric, and hydrospheric data reinforces the interconnectedness of environmental systems. Areas with greater vegetation cover and higher soil permeability exhibited better water quality indicators, supporting the hypothesis that

environmental variables directly influence water treatment efficiency. Additionally, the use of three-dimensional educational models facilitated environmental understanding and engagement, particularly among students involved in citizen science activities.

6. CONCLUSION

This study demonstrated that the integration of citizen science, environmental education, and low-cost sustainable technology constitutes an effective approach for investigating and improving water quality in semi-arid regions. The combined use of GLOBE/NASA protocols, the GLOBE Observer application, and hands-on experimental activities enabled a comprehensive analysis of atmospheric, soil, biological, and hydrological variables and their influence on local water systems.

The results indicate that environmental factors such as soil texture, vegetation cover, and atmospheric conditions directly affect water quality parameters, particularly turbidity, electrical conductivity, and nitrogen compounds. The experimental ecofilter proved to be an accessible and efficient tool for improving key physicochemical parameters of surface water, with partial effectiveness in reducing microbiological contamination. Although the ecofilter does not ensure full potability, its performance highlights its potential as an educational and preventive technology for water quality improvement in vulnerable contexts.

Beyond the technical outcomes, the study reinforces the pedagogical value of inquiry-based learnin and participatory science. The involvement of high school students—including students with special educational needs—promoted scientific literacy, environmental awareness, and active engagement with local socio-environmental challenges. The use of three-dimensional models and real environmental data facilitated meaningful learning and strengthened students' connection to their territory.

Overall, the methodological approach presented here is replicable, scalable, and adaptable to different school and community settings, particularly in semi-arid and resource-limited regions. By integrating education, sustainability, and citizen science, this research contributes to environmental monitoring, water resource management, and the promotion of responsible practices aligned with global sustainability goals. Future studies should explore long-term monitoring, optimization of filter materials, and the integration of complementary disinfection methods to enhance microbiological safety.

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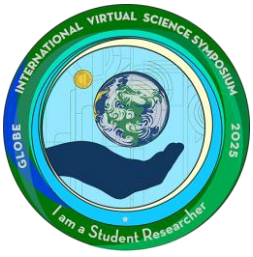
8. OPTIONAL BADGES FOR SCIENTIST SKILLS

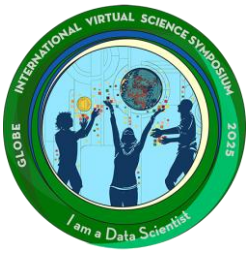
I AM A STUDENT RESEARCHER



In the context of this project, a study was conducted on water quality in the Barra Nova River, with the development of an ecofilter and the application of GLOBE protocols for data collection and monitoring. The involvement in this scientific investigation process justifies the receipt of this badge.

I AM A DATA SCIENTIST

The project involved the collection and analysis of water quality data, utilizing GLOBE protocols, such as the Hydrosphere protocol. Water samples were collected before and after filtration to analyze physicochemical parameters (pH, conductivity, turbidity, etc.) and microbiological parameters (such as the presence of *Vibrio cholerae*). The use of scientific data, conducting calculations, and interpreting results to answer the research questions justify earning this badge.



I AM AN EARTH SYSTEM SCIENTIST

This badge is relevant due to the analysis of the interconnectedness of Earth's systems, including the hydrosphere and biosphere, in the context of water pollution in the Barra Nova River and its impact on public health. GLOBE protocols were applied to monitor essential parameters for ecological balance, such as pH and turbidity, and the impact of sustainable solutions (such as the ecofilter) on environmental improvement was discussed. The application of GLOBE protocols and understanding the interactions between ecological systems supports the relevance of this badge.

I AM A PROBLEM SOLVER

This badge is fitting because the project aims to solve the water pollution problem in the Barra Nova River. An ecofilter was developed using sustainable materials like activated charcoal and coconut shell, with the goal of improving water quality, reducing waterborne diseases, and benefiting public health. The focus on applying practical, accessible solutions to real environmental problems justifies the award of this badge.

I AM A COLLABORATOR

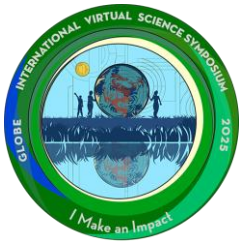
Through effective teamwork and mutual cooperation, the project was successfully executed, with each participant playing an integral role in ensuring the quality and depth of the research. Every team member brought a unique set of skills and strengths, which collectively contributed to the overall success of the work. The collaborative environment fostered the sharing of ideas and experiences, enhancing the learning process and the impact of the research.

- **Salma Sophia Felix dos Santos**: led the research on the theoretical framework and contributed to the environmental awareness section.
- **Fernanda Sofia Soares Santos**: contributed to the development and construction of the ecofilter, focusing on the integration of sustainable materials.
- **Emilly Talita da Silva Xavier**: worked on the data collection and analysis of water quality parameters using GLOBE protocols.
- **Janniely Lívia dos Santos Medeiros**: assisted in gathering water samples and conducted microbiological analysis.
- **Thaynara Mayane Fernandes de Souza**: contributed to the preparation of educational materials and the dissemination of findings to the local community.
- **Alaine Maria dos Santos Silva**: coordinated the overall project logistics, ensuring smooth communication and collaboration between all team members.

In this project, each participant demonstrated effective collaboration and played a crucial role in the development, data collection, and analysis processes, ultimately contributing to the successful outcome of the research and community involvement

I MAKE AN IMPACT

This badge is granted to projects that make a direct impact on communities. The project had a positive impact on the local community by improving water quality, reducing water-related diseases, and promoting sustainable practices through the implementation of the ecofilter. Additionally, conducting workshops and creating educational materials increased awareness about environmental conservation, reinforcing the positive impact of the project on the community.



I AM AN ENGINEER

This badge is appropriate due to the application of engineering principles in the development of the ecofilter. The use of sustainable materials such as activated charcoal and coconut shell to create a functional and low-cost filtration system reflects the application of engineering knowledge. The optimization of the ecofilter design to address the water pollution problem in the Barra Nova River characterizes the awarding of this badge.