Benchmarking of Hydroponics System

for the Technical Assistance on

Empowering Communities with Sustainable Agricultural Systems; Piloting a Small-Scale Hydroponics System (EMSAS)

Kubau LGA, Kaduna State, Nigeria.

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Executive Summary

This report presents a benchmarking of hydroponic Technology for the EMSAS-hydroponic project, it is an in-depth analysis of three hydroponic systems, Nutrient Film Technique (NFT), Deep Water Culture (DWC), Aeroponic and a soilless system (trough system) evaluating their suitability for implementation in Kubau, a rural area in Kaduna State, Nigeria. The primary objective is to identify the most appropriate hydroponic technology that aligns with Kubau's local conditions, resources, infrastructure, and climatic factors, ultimately contributing to sustainable

agricultural practices in the region. Hydroponics, a soilless method of cultivating plants using nutrient-rich water, offers a controlled environment that optimizes plant growth. This approach has gained global recognition for its ability to produce high yields with efficient resource use, making it a viable alternative for regions facing challenges such as limited arable land, water scarcity, and climate variability.

In this report, four key systems were evaluated: Nutrient Film Technique (NFT), Deep Water Culture (DWC), Aeroponic and trough soilless system. The NFT system involves a thin film of nutrient solution flowing continuously over the plant roots, which are supported by channels. This system is highly efficient and scalable, though it depends on electricity and requires regular maintenance to prevent root diseases. The DWC system suspends plants in nutrient-rich water with roots submerged, receiving direct oxygenation. While simple to set up and maintain, DWC is vulnerable to root diseases and algae growth. The Aeroponic system suspends roots in the air, delivering nutrients through a misting system. It provides maximum oxygenation and efficient water use, but its complex setup and high maintenance requirements pose challenges. The trough system is a soilless system. In this kind of system, plants are grown in high-density plastic troughs, wherein growing media like cocopeat is placed to hold the moisture, provide nutrient solution, retain nutrients against leaching, and buffer supply.

The four systems were assessed based on cost, efficiency, ease of use, and maintenance. Aeroponic is the most expensive, while DWC offers the lowest cost, with NFT and trough systems falling between the two. NFT, trough and Aeroponic are highly efficient in terms of nutrient delivery and growth rates, while DWC is moderately efficient. DWC is the simplest to operate, followed by NFT and trough, while Aeroponic requires a higher level of technical expertise. DWC has the lowest maintenance requirements, whereas NFT and Aeroponic require more frequent monitoring and upkeep.

Based on this evaluation, the NFT, Trough and DWC systems are recommended for Kubau. It strikes a balance between cost, efficiency, and ease of use, making it the most viable option for the region. These system’s ability to deliver high yields with relatively moderate maintenance and resource use aligns well with the local conditions in Kubau, including the availability of water resources, the need for scalable solutions, and the existing infrastructure.

Adopting the NFT, DWC hydroponic system and trough soilless system in Kubau presents a promising opportunity to enhance local agricultural productivity sustainably. This technology not only addresses the challenges posed by traditional farming methods but also contributes to food security, economic development, and environmental conservation in the region. The successful implementation of this system could serve as a model for other rural areas in Nigeria and beyond, demonstrating the potential of hydroponics in transforming agricultural practices.

1.0 INTRODUCTION

1.1 Overview of EMSAS Project

The technology concept support is a technical assistance initiative provided to a sub-national agency in Nigeria, specifically implemented within the Kubau Local Government Area (LGA). The initiative is aimed at addressing critical issues such as climate change, insecurity, and food security. This effort is part of the joint European Union - Climate Technology Centre and Network (EU-CTCN) programme, which forms a component of the EU Multi-Annual Indicative Programme for the Thematic Programme on Peace, Stability, and Conflict Prevention (2021-2027). The EU-CTCN programme is designed to bolster the resilience of conflict-affected communities by promoting and facilitating conflict-sensitive, community-based technological solutions to climate change.

The Technical Assistance (TA), titled "Empowering Communities with Sustainable Agricultural Systems - Piloting a Small Scale Hydroponics System (EMSAS)," aims to pilot a small-scale hydroponics system within the Kubau LGA. The primary objective of this TA is to enhance agricultural resilience through the use of innovative technology and community engagement. By reducing reliance on erratic weather patterns and mitigating the impact of conflict-driven disruptions to traditional farming practices, the TA contributes to sustainable development in regions affected by conflict.

Green Habitat Initiative (GHI), a nonprofit organization based in Nigeria, has been selected as the National Implementing Entity (NIE) to provide technical assistance. GHI has entered into an agreement to pilot and implement the hydroponics system in rural communities within Kubau LGA in Kaduna State, Nigeria. The implementation of this TA is scheduled to take place over a 12-month period**,** from May 2024 to April 2025.

As part of the TA, a benchmarking study of different hydroponic systems will be conducted to identify the most suitable system for the EMSAS project, considering the specific location and context of Kubau. Additionally, a study tour will be undertaken to deepen the understanding of project implementation and sustainable hydroponic systems. This tour will provide valuable insights into best practices, innovative techniques, and lessons learned from successful hydroponic projects. Furthermore, it will inform the risk assessment and mitigation action plan by identifying potential challenges and opportunities for implementing hydroponic systems within the context of this project.

1.2 Overview of Hydroponic Technology

Hydroponics is a method of growing plants without soil, where plants receive nutrients directly from water fortified with mineral nutrients. This system allows for precise control over plant nutrition, water usage, and environmental conditions, leading to increased growth rates and yields compared to traditional soil-based farming.

In hydroponics, plants are typically grown in an inert medium like water-retainable foam, rock wool, or coconut coir to provide support for the roots. Nutrient solutions are then delivered directly to the roots, either through a continuous flow system like NFT or by submerging the roots in a nutrient solution as in DWC.

Hydroponics has been widely studied for its efficiency in nutrient use and water conservation. Various systems. According to Jensen and Collins (1985), hydroponic systems can produce higher yields compared to traditional soil-based agriculture due to the optimized delivery of nutrients and water.

The NFT system, in particular, has been praised for its water efficiency and scalability, making it suitable for both small-scale and commercial operations. DWC systems, while simpler in design, have been noted for their rapid plant growth, owing to the direct oxygenation of roots (Jones, 2005). Aeroponics, the most technologically advanced of the three, offers maximum oxygenation and nutrient efficiency, although it requires significant technical expertise and infrastructure (Díaz-Pérez *et al.,* 2007).

Plate 1: *Hydroponic System*

1.2.1 Historical Background

The concept of soilless plant cultivation dates back to ancient civilizations. The Hanging Gardens of Babylon, one of the Seven Wonders of the Ancient World, are believed to have used a form of hydroponics. The Aztecs also practised a type of hydroponics with their floating gardens, known as chinampas. The modern term "hydroponics" was coined in the early 20th century by Dr. William Frederick Gericke, who demonstrated that plants could be grown to maturity in a solution of water and nutrients.

The role of hydroponics in promoting sustainable agriculture has been widely discussed in recent literature. Hydroponic systems are known for their ability to reduce water usage by up to 90% compared to traditional farming methods, which is crucial in arid and semi-arid regions (Savvas *et al.,* 2007). Additionally, they offer a solution to the degradation of arable land, a significant issue in many parts of Africa, including Nigeria (FAO, 2015).

Studies have also highlighted the potential of hydroponics to address food security in conflict-affected regions. Hydroponic farming can be implemented in controlled environments, reducing the reliance on unpredictable weather patterns and enabling year-round crop production (Birkby, 2016). This is particularly relevant for regions like Kubau, where traditional farming practices are increasingly challenged by climate change and socio-political instability.

1.2.2 Basic Principles of Hydroponic

Hydroponics involves growing plants with their roots exposed to a nutrient-rich water solution, rather than soil. This method relies on providing plants with the essential elements they need for growth directly to their roots. The key components of a hydroponic system include:

1. **Water**: The primary medium in which nutrients are dissolved and delivered to plants.
2. **Nutrients**: Essential minerals and elements required for plant growth, such as nitrogen, phosphorus, potassium, calcium, magnesium, and trace elements.
3. **Oxygen**: Necessary for root respiration; oxygenation of the nutrient solution is crucial for plant health.
4. **Light**: For photosynthesis, can be provided by natural sunlight or artificial grow lights.
5. **Growing medium**: A medium or structure to support the plant's roots and stems, which can include materials like water-retainable foam, rock wool, clay pellets, or perlite.

1.3 Types of Hydroponics Technology

Numerous hydroponic techniques are used in modern times, below are specific factors to consider when choosing the right technique.

1. Available resources,
2. Space,
3. Expected productivity,
4. Growing media,
5. Quality of the product.

There are several types of hydroponic systems, each with its own method of delivering nutrients and water to plants. The most common systems include:

1.3.1. Deep Water Culture (DWC)

In deep water culture, the roots of plants are suspended in nutrient-rich water, and air is provided directly to the roots by an air stone. The Hydroponics buckets system is a

definitive example of this system. Plants are placed in net pots and roots are suspended in a nutrient solution where they grow fast in a large mass. It is mandatory to monitor the oxygen and nutrient concentrations, salinity, and pH as algae and moulds can grow fast in the reservoir. This system works well for larger plants that produce fruits, especially cucumber and tomato, grow well in this system.

1.3.2. Ebb and Flow (Flood and Drain)

Plant roots grow through a medium. Nutrient-filled water is pumped frequently (e.g., every 30 minutes) to the root zone area and allowed to drain back into a water reservoir.

1.3.3. Drip System

The drip hydroponic system is a widely used method by both home and commercial growers. Water or nutrient solution from the reservoir is provided to individual plant roots in appropriate proportion with the help of a pump. Plants are usually placed in a moderately absorbent growing medium so that the nutrient solution drips slowly. Various crops can be grown systematically with more water conservation.

1.3.4. Wick System

Plant roots grow down through a medium while an absorbent "wick" draws nutrient-filled water to the plant from the reservoir to the root system zone. The growing medium allows for air (oxygen) to reach the roots.

1.3.5. Aeroponic System

Tubers and roots are ideal to grow using aeroponics. In this configuration, the plants, with their roots hanging down in the air, get their nutrients from periodic spraying by a system of sprinkles. The main advantage of this technique is that it does not require an airing system as oxygen is carried along with the sprayed nutrient solution.

1.4 Benefits of Hydroponic Farming

Plants grown in soil need to spread their roots to find water and all the nutrients they need to survive. In hydroponic systems, roots don't need to spread because water and nutrients are

delivered right to them. As a result, hydroponic systems can grow more plants in the same amount of space as soil-based systems.

1. **Water Conservation:** Field farming uses so much water because so much of it is lost. Hydroponic systems use about 10 times less water because it's delivered in a controlled way.
2. **Fewer Chemicals:** While hydroponic systems don't eradicate pest issues, it does lower the potential of this happening, resulting in less need for pesticides and herbicides.
3. **Faster Growth:** Plants grown in hydroponic systems grow 30% to 50% faster than those grown in soil. Crops grow faster in hydroponic systems because they receive an ideal amount of nutrients and, if grown indoors, have less environmentally induced stress (like weather and pests).
4. **Nutrient Control:** Hydroponic systems feed plants a nutrient solution mixed with water, giving the farmer better control over what nutrients their crops soak up.
5. **Grow Indoors:** Another benefit of hydroponic farming is that it's easy to do indoors. Growing indoors comes with its benefits such as the ability to grow year-round, temperature and climate control, and fewer pests.
6. **Healthier Plants:** In hydroponic farming, plants grow healthier than in soil. For one thing, soil-borne diseases aren't an issue in hydroponics because there is no soil for those diseases to fester and spread.
7. **Bigger Yields:** Because more plants can be grown in small spaces with hydroponic farming than soil farming, hydroponic systems typically yield more per square foot. Additionally, plants are healthier and grow faster, generating more produce faster.
8. **No Soil Erosion:** Field agricultural practices have eroded half of the soil on Earth in the last 150 years, decreasing the availability of arable land. Hydroponic systems don't use soil. No soil means no soil erosion. It's that simple.
9. **No Weeds:** Hydroponic systems are not habitable for the seeds of weeds. Weeds need the same things as other plants to sprout, but seeds aren't typically sowed in hydroponic systems. Since the seeds can't start germinating, weeds won't take root and steal your crops' precious nutrients.

1.5 Importance of Hydroponic Technology in Sustainable Agriculture

Sustainable agriculture aims to meet the needs of the present without compromising the ability of future generations to meet their own needs. It emphasizes practices that protect the environment, maintain soil fertility, conserve resources, and ensure economic viability. Hydroponic systems, as a soilless method of growing plants, play a significant role in achieving these goals by offering a more efficient and controlled approach to agriculture.

1.5.1 Efficient Resource Use

1. **Water Conservation**

    I. Hydroponic systems use significantly less water compared to traditional soil-based agriculture. Water is recirculated within the system, reducing wastage and conserving this precious resource. This is particularly important in arid regions or areas facing water scarcity.

    II. Since hydroponic systems are often enclosed, there is minimal water loss due to evaporation. This contrasts with conventional farming, where a substantial amount of water is lost to the atmosphere.

2. **Nutrient Efficiency**

    I. Hydroponics allows for the precise delivery of nutrients directly to the plant roots, ensuring that plants receive the exact amount of nutrients they need. This reduces nutrient runoff into the environment, which can cause soil and water pollution.

    II. Because of the efficiency in nutrient delivery, hydroponic systems require less fertilizer, lowering the environmental impact associated with fertilizer production and application.

1.5.2 Higher Yields and Faster Growth

1. **Optimized Growing Conditions**

I. Hydroponic systems typically begin in controlled environments, such as greenhouses or indoor farms. This allows for optimization of temperature, humidity, light, and nutrient levels, promoting faster plant growth and higher yields.

II. With the ability to control environmental factors, hydroponics enables year-round crop production. This continuous growing cycle increases food availability and can help stabilize market prices.

2. Reduced Crop Loss

I. The absence of soil in hydroponic systems reduces the risk of soil-borne pests and diseases. This leads to healthier plants and fewer crop losses, contributing to higher overall productivity.

1.5.3 Space Utilization

1. Vertical Farming

I. Hydroponic systems can be designed vertically, making efficient use of limited space. This is particularly advantageous in urban areas where land is scarce and expensive.

II. By utilizing rooftops, abandoned warehouses, and other spaces, hydroponics can bring food production closer to consumers. This reduces the need for long transportation routes, lowering carbon emissions and improving food freshness.

1.6 Challenges and Considerations for Implementation

Despite the advantages, the implementation of hydroponic systems in rural areas such as Kubau poses certain challenges. A key concern is the initial cost and technical expertise required to set up and maintain these systems. Moreover, the lack of infrastructure, such as stable electricity and water supply, can impede the successful operation of systems like NFT and Aeroponics, which rely on continuous nutrient flow and misting, respectively (Resh, 2022).

Another important consideration is the socio-economic context. The adoption of hydroponic systems requires not only technical training but also a shift in traditional farming practices. Studies suggest that community engagement and education are critical to ensuring the successful adoption of these systems in rural areas (Hu *et al.,* 2022). Therefore, any pilot project in Kubau must include a strong capacity-building component to empower local farmers with the knowledge and skills necessary for sustainable operation.

The reviewed literature underscores the potential of hydroponic systems to transform agriculture in resource-constrained settings by improving water efficiency, increasing yields, and offering resilience against climate change. However, successful implementation in Kubau will require careful consideration of local conditions, infrastructure, and community engagement. This literature review provides a foundation for selecting the most appropriate hydroponic system for the EMSAS project, with an emphasis on sustainability and scalability in the context of rural Nigeria.

1.7 Specific Considerations for Kubau

1.7.1 Climate and Weather Conditions

1. **Temperature**: Kubau experiences a tropical savanna climate, with distinct wet and dry seasons. The temperature ranges between 22 and 33 degrees Celsius in the wet season (between mid-April to October) while the dry (between November and April) season can reach up to 43 degrees Celsius in day time. Hydroponic systems in this area must be designed to handle high temperatures during the dry season. Cooling systems or shade structures may be necessary to prevent heat stress on plants.

2. **Humidity**: The humidity levels in Kubau can vary significantly between 55% to 87% during the wet and dry seasons. Monitoring and controlling humidity within hydroponic setups will be essential to prevent diseases such as powdery mildew and root rot.

3. **Rainfall**: The rainy season brings substantial rainfall, the wet season lasts for about six months, from April to October, with an average annual rainfall of about 1178 mm per annum. The rainfall intensity is very high within the months of July and August which can

be utilized for water harvesting. This harvested rainwater can be filtered and used in hydroponic systems, reducing dependency on other water sources.

1.7.2 Water Availability and Quality

1. **Water Sources**: Kubau's hydroponic systems should leverage available water sources such as boreholes, wells, or rivers. Ensuring a reliable and consistent water supply is critical for the success of hydroponic farming.
2. **Water Quality**: Water used in hydroponics must be free from contaminants and have an appropriate pH level. Regular testing and, if necessary, treatment of water will be important to maintain the health of the plants.

1.7.3 Economic Factors

1. **Initial Investment**: While hydroponic systems can be cost-effective in the long run, the initial setup cost can be a barrier. Identifying funding opportunities, grants, or subsidies from the government or NGOs can help farmers in Kubau overcome this hurdle.
2. **Operating Costs**: The ongoing costs of running hydroponic systems, including electricity for pumps and lighting, should be considered. Using renewable energy sources such as solar power can help reduce these costs.

1.7.4 Local Knowledge and Training

1. **Farmer Training**: Successful implementation of hydroponic systems in Kubau will require comprehensive training programs for local farmers. These programs should cover the basics of hydroponics, system maintenance, pest and disease management, and harvesting techniques.
2. **Community Engagement**: Involving the local community in planning and decision-making processes will enhance the acceptance and sustainability of hydroponic projects. Community leaders and influencers should be engaged to champion the initiative.

1.7.5 Crop Selection

1. **Suitable Crops**: Lettuce, tomatoes, peppers, and herbs are well-suited for hydroponic cultivation in Kubau. Selecting crops that have a high market demand and are well-accepted by the local population will ensure economic viability.
2. **Crop Rotation**: Implementing crop rotation strategies within hydroponic systems can help prevent nutrient depletion and pest build-up, contributing to the sustainability of the farming practice.

1.7.6 Infrastructure and Technology

1. **Greenhouse Structures**: Building simple, cost-effective greenhouse structures can help protect hydroponic systems from extreme weather conditions and pests. These structures should be designed to maximize natural ventilation and light.
2. **Technological Adaptation**: Introducing appropriate technologies that are easy to use and maintain in a rural setting is crucial. Low-tech, gravity-fed systems or solar-powered pumps can be more practical and sustainable for Kubau.

1.7.7 Sustainability and Environmental Impact

1. **Sustainable Practices**: Promoting sustainable practices such as using organic nutrients, recycling water, and implementing integrated pest management will enhance the environmental benefits of hydroponics.
2. **Biodiversity Conservation**: Hydroponic systems can help reduce the pressure on natural ecosystems by providing an alternative to land-intensive farming practices. Ensuring that these systems are part of a broader strategy to conserve local biodiversity is important.

1.8 Basic Principles of Soilless Systems

The fundamental principle behind soilless farming is that plants do not require soil but rather the nutrients that soil provides. By bypassing the soil, growers can control the exact nutrient balance delivered to plants, ensuring optimal growth conditions. The key elements of a soilless system include:

1) **Growing Medium**: Inert or organic materials like cocopeat, perlite, or vermiculite serve to anchor the plants and sometimes help retain moisture.
2) **Nutrient Solution**: A balanced mix of essential nutrients, dissolved in water, that is provided directly to the plant roots.
3) **Watering System**: Methods like drip irrigation, recirculation, or periodic flooding ensure plants receive adequate moisture and nutrients.
4) **Environmental Control**: Light, temperature, and humidity are managed to create optimal conditions for plant growth.

Types of Soilless Systems

a. Trough System

The trough system is a type of soilless farming where plants are grown in long, shallow troughs or channels filled with a growing medium (e.g., cocopeat) or nutrient-rich water. This system is particularly well-suited for crops like leafy greens and is often used in hydroponic setups, where the troughs allow nutrient solutions to flow through, ensuring consistent nutrient delivery.

b. Grow Bags: Cocopeat is placed in bags where plants are grown directly. Drip irrigation systems deliver nutrients to the plants.

c. Container Gardening: Cocopeat is commonly used in pots and containers for home gardening or greenhouse production.

Importance of Soilless Systems in Sustainable Agriculture

Soilless systems play a crucial role in sustainable agriculture. They maximize resource use efficiency, particularly water, nutrients, and space, making them suitable for areas with limited arable land. By reducing the need for chemical inputs and soil-based challenges, they offer an eco-friendly alternative to traditional farming. Moreover, soilless systems can help reduce deforestation and soil erosion by minimizing the need to clear land for agriculture. Urban and peri-urban agriculture using soilless methods also reduces the carbon footprint associated with long-distance transportation of food.

Challenges and Considerations for Implementation i

While soilless farming offers many benefits, its implementation in local areas may present challenges, such as:

1. **Initial Setup Cost**: The infrastructure required for soilless systems, such as growing media, nutrient solutions, and irrigation systems, can be expensive.
2. **Technical Knowledge**: Farmers may require training to operate and maintain soilless systems effectively.
3. **Water Quality**: Poor water quality (e.g., high salinity or pollutants) can negatively impact plant health and system longevity.
4. **Electricity Dependence**: Many soilless systems, especially hydroponics, rely on consistent electricity to pump water and nutrients.

Specific Considerations for Kubau

When implementing soilless systems in a local area, several factors must be considered:

a. Climate and Weather Conditions:

I. In hot or dry climates, temperature control and humidity management are crucial. Systems like shade nets or greenhouses may be needed to prevent excessive heat stress on plants.

b. Water Availability and Quality:

1. Reliable water sources with good quality (low in salts and contaminants) are essential for successful soilless farming. In areas with water scarcity, drip irrigation and recirculating systems can help conserve water.

c. Economic Factors:

1. The cost of initial setup, including purchasing cocopeat, nutrient solutions, and irrigation systems, needs to be evaluated. The potential economic benefits, such as higher yields and reduced input costs (pesticides, fertilizers), should be factored in.

d. Local Knowledge and Training:

1. Adequate training must be provided to local farmers to manage soilless systems, particularly in nutrient management, irrigation scheduling, and troubleshooting.

e. Crop Selection:

1. Selecting crops suited to local market demand and the specific soilless system is important for economic sustainability. Leafy greens, herbs, and certain vegetables often perform well in soilless systems.

f. Infrastructure and Technology:

1. Access to reliable infrastructure, such as electricity and quality materials, is key to implementing soilless systems effectively. Automated nutrient dosing systems can enhance productivity.

g. Sustainability and Environmental Impact:

1. Care should be taken to minimize the environmental impact, such as using biodegradable or recyclable materials for growing media and reducing chemical runoff. Sustainable sourcing of cocopeat and nutrient solutions is important.

By considering these specific factors, soilless systems can be effectively tailored to the unique conditions and needs of Kubau, enhancing their potential for success and sustainability in this rural community.

1.9 Difference between soilless and hydroponics system

The terms "soilless" and "hydroponics" are often used interchangeably, but they have distinct meanings:

1. Soilless Growing:

Definition: Soilless growing refers to any method of cultivating plants without using natural soil. Instead, plants are grown in various alternative media such as peat moss, coconut coir, perlite, vermiculite, or rock wool.

1. Growing Medium: Soilless systems rely on physical media to support the plants and hold water and nutrients.
2. Watering: Nutrients are delivered through irrigation or watering systems, and these systems can range from manual to fully automated setups.
3. Examples: Soilless methods include trough system, traditional container gardening with peat-based mixes or commercial soilless mixes used in greenhouses.

2. Hydroponics:

Definition: Hydroponics is a subset of soilless growing where plants are grown directly in water, often without any solid growing medium. Instead, nutrient-rich water provides all the essential nutrients needed for plant growth.

1. Growing Medium: In many hydroponic systems, plants are suspended in water or use inert media like clay pebbles or perlite to anchor the roots.
2. Watering: Nutrients are delivered directly through water, with systems like NFT, DWC, or aeroponics circulating or misting nutrient solutions to the roots.
3. Examples: Hydroponic systems include NFT (Nutrient Film Technique), DWC (Deep Water Culture), and aeroponics.

Key Differences:

1. **Growing Medium:** Soilless growing uses a solid medium (e.g., peat, perlite), while hydroponics primarily uses water as the medium for nutrients.

2. **Water Usage:** Hydroponic systems often use recirculating water, making them more water-efficient than traditional soilless methods, where water can be lost through runoff or evaporation.
3. **Nutrient Delivery:** In hydroponics, nutrients are dissolved directly into the water, whereas in soilless growing, nutrients are added to the medium or water but not always in a continuous recirculation.

In general, all hydroponics is soilless, but not all soilless growing methods are hydroponic.

1.10 Purpose and Scope of the Report

The purpose of this report is to evaluate and recommend the most suitable hydroponic and soilless system for implementation in Kubau Local Government Authority (LGA) in Kaduna State, Nigeria, as part of the "Empowering Communities with Sustainable Agricultural Systems - Piloting a Small Scale Hydroponics System (EMSAS)" initiative. This initiative is a component of the joint European Union - Climate Technology Centre and Network (EU-CTCN) programme, which aims to strengthen the resilience of conflict-affected communities through innovative, climate-resilient agricultural practices.

The scope of this report includes an in-depth analysis of three hydroponic systems—Nutrient Film Technique (NFT), Deep Water Culture (DWC), Aeroponic and a soilless (trough system). The analysis covers the explanation, components, advantages, challenges, and design considerations of each system, with a specific focus on their suitability for the local conditions in Kubau. The report also provides a comparison of the systems based on key criteria such as cost, efficiency, ease of use, and maintenance, leading to a recommendation of the most appropriate system for the EMSAS project.

This report serves as a critical tool for decision-making in the selection of a hydroponic system that aligns with the goals of sustainable development, climate resilience, and food security in the rural communities of Kubau LGA.

2.0 NUTRIENT FILM TECHNIQUE SYSTEM

2.1 Introduction

The Nutrient Film Technique (NFT) is a popular hydroponic system that involves the continuous flow of a nutrient-rich solution over the roots of plants. This system is particularly efficient and effective for growing leafy greens and herbs, making it a favoured choice among hydroponic growers. In an NFT system, plants are typically grown in channels or tubes with their roots exposed to a thin film of nutrient solution, which is constantly recirculated. The minimal amount of nutrient solution ensures that the roots receive sufficient oxygen, promoting healthy and rapid growth.

Plate 2: *NFT Hydroponic System*

2.2 Components of an NFT System

1. **Channels or Troughs**: These are long, shallow channels where the plants are placed. They are usually made of food-grade plastic and have a slight slope to facilitate the flow of the nutrient solution.
2. **Nutrient Solution Reservoir**: This is a container that holds the nutrient solution. It is typically positioned below the channels to allow gravity to return the solution to the reservoir after it has flowed through the channels.
3. **Water Pump**: A pump is used to deliver the nutrient solution from the reservoir to the channels. The pump needs to run continuously to maintain the flow of the solution over the roots.

4. **Air Pump and Air Stone**: These components help oxygenate the nutrient solution in the reservoir, ensuring that the plant's roots receive adequate oxygen.
5. **Delivery System**: This includes tubing or piping that transports the nutrient solution from the reservoir to the top end of the channels.
6. **Drainage System**: This system collects the nutrient solution after it has flowed through the channels and returns it to the reservoir for recirculation.
7. **Grow Tray or Net Pots**: These hold the plants in place within the channels. Net pots allow the roots to grow out and come into contact with the nutrient film.

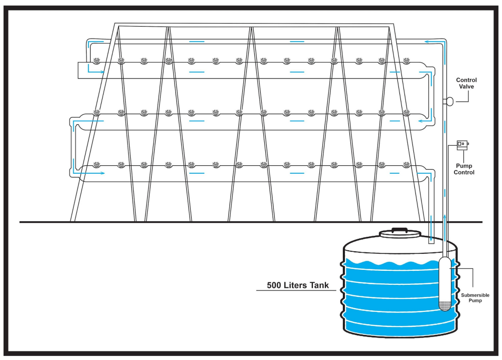

Plate 3: *Component of NFT Hydroponic System*

2.3 How the NFT System Works

1. **Preparation and Planting**: Plants are generally started in a separate nursery or propagation area until they develop a strong root system. Once ready, the plants are transferred to net pots and placed into the channels of the NFT system.

Plate 4: *Nursery tray filled with cocoa peat*

2. **Nutrient Solution Delivery**: The nutrient solution, which contains all the essential nutrients required for plant growth, is mixed in the reservoir. The water pump continuously delivers this nutrient solution from the reservoir to the upper end of each channel.

3. **Nutrient Film Flow**: The channels are set at a slight incline, allowing the nutrient solution to flow by gravity from the top of the channel to the bottom. As the solution flows over the roots, it forms a thin film that provides nutrients and moisture while leaving some parts of the roots exposed to air for oxygen absorption.

4. **Oxygenation**: The air pump and air stone in the reservoir keep the nutrient solution well-oxygenated, which is crucial for root respiration and overall plant health.

5. **Recirculation**:After flowing through the channels, the nutrient solution drains back into the reservoir, where it is recirculated by the pump. This continuous recirculation ensures that the plants have a constant supply of fresh nutrients.

6. **Monitoring and Maintenance**: Regularly checking the nutrient solution's pH and EC (electrical conductivity) levels is essential to maintain optimal nutrient availability. The system needs to be checked for proper flow rates and any blockages or leaks that could disrupt nutrient delivery.

7. **Harvesting**: As the plants grow and reach the maturity stage, they can be harvested directly from the channels. The continuous nature of the NFT system allows for staggered planting and harvesting, providing a consistent supply of fresh produce.

Plate 5: *Harvested Lettuce from NFT Hydroponic System*

2.4 Advantages of NFT System

1. **Water and Nutrient Efficiency**: The continuous recirculation of the nutrient solution minimizes water and nutrient waste.
2. **Oxygenation**: The thin film of nutrient solution ensures that roots have access to ample oxygen, promoting healthy growth.
3. **Scalability**: NFT systems can be easily scaled up or down, making them suitable for both small-scale home gardens and large commercial operations.
4. **Reduced Soil-Borne Diseases**: The absence of soil reduces the risk of soil-borne pests and diseases.

2.5 Challenges of the NFT System

1. **Dependence on Electricity**: Continuous operation of the water pump requires a reliable power source. Power outages can disrupt the nutrient flow and harm the plants.
2. **Root Disease**: If not properly managed, the constant moisture can lead to root diseases such as root rot.

3. **Clogging and Maintenance**: The channels and delivery system need regular maintenance to prevent clogs and ensure even nutrient distribution.

The NFT system is an efficient and effective hydroponic method, particularly suited for growing leafy greens and herbs. Its continuous nutrient flow and oxygenation capabilities make it a popular choice for hydroponic growers aiming for high yields and sustainable farming practices.

2.6 Design Considerations for NFT System

2.6.1 System Setup

1. **Channel Selection**:

   I. **Material**: Choose PVC pipe for the channels to ensure durability and safety.

   II. **Size**: Select channels with appropriate width and depth to accommodate the root system of the plants being grown. Common dimensions are around 10 cm wide and 5 cm deep.

   III. **Length**: To ensure efficient nutrient distribution, it is recommended that channels are not excessively long. In-home systems, a length of 2-3 meters is common, whereas commercial setups may employ longer channels with multiple nutrient inlets to prevent depletion along the way.

Plate 6: *Showing PVC pipe used for channels*

2. **Channel Layout**:

    I. **Slope**: To maintain a steady flow of nutrient solution, it is important to sustain a slight slope of 1-3% (equivalent to a 1-3 cm drop per meter) along the channel.

    II. **Spacing**: To facilitate plant development and ensure sufficient light penetration, it is advisable to space channels appropriately. The standard practice is to have channels positioned 15-20 cm apart.

Plate 7: *Showing space between channels and cup holder with water retainable foam holding the plant.*

3. **Support Structure**:

    I. **Material**: Use a sturdy frame made from metal, wood, or plastic to support the channels.

    II. **Height**: Ensure the structure is at a comfortable working height for easy planting, maintenance, and harvesting. Adjustable supports can help accommodate different crops.

4. **Reservoir Placement**:

    I. Position the nutrient solution reservoir below the channels to facilitate gravity-fed drainage back into the reservoir.

    II. Ensure easy access for monitoring and refilling the reservoir.

2.6.2 Nutrient Delivery

1. **Water Pump**:

   I. **Capacity**: Choose a pump with sufficient capacity to deliver the nutrient solution to the highest point of the system. Consider the total length of the channels and the required flow rate.

   II. **Reliability**: Opt for a reliable, energy-efficient pump to ensure continuous operation. Backup pumps or battery systems can provide redundancy in case of power outages.

2. **Nutrient Solution**:

   I. **Composition**: Use a well-balanced hydroponic nutrient solution tailored for the specific crops being grown. Ensure it contains all essential macro and micronutrients.

   II. **Mixing**: Mix the nutrient solution thoroughly in the reservoir to prevent the settling of nutrients and ensure even distribution.

3. **Flow Rate**:

   I. **Adjustment**: Use valves or flow regulators to adjust the flow rate of the nutrient solution to maintain a thin film over the roots. Typical flow rates range from 1-2 litres per minute.

   II. **Monitoring**: Regularly monitor the flow rate to ensure consistent nutrient delivery. Inadequate flow can lead to nutrient deficiencies, while excessive flow can cause root damage.

4. **Oxygenation**:

   I. **Aeration**: Air pumps and air stones are used to oxygenate the nutrient solution in the reservoir. Oxygen-rich solutions promote healthy root growth and prevent root rot.

II. **Temperature Control**: Maintain the nutrient solution at an optimal temperature (18-24°C) to enhance oxygen solubility and nutrient uptake.

2.6.3 Maintenance

1. **Regular Monitoring**:

   I. **pH and EC Levels**: Check and adjust the pH (5.5-6.5) and electrical conductivity (EC) of the nutrient solution regularly to ensure optimal nutrient availability.

   II. **Nutrient Levels**: Replenish and replace the nutrient solution as needed to prevent imbalances and deficiencies.

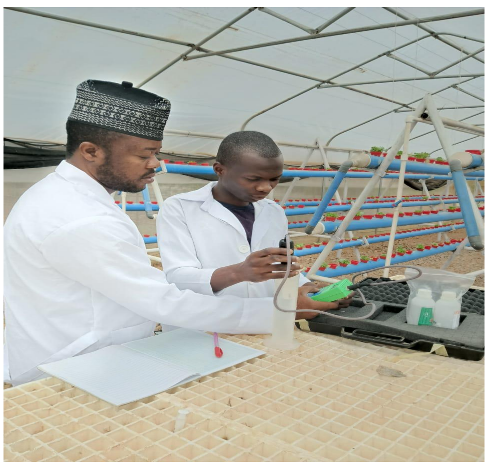

Plate 8: *Showing how to check the pH and EC*

2. **System Cleanliness**:

   I. **Channel Cleaning**: Periodically clean the channels to prevent algae growth, root clogs, and biofilm formation. Use food-safe cleaning agents and rinse thoroughly.

   II. **Reservoir Cleaning**: Clean the reservoir regularly to prevent sediment buildup and contamination.

3. **Pump and Tubing Maintenance**:

    I. **Inspection**: Regularly inspect the pump and tubing for blockages, wear, and leaks. Replace or repair components as necessary to ensure consistent nutrient flow.

    II. **Backup Systems**: Have backup pumps and spare parts on hand to minimize downtime in case of equipment failure.

4. **Pest and Disease Management**:

    I. **Integrated Pest Management (IPM)**: Implement IPM practices, including regular inspections, biological controls, and environmentally friendly treatments, to manage pests and diseases.

    II. **Root Health**: Monitor root health closely and take prompt action if signs of root diseases (e.g., root rot) are detected.

5. **Environmental Control**:

    I. **Temperature and Humidity**: Maintain optimal environmental conditions (temperature, humidity, light) in the growing area to support healthy plant growth and reduce stress.

    II. **Light Management**: Ensure adequate lighting (natural or artificial) for the crops. Use grow lights with appropriate spectra and intensity if growing indoors or in low-light conditions.

By considering these design elements and implementing robust nutrient delivery and maintenance practices, an NFT system can provide a highly efficient and productive method for hydroponic farming.

2.7 Suitability of NFT System for Kubau

2.7.1 Local Resources

1. **Water Availability**:

The NFT system is highly water-efficient, which is advantageous for Kubau, where water resources may be limited or inconsistent. The system recirculates water, minimizing wastage and making efficient use of available water sources such as wells, rivers, or harvested rainwater. Local water sources need to be tested and treated to ensure they meet the quality requirements for hydroponic farming.

2. **Nutrient Supply**:

Hydroponic nutrient solutions are required for the NFT system. These solutions can be sourced from local suppliers or prepared using commercially available nutrient mixes. Training local farmers in the preparation and management of nutrient solutions will be essential to ensure the health and productivity of the crops.

2.7.2 Infrastructure

1. **Electricity**:

Reliable electricity is needed to run water pumps continuously in the NFT system. Kubau's infrastructure should be assessed to ensure a consistent power supply. In areas where electricity is unreliable, incorporating renewable energy solutions such as solar power can help maintain the continuous operation of the system.

2. **Construction Materials**:

The materials needed to construct an NFT system, such as PVC pipes, channels, reservoirs, and pumps, should be readily available or easily sourced in Kubau or nearby regions. Utilizing local materials and resources can reduce costs and support the local economy.

2.7.3 Climatic Condition

1. **Temperature and Humidity**:

Kubau experiences a tropical savanna climate with distinct wet and dry seasons. The high temperatures during the dry season can be managed by implementing cooling systems, shade structures, or ventilation to prevent heat stress on plants.

During the rainy season, managing excess humidity and ensuring proper drainage will be important to prevent root diseases and maintain optimal growing conditions.

2. **Seasonal Variations**:

The ability to grow crops year-round using the NFT system is a significant advantage in Kubau, where traditional farming is often limited by seasonal variations.

Controlled environment agriculture (CEA) practices, such as using greenhouses or shade nets, can help mitigate the effects of extreme weather and ensure consistent crop production.

2.7.4 Economic Factors

1. **Initial Investment and Operating Costs**:

   I. The initial investment for setting up an NFT system may be high, but the long-term benefits of increased yields, water efficiency, and reduced pesticide use can offset these costs.

   II. Identifying funding opportunities, grants, or subsidies from government programs or NGOs can help local farmers in Kubau afford the initial setup costs.

   III. Operating costs, including electricity and nutrient solutions, need to be factored in. Exploring cost-effective solutions such as solar power and bulk purchasing of nutrients can help manage these expenses.

2. **Market Demand**:

I. Assessing the local market demand for hydroponically grown produce is crucial. Crops like lettuce, herbs, and leafy greens, which are well-suited for the NFT system, should have a viable market in Kubau or nearby urban centres.

II. Creating cooperatives or farmer groups can help in collective bargaining, accessing larger markets, and improving profitability.

2.7.5 Local Knowledge and Training

1. **Training Programs**:

    I. Comprehensive training programs for local farmers on hydroponic farming, specifically the NFT system, will be essential for successful implementation. These programs should cover system setup, nutrient management, pest and disease control, and harvesting techniques.

    II. Continuous support and extension services can help farmers troubleshoot issues and optimize their hydroponic systems.

2. **Community Engagement**:

    I. Engaging the local community and involving them in the planning and implementation process can enhance the acceptance and sustainability of the NFT system.

    II. Utilizing local labour for system setup and maintenance can create job opportunities and support the local economy.

2.7.6 Environmental Considerations

1. **Sustainable Practices**:

    I. Implementing sustainable practices such as recycling water, using organic nutrients, and integrated pest management (IPM) can enhance the environmental benefits of the NFT system.

II. By reducing the pressure on soil and natural ecosystems, hydroponic farming can contribute to biodiversity conservation and sustainable land use in Kubau.

The NFT hydroponic system holds significant potential for Kubau due to its efficient use of water and nutrients, adaptability to local climatic conditions, and ability to produce high yields. However, careful consideration of local resources, infrastructure, and economic factors is crucial for its successful implementation. With proper training, support, and community engagement, the NFT system can contribute to sustainable agriculture and improved livelihoods for local farmers in Kubau.

3.0 Deep Water Culture System

3.1 Introduction

Deep Water Culture (DWC) is a hydroponic method where plant roots are suspended in a nutrient-rich, oxygenated water solution. The roots are submerged in the solution, which provides all the necessary nutrients, water, and oxygen directly to the plant. This method is simple and effective, particularly for growing fast-growing, water-loving plants such as lettuce, spinach, and herbs.

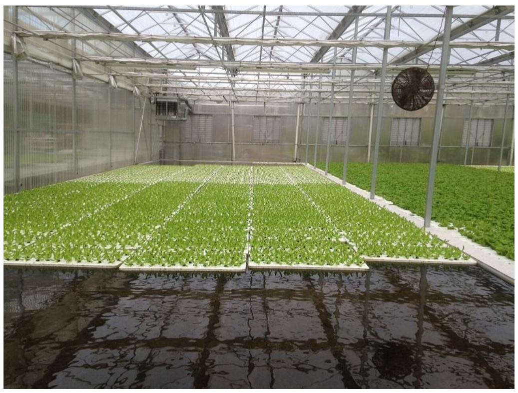

Plate 9: *DWC Hydroponics System*

3.2 Components of a DWC System

I. **Growing Container**: Typically a large, opaque container or reservoir is filled with the nutrient solution. The container should be deep enough to allow adequate space for root growth.

II. **Net Pots**: Small containers or pots with mesh bottoms that hold the plants in place. These are placed in holes cut into the lid of the growing container.

III. **Lid or Cover**: A lid with holes cut to fit the net pots. This cover keeps the plants in place and blocks light from reaching the nutrient solution, which helps prevent algae growth.

IV. **Nutrient Solution**: A water-based solution containing all the essential nutrients needed for plant growth. The solution should be regularly monitored and maintained.

V. **Air Pump and Air Stone**: An air pump connected to an air stone is placed in the nutrient solution to oxygenate the water. This is crucial for preventing root rot and ensuring healthy plant growth.

3.3 How the DWC System Works

I. **Preparation and Planting**: Seeds are germinated in a separate nursery or seedling tray until they develop a healthy root system. Young plants are then placed in net pots filled with a growing medium such as clay pellets or rock wool.

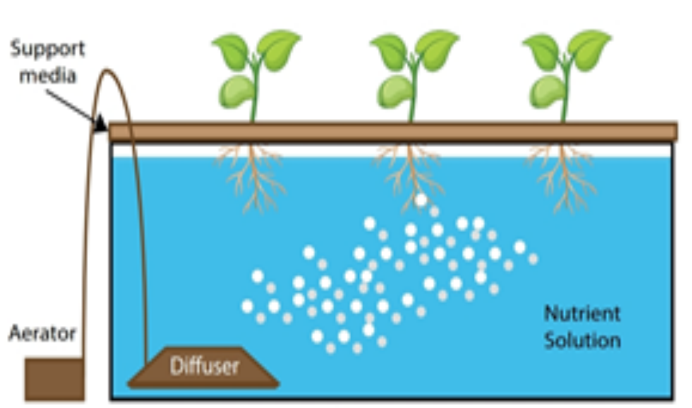

Plate 10: *Showing how the DWC System works*

II. **Submersion in Nutrient Solution**: The net pots are placed into holes in the lid of the growing container, with the roots suspended in the nutrient solution. The nutrient solution must cover the roots but not reach the stem of the plant to prevent stem rot.

III. **Oxygenation**: An air pump pushes air through tubing to an air stone, which releases bubbles into the nutrient solution. The bubbles oxygenate the water, providing the roots with the necessary oxygen to prevent root suffocation and promote healthy growth.

IV. **Monitoring and Maintenance**: The nutrient solution's pH and electrical conductivity (EC) levels should be regularly monitored and adjusted to ensure optimal nutrient availability. The solution should be topped up and replaced periodically to maintain nutrient balance and prevent the buildup of salts or contaminants.

V. **Harvesting**: As the plants grow and reach maturity, they can be harvested directly from the net pots. Also, continuous or staggered planting allows for regular harvesting and a consistent supply of produce.

3.4 Advantages of DWC System

I. **Simplicity**: The DWC system is relatively simple to set up and maintain, making it suitable for beginners and small-scale growers.

II. **Rapid Growth**: Plants in a DWC system can grow faster due to constant access to water, nutrients, and oxygen.

III. **Water Efficiency**: The closed-loop system recirculates water, reducing overall water usage.

IV. **Cost-Effective**: Lower initial and operational costs compared to more complex hydroponic systems.

3.5 Challenges of the DWC System

I. **Oxygenation Dependency**: Continuous oxygenation is crucial to prevent root suffocation. Power outages or pump failures can lead to rapid root damage.

II. **Water Temperature**: Maintaining optimal water temperature (18-24°C) is important to prevent root diseases and promote nutrient uptake.

III. **Root Diseases**: Stagnant water conditions can lead to root diseases such as root rot if not properly managed.

3.6 Design Considerations for the DWC System

3.6.1 System Setup

I. **Container Selection**: Choose opaque containers to prevent light penetration and algae growth. The container size should match the number and size of plants being grown. Ensure the container is made from food-grade materials to avoid chemical leaching.

***Plate 11:** Showing an example of an opaque container for the DWC System*

II. **Lid and Net Pots**: Use a sturdy lid with appropriately sized holes for the net pots. The lid should fit securely on the container to support the weight of the plants. Select net pots that are large enough to support the plant and allow for adequate root growth.

III. **Air Pump and Air Stone**: Choose a reliable air pump with sufficient capacity to oxygenate the entire volume of nutrient solution. Place air stones evenly distributed within the container to ensure even oxygenation.

IV. **Nutrient Solution**: Prepare a balanced nutrient solution tailored to the specific crops being grown. Ensure the solution is mixed thoroughly and monitored regularly.

3.6.2 Nutrient Delivery

I. **Solution Preparation**:

I. Use high-quality hydroponic nutrients and maintain the appropriate concentration levels. Regularly check and adjust the pH (5.5-6.5) and EC of the solution.

II. Maintain a stable water temperature to ensure optimal nutrient uptake and prevent root diseases.

2. **Oxygenation**:

I. Continuously oxygenate the nutrient solution using air pumps and air stones. Adequate oxygen levels prevent root suffocation and promote healthy root growth.

II. Monitor and maintain the air pump and air stones to ensure consistent performance.

3.6.3 Maintenance

1. **Regular Monitoring**:

I. Check the pH and EC levels of the nutrient solution daily and adjust as needed.

II. Monitor water levels in the container and top up with a fresh nutrient solution as required.

2. **Cleaning and Sanitation**:

I. Regularly clean the container, lid, and net pots to prevent algae growth and contamination.

II. Replace the nutrient solution periodically to maintain nutrient balance and prevent the buildup of harmful substances.

3. **Pump and Air Stone Maintenance**:

I. Inspect the air pump and tubing regularly for blockages or wear. Clean or replace air stones as needed to ensure effective oxygenation.

II. Have backup pumps and spare parts available to minimize downtime in case of equipment failure.

4. **Pest and Disease Management**:

   I. Implement integrated pest management (IPM) practices to prevent and control pests and diseases.

   II. Monitor root health closely and take prompt action if signs of root diseases are detected.

3.7 Suitability of DWC System for Kubau

3.7.1 Local Resources

1. **Water Availability**:

   I. The DWC system is highly water-efficient, making it suitable for Kubau, where water resources may be limited. The system recirculates water, minimizing wastage.

   II. Local water sources need to be tested and treated to ensure they meet the quality requirements for hydroponic farming.

2. **Nutrient Supply**:

   I. Hydroponic nutrient solutions are required for the DWC system. These can be sourced locally or prepared using commercially available nutrient mixes.

   II. Training local farmers in nutrient management will be essential for successful implementation.

3.7.2 Infrastructure

1. **Electricity**:

   I. Reliable electricity is necessary to run air pumps continuously in the DWC system. Assess the local power infrastructure to ensure consistent supply.

II. In areas with unreliable electricity, incorporating renewable energy solutions such as solar power can help maintain continuous operation.

2. **Construction Materials**:

I. The materials needed for a DWC system, such as containers, net pots, air pumps, and air stones, should be readily available or easily sourced in Kubau or nearby regions.

II. Using local materials and resources can reduce costs and support the local economy.

3.7.3 Climatic Condition

1. **Temperature and Humidity**:

I. Kubau's tropical savanna climate requires careful management of water temperature in the DWC system. Cooling methods or shading may be necessary during the hot dry season.

II. Managing humidity levels, especially during the rainy season, will be important to prevent root diseases and maintain optimal growing conditions.

2. **Seasonal Variations**:

I. The ability to grow crops year-round using the DWC system is a significant advantage in Kubau, where traditional farming is often limited by seasonal variations.

II. Controlled environment agriculture (CEA) practices, such as using greenhouses or shade nets, can help mitigate the effects of extreme weather and ensure consistent crop production.

3.7.4 Economic Factors

1. **Initial Investment and Operating Costs**:

I. The initial investment for setting up a DWC system may be high, but the long-term benefits of increased yields, water efficiency, and reduced pesticide use can offset these costs.

II. Identifying funding opportunities, grants, or subsidies from government programs or NGOs can help local farmers in Kubau afford the initial setup costs.

III. Operating costs, including electricity and nutrient solutions, need to be factored in. Exploring cost-effective solutions such as solar power and bulk purchasing of nutrients can help manage these expenses.

2. **Market Demand**:

I. Assessing the local market demand for hydroponically grown produce is crucial. Crops like lettuce, herbs, and leafy greens, which are well-suited for the DWC system, should have a viable market in Kubau or nearby urban centres.

II. Creating cooperatives or farmer groups can help in collective bargaining, accessing larger markets, and improving profitability.

3.7.5 Local Knowledge and Training

1. **Training Programs**:

I. Comprehensive training programs for local farmers on hydroponic farming, specifically the DWC system, will be essential for successful implementation. These programs should cover system setup, nutrient management, pest and disease control, and harvesting techniques.

II. Continuous support and extension services can help farmers troubleshoot issues and optimize their hydroponic systems.

2. **Community Engagement**:

I. Engaging the local community and involving them in the planning and implementation process can enhance the acceptance and sustainability of the DWC system.

II. Utilizing local labour for system setup and maintenance can create job opportunities and support the local economy.

3.7.6 Environmental Considerations

1. **Sustainable Practices**:

I. Implementing sustainable practices such as recycling water, using organic nutrients, and integrated pest management (IPM) can enhance the environmental benefits of the DWC system.

II. By reducing the pressure on soil and natural ecosystems, hydroponic farming can contribute to biodiversity conservation and sustainable land use in Kubau.

The DWC hydroponic system is suitable for Kubau due to its water efficiency, adaptability to local climatic conditions, and potential for high yields. Careful consideration of local resources, infrastructure, and economic factors is crucial for its successful implementation. With proper training, support, and community engagement, the DWC system can contribute to sustainable agriculture and improved livelihoods for local farmers in Kubau.

4.0 Aeroponic System

4.1 Introduction

Aeroponic is a type of hydroponic system where plant roots are suspended in the air and misted with a nutrient-rich solution. Unlike traditional soil-based agriculture or other hydroponic methods that immerse roots in water or nutrient solutions, aeroponic delivers nutrients directly to the roots in the form of a fine mist. This method allows for optimal oxygenation and nutrient absorption, leading to rapid plant growth and high yields.

Plate 12: *Aeroponic System*

4.2 Components of Aeroponic System

I. **Growth Chamber**: An enclosed space where plant roots are suspended in the air.

II. **Misting System**: Includes nozzles that spray a fine mist of nutrient solution onto the roots. This system is connected to a nutrient reservoir.

III. **Nutrient Reservoir**: Contains the nutrient solution, which is pumped to the misting system.

IV. **Pump**: Circulates the nutrient solution from the reservoir to the misting nozzles.

V. **Timer**: Controls the misting intervals to ensure that roots are regularly misted with nutrients.

VI. **Support Structure**: Holds the plants in place, often using net pots or foam collars to suspend the plants above the growth chamber.

4.3 How Aeroponic System Works

I. **Nutrient Misting**: The pump circulates the nutrient solution from the reservoir to the misting nozzles, which then spray a fine mist onto the roots.

II. **Oxygenation**: The roots are suspended in air, allowing maximum oxygen exposure. This enhances nutrient uptake and promotes faster growth.

III. **Controlled Environment**: The misting intervals are regulated by a timer to ensure the roots receive consistent moisture and nutrients.

IV. **Recirculation**: Excess nutrient solution can be collected and recirculated back into the reservoir, improving efficiency and reducing waste.

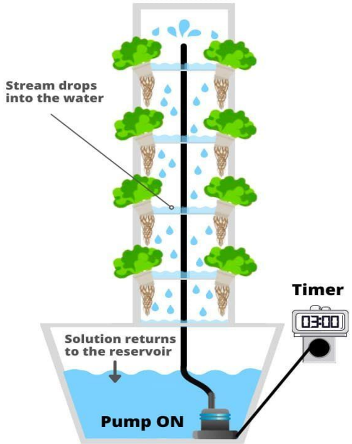

Plate 13: *Showing how the Aeroponic System works*

4.4 Advantages of Aeroponic System

I. **Water Efficiency**: Aeroponics uses significantly less water than traditional soil-based agriculture and even other hydroponic systems. The misting system recirculates water, ensuring minimal waste.

II. **Nutrient Efficiency**: Nutrients are delivered directly to the roots in a fine mist, ensuring efficient uptake and reducing nutrient waste. This precision feeding results in healthier plants and higher yields.

III. **Enhanced Oxygenation**: Roots are suspended in the air, allowing for maximum oxygen exposure. This promotes faster growth and improves root health.

IV. **Faster Growth Rates**: Due to the optimal nutrient and oxygen supply, plants in an aeroponic system tend to grow faster and produce higher yields compared to other growing methods.

V. **Space Efficiency**: Aeroponic systems can be designed vertically, making efficient use of space. This is particularly beneficial in areas with limited land availability.

VI. **Disease Control**: The risk of soil-borne diseases is eliminated, and the controlled environment reduces the incidence of pests and pathogens. This leads to healthier plants and less need for chemical treatments.

VII. **Scalability**: Aeroponic systems can be easily scaled to fit various sizes of operations, from small home gardens to large commercial farms.

VIII. **Flexibility**: Aeroponics can be used to grow a wide variety of crops, including leafy greens, herbs, and even some root vegetables.

4.5 Challenges of Aeroponic System

I. **Initial Setup Cost**: The initial investment for an aeroponic system can be high due to the need for specialized equipment such as misting nozzles, pumps, and growth chambers.

II. **Technical Complexity**: Setting up and maintaining an aeroponic system requires technical knowledge and expertise. Proper design and regular monitoring are essential for system efficiency.

III. **Power Dependency**: Aeroponic systems rely heavily on continuous electricity to operate pumps and misting systems. Power outages can lead to plant stress or loss if not managed properly.

IV. **Maintenance Requirements**: The misting nozzles can become clogged, and the system requires regular cleaning and maintenance to prevent the buildup of algae and mineral deposits.

V. **Environmental Control**: Maintaining the optimal humidity and temperature inside the growth chamber is crucial. Fluctuations in environmental conditions can impact plant health and growth rates.

VI. **Risk of Root Drying**: If the misting intervals are not properly managed, roots can dry out quickly, leading to plant stress or death. Continuous monitoring and precise control of misting are necessary.

VII. **Access to Supplies**: Finding the necessary components and supplies for an aeroponic system can be challenging, especially in rural or remote areas.

4.6 Design Considerations

4.6.1 System Setup

I. **Growth Chamber Design**: Ensure the chamber provides adequate space for root expansion and proper mist coverage. The chamber should be sealed to maintain humidity and prevent nutrient loss.

II. **Misting System**: Use high-quality nozzles to create a fine mist that evenly covers the roots. The nozzles should be positioned to avoid clogging and ensure consistent nutrient delivery.

III. **Support Structure**: Design a stable support system that can securely hold plants in place while allowing easy access to roots for misting.

Plate 14: *Showing Aeroponic System Setup*

4.6.2 Nutrient Delivery

I. **Nutrient Solution**: Formulate a balanced nutrient solution tailored to the specific needs of the plants being grown. Regularly monitor and adjust nutrient concentrations.

II. **Misting Intervals**: Set the timer to mist the roots at regular intervals. Frequent misting ensures the roots remain moist and well-nourished without drying out.

III. **pH and EC Monitoring**: Maintain optimal pH and electrical conductivity (EC) levels in the nutrient solution to ensure efficient nutrient uptake.

4.6.3 Maintenance

I. **Cleaning**: Regularly clean the misting nozzles and growth chamber to prevent clogs and buildup of algae or debris.

II. **Monitoring**: Continuously monitor the system for any issues with nutrient delivery, misting intervals, or plant health. Adjust settings as needed.

III. **Reservoir Management**: Keep the nutrient reservoir clean and replenish the nutrient solution regularly to maintain consistent nutrient availability.

4.7 Suitability for Kubau

4.7.1 Assessing Suitability Based on Local Conditions

I. **Resources**: Aeroponic is highly efficient in water use, making it suitable for areas with limited water resources like Kubau. The system also uses less nutrient solution compared to other methods.

II. **Infrastructure**: Setting up an aeroponic system requires access to reliable electricity for the pump and timer. Solar power can be a viable option in areas with unreliable electricity supply.

III. **Climate**: Aeroponic can be adapted to various climates, but controlling the environment within the growth chamber is crucial. In Kubau, maintaining the right humidity and temperature levels inside the chamber is essential for optimal plant growth.

The aeroponic system offers a highly efficient, sustainable, and productive method of agriculture, particularly suited for areas with limited water resources. Its ability to provide optimal oxygenation and nutrient delivery to plant roots results in rapid growth and high yields. With the right setup and maintenance, aeroponic can be a transformative agricultural solution for Kubau, improving food security and supporting sustainable farming practices in the region.

5.0 Trough System

5.1 Introduction

The trough soilless system is a method of cultivating plants without the use of traditional soil, utilizing long, shallow channels or troughs filled with an inert growing medium, such as cocopeat, or nutrient-rich water solutions. This system is designed to efficiently deliver water and nutrients directly to plant roots, promoting faster growth and higher yields. Trough systems are especially popular in hydroponic setups and controlled environment agriculture, where they provide a high level of control over nutrient management, water usage, and environmental conditions. Ideal for growing crops like leafy greens, herbs, and vegetables, the trough system offers a sustainable and space-efficient solution, making it suitable for both commercial and urban farming.

Plate 15: Trough soilless system

5.2 Components of a Trough Soilless System

1. **Trough System:** Plants are grown in long, narrow troughs (containers) filled with a growing medium (e.g., cocoa peat, sawdust, rice husk), overhead tank, Submersible pump, nutrient solution tank and drip lines.
2. **Nutrient Solution:** Water is automatically dropped to the trough by gravity from the overhead tank, ensuring the plants receive their nutrients.
3. **Support Structures:** Troughs are placed on simple supports that allow water to drain back to the nutrient solution tank.
4. **Growing Medium:** The medium is used instead of soil to anchor the roots and provide moisture and nutrients to the plants.

5.3 How the trough soilless system works

The trough soilless system operates by using long, shallow channels or troughs as growing beds, where plants are cultivated in a nutrient-rich environment without soil. Here's a step-by-step explanation of how it works:

A. **Trough Setup:**

I. **Trough Design**: The system uses troughs or channels, typically made of materials like plastic or metal, to support the plants. These troughs are arranged either horizontally or on a slight incline to facilitate nutrient flow.

II. **Growing Medium**: Instead of soil, an inert medium like cocopeat, sawdust, or rice husk is often used. In some cases, the roots are covered by the growing medium unlike hydroponic where the roots are exposed directly to the nutrient solution, without any solid medium.

B. **Plant Placement:**

I. Plants are placed along the length of the troughs, either directly in the growing medium or suspended in net pots that hold their roots. The medium provides support for the plants and allows the roots to anchor.

C. **Nutrient Solution Delivery:**

I. **Watering System**: A nutrient-rich water solution is pumped or gravity-fed through the troughs. This solution contains all the essential nutrients plants need for growth, such as nitrogen, phosphorus, potassium, and trace minerals.

II. **Flow of Nutrients**: In hydroponic variations of the trough system, the nutrient solution is allowed to flow continuously (or intermittently) through the troughs, bathing the plant roots in nutrients. The incline in the troughs ensures that the solution flows evenly from one end to the other, reaching all plants.

III. **Recirculation**: Excess nutrient solution is often collected at the end of the trough and recirculated back into the system to be reused, making the system highly water-efficient.

D. **Root Aeration:**

I. The design of the trough system ensures that plant roots are exposed to a well-balanced mix of water, nutrients, and oxygen. The growing medium (e.g., cocopeat) helps retain moisture while allowing sufficient airflow to the roots, preventing root rot and promoting healthy growth.

E. Environmental Control:

1. The system can be integrated into controlled environments like greenhouses, where factors such as light, temperature, and humidity are carefully managed. This ensures optimal growing conditions for the plants, leading to faster growth and higher yields.

F. Harvesting:

I. Plants are harvested directly from the troughs when they reach maturity. The system's structure allows for easy monitoring and harvesting, making it ideal for continuous or staggered planting cycles.

5.4 Advantages of Trough Soilless System

A. Water Efficiency:

a. The trough system uses a recirculating nutrient solution, which conserves water compared to traditional soil farming. Water loss through evaporation or runoff is minimized, making it ideal for water-scarce regions.

B. Precise Nutrient Delivery:

a. Nutrients are delivered directly to plant roots in a controlled manner, ensuring that plants receive the exact nutrients they need for optimal growth. This leads to faster growth rates and higher yields.

C. Space Efficiency:

a. The horizontal or inclined design of the trough system allows for dense planting, maximizing the use of space. This makes it suitable for urban or confined farming environments where space is limited.

D. Reduced Soil-Borne Diseases:

a. Since no soil is used, the risk of soil-borne pests, diseases, and weeds is eliminated, reducing the need for pesticides and other chemical inputs.

E. **Consistent and Faster Plant Growth:**
    a. With controlled water, nutrient, and oxygen levels, plants in trough systems tend to grow uniformly and often faster than in traditional farming systems, leading to more predictable harvests.
F. **Flexibility in Crop Selection:**
    a. The system supports a wide range of crops, particularly leafy greens, herbs, and some vegetables. This adaptability allows growers to diversify their produce.
G. **Year-Round Cultivation:**
    a. Trough systems can be set up in controlled environments like greenhouses, enabling year-round cultivation regardless of external weather conditions. This ensures continuous production.

5.6 Challenges of Trough Soilless System

A. **High Initial Setup Cost:**
    a. The infrastructure for a trough system, including troughs, pumps, nutrient delivery systems, and possibly climate control, can be expensive to set up. This may be a barrier for small-scale or resource-limited farmers.
B. **Dependence on Power:**
    a. Many trough systems, especially hydroponic variations, rely on electricity to pump water and nutrients. Any disruption in power supply can affect plant health, especially in areas without reliable electricity.
C. **Water Quality:**
    a. The quality of water used in the system is critical. High levels of salts or contaminants in the water can damage plants and affect yields. Regular monitoring and filtration of the water may be required, adding to operational costs.
D. **Technical Knowledge Requirement:**
    a. Operating and maintaining a trough system requires specialized knowledge in nutrient management, irrigation, and troubleshooting. Farmers may need training

to ensure proper functioning, which could be a challenge in regions with limited access to agricultural education.

E. Potential for Root Diseases:

a. Though soil-borne diseases are avoided, waterborne pathogens can still affect the system. Inconsistent nutrient flow or poor oxygenation can lead to issues like root rot if not properly managed.

F. Limited Crop Variety:

a. While ideal for leafy greens, herbs, and some vegetables, the trough system may not be suitable for all types of crops, particularly those with deeper root systems or that require specific soil conditions.

G. Maintenance:

a. Trough systems require regular monitoring and maintenance, including checking the nutrient solution, cleaning the troughs, and maintaining pumps. This can be labour-intensive, especially in larger setups.

H. Environmental and Sustainability Considerations:

a. The use of synthetic nutrients and reliance on non-biodegradable materials for troughs and other components can raise sustainability concerns. It's important to ensure that the system is managed in an environmentally responsible way, with minimal chemical runoff and sustainable material sourcing.

5.7 Design Consideration for Trough System

A. Trough Dimensions:

a. The troughs are long and shallow, suited for plants like tomatoes. The dimensions should be chosen according to the crop type and available space. A typical size could be:

   i. Length: 2-3 meters per trough section.

   ii. Width: 20-30 cm wide for individual troughs.

   iii. Depth: 10-15 cm to hold enough growing medium.

B. Material:

a. The troughs should be made of a non-corrosive, food-safe material like UV-resistant plastic or galvanized steel to prevent degradation from sun exposure and water.

C. Slope Design:

a. Ensure that each trough has a slight slope (1-2%) to allow any excess water to drain properly and prevent stagnation, which can lead to root diseases.

D. Growing Medium:

a. The primary medium could be cocopeat. Cocopeat is ideal for water retention, aeration, and root support. Mix it with perlite to increase drainage and aeration.

E. Nutrient Solution System

I. Nutrient Solution Tank:

A. Size: The nutrient tank size depends on the scale of the system. A 500-liter tank is typical for a small farm.

B. Location: Place the nutrient solution tank on the ground to allow easy refilling, mixing, and monitoring of the nutrient solution.

II. Overhead Tank:

A. Elevation: Install the overhead tank at a height sufficient to allow gravity to deliver nutrient solution to the drip lines. A height of 3-4 meters should be enough for steady flow.

B. Capacity: The overhead tank should hold enough water for several irrigation cycles. A tank with a capacity of around 500 liters is suitable for smaller systems.

C. Refilling System: The nutrient solution will be pumped from the ground tank to the overhead tank at intervals. The pump should be able to handle the flow rate required to fill the overhead tank quickly.

4. Drip Irrigation Setup

1. **Drip Lines:**

a. Install drip lines along the top of the troughs. These lines should have emitters that deliver a consistent, slow drip of nutrient-rich water directly to the plant roots.
b. Flow Rate: Use emitters with a flow rate of 1-2 litres per hour for each plant to ensure a consistent supply of nutrients.
c. Spacing: Place emitters approximately 20-30 cm apart to cover each plant evenly.

5. Gravity-Driven Irrigation System

1. **Gravity Flow:**
    a. The overhead tank will be connected to the drip lines by a network of PVC or PE pipes. Gravity will drive the nutrient solution down into the drip lines.
    b. Install valves to control the flow rate and adjust the pressure to ensure all plants receive the same amount of water.

6. Drainage and Recirculation

1. **Drainage System:**
    a. Each trough should have a drainage outlet at the lower end to allow excess nutrient solution to drain into a collection pipe.
    b. Recirculation: The collected solution can be directed back into the nutrient solution tank for reuse, making the system highly water-efficient. Install a filter before returning the solution to the tank to remove any debris.

7. Additional Components

1. **Water Pump:**
    a. The pump needs to have enough capacity to pump the nutrient solution to the overhead tank. Choose a pump based on the height of the overhead tank and the volume of water needed per day.

2. **Automation (Optional):**

a. For ease of management, consider adding a timer or sensor-based automation system to control the pump and irrigation intervals.

8. Maintenance Considerations

1. Cleaning: Regularly clean the drip lines and troughs to prevent blockages from salt buildup or debris.
2. Water Quality: Ensure that the water used is free of contaminants and has the appropriate pH and electrical conductivity (EC) for plant growth.

9. Monitoring

1. Nutrient Levels: Regularly monitor the nutrient solution in the ground tank for pH and EC to ensure optimal plant health.
2. Flow Rate Check: Periodically check the drip lines and emitters to ensure uniform delivery across all plants.

5.8 Suitability of Trough Soilless System for Kubau LGA, Kaduna State

To assess the suitability of a trough soilless system for Kubau Local Government Area (LGA) in Kaduna State, Nigeria, we must consider various factors including **climatic conditions**, **local resources**, **infrastructure**, **economic factors**, **local knowledge and training**, and **environmental considerations**.

1. Climate Condition

I. **Temperature**: The region experiences high temperatures, especially during the dry season, with temperatures often exceeding 35°C. Trough systems are well-suited for this kind of climate since they can be integrated into **controlled environments** like greenhouses to protect plants from extreme heat and maintain optimal growing conditions.

II. **Rainfall**: The rainy season typically lasts from April to October, but it is not evenly distributed throughout the year. A trough system with **water-efficient irrigation** (like drip irrigation) is ideal, as it ensures plants receive adequate water even during dry periods.

This system also minimizes water wastage, which is crucial given the seasonal nature of rainfall in Kubau.

III. **Humidity and Dry Season**: During the dry season, humidity levels drop, which can affect water retention in soil-based farming. However, with a trough soilless system, the closed-loop irrigation system prevents moisture loss, ensuring the plants remain hydrated.

2. Local Resources

I. **Water Availability**: The availability of water resources is critical for the success of any soilless system. While Kubau may have seasonal water availability, the **trough system's water recirculation capability** makes it highly efficient. Rainwater harvesting and small-scale reservoirs could also be used to collect water during the rainy season for use in the dry season.

II. **Growing Medium**: **Cocopeat**, which is a common medium used in trough systems, may need to be imported as it is not locally abundant in this area. However, it is affordable and lightweight, which makes transport easy. Other organic growing media like rice husk could be explored as an alternative, depending on local availability.

3. Infrastructure

I. **Electricity and Power Supply**: Reliable electricity is a concern in many parts of rural Nigeria, including Kubau. The **trough system** relies on pumps to circulate nutrient solutions, meaning power supply is important. Solutions like **solar-powered pumps** could be implemented to ensure consistent water flow, especially during the dry season when solar power is abundant.

II. **Road and Market Access**: Infrastructure for transporting materials (growing medium, equipment, crops) to and from farming areas must be considered. While some parts of Kubau LGA may have access to roads, improvements might be necessary to ensure seamless access to markets and suppliers.

4. Economic Factors

I. **Initial Investment**: The **initial cost** of setting up a trough system can be high due to the need for trough materials, pumps, and growing medium. However, the system's ability to conserve water, reduce nutrient wastage, and avoid soil-borne diseases could lead to **long-term cost savings**. Moreover, high-value crops like tomatoes and leafy greens grown in the trough system could command premium prices, especially during the off-season when traditional soil farming is less productive.

II. **Operating Costs**: Recurring expenses include nutrients and energy for running pumps. However, if solar power is implemented, this could significantly reduce operating costs in the long run.

5. Local Knowledge and Training

I. **Farming Practices**: Most farmers in Kubau are likely more familiar with traditional soil-based farming. Transitioning to a trough soilless system would require **comprehensive training** on operating the system, maintaining proper nutrient levels, managing water recirculation, and troubleshooting common issues (e.g., clogging of drip lines or imbalanced pH in the nutrient solution).

II. **Training Needs**: Collaborating with agricultural extension services and NGOs could help to organize **training workshops** for local farmers. This would enable them to acquire the necessary skills to manage a soilless farming system successfully. Moreover, simple and **affordable designs** of the trough system should be emphasized to make it more accessible to farmers with limited technical knowledge.

6. Environmental Considerations

I. **Sustainability**: The **trough system** offers a sustainable farming solution by conserving water and avoiding harmful chemical runoff into local water sources. Given the **fragile ecosystems** in northern Nigeria, a system that reduces environmental impact would be a great advantage.

II. **Reduction of Soil Degradation**: Since the system is soilless, it helps to **combat land degradation**—a pressing issue in northern Nigeria where overgrazing and unsustainable farming practices have led to soil depletion. The trough system also avoids soil compaction and erosion, which are common in traditional farming systems.

III. **Waste Management**: Nutrient solution waste and plastic trough materials need to be managed properly. While the nutrient solution is recirculated, there may be a need to discard some of it after several cycles. Care must be taken to dispose of it responsibly to prevent environmental harm.

7. Crop Selection

I. **Crops Suited for Trough Systems**: The system is ideal for **vegetables, herbs, and leafy greens**, which have high market demand in urban areas. Tomatoes, peppers, and spinach are popular in local diets and thrive in controlled environments. Introducing high-value crops to Kubau farmers could improve both local food security and incomes.

8. Sustainability and Long-Term Impact

I. **Water Conservation**: Water management is key in Kubau due to periodic droughts and dry spells. The **recirculation** and **efficiency** of the trough system make it a sustainable choice for the region, especially if combined with **rainwater harvesting** systems.

II. **Economic Sustainability**: Once the initial setup costs are recouped, the system can provide consistent yields and income. With proper management, trough systems could lead to **year-round farming**, which would be a major boost for local farmers.

III. **Environmental Sustainability**: The reduced need for chemical fertilizers, efficient water use, and minimal land use make the system environmentally sustainable in the long term. It could contribute to **climate-resilient agriculture** in Kubau, where traditional farming may be more vulnerable to climate change.

6.0 Benchmarking Methodology

6.1 Justification for Selecting the Three Hydroponic Systems and a Soilless System

The selection of the Nutrient Film Technique (NFT), Deep Water Culture (DWC), Aeroponics and trough soilless systems for consideration in Kubau is based on their varying levels of complexity, resource requirements, and potential adaptability to local conditions. These systems were chosen because they represent a spectrum of hydroponic methods, each with distinct advantages and challenges that make them suitable for different environmental and socio-economic conditions.

I. **Nutrient Film Technique (NFT) System:** The NFT system is widely recognized for its efficiency in nutrient delivery and water use, making it a popular choice in regions where water conservation is crucial. It also offers a moderate level of technological complexity, which can be manageable with some basic training. Its scalability and adaptability to different crop types make it a strong candidate for Kubau, where agriculture is a primary livelihood.

II. **Deep Water Culture (DWC) System:** The DWC system is simple to set up and operate, requiring fewer materials and less technical knowledge compared to other hydroponic systems. This simplicity makes it an ideal choice for rural areas like Kubau, where technical support may be limited. The DWC system is also robust and resilient, with the ability to maintain plant growth even in less-than-ideal conditions, which is beneficial in areas with inconsistent electricity supply.

III. **Aeroponics System**: The Aeroponics system, though more complex and technologically advanced, was selected for its potential to achieve the highest yields and plant health. Its use of air and mist to deliver nutrients directly to the roots can lead to faster growth and more efficient use of nutrients. This system was included in the evaluation to explore its feasibility in Kubau, especially as a potential high-tech solution for future agricultural innovations.

IV. **Trough Soilless System:** The trough soilless system is widely recognized for its efficiency in nutrient delivery, making it a popular choice in regions where water conservation is crucial. It also offers a moderate level of technological complexity, which can be manageable with some basic training. Its scalability and adaptability to different crop types make it a strong candidate for Kubau, where agriculture is a primary livelihood.

5.2 Aim and Objectives for the Benchmarking

Aim: The aim of the benchmarking process is to identify the most suitable hydroponic system for implementation in Kubau, taking into account the local environmental conditions, resource availability, technical expertise, and the socio-economic context of the community. The goal is to ensure that the selected system will not only be viable and sustainable but also enhance agricultural productivity and resilience in the region.

Objectives:

I. To assess the technological requirements and feasibility of the NFT, DWC, Aeroponics and trough systems within the context of Kubau's local conditions.

II. To compare the cost-effectiveness and resource efficiency of each system, considering the availability of materials, water, and energy in Kubau.

III. To evaluate the ease of use and maintenance of each system, particularly in relation to the literacy levels and technical skills of the local farmers.

IV. To determine the potential yield and scalability of each system to ensure long-term sustainability and impact in Kubau.

5.3 Criteria for Benchmarking

The benchmarking process employed a comprehensive set of criteria to evaluate the suitability of the three hydroponic systems for Kubau. These criteria were carefully chosen to ensure that the selected system would be both practical and effective in the local context. The key criteria used were:

I. **Cost:** This criterion evaluated the initial setup costs, ongoing operational costs, and potential return on investment for each system. The affordability of materials, the cost of electricity or alternative energy sources, and the overall economic feasibility were considered to ensure that the system would be financially sustainable for the local farmers.

II. **Efficiency:** Efficiency was measured in terms of water and nutrient usage, as well as the potential yield of each system. This criterion was critical in assessing how well each system could maximize resource use in Kubau, where water availability may be limited, and nutrient conservation is essential for sustainable agriculture.

III. **Ease of Use and Maintenance:** Given the varying levels of literacy and technical skills among the local population, this criterion focused on the simplicity of system operation, the level of training required, and the ease of ongoing maintenance. Systems that required minimal technical expertise and could be easily maintained with locally available resources were prioritized.

IV. **Community Impact and Scalability:** The potential for each system to be scaled up or replicated in other parts of Kubau or similar regions was assessed. Additionally, the impact on the local community, including the creation of jobs, improvement in food security, and contribution to sustainable development, was a crucial consideration.

5.4 Suitability and Challenges of Hydroponic Techniques to the Beneficiaries

When implementing hydroponic systems in rural areas like Kubau, it's essential to consider not only the technical aspects of the systems but also the capabilities and needs of the local beneficiaries. These systems must align with the local community's literacy levels, technical skills, and available resources. The following table provides a comparison of the Nutrient Film Technique (NFT), Deep Water Culture (DWC), Aeroponics and trough systems based on their technological requirements, material needs, usage and maintenance, and the ability of human beneficiaries to effectively use and maintain the systems.

Table 1: *Suitability and Challenges of the hydroponic system to the beneficiaries*

Criteria	NFT System	DWC System	Aeroponics System	Trough System
Technological Requirement	Requires moderate technical expertise for setup and monitoring.	Simple technology, but requires a consistent electricity supply for aeration.	High-tech system requiring advanced knowledge for operation.	Requires moderate technical expertise for setup and monitoring.
Materials	Uses easily available materials; some specialized items may be imported.	Requires readily available containers and air pumps.	Requires a lot of specialized materials that will be imported.	Requires a lot of specialized materials that will be imported.
Usage & Maintenance	Moderate maintenance; frequent checking of nutrient flow needed.	Moderate maintenance, but oxygenation must be ensured continuously.	Intensive maintenance; system failure can lead to rapid plant loss.	Moderate maintenance; frequent checking of nutrient flow needed.
Direct Beneficiaries	Requires basic literacy for reading manuals and conducting regular checks.	Requires basic literacy for reading manuals and conducting regular checks.	Challenging for communities with low literacy; high-level training is required.	Requires basic literacy for reading manuals and conducting regular checks.

5.5 Narrative Explanation

The **NFT system** offers a balanced approach, combining moderate technological requirements with the accessibility of materials. It does require basic literacy and technical skills to manage nutrient flow and system maintenance, making it suitable for a community with some education and willingness to learn.

The **DWC system** is simpler in design and requires minimal technical knowledge, which makes it a favourable option for communities with lower literacy levels. However, its reliance on consistent electricity could be a potential challenge in rural areas like Kubau.

The **Aeroponics system**, while highly efficient, poses significant challenges due to its complex setup and maintenance requirements. It is less suited to areas with low literacy and limited access to technical support, which may hinder its successful adoption in Kubau.

The **Trough system** offers a balanced approach, combining moderate technological requirements with the accessibility of materials. It does require basic literacy and technical skills to manage nutrient flow and system maintenance, making it suitable for a community with some education and willingness to learn.

6.0 Comparison and Recommendation

Table 2: Comparison table

S/N	NFT System	DWC System	Aeroponic System	Trough Soilless System
1	**Cost**			
	Initial Investment: Moderate to high, depending on the scale and quality of components. The estimated material cost for a complete system is around $6,250 - $8,125 (₦10 - ₦13 million) **Operating Costs**: Includes electricity for pumps and nutrient solution management, with regular maintenance needs.	**Initial Investment**: Generally lower than NFT, with basic components like containers, air pumps, and net pots. The estimated material cost for a complete system is around $5,000 - $6,875 (₦8 - ₦11 million) **Operating Costs**: Lower ongoing costs, primarily for electricity to run air pumps and occasional nutrient solution replacement.	**Initial Investment**: High, due to the need for specialized equipment like misting nozzles, pumps, and growth chambers. The estimated material cost for the complete system is around $10,625 - 11,875 (₦17 - ₦19 million) **Operating Costs**: Includes continuous electricity for pumps and misting system, with regular cleaning and maintenance.	• **Initial Investment**: Moderate to high, depending on the scale and quality of components. **Operating Costs**: Includes electricity for pumps and nutrient solution management, with regular maintenance needs.
2	**Efficiency**			
	Water Efficiency: Highly efficient due to recirculating nutrient solution.	**Water Efficiency**: Efficient, but slightly less than NFT due to potential water evaporation and root system size.	**Water Efficiency**: The most water-efficient of the three, using minimal water through misting.	• **Water Efficiency**: Highly efficient due to the recirculating system of nutrient solution.

	Growth Rate: Promotes rapid growth with continuous nutrient delivery, especially suitable for leafy greens and herbs.	**Growth Rate**: Supports fast growth with continuous access to nutrients and oxygen.	**Growth Rate**: Fastest growth rate due to optimal oxygenation and nutrient delivery.	**Growth Rate**: Supports fast growth with continuous access to nutrients and oxygen.
3	**Ease of Use**			
	Setup Complexity: Requires precise setup with a proper slope for channels, more challenging for beginners. **Operation**: Needs regular monitoring of flow rates and nutrient levels, requiring training for effective management.	**Setup Complexity**: Simple setup, making it accessible for beginners. **Operation**: Easier to manage with fewer variables, less intensive training required.	**Setup Complexity**: Technically complex with specialized equipment and precise environmental control. **Operation**: Requires constant monitoring and maintenance, demanding higher technical expertise.	**Setup Complexity**: Requires precise setup with a proper slope for channels, more challenging for beginners. **Operation**: Easier to manage with fewer variables, less intensive training required.
4	**Maintenance**			
	Regular Monitoring: Frequent checks of nutrient levels, pH, and flow rates, with regular cleaning of channels. **Pump Dependency**: Continuous operation of water pumps is	**Regular Monitoring**: Regular checks of nutrient and oxygen levels, simpler cleaning of containers and air stones. **Oxygenation Dependency**: Reliable air pumps are crucial, but have lower power requirements.	**Regular Monitoring**: High-frequency checks of the misting system, nozzles, and environmental conditions. **Maintenance**: Regular cleaning to prevent clogs and algae buildup, with higher technical demands.	**Regular Monitoring**: Frequent checks of nutrient levels, pH, and flow rates, with regular cleaning of channels. **Pump Dependency**: Continuous operation of water

	critical, making them vulnerable to power outages.			pumps is critical, making them vulnerable to power outages.

6.1 SWOT Analysis of the Evaluated Hydroponic Technology

Table 3: *SWOT Analysis of the NFT System*

S STRENGTH	W WEAKNESS
Efficient Nutrient Use: Continuous flow of nutrient solution allows for precise control and minimal waste. **Water Conservation:** Uses less water compared to traditional agriculture and other hydroponic systems. **Scalability:** Easily scalable from small setups to larger commercial systems. **Compact Design:** Requires less space, making it ideal for areas with limited land availability.	**Vulnerability to Power Outages:** Relies on continuous electricity; any power failure can disrupt nutrient flow and damage plants. **Root Diseases:** Constant exposure to a nutrient film can increase the risk of root-related diseases if not properly managed. **Maintenance:** Requires regular monitoring and maintenance to ensure optimal flow and prevent blockages.

O	T
OPPORTUNITY	**THREAT**
Adaptability: Can be adapted to various plant types, making it versatile for different crops. **Technology Integration:** Opportunities to integrate automated monitoring systems to enhance efficiency and reduce labour. **Sustainability:** Aligns well with sustainable agricultural practices, offering potential for expansion into new markets focused on eco-friendly solutions.	**Technical Expertise Required:** May be challenging for local farmers with limited technical knowledge to operate and maintain. **Climate Sensitivity:** External environmental factors, such as temperature fluctuations, can impact the effectiveness of the system. **Competition:** Competing hydroponic systems or alternative sustainable agricultural technologies may present a challenge to its adoption.

Table 4: *SWOT Analysis of DWC System*

S	W
STRENGTH	**WEAKNESS**
Simple Setup: Easy to construct and operate, making it accessible for beginners. **Rapid Plant Growth:** Direct oxygenation to roots accelerates plant growth. **Low Cost:** Generally cheaper to set up compared to other hydroponic systems. **Minimal Clogging:** Fewer components mean less risk of system blockages.	**Oxygenation Dependency:** The system's success heavily relies on constant oxygenation, which, if interrupted, can lead to root suffocation. **Water Temperature Sensitivity:** The large water reservoir can be difficult to cool or heat, making the system sensitive to temperature changes. **Root Diseases:** The constant water immersion increases the risk of root rot and other waterborne diseases.

O **OPPORTUNITY**	T **THREAT**
Education and Training: DWC can serve as an entry point for farmers new to hydroponics, with potential for training and expansion into more complex systems. **Resource Efficiency:** Promotes water conservation, a critical advantage in regions facing water scarcity. **Community Engagement:** Its simplicity makes it ideal for community-based agricultural projects.	**Power Outages:** Loss of power can quickly lead to oxygen deprivation and plant death. **Pest and Disease Management:** The open water surface can attract pests, and poor water management can lead to disease outbreaks. **Environmental Impact:** If not managed correctly, nutrient-rich runoff could pose an environmental risk.

Table 5: *SWOT Analysis of Aeroponic System*

S **STRENGTH**	W **WEAKNESS**
Maximum Oxygenation: Roots receive high levels of oxygen, leading to faster plant growth and higher yields. **Water and Nutrient Efficiency:** Uses less water and nutrients compared to other hydroponic systems. **Space Efficiency:** Can be designed vertically, making it highly space-efficient.	**Complex Setup:** Requires advanced technical knowledge to design, set up, and maintain. **High Initial Costs:** More expensive to install and operate due to the need for specialised equipment. **Vulnerability to Failures:** Any system malfunction, such as pump failure, can quickly damage plants due to the lack of a nutrient buffer.

Controlled Environment: Allows for precise control over nutrient delivery and environmental conditions.	
O **OPPORTUNITY** **Innovation Potential:** High potential for innovation and automation, which can drive future growth and development in precision agriculture. **High-Value Crops:** Suitable for growing high-value crops that require precise nutrient management. **Research and Development:** Opportunities for further research into optimising nutrient delivery and system efficiency.	**T** **THREAT** **Technical Expertise Required:** The complexity of the system may deter adoption by local farmers with limited experience. **Infrastructure Dependency:** Relies heavily on stable infrastructure, including consistent power and water supply. **Cost Competitiveness:** Higher costs may limit adoption, particularly in low-income regions.

Table:6 *SWOT Analysis of Trough System*

S **STRENGTH** **Water Efficiency:** Trough soilless systems recirculate water, reducing waste and optimizing usage, making it ideal for areas with limited water availability. **Reduced Soil-Related Problems:** Since no soil is used, there is no risk of soil-borne diseases, pests, or weeds, reducing the need for pesticides and herbicides. **Year-Round Cultivation:** The system can be used in controlled environments like greenhouses, enabling continuous production throughout the year.	**W** **WEAKNESS** **Complex Setup:** Requires advanced technical knowledge to design, set up, and maintain. **High Initial Costs:** More expensive to install and operate due to the need for specialised equipment. **Vulnerability to Failures:** Any system malfunction, such as pump failure, can quickly damage plants due to the lack of a nutrient buffer. **Growing Media Replacement**: Cocopeat or other growing media need to be replaced or replenished after several growing cycles, which can add to operational costs.
O **OPPORTUNITY** **Innovation Potential:** High potential for innovation and automation, which can drive future growth and development in precision agriculture. **High-Value Crops:** Suitable for growing high-value crops that require precise nutrient management. **Research and Development:** Opportunities for further research into optimising nutrient delivery and system efficiency.	**T** **THREAT** **Technical Expertise Required:** The complexity of the system may deter adoption by local farmers with limited experience. **Infrastructure Dependency:** Relies heavily on stable infrastructure, including consistent power and water supply. **Cost Competitiveness:** Higher costs may limit adoption, particularly in low-income regions.

6.2. Recommendation for Kubau

6.2.1. Recommended System: Nutrient Film Technique (NFT)

The NFT system is recommended for training and research purposes.

6.2.1.1. Justification

I. **Water Efficiency:** The NFT system is highly efficient in water usage, which is crucial for Kubau where water resources may be limited. Its recirculating nature ensures minimal water wastage, making it an ideal choice for the local environment.

II. **Tutelage:** The NFT system can be used for training and demonstration of other hydroponic systems. It is easier to understand and all other hydroponic systems can be deduced from the NFT system.

III. **Cost-Effective:** While the initial investment for the NFT system is moderate, its operating costs are manageable. It strikes a balance between the lower initial costs of DWC and the higher efficiency and productivity benefits, offering better long-term value.

IV. **High Productivity:** The continuous flow of nutrient solution in the NFT system promotes rapid plant growth and higher yields. This increased productivity can significantly benefit local farmers, enhancing food security and income.

V. **Space Efficiency:** The NFT system makes excellent use of vertical space, allowing for the cultivation of a large number of plants in a relatively small area. This is particularly beneficial for Kubau, where arable land may be limited.

VI. **Scalability:** The NFT system can be easily scaled to fit various operational sizes, from small-scale growers to larger commercial setups. This flexibility is crucial for adapting to the diverse needs and resources of local farmers in Kubau.

VII. **Technical Feasibility:** Although the NFT system requires more technical knowledge and precise setup than DWC, it is less complex than aeroponic. With proper training and support, local farmers can effectively manage the NFT system.

VIII. **Disease Control:** The continuous flow of the nutrient solution in the NFT system helps prevent root diseases that are common in stagnant water conditions. This leads to healthier plants and more reliable crop production, which is essential for consistent agricultural output.

IX. **Energy Efficiency:** The NFT system's energy requirements are relatively low compared to aeroponic. Solar-powered pumps can further reduce energy costs and enhance sustainability, which is important for areas with unreliable electricity supply.

X. **Gender consideration:** The NFT systems can provide women with access to nutrient-rich crops, improving household nutrition and food security.

By adopting the NFT hydroponic system, Kubau's farmers can leverage a highly efficient, productive, and sustainable method of agriculture. The system's ability to conserve water, maximise space, and enhance crop yields aligns well with the local conditions, offering a viable pathway to improved agricultural productivity and economic development in the region. With appropriate training and community engagement, the NFT system training centre has the potential to transform local agriculture in Kubau, ensuring a sustainable and prosperous future for the community.

6.2.2. Recommended System: Deep Water Culture (DWC)

The Deep Water Culture (DWC) technique is recommended for household usage.

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6.2.2.1. Justification

I. **Cost**: The DWC system has a lower initial investment and operating costs, making it more accessible for local farmers in Kubau with limited financial resources. All the materials can be locally sourced at a very cheap rate.

II. **Ease of Use**: The simplicity of setting up and managing the DWC system makes it ideal for beginners and small-scale farmers. It requires less technical expertise and training compared to the Aeroponic system.

III. **Maintenance**: The DWC system demands less frequent and intensive maintenance. Its reliance on air pumps rather than water pumps reduces the risk associated with power outages, which can be a concern in rural areas with unreliable electricity.

IV. **Suitability to Local Conditions**: The DWC system's ability to operate efficiently with minimal resources and infrastructure aligns well with the conditions in Kubau. The simpler setup and lower dependency on precise infrastructure make it more adaptable to the local environment.

V. **Gender considerations:** The DWC systems are relatively simple to manage, making them accessible to rural women with limited technical expertise.

6.2.2. Recommended System: Trough Soilless System

The trough soilless system is recommended for training in soilless system.

Justification

1. Water Efficiency

The trough soilless system is highly water-efficient, which is crucial for Kubau, where water resources may be limited. In this system, water is delivered directly to the plants' roots through a controlled irrigation method, significantly reducing water wastage due to evaporation or runoff. This ensures that the limited water supply is used effectively, making it ideal for the semi-arid environment of Kubau.

2. Tutelage

The trough system can be used for training and demonstration purposes for other soilless farming techniques, especially systems that utilize growing media like cocopeat. It is simple to understand, making it an excellent introductory system for local farmers. Once familiar with the trough system, farmers can easily adapt to more complex soilless systems like NFT (Nutrient Film Technique) or drip irrigation systems.

3. Cost-Effective

While the initial setup cost of the trough system might be moderate, the operational costs are relatively low, making it a cost-effective option for local farmers. Using locally available materials, such as wood for the troughs and cocopeat as a growing medium, can further reduce costs. The system offers a balance between affordability and efficiency, providing good long-term value for farmers in Kubau.

4. High Productivity

The trough system provides plants with optimal growing conditions, leading to faster growth rates and higher yields compared to traditional soil farming. This can significantly benefit local farmers by increasing their agricultural productivity and income. Additionally, the use of cocopeat as a growing medium enhances root aeration and water retention, further promoting healthy plant development and higher yields.

5. Space Efficiency

The trough system makes efficient use of space, allowing for the cultivation of a larger number of plants in a relatively small area. This is particularly beneficial for Kubau, where available arable land may be limited. Vertical arrangements or tiered setups can be implemented to maximize the use of space, enabling farmers to produce more crops per square meter.

6. Scalability

The trough system is highly scalable, allowing farmers to start small and expand as needed. Whether used by

small-scale growers or larger commercial operations, the system can be adjusted to fit the available resources and land size. This flexibility is crucial for Kubau's diverse farming community, enabling both subsistence and commercial farmers to adopt the system according to their needs.

7. Technical Feasibility

The trough system is relatively simple to operate and maintain, requiring less technical expertise than more complex soilless systems like aeroponics or NFT. With proper training and support, local farmers in Kubau can easily manage the system, making it a feasible option for the community. The simplicity of the system ensures that farmers can quickly adopt it and start benefiting from its advantages.

8. Disease Control

Soilless systems like the trough system reduce the risk of soil-borne diseases and pests, which are common in traditional farming. In Kubau, where access to advanced pest control methods may be limited, the trough system offers a natural way to minimize pest-related crop losses. Healthier plants mean more reliable crop production, contributing to food security and economic stability in the area.

9. Energy Efficiency

The trough system's energy requirements are minimal compared to other soilless systems that rely heavily on pumps or complex technology. Basic irrigation systems, which can even be powered by gravity or solar-powered pumps, can be used to deliver nutrient solutions to the plants. This reduces energy costs and makes the system more sustainable, particularly in areas with limited access to electricity like Kubau.

10. Gender Consideration

The trough soilless system can be easily managed by women, offering them opportunities to engage in agricultural activities that improve household nutrition and food security. The system's simplicity and scalability make it accessible to all members of the community, promoting gender inclusivity in local agricultural practices.

Adopting the trough soilless system in Kubau will allow local farmers to leverage a sustainable, efficient, and productive farming method. The system's ability to conserve water, maximize space, and increase yields aligns perfectly with the local climate, economic conditions, and resource constraints. With proper training and community engagement, the trough system has the potential to significantly enhance agricultural productivity, improve food security, and promote economic growth in Kubau, ensuring a more prosperous future for the region.

6.3. Conclusion

Hydroponic systems represent a groundbreaking approach to sustainable agriculture, offering numerous benefits that are particularly suited to the conditions in Kubau. Hydroponics, by enabling soilless cultivation, addresses critical issues such as limited arable land and water resources and provides a pathway to consistent and high-yield crop production.

Three hydroponic systems were evaluated for their potential application in Kubau: Nutrient Film Technique (NFT), Deep Water Culture (DWC), Aeroponic and trough soilless system. Each system has distinct advantages and challenges:

I. **NFT System** is highly efficient in water and nutrient usage, promotes rapid plant growth, and makes excellent use of vertical space. It requires precise setup and regular monitoring but offers scalability and significant productivity benefits.

II. **DWC System** is simpler to set up and manage, with lower initial and operating costs. It supports robust plant growth but is slightly less efficient in water usage compared to NFT and requires reliable oxygenation.

III. **The Aeroponic System** provides the highest efficiency in water and nutrient delivery, with the fastest growth rates due to optimal oxygenation. However, it has the highest initial setup cost and technical complexity, requiring continuous monitoring and maintenance.

IV. **The trough system** is highly efficient in water and nutrient usage, promotes rapid plant growth, and makes excellent use of vertical space. It requires precise setup and regular monitoring but offers scalability and significant productivity benefits.

Considering the local conditions in Kubau, including resource availability, infrastructure, and climate, the **NFT and DWC techniques** are recommended as the most suitable hydroponic system and the **trough system** is recommended as a soilless system. The NFT technique's balance of cost-effectiveness, high productivity, water and space efficiency, and technical feasibility make it an ideal choice for enhancing agricultural productivity and sustainability in the region. DWC technique is cheap and easy to use and materials can be sourced locally, making it an ideal choice for households for enhancing agricultural productivity and continuous practice of hydroponics in the community. The trough system is the most sustainable type of soilless system, making it an ideal choice for soilless training.

The NFT and DWC hydroponic systems and trough soilless systems are relatively simple to manage, requiring minimal technical expertise by women. These systems require less physical labor thereby making them accessible to women with multiple responsibilities or physical limitations. These systems also facilitate community engagement and networking among women, promoting knowledge sharing and support. By adopting these hydroponic techniques, Kubau's farmers can achieve significant improvements in crop yields and resource efficiency. This innovative approach to agriculture not only aligns with sustainable farming practices but also provides a viable solution to food security challenges and economic development in the community. With proper training and support, the implementation of the system can transform local agriculture in Kubau, ensuring a sustainable and prosperous future for its farmers.

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