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MORALITY BEFORE KNOWLEDGE

Development of hydroponic business in coastal areas: Integration of technology with organic fertilizers for food independence

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ABSTRACT

Background: As an archipelagic country, Indonesia has an extensive coastline; however, coastal areas often face challenges in vegetable availability. The limited understanding of plant cultivation among coastal communities and unfavorable environmental conditions may contribute to this issue. Hydroponic technology offers a potential solution, as it enables plant growth without soil, making fertilizer and water use more efficient. **Methods**: This study employs a literature review and a mini-experiment utilizing a circulating hydroponic Ebb and Flow system with sand as a substrate and rainwater as the primary water source. The system integrates liquid organic fertilizer (POC) and manure to support sustainable agriculture. This development model is implemented through a penta-helix collaboration involving the community, academics, businesses, the government, and the media. **Findings:** The Ebb and Flow hydroponic system has proven effective in cultivating vegetables, enhancing both the quantity and quality of vegetable production in coastal areas. However, the success of this initiative relies on penta-helix collaboration. The government plays a role in providing funding and regulatory support, academics contribute by offering training and education, business actors manage product distribution, and media—particularly online marketplaces and social media—facilitate marketing efforts. **Conclusion**: The Ebb and Flow hydroponic system presents a viable solution for addressing vegetable scarcity in coastal areas while also generating employment opportunities. However, further research and collaborative support from multiple stakeholders are essential to optimize its outcomes. **Novelty/Originality of this article:** This article proposes a hydroponic system incorporating a penta-helix approach to develop sustainable vegetable farming in coastal regions, offering a new perspective on the application of technology in areas with limited arable land.

KEYWORDS: Penta-Helix Collaboration, Sustainable Coastal Agriculture, Ebb and Flow Hydroponics.

1. Introduction

Indonesia, as an archipelagic country, has an extensive coastline. According to data from the Central Statistics Agency (Badan Pusat Statistik/BPS) in 2016, the total length of Indonesia's coastline reaches 54,716 km, ranking second globally after Canada. Despite

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having abundant marine resources, over 22% of the population residing in coastal areas live below the poverty line. In 2018, the total number of poor people in Indonesia reached 26.58 million, with 61.36% of them living in coastal and rural areas (BPS, 2018). Most people in coastal areas rely on marine products as their main livelihood, while agriculture, particularly vegetable cultivation, is minimal due to limited land available for farming. Therefore, a system that utilizes surrounding natural resources, such as the use of sand for vegetable cultivation in coastal areas, is necessary. Hydroponics, a modern agricultural technique, offers an alternative method to address the challenges of future agriculture, such as the increasing global population, shrinking agricultural land, and climate change. The rise in the global population and improved living standards in many countries have led to increased demand for high-quality food products, especially off-season crops. Hydroponic cultivation can address these challenges, as this system is capable of producing crops with better quantity and quality, and more rapidly compared to traditional soil-based cultivation (Aini & Azizah, 2018).

In just over 65 years, hydroponics has developed significantly due to its adaptability in various environments, from open fields to greenhouses and even specialized cultivation in space programs. Hydroponic systems can be applied in developing countries to intensively increase food production in areas with limited land or regions with vast barren areas, such as deserts. In areas where freshwater is scarce, hydroponics can utilize seawater that has undergone desalination. Such applications of hydroponics are found along coastal areas in combination with desalination units (Resh, 2013). Hydroponics is a method of cultivating crops without the use of soil, allowing it to utilize small spaces efficiently. The advantages of hydroponics include easy implementation, pest control, efficient fertilization, and the ability to replace dead or damaged plants quickly. It does not require large labor or land, is hygienic, produces high-value crops, and can be practiced in confined spaces (e.g., terraces, garages, rooftops, or even kitchens). One popular hydroponic technique used by farmers in Indonesia is the ebb and flow system. The ebb and flow system is a passive hydroponic technique that uses aggregate (Karsono, 2013).

Hydroponics offers numerous advantages over conventional soil-based farming systems. It minimizes the use of pesticides because the plants go through a sterile germination and harvesting process, free from soil-borne pests and diseases. Hydroponic systems are also easy to maintain, have high market value, and do not require large plots of land (Iqbal, 2016). A key distinction between hydroponic and conventional cultivation lies in the provision of nutrients. In conventional farming, plant nutrition is highly dependent on the soil's ability to provide a complete range of nutrients, which are usually derived from the decomposition of organic and inorganic materials in the soil. In contrast, hydroponic systems provide all the necessary nutrients for plant growth in a controlled manner (Pratama, 2017).

Hydroponic technology can be a solution for farming in coastal areas because it allows for plant production without soil. This method leads to high quantities and quality of crops, with more efficient use of fertilizer and water. Compared to conventional farming, hydroponics also minimizes pesticide exposure, as the growing process is kept sterile and free from soil-borne pests and diseases. The benefits of hydroponics include easy maintenance, high market value, and no requirement for large land areas (Iqbal, 2016). One hydroponic system that uses sand as a substrate is the ebb and flow circulation system. The ebb and flow hydroponic system works by providing nutrients to plants using a tidal flow pattern. When the media is submerged in water, the gases released by the plants are expelled through the roots. Similarly, when the water drains away from the media, oxygen-rich air from outside is absorbed by the plants, promoting healthy growth (Rosliani, 2005).

The development of hydroponics in coastal areas presents promising prospects. In addition to providing vegetables for local consumption, hydroponically grown vegetables are increasingly in demand in the market. Thus, cultivating vegetables using the ebb and flow hydroponic system could enhance local incomes and contribute to the economic development of coastal communities. After learning how to cultivate vegetables using the ebb and flow hydroponic system, a specific strategy needs to be developed to turn hydroponic vegetable farming into a new job field with promising prospects. This can be achieved through a penta-helix collaboration involving the community as the main actor in developing and supplying hydroponic vegetables, academics as facilitators to empower local communities regarding hydroponic farming, and business actors who invest and help sell hydroponic vegetables. Furthermore, the government plays a role in providing infrastructure to support hydroponic farming activities. Media, particularly online marketplaces and social media, can assist in marketing the products. The rapid spread of information in the era of Industry 4.0 presents a golden opportunity to leverage technology as a communication tool to facilitate penta-helix collaboration. According to the Indonesian Internet Service Providers Association (2017), internet usage in Indonesia reached 54.68%, or approximately 143.26 million people, making it an excellent opportunity to utilize this technology as a platform for information dissemination. Based on this background, the research objectives of this paper are to explore how to address the issue of limited vegetable supply in coastal areas, how to create employment opportunities through hydroponic vegetable farming, and how to develop a marketing strategy for hydroponic products.

2. Methods

The methodology of this research is carried out through a systematic series of stages, beginning with observations of the issues in coastal areas. This is followed by the collection and analysis of data using document analysis techniques. The data sources are obtained from various credible literatures, both in print forms such as journals, proceedings, and books, as well as electronic sources, including relevant e-journals related to the research topic. The data collection process is conducted in a structured manner, analyzing documents from trusted sources to draw accurate conclusions and provide appropriate recommendations. The use of document analysis ensures that the research is grounded in reliable information, which strengthens the validity of the findings and supports the development of feasible solutions.

The final stage of the research focuses on the design and modeling of the Ebb and Flow hydroponic system, tailored to the specific characteristics of coastal areas. The design and technical specifications are determined based on the observations and data analysis conducted in earlier stages. This phase ensures that the proposed hydroponic system is suitable for the environmental conditions of coastal regions, addressing both practical and ecological factors. The results of this research aim to offer a viable solution for enhancing local agricultural practices in coastal areas, contributing to sustainable food production and improving the livelihoods of coastal communities.

3. Results and Discussion

3.1 Tidal hydroponics for vegetable supply

Hydroponics has become a solution for locations facing space and land constraints in farming. This could be due to poor soil quality or limited space, such as in coastal areas. Coastal areas often struggle with farming due to sandy soil and salty water. Hydroponics can be an option for coastal communities to cultivate plants without needing fertile soil or dealing with salty water.

Farming on sandy soil is no longer an issue. This has been demonstrated by the farming community in Kulon Progo, which cultivates directly on sandy land (Indonews, 2019). This area is even well known for its chili harvest, particularly the Wates chili. The fertilizers or plant nutrients used come from animal manure or compost, and the water used is groundwater. This area might be fortunate as its groundwater is not salty. But what about other coastal areas?

The solution could be the Ebb and Flow hydroponic technology. The Ebb and Flow hydroponic system works by providing nutrients to plants with a tidal pattern. When the medium is flooded with water, waste gases from the plants are expelled through the roots. Likewise, when the medium is drained, oxygen-rich air from the outside is absorbed by the plants, promoting healthy and vigorous growth.

Generally, AB Mix nutrients are used in hydroponics, but these nutrients are considered too expensive. As a result, many hydroponic practitioners have started switching to the use of liquid organic fertilizers (POC). Liquid organic fertilizers are solutions derived from the decomposition of organic materials, such as plant residues and animal manure, containing more than one essential nutrient. Liquid organic fertilizers are beneficial for plants and the environment because they provide essential nutrients for plant growth, development, and health. These fertilizers contain nitrogen (N), phosphorus (P), and potassium (K). Nitrogen (N) is needed by plants to promote the growth of shoots, stems, and leaves. Phosphorus (P) helps stimulate root, fruit, and seed growth. Meanwhile, potassium (K) enhances plant resistance to pests and diseases.

The idea to be presented is a modification of the farming technique in Kulon Progo, using nutrients or fertilizers from animal manure or compost. However, because it is a hydroponic system, the manure will be turned into liquid form, or what is known as compost tea. Compost tea has recently attracted attention from researchers and practitioners in organic farming because it serves a dual purpose as a nutrient source and a biopesticide, especially in organic farming due to the limited options for pest control (Berek, 2017).

Table 1. Organic Liquid Fertilizer Composition

Composition	Quantity
Sheep/Goat manure	2 kg
Clean water	40 L
EM4	40 mL
ZA (Ammonium Sulfate)	1 kg
Sugar	0.5 kg

The monitoring process for the preparation of organic liquid fertilizer should be done routinely and intensively to ensure good fertilizer quality. The steps include stirring the mixture twice a day for 2 minutes per fermentation bucket, once in the morning and once in the afternoon. Once a week, the pH and EC of the solution should be monitored. After two weeks, filtering is done to separate solid and liquid parts to obtain the desired fertilizer solution.

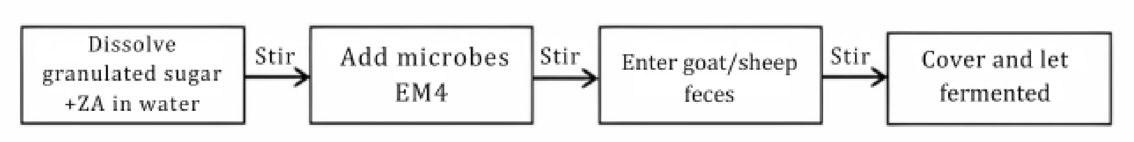

Fig 1. How to make hydroponic organic liquid fertilizer

Regarding the issue of freshwater availability in coastal areas, this can be addressed by using rainwater or distilled seawater. The quality of water from evaporation (such as rainwater) using solar energy has provided an alternative solution for coastal and island communities to reduce the difficulty of obtaining clean water (Iswadi, 2016). This water is not only suitable for drinking but also for dissolving hydroponic nutrients (compost tea), as it does not contain materials that would cause nutrient elements to coagulate.

The hydroponic system used is the Ebb and Flow system. Similar to the tides, hydroponic nutrients will be provided to the plants at certain intervals. The plants will receive nutrients when they need them. When the plants have enough nutrients, the compost tea will be drained. The time for flooding and draining will be regulated using a simple timer, so the coastal community does not need to water the plants daily. Therefore, the tidal hydroponic system can be an income source, either as a primary or supplementary livelihood for fishermen in coastal areas.

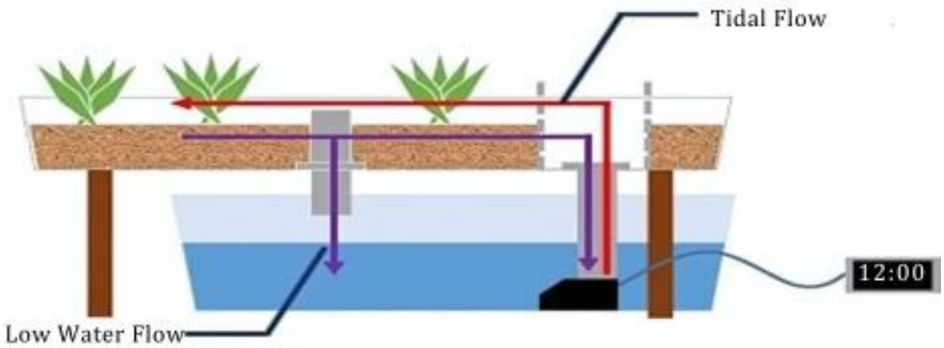

Fig 2. Principle of the Ebb and Flow Hydroponic System

For the growing medium, coconut coir waste, which is commonly found in coastal areas, can be used. Coconut coir is chosen because it can absorb nutrients, ensuring the availability of nutrients for the plants. The preparation process is quite simple, involving cutting or shredding the coir. The coconut coir and sand will then be mixed. This medium serves as a support for the roots and as a temporary storage for nutrients when the system is drained.


Fig 3. Cutting the Growing Medium

The Ebb and Flow hydroponic technique in this cultivation uses the concept of sustainable agriculture, where this hydroponic farming will produce high yields without damaging the environment, ensuring that the environment is preserved while continuous plant production is maintained. This is because the farming materials use local resources, utilizing abundant coconut coir as the medium, sand as another medium, seawater distilled into clean water using sunlight to dissolve nutrients, and compost tea made from kitchen waste and animal manure. These materials are readily available in coastal areas. However, capital investment would involve the participation of the Penta-Helix stakeholders, which include ABCGM (Academics, Businessmen, Community, Government, Media).

3.1.2 Mini experiment

A mini experiment on hydroponic plants was conducted from January 13-24, 2020 (starting from transplanting into the hydroponic system). The materials used were lettuce aged 10-14 days, which had been previously planted in trays. The first step was to prepare the growing medium, which consisted of Malang black sand and coconut coir. The Malang black sand was chosen because it was available at the Faculty of Agriculture UNS Greenhouse. The fine texture of the sand helps absorb water and nutrients. The absorption of nutrients by plants is influenced by the growing medium, which is where plant roots absorb the essential nutrients. A good growing medium is one that supports the growth and life of plants. The success of the hydroponic system depends on a medium that is porous and has good aeration, as well as sufficient nutrients for plant growth (Perwtasari et al., 2012).

Fig 4. Washing the Sand Medium

Before using the medium, it should be cleaned by washing it with water. Sand needs to be washed first to ensure it is free from unwanted foreign objects (e.g., plant roots and foreign plants). Multiple washings are required to ensure the medium is ready for use. After washing, the medium should be drained to separate it from the water.

Once the medium/substrate is ready, the next step is to plant the seeds. The seeds were planted in cups filled with sand. After planting, coconut coir was added on top of the medium to prevent moss growth and to ensure the plants stand upright. In this experiment, 35 cups were used. After planting and filling the cups with the growing medium, they were arranged properly.

Fig 5. Ebb and Flow System

The Ebb and Flow system is a circulating hydroponic system where irrigation occurs every 10 minutes for 30 seconds. The water rises to wet the roots and then drains back down. The plants receive water, nutrients, and oxygen adequately since the roots are not continuously submerged. The irrigation time is controlled using a timer, which is programmed to operate every 10 minutes. The timer is connected to the water pump. In this experiment, the reservoir is placed below, so a water pump is needed to lift the water to irrigate the plants. The nutrient solution in the reservoir is pumped by the pump into the planting container through an irrigation pipe network. The solution then flows back to the nutrient reservoir, and the system is placed in a shaded area. A total of 35 plants were planted.

3.1.3 Overview of leafy vegetable products

Leafy vegetables are commonly grown in hydroponic systems because their stems are not too large or heavy, making them suitable for hydroponic cultivation. According to the Food Security Agency of the Ministry of Agriculture (2012), vegetables provide essential nutrients for the body. The per capita consumption target for vegetables in Indonesia from 2011-2015 shows a 7.0% annual growth rate.

Leafy vegetables that can be cultivated using hydroponic systems with high yields include lettuce, spinach, kale, pakcoy, and other types of leafy vegetables. According to Wahyuningsih et al. (2016), pakcoy and mustard can grow in both highland and lowland areas. The use of hydroponic systems is expected to improve the growth and yield of leafy vegetables. Based on this research, leafy vegetables, especially mustard and pakcoy, can be grown in coastal areas using hydroponic technology.

3.2 Leafy vegetables in hydroponics as business opportunities

The quality of leafy vegetables produced through conventional farming methods is often deemed insufficient due to various factors such as soil degradation, limited access to water, and vulnerability to pests and diseases. As a result, there is a growing interest in alternative cultivation methods, with hydroponics emerging as a promising solution. Hydroponic farming, unlike traditional soil-based cultivation, uses water as the growing medium, providing a controlled environment that allows for more precise management of nutrient levels. This method not only improves the quality of vegetables but also increases the efficiency of water usage, making it particularly beneficial in areas with limited water resources, such as coastal regions. By using nutrient-rich water, hydroponics can ensure that plants receive optimal nutrients for growth, leading to healthier, high-quality produce.

In coastal areas, certain leafy vegetables, such as spinach, mustard, pakcoy, and caisim, are well-suited for hydroponic cultivation due to their adaptability to various environmental conditions. These vegetables are a vital part of the local diet because they are rich in essential nutrients, particularly vitamins and minerals, which are crucial for maintaining good health. The growing demand for these leafy vegetables is driven by their popularity in everyday meals, as well as their nutritional benefits, especially for children who require adequate vitamins and minerals for their growth and development. As the demand for these vegetables continues to rise, particularly in coastal areas where traditional farming may face challenges, hydroponic farming offers a sustainable and reliable solution to meet this demand while ensuring the nutritional needs of the community are fulfilled.

4. Conclusions

The application of hydroponic technology, particularly through the Ebb and Flow system, presents a solution to the issue of limited vegetable supply in coastal areas, where agricultural conditions are less favorable. By using sand as a substrate and utilizing locally sourced nutrients, this approach eliminates the need for soil and is aligned with the concept of sustainable agriculture. The marketing of hydroponic leafy vegetables is focused on three key sales channels: first, through traders or collectors to supply local markets in coastal regions; second, through supermarkets and restaurants; and third, by processing the vegetables into snacks such as chips to enhance the product's value and introduce innovative sales methods. Through the collaboration of the Penta Helix ABCGM (Academics, Businessmen, Community, Government, Media), this initiative has the potential to develop into a promising agricultural business.

For future development, several recommendations are offered to academics, business owners, government officials, and the public. First, academic researchers should conduct further studies on hydroponic technology and product innovation. Second, business owners can explore opportunities to expand their ventures by innovating agricultural products, tools, and materials, as well as contributing to the marketing of hydroponic products. Third, the government should consider the potential of hydroponic businesses in coastal areas when formulating policies. Fourth, coastal communities should pay greater attention to the agricultural sector as it is a vital source of food. Finally, media outlets should amplify their role, especially in the context of Industry 4.0, where media plays a significant and influential role in society.

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Author Contribution
All authors was responsible for the conceptualization, data collection, analysis, and manuscript writing. All aspects of the research, including the formulation of research questions, literature review, and interpretation of findings, were conducted independently. The author also reviewed and approved the final version of the manuscript.

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