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The viability of hydroponic agriculture in tropical developing regions: A case study of Nueva Ecija, Philippines

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ABSTRACT
This case study examines the viability of hydroponic agriculture as a sustainable alternative to traditional farming in Nueva Ecija, Philippines, a tropical developing region facing rising production costs and climate change. It investigates the opportunities and challenges of adopting hydroponics in San Isidro, Lupao, and Bongabon, where pioneering farmers utilize this soilless cultivation. Data from early adopters, gathered via convenience sampling, offer insights into their management, technical adaptations, market access, and financial outcomes. The study analyzes hydroponics' potential to enhance crop yields, reduce resource consumption (water, fertilizers, pesticides), and improve economic returns for smallholder farmers, aligning with Sustainable Development Goals. It also identifies barriers to wider adoption, such as initial investment and the need for specialized knowledge. Ultimately, this research aims to develop a strategic action plan to support the growth and sustainability of hydroponic agriculture in Nueva Ecija, providing a path for traditional farmers to overcome challenges and achieve greater productivity and profitability.

Contribution/Originality: While prior studies may have explored hydroponics in developing contexts, this research uniquely focuses on Nueva Ecija, Philippines, a significant agricultural region facing specific climate and economic pressures. It provides an in-depth, localized analysis of early adopters' experiences, offering targeted insights for the region's agricultural transition.

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1. INTRODUCTION
The Sustainable Development Goals (SDGs) represent a global commitment to address some of the most pressing challenges facing humanity. Among these, the goal of ensuring a sustainable food supply and eradicating hunger stands as a fundamental pillar. It's a multifaceted ambition that aims not only to feed every individual but also to ensure that this sustenance is achieved without compromising the future. The role of smallholder farmers, as highlighted in the article on Securing Food Systems, is pivotal in this pursuit. These farmers serve as the backbone of healthy global food systems, bridging the gap between production and consumption in both rural and urban settings. Their contributions extend far beyond merely cultivating crops or raising livestock; they serve as custodians of local food supplies and nutrition, providing not just sustenance but also economic stability to their communities. By nurturing and distributing essential foodstuffs within local markets, these farmers not only sustain livelihoods but also foster economic growth at the grassroots level.

However, the significance of smallholder farmers transcends mere economic value. Their practices often align with principles of inclusivity and sustainability, contributing to the overarching goal of the SDGs. They are essential players in fostering inclusive economic growth, ensuring that the benefits of agricultural development reach marginalized or rural communities, reducing disparities in access to resources and opportunities. Moreover, these farmers operate within a framework that inherently promotes sustainable agricultural practices. They are stewards of the land, employing techniques that minimize environmental harm while maximizing productivity. Their involvement in protecting high-biodiversity ecosystems, such as coral reefs, mangrove forests, soil, and water resources, underscores their role as guardians of the environment. By preserving these vital ecosystems, they not only safeguard biodiversity but also ensure the long-term viability of their own agricultural activities. In essence, recognizing and supporting smallholder farmers isn't just about acknowledging their immediate contributions to food systems; it's about embracing a holistic approach to sustainable development. Their integration into global strategies and policies is crucial to achieving not just food security but also environmental preservation and inclusive economic growth. Empowering these farmers through education, access to resources, and supportive policies is pivotal in realizing the aspirations outlined in the SDGs. Absolutely, the interdependence of smallholder farmers with natural resources renders them particularly vulnerable to the adverse impacts of human activities like overfishing, deforestation, and climate change. These challenges directly threaten their local food supply and livelihoods, emphasizing the urgency of empowering these communities to safeguard their resources.

For small-scale fishers and farmers, the intricate balance between resource management and sustenance is crucial. Overfishing depletes aquatic ecosystems, affecting not only fish populations but also disrupting the livelihoods of those reliant on these resources. Similarly, deforestation not only diminishes the availability of land for cultivation but also leads to soil degradation and reduced biodiversity, impacting agricultural productivity. Climate change exacerbates these issues, causing unpredictable weather patterns, altering growing seasons, and increasing the frequency of extreme weather events, all of which significantly affect crop yields and fishing activities.

Empowering these communities involves equipping them with the knowledge, tools, and resources to implement sustainable practices that ensure the conservation of their natural resources while enabling continued production. This empowerment extends beyond providing technical know-how; it involves granting them ownership and decision-making authority over the resources they depend on daily. Implementing strategies that balance effective protection with sustainable production is essential. This could involve measures such as community-based resource management, where local farmers and fishers play an active role in setting rules and regulations for resource use. It might also include education and training programs focused on sustainable agricultural and fishing practices that maximize yields without compromising the ecosystem's health.

Moreover, integrating traditional knowledge with modern, sustainable techniques can be immensely beneficial. Often, local communities possess invaluable insights into the environment they inhabit, knowledge passed down through generations. Combining this wisdom with innovative, environmentally friendly approaches can create a more holistic and effective framework for resource management. Ultimately, empowering smallholder farmers and fishers to manage and protect their natural resources isn't just about securing their livelihoods; it's a critical step toward building a more resilient and food-secure world—one that harmonizes human activities with the health and sustainability of the ecosystems on which we all depend.

Nueva Ecija's reliance on traditional farming methods, especially those tied to farmlands, has indeed been a cornerstone of its agricultural heritage. The province's historical prominence in cultivating key crops like palay, onions, and diverse vegetables has been pivotal in bolstering the region's agricultural productivity. However, despite this rich agricultural legacy, Nueva Ecija has encountered challenges that have significantly impacted its agricultural sector. The reliance on traditional methods, while steeped in local knowledge and experience, has often made the province vulnerable to certain modern challenges. The agricultural landscape in Nueva Ecija has indeed undergone shifts and faced challenges, among which the rapid escalation in the cost of production stands out prominently. This surge in production costs has emerged as a significant concern for local farmers, acting as a deterrent that hampers their ability to fully harness the potential of their farmlands. The heightened cost of production has imposed a considerable financial burden on farmers, particularly in relation to the procurement of essential inputs for traditional farming practices. Inputs such as fertilizers, pesticides, and other resources necessary for cultivation have witnessed a notable increase in prices over time. This upsurge in costs has forced farmers to reassess their farming strategies and adapt to this new economic reality. For many, the escalating costs have challenged the sustainability of their farming operations. The financial strain has often limited their capacity to invest in necessary inputs, impacting the quality and quantity of their produce. Consequently, some farmers find themselves unable to maximize the potential yield from their lands, leading to reduced profitability and economic viability.

One of the significant issues faced by Nueva Ecija's agricultural sector is the evolving landscape of farming practices. As technology advances and global markets shift, there is a need to adapt to more modern and efficient agricultural techniques. Embracing advancements in farming technology, irrigation systems, and crop management could potentially enhance productivity and resilience against various environmental and market-related risks. Furthermore, the agricultural sector in Nueva Ecija, like in many other regions, faces challenges related to climate change. Unpredictable weather patterns, increased occurrences of extreme weather events, and changes in rainfall distribution pose significant threats to crop yields and agricultural stability. Adapting farming practices to mitigate these climate risks is crucial for ensuring sustained agricultural productivity in the region. Additionally, issues related to land use and sustainability need consideration. With urbanization and population growth, there is increased pressure on agricultural lands. Balancing the need for urban development with preserving fertile farmlands becomes a critical challenge.

Addressing these challenges requires a multifaceted approach. It involves not only embracing modern agricultural technologies but also implementing sustainable farming practices that mitigate the impact on the environment. Furthermore, empowering local farmers through education, access to resources, and support programs can aid in the transition toward more resilient and productive agricultural systems.

Preserving Nueva Ecija's agricultural legacy while adapting to the demands of a changing world is key to ensuring the continued prosperity of the region's agricultural sector. Through a blend of traditional wisdom and innovative strategies, the province can navigate these challenges and further contribute to the nation's agricultural landscape. Farmers in Nueva Ecija, faced with these economic challenges, began seeking alternative approaches to ensure the sustainability of their agricultural endeavors. This context set the stage for exploring and adopting innovative farming techniques, such as hydroponics, which offer the potential for increased efficiency, reduced costs, and enhanced yields compared to traditional farming methods. The transition to modern and sustainable farming practices has become a viable option for those aiming to overcome the economic barriers associated with conventional agriculture.

Absolutely, in response to the challenge of insufficient food supply and the need for more sustainable agricultural practices, some farmers have embraced modern farming techniques such as hydroponics. Hydroponic farming, which utilizes water and air instead of traditional soil-based methods, has gained attention for its efficiency and sustainability.

One of the key advantages of hydroponic farming is its ability to produce significantly higher yields compared to traditional methods. Studies have shown that hydroponics can yield up to three times more food than conventional soil-based agriculture. This increased productivity is primarily due to the precise control of nutrient delivery directly to plant roots, allowing for optimized growth conditions. Moreover, hydroponics is considered more sustainable because it requires less land compared to traditional farming. This method operates in controlled environments, such as greenhouses or indoor setups, allowing for year-round production without being limited by seasonal changes or adverse weather conditions. By utilizing vertical space and efficient water usage, hydroponics maximizes land utilization and minimizes the environmental footprint of agriculture.

Another notable benefit of hydroponic farming is its reduced reliance on pesticides and fertilizers. With the controlled nutrient solutions and sterile growing environments, hydroponic systems are less prone to pest infestations and diseases. This reduces the need for chemical inputs, making it an environmentally friendly and potentially healthier option for food production.

The rising popularity of hydroponic farming can be attributed to its ability to utilize natural inputs more efficiently while addressing key challenges faced by traditional farming methods. As the world grapples with limited agricultural land, water scarcity, and the need for sustainable food production, hydroponics presents itself as a promising solution that aligns with the goals of ensuring food security while minimizing environmental impact.

Thus, this study assessed the opportunities and challenges of hydro farming. It was a valuable resource for those planning to engage in this activity, as well as for traditional farmers who might have found hope in continuing to produce farm products without vast farmlands and the use of inputs like pesticides and fertilizers. The study developed a strategic plan or action plan that benefited traditional farmers, alleviating the burden of production costs and helping them regain the high income levels they once earned before.

2. LITERATURE REVIEW

Hydroponics: The Power of Water to Grow Food. According to Lagomarsino (2019), while hydroponic technology may not completely replace conventional farming, it is certainly challenging the traditional paradigm of food production. The emergence of hydroponics has paved the way for a new generation of modern farmers who are exploring innovative ways to grow fresh produce throughout the year, whether inside their homes or community centers. The advantages of hydroponic systems are numerous. One of the key benefits is that it eliminates the need for soil, thereby reducing concerns about having access to vast plots of land, dealing with weeds, or combating soil-borne pathogens with pesticides.

Hydroponics also leads to significant water conservation, as the nutrient-rich water can be recycled and reused multiple times. Additionally, since many hydroponic farms are established indoors, they can operate year-round, regardless of the external weather conditions, making it possible to produce food in the heart of urban areas. The adoption of hydroponics is gaining momentum, with more farms sprouting up not only in the United States but also worldwide. This method of farming offers the potential to revolutionize agriculture by utilizing fewer water resources and other resources, making it an environmentally sustainable and economically viable option for the future.

Hydroponics and Quality of Vegetable Produce. According to Savvas (2003), hydroponic production is defined as the method of growing plants under soilless (i.e., soil-less) conditions with nutrients, water, and an inert medium (gravel, sand, perlite, among others).

From the perspective of plant science, there are no differences between soilless and soil-grown plants because, in both systems, the nutrients must be dissolved in water before plants can absorb them (Bridgewood, 2003). The differences reside in the availability of nutrients to the plants. In hydroponics, the nutrients are dissolved in water, and the solution goes into the plant roots, which uptake the water with minerals toward different parts of the plant. In soil-based production, the elements adhere to the soil particles, pass into the soil solution, where they are absorbed by the plant roots (Jones, 2005).

There are different types of hydroponics, depending on how they are characterized. One criterion is to classify them as closed or open hydroponic systems (Resh, 2012). The hydroponic systems that do not use growing media are usually referred to as closed systems, while hydroponic systems with growing media in a container may be closed or open depending on whether the nutrient solution is recirculated (closed) or introduced in every irrigation cycle (open).

In closed systems, the nutrient concentrations are constantly recycled, monitored, and adjusted, while in open systems, the nutrient solution is discarded (but stored) after each nutrition cycle.

Another approach to classify hydroponic systems is to categorize them based on the movement of the nutrient solution: active or passive. Active means that the nutrient solution can be moved, usually by a pump, while passive relies on a wick or the anchor of the growing media. Others characterize hydroponics using recovery or non-recovery criteria (Hughes, 2017). Recovery is when the nutrient solution is reintroduced into the system, while non-recovery means that the nutrient solution is applied to the growing media and vanishes afterward.

Although there is a diverse range of criteria, three fundamental elements are crucial for plant growth: (1) water/moisture, (2) nutrients, and (3) oxygen. To achieve success in plant production, all hydroponic systems, despite their diversity, must effectively deliver these essential elements. The criteria most commonly utilized by growers, farmers, private companies, and researchers categorize hydroponic systems into six different types (Lennard & Leonard, 2006): Nutrient Film Technique (NFT), Wick System, Ebb and Flow (Flood and Drain), Water Culture, Drip System, and Aeroponic System.

Hydroponics farming in the Philippines, as discussed by Jagdish (2023), is an innovative form of agriculture that involves growing plants in a nutrient-rich, water-based solution instead of traditional soil. This method of indoor gardening utilizes specialized equipment like hydroponic tanks and hydroponic lighting to create an optimal environment for plant growth. The popularity of hydroponics gardening is steadily increasing, as it offers a sustainable and efficient way to produce healthy and organic crops.

One of the key advantages of hydroponics is its ability to maximize space and water usage. Unlike traditional farming, hydroponic systems require less physical space, making them particularly suitable for urban and indoor settings where land may be limited. Additionally, hydroponics uses water more efficiently, contributing to water conservation efforts. Moreover, hydroponics employs a closed-loop system, which significantly reduces the risk of pests, weeds, and diseases that often plague traditional farming. This promotes a cleaner and more controlled environment for plant growth, ensuring the production of high-quality crops. Furthermore, the indoor nature of hydroponics enables year-round farming, allowing for a continuous and consistent supply of nutrient-rich food.

Overall, hydroponics presents a promising and sustainable approach to agriculture, offering numerous benefits for farmers, consumers, and the environment. As its popularity grows, hydroponics has the potential to play a significant role in ensuring food security and promoting environmentally friendly practices in the agricultural sector (Brosas, 2023).

Hydroponics: The Future of Farming. According to a study by Boylan (2020), our current agricultural system faces significant challenges in meeting the caloric needs of a rapidly growing global population. By 2050, food production needs to increase by approximately 70%, but linear growth in agricultural output is insufficient to achieve this goal. Traditional agriculture already consumes a substantial amount of resources, with unsustainable irrigation practices accounting for 70% of water usage globally. To meet the growing demand for food, the intensification and expansion of agricultural land have been proposed as solutions. However, this approach poses significant environmental risks, such as deforestation, loss of biodiversity, and disruption of ecosystem functions.

Deforestation for agricultural expansion has led to the loss of essential ecosystems, including rainforests that regulate the biosphere and support biodiversity. Moreover, climate change further threatens agricultural yields, exacerbating food insecurity in vulnerable regions. The impacts of these practices are evident in the COVID-19 pandemic, which has highlighted the consequences of encroaching on natural habitats and increasing contact with wildlife.

In light of these challenges, hydroponic farming emerges as a potential solution. Controlled environment agriculture, including hydroponic farming, offers a more sustainable and efficient approach to food production. By eliminating unnecessary components of traditional farming and growing crops indoors with precise climate control, hydroponics can optimize the use of water, nutrients, and light. This method allows crops to be grown anywhere, regardless of weather conditions or soil quality, providing fresh and local food even in areas with extreme drought or poor soil.

Thus, hydroponic farming presents a promising alternative to address the limitations and negative impacts of conventional agriculture. By embracing controlled environment agriculture, we can work towards a more sustainable and food-secure future.(Boylan, 2020)

Hydroponics: A crop technique allied to sustainability. According to Masa (2023) in her article, hydroponics presents a promising alternative in sustainable agriculture. Unlike traditional farming methods, hydroponics requires significantly fewer resources, reducing water usage by up to 90% compared to conventional farming. Additionally, hydroponic farms can operate year-round, providing fresh produce locally regardless of weather conditions or seasonal changes, which eliminates the need for long-distance transportation.

The vertical farming aspect of hydroponics maximizes space utilization, making it particularly beneficial in urban areas where agricultural land is limited. By utilizing LED lighting technology and growing crops vertically, hydroponic systems can produce more food in smaller spaces while minimizing environmental impact. Furthermore, hydroponics allows for precise nutrient management and pest control, reducing the need for harmful pesticides and herbicides commonly used in traditional agricultural practices.

Despite the many benefits, hydroponics also comes with challenges that can hinder its adoption by farmers. The initial setup cost can be high, and specialized knowledge may be required for installation and maintenance. Pest management poses another challenge, as the absence of soil in hydroponic systems makes plants more susceptible to pests.

Maintaining optimal nutrient levels in a soilless environment is also a challenge, requiring farmers to ensure proper nutrient supply at all stages of plant growth. Moreover, power outages or equipment malfunctions can disrupt the sensitive closed-loop system of hydroponics, which relies on precise temperature control. However, the industry is actively working on solutions to address these challenges. Automation systems and improved pest management methods are being developed to overcome obstacles and facilitate the successful adoption of hydroponics in mainstream agricultural practices.

In conclusion, hydroponics offers various benefits, including increased yield, efficient nutrient usage, and reduced water consumption, making it an attractive option for sustainable agriculture. While challenges exist, ongoing research and technological advancements aim to make hydroponics a more accessible and viable farming technique for the future (Masa, 2023).

Benefits of Hydroponics Farming. As claimed by Katsiroubas (2021) hydroponics farming offers numerous benefits that empower farmers to grow crops more efficiently and effectively. One of the significant advantages of hydroponics is the ability to cultivate crops without using soil, simplifying maintenance and management. Compared to traditional agricultural methods, hydroponics requires fewer resources while producing higher yields of consistent quality crops with minimal waste.

Water conservation is another key benefit of hydroponics, as the system circulates water, allowing for its reuse. This reduces overall water usage compared to conventional farming methods. Moreover, the controlled environment of hydroponics provides crops with greater resistance to pests and diseases, reducing the need for chemical treatments and promoting healthier plants.

The flexibility of hydroponics also allows farmers to grow crops in limited spaces, making it a suitable method for indoor urban farming. Farmers have the capability to manage pH and nutrients precisely, ensuring that plants receive the exact nutrients they need for optimal growth. The closed-loop system of hydroponics recycles water that is not used by plants, further contributing to resource efficiency.

Indoor farming through hydroponics enables farmers to regulate temperatures and lighting schedules, enhancing plant production throughout the year. Additionally, hydroponic systems can be designed to make use of vertical space, increasing planting density and maximizing land utilization. Furthermore, hydroponics opens up the possibility of establishing farms in locations where soil conditions are unsuitable for conventional farming or where space is limited, making it a viable solution for addressing food production challenges.

Thus, the benefits of hydroponics farming are manifold and offer a more sustainable and efficient approach to agriculture. By embracing hydroponics, farmers can improve crop yield, resource utilization, and environmental sustainability.

Environmental Benefits. Hydroponic farming and gardening provide numerous environmental benefits. For one, it significantly reduces water consumption compared to traditional soil farming, making it a sustainable practice for arid and water-scarce areas. Additionally, hydroponics systems eliminate the need for pesticides, herbicides, and other chemical fertilizers, thus helping to protect soil and water from the threats posed by pollution. Hydroponics farming not only has the capacity to increase crop yield and reduce water consumption, but it also helps to protect the environment by reducing the use of harmful chemicals.

Cost Savings. Hydroponics farming is a cost-effective way to grow food in comparison to traditional farming. Unlike traditional farming, hydroponics requires fewer resources and requires less land. Additionally, hydroponics farming requires fewer labor and water resources, which can lead to substantial cost savings. Because hydroponics farming is soilless, there is no need to purchase soil, mulch, or fertilizer, further reducing the costs to start and maintain a hydroponics system. Furthermore, because hydroponics systems are so water-efficient, farmers can save water costs, making it an even more cost-effective option. With all the cost savings associated with hydroponics farming, it's no wonder that it is becoming an increasingly popular way to grow food.

High Yields. One of the major benefits of hydroponics farming is its potential to produce high yields with relatively little effort. This is because hydroponics systems require less space and fewer resources than traditional farming methods, meaning more crops can be grown in a shorter period of time. Additionally, hydroponic crops can be harvested within weeks of planting, whereas traditionally grown crops require several months before harvesting. With hydroponics, crops can achieve higher yields with greater nutritional value and improved flavor. Furthermore, hydroponics is not only better for producing high yields, but also for environmental sustainability as there is no need for tillage, pesticides, and other wasteful practices.

Market Demand for Hydroponics in the Philippines. As stated in the article of Jagdish (2023) the global hydroponics crop market is valued at approximately 37.7 billion USD, projected to grow at a CAGR of 7% and reach 54.4 billion USD by 2027. The Asia-Pacific region, including the Philippines is expected to be one of the fastest -growing markets with a CAGR of 17%.

Hydroponics farming in the Philippines offers a cost-effective solution for sustainable agriculture. The initial set-up cost for small-scale hydroponic systems can range from P40,000.00 to P200,000.00. This includes essential components like nutrient solutions, growing media, and equipment such as pumps and reservoirs. Operational costs mainly involve electricity for lighting and nutrient supplementation, which can amount to approximately P3,000 to P5,000 per month. These costs can vary depending on the scale and complexity of the hydroponic set-up. Despite the initial investment, hydroponic farming can yield higher crop productivity and faster growth rates, leading to potential long-term cost savings.

3. METHODOLOGY

The study conducted in Nueva Ecija utilized the descriptive method of research, as outlined by Aggarwal (2008), to comprehensively describe the phenomenon of hydro farming in the region. It focused on key aspects such as organizational structures, technical practices, market strategies, and financial considerations within hydroponic farming. The study provided a detailed description of the profile of hydro farming in municipalities like San Isidro, Lupao, and Bongabon. It also provided insights into the management practices, innovative techniques, market access strategies, and financial aspects specific to hydroponic agriculture. Additionally, the study delved into the opportunities and challenges faced by hydro farming in Nueva Ecija, culminating in a proposed action plan designed to improve efficiency, productivity, and sustainability in this burgeoning agricultural sector.

3.1. Sampling Procedure

The convenience sampling technique was employed in this study. As described by Lavrakas (2008), convenience sampling involves collecting data from individuals who are conveniently available and accessible to participate in the research. In this study, the sample consisted of hydroponics farmers from the municipalities of San Isidro, Lupao, and Bongabon, located in the province of Nueva Ecija.

3.2. Respondents

The study carefully selected respondents who were pioneers in introducing hydro farming in Nueva Ecija. This deliberate selection was based on the premise that these individuals, due to their unique position and extensive experience, possess invaluable insights into the nascent stages and development of the hydroponic agriculture sector in the region. They were identified through a combination of local agricultural network referrals, government extension service records, and industry association recommendations, ensuring a comprehensive identification of key informants. These pioneers were considered primary sources of data owing to their firsthand experiences and in-depth knowledge about the practical aspects of establishing, managing, and navigating the challenges inherent in hydroponic farm operations. Their insights offered a unique perspective on the evolution of this agricultural practice in Nueva Ecija, shedding light on the initial adoption barriers, the adaptation strategies employed, and the long-term sustainability of hydroponic farming in the local context.

Table 1 details the distribution of respondents involved in this study. It shows that the research includes three key informants: Respondent 1 from Hydrodads (3RJ) hydroponics farm located in San Isidro, Nueva Ecija; Respondent 2 from Lupao hydroponics farming in Lupao, Nueva Ecija; and Respondent 3 from Kaberde Hydroponics in Bongabon, Nueva Ecija.

Table 1. Distribution of respondents.

Hydroponic farming	Address
Hydrodads (3RJ) hydroponics farm (Respondent 1)	San Isidro, Nueva Ecija
Lupao hydroponics farming (Respondents 2)	Lupao, Nueva Ecija
Kaberde hydroponics (Respondent 3)	Bongabon, Nueva Ecija

3.2.1. Research Site

This study was strategically conducted in the municipalities of San Isidro, Lupao, and Bongabon, located in the province of Nueva Ecija. These municipalities were selected as significant focal points due to their pioneering adoption of hydroponic farming as a modern and innovative agricultural practice. This early adoption signifies a proactive approach to addressing agricultural challenges and a willingness to embrace new technologies within the region.

The selection of these specific municipalities was not arbitrary. San Isidro, Lupao, and Bongabon demonstrated a clear recognition of the potential benefits that hydroponics offered, including increased efficiency, reduced water usage, and higher yields compared to traditional farming methods. This recognition was translated into concrete action, as these municipalities actively promoted and implemented hydroponic farming techniques within their respective communities. This involved providing resources, training, and support to local farmers, fostering an environment conducive to the successful integration of hydroponics into their agricultural practices.

Furthermore, the pioneering adoption in these municipalities suggests a potential for wider adoption of hydroponics in the region and beyond. Their experiences can serve as a model for other communities seeking to modernize their agricultural practices. By studying the factors that contributed to their successful implementation, researchers can identify best practices and potential challenges associated with the adoption of hydroponics, providing valuable insights for future agricultural development initiatives.

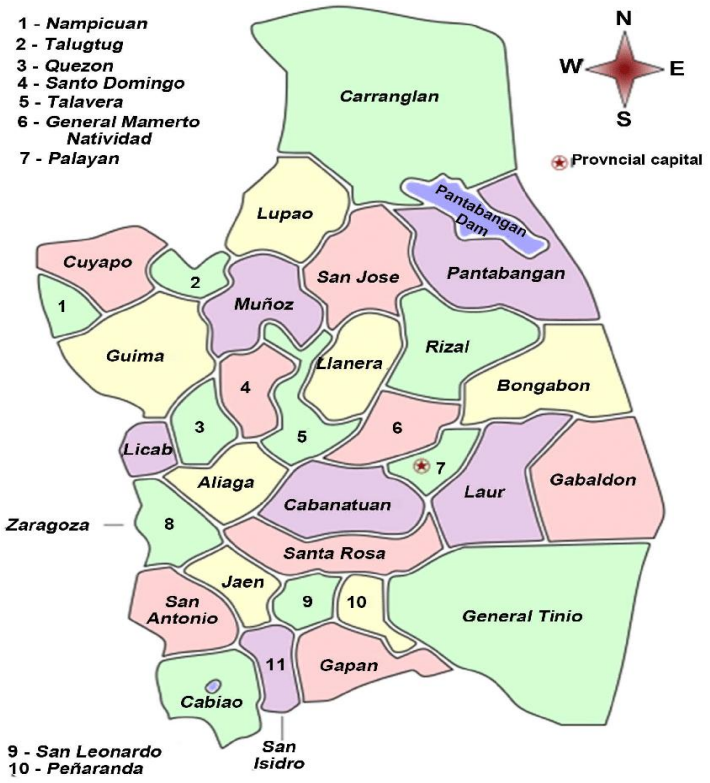

Figure 1. Map of Nueva Ecija.

Figure 1 illustrates the political map of Nueva Ecija, Philippines, highlighting its various municipalities and the location of the provincial capital. The different colors delineate the boundaries of each municipality, and a legend provides numerical keys corresponding to specific towns: 1-Nampicuan, 2-Talavera, 3-Quezon, 4-Santo Domingo, 5-Talavera, 6-General Mamerto Natividad, and 7-Palayan. Additionally, the map shows the Pantabangan Dam in the northeastern part of the province and pinpoints the provincial capital. The municipalities where the study was conducted – San Isidro, Lupao, and Bongabon – are also clearly visible in the southern, northwestern, and eastern parts of the province, respectively. A compass rose indicates the cardinal directions (North, South, East, West) for geographical orientation.

4. RESULTS AND DISCUSSION

4.1. Hydroponics Farming Industry in Nueva Ecija

This study delved into the profiles of the farmers engaged in hydroponic farming in the province of Nueva Ecija and the business profile.

4.1.1. Profile of the Farmer-Respondents

The demographic profile of the farmers participating in this study revealed a predominantly middle-aged and male population. This observation aligns with the prevailing societal perception that agriculture, particularly traditional farming, is often associated with physically demanding labor, which may disproportionately attract male participation. However, it is important to acknowledge that this demographic distribution may not fully represent the evolving landscape of modern agriculture, where technological advancements and innovative practices like hydroponics are increasingly accessible to diverse populations.

Many of the respondents were seasoned hydroponic farmers, boasting over seven years of experience, spanning both pre-pandemic and pandemic periods. Their longevity in the sector suggests a strong commitment to and familiarity with hydroponic techniques. When asked about their initial motivations for adopting hydroponics, farmers frequently cited the relatively low capital investment required compared to traditional farming and the significant advantage of not needing extensive farmland. This latter point is particularly salient in regions where land scarcity or high land prices pose significant barriers to traditional agriculture.

Furthermore, the study highlighted the increasing reliance on hydroponic farming as a primary source of income for these farmers. This trend was especially pronounced during the pandemic, a period marked by economic uncertainty and limited alternative job opportunities. Hydroponics, with its potential for consistent yields and market adaptability, provided a stable income stream for many participants, underscoring its resilience in the face of economic disruptions.

4.1.2. Business Profile

The respondents, leveraging their extensive experience of over seven years in hydroponic farming, consistently highlighted the critical role of initial training and seminars in acquiring the essential skills for successful operation. This emphasis underscores the importance of knowledge transfer and capacity building in the adoption of innovative agricultural practices. Many of these farmers initiated their ventures with modest capital and backyard setups, initially

focusing on lettuce cultivation. This starting point reflects the accessibility of hydroponics for small-scale entrepreneurs and its potential for gradual expansion. Furthermore, the farmers expressed a clear intention to diversify their crop selection in the future, indicating a forward-looking approach and a desire to capitalize on market opportunities beyond a single crop.

Despite the initial financial constraints, with monthly earnings below 10,000 pesos, the farmers reported a significant increase in income, reaching levels of 50,000 pesos or more per month. This substantial growth can be attributed to the combined effect of improved technology adoption and accumulated experience. This demonstrates the potential for hydroponic farming to provide a viable and increasingly lucrative livelihood, especially as farmers refine their techniques and scale their operations.

The farmers also identified a robust demand for hydroponically grown vegetables within the province, driven by a growing preference among Filipino consumers for vegetables over meat. This dietary shift aligns with broader trends toward healthier eating habits and presents a significant market opportunity for hydroponic farmers. The identification of diverse market channels, including restaurants, traditional markets, and direct sales to consumers seeking fresh produce, further underscores the market potential for hydroponic products. This diversified market access provides farmers with multiple avenues for selling their produce, enhancing their income stability and resilience.

4.2. Hydroponics Farming Practices of the Farmer-Respondents

4.2.1. Organization and Management

The farmers participating in the study exhibited a strong consensus regarding the critical importance of proper management and rigorous daily monitoring for the successful operation of hydroponic farming activities. This unanimous agreement underscores the inherent complexity and precision required in hydroponic systems, where even minor deviations can significantly impact yield and quality. The emphasis on daily monitoring suggests a proactive approach to identifying and addressing potential issues before they escalate, reflecting a deep understanding of the delicate balance within these controlled environments.

However, while there was a general agreement on the necessity of management and monitoring, certain aspects, such as hands-on involvement and regular inspections, received slightly lower agreement scores. This nuanced perspective suggests a potential variation in the interpretation of these practices or a difference in the level of direct engagement among the farmers. It may also indicate a reliance on delegated responsibilities in larger operations or a preference for technology-driven monitoring systems in some cases.

Despite these slight variations, the respondents consistently highlighted the importance of effective management, particularly when overseen by owners or dedicated managers. This emphasis on managerial oversight underscores the need for strong leadership and accountability in hydroponic ventures. Furthermore, the farmers stressed the value of continuous skills upgrading, recognizing the dynamic nature of hydroponic technology and the need for ongoing professional development. The importance of hands-on involvement in inventory management was also consistently cited, indicating a practical understanding of the need to closely track resources and inputs for optimal efficiency.

4.2.2. Technical/ Production

The data revealed a strong consensus among farmer-owners and managers regarding the importance of adhering to regulatory frameworks and embracing technological advancements in hydroponic farming. This agreement on obtaining necessary permits, strictly following food safety regulations, and demonstrating a willingness to adopt new technologies underscores a proactive and responsible approach to modern agriculture. These aspects are critical for ensuring the technical and production integrity of hydroponic operations, directly impacting safety, quality, and efficiency, as supported by existing literature (Smith, Johnson, & Williams, 2020). This alignment with regulatory standards and technological innovation suggests a mature and forward-thinking perspective among the farmers, recognizing the need to operate within established guidelines while leveraging advancements for optimal performance.

However, alongside this agreement, the respondents also highlighted several critical challenges that demand continuous attention and refinement. Issues such as ensuring the authenticity and consistency of nutrient solutions, maintaining precise measurement protocols, and implementing timely harvesting practices were frequently cited. These challenges point to the inherent complexities of hydroponic systems, where even minor deviations can significantly affect crop yield and quality. The emphasis on continuous monitoring and adherence to best practices underscores the need for ongoing education, training, and technical support to ensure the long-term sustainability and profitability of these operations.

4.2.3. Market and Marketing

The data indicated a strong consensus among farmer-owners and managers regarding the critical role of effective market and marketing strategies in the success of hydroponic farming ventures. This agreement was particularly pronounced in the adoption of online selling platforms and direct buyer communication, evidenced by an average weighted mean of 3.29 (Kaisser, Smith, & Brown, 2021). This finding underscores the farmers' recognition of the evolving market landscape and the increasing importance of digital tools in reaching consumers and expanding market reach.

Respondents specifically emphasized strategies such as leveraging social media platforms to showcase their produce and ensuring a consistent and sufficient supply to meet market demand. This focus on social media marketing reflects a contemporary approach to consumer engagement, allowing farmers to directly interact with potential buyers, build brand awareness, and promote the freshness and quality of their hydroponically grown products. The emphasis

on consistent supply, particularly for lettuce, which holds a substantial market presence, highlights the farmers' understanding of the need to maintain reliability and meet consumer expectations in a competitive market.

4.2.4. Financial

The data demonstrated a strong consensus among farmer-owners and managers regarding the critical importance of robust financial management in hydroponic farming operations. This agreement was particularly evident in their emphasis on considering available financing sources and diligently managing maintenance costs, as reflected by an average weighted mean of 3.21 (Financial Aspects of Business, 2019). This finding underscores the farmers' recognition of the capital-intensive nature of hydroponics and the need for strategic financial planning to ensure long-term viability and profitability.

Respondents consistently emphasized the necessity of meticulous financial planning, which includes diligently monitoring cash flow, generating consistent income, and maintaining healthy working capital. These aspects are critical for sustaining operations, reinvesting in technology upgrades, and mitigating financial risks. The farmers' focus on these financial fundamentals indicates a sophisticated understanding of the business aspects of hydroponics, moving beyond mere production to encompass comprehensive financial stewardship.

Furthermore, the respondents stressed the need for enhanced financial literacy and nuanced management abilities to effectively navigate financial challenges and optimize financial strategies. This highlights the importance of equipping farmers with the knowledge and skills necessary to make informed financial decisions, manage debt, and maximize profitability. The recognition of these needs suggests that ongoing training and education in financial management could significantly enhance the economic resilience of hydroponic farming ventures.

Table 2 summarizes the profitability, return on investment (ROI), and payback period (PEP) as perceived by the respondents. The table presents the mean scores for five indicators related to the financial aspects of hydroponic farming. All individual indicators, such as "Hydroponic farming is a profitable venture" (mean 3.50), "Hydroponic farming has a fast return on investment" (mean 3.35), and "Hydroponic farming has a quick payback period" (mean 3.40), received a verbal description of "Strongly agree." Similarly, the statement "Hydroponic farming can be started for as low as P1,000.00 as start-up" garnered a mean of 3.60 ("Strongly agree"), and "Hydroponic farming is a promising business venture for beginners in business" achieved a mean of 3.55 ("Strongly agree"). The average weighted mean across all indicators is 3.48, which also corresponds to a verbal description of "Strongly agree," indicating an overall positive perception of the financial viability of hydroponic farming among the respondents.

Table 2. Profitability, ROI, PBP.

No	Indicator/s	Mean	Verbal description
1	Hydroponics farming is profitable venture	3.50	Strongly agree
2	Hydroponic farming has a fast return on investment	3.35	Strongly agree
3	Hydroponic farming has a quick payback period	3.40	Strongly agree
4	Hydroponic farming can be started as low as P1,000.00 as start-up	3.60	Strongly agree
5	Hydroponic farming is a promising business venture to beginners in business.	3.55	Strongly agree
	Average weighted mean	3.48	Strongly agree

4.3. Feasibility of Hydroponics Farming

4.3.1. Profitability, Return on Investment, Payback Period

The data indicate a strong consensus among respondents regarding the profitability, return on investment (ROI), and relatively short payback period associated with hydroponic farming, as evidenced by an average weighted mean of 3.48. This high level of agreement underscores the perceived economic viability and attractiveness of hydroponics as a business venture. The emphasis on a quick payback period suggests that farmers are not only focused on long-term profitability but also on the rapid recoupment of initial investments, a critical consideration for small-scale entrepreneurs and those seeking to minimize financial risk.

Kathy (2021) further supports this perspective, highlighting lettuce as a particularly popular and profitable crop in hydroponic systems. The author emphasizes lettuce's high yield potential and relative simplicity to cultivate, making it an ideal entry point for beginners in hydroponics. This alignment with existing literature reinforces the respondents' positive outlook on the economic prospects of lettuce hydroponics.

The respondents specifically emphasized that lettuce hydroponics farming presents a promising and accessible business venture, particularly for those new to the field. They highlighted its potential to begin with a low initial investment while achieving profitability and returns within a relatively short timeframe. This accessibility, combined with the potential for rapid returns, makes lettuce hydroponics an attractive option for individuals seeking to diversify their income streams or enter the agricultural sector with limited capital.

This strong agreement on profitability, coupled with the supporting literature and the respondents' emphasis on accessibility, suggests a significant potential for the growth of lettuce hydroponics in the region. It highlights the opportunity for small-scale farmers and entrepreneurs to leverage this technology for economic empowerment and sustainable agricultural practices.

Table 3 presents the respondents' perceptions regarding the demand for hydroponic farming. The table shows the mean scores and corresponding verbal descriptions for five indicators related to market demand and income potential. The statement "Hydroponics farming is in demand nowadays" received a mean score of 3.70, indicating "Strongly agree." Similarly, "Hydroponics farming is suitable in urban areas where the demand for fresh produce is notably higher" garnered a mean of 3.50 ("Strongly agree"). The perception that "Hydroponics farming is environmentally

friendly, resulting in high demand" also received strong agreement with a mean of 3.60. Furthermore, respondents strongly agreed that "Hydroponics farming is a promising agribusiness in terms of demand" (mean 3.67) and that "Hydroponics farming is a good source of income, thus motivating people to engage in the hydro farming business" (mean 3.72). The average weighted mean across all demand indicators is 3.63, which corresponds to a verbal description of "Strongly agree," suggesting a strong perceived demand for hydroponically farmed produce and the business itself.

Table 3. Demand.

No.	Indicator/s	Mean	Verbal description
1	Hydroponics farming is in demand nowadays.	3.70	Strongly agree
2	Hydroponics farming is suitable in the urban areas where demand for fresh produce is notably higher	3.50	Strongly agree
3	Hydroponics farming is environmental friendly resulting into high demand	3.60	Strongly agree
4	Hydroponics farming is promising agribusiness in terms of demand	3.67	Strongly agree
5	Hydroponics farming is a good source of income thus motivating people to engage in the hydro farming business.	3.72	Strongly agree
	Average weighted mean	3.63	Strongly agree

4.3.2. Current and Future Demand

The data strongly suggest a promising trajectory for hydroponic farming, particularly in lettuce cultivation, driven by robust market demand that serves as a significant motivator for entrepreneurial engagement. This high demand, as corroborated by the respondents' perspectives and supported by existing literature (Kathy, 2021) underscores the growing consumer preference for fresh, locally sourced, and sustainably produced vegetables.

Farmers engaged in lettuce hydroponics can anticipate substantial income potential by consistently adhering to stringent quality and quantity standards. This emphasis on maintaining high standards aligns with the broader trend of shifting consumer preferences towards healthier food options, where freshness, nutritional value, and consistent supply are paramount. The respondents' firsthand experiences, such as achieving competitive pricing through efficient harvesting and strategic marketing, further validate the lucrative nature of hydroponic farming in meeting the escalating demand for fresh and nutritious produce.

This confluence of market demand, profitability, and consumer preferences creates a fertile ground for the expansion of hydroponic farming. The ability to control growing conditions, minimize environmental impact, and produce high-quality yields consistently positions hydroponics as a viable and sustainable solution for addressing the growing need for food security and healthy diets. The potential for vertical farming and urban agriculture further enhances the accessibility and scalability of hydroponic systems, making it a promising avenue for both established farmers and aspiring entrepreneurs.

Table 4 summarizes the financial computation for lettuce hydroponics farming. It indicates an initial investment of ₱50,000, described as "minimal capital." The projected gross income is ₱51,609.60, with a remark stating this is a projected average that could increase based on actual farming activity. The projected net income is ₱22,161.60, representing the estimated profit after deducting costs from the gross income. The payback period is calculated to be 2.25 years, which the remarks elaborate as approximately 2 years and 3 months to break even and recover the initial investment. The overall analysis concludes that lettuce hydroponics farming is viable/feasible.

Table 4. Summary of computation on lettuce hydroponics farming.

Items	Value/Amount	Remarks
Initial investment	P50,000	Minimal capital
Projected gross income	P51,609.60	This is only projected average, it could be increase base on the actual farming activity
Projected net income	P22,161.60	
Payback period	2.25 years	This particular farming method typically takes approximately 2 years and 3 months to break even and cover the initial investment
Analysis		Viable/Feasible

The profitability and viability of lettuce hydroponic farming, as evidenced in the accompanying table, underscore its potential as a lucrative and safe alternative to traditional agricultural practices. This economic attractiveness stems from several factors, including the controlled environment that minimizes crop losses due to pests and weather, the efficient use of resources (water and nutrients), and the ability to achieve consistent yields throughout the year.

Moreover, hydroponics demonstrates a remarkable adaptability to urban environments where land scarcity and high demand for fresh produce create a unique market opportunity. Its vertical farming capabilities allow for maximizing production in limited spaces, making it a viable solution for urban agriculture. This proximity to consumers reduces transportation costs and ensures the delivery of fresher produce, further enhancing its market appeal.

The controlled environment of hydroponic systems also minimizes the need for chemical pesticides and herbicides, leading to safer and healthier produce. This aligns with the growing consumer preference for organic and sustainably

grown food, positioning hydroponics as an environmentally responsible and consumer-friendly alternative to traditional farming.

Therefore, the viability of lettuce hydroponics, as supported by the data, positions it as an innovative and promising method for generating income within the agricultural sector. Its adaptability to urban settings, coupled with its ability to produce safe and high-quality yields, makes it a compelling option for both aspiring and established farmers seeking to capitalize on the growing demand for fresh, locally sourced produce.

4.4. Proposed Action Plan

The proposed action plan is designed to holistically enhance the hydroponics farming sector by focusing on key areas critical for sustainable growth and profitability. This comprehensive plan aims to improve organizational efficiency through streamlined management practices and resource optimization, fostering a more productive operational environment. It seeks to bolster technical knowledge by providing access to cutting-edge research, training programs, and expert consultations, ensuring farmers are equipped with the latest advancements in hydroponic techniques. Furthermore, the plan addresses the need for effective marketing strategies by facilitating access to digital platforms, market analysis tools, and branding workshops, enabling farmers to expand their market reach and connect with consumers directly.

Recognizing the importance of financial stability, the plan includes initiatives to improve financial literacy through workshops on budgeting, financial planning, and accessing financing options. This will empower farmers to make informed financial decisions and secure the necessary capital for expansion and innovation. Finally, the plan emphasizes collaboration by fostering partnerships between farmers, researchers, policymakers, and industry stakeholders. This collaborative approach aims to create a supportive ecosystem for knowledge sharing, resource pooling, and collective problem-solving.

Active participation from all stakeholders, a commitment to continuous learning, and the cultivation of strategic partnerships are pivotal for driving the success and ensuring the long-term sustainability of hydroponic farming ventures in the studied region. By addressing these key areas, the proposed action plan aims to create a resilient and thriving hydroponics sector that contributes to food security, economic development, and environmental sustainability.

5. CONCLUSIONS

This study underscores the accessibility of hydroponic farming as a viable entrepreneurial avenue, particularly for individuals with limited capital and those seeking to minimize physical labor compared to traditional agricultural practices. The relatively low initial investment, driven by the modular nature of hydroponic systems and the potential for utilizing existing spaces, lowers the barrier to entry for aspiring farmers. Furthermore, the controlled environment of hydroponics reduces the need for strenuous physical labor associated with soil preparation, weeding, and pest management, making it an attractive option for a wider demographic.

However,the study also reveals that success in hydroponics is not solely dependent on low investment and reduced labor.It hinges on the acquisition of essential skills and knowledge, encompassing both technical and managerial expertise.The findings emphasize the significance of various business elements, including organizational efficiency, technical proficiency in hydroponic systems, a comprehensive understanding of market dynamics, and robust financial acumen.These elements are crucial for ensuring the profitability and long-term sustainability of hydroponic ventures, highlighting the need for continuous learning and professional development within the sector.

The study's insights further shed light on the economic attractiveness of hydroponics, particularly in terms of its potential for achieving profitability, a quick return on investment, and a relatively short payback period. This economic viability, coupled with manageable capital requirements and maintenance efforts, positions hydroponics as a lucrative and promising business venture. The ability to achieve rapid returns on investment, driven by consistent yields and efficient resource management, makes hydroponics an appealing option for individuals seeking to diversify their income streams or establish a sustainable agricultural enterprise.

In essence, the study demonstrates that while hydroponics offers accessibility and potential for rapid returns, it also demands a strategic approach encompassing technical expertise, business acumen, and a commitment to continuous learning. This nuanced perspective highlights the need for comprehensive support systems, including training programs, mentorship initiatives, and access to financial resources, to ensure the success and sustainability of hydroponic farming ventures.

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