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Exploring the Potential of Barangay Calawisan, Lapu-Lapu City for Sustainable Aquafarming: Developing a Regression Model to Enhance Sea Grape (*Caulerpa lentillifera*) Yield in a Closed System Environment

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Abstract

This study aims to develop a regression model to optimize sea grape (*Caulerpa lentillifera*) yield in a controlled farming environment in Barangay Calawisan, Lapu-Lapu City, Philippines. Using secondary data extracted from a 2020 study, the research addresses challenges such as limited coastal farming space and environmental constraints by exploring closed-container aquafarming as an innovative solution. A multiple linear regression analysis identifies key growth factors—light intensity, ammonia nitrogen (NH_3-N), nitrite nitrogen (NO_2-N), and nitrate nitrogen (NO_3-N)—that significantly enhance algal productivity. The findings indicate that increased light intensity and nitrogen levels positively correlate with improved sea grape yield, suggesting actionable strategies for optimizing aquafarming practices. Additionally, the study introduces an Excel-based tool that enables farmers to predict sea grape yields under various conditions, providing a resource for effective farm management. Through promoting sustainable farming practices, this research aligns with national goals for urban agriculture and food security and positions Lapu-Lapu City as a leader in innovative aquafarming. Future research could further refine this model, offering valuable insights into scaling sustainable agricultural practices in similar regions.

Keywords: Sea Grapes, Aquafarming, Regression Model, Sustainable Agriculture

Introduction

Sea grapes (*Caulerpa lentillifera*) which are commonly known as "lato" in the Visayas region, have long been an important crop in the Philippines, particularly in coastal areas where they are traditionally farmed in open waters. Due to their distinct flavor, texture, and numerous health benefits, sea grapes have become a staple food source and a key economic commodity in both local and international markets (Estrada et al., 2020).

Lapu-Lapu City's coastal location makes it an ideal area for sea grape (lato) farming in Cebu. Because of this geographical location, the researchers identified significant potential for the city to become a leading producer in the region. Barangay Calawisan and other coastal barangays have already initiated lato farming in ponds, but these efforts have not been documented. As demand for sustainable farming grows and coastal farming spaces become limited due to environmental challenges like pollution, the need to explore alternative cultivation methods has become increasingly urgent.

An innovative approach to sea grape cultivation is close-container aquafarming, which allows for the controlled farming of lato in urbanized areas. This method is particularly suited to densely populated regions like Lapu-Lapu City, where space constraints and environmental concerns are growing. By replicating ideal conditions—such as precise salinity, temperature, and water quality—close-container farming extends sea grape production to unconventional spaces like rooftops and aquaponic systems. This solution not only overcomes the spatial limitations of traditional coastal farming but also offers a more consistent and climate-resilient method for cultivating lato (Van Klompenburg et al., 2020).

Furthermore, this method aligns with Republic Act No. 10068, also known as the Organic Agriculture Act of 2010, which promotes sustainable farming practices that protect biodiversity and ensure food security. By adopting organic and environmentally friendly techniques, this study contributes to increasing agricultural productivity while minimizing its environmental impact. Additionally, Republic Act No. 10654, which strengthens the Philippine Fisheries Code of 1998, highlights the importance of sustainable aquatic resource management, making this study highly relevant for conserving marine biodiversity while optimizing lato farming in urban environments.

The objective of this research is to develop a mathematical model that optimizes the artificial environment for lato cultivation in controlled settings. The model will identify and adjust key factors such as light intensity, ammonia nitrogen (NH3-N), nitrite nitrogen (NO2-N), and nitrate nitrogen (NO3-N), which are critical for successful sea grape growth. Additionally, this model will serve as the basis for creating an Excel-based program that allows users to easily calculate algal productivity under varying conditions in artificial closed systems. By analyzing these variables, the model will provide valuable insights into establishing and maintaining enhanced conditions, enabling farmers to maximize yields and ensure consistent quality. This predictive tool will help farmers adapt to environmental challenges, and utilize resources more efficiently, which promotes a more sustainable farming process.

Moreover, this project is aligned with the TUKLAS mathematics and computational sciences objective, which focuses on applying mathematical and statistical methods to real-world challenges (DepEd, 2023). Through using mathematical models to predict and maximize the growing conditions for sea grapes, this research showcases the practical application of mathematics in solving agricultural problems. It contributes to educational goals by demonstrating how data-driven approaches can inform decision-making in urban agriculture, improving food security, environmental sustainability, and urban development. The predictive model bridges the gap between theory and practice, supporting the TUKLAS program's vision of using data to address real-world issues while advancing sustainable farming practices.

With Lapu-Lapu City poised to become a leader in *lato* production, this mathematical model will enhance the city's capacity to produce high-quality sea grapes in urban environments. This innovative approach not only supports economic growth and food security but also promotes environmentally sustainable farming practices crucial for the future of urban agriculture.

Methodology

This study employed secondary data analysis based on research by Sompong et al. (2020), which focused on the cultivation of sea grapes (*Caulerpa lentillifera*) in artificial closed systems. Data extracted from this study were used to develop a regression model within the Mathematical Modeling Framework (Galbraith & Holton, 2018). The research process began with an extensive literature search using keywords such as "Sea Grape," "Caulerpa lentillifera," "cultivation," "artificial seawater," and "closed system" on Google Scholar, chosen for its extensive collection of peer-reviewed articles. This search identified three key studies published in the last five years that directly focused on sea grape cultivation in artificial seawater closed systems, ensuring the data was both relevant and up to date. Studies not meeting these criteria, including those on non-closed systems or other algae species, were excluded.

After selecting the relevant studies, the researchers employed a checklist to evaluate critical factors influencing algal productivity in closed systems. The key factors examined included light intensity, ammonia nitrogen (NH_3-N), nitrite nitrogen (NO_2-N), nitrate nitrogen (NO_3-N), and the resulting algae yield. To ensure data accuracy, one teacher-researcher conducted a detailed review of the selected studies. The findings were compared across the studies to identify trends that could enhance the productivity of *Caulerpa lentillifera*.

Multiple linear regression analysis was performed using the Statistical Package for the Social Sciences (SPSS) software (IBM) to determine how key factors such as light intensity and nitrogen compounds impacted sea grape growth. One of the studies, *Sea Grape (Caulerpa lentillifera) Cultivation in Artificial Seawater Closed System* (Udomluk Sompong et al., 2020), provided experimentally validated data on how these factors work synergistically to improve algal productivity.

In the study, sea grapes were cultured in triplicate 3.00 m³ cement tanks containing artificial seawater. The algae were placed on 0.50 x 0.50-meter PVC pipe panel frames, supported by a 1 cm mesh-size net. Each panel held 500 grams of fresh sea grapes, with six panels per tank, resulting in a total of three tanks. The panels were submerged 10 cm below the water surface, with 16-16-16 fertilizer added at a ratio of 5 g per cubic meter of water, along with oxygen aeration. The algae were grown for 30 days, with their growth assessed weekly.

The Mathematical Modeling Framework applies multiple linear regression analysis to predict sea grape productivity in a controlled, closed-system aquafarming environment. This methodology is organized into several key steps that guide the process of formulating and evaluating the regression model to optimize sea grape yields under specific environmental conditions.

Figure 1 illustrates the flow of the Mathematical Modeling Framework, beginning with the identification of the real-world problem. In this study, the main challenge is optimizing sea grape farming in closed-system aquafarming to promote sustainable practices and address the constraints of coastal farming spaces affected by pollution and environmental degradation.

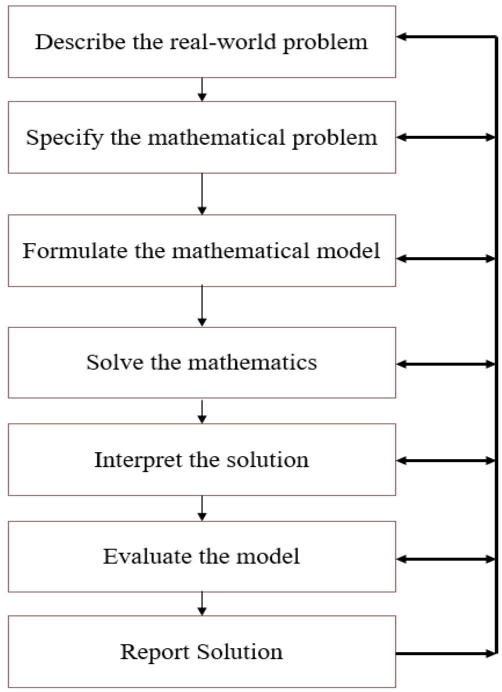


Figure 1. Mathematical Modelling Framework utilized in this Study

The next step involves specifying the mathematical problem, which is guided by two key research questions that the framework aims to address:

1. What is the relationship between environmental factors, such as light intensity, nitrogen compounds, and sea grape productivity in a controlled, closed-system aquafarming environment?
2. How can a mathematical model be developed to predict and optimize sea grape productivity based on these key environmental variables?

The third step is to formulate the mathematical model, which in this study is achieved through multiple linear regression analysis. This method helps identify the relationships between various environmental factors and sea grape growth by examining how these factors collectively influence productivity. The resulting multiple linear regression model is expressed as:

$$\text{Algal Productivity} = \beta 0 + \beta 1 \times L + \beta 2 \times NH3\text{-}N + \beta 3 \times NO2\text{-}N + \beta 4 \times NO3\text{-}N + \epsilon$$

β0 is the constant of the model, representing the baseline level of productivity when all other factors are zero.
β1, β2, β3, and β4 are the coefficients that show how much sea grape productivity changes when each factor (e.g., light intensity, ammonia nitrogen) increases by one unit.
ϵ accounts for any variation not explained by the model.

The key environmental factors included in the model are:

Light intensity (L): Crucial for photosynthesis, which drives algal growth.
Ammonia nitrogen (NH3-N): An important nutrient for algae, supporting their growth.
Nitrite nitrogen (NO2-N): A nutrient that contributes to sea grape growth.
Nitrate nitrogen (NO3-N): Another form of nitrogen, though its effect on growth is less consistent in this study.

The final three steps—interpreting the solution, evaluating the model, and reporting the solution—are integral components of the framework. These steps will be further elaborated and discussed in the findings section, where the results of the mathematical model and its effectiveness in predicting sea grape productivity will be analyzed.

Findings

The multiple linear regression analysis was conducted to determine the effects of several environmental factors—light intensity, NH3-N (ammonia nitrogen), NO2-N (nitrite nitrogen), and NO3-N (nitrate nitrogen)—on the productivity of *Caulerpa lentillifera* in an artificial closed system. The coefficients from the model, along with their significance, are summarized in **Table 1**. These results provide insights into how each factor contributes to algal productivity.

Table 1. Coefficients and Significance Levels for Environmental Variables Influencing Algal Productivity

Variable	Coefficient (B)	Significance (Sig.)
Constant	-0.901	0.284
Light Intensity (Lux)	0.0000308	0.032
NH3-N $(mg.L^{-1})$	0.02	0.013
NO2-N $(mg.L^{-1})$	0.043	0.038
NO3-N $(mg.L^{-1})$	0.125	0.326

Light Intensity had a significant and positive effect on productivity, with an unstandardized coefficient (B) of 3.08E-05 and a p-value of 0.032. This indicates that increased light exposure enhances algal growth, which is consistent with the biological process of photosynthesis that is crucial for algae. NH3-N (ammonia nitrogen) also showed a significant positive relationship with productivity (B = 0.02, p-value = 0.013). Ammonia serves as an essential nitrogen source for algae, which supports their growth and development in artificial systems.

Similarly, NO2-N (nitrite nitrogen) had a positive and statistically significant impact on productivity, with a coefficient (B) of 0.043 and a p-value of 0.038, suggesting that increased nitrite levels contribute to higher algal growth. Nitrite, as an intermediate in the nitrogen cycle, provides a nutrient source for the algae, further emphasizing the importance of managing nitrogen compounds in closed systems.

On the other hand, NO3-N (nitrate nitrogen) did not show a statistically significant effect on productivity (B = 0.125, p-value = 0.326). This implies that nitrate nitrogen may not play as crucial a role in driving the growth of *Caulerpa lentillifera* in the conditions of this study, where ammonia and nitrite appear to be more critical nitrogen sources.

The mathematical model presented was derived from the multiple linear regression analysis conducted to predict *Caulerpa lentillifera* (sea grape) productivity based on several environmental factors: light intensity, NH3-N (ammonia nitrogen), NO2-N (nitrite nitrogen), and NO3-N (nitrate nitrogen). The model equation is:

Algal Productivity=−0.901+ 0.0000308 (L)+ 0.020 (NH3-N)+ 0.043 (NO2-N)+0.125 (NO3-N)

The coefficient for **Light Intensity** is *0.0000308*, which shows that for every unit increase in light intensity (Lux), algal productivity increases by a very small but positive amount. This indicates that light intensity plays a significant role in enhancing algal growth, which aligns with the necessity of light for photosynthesis. As the p-value in the model was statistically significant (0.032), it can be inferred that light intensity has a meaningful effect on productivity in the artificial closed system.

The coefficient for **Ammonia Nitrogen** (NH3-N) is 0.020. This means that for every increase in ammonia nitrogen concentration (mg/L), algal productivity increases by 0.02 kg. Since NH3-N serves as a vital nitrogen source for algae, this positive coefficient confirms its importance in promoting growth. The significance level (0.013) further supports that NH3-N is a key factor influencing productivity.

Nitrite Nitrogen (NO2-N) has a coefficient of 0.043, which shows that an increase in nitrite nitrogen concentration results in an increase in algal productivity. This positive relationship indicates that nitrite can be utilized by algae as an important nutrient. The significance level for NO2-N was 0.038, indicating that nitrite is a significant contributor to algal productivity in the closed system environment.

Nitrate Nitrogen (NO3-N) has the largest coefficient (0.125) in the equation, indicating a potential positive effect on algal productivity. Although the regression analysis produced a p-value of 0.326, making it not statistically significant, nitrate nitrogen was still included in the model due to its potential contribution. Its effect, while less consistent than that of ammonia and nitrite nitrogen, could still play a role in influencing productivity and was therefore considered important for the overall predictive model.
The model developed highlights the relative importance of different environmental factors on *Caulerpa lentillifera* productivity. Light intensity, ammonia nitrogen (NH3-N), and nitrite nitrogen (NO2-N) were found to have significant and positive effects on productivity, suggesting that these factors should be carefully monitored and maximized in artificial seawater closed systems to enhance algal yield. While nitrate nitrogen (NO3-N) showed a positive relationship with productivity, its effect was less consistent compared to the other nitrogen compounds.

This mathematical model offers practical insights into how environmental conditions can be adjusted to optimize *Caulerpa lentillifera* cultivation. Future studies could further investigate the role of nitrate nitrogen and explore other environmental parameters that may also influence productivity in closed systems.

Table 2. Model Summary of Environmental Factors Influencing *Caulerpa lentillifera* Productivity

Model	R	R Square	Adjusted R Square	Standard Error of the Estimate
1	0.922	0.85	0.775	0.05878

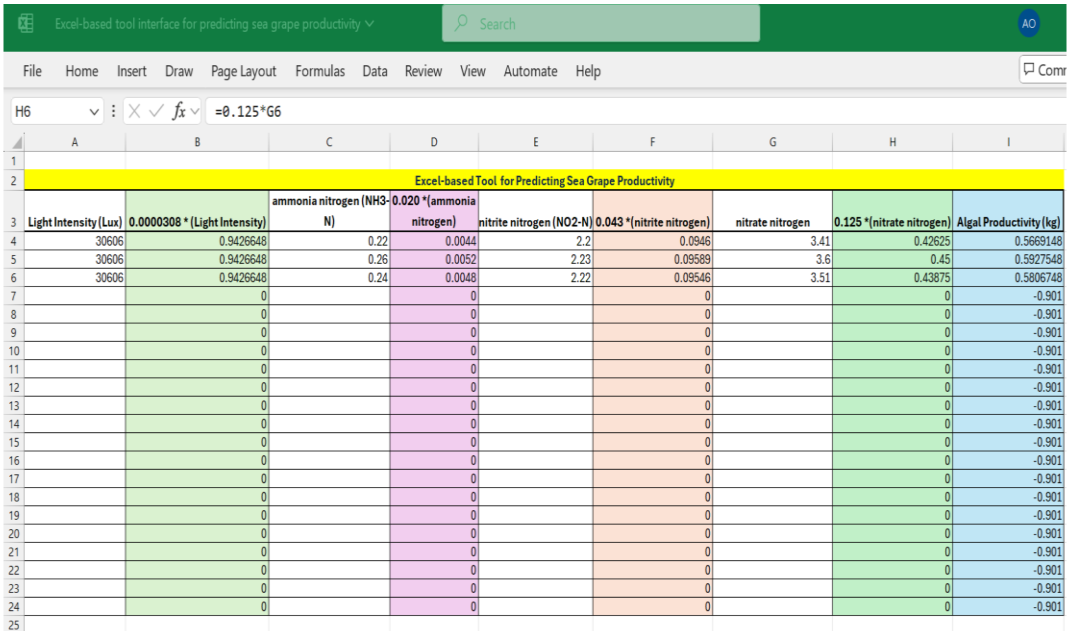
The model summary shows strong performance based on key metrics. The R value of 0.922 indicates a strong positive correlation between the independent variables (light intensity, NH3-N, NO2-N, NO3-N) and the dependent variable (*Caulerpa lentillifera* productivity). The R Square value of 0.850 demonstrates that 85% of the variation in algal productivity can be explained by the model, suggesting a very good fit. Additionally, the Adjusted R Square of 0.775 accounts for the number of predictors in the model and indicates that the model remains robust without overfitting. Finally, the Standard Error of the Estimate of 0.05878 shows that the model's predictions are relatively accurate, with an average prediction error of around 0.059 kg. Overall, the model provides strong predictive power and reliability in explaining *Caulerpa lentillifera* productivity.

Conclusion

This study successfully developed a mathematical model to maximize the yield of sea grapes (*Caulerpa lentillifera*) in a controlled, closed-system aquafarming environment. By analyzing key environmental factors such as light intensity, ammonia nitrogen (NH3-N), nitrite nitrogen (NO2-N), and nitrate nitrogen (NO3-N), the model offers valuable insights into the specific conditions that enhance sea grape productivity. The results show that light intensity, ammonia nitrogen, and nitrite nitrogen play significant roles in promoting algal growth, while nitrate nitrogen, although showing a positive influence, was not statistically significant in this system. The model's strong performance, based on its R value and an R Square value, confirms its reliability in predicting productivity under varying conditions.

An important implication of this study is that the mathematical model can serve as a practical tool for optimizing sea grape farming in urban environments, particularly in regions where space or environmental conditions limit traditional open-water cultivation. By enabling farmers to predict productivity based on key environmental factors, the model could help them efficiently manage resources such as light and nitrogen compounds, potentially leading to increased yields and more sustainable farming practices. For policymakers, the model provides data-driven insights that can inform policies promoting urban aquafarming and the sustainable use of environmental resources. This not only supports the growth of urban agriculture but also aligns with local environmental policies and the TUKLAS program's objectives, contributing to food security, economic growth, and the broader application of sustainable farming methods in urban agriculture.

As a direct outcome of the developed mathematical model, an Excel-based program was created to provide a practical tool for sea grape farmers and researchers. The program allows users to input key environmental factors such as light intensity, ammonia nitrogen (NH3-N), nitrate nitrogen (NO3-N) and nitrite nitrogen (NO2-N). Using the equation derived from the study, it calculates predicted sea grape productivity in closed-system environments:



	A	B	C	D	E	F	G	H	I
1									
2	Excel-based Tool for Predicting Sea Grape Productivity								
3	Light Intensity (Lux)	0.0000308 * (Light Intensity)	ammonia nitrogen (NH3-N)	0.020 *(ammonia nitrogen)	nitrite nitrogen (NO2-N)	0.043 *(nitrite nitrogen)	nitrate nitrogen	0.125 *(nitrate nitrogen)	Algal Productivity (kg)
4	30606	0.9426648	0.22	0.0044	2.2	0.0946	3.41	0.42625	0.5669148
5	30606	0.9426648	0.26	0.0052	2.23	0.09589	3.6	0.45	0.5927548
6	30606	0.9426648	0.24	0.0048	2.22	0.09546	3.51	0.43875	0.5806748
7		0		0		0		0	-0.901
8		0		0		0		0	-0.901
9		0		0		0		0	-0.901
10		0		0		0		0	-0.901
11		0		0		0		0	-0.901
12		0		0		0		0	-0.901
13		0		0		0		0	-0.901
14		0		0		0		0	-0.901
15		0		0		0		0	-0.901
16		0		0		0		0	-0.901
17		0		0		0		0	-0.901
18		0		0		0		0	-0.901
19		0		0		0		0	-0.901
20		0		0		0		0	-0.901
21		0		0		0		0	-0.901
22		0		0		0		0	-0.901
23		0		0		0		0	-0.901
24		0		0		0		0	-0.901
25									

Figure 2. Excel-based tool for predicting sea grape productivity

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