

Studying the wastewater treatment efficiency and carbon sequestration capabilities of duckweed and water hyacinth.

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Abstract

This research aimed to comparatively investigate the efficiency of pig farm wastewater treatment and the carbon sequestration capacity of aquatic plants in the family Lemnaceae, namely *Wolffia* spp. (watermeal) and *Lemna perpusilla* (small duckweed). The experiment was conducted over a 28-day period under experimental conditions that varied wastewater concentrations (0%, 20%, and 40%) and planting ratios (1:1, 0:1, and 1:0). Data analysis followed the standard methodologies of the GLOBE Program (GLOBE Protocols), covering both Hydrosphere and Biosphere investigations. The results indicated that both aquatic plant species significantly improved wastewater quality, particularly by increasing dissolved oxygen (DO) levels and stabilizing pH toward neutrality. *Lemna perpusilla* demonstrated the highest efficiency in restoring DO levels in 20% wastewater, achieving an increase of up to 797%, whereas *Wolffia* spp. showed greater tolerance to pollution under critical conditions (40% wastewater). In terms of carbon sequestration, *Wolffia* spp. grown in 20% wastewater exhibited the highest potential as a carbon sink, storing up to 1.975 grams of carbon per experimental unit in the form of biomass. In conclusion, small aquatic plants such as *Wolffia* spp. and *Lemna perpusilla* possess high potential for livestock wastewater treatment.

Keywords: *Wolffia*, *Lemna perpusilla*, pig farm wastewater treatment, carbon sequestration, dissolved oxygen

Research Questions

1. Do *Wolffia* spp. and *Lemna perpusilla* differ in their ability to treat pig farm wastewater, and if so, how?
2. Do *Wolffia* spp. and *Lemna perpusilla* differ in their carbon sequestration capacity, and if so, how?

Hypotheses

1. *Wolffia* spp. and *Lemna perpusilla* differ in their ability to treat pig farm wastewater.
2. *Wolffia* spp. and *Lemna perpusilla* differ in their carbon sequestration capacity.

Introduction

The current environmental crisis is driven by two major factors: the widespread discharge of water pollution from industrial agriculture and the increasing concentration of greenhouse gases in the atmosphere. Pig farm wastewater is a significant source of pollution, rich in nitrogen and phosphorus compounds that accelerate eutrophication, severely disrupting the balance of aquatic ecosystems (Hydrosphere). Consequently, the search for highly efficient and environmentally friendly nature-based solutions has become a major focus of contemporary research.

Among these solutions, small aquatic plants such as watermeal (*Wolffia* spp.) and duckweed (*Lemna*) have attracted considerable attention. Conventional wastewater treatment systems, such as mechanical aerators or treatment balloons, are costly and inaccessible to small-scale pig farms. In contrast, plants in the family Lemnaceae possess notable physiological characteristics, including rapid exponential growth and high efficiency in nutrient uptake from wastewater for biomass production. This biological treatment process not only improves wastewater quality but also aligns with carbon sequestration through highly efficient photosynthesis. Therefore, this study integrates standard environmental monitoring methods from the GLOBE Program (GLOBE Protocols) to evaluate the wastewater treatment efficiency and carbon sequestration capacity of *Wolffia* spp. and *Lemna*.

Accordingly, investigating the ability of these aquatic plants to treat pig farm wastewater and sequester carbon presents a practical, low-cost, and environmentally friendly approach. This approach promotes sustainable application, elevates local plant species as valuable resources in the circular economy, and contributes to mitigating global climate change.

Materials

1. NPK Test Kit
2. Universal indicator
3. DO meter
4. Thermometer /Infrared thermometer
5. Hot air oven
6. Plastic basins (27 units)
7. Clean water (86.4 L)
8. Pig farm wastewater (17.6 L)
9. Digital balance (1 unit)

Methods

1. Study Site

7°59'09"N 99°37'51"E



(A)



(B)

2. Water Quality Data Collection

Water quality parameters were measured according to the GLOBE Water Quality Protocol, including surface water temperature, water temperature, pH, and dissolved oxygen (DO), following these steps:

1. Selection of water sampling locations
2. Survey and classification of land use using GLOBE Land Cover Protocol via the GLOBE Observer application
3. Measurement of water quality parameters using appropriate instruments: thermometers for temperature, pH meter for acidity–alkalinity, and DO meter for dissolved oxygen
4. Each parameter was measured three times, averaged, recorded, and submitted to the GLOBE Data Entry system

3. Experimental Design

Research Methodology

This study integrated GLOBE environmental investigation methods into three main components:

1) Experimental Design and Site Definition

A macrocosm simulation system was established using 27 experimental basins. Each basin contained 4 liters of mixed water, with wastewater concentrations set at 0% (control), 20%, and 40%.

For the biosphere component, planting ratios of *Wolffia* spp. and *Lemna perpusilla* were set at 1:1, 0:1, and 1:0, with an initial biomass of 50 grams per basin. All experimental units were placed under partial sunlight to control solar energy and air temperature in accordance with the GLOBE Atmosphere Protocol. The experiment lasted 28 days.

2) Hydrosphere Investigation: Wastewater Treatment Efficiency

Water quality was monitored on a weekly basis in accordance with the GLOBE Water Quality Protocol to evaluate changes in the physicochemical characteristics of the water throughout the experimental period. Key parameters included nutrient status, dissolved oxygen, and acidity–alkalinity balance. Nitrogen concentration was analyzed using standard nutrient test kits to assess nutrient uptake by aquatic plants. Dissolved oxygen (DO) levels were measured with a calibrated DO meter to determine the effects of photosynthetic activity and gas exchange within the water system. In addition, pH values were measured using a universal indicator to monitor changes in water chemistry that could influence both plant growth and wastewater treatment efficiency.

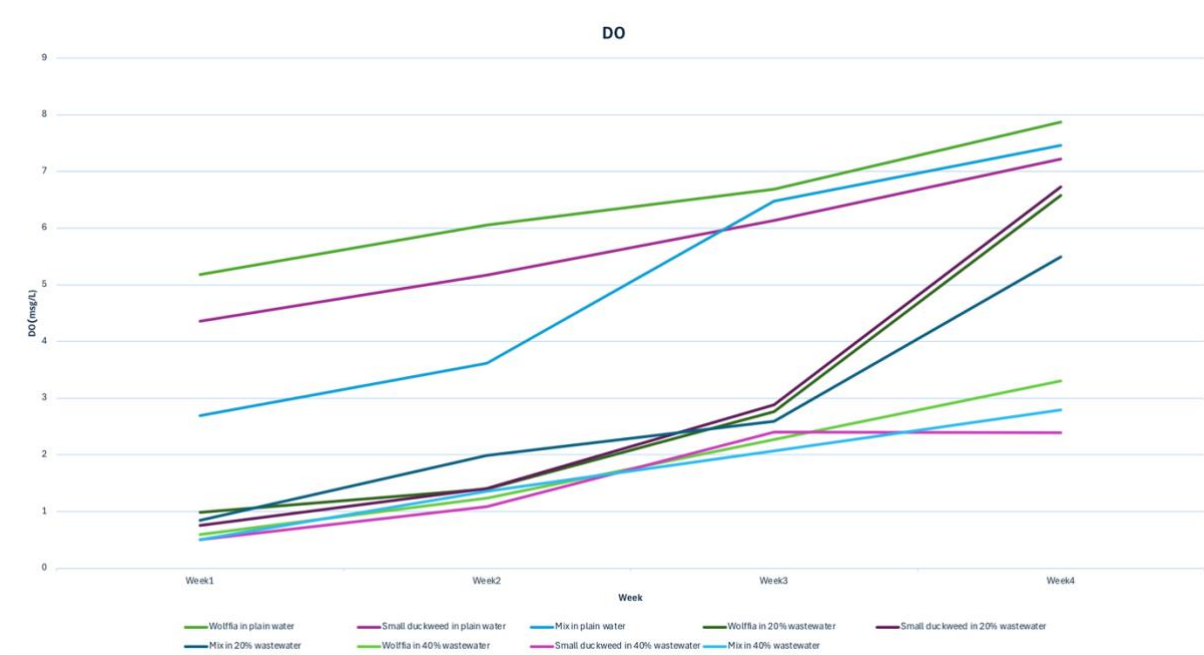
3) Biometry and Carbon Sequestration Analysis

At the end of the 28-day experimental period, biomass production and carbon sequestration were assessed in accordance with the Land Cover/Biology Protocol. Aquatic plants from each experimental unit were harvested and gently blotted dry to remove excess surface water before fresh mass was recorded using a digital balance. The samples were then subjected to a moisture reduction process, beginning with sun-drying for 8 hours followed by oven-drying at 60°C for 24 hours until a constant dry weight was achieved. The resulting dry biomass data were subsequently used to estimate carbon storage by applying standard carbon fraction equations, thereby determining the carbon sink potential of each plant species.

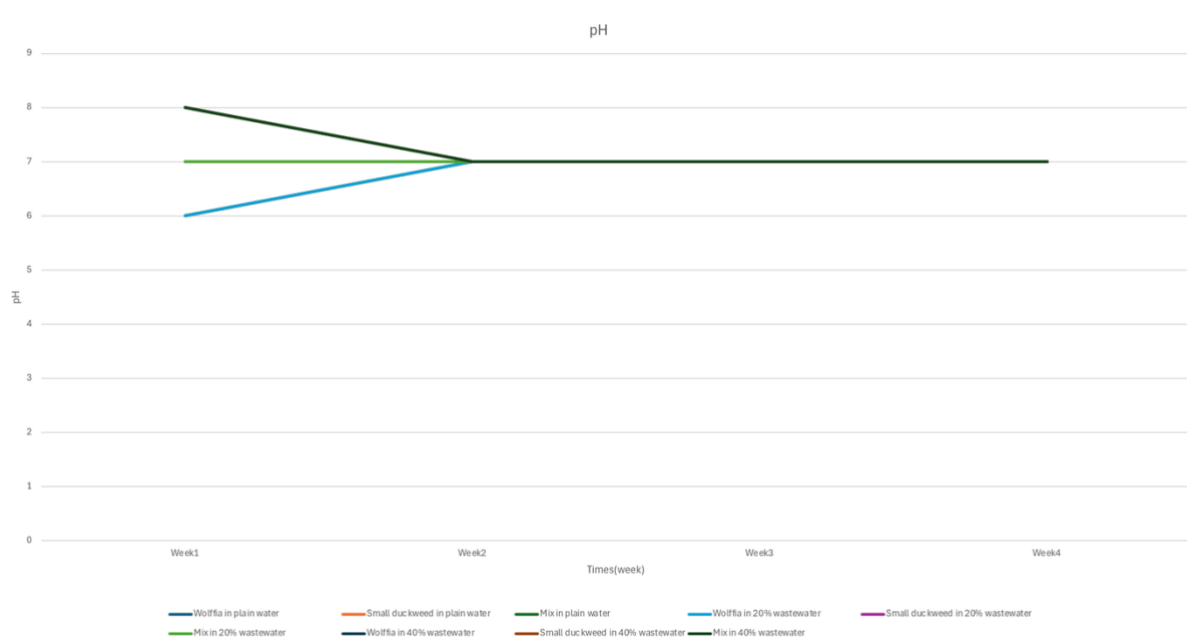
Results

Dissolved oxygen (DO) levels increased significantly, and pH values shifted toward neutrality.

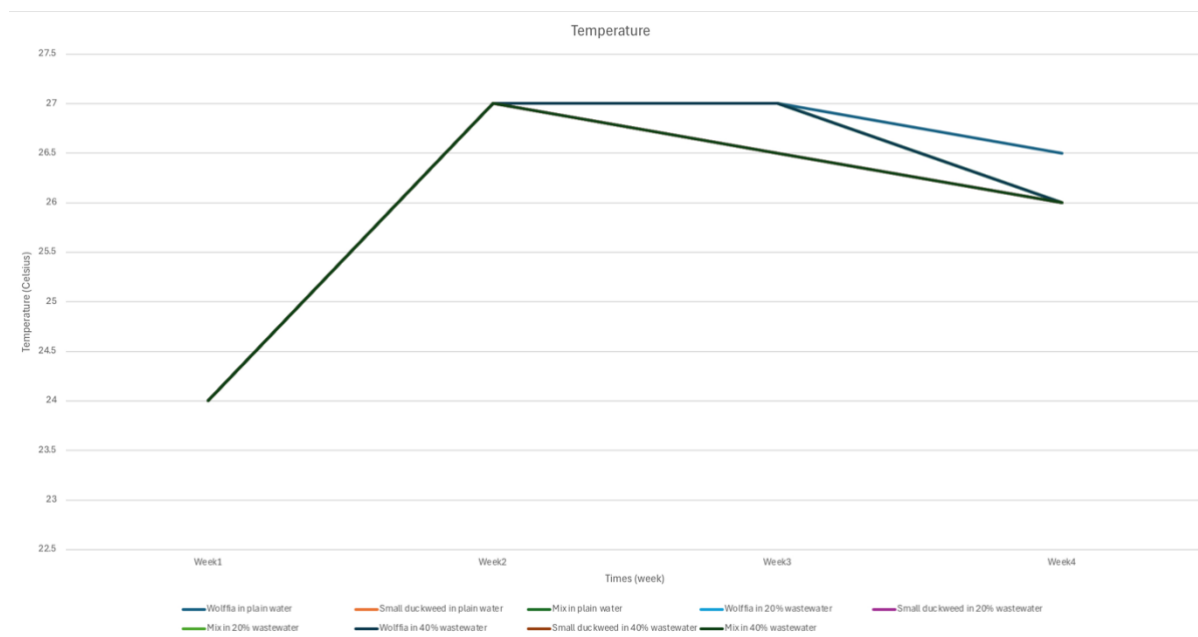
Graph 1 Dissolved Oxygen (DO)



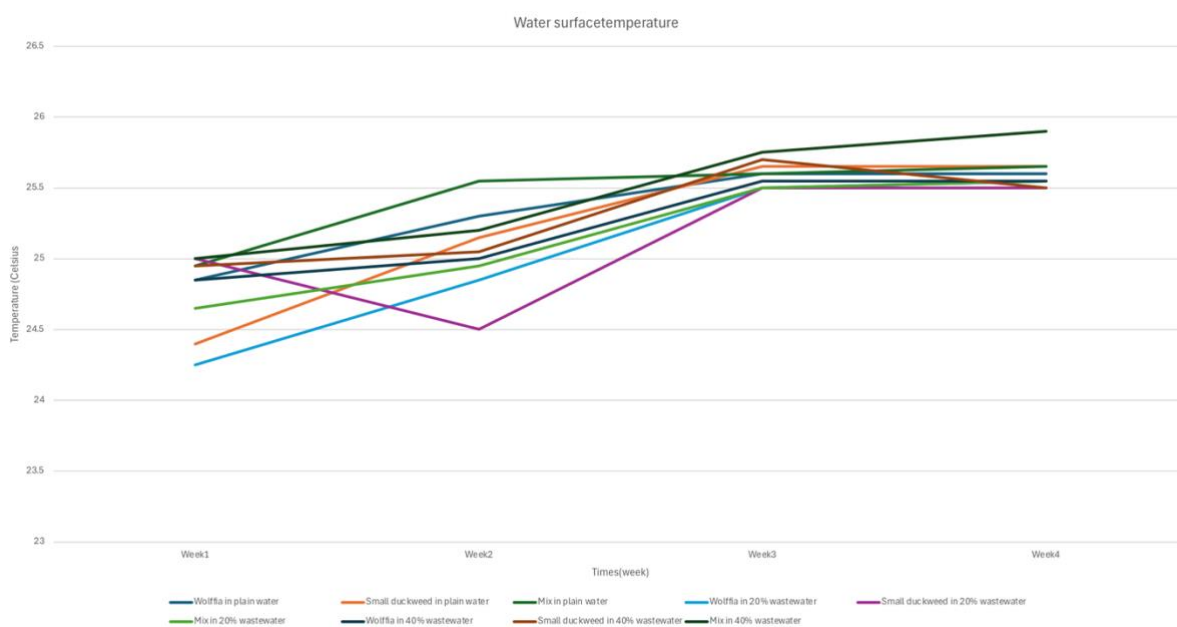
Graph 2 pH



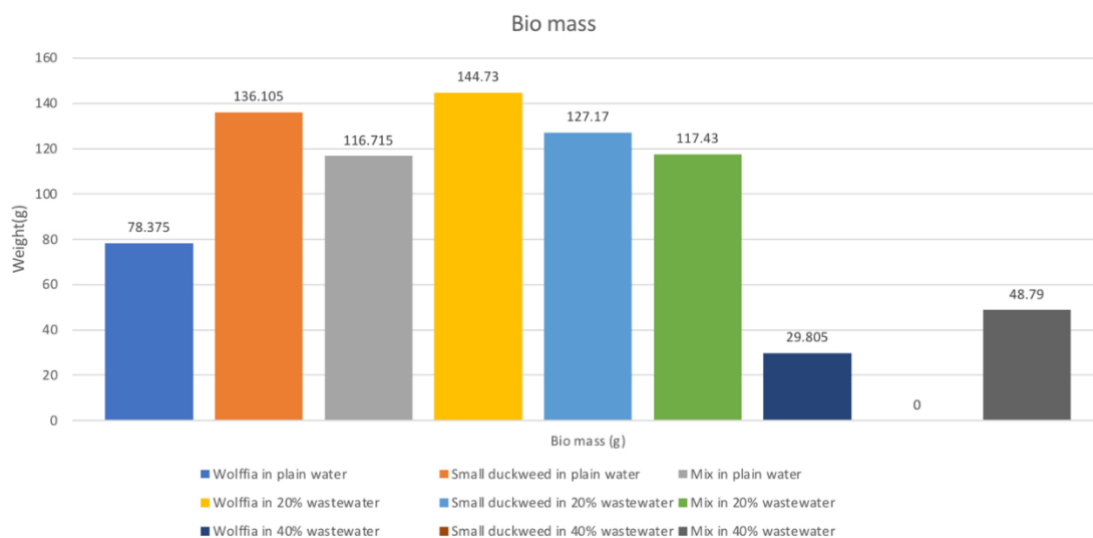
Graph 3 Water Temperature



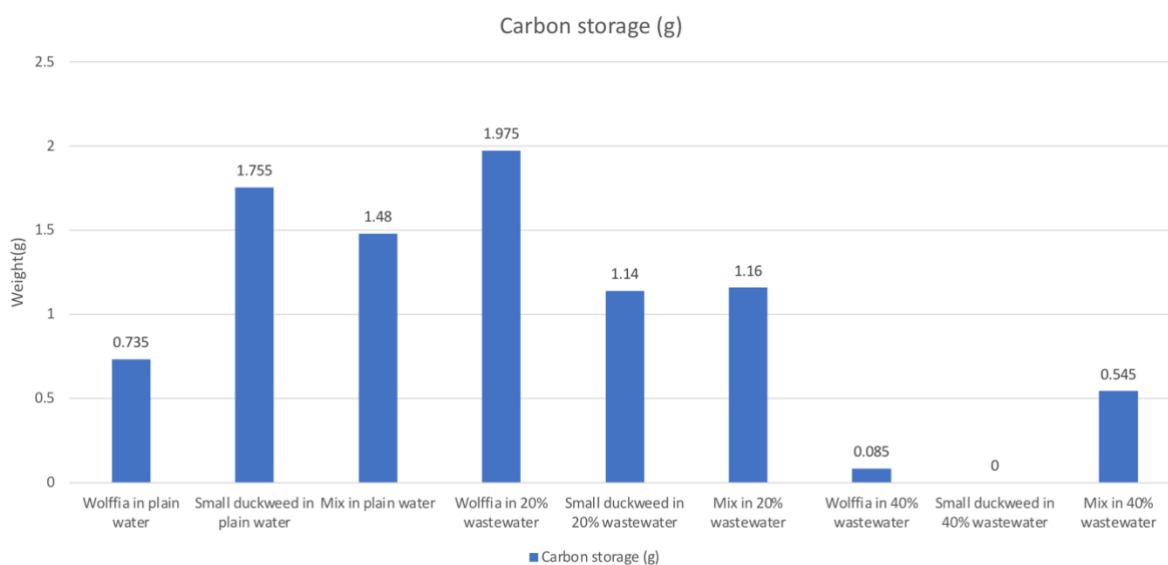
Graph 4 Water Surface Temperature



Graph 5 Biomass



Graph 6 Carbon storage



Discussion and Conclusions

The results of this study provide critical insights into the biological roles of *Wolffia* spp. and *Lemna perpusilla* in environmental restoration, specifically addressing the two primary research questions.

1. Comparative Wastewater Treatment Efficiency (Research Question 1)

The data reveals that while both aquatic plants effectively improve water quality, they possess distinct operational strengths. *Lemna perpusilla* (Small Duckweed) demonstrated

exceptional efficiency in moderate environments. At a 20% wastewater concentration, it achieved a remarkable 797% increase in Dissolved Oxygen (DO), restoring the water to a state nearly equivalent to clean water (6.73 mg/L). Conversely, *Wolffia* spp. (Water Meal) exhibited superior resilience under high-stress conditions. In the 40% wastewater set, *Wolffia* maintained significantly higher oxygenation levels (3.3 mg/L) compared to *Lemna* (2.39 mg/L), which showed signs of physiological decline. This suggests a strategic trade-off: *Lemna* is a high-performance oxygenator in stable conditions, while *Wolffia* serves as a robust bio-filter for highly concentrated effluents.

2. Carbon Sequestration Capacity (Research Question 2)

The carbon sequestration potential is inherently linked to the rate of biomass accumulation. *Wolffia* spp. outperformed *Lemna perpusilla* as a carbon sink, particularly in the 20% wastewater concentration where it reached its peak growth. *Wolffia* sequestered 1.975 g of carbon per experimental unit, significantly higher than the 1.14 g recorded for *Lemna*. This disparity is due to the rapid doubling time and dense biomass structure of *Wolffia*, which allows it to convert absorbed nutrients and atmospheric CO₂ into organic tissue more effectively. The physiological transition of the plants from the "Lag phase" to the "Log phase" around the third week further accelerated this carbon capture process.

In conclusion, the study successfully addresses the research objectives with the following findings: Treatment Specialization: *Wolffia* spp. and *Lemna perpusilla* are not interchangeable but rather complementary. *Lemna* is ideal for final-stage polishing of wastewater to maximize oxygen levels, whereas *Wolffia* is more effective for the primary treatment of high-strength swine wastewater. Carbon Sequestration: *Wolffia* spp. is a more potent agent for carbon sequestration, offering a higher yield of biomass and carbon storage per unit of treatment. These findings advocate for a "Circular Economy" model in livestock farming, where these aquatic plants can be utilized to simultaneously mitigate water pollution and combat climate change through effective carbon capture.

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Citations

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GLOBE's Databases

The screenshot displays the GLOBE Visualization System interface. A pop-up window titled "School: Princess Chulabhorn Science High School Trang" and "Site: Innovation Room" is open over a map. The window contains the following information:

Site Information	
Site ID	377016
Name	Innovation Room
Latitude	7.553547°
Longitude	99.557993°
Elevation	1.0m
Location Source	gps

Below the site information, there are sections for "Atmosphere Site" and "Hydrology Site". Under "Atmosphere Site", the "Activated At" date is listed as 2026-01-29 11:30:49.520052. The "Hydrology Site" section is currently empty.

https://vis.globe.gov/GLOBE/popUpContents.jsp?site_id=377016¤t_date=2026-01-29

(Optional) Badges

1. Badge: I am an Earth System Scientist

Reason for selection: This project transcends the isolated study of flora or water quality by investigating the intricate **interactions** between the **Biosphere** (represented by *Wolffia spp.* and *Lemna perpusilla*) and the **Hydrosphere** (contaminated by pig farm effluent), while further establishing a connection to the **Atmosphere** through carbon sequestration processes.

Academic Description: This report demonstrates a profound understanding of the Earth's interconnected systems. The researchers integrated multiple GLOBE Protocols from both the Hydrosphere and Biosphere to analyze ecosystem dynamics. The findings elucidate the biochemical processes by which plants in the family Lemnaceae assimilate nutrients and organic matter from wastewater for biomass production, directly resulting in water quality improvement and carbon immobilization. Such an integrated analysis, linking matter cycling and energy transfer across Earth's spheres, clearly reflects a high level of competence in Earth System Science.

2. Badge: I am a Problem Solver

Reason for selection: The research originated from the identification of a tangible local issue (pig farm wastewater) and employed rigorous scientific methodology to develop effective, feasible solutions tailored to the community's context.

Academic Description: During environmental investigations, the researchers identified significant water pollution resulting from local livestock activities, which threatened regional ecological health. This project focuses on applying Earth System Science to identify viable and effective solutions. Through comparative experimental analysis, it was determined that *Lemna perpusilla* and *Wolffia spp.* significantly enhance dissolved oxygen (DO) levels and remediate wastewater. By proposing a cost-effective, nature-based solution (Bioremediation), this study exemplifies the role of GLOBE researchers in utilizing evidence-based practices to foster a more sustainable and better world.

3. Badge: I Make an Impact

Reason for selection: The research outcomes offer actionable strategies that create positive change (Impact) at both the local level (wastewater treatment) and the global level (greenhouse gas reduction).

Academic Description: This research generates a positive impact by bridging the gap between local environmental remediation and global sustainability goals. Evidence confirming that *Wolffia spp.* can sequester up to 1.975 grams of carbon per experimental unit provides a strong foundation for supporting a Circular Economy. The researchers propose transforming pig farm waste into carbon sinks and alternative protein sources, thereby reducing atmospheric greenhouse gas emissions while restoring local water resources. To ensure a tangible impact and satisfy the criteria of "making recommendations or taking action based on findings," the research outcomes were shared with local farm owners and community members. We provided guidance on sustainable wastewater management and the utilization of the harvested biomass as nutrient-rich feed for aquaculture (e.g., fish and frogs), promoting a sustainable agricultural cycle.