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An Overview of Smart Farming Production Technology for the Advancement of Home-grown Farmers in the Philippines

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ABSTRACT

This article explores the technologies that can be used to establish smart farming in the Philippines, as well as the various smart systems that have been used to aid home-grown farmers. The emergence of smart agriculture and farming is a method that heavily integrates digital technology in order to increase food production while minimizing input costs. The importance of this technology has a significant effect on farmers and investors as a result of technological advancements. It should also be recognized that numerous promotions requiring government funding for the establishment of smart farming technology in the Philippines has been addressed.

Keywords: Smart Farming; Hydroponics; Aquaponics; Aeroponics

INTRODUCTION

In the Philippines, almost half of the population lives in rural areas and relies on agriculture for a living; among them are indigenous people, landless farmers, and fishermen [1]. In general, farmers on different islands in the Philippines operate independently using conventional methods, and their management of farm produce to end-users is facilitated at low prices by middlemen. Micro-propagation protocols for bananas, coconuts, legumes, and oilseed crops are well known [2].

In the first quarter of 2021, the value of agricultural output fell by -3.3 percent at constant 2018 rates. This was attributed to a decrease in livestock and poultry demand. Crops and fisheries, on the other hand, also increased productivity [3]. Despite this condition, the Philippines is working to modernize and improve its agriculture industry, with both the government and private firms encouraging the use of advanced technologies and smart farming practices to raise harvests and reduce losses [4].

Agriculture's creation was a watershed moment in human history. The willingness of fully modern humans to change the atmosphere to produce enough food to support population growth is the first major improvement in the relationship between fully modern individuals and society. Agriculture ushered in a slew of new developments, ranging from the use of fire and cooked food to self-driving machinery [5].

Hence, smart farming is seen as the agricultural future because it produces higher quality crops by making farms more intelligent in sensing their controlling parameters [6].

SIGNIFICANCE OF SMART FARMING TECHNOLOGY

Agriculture routinely uses sophisticated technologies such as robots, temperature and moisture sensors, aerial images, and GPS technology. These cutting-edge devices, precision agriculture, and robotic systems enable businesses to be more profitable, efficient, safe, and environmentally friendly [7].

Thus, technology is critical to the development of the farming industry and the improvement of agribusiness. Researchers have successfully grown crops in deserts and other harsh environments using genetic engineering, which involves inserting traits into established genes in order to produce pest-resistant, drought-resistant, and plant pathogen-resistant crops.

Moreover, this technology will enhance insect or pest resistance, herbicide or drought tolerance, and disease resistance, providing farmers with a new tool for increasing crop yield. Farmers have used plant breeding and selection techniques to increase crop yield with the assistance of researchers. Technology is also used to protect crops by tracking growth and detecting plant diseases. Without the physical involvement of farmers, automation allows for the consistent distribution of fertilizers, pesticides, and water throughout fields [8].

Lastly, innovative agriculture ensures that new farming and agricultural development models emerge, introducing innovative techniques on how food is produced and distributed. These methods allow more economies and regions to keep up with changing trends and meet the demands of modern living while ensuring sustainably grown food. [9].

SMART FARMING TECHNOLOGY

Hydroponics Farming

Hydroponic farming is a method of growing plants in water without soil using mineral nutrient solutions. The hydroponic gardener controls the nutrient content of the liquid solution used to water the plants [10].

Common Types of Hydroponics System

1. Nutrient Film Technique (NFT)

A method of cultivating plants in which plant roots grow in shallow and circulating hydroponic nutrient layers, allowing plants to receive adequate water, nutrients, and oxygen. Plants grow in layers of polyethylene, with plant roots immersed in nutrient-rich water that is constantly pumped by a pump [11].

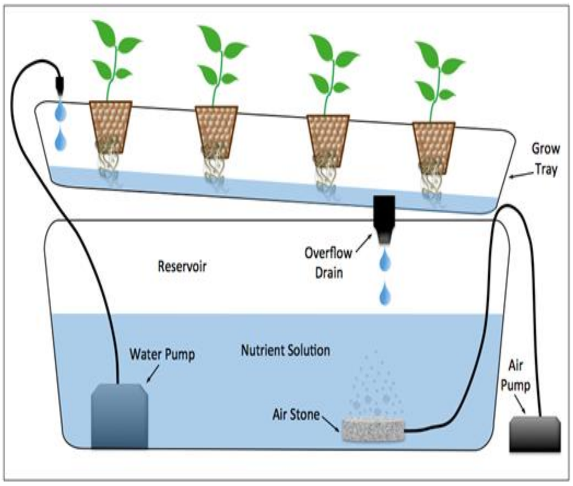

Figure 1. Diagram of the Nutrient Film Technique (NFT) hydroponic system [12]

2. Wick Systems

It is considered the most basic hydroponic device. The Wick system is classified as a passive system, which means it has no moving parts. Your unique Growth Technology nutrient solution is drawn up into the expanding medium through a number of wicks from the bottom reservoir. This device will work with a number of mediums, including perlite, soil, and coco [13].

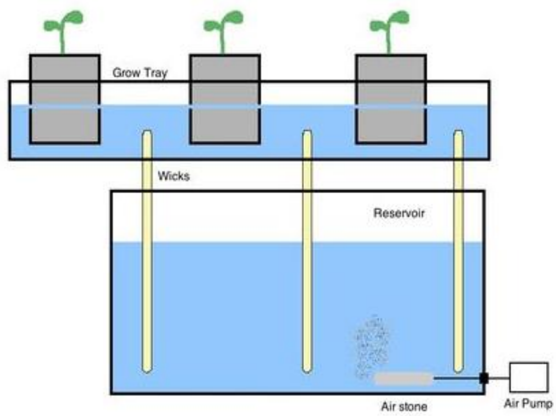

Figure 2. Diagram of the Wick System [14]

3. Deep Water Culture (DWC)

It is a hydroponic method of plant production by suspending the roots of the plant in a solution of oxygenated, rich in nutrients. This system uses rectangular tanks of less than one foot deep filled with a nutrient-rich solution and plants floating on

Styrofoam panels, also known as Deep Flow Technique (DFT), Floating Raft Technology (FRT), or Raceway [15].

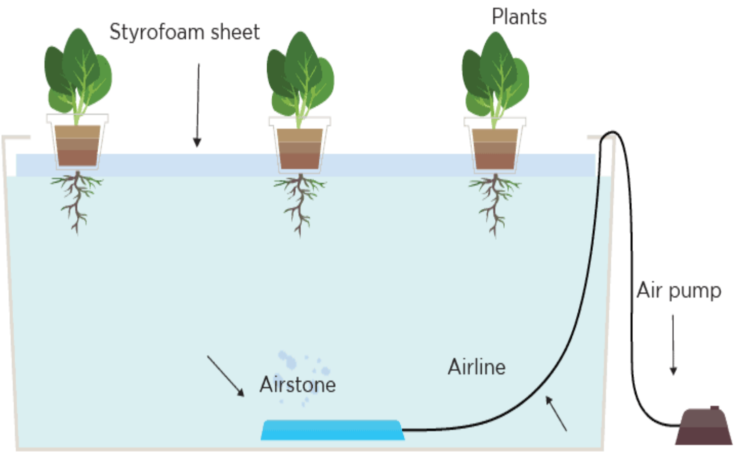

Figure 3. Diagram of the Deep Water Culture [16]

4. Ebb and Flow (Flood and Drain)

It is a hydroponics technique that involves flooding the growth media with nutrient solution for a set period of time, after which the unabsorbed nutrient is returned to the tank. Normally, this hydroponics device uses a timer to fill the water, resulting in inefficient usage of nutrient solution [17].

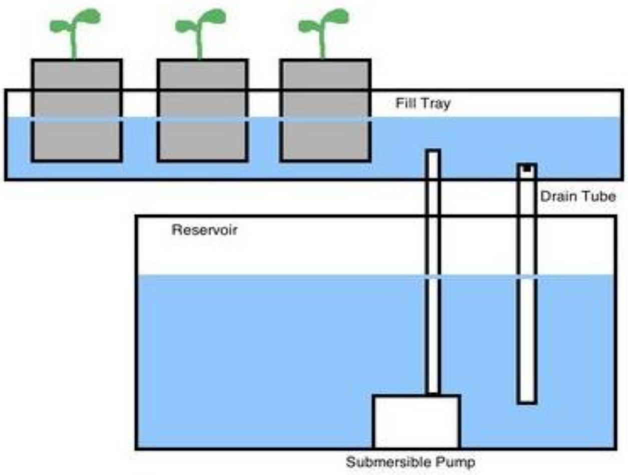

Figure 4. Diagram of the Ebb and Flow [18]

Aquaponics Farming

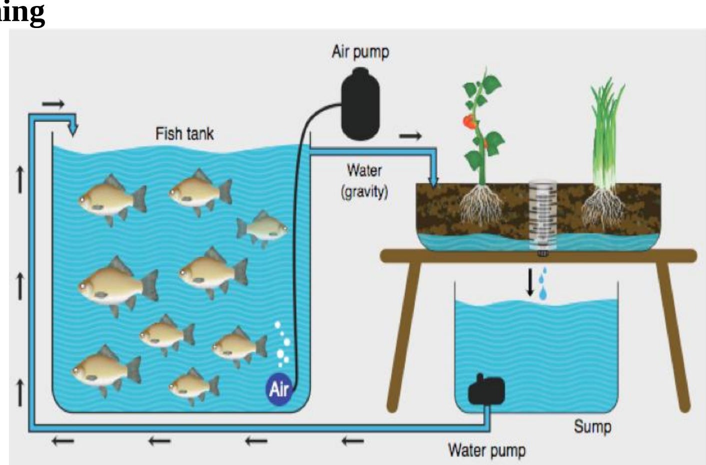

Figure. 5. Diagram of the Aquaponics [19]

In an aquaponics system, water from an aquaculture system is fed into a hydroponic system where by-products' are broken down by nitrifying bacteria first into nitrites and then into nitrates, which are used as nutrients by the plants [19]. A symbiotic relationship between two food production disciplines: (1) aquaculture, the farming of aquatic species, and (2) hydroponics, the cultivation of plants in water without soil. Aquaponics is a closed recirculating device that incorporates the two. A typical recirculating aquaculture system filters and eliminates organic matter ("waste") that accumulates in the water, ensuring that the water is safe for the fish [20].

Aeroponics Farming

In Aeroponics, the nutrient solution is sprayed onto the roots by moving it through misters inside the root region, either continuously or several times per hour [21].

The plant you want to develop is suspended in an air space with an atmosphere that is either completely closed or semi-closed. As a result, it is best achieved in a closed, regulated environment where you can monitor the amount of light, air, and nutrient-rich water spray that is fed into the plant [22].

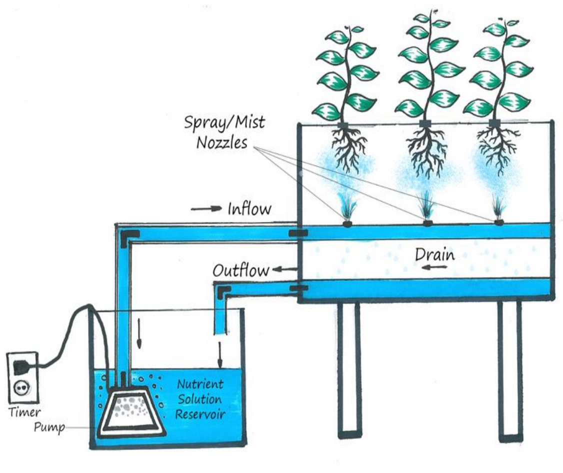

Figure 6. Diagram of Aeroponics [22]

GOVERNMENT SUPPORT TO SMART FARMING

In the Philippines, the local government, led by the Department of Agriculture, is aiming for a 2.5 percent growth this year through further incorporation of technology in agriculture to increase productivity, connectivity, and service delivery to beneficiaries. By focusing on and closely implementing 'Agriculture 4.0,' or the fourth agricultural revolution that encourages the use of smart farming technology, the country would have a better chance of having a better 2021 in terms of agriculture [23].

Agriculture Secretary William Dar released a memorandum to all DA executives, attached agencies and companies, services, and regional offices directing them to "pursue an inclusive approach on these main strategies to accelerate the transition into a new and industrialized Philippine agriculture." [24].

Another agency distinguished in its Labor Market Intelligence report "Soils to Satellites," the Technical Education and Skills Development Authority (TESDA) has been published covering practical topics such as automation in smart greenhouses, agricultural drones, IoT solutions to agricultural problems, and case studies in selected ASEAN countries in smart agriculture applications [25].

CONCLUSION

Some technologies will need to be developed specifically for agriculture, while other technologies already developed for other areas could be adapted to the modern agricultural domain such as autonomous vehicles, artificial intelligence and machine vision and smart farming.

Moreover, as farming in the Philippines faces several problems, proactive solutions like ICT must be implemented together with the full support of the government. Similarly, other major players, such as multinational companies, agricultural and fisheries industry leaders and organizations, and agricultural state universities and colleges (SUCs), should work together to elevate home-grown farmers in the country.

Lastly, if modern agriculture is applied widely in the near future, millions of farmers will be able to benefit from the acquisition and development of smart farming production technology.

ACKNOWLEDGEMENT

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Biochar from Corn Waste as Biofilter in a Recirculating Aquaculture System

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Abstract: The use of biofilter with the application of biochar technology for the improvement of water in a recirculating aquaculture system (RAS) provides a lot of advantages in aquaculture production. The research aimed to devise a biofilter system for the enhancement of TAN and un-ionized ammonia levels in a RAS using biochar from corn cobs for Nile tilapia Oreochromis niloticus production. It has five main parts: fish tank, biochar filtration tank, sediment filter, sludge filter and pump. The fish tank used is a 1 m^3 plastic cubical tank. The biochar filtration tank with a height of 85 cm and a diameter of 30 cm. The sludge filter has a height of 52 cm with a diameter of 13 cm. An electric water pump was used to recirculate the water. The system was fabricated and were able to effectively enhance the level of total ammonia nitrogen (TAN) at a rate of 0.56 ppm per hour for every 1kg biochar and 0.72 ppm per hour for the reduction of un-ionized ammonia. The devised biofilter proved to reduce the level of TAN by 9.45 ppm and un-ionized ammonia levels by 2.18 ppm in 6 hours and 30 minutes using corn cob biochar.

Keywords: Biochar, Biofilter, Recirculating Aquaculture Systems (RAS), Total Ammonia Nitrogen (TAN), Un-ionized ammonia

I. INTRODUCTION

Research and studies about biochar technology are vastly growing over the years because of its multidisciplinary approach and different applications. Biochar is a carbon- rich solid material produced by thermal decomposition of organic material or biomass in the absence or under limited supply of oxygen (Lehman and Joseph, 2009).

Ammonia and nitrite are toxic to fish. Ammonia in water occurs in two forms: ionized ammonium (NH_4^+) and un-ionized ammonia (NH_3). The latter, NH_3, is highly toxic to fish in small concentrations and should be kept at levels below 0.05 mg/l. The total amount of NH_3 and NH_4^+ remains in proportion to one another for a given temperature and pH, and a decrease in one form will be compensated by conversion of the other. The amount of un-ionized ammonia in the water is directly proportional to the temperature and pH. As the temperature and pH increase, the amount of NH_3 relative to NH_4^+ also increases. The ammonia poisoning of fish is as imminent danger in a RAS (Helfrich and Libey, 2019). With this, a biofiltration system plays a vital role in maintaining a good aquaculture water quality.

Recirculating Aquaculture Systems (RAS) has been in existence, in one form or another, since the mid-1950s. However, only in the past few years has its potential to grow fish on a commercial scale been realized. New water quality technology, testing and monitoring instrumentation, and computer enhanced system design programs, much of it developed for the wastewater treatment industry, have been incorporated and have revolutionized our ability to grow fish in tank culture. Nevertheless, despite its apparent potential, RAS should be considered a high-risk, experimental form of agriculture at this time. It can be used to culture high densities of fish annually, but its ability to do so economically remains to be demonstrated, conclusively and repeatedly (Helfrich and Libey, 2019).

With these characteristics, a potential to develop biochar from corn cobs for improving TAN and un-ionized ammonia levels in a RAS shows a potential researchable area since corn cobs are abundant in supply, low-cost, and readily available in the area. With the expansion of tilapia culture, together with the shortage of freshwater and competition of the water use into different applications, and with the growing number of human populations through the years, tilapia farming has been shifted from traditional semi-intensive systems to more intensive production systems such as the production in fish tanks and fish cages with the use of a RAS.

RAS is characterized by its ability to support extremely high stocking densities and high net production with a limited volume of water requirements. However, high stocking density will result in high fish wastes which are toxic ammonia compounds in the form of TAN and un-ionized ammonia excreted into the water and uneaten feed particles that need to be removed.

Biochar has the potential role in improving aquaculture water quality in fish culture by lowering the level of TAN and un-ionized ammonia in a RAS.

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Also corn cobs has a potential media in improving aquaculture water. The use of charcoal for water purification to remove unwanted dissolved organic pollutants is well established. However, there has been limited research on the potential of biochar to improve the quality of aquaculture water in RAS for fish production. Therefore, the project will contribute to the aquaculture sector by establishing the potential of biochar filtration in improving the quality of aquaculture water specifically in reducing the TAN concentration.

II. MATERIALS AND METHODS

A. Preparation and Carbonization of Corn Cobs

Corn cobs samples were collected. Impurities and other foreign materials were removed to attain the uniformity of the samples. A pyrolytic converter was used to carbonize the corn cobs. For each batch of the biomass samples, ten kilograms (10 kg) of samples were loaded inside the kiln. Rice hulls were fed around the fuel feeder every 20 min and when the fire reached the top feeder until the samples were fully carbonized.

The biomass samples were subjected to heat with minimum presence of oxygen at an average of five hours. Carbonized samples were left inside the kiln overnight to release the heat inside the kiln and to make sure that it would not become ash when in contact with air. After carbonization, samples were crushed to achieve uniformity then sieved manually within wire mesh sizes of 1 and 5 mm to attain a 1-5 mm biochar sample size. Figure 1 shows biochar production and utilization method.

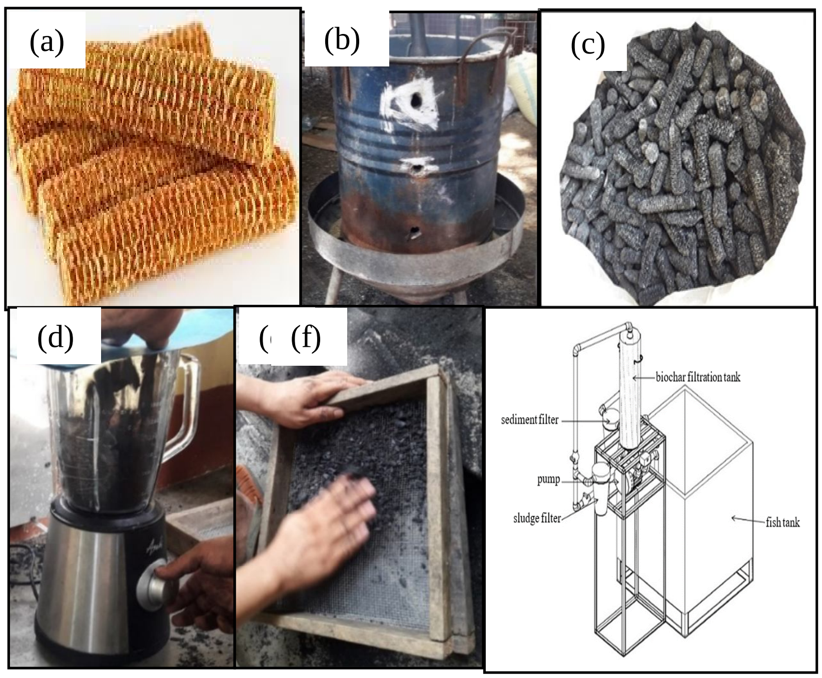

Fig 1. Biochar production and utilization (a) corn cobs (b) pyrolytic converter (c) carbonized biochar from corn cobs (d) crushing of samples (e) sieving (f) biochar filtration system

B. Devising a Biochar Filtration System in RAS

A biochar filtration system for the reduction of TAN and un-ionized ammonia, removal of the feed residues, and aeration in grow out tank was devised. The system was devised from the principle of operation of a commercial water filtration system (Figure 2). The first stage of the system aimed to remove the feed residues by suctioning the bottom layer of the tank using a water pump. After the residues were filtered, the water was then transported to the biochar container wherein the TAN was adsorbed and reduced. To avoid the black coloring of the water in the biochar container, another filter system was installed. Lastly, the filtered water was released back to the fish tanks.

The flow of water into the tank was then used as aeration in the fish tanks during the biochar filtration process. With this, there was no need for an aerator to provide for the desired dissolved oxygen level during the operation of the biochar filtration system.

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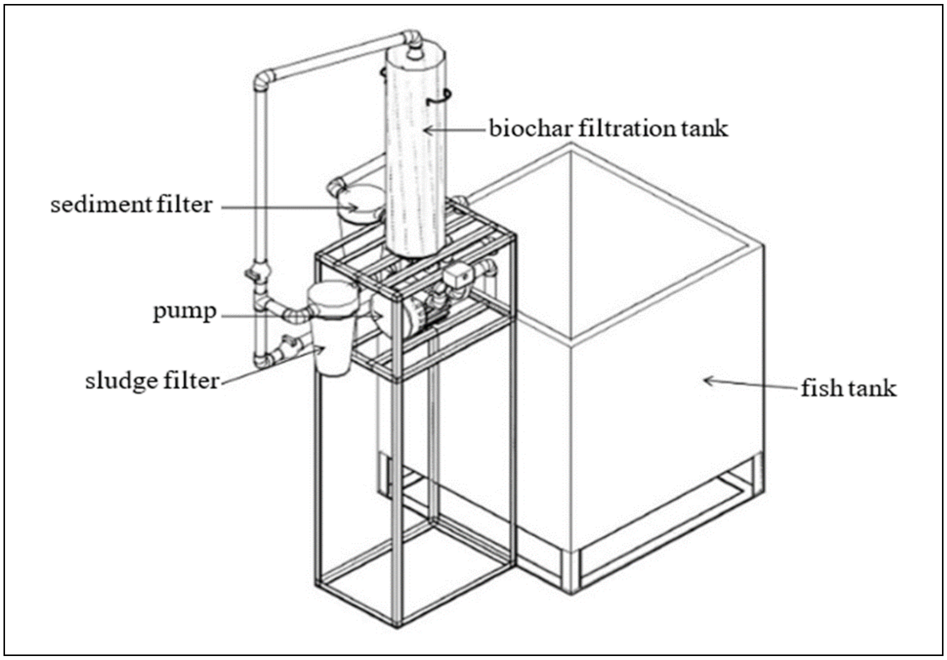

Fig 2. The biochar filtration system

C. Un-ionized Ammonia Adsorption Capacity of Biochar

Un-ionized ammonia (NH_3) which was more toxic to fish than ionized ammonia (NH_4^+) was calculated from total ammonia readings (Emerson *et al*., 1975). Total ammonia is the sum of ammonia (NH_3) and ammonium (NH_4^+) concentrations. A multi-parameter tester was used to determine the adsorption capacity of biochar in terms of the total ammonia.

D. Amount of TAN Adsorbed and Removal Efficiency using Biochar

The amount of TAN adsorbed and removal efficiency of using biochar was computed using Equation 1.

$$q_e = V/W \times (C_f - C_i) \qquad \text{(Equation 1)}$$

where: q_e - the amount of TAN and un-ionized ammonia removed ($mg \cdot g^{-1}$)
C_f - final TAN concentration, ($mg \cdot L^{-1}$)
C_i - initial TAN concentration, ($mg \cdot L^{-1}$)
V - volume of the aquaculture water in tank, L
W - weight of the biochar, g

Two basic approaches were used in interpreting the experimental results for adsorptive capacity. Nameni et al (2008) computed the percent of MB adsorbed (adsorption efficiency, %) using the formula in Equation 2.

$$\%\ \text{TAN adsorbed} = [(C_i - C_f) / C_i] \times 100 \qquad \text{(Equation 2)}$$

where: C_i - initial concentration,
C_f - final concentration

E. Statistical Analysis

Paired t-test was performed for the validation of the results in an actual RAS using the devised biochar filtration systems. Comparison among treatment means was analyzed using Duncan Multiple Range Test (DMRT) at 5% level of significance.

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III.RESULTS AND DISCUSSION

A. Corn Cob Properties

Corn cobs properties were determined by performing proximate analysis. Properties such as percent moisture, volatile combustible matter, ash and carbon content were determined to assess its quality. The higher the fixed carbon from biomass, the higher the biochar yield.

Proximate analysis revealed that the percent moisture of the corn cobs samples was 4.43 percent. Results revealed that the amount of water in biochar is within the acceptable value and much lower than the accepted moisture content of 10%. The moisture content has no effect on the adsorptive property of the biochar. Hence, if the moisture content is high, the more susceptible is the carbon to fungi growth, thus, the shelf life is reduced.

The carbon, oxygen and hydrogen component of corn cobs also known as the volatile combustible matter revealed a 14%. The result of the volatile matter is considered excellent which means that the carbonization is prolonged and at a high temperature. This also signifies that the corn cobs used is of good quality. The ash content of the biochar samples revealed that corn cob has only 6.65% which was within the acceptable values. The desirable value of ash content of activated carbon ranges from 1-20 % as mentioned by Abdul (2007). Ash content dictates the quality of an activated carbon since it reduces its mechanical strength. Corn cob has fixed carbon content of 80.3%.

The amount of TAN adsorbed and removal efficiency using biochar was attributed to thermolysis of cellulose. This cellulose or lignin is considered as the main component of biochar which formed carboxyl groups. This functional groups were the basis for the effective adsorption of ammonia (Asada, *et.al*. 2002).

B. Biochar Filtration in a Recirculating Aquaculture Systems

The devised biochar filtration system in RAS (Figure 3) aimed to enhance the TAN and un-ionized ammonia level in RAS. It also served as a device to take in the sludge and sediment particles from grow out tank; filter the accumulated sludge, solid particles, and sediments; and for additional aeration inside the tank during the biochar filtration process.

The biochar filtration system was composed of five main parts, namely: fish tank, pump, biochar filtration tank, sediment filter, sludge filter and pump. The fish tank used for Nile tilapia production was a 1 m^3 plastic cubical tank. The biochar filtration tank with a height of 85 cm and a diameter of 30 cm was filled with 5-9 mm gravel at the bottom, 1 kg of 5-10 mm corn cob above the gravel, and then followed by 1-5 mm of sand on top of the corn cob (Figure 4).

Fig 3. The devised biochar filtration system

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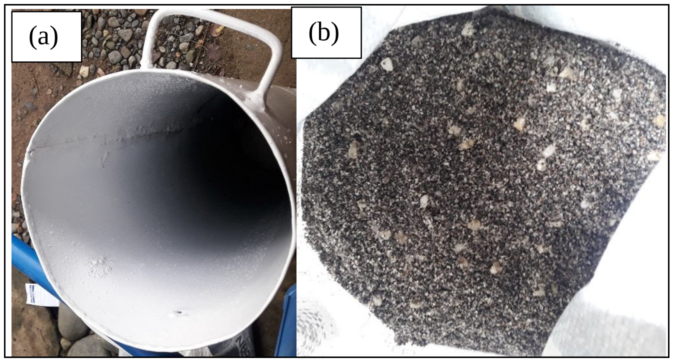

Fig 4. The biochar container (a) the biochar container (c) fine sand

The sediment filter aims to filter the sediments as well as the black coloring of the water when mixed with biochar (Figure 5). The sludge filter was used to filter the accumulated sludge and other solid particles inside the tank such as unconsumed feeds and fish excreta that settled at the bottom part of the tank (Figure 6). A sweeper/ suction pipe was connected to the filter to suck the sludge particles below the experimental tank. Also, this served as a first stage filtration so that the sludge particles were not transported to the biochar container. The sludge filter has a height of 52 cm with an inside diameter of 12 cm and an outside diameter of 13 cm.
An electric water pump was used to circulate the aquaculture water from the experimental tank, passing it through the sludge/solid filter, to the biochar filtration tank, to the sediment filter tank and lastly, to transport back the water to the experimental tank;

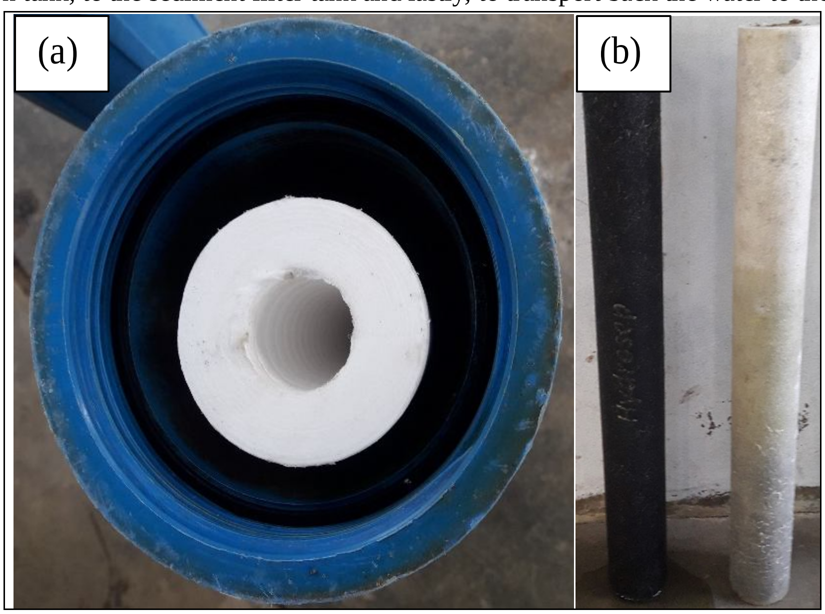

Fig. 5. The sediment filter (A) top view (B) filter media

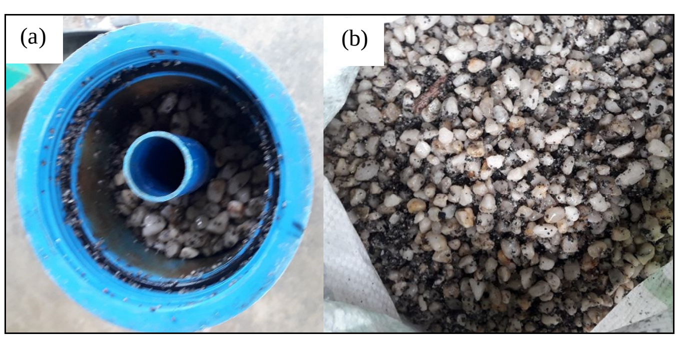

Fig. 6. The sludge filter (a) top view (b) gravel particles

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C. Operation of a Biochar Filtration System

The biochar filtration system was operated by pumping the water from the RAS tank passing to the sludge filter then filled up to the biochar container wherein biochar filtration takes place. The aquaculture water was then pass through to the sediment filter then flows back to the RAS tank (Figure 7).

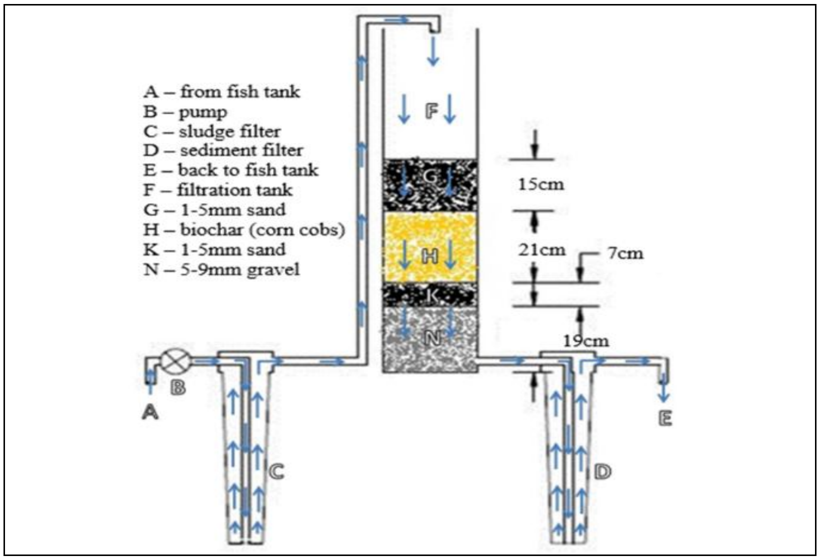

Fig. 7. Flow diagram of the biochar filtration system

D. Performance of the Devised Biochar Filtration System in a RAS

The performance of the devised biochar filtration system was evaluated through actual validation of the TAN and un-ionized ammonia reduction in an actual fish production environment (fish tank) in a RAS and was compared to the fish tank without biochar filtration.

E. TAN Reduction using the Biochar Filtration System

Results of the TAN reduction using the biochar filtration system revealed that for eight hours of operating the biochar filtration system, there is an evident enhancement of TAN in the grow-out tank. First run showed a decrease of 4.48 ppm from 6.12 ppm to 1.64 ppm. Another run showed a 4.47 ppm decrease from 5.8 to 1.33 ppm and lastly, a decrease of 3.35 ppm from the initial reading of 4.97 to 1.43 ppm (Figure 8).

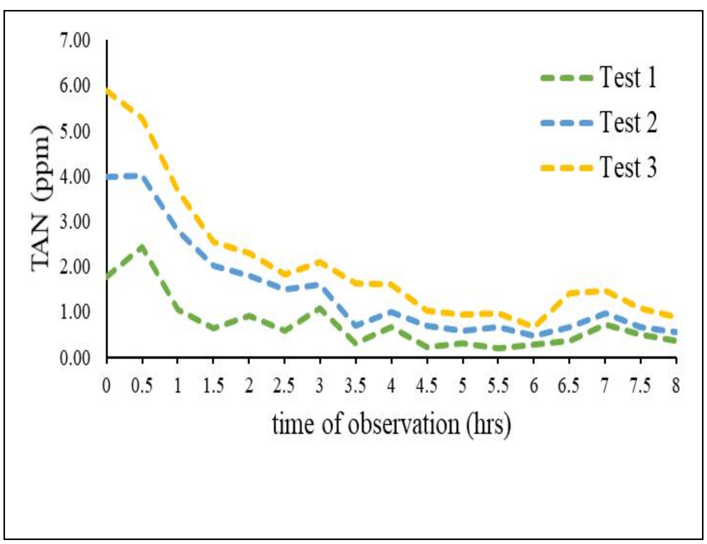

Fig.8. TAN reduction using biochar filtration system

F. Un-ionized Ammonia Reduction using Biochar Filtration System

Un-ionized ammonia reduction using biochar filtration system was calculated from total ammonia readings (Emerson, et al., 1975). Data showed that the average un-ionized ammonia levels were above the desirable level (Figure 11). The ideal un-ionized ammonia level for fish production was 0.01 ppm.

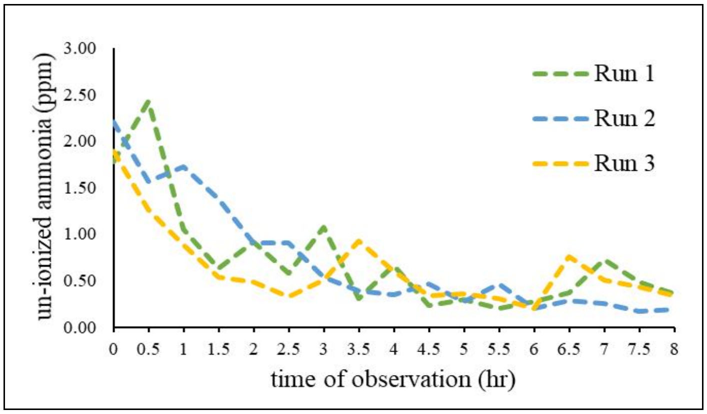

Fig. 9. Un-ionized ammonia reduction using the biochar filtration system

G. TAN Reduction at Different Stages of Biochar Filtration

The amount of TAN reduced at different filter stages was measured and evaluated. Results revealed that RAS tank had the lowest TAN reduction of 3.45 ppm after seven-hours of observation at a rate of 0.49 ppm per hour.

Time of observation (hr)	RAS Tank (ppm)	Filter 1 (Sludge Filter) (ppm)	Filter 2 (Biochar Filter) (ppm)	Filter 3 (Sediment Filter) (ppm)
0.0	4.97	5.20	5.35	5.17
0.5	5.03	4.80	3.09	3.72
1.0	4.73	4.56	3.94	3.93
1.5	4.26	4.19	3.77	3.78
2.0	4.01	3.97	2.80	3.01
2.5	3.55	3.22	2.08	2.23
3.0	2.87	2.66	1.90	1.86
3.5	2.43	2.33	1.71	1.65
4.0	2.09	1.98	1.53	1.57
4.5	2.01	1.92	1.23	1.42
5.0	1.86	1.70	1.15	1.11
5.5	1.67	1.75	1.09	1.03
6.0	1.73	1.64	1.26	1.15
6.5	1.55	1.71	1.05	1.08
7.0	1.52	1.43	1.12	1.10

Table 1. TAN reduction at different stages of biochar filtration

Biochar filtration (biochar filter) tank had the highest TAN reduction of 4.23 ppm with a rate of 0.60 ppm per hour, followed by the sediment filter of 4.07 ppm at a rate of 0.58 ppm per hour. Next was the sludge filter with 3.77 ppm at a rate 0.54 ppm per hour (Table 2). Results revealed that at the first filter (sludge), there was no significant difference on the reduction of TAN after passing through it while there was a significant difference on the second filter (biochar filter) before and after the biochar filtration. On the last filter, (sediment filter) results showed that there was no significant difference before and after passing.

IV. CONCLUSIONS

Results indicated that biofilter using corn cobs has a potential for the enhancement of TAN and un-ionized ammonia levels in RAS. It can be concluded that the percent moisture of the corn cobs samples was 4.43 percent, volatile combustible matter of 14%, ash content of 6.65% and fixed carbon content of 80.3%. The biochar filtration system successfully reduced the level of TAN at a rate of 0.56 ppm per hour for every 1kg biochar and 0.72 ppm per hour for the reduction of un-ionized ammonia in a 1 cubic meter fish tank under RAS. These results indicated that unutilized corn cobs in a biofilter can be used to mitigate the negative effect of un-ionized ammonia in a RAS.

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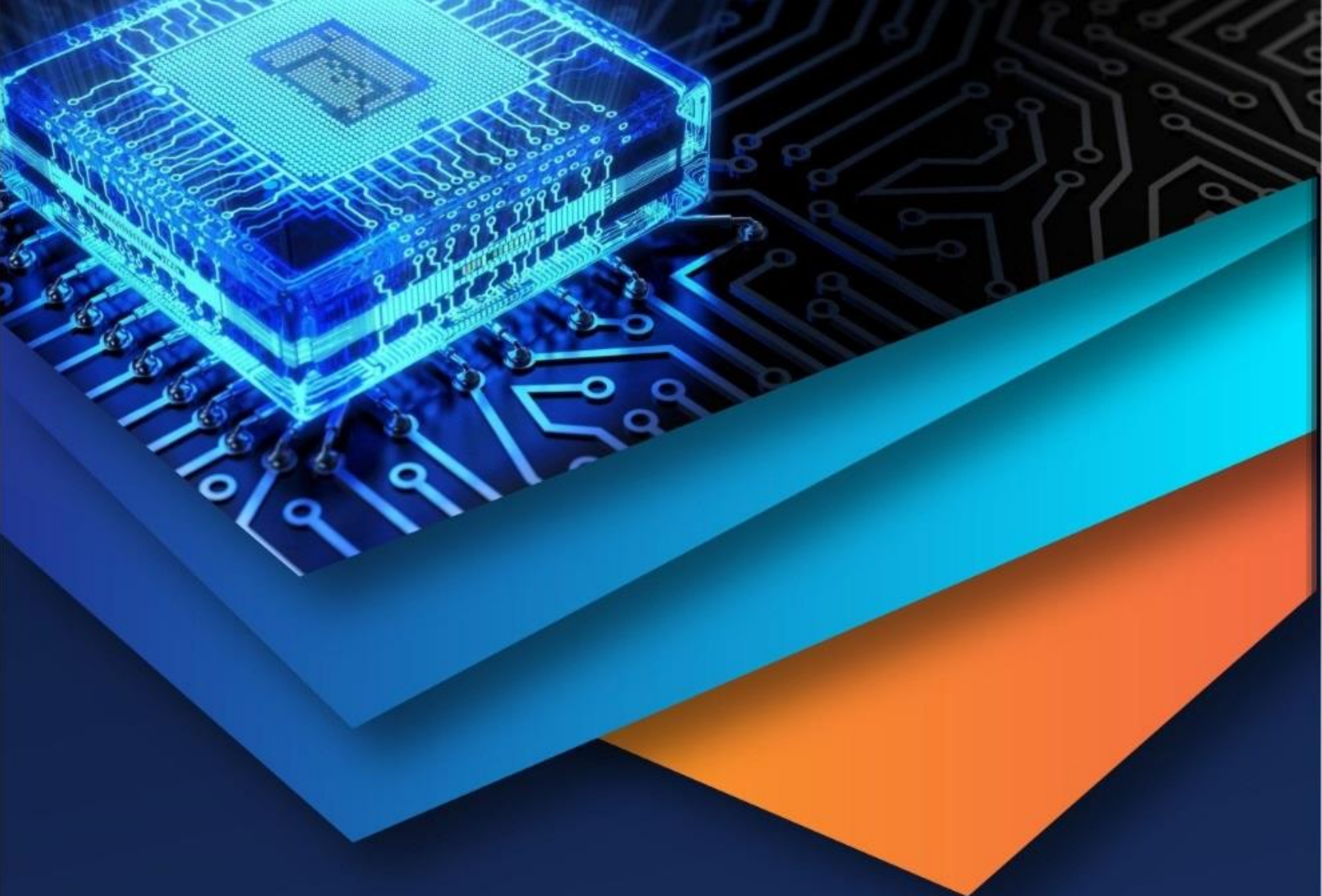

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Quantifying Arborescent Flora Diversity in a Secondary Forest Ecosystem: A Comprehensive Assessment in Nambalan, Mayantoc, Tarlac, Philippines

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Abstract

Forest plays a crucial role in providing essential ecosystem services, including water supply, climate regulation, and biodiversity conservation. This study aimed to assess the current state of the forest in Barangay Nambalan, Mayantoc, Tarlac. The specific objectives were to identify tree species in the area and determine the tree diversity index, with a focus on endemism and conservation status. Two transect lines, each spanning one kilometer, were established and a total of 10 sampling quadrats were surveyed. Ecological parameters (relative frequency, relative density, relative dominance, and importance value index) and diversity indices (Shannon-Weiner index, Simpson's index) were computed using the Paleontological Statistic Software Package for Educational Analysis (PAST 4.03). A comprehensive inventory revealed a total of 756 individuals representing 52 species, 46 genera, and 25 families. Among the recorded species, 10 (17.2%) were endemic and 11 (21.6%) were classified as threatened. The Fabaceae (20.8%), Moraceae (14.6%), and Euphorbiaceae (8.3%) were identified as the most abundant families. The computed diversity indices indicated that Barangay Nambalan retains a diverse forest cover; however, species composition was found to be relatively low. Based on the finding, this study recommends the strict enforcement of protective measures and legislation to mitigate further degradation of the remaining forest in Barangay Nambalan.

Keywords

Forest Diversity, Tree Species, Endemism, Conservation Status, Transect Survey, Diversity Indices

1. Introduction

Arborescent flora, comprising trees, plays a crucial role in forest ecosystems, serving as a key component for resource conservation and management in both rural and urban areas [1]. Forest provide a wide range of valuable services, including water supply and rainfall maintenance, security and nutrition, climate control, and biodiveristy conservation [2], which are essential for meeting immediate human needs. However, the future of global forests and trees is confronted by significant environmental and development challenges on a global scale [3].

The Philippines is recognized as one of the world's megadiverse countries, harboring a rich diversity of life forms in both aquatic and terrestrial ecosystems [4]. Nevertheless, biodiversity is currently under critical threat as human activities contribution to the degradation of natural resources, particularly forests [5]. According to the DENR-FMB [6], the Philippines has witnessed a staggering 70 percent decline in forest cover from 1900 to 2007, with forest area decreasing from 21 million hectares to a mere 6.5 million hectares due to extensive logging activities.

Central Luzon, a significant contribution to the country's economic growth, has witnessed the ongoing degradation of its remaining forestlands and watersheds due to rapid urbanization and development [7]. In Tarlac, located in Central Luzon, a substantial decrease in closed forest area has been observed, declining from 5407 hectares in 2010 to a mere 4.0 percent of the total tree cover by 2020. This decline can be primarily attributed to forest fires and extensive logging activities [6] [8]. Notably, Mayantoc, one of the municipalities in Tarlac, has experienced considerable tree cover loss compared to other regions [9]. Consequently, there exists an urgent imperative to undertake a comprehensive inventory and assessment aimed at identifying the trees species in the area, evaluation their conservation status, and formulating informed plans to safeguard the remaining forest cover. Hence, the main objective of this research was to assess the diversity of tree species in Barangay Nambalan, Mayantoc, Tarlac. Specifically, the study aimed to 1) Identify and Quantify tree species in the area; 2) Determine the tree diversity index and ecological parameters of forest communities; 3) Determine the endemism and conservation status of the tree species present in the area; and 4) To provide a recommendation regarding the present condition of forest in Barangay Nambalan, Mayantoc.

2. Review of Related Literature

2.1. Tree Diversity

An essential aspect of tree diversity research is the assessment of species richness, which refers to the number of tree species present in a given area. High species richness is frequently linked to various ecological functions, such as increased productivity, nutrient cycling, and resistance to disturbances [10]. Chao *et al.* [11] discovered that areas with higher tree species richness exhibited more significant biomass accumulation and carbon storage in a tropical rainforest.

In addition to species richness, tree diversity studies often examine species composition and evenness. Species composition refers to the specific combination of tree species present in an area, while evenness refers to the relative abundance of different species. Both factors are crucial in understanding community dynamics and ecosystem processes [12]. For instance, a study by Baraloto *et al.* [13] in a neotropical forest revealed that changes in species composition and evenness influenced the functional diversity of tree communities, affecting key ecosystem processes such as nutrient cycling and productivity.

Furthermore, research into the factors that influence tree diversity has provided insights into the mechanisms that shape forest ecosystems. Climate, topography, and soil characteristics have all been shown to influence tree species distribution and diversity [14]. Quesada *et al.* [15] found that tree species composition and diversity varied with soil fertility and hydrological conditions in the Amazon rainforest, highlighting the importance of edaphic factors in shaping forest communities.

Human activities and land-use changes also significantly impact tree diversity. Deforestation, habitat fragmentation, and conversion of forests to agricultural or urban areas have led to the loss of tree species and the homogenization of tree communities [16]. Studies have shown that human disturbances can decrease tree diversity and alter community dynamics, disrupting ecosystem functions [17]. For instance, a study by Laurance *et al.* [18] revealed that selective logging reduced tree species diversity and altered community composition in a tropical forest, affecting carbon storage and nutrient cycling.

Overall, research on tree diversity has emphasized its importance for ecosystem functioning and conservation. Understanding the patterns, drivers, and ecological implications of tree diversity is crucial for effective forest management, conservation strategies, and the sustainable use of forest resources.

2.2. Importance of Biodiversity

Biodiversity, the variety of life on Earth, is critical component of our planet's ecosystems and plays a fundamental role in sustaining the functioning and resilience of natural systems. According to Kanieski *et al.* [19], biodiversity is considered a key indicator of ecosystem well-being and directly reflects the conservation status of a particular area. A diverse and healthy biodiversity provides numerous natural services that are essential for human well-being. People living in rural areas near forests rely on a wide range of forest products for their subsistence, and the income generated from trees and forests is crucial for both rural and urban populations. Biodiversity conservation offers significant benefits in meeting immediate human needs, such as ensuring clean and reliable water resources, protection against floods and storms, and maintaining a stable climate. It also provides social benefits, including education, monitoring, recreation, tourism, and cultural values [20].

In the study conducted by Ludwig and Reynolds [21], several steps were identified in the investigation of biodiversity, including defining study objectives, delineating the study area, determining sampling methods, collecting and organizing data, measuring species similarity, and characterizing biotic factors. Inventory studies serve as the foundation for biodiversity conservation efforts, as they provide essential information for the sustainable use and protection of biodiversity components. Biodiversity assessments are globally recognized as fundamental activities in achieving sustainable biodiversity conservation [22].

Aureo *et al.* [23] emphasized the importance of understanding biogeographical patterns, species richness variations, and endemic trends in elevationally diverse areas for effective conservation strategies. By comprehending these patterns, conservation efforts can be targeted towards protecting and managing areas of high species richness and endemism.

Ganivet and Blomberg [24] highlighted the need for assessing both tree species diversity and forest structure at local and regional levels to gain insights into the current state of tropical forests and develop effective management strategies for their conservation. While assessments at local scales provide accurate estimates of species richness and forest structure, it is important to extrapolate these findings to regional scales to understand the broader picture of tree species diversity and forest structure.

2.3. Biodiversity Conservation

Biodiversity conservation is a crucial aspect of environmental management and sustainable development. One key aspect of biodiversity conservation is the recognition of the intrinsic value of biodiversity. Biodiversity encompasses a variety of life forms, including genes, species, and ecosystems, and its conservation is essential for maintaining ecological balance and resilience [17]. Biodiversity conservation efforts aim to prevent the loss of species and ecosystems and ensure their long-term survival.

The benefits of biodiversity conservation extend beyond ecological considerations. Biodiversity provides numerous ecosystem services that are vital for human well-being. For instance, intact ecosystems with high biodiversity can enhance water quality, regulate climate, and provide various industries with natural resources such as food, medicines, and materials [25]. Biodiversity conservation also plays a crucial role in supporting livelihoods, particularly for communities that rely on natural resources for their sustenance and income [26].

Biodiversity preservation is critical for ecosystems' continued functioning and resilience. Studies have shown that higher levels of biodiversity contribute to increased ecosystem productivity, stability, and resistance to disturbances [27]. Biodiversity conservation helps protect and restore vital ecological processes, such as pollination, nutrient cycling, and pest regulation, which are essential for maintaining the health and productivity of ecosystems [28].

Various strategies and approaches guide biodiversity conservation efforts. National parks and nature reserves are established to protect critical habitats and species [29]. Additionally, habitat restoration and rewilding initiatives aim to rehabilitate degraded ecosystems and reintroduce species to their historical ranges [30]. Collaborative efforts involving local communities, government agencies, and non-governmental organizations are crucial for effective biodiversity conservation, as they promote local participation and sustainable resource management [31].

Furthermore, incorporating indigenous knowledge and traditional practices into biodiversity conservation strategies has gained recognition. Indigenous communities often possess valuable knowledge about local ecosystems and have a deep understanding of sustainable resource use [32]. Engaging with indigenous communities can lead to more effective and culturally sensitive conservation practices.

Biodiversity conservation is paramount for maintaining ecological integrity, supporting human well-being, and ensuring sustainable development. It involves preserving species, ecosystems, and ecological processes and requires collaborative efforts and the integration of traditional knowledge. By conserving biodiversity, we can protect the planet's natural heritage and secure a more sustainable future for future generations.

2.4. Conceptual Framework

The INPUT-PROCESS-OUTPUT Model was used by the researcher to provide a general structure and direction for the study. **Figure 1** depicts the study's conceptual framework, in which the input consists of data collection through field inventory, transect and quadrat establishment, and specimen collection and preservation.

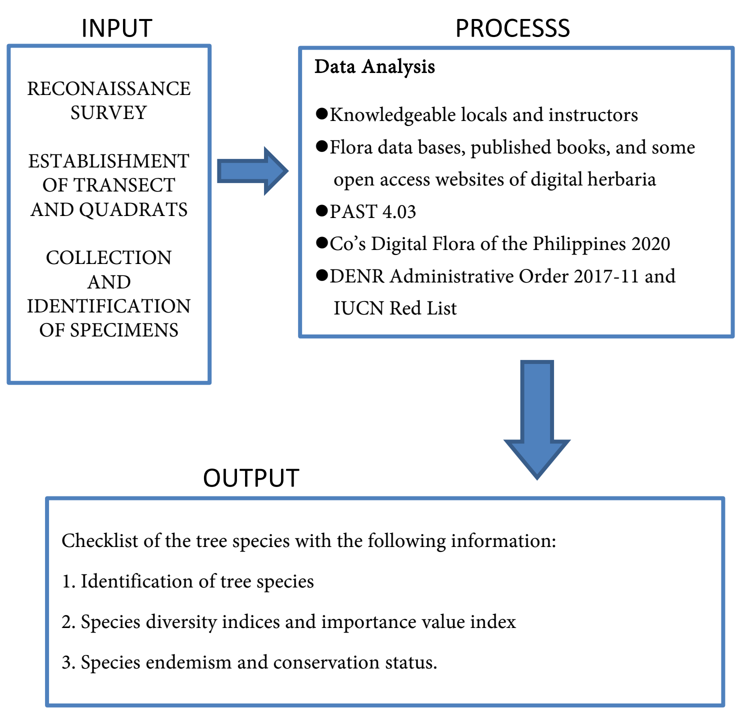


Figure 1. Conceptual framework of the study.

Plant names from family to species level are gathered, the number of individuals of each species, bio-measurements on diameter at breast height (cm), total height (m), and GPS coordinates of all corners of each quadrat. On the other hand, identification of the species was sought with the assistance of knowledgeable locals and instructors, as well as from databases, published books, and some open-access websites of digital herbaria.

For diversity indices, the Shannon Diversity Index formula was used as follows from the studies of Coracero *et al.*, [4]. Species endemicity and conservation status were determined using Co's Digital Flora of the Philippines 2020, D.E.N.R. Administrative Order 2017-11, and the I.U.C.N. Red List. The input and process resulted in identifying tree species present in the area, a tree diversity index, endemism, and the conservation status of tree species in Barangay Nambalan.

3. Methodology

3.1. Locale of the Study

This research was conducted in Barangay, Nambalan, Mayantoc, Tarlac, located in the Northwest part of the Tarlac Province. It is situated at approximately 15.3166 latitude, 120.3166 longitude on the island of Luzon. It is bounded on the west by the Zambales mountain ranges, on the south by the Municipality of San Jose, on the north by the towns of San Clemente and Camiling, and on the east by Santa Ignacia (**Figure 2**). Nambalan is generally a rough and mountainous area that falls under the climatic Type 1 of the Coronas system of classification, having two pronounced seasons: the dry season from November to May and the wet season during the rest of the year. Its population, as determined by the 2020 Census, was 1570. This represents 4.82% of the total population of Mayantoc as stated [33].

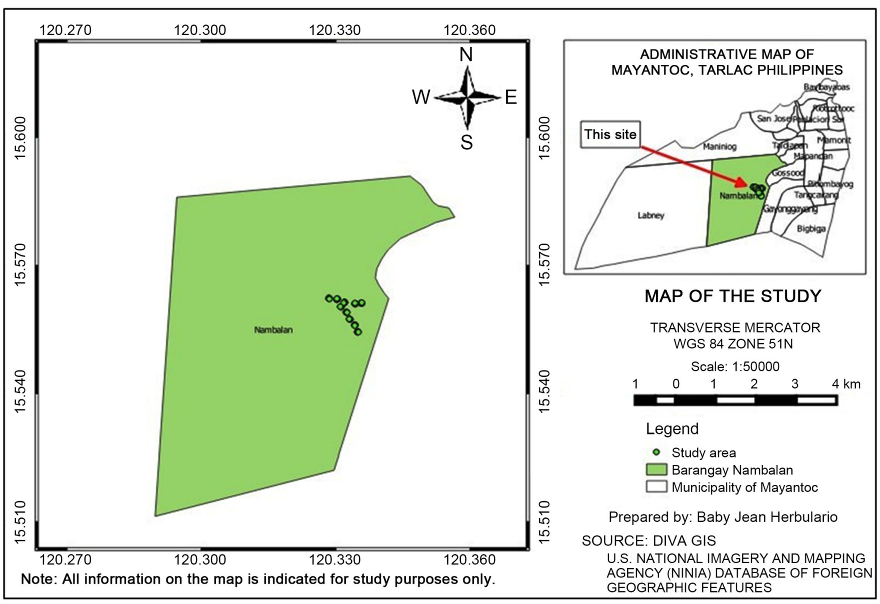


Figure 2. Map showing the location of the study area.

3.2. Data Collection Instruments

The instruments used in data collection were as follows: Procedural activities and formulas were obtained from references, such as previous studies by various researchers, specifically the study conducted [4]. Primary data gathering was through fieldwork activities, mapping and on-site observations, geotagging and tracking using locus map and GeoCam were used to document the activities within the research area.

3.3. Data Collection Procedure

Preliminary procedures were carried out before the conduct of the study. First, the researcher wrote an official letter informing the Barangay captain of the study's purpose and requesting permission to conduct it in the Barangay. This ensured the success of data collection while avoiding suspicion from members of the community. Second, prior to the plot's establishment, a reconnaissance survey was conducted. A mix of quantitative and qualitative analyses was performed. The qualitative component involved identifying the trees encountered per quadrat, while the quantitative component involved computing diversity indices and importance value indices for each species. Field visits, direct observation, and photo documentation were used to characterize the site's vegetation. Secondary data such as area, climatic data, soil, elevation, and other related information were gathered from the Barangay Nambalan Forest Land Use Plan and other online references. The study's mapping activity was created using Quantum GIS (QGIS 2.18) and data generated from the National Imagery and Mapping Agency (NIMA) database, which is accessible online through Diva GIS.

3.4. Transect and Quadrats Establishment

Two (2) transect lines were established with a length of one (1) kilometer each and with ten (10) sampling quadrats having a size of 20 × 20 meters (**Figure 3**). The sampling plots were established in alternating directions on the transect line with 250 meters regular interval.

3.5. Sampling and Data Collection

Biodiversity Assessment

A total of ten (10) 20 × 20-meter sampling plots were established for the identification of trees with at least 5 centimeter in diameter at breast height (DBH). **Figure 4** shows the actual establishment of the plot. Within the 20 m × 20 m sampling plot, tree species with a DBH of at least 5 centimeters were accounted for and measured. DBH, total height, and the number of individuals of each species found in the study area were collected, including GPS coordinates of all corners of each plot. DBH measurements were taken with a diameter tape. The total height of the trees was measured with the aid of an Abney hand level. The crown height and width were measured using estimation, as recommended by Lillo *et al.* [34]. Elevation and trees with flowers and fruits were also observed.

Figure 3. Location of 20 × 20 meters sampling plots.

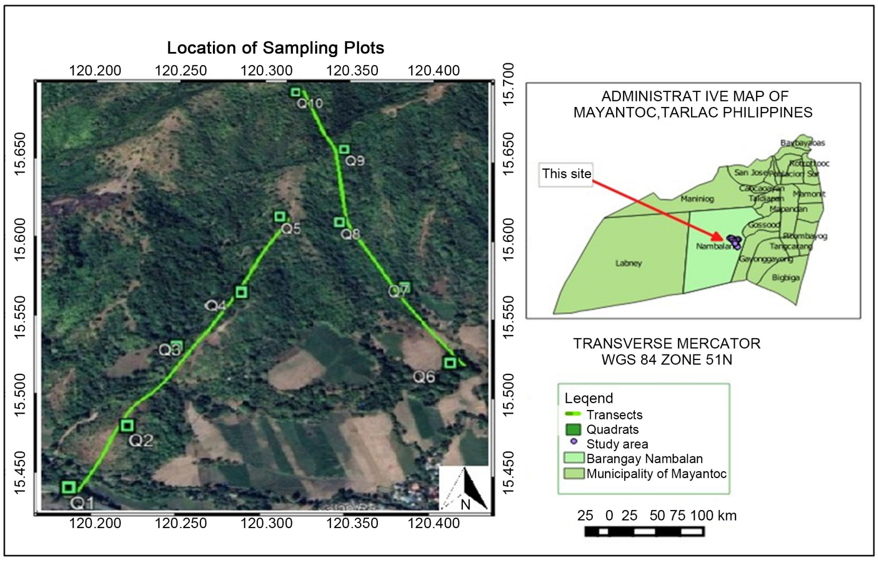


Figure 4. Location of 20 × 20 meters sampling plots.

3.6. Data Analysis

The process of vegetation analysis, including the assessment of tree diversity, computation of diversity indices, identification of tree species, determination of conservation status, and evaluation of species endemism, in this comprehensive discussion. The methods and references cited are based on the research of Coracero and Malabrigo [4], Aureo *et al.* [23], and Lillo *et al.* [34], as well as the use of various botanical resources.

The data collected for the study were utilized for vegetation analysis, specifically focusing on tree species. The evaluation of tree diversity involved the implementation of species abundance measures, such as density, frequency, and dominance. These measures are essential for determining the importance value of each species, which is a standard measurement in forest ecology to establish the rank relationship among different species [34].

The importance value was computed as the cumulative value of relative density, relative frequency, and relative dominance combined into a single metric [23]. This metric provides a comprehensive assessment of the significance of each species within the ecosystem.

Furthermore, diversity indices were computed using the Paleontological Statistics Software Package for Education and Data Analysis (PAST v.4.03). The interpretation of these diversity indices was based on the Fernando Biodiversity Scale (**Table 1**), as outlined in the study conducted by Coracero and Malabrigo [4]. This scale enables the researchers to understand the level of biodiversity present in the studied area.

To accurately identify tree species, a combination of resources was employed. Local experts, instructors, and knowledgeable locals were consulted to aid in species identification. Additionally, flora databases such as Co's Digital Flora of the Philippines [35] and the International Plant Name Index (IPNI) [36] were utilized. Published books, including Flora Malesiana [37] and Merrill [38], were also consulted. Furthermore, open-access websites of digital herbaria were referenced to access relevant information. The methodologies for species identification and the utilization of these resources were based on the studies conducted by Coracero and Malabrigo [4].

In order to determine the conservation status of each tree species in the Philippines, the researchers relied on the DENR Administrative Order 2017-11. This administrative order provides guidelines and regulations for the conservation of species in the Philippines. Additionally, the conservation status of the species worldwide was determined based on the IUCN Red List, which is maintained by the International Union for Conservation of Nature (IUCN) and provides a comprehensive assessment of the threatened species globally [39].

Furthermore, species endemism was determined using the plant species archive available in the Philippines, namely Co's Digital Flora of the Philippines [35], which is accessible online. This archive provides valuable information on the distribution and endemism of plant species within the Philippines.

The formulas for the computation of various parameters, including importance values, diversity indices, and other relevant metrics, were based on the studies conducted by Coracero and Malabrigo [4]. These studies provided the necessary mathematical frameworks for calculating these parameters accurately and effectively.

$$\text{Dominance} = (0.7854) \times \text{Diameter}^2$$

$$\text{Relative dominane} = \frac{\text{Dominance of a species}}{\text{Sum of the dominance of all species}} \times 100$$

$$\text{Frequency} = \frac{\text{Total number quadrats in which species occured}}{\text{Total number of quadrats studied}}$$

$$\text{Relative Frequency} = \frac{\text{Frequency of a species}}{\text{Sum of frequency of all species}} \times 100$$

$$\text{Density} = \frac{\text{Total number of individuals of species}}{\text{Total number of individual of all species}}$$

$$\text{Relative Density} = \frac{\text{Density of a species}}{\text{Sum of density of all species}} \times 100$$

$$\text{IV} = \text{Relative dominance} + \text{Relative frequency} + \text{Relative density}$$

Table 1. Fernando biodiversity scale.

Relative Values	Shannon Index	Evenness Index
Very high	3.5 and above	0.75 - 100
High	3.0 - 3.49	0.5 - 0.74
Moderate	2.5 - 2.99	0.25 - 0.49
Low	2.0 - 2.49	0.15 - 0.24
Very low	1.9 and below	0.05 - 0.14

4. Results and Discussion

4.1. Tree Species Diversity

The study identified a total of 756 individual trees belonging to 26 families, 46 genera, and 52 species within the two transects. The number of tree individuals per quadrat varied from 35 to 118, with DBH ranging from 5 centimeters to 80 centimeters. Remarkably, *Artocarpus blancoi* and *Syzygium cumini* were the only trees with a DBH of 80 centimeters, suggesting their potential significance in the ecosystem. The majority of species exhibited a DBH of less than 30 cm, indicating that the study area consists of secondary forests in the early stages of vegetation succession [4] [40].

The most abundant families observed were Fabaceae (20%) with ten identified species, Moraceae (13%) with seven identified species, and Euphorbiaceae (9%) with five identified species. This finding suggests that these families play a critical role in influencing the growth and survival of other species in the area [41]. Additionally, Fabaceae species were found to be easily germinating due to their nitrogen-fixing capability [42]. Moraceae and Euphorbiaceae were identified as important food sources for bats and birds, leading to high rates of seed dispersal and successful recolonization [43]. A similar study conducted by Cruz *et al.* [44] in Minalungao National Park in Nueva Ecija reported a high number of Fabaceae species (seven), followed by Moraceae and Euphorbiaceae with six and five species, respectively.

The dominance of Fabaceae, Moraceae, and Euphorbiaceae families highlights their significant role in shaping the vegetation dynamics and supporting the growth and survival of other species. Understanding these ecological relationships is crucial for effective forest management and conservation strategies.

Table 2 shows that quadrat 4 had the highest number of identified species and individual trees, with a total of 33 species and 118 individual trees. In terms of families, quadrat 5 had the highest number, with 23 families. While, quadrat 2, which is dominated by cogon (*Imperata cyclindrica*), was discovered to have the fewest number of individual trees, with a total of 35 individuals, and quadrat 10 was discovered to have the fewest number of families, with 12 families.

These findings demonstrated that variation in species richness was caused by differences in how different species respond to environmental conditions in each plot [45]. Furthermore, dominant species were more likely to maximize their

Table 2. Table summarizing the species composition of the ten sampling quadrats.

Number of Individual		No. of Species	No. of Families
Quadrat	Species		
1	35	19	16
2	37	14	113
3	59	23	21
4	118	33	22
5	94	31	23
6	73	28	20
7	93	32	21
8	100	27	18
9	95	31	19
10	52	22	12
TOTAL	**756**		

ability to capture more resources, resulting in the proliferation of their population over time compared to others [46]. Moreover, the density of species per area influences the development of stem diameter, but other factors such as edaphic and climatic factors may also influence the secondary growth of tree species [47].

Plant species identification was very much dependent on reproductive structures [48]. As a result, in order to perform a more accurate and convenient identification, the reproductive parts of the species must be collected in the field [4]. Furthermore, it could be a source of native species seeds for landscaping and seedling production in the area.

Out of the 52 tree species documented, 13 species were observed with reproductive parts within the sampling sites, as shown in **Figure 5**. These species include *Antidesma ghaesembilla* (Gaertn., Fruct), *Aglaia edulis* (Roxb) Wall., *Buchanania arborescens* (Blume), *Ficus nota* (Blanco) Merr., *Ixora philippinensis* Merr., *Macaranga grandifolia* (Blanco) Merr., *Melanolepis multiglandolusa* (Reinw. Ex Blume) Rchb.f. & Zoll., *Psychotria luzoniensis* (Cham. & Schltdl.) Fern.-Vill, and *Pittosporum pentandrum* (Blanco) Merr. It is noteworthy that all the recorded flowering plant species, like *Pittosporum pentandrum has the ability to suppress and inhibit the growth of Cogon* (*Imperata cylindrica*) *and Talahib* (*Saccharum spontaneum*); *it also produces good soil cover in denuded areas*, *which is useful for vegetative rehabilitation of degraded areas* [49]. This emphasizes the rich native floral diversity present within the study area and highlights the importance of conserving these native plant species to maintain the ecological balance and support local ecosystems.

In the study area, the presence of reproductive parts in a subset of tree species indicates active reproduction and ecological resilience. Understanding these species' reproductive patterns and characteristics adds to our understanding of their life history strategies and facilitates the development of effective conservation and management plans.

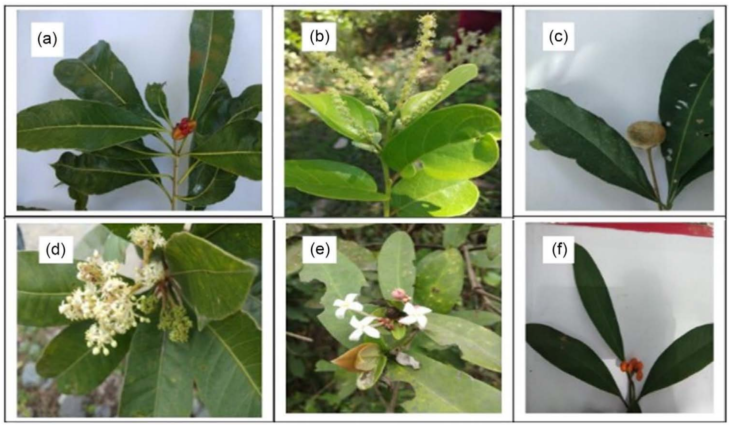


Figure 5. Tree species recorded with reproductive parts within the sampling site. (a) *Pittosporum pentandrum*, (b) *Antidesma ghaesembilla*, (c) *Aglaia edulis*, (d) *Buchanania arborescens*, (e) *Ixora philippinensis*, (f) *Psychotria luzoniensis*.

The predominance of native flowering plant species among the individuals recorded emphasizes the importance of native plant conservation. Native species are frequently better adapted to local environmental conditions and play critical roles in sustaining local biodiversity, ecosystem functions, and overall ecosystem stability.

4.2. Diversity Indices

In the case of Barangay Nambalan, the computed diversity index classifies it as a high diversity area based on the Fernando Biodiversity Scale, with a Shannon diversity index of 3.486 and an evenness index of 0.7098. This indicates a wide variety of species and an even distribution of individuals among them. According to Lillo *et al.* [34], high species diversity in an area contributes to a more stable and productive ecosystem, as diversity is associated with stability, productivity, and trophic structure [50].

Further analysis reveals that six quadrats, specifically two from Transect 1 and four from Transect 2 (**Table 3**), were classified as having high diversity per quadrat. This suggests that these specific areas within Barangay Nambalan contain a considerable number of different species. However, it is important to note that the diversity in Barangay Nambalan is primarily driven by the number of individual species rather than species composition.

This finding aligns with the assertion made by Guiang [51] that a forest community with a higher number of individual species is considered to have high diversity. Additionally, it is known that certain tree species develop specific adaptations that allow them to thrive better than others in a given area [52].

Figure 6 displays the quadrat with the highest number of identified species and individual counts, totaling 33 species and 118 individuals. Prominent species in this quadrat include Alibangbang (*Piliostigma malabaricum* Roxb.), Antipolo (*Artocarpus blancoi* El. Merr), Duhat (*Syzygium cumini* L.), Ipil-ipil (*Leucaena leucocephala*, Lam. De Wit), Kalios (*Streblus asper* Lour., Fl.), Niog-niogan (*Ficus pseudopalma*), Takip-asin (*Macaranga grandifolia*), Tibig (*Ficus nota*), and Yemane (*Gmelina arborea* Roxb).

Table 3. Diversity Indices per quadrats.

Quadrat	Species	Individual	Shannon	Simpson
1	19	35	2.837	0.9355
2	14	37	2.468	0.9028
3	59	23	2.943	0.9371
4	33	118	3.277	0.9563
5	31	94	3.213	0.9529
6	28	73	3.219	0.9559
7	32	93	3.307	0.9573
8	27	100	3.106	0.9472
9	31	95	3.264	0.9567
10	22	52	2.962	0.9423

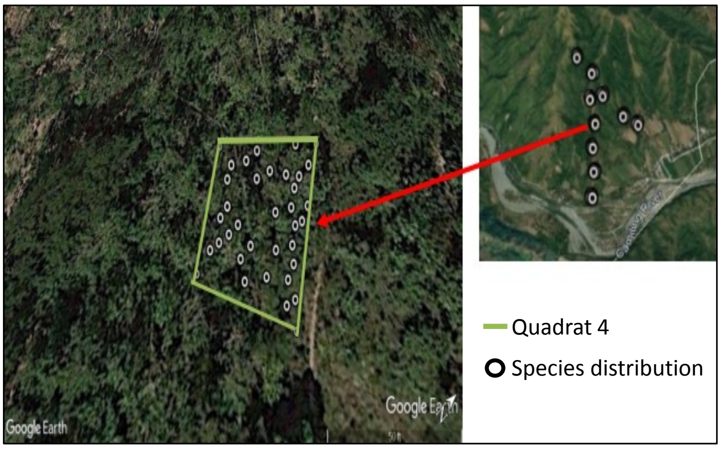


Figure 6. Quadrat with the highest species distributions in the study area.

The diversity observed in this particular plot can be attributed to various factors, including the type of soil, the presence of specific species, and the ground cover. As noted by Cordova *et al.* [53], the role of leaf litter in facilitating plant growth depends on the species. In the case of quadrat 4, which was characterized by a forest floor covered with leaf litter from dominant species, particularly the Fabaceae family, the high diversity observed was expected. Leaf litter promotes soil fertility through microbial activities that are essential for plant growth [53].

Figure 7 shows the plot with the lowest number of identified species and individual species. There were 14 identified species in the area, with 37 individual species. Alibangbang (*Piliostigma malabaricum* (Roxb.) Benth), Akleng parang (*Albizia procera* (Roxb.) Benth), Banato (*Mallotus philippensis* (*Lam.*) *Muell. Arg.*), Binayuyo (*Antidesma ghaesembilla Gaertn*), Hauili (*Ficus septic* (Blanco) Merr.), Lamio (*Dracontomelon edule* (Blanco) Merr.), Mamalis (*Pittosporum pentandrum* (*Blanco*) *Merr*), Molave (*Vitex parviflora* Juss.), Tagpong-gubat (*Psychotria luzoniensis* (*Cham.* & *Schltdl.*) *Fern.-Vill*, *Pitt*) and Takip-asin (*Macaranga grandifolia* (Blanco) Merr.).

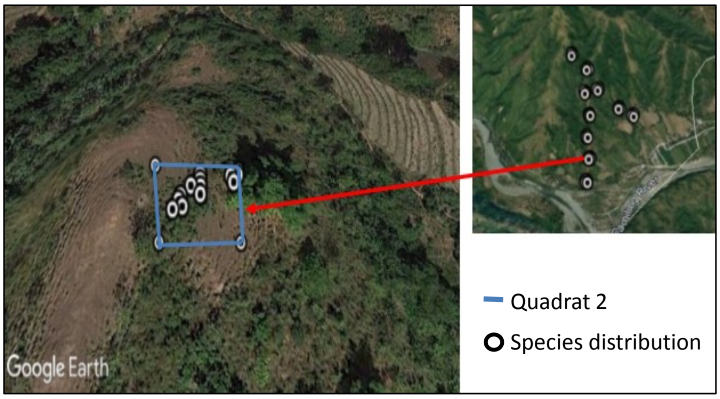


Figure 7. Quadrat with lowest number of identified species.

Based on the observations made during the establishment of the transect, this area was dominated by Cogon grass (*Imperata cylindrica*), which affects the species diversity in the ground cover because cogon commonly over-dominates the vegetation that is prone to burning or fire [53], as well as in areas that are overgrazed and intensively cultivated [54].

Table 4 shows that Transect 1 was more diverse compared to Transect 2, with an average species diversity of 3.46. In terms of species richness, transect 1 had the highest number with 44 species compared to transect 2 with only 41 species, but in terms of number of individual species, transect 2 had the highest number of individuals with 413 individuals, while transect 1 had only 343 individuals.

These findings demonstrated that forest structure varies from lowest to highest elevation in terms of tree diameter, height, and species composition. The type of soil in the area, ground cover, species types, elevation, and climatic conditions all had an impact on these findings. This result confirmed Amoroso *et al.* [55] finding that elevation influences species composition by providing complex environmental gradients such as temperature, rainfall, and relative humidity, as well as different nutrient requirements of the tree species in the area.

4.3. Species Importance Values Index (IVI)

The ten most important species in terms of dominance, frequency, and density were *Piliostigma malabaricum* (18.75), *Artocarpus blancoi* (17.28), *Gmelina arborea* (16.82), *Syzygium cumini* (15.64), *Mangifera indica* (12.64), *Ficus nota* (11.40), and *Psychotria luzoniensis* (Cham). **Figure 8** shows values for *Buchanania arborescens* (11.19), *Ficus septica* (9.74), and *Albizia procera* (9.36). These species are divided into seven (7) families. According to Lillo *et al.* [34], importance value is a quantity that measures the degree of significance of tree species in a given forest community and is derived from three variables, namely density, cover and frequency.

These results indicate that these plants were the most common and the most dominant species in the area [56]. It confirmed that the relative density of each species contributed most to their IV and the floristic composition and vegetation structure of this area were dependent from these species [53]. In addition, species with high importance value index as shown in **Figure 9**, indicates that the species was well-represented due to a large number of individuals observed compared with other species [57] at the same time it provides an overall estimate of the influence of these species in the community [53].

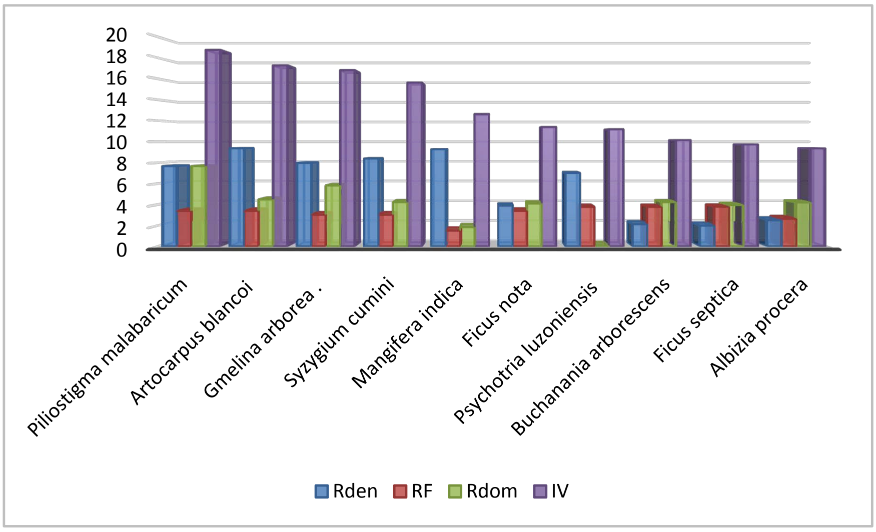
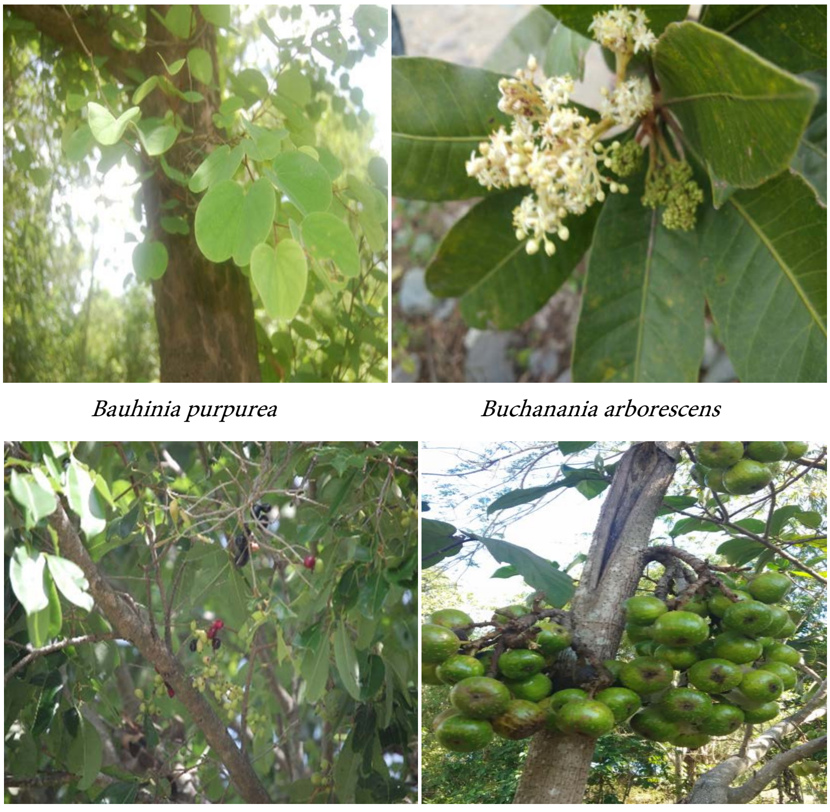


Figure 8. List of species with high Importance Value (IV).



Bauhinia purpurea *Buchanania arborescens*

Syzygium cumini *Ficus nota*

Figure 9. Tree species with high importance value index in the area.

Table 4. Diversity indices values per transect.

Diversity indices	Transect 1	Transect 2	Brgy. Nambalan
Taxa/Species	44	41	46
Individuals	343	413	756
Shannon	3.46	3.413	3.43
Simpson Evenness	0.9617	0.9602	0.9622

4.4. Species Endemism and Conservation Status

As shown in **Table 5** species endemicity assessment revealed nine (9) endemics species comprising 18.8% of the total tree species. It includes *Buchanania arborescens* (Blume), *Semecarpus cuneiformis* Blanco, *Canarium hirsutum* Willd, *Macaranga grandifolia*, *Artocarpus blancoi* (Elm.), *Broussonetia luzonica* Merr, *Ficus nota* (Blanco) Merr., *Ficus pseudopalma* Blanco, FL., *Psychotria luzoniensis* (Cham. & Schltdl.) Fern.-Vill. All endemic species was present both in transect 1 and 2 except for *Canarium hirsutum Willd* which was present only in Transect 2 as shown in **Table 5**.

This result confirmed that endemic species in the area should be given priority in conservation planning because these species are more vulnerable to threats due to their narrow range [58]. In addition, information on the geographic distribution of plant species in the area helps avoid species extinction and, at the same time, it plays an integral basis for the formulation of conservation and management strategies [53].

The conservation assessment was based on the International Union for the Conservation of Nature (2021-3) and DENR Administrative Order No. 2017-11. The assessment result showed that of the 52 species collected, only 11 (21.6%) of the total species were threatened as shown in **Table 6**.

In the IUCN Redlist, seven (7) species were categorized as Vulnerable, namely *Macaranga grandifolia*, *Afzelia rhomboidea*, *Vitex parviflora* Juss., *Sandoricum koetjape* (Burm.f.) Merr., *Artocarpus blancoi* (Elm.) Merr., and *Eucalyptus deglupta* Blume, while *Pterocarpus indicus* was listed as Endangered and *Aglaia edulis* was in the not threatened category (**Table 6**).

While in the DAO 2017-11, or the Updated National List of Threatened Philippine Plants and their Categories, only six (6) species were threatened. Apunan (*Diospyros cauliflora*), Rambutan (*Nephelium lappaceum*), and Narra (*Pterocarpus indicus*) were listed as vulnerable, while Tindalo (*Afzelia rhomboidea*) and Molave (*Vitex parviflora*) were endangered, and *Aglaia edulis* fell into the category of other threatened species, while the remaining five (5) species were not assessed. Among the notable species were Molave (*Vitex parviflora*) and Tindalo (*Afzelia rhomboidea*) (**Table 6**).

This result showed that there were eleven species recorded in this inventory that should be given priority for conservation because the ecological significance of any land formation relies not only on species richness but also on the number of native, endemic, and even threatened species present in the area [59].

Table 5. List of endemic species in the study area.

Family Name	Scientific Name	Common Name	Transect
Anacardiaceae	*Buchanania arborescens*	Balinghasai	1 & 2
	Semecarpus cuneiformis	Kamiring	1 & 2
Burseraceae	*Canarium hirsutum*	Pagsahingin	2
Euphorbiaceae	*Macaranga grandifolia*	Takip-asin	1 & 2
Moraceae	*Artocarpus blancoi*	Antipolo	1 & 2
	Broussonetia luzonica	Himbabao	1 & 2
	Ficus nota	Tibig	1 & 2
	Ficus pseudopalma	Niog-niogan	1 & 2
Rubiaceae	*Psychotria luzoniensis*	Tagpong-gubat	1 & 2

Table 6. Taxonomic list of Threatened species in the study area.

Family Name	Scientific Name	Common Name	DAO 2017-11	IUCN Redlist
Ebenaceae	*Diospyros cauliflora*	Apunan	VU	-
Euphorbiaceae	*Macaranga grandifolia*	Takip-asin	-	VU
Fabaceae	*Afzelia rhomboidea*	Tindalo	EN	VU
	Pterocarpus indicus	Narra	VU	EN
Lamiaceae	*Vitex parviflora Juss.*	Molave	EN	VU
Meliaceae	*Aglaia edulis*	Malasaging	OTS	NT
	Swietenia macrophylla	Mahogany	-	VU
	Sandoricum koetjape	Santol	-	VU
Moraceae	*Artocarpus blancoi*	Antipolo	-	VU
Myrtaceae	*Eucalyptus deglupta*	Bagras	-	VU
Sapindaceae	*Nephelium lappaceum*	Rambutan	VU	-

Legend: **VU**—Vulnerable; **EN**—Endangered; **OST**—Other Threatened Species; **NT**—Not assessed.

5. Conclusion and Recommendation

Based on the results, Barangay Nambalan is dominated by families Fabaceae, Moraceae, and Euphorbiaceae. There were 10 (17.2%) endemic species and 11 (21.6%) threatened species recorded in the area out of 52 species. From low to high elevation, the forest structure varies in terms of tree diameter, height, and species composition. These findings were influenced by the type of soil in the area, ground cover, types of species, elevation, and climatic conditions. The survey documented 52 species belong to 26 families and 46 genera, with 756 individuals. The most abundant, most frequent, and most important species found in the area was *Piliostigma malabaricum*, with 59 individual species, occurring in 9 out of 10 quadrats. In terms of species diversity, Barangay Nambalan is still diverse in terms of individual species but low in terms of species composition, with a Shannon-Weiner Index of 3.43 and Simpson Evenness of 0.7068.

The researcher recommends that laws governing timber cutting as stated in Section 77 of Presidential Decree (PD) 705 should be strictly enforced in order to reduce human activity in the area, such as illegal logging. Barangay local government units should craft a policy regarding land use plans to allocate their resources and protect the area's diversity. Also, the Barangay should conduct tree planting activities every year to conserve and protect their remaining resources in denuded forestland. Additionally, educate local residents, as well as the tourists who visit the area about the importance of native and endemic species through information education and communication publications. Furthermore, studies in other parts of the forest would be preferable to better assess its diversity so that the initial information gathered can be supplemented by additional survey data to create a good reference document for conservation and management in the area.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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SITE SUITABILITY ASSESSMENT AND CLIMATE VULNERABILITY FOR SWEETPOTATO IN MONCADA, TARLAC, PHILIPPINES

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ABSTRACT

Sweetpotato is a very resilient crop, needs plenty of sunshine, can tolerate drought to some extent but cannot survive water logging, on the other hand, storage roots are sensitive to changes in soil temperature, depending on the stage of its root development. Majority of the farm areas in sweetpotato production are lowland to hilly in which some of the farm lands are highly affected by flood, drought and erosion. Thus, there is a need to assess areas which are vulnerable to climate changes. Moreover, there is a need to evaluate possible suitable areas to meet the increasing demands in sweetpotato delicacies. To address this problem, identifying suitable sites for sweetpotato production and generating climate vulnerability maps could help farmers and local government units (LGU) to assess the proper use of different resource maps for decision making and planning. Five parameters (land use, soil type, groundwater, slope and road accessibility) were used in suitability assessment while the bioclimatic factors, hazards and the existing sweetpotato areas were used for the climate vulnerability analysis. Data were gathered from different agencies and field survey that was processed using MaxEnt and GIS software. Based on the result, majority of the municipality were suitable to highly suitable for sweetpotato production. On the other hand, climate vulnerability assessment shows that the effect climate and hazards to these areas was moderate to extremely vulnerable to these changes in the coming years.

KEYWORDS: Site assessment, Climate vulnerability, Sweetpotato.

1 INTRODUCTION

Sweetpotato is an important staple and emergency food in many countries and is appreciated for its very high nutritional value, both of the tubers and of the young aerial parts.[1] It is also considered as a vegetable, a snack food, ingredients in animal diets and now being used for processed products. Sweetpotatoes are of tropical origin, warm climates is well adapt and grow best during summer. A well- drained sandy loam is desired and heavy clay soils should be avoided as they can delay root development, causing in growth cracks and poor root shape. Sweetpotato needs plenty of sunshine, but shade causes yield reduction.[2] Sweetpotato can tolerate drought to some extent but cannot survive water logging.[3]

The Philippines is reported as one of the most affected countries in terms of climate related risks to agriculture.[4] Crops are both affected by extreme weather as well as the different climate hazards. These include typhoon, landslides, flooding and soil erosion and the magnitude and incidence of these hazards is projected to rise under a climate change scenario.[5] Rainfall is becoming more variable and temperatures are rising consequently leading to increase occurrence of droughts and floods, and changes in the timing and length of growing seasons.[6] Exposure and sensitivity together describe the potential impact that climate change can have on a system.

Site specific sustainable agro-techniques through well designed research is important to improve sweetpotato productivity. Areas, where sweetpotato is already staple food has great potential to improve the farming practices. Thus, identifying a suitable site for sweetpotato production and generating a climate vulnerability map could help farmers and Local Government Units for decision making and planning.

2 MATERIALS AND METHODS

2.1 Study Area

The area for this study focused on the land of Tarlac Province where the total area of 3,053.45 km^2 (305,345 ha) with 37 barangays (Figure 1). Tarlac has dry and wet season. Sweetpotato is the pride of Tarlac, as the province is one of the largest commercial producers of rootcrop in the country. In this study, the three (3) barangay with the largest areas in the municipality was chosen.

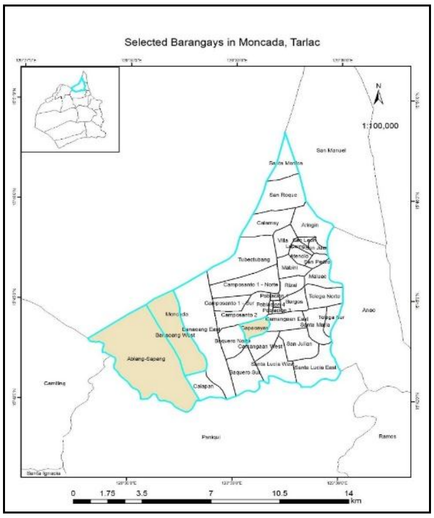


Fig. 1: Map of Moncada, Tarlac, Philippines.

2.2 Site Suitability Analysis

Secondary data and demographic data was collected from different Government organizations. Primary data was gathered through key informant interviews (KIIs) and focus group discussion (FGDs) in relation to sweetpotato areas and the existing farmer practices and management in sweetpotato production.

The five parameters used for the site suitability analysis were processed and analyzed using ArcGIS software. The given parameters are the soil type, slope, land use, groundwater and road accessibility (Figure 2).[7] The identified categories of each parameters have a different score based on its suitability.

The site suitability scoring and weighting system was based in five different parameters with suitability scoring (Table 1). Developing the suitability map of the municipality were done by overlaying the reclassified suitability parameters with their corresponding weights using the Equation 1. Then, it was classified into five suitability classes (Table 2).

Suitability Score = (Land use)*30 + (Soil type)*10 + Groundwater)*5 (1)
+ (Slope)*3 + (Road accessibility)*2

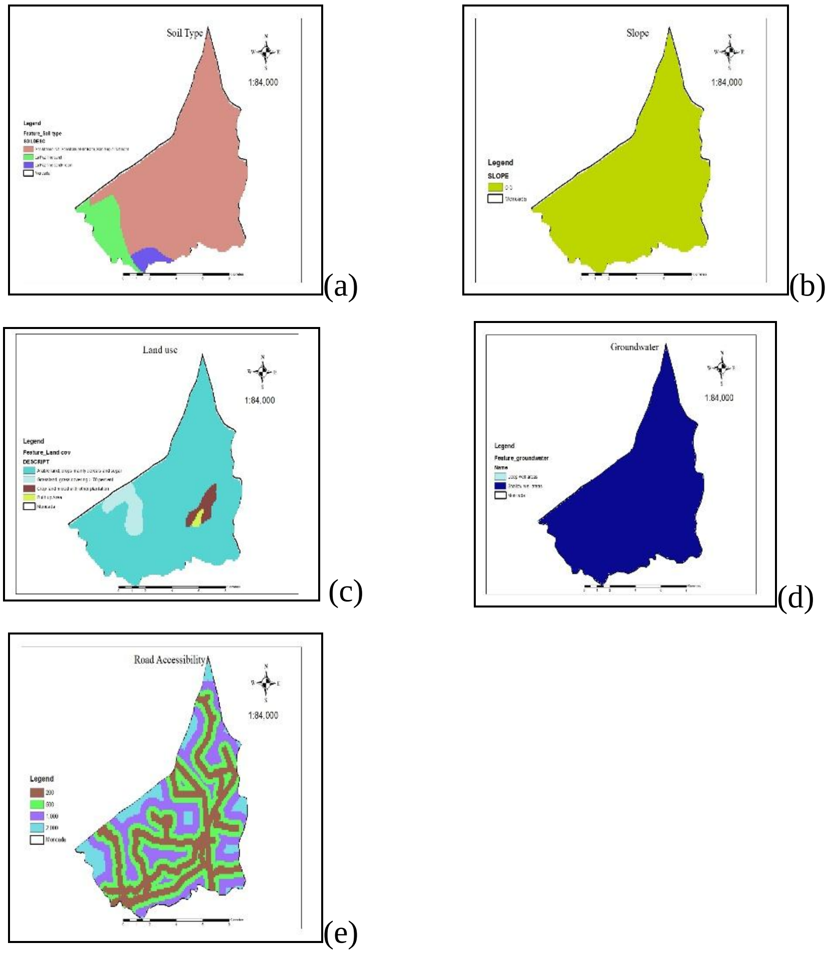


Fig. 2: Site Suitability Parameters Maps (a) Soil type Map (b) Slope Map (c) Land use Map (d) Groundwater Map (e) Road accessibility Map.

Table 1: The Suitability Scoring and Weighting.

Parameters	Category	Scoring	Weighting
Land use	Arable land Grassland, grass covering >70% Build-up area	10 7 0	30
Soil type	Sandy loam Clayloam Fine sand Other types	10 8 5 1	10
Groundwater	Deep well areas Shallow well areas	10 7	5
Slope	0-3 3-8 8-15 15-30 30 and up	10 8 6 2 0	3
Road accessibility (Buffer, meter)	0-200 200-500 500-1000	10 7 4	2

Table 2: The Suitability Classes.

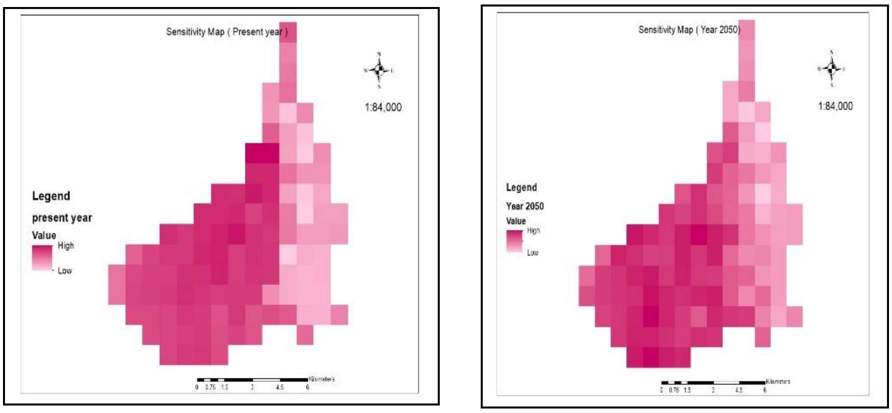
Class	Suitability Score
Highly Suitable	14-13.0001
Moderately Suitable	13-12.0001
Suitable	12-11.0001
Less Suitable	11-10.0001
Not Suitable	10-0.0000

2.3 Climate Vulnerability (Sensitivity-Hazard) Analysis

Sensitivity and exposure together describe the potential impact that climate change can have on a system. This was done by overlaying the sensitivity and hazard within the municipality.

Exposure I. Sensitivity analysis (changes of temperature and precipitation)

Sensitivity analysis was done by identifying the existing crop distribution through focus group discussion in participation of the Municipal Agriculture staff and sweetpotato farmers and the incorporation of bioclimatic data (temperature and rainfall) from the WorldClim. This was processed on the MaxEnt software, a species distribution model (SDM)[4] to produce the sensitivity map (Figure 3).



(a) (b)

Fig. 3: Sensitivity Map (a) Sensitivity Map of Present Year, (b) Sensitivity Map of Year 2050.

Exposure II. Hazards

Exposure represents the climate conditions that stimuli against extreme changes. The hazards such as typhoon, flood, erosion and drought (Figure 4) was considered which mostly affects the area. Secondary data on these hazards were gathered from different organizations and agencies. Hazard weights identification (Table 3) were participated by PDRRMC/MDRRMC staff and AEWs.

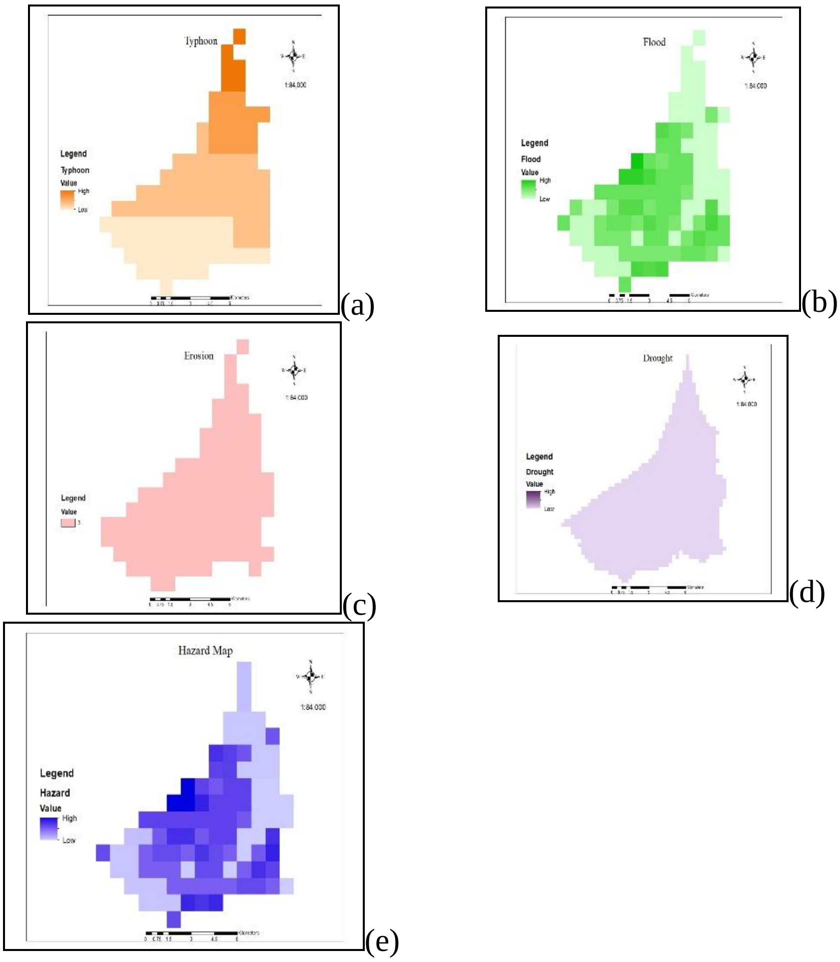


Fig. 4: Hazard Maps (a) Typhoon Map (b) Flood-prone Map (c) Erosion Map (d) Drought Map (e) Final Hazard Map.

Table 3: Hazard Weights.

Exposure II. Biophysical	**Probability of Occurrence**	**National Economy**	**Food Security**	**Houshold Income**	**Key Natural Resources to Sustain Productivity**	**Weight**
Typhoon	3	3	4	4	1	15
Flood	3	4	4	4	1	16
Erosion	1	1	1	1	1	5
Drought (Agricultural/Hydrological)	3	3	3	3	3	15

Note: Weighting the natural hazards into a climate risk exposure

Probability of occurrence: 1 in 1 year = 5, every 5 years = 3, 1 every 10 years = 1

Impact: Insignificant = 1, minor = 2, moderate = 3, significant = 4, disastrous = 5

3 RESULTS AND DISCUSSION

3.1 Sweetpotato Production Areas

The largest area for sweetpotato production in province of Tarlac is Moncada. Three barangays in Moncada were selected in the inventory of the existing crops. The largest area with sweeetpotato production is Ablang Sapang followed by Banaoang West and lastly, Capaoayan having a total farm area of 352.8 hectares with 317 number of famers, 50.9 hectares with 57 numbers of farmers and 3.5 hectares with 2 numbers of farmers, respectively (Figure 5).

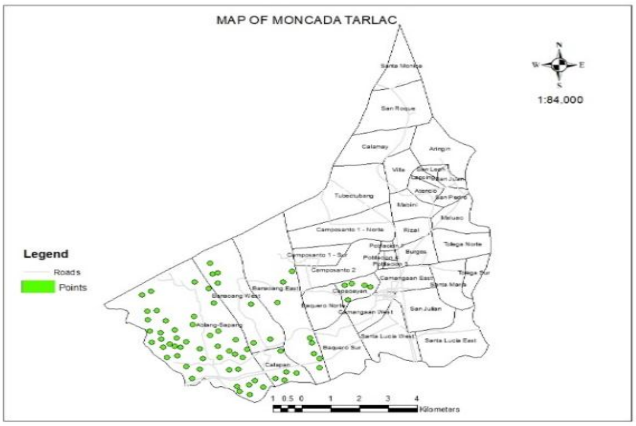


Fig. 5: Sweetpotato Production Areas with 3 Selected Barangays.

3.2 Site Suitability Map

The suitability map shows that the area in Municipality are classified as moderately suitable to highly suitable for sweetpotato production (Figure 6).

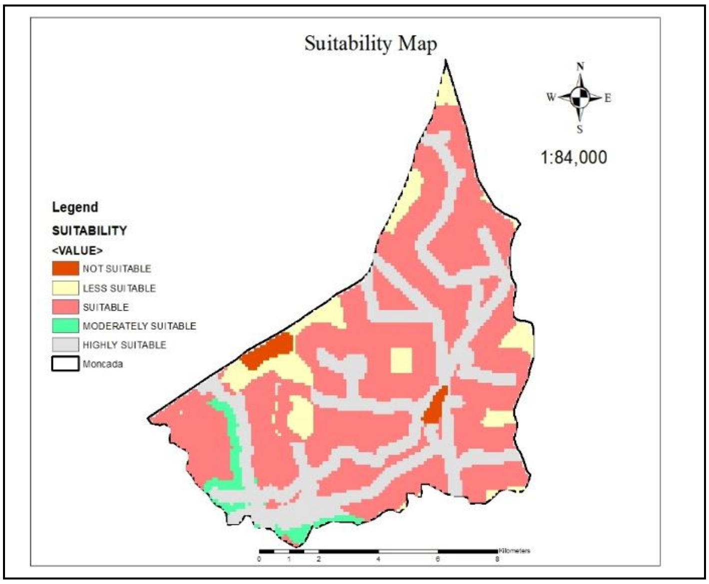
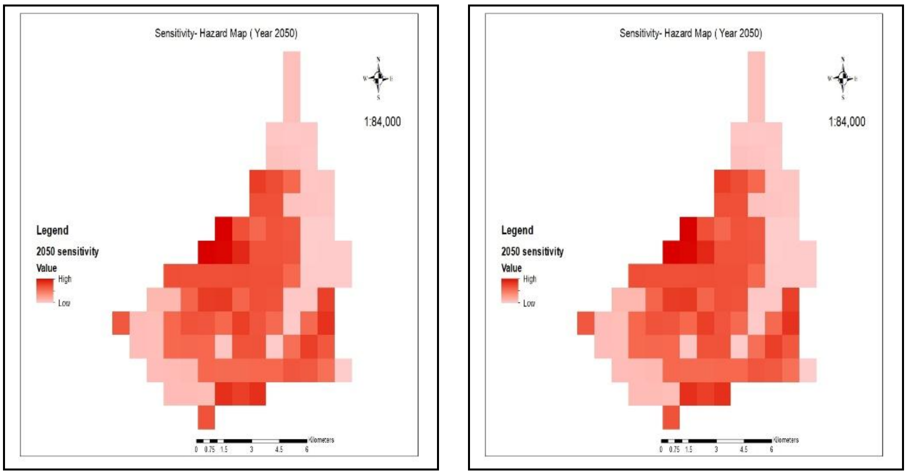


Fig. 6: Site Suitability Map of Sweetpotato in Moncada, Tarlac, Philippines.

3.3 Climate Vulnerability (Sensitivity-Hazard) Map

The impact of the sensitivity-hazard from the present up to year 2050 is moderate to extreme because of the changes in climate (Figure 7). This means that area is vulnerable for crop production.



(a) **(b)**

Fig. 7: Sensitivity-Hazard Map of Sweetpotato in Moncada, Tarlac, Philippines.

4 CONCLUSION

The area of the selected barangays in this study were found out that it is highly suitable, moderately suitable and suitable for sweetpotato production based on the parameters. The information of the impact of climate in the area is also identified together with the hazards defining the risks posed by climate change. This study provides information on sweetpotato that can be used for identifying measures to adapt to climate change impacts.

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Hydroponics Reservoir Temperature Monitoring and Controlling System under Greenhouse Condition

Amy Lizbeth J. Rico

Abstract: An automated reservoir temperature monitoring and controlling system for hydroponic system was developed, calibrated and validated in this study. The automated monitoring and controlling system was developed to monitor and control the reservoir temperature of nutrient solution in hydroponic system. The greenhouse available at the Center for Hydroponics and Aquaponics Technology (CHAT) and locally available materials and hardware for the hydroponics and automation were used in the development of the system. These devices were designed and assembled based on the conceptual framework of the study. The reservoir temperature sensor sends signal to the microcontroller which triggers the turning on/off of water chiller and the mixer. The instruments used were calibrated prior to the performance evaluation and obtained calibration equation for the water temperature sensor is y = x + 0.37. Validation of the automated reservoir temperature monitoring and controlling system was done and the recorded maximum temperature is 31 °C and the minimum temperature is 24 °C. The lettuce planted during the validation has an average height of 14.61 cm and the average leaf count of 12 for the lettuce crops during the 4th week after planting. A total of 4.78 kg of lettuce crop was harvested with an average of 20.6 grams per lettuce crop was obtained. Based on the performance evaluation and validation done on the automated reservoir temperature monitoring and controlling system, it was found to be reliable. This system becomes useful in reducing labor cost, and allows for real-time monitoring of reservoir temperature, therefore increasing farmers' crop productivity and income.

Index Terms: automation, greenhouse, hydroponics, reservoir temperature, sensor

I. INTRODUCTION

In the present scenario, almost everything can be controlled and operated automatically, but there are still a few important sectors in our country where automation has not been adopted or not been put to a full-fledged use, perhaps because of several reasons such as cost. Agriculture has been one of the primary occupations of man since early civilizations and even today manual interventions in farming are inevitable. Without automation in hydroponics, many growers spend approximately 15-30 minutes a day testing and correcting the system levels. This means that beginning growers will often spend more time on testing parameters until the farmers familiarize themselves with the nutrient levels needed. Also, farmers tend to over-correct one or two of the variables. The automated reservoir temperature monitoring and controlling system keeps the system levels stable and provides the optimal environment for the plants which results to bigger and healthier plants.

Hence, this study is conceptualized to develop an automated system by monitoring the reservoir temperature of the nutrient solution in a hydroponic system for optimum plant growth as this factor can greatly affect the growth of lettuce. Specifically, the study aimed to; (1) install an automated reservoir temperature monitoring and controlling mechanism for the nutrient solution, (2) evaluate the performance of the automated monitoring and controlling device, and (3) determine the response of lettuce on the automated monitoring and controlling device

II. MATERIAL AND METHODS

A. Conceptualization of the Study

The conceptual paradigm of the study is presented in Figure 1. The study aimed to monitor and control the reservoir temperature of the nutrient solution using hydroponic system under greenhouse condition. Through this process, time and labor can be saved as well as real time monitoring of the parameters can be achieved.

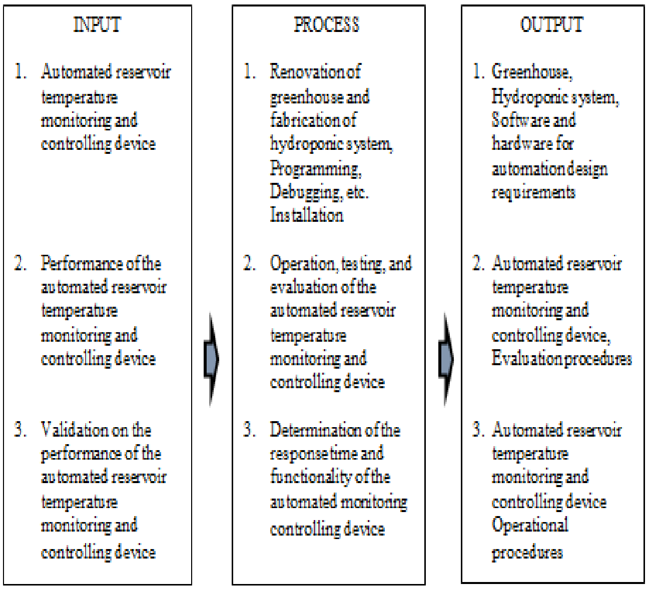

Figure 1. Conceptual framework of the study.

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B. The Production System

The automated hydroponic system used in the study is composed of the structural system, the hydroponic system, and the automation system.The automated reservoir temperature monitoring and controlling was tested in one of the greenhouse facilities located at the Center for Hydroponics and Aquaponics Technology (CHAT) measuring 3.0 meters in width, 4.0 meters in length, and 3.5 in meters height. The frames of the greenhouse are made from 2.54 cm galvanized iron pipes bended and welded together to form a Quonset-type structure. The structure is provided with three roof covers: the insect-proof net in the inner side, the ultraviolet- resistant plastic film in the middle and the gravy woven net shade on the outer side that offers strength and improve aerodynamics to withstand strong wind gust and heavy rains. The available water supply and power supply was used in the operation of the hydroponics system.

The recirculating tube culture system was used in hydroponic system. The hydroponic system was enclosed in the structural system. The grow pipes used was 300.0 cm in length and 0.075 cm diameter. A slope of 1 cm/100 cm of the pipe length was employed for the water to flow through the pipe with ease. The PVC pipes were drilled with 5.08 cm diameter holes and were spaced at 16.5 cm between holes (center to center) and made in 2-layer and 4-column pipe layout. A 150 L reservoir served as the source of water in the hydroponics system where the water was pumped to each growing tubes. The water flow in the hydroponic system was run by a 65-watt submersible pump, 1-2 liters/min flow for each growing tube that lifts the water to the upper layer of the growing tubes. A mixer inside the reservoir was installed to equally dispense the nutrient solution to the reservoir water.

Figure 2 shows the set-up of the automated pH monitoring and controlling device. The automation system served as the main component of the study and was composed of the controls, sensors, and hardware.

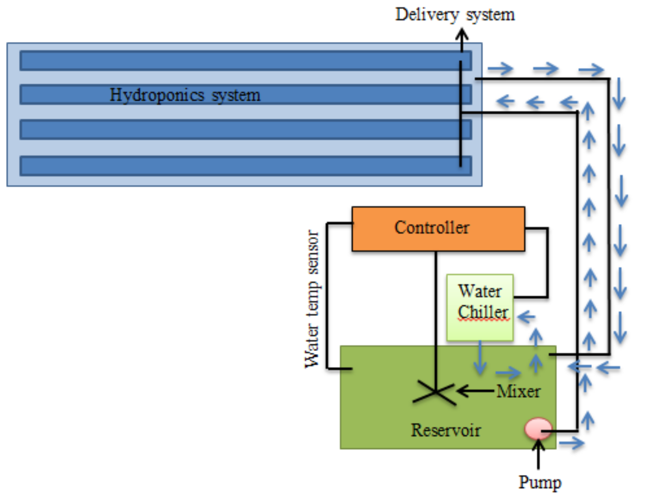

Figure 2. Set-up of the automated reservoir temperature monitoring and controlling device

C. Automation of the Reservoir Temperature Monitoring and Controlling Device

The automated reservoir temperature monitoring and controlling device basically monitor and control the temperature of the nutrient solution in a hydroponic system under greenhouse condition. Sensors were used to determine the reservoir temperature in the reservoir. The block diagram shown in Figure 3 is the layout of the hardware design that was used for the automated monitoring and controlling device. A microcontroller using the Arduino platform was used in programming the automation of the reservoir temperature monitoring and controlling device. Using this data, the microcontroller adjusts the temperature of the water in the system by turning on the mixer and the water chiller

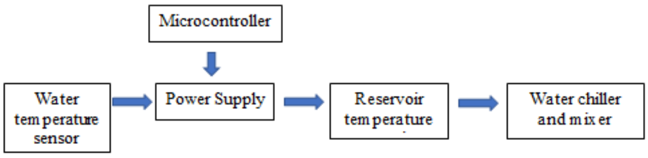

Figure 3. Block diagram of the automated reservoir temperature monitoring and controlling system

Shown in Figure 4 is the flow diagram of the automation used in the study. The LCD is initialized when the automation system is turned on. The reservoir temperature range of 24ºC - 30ºC for the nutrient solution was entered in the system. These ranges determine when the chiller and the mixer will be turned on. and determined using the water temperature sensor submersed into the reservoir. If the reservoir temperature reading is above 30ºC , the sensor sends signal to the microcontroller to trigger the chiller and the mixer to turn on. When the entered reservoir temperature range is attained, the sensors send signal the microcontroller to turn off the chiller and the mixer.

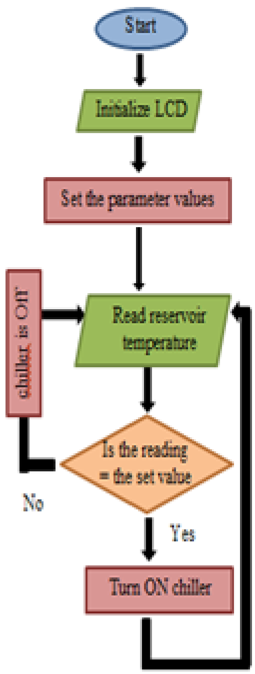

Figure 4. Flow diagram of the automated system

D. Calibration of the Water Temperature Sensor

The water temperature sensor was calibrated in order to achieve precision and accuracy.

The hourly reading for 24-hour period in the sensor was compared with the reading from the calibrated instruments. The difference in reading from the sensor and the calibrated instrument were recorded and graphed. Linear regression of the sensor reading and the calibrated instruments was obtained. The equation from the linear regression was inputted into the program for the water temperature sensor.

E. Final Testing

The reservoir temperature was monitored every day based on their response to the whole system. Automatic turning on of the device when the parameters are beyond the threshold range, response time of the device to be able to attain the threshold range, and automatic turning off of the devices when threshold range is attained were among the data gathered and recorded.

F. Lettuce Production

The leafy variety of lettuce (*Lollo rossa*) was used as planting material in the automated hydroponics system as this is commonly used as planting material in hydroponics system. Media composed of carbonized rice hull, sand and rice hull was used as planting media in the automated hydroponics system since these contain most nutrients needed by the plants. The planting cups containing 2-3 lettuce seeds were placed in cups. The cups were placed on individual cut-outs of the growing tubes. The net cups should touch the flowing water in the growing tubes to avoid the plants to be dehydrated. The pump continuously lifts the water and nutrient solution allowing the roots to avail of the nutrients. The reservoir temperature level of the nutrient solution was maintained at a range of 24ºC - 30ºC level which is the recommended reservoir temperature level for lettuce production under hydroponics system. At this reservoir temperature level, the needed nutrients were made available to the lettuce plants. These parameters were maintained throughout the growing stage until harvesting stage of the lettuce. The lettuce was harvested 27 days after planting.

G. Validation

Validation refers to the process of checking that a system meets the specifications and that it fulfils its intended purpose. In the automated hydroponics system, the data gathered from the final testing was analysed and graphed. The automation system was modified to optimize the production system based on the data gathered. Another growing cycle of the lettuce was planted in the automated hydroponics system. Response of the system was monitored from planting to harvesting of the lettuce. The gathered data during validation was compared from the gathered data from the final testing. The differences from the two growing cycle and their relationship was obtained.

III. RESULTS AND DISCUSSION

The microcontroller used in the automated hydroponics system is Arduino Mega 2560 which served as the brain of the system and served as the trigger. It also processes the sensor data. Most of the parts were connected to the Arduino using simple jumper wires and the wires were soldered to ensure that they would not get loose. All of the electronic parts were then placed into plastic enclosure to protect delicate electronic parts from dust and moisture.

A. Installation of the Automated Reservoir Temperature Monitoring and Controlling System for Nutrient Solution

The microcontroller used in the automated hydroponics system is Arduino Mega 2560 which served as the brain of the system and served as the trigger. It also processes the sensor data. Most of the parts were connected to the Arduino using simple jumper wires and the wires were soldered to ensure that they would not get loose. All of the electronic parts were then placed into plastic enclosure (Figure 5) to protect delicate electronic parts from dust and moisture.

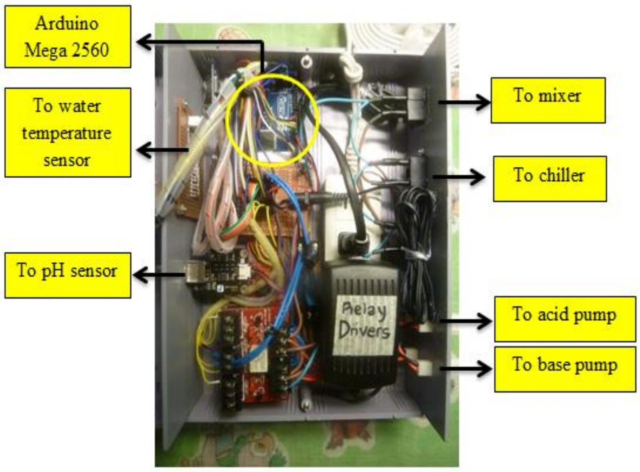

Figure 5. Electronic parts used in the automated hydroponic system

B. Water Temperature Sensor

The DS18B20 water temperature sensor shown in Figure 6 was used to determine the temperature of the reservoir in the hydroponics systems. The water temperature sensor was submerged to the reservoir and sends trigger signals to the microcontroller to activate the chiller thermostat and the mixer in the reservoir.

Figure 6. The water temperature sensor used in the study

C. Calibration of the pH Monitoring and Controlling System

Calibration of the reservoir temperature sensor used was done at the Center for Hydroponics and Aquaponics Technology in a 24-hour period before the data gathering. The reading from the sensor and calibrated instrument was obtained, recorded and graphed.

The graph of the calibration for the reservoir temperature sensor is shown in Figure 7. The graphs show linear relationship between the sensor reading and the instrument reading which also obtained an r^2 of 0.84. Based on the data gathered, the calibration equation for the reservoir temperature is $y = x + 0.37$. This equation was inputted in the program for the automation of the hydroponics system.

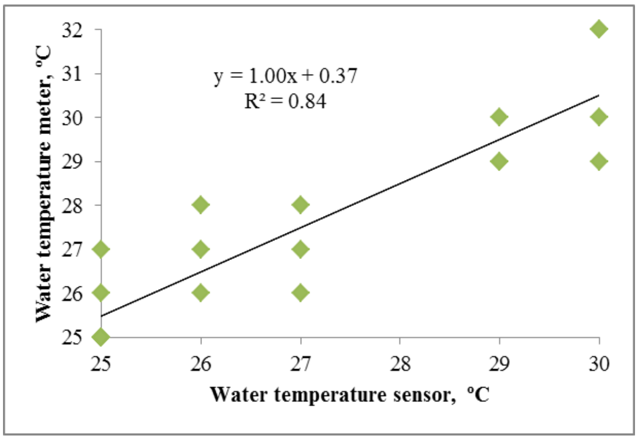

Figure 7. Calibration curve for water temperature sensor

D. Performance Evaluation

Based on the results, the obtained maximum reservoir temperature is 31ºC and minimum is 22ºC. The ability of the system to respond to the set threshold level, the response time of the system to the parameters, and the difference from the calibrated instrument were observed to be able to determine the reliability of the automated hydroponics system. Results showed that turning on of the chiller and mixer when the reading is beyond the threshold range is attained immediately after the reading is beyond the set value in the hydroponics system.

E. Validation of the Automated Reservoir Temperature Monitoring and Controlling System

During the validation period, the system was observed based on the criteria set for the reservoir temperature of the nutrient solution. Based on the results, the reservoir temperature reading and responses were accepted during the validation. Similar performance of the system during the validation and during the performance evaluation was observed. During the validation of the automated temperature monitoring and controlling system, the growth and number of leaves of the lettuce (test crop) were gathered and recorded weekly and the yield of the lettuce was obtained during harvesting. The lettuce crops obtained a total yield of 4.78 kg and an average of 20.6 grams per crop.

IV. CONCLUSIONS

Based on the objectives, the following conclusions were drawn:

1. the installed automated reservoir temperature controller was able to maintain the desired condition for the hydroponic system;
2. based on the observed successes and failures in monitoring the reservoir temperature, the performance of the developed automated reservoir temperature controller was found to be reliable, and;
3. the automated reservoir temperature controlling and monitoring device was able to grow lettuce with yield and responses similar to normal growing conditions.

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The author was born on March 30, 1984 in Camiling, Tarlac. She is the second among the five children of Mr. Carlos O. Rico and the late Mrs. Estela J. Rico. She finished her elementary education at the Camiling West Central Elementary School in 1996 and took secondary level of education at the Tarlac College of Agriculture-Laboratory School, Camiling, Tarlac in 2000. She earned her Bachelor of Science in Agricultural Engineering degree from the University of the Philippines-Los Baños major in Land and Water Resources Engineering and Technology in 2005 and passed the Licensure Examination for Agricultural Engineer the same year. Months after, she was able to work as an Instructor at the then Tarlac College of Agriculture (now Tarlac Agricultural University). In 2009, she decided to pursue a higher degree and enrolled at the Central Luzon State University under the Master of Science in Agricultural Engineering, blessed to be accepted as one of the scholars in the Engineering Research, Development and Technology of the Department of Science and Technology (DOST-ERDT). Through hard work and dedication, she was able to finish her MS degree in 2014. With her goal to further enhance her skills and competencies, she pursued a PhD degree program in Agricultural Engineering at CLSU, again, through the Engineering Research and Development for Technology Scholarship Program of the Department of Science and Technology.