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Evaluating the Potential of Vertical Farming Business Models for Sustainable Agriculture and Food Security in Cameroon

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1 ABSTRACT

This research investigates the possibility of using vertical farming business models as a sustainable solution to address issues such, as land degradation, urbanization, and climate change in Cameroon to increase agricultural output and ensure food security. The study highlights gaps in the need for a region-specific customized vertical farming business model and identifies gaps in understanding the economic and environmental feasibility of vertical farming in Cameroon. Qualitative methods, including interviews with stakeholders and content analysis using MaxQDa, were employed for analysis purposes. The research explores the advantages, challenges, barriers, and potential technologies and business models associated with vertical farming in Cameroon. It emphasizes the importance of stakeholder involvement, financial support, government support, favorable policies, sensitization and campaigns, education and training, and overall support for its adoption and profitability. Key findings indicate that vertical farming holds promise for improving food security and sustainability in urban areas of Cameroon. Additionally, aquaponics is identified as a cost-effective technology and model within this context. However, some obstacles need to be addressed to adopt vertical farming in Cameroon. These include high initial costs, technological and infrastructural challenges, the need for supportive/favorable policy frameworks, clear vertical farming policies, education and training, and the urgent need for collaboration among stakeholders. A final model “Vertical Farming Business Model for Cameroon" was suggested which proposes an implementation model specifically tailored to suit local conditions while considering stakeholder expectations. Conclusively it is going to be a very profitable business.

Keywords: Business models, Agricultural sustainability, Food security, Stakeholders, Vertical farming

2 INTRODUCTION

2.1 Background

The issue of food security, in Cameroon is being impacted by the growth of areas and the increasing population, which in turn affects farming practices. Climate change, unrest, and changes in land use exacerbate this situation. To address these challenges vertical farming has emerged as a solution. This innovative approach involves growing crops in stacked layers under controlled conditions to maximize space and resources specifically targeting the constraints faced by agriculture (Fonjong & Gyapong 2021; Kountchou et al., 2021; Kenette et al., 2019; Njuh et al., 2022; Siregar et al., 2022; Sonhafouo Chiana et al., 2022).

This study aims to assess the feasibility of implementing vertical farming business techniques and models in Cameroon as a means to enhance both food security and environmental sustainability when compared to traditional farming and regenerative traditional farming methods. It delves into the aspects of adopting business models for vertical farming within Cameroon's unique context while exploring their potential contributions, to sustainability and food security. By referencing Siregar et al. (2022) this research seeks to address the challenges posed by urbanization, climate change, and other agricultural factors while emphasizing how a vertical farming business model can serve as a solution tailored to Cameroon's circumstances.

2.2 Research Gap and Objectives

Cameroon is currently facing food security challenges because of growth and agricultural difficulties. To address these issues vertical farming has been recognized as a solution. However, there are some challenges related to adaptation, environmental factors, and regulations that need to be addressed (Appolloni et al.,

2020; Baumont de Oliveira et al., 2022). It is crucial to develop localized models and understand the impact to effectively tackle these challenges (Araújo et al., 2021; Martin & Bustamante 2021; Tabe Ojong et al., 2023).

Due, to climate change and urbanization traditional agriculture in Cameroon is struggling. This has led to an increasing need for approaches like farming under controlled conditions, which can ensure both food security and sustainability (Fonjong & Gyapong 2021; Kountchou et al., 2021; Kenette et al., 2019; Njuh et al., 2022; Siregar et al., 2022; Sonhafouo Chiana et al., 2022).

The research findings highlight a gap in a region-specific business model for vertical farming in Cameroon. Existing studies primarily focus on concepts derived from countries, which may not fully align with the circumstances of a developing nation, like Cameroon (Nchu et al., 2019; Sneyd, 2013).

It highlights the significance of developing business models for vertical farming that consider Cameroon factors, such, as available resources, climate conditions, crop preferences, and local market dynamics. This emphasizes the need for customized solutions that address Cameroon's circumstances.

Examining the feasibility of vertical farming business models in Cameroon is crucial for ensuring sustainability. Research objective one is to evaluate the advantages, challenges, and obstacles associated with vertical farming in comparison to traditional farming methods. Research objective two seeks to identify technologies and models that can be applied in Cameroon. The goal is to provide insights not for Cameroon but also, for other Sub-Saharan African countries facing similar issues related to urbanization and food security.

3 LITERATURE REVIEW

3.1 Food Security in Cameroon

Ensuring that Cameroon has food is extremely important because it directly affects the well-being and livelihoods of its people. In this section we will take a look, at why food security is so crucial, especially considering the challenges related to agriculture and the various factors that impact both food production and access. Furthermore, we will delve into the principles and techniques of vertical, farming, business models, and successful vertical farming examples. Lastly, we will discuss our plans to address any existing gaps through a framework.

3.1.1 Overview of food security

Food security encompasses the aspects of ensuring that a specific population has access, to nutritious food. This includes factors like food production, distribution, and consumption (Ronzhin & Savel'ev 2022; Saint Ges et al., 2022). In the context of Cameroon, where providing reliable food for its people is a top priority (Mkong et al., 2021; Sikod, 2007) addressing the issue of food provision becomes even more vital due to rapid population growth, particularly in urban centers such as Douala and Yaoundé. Achieving food security, in Cameroon is complex. Influenced by urbanization changing habits and economic disparities (Njuh et al., 2022; Sonhafouo Chiana et al., 2022). To effectively develop strategies and policies to tackle these challenges it is essential to have an understanding of the aspects associated with food security (Suh et al., 2023).

3.1.2 Agricultural Sustainability Challenges

In Cameroon, there are challenges when it comes to establishing agricultural practices, which are vital, for ensuring food security. The changing climate has disrupted weather patterns making it increasingly difficult for farmers to anticipate and adapt to the conditions for crop growth (Adams et al., 2022). Additionally, conventional farming methods face problems due to soil degradation leading to reduced fertility (Fonjong & Zama 2023; Kenette et al., 2019). Furthermore, factors like urbanization and other influences are causing farmland availability to shrink, posing an obstacle to maintaining levels of food production (Baumont de Oliveira et al., 2022). To overcome these difficulties, it becomes essential to implement farming techniques that can effectively address and mitigate these issues (Santini et al., 2021; Tabe Ojong et al., 2021). These challenges highlight the importance of adopting approaches in the field of food production (Ntsama et al., 2020; Saad et al., 2021).

3.1.3 Factors Affecting Food Production and Access

Several factors impact the production and accessibility of food in Cameroon. One crucial concern is the harvest losses, which can be attributed to inadequate storage facilities, transportation challenges, and infrastructure issues (Fungo et al., 2023; Nchu et al., 2019). These losses particularly affect the country's ability to meet the increasing needs of its population (Biancone et al., 2022). Additionally, declining soil fertility plays a role in determining productivity. To maintain production levels, it becomes necessary to embrace techniques and technologies that can address this issue. (Blom et al., 2022; Nchu et al., 2019). The scarcity of land due to expansion primarily contributes to constraint food production (Thomson, 2022). Farmers often encounter difficulties in cultivating plots of land posing a challenge in meeting the growing demands (Hutton et al., 2021; Sneyd, 2013).

3.2 Existing Initiatives and Policies

Cameroon understands the significance of prioritizing food security and agricultural sustainability. The government has taken steps to address these challenges by implementing policies and initiatives (Fonjong & Gyapong 2021; Kenfack, 2017). These efforts include programs aimed at increasing production, improving infrastructure, and advocating for farming practices (Deepthi et al., 2021). The National Agricultural Investment Plan (NAIP) aims to enhance output develop infrastructures and provide support to smallholder farmers (Fonjong & Gyapong 2021; Siregar et al., 2022). Moreover, there are initiatives to promote climate farming practices and encourage the widespread adoption of sustainable approaches, in agriculture (Marius et al., 2023; Ngetleh et al., 2023)

3.3 Vertical Farming

3.3.1 Definition and Principles

Vertical farming focuses on maximizing resource efficiency and promoting sustainability by utilizing technologies such, as hydroponics, aeroponics, and aquaponics to control conditions. These techniques enhance plant growth and productivity (Ngetleh et al., 2023; Siregar et al., 2022; Ambagna et al., 2012; Chimi et al., 2022; Baumont De Oliveira et al., 2021; Nana et al., 2022; Wood et al., 2020). Its advantages are particularly evident in confined spaces where vertical designs optimize land usage (Chimi et al., 2023; Tabe Ojong et al., 2023).

3.3.2 Advantages of Vertical Farming

Vertical farming enhances agricultural productivity, enabling controlled environments for faster plant growth and higher yields (Martin & Bustamante 2021; Carine, 2019; Tabe Ojong et al., 2023). It significantly reduces water use through recirculation techniques and allows for year-round cultivation, independent of weather (Naranjani et al., 2022). Additionally, it minimizes pesticide reliance, supports sustainable farming (Avgoustaki & Xydis 2020), and reduces transport emissions by enabling closer-to-consumer farming locations (Ntsama et al., 2018; Appolloni et al., 2020).

3.3.3 Disadvantages and Challenges

Vertical farming, while promising, comes with challenges like high setup costs for infrastructure and technology (Ntsama et al., 2018; Oh & Lu, 2023), increased energy demand for maintaining the controlled environment (Tambi et al., 2017; Sotamenou & Parrot, 2013), and navigating complex regulatory frameworks in urban settings (Awazi, 2022; Kalantari et al., 2018). These factors necessitate careful planning and management to ensure the sustainability and feasibility of vertical farms.

While vertical farming enables the cultivation of various crops, challenges arise with larger staple crops like maize and wheat due to spatial requirements (Fonjong & Gyapong 2021; Sneyd, 2013). Success in vertical farming demands expertise across horticulture, engineering, and technology, with knowledge gaps posing potential obstacles (Jeh Mkong, 2018; Sogang & Monkouop, 2022). Yet, its resource efficiency and ability for year-round production align well with addressing agricultural issues in regions like Cameroon (Sonwa et al., 2019).

3.3.4 Vertical Farming Technologies

Vertical farming employs technologies such, as hydroponics aeroponics, and aquaponics. Each of these techniques offers advantages. Hydroponics is gaining popularity due, to its cultivation of plants without soil using water solutions. It allows for control over nutrients. Promotes faster plant growth, particularly suitable for leafy greens, herbs, and certain fruits (Jeh Mkong, 2018; Tabe Ojong et al., 2023; Mir et al., 2022; Sonwa et al.,2019)

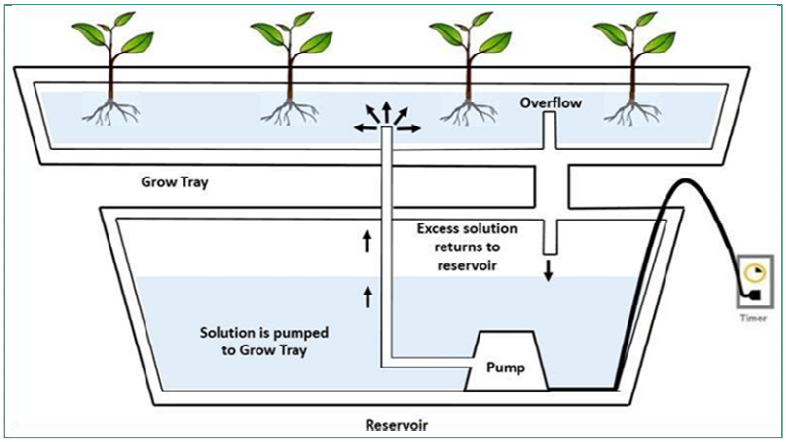

Figure 1: Diagram of a hydroponic system (Gupta & Ganapuram 2019, P.4)

Aeroponics improves water efficiency by misting nutrients onto plant roots in the air. This method optimizes oxygen supply and water usage (Bayiha et al., 2019; Kountchou et al., 2021). Aquaponics combines fish cultivation（aquaculture） with hydroponics, where fish waste nourishes plants while the plants purify the water for the fish. This creates a cycle of resource utilization and waste reduction (Bayiha et al., 2019; Ewoukem et al., 2017). The choice of farming technology depends on factors such as crop type, available resources, and location (Ewoukem et al., 2017; Awazi, 2022; Gerrewey et al., 2022).

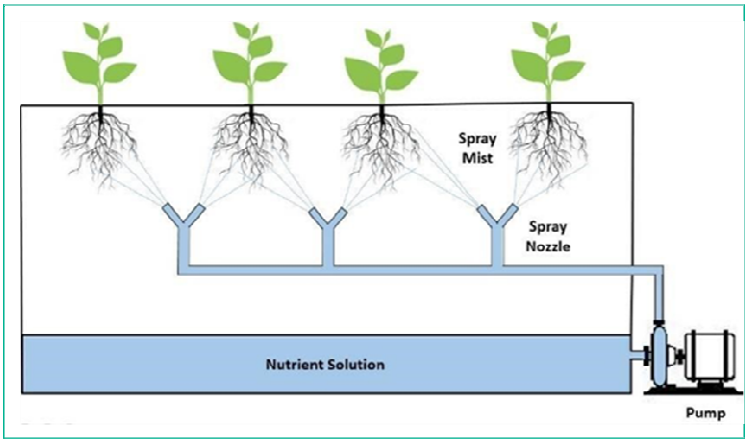

Figure 2: Diagram of an aeroponic system (Gupta & Ganapuram 2019, P.5)

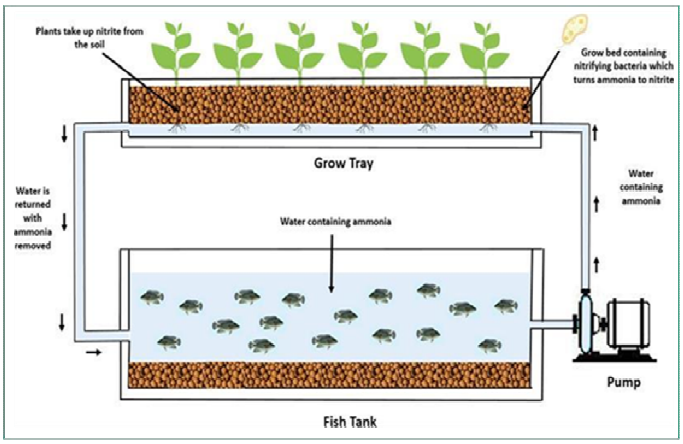

Figure 3: Diagram of an aquaponics system (Gupta & Ganapuram 2019, P.6)

3.3.5 Vertical Farming Business Models

Vertical farming models vary based on cultivator goals and resources, from individual operations funded by stakeholders to collaborative ventures with agribusinesses. The choice of the model influences management, funding, and expansion strategies, which are crucial for overcoming vertical farming's challenges. Financial support can come from private investors, startup capital, and government grants (Jeh Mkong, 2018; Ntsama et al., 2018; Sotamenou & Parrot, 2013; Awazi, 2022; Kalantari et al., 2018; Kenfack, 2017; Sogang & Monkouop, 2022; Sonwa et al., 2019; Mkong et al., 2021; Mir et al., 2022).

Aquaponics Business Model Framework

The Aquaponics business model combines fish farming and hydroponics, in systems, which is particularly advantageous in areas with limited water and crowded urban environments. It maximizes the use of water and space by creating a relationship between fish and plants. The plants utilize the waste produced by the fish as nutrients while also purifying the water. This model can be adapted for garden setups or scale commercial operations providing a sustainable solution for food production (Nana et al., 2022; Mir et al., 2022; Sonwa et al., 2019).

Araújo et al. (2021) have presented a framework for an aquaponics business that considers factors such as environmental, political, economic, social, technological, legal, and ecological aspects to ensure success. This framework includes strategies for market penetration components of the value chain, synergy among system elements considerations for investments, and analysis of viability with emphasis on risk management generating cash flow, and meeting stakeholder expectations. Financing strategies based on analysis are implemented to guarantee returns on investment for all parties with a focus, on ventures that carry lower risks (Brigham et al., 2014).

The structure developed by Araújo et al. (2021) aims to integrate sources and components while emphasizing not only their incorporation but also their interrelationships.

The primary objective of this method is to prioritize profitability. It does so by considering factors such, as the choice of fish and plant species, the type of system used, and the sales channels employed. This highlights the significance of comprehending how different components work together in aquaponics business planning.

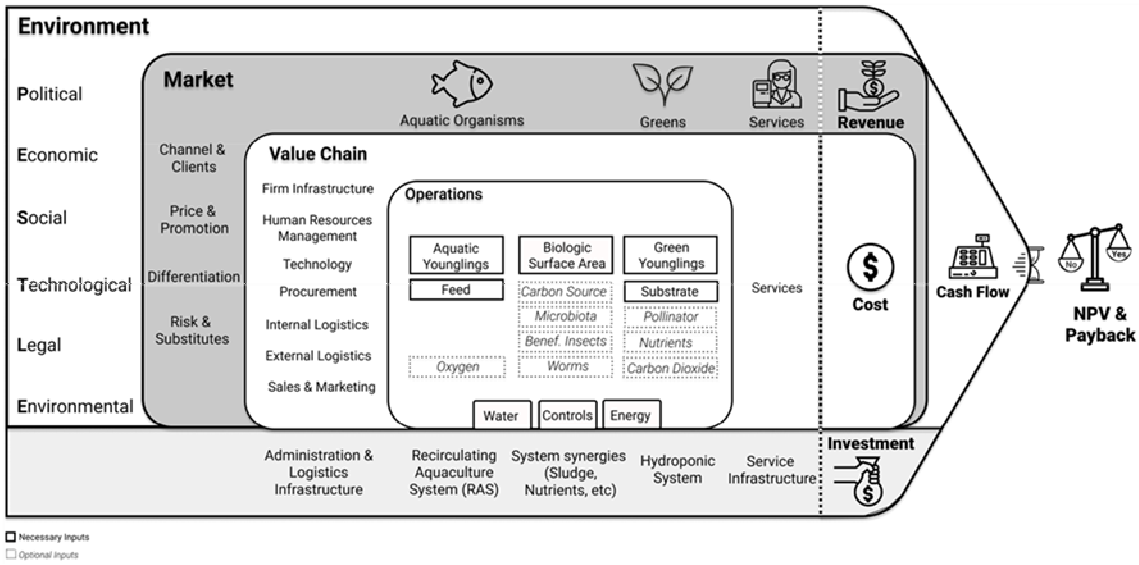

Figure 4: Making Aquaponics a Business Framework. (souce: Araújo et al. 2021)

Business Model Canvas

The Business Model Canvas (BMC), created by Alexander Osterwalder in 2008 and detailed in Osterwalder & Pigneur (2010), consists of nine components providing a comprehensive overview of a business's key drivers. Pölling et al. (2017) noted BMC's suitability for strategic management in vertical farming, highlighting its ability to outline value creation, relationships, and success factors. BMC aids in identifying success components, obstacles, competitor analysis, and in generating new ideas, widely used by entrepreneurs for evaluating business concepts, as supported by Henriksen et al. (2012).

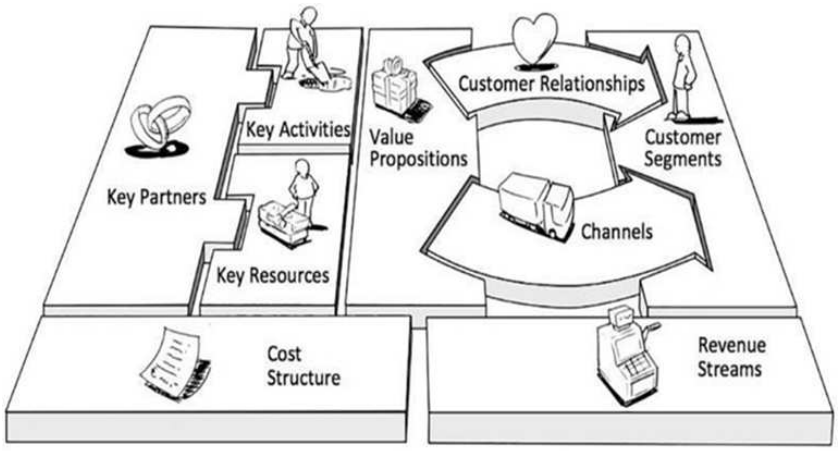

Figure 5: Business Model of Canvas (source; Osterwalder and Pigneur, 2010(page18-19))

The Business Model Canvas (BMC) by Osterwalder and Pigneur (2010) outlines nine key elements: customer segments, value proposition, channels, client relationships, revenue streams, activities, key resources, partners, and cost structure. These components collectively facilitate a strategic overview for businesses to tailor products/services, understand customer relations, manage resources, and outline financial structures. BMC's practical application in enterprises like Techno Farm in Japan showcases its effectiveness in crafting and enhancing business strategies (Aruni et al., 2019).

Vertical Farming as a Service (VFAAS) Model

This emerging business model offers vertical farming solutions as a service, allowing customers to access fresh agricultural products without investing in infrastructure. Enterprises manage crop cultivation, offering subscriptions for produce or investment opportunities in specific crops' cultivation. This approach minimizes customers' financial commitments while ensuring access to locally produced fresh products (Nana et al., 2022).

B2B Vertical Farming Model

B2B models in vertical farming involve providing technology and solutions to other businesses, with a growing number of companies specializing in systems, LED lighting, hydroponics, aeroponics, and data analytics. These companies support the vertical farming industry by servicing both new and established enterprises, contributing to the sector's growth (Baumont de Oliveira et al., 2022; Thomson, 2022).

3.3.6 Successful Case Studies

Analysing vertical farming case studies, like Sky Greens in Singapore for leafy greens production, and Japan's year-round vegetable cultivation, demonstrates vertical farming's potential to enhance food security and sustainability (Mir et al., 2022; Sonwa et al., 2019; Sikod, 2007). Additionally, advancements by Panasonic in Singapore highlight technological progress in the field (Bayiha et al., 2019; Kountchou et al., 2021; Ewoukem et al., 2017; Gerrewey et al., 2022). These studies support vertical farming's feasibility and adaptability for countries like Cameroon facing similar agricultural challenges.

3.3.7 Significance of a Vertical Farming Business Model Framework in Cameroon

In Cameroon, vertical farming addresses food security and sustainability amid urban growth, offering a controlled environment for agriculture, enhancing crop productivity, and reducing transport costs. This approach supports local food production, reduces import reliance, and adapts to Cameroon's diverse climates for year-round cultivation (Hutton et al., 2021; Oh & Lu, 2023; Fungo et al., 2023; Jeh Mkong, 2018; Sonwa et al., 2019; Kalantari et al., 2018; Sotamenou & Parrot, 2013).

3.4 Profitability in Vertical Farming Business Models

Vertical farming optimizes space and resources, increasing financial viability through year-round crop production and automation to reduce labor costs. Customization for specific crops targets niche markets, enhancing profit margins. Collaborations with tech firms and researchers to further profitability by staying ahead in innovation and compliance (Suh et al., 2023; Tabe-Ojong et al., 2021, 2023; Fonjong & Gyapong, 2021; Sneyd, 2013).

3.5 Comparative Analysis of Business Models

Assessing vertical farming models highlights their adaptability to Cameroon's agricultural context, influenced by strategy, technology, and market specifics. Adapting models to local conditions, climate, market demands, and technology, is critical. Direct application of international models requires assessing their relevance to Cameroon, considering resilience, local market needs, and community engagement. Profitability varies by focus, emphasizing the need for models responsive to Cameroon's unique agricultural environment (Jeh Mkong, 2018; Bayiha et al., 2019; Sonwa et al., 2019).

3.6 Initial Framework for Vertical Farming Business Model in Cameroon

This study aims to evaluate the feasibility of vertical farming business models as a solution to enhance food security in Cameroon. It emphasizes the need to adapt to the conditions of Cameroon and addresses gaps in existing literature. To achieve this a business model framework is proposed by combining "Making Aquaponics a Business; A Framework", with "the Business Model Canvas" specifically tailored for the climates of Cameroon. The framework is designed to address environmental and resource challenges by incorporating models that engage stakeholders effectively and implementing strategies for market and consumer alignment within Cameroon.

The vertical farming framework for Cameroon prioritizes aspects such as maximizing space efficiency adopting technologies, managing resources effectively, and fostering community engagement. Its main goal is to meet stakeholder expectations while adapting to the climate available resources and economic conditions to ensure profitability. This model highlights the importance of community involvement and cost-effective automation methods. Selecting crops based on market demand as factors, for long-term success (Mir et al., 2022; Maleki, 2022; Santini et al. 2021; Saad et al., 2021).

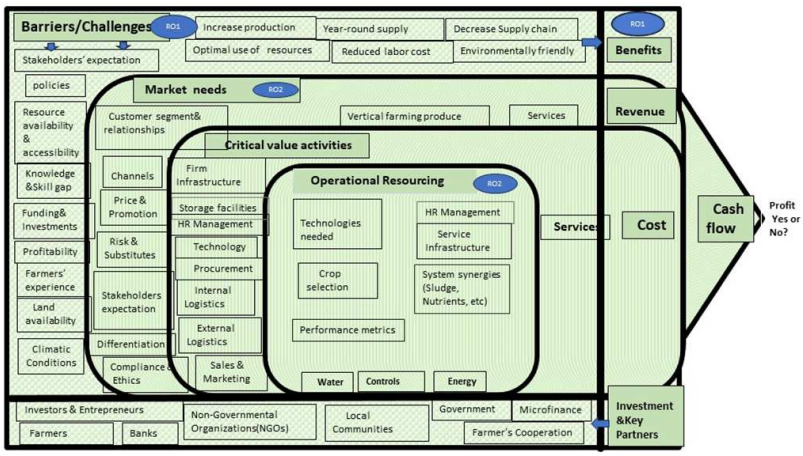

Figure 6: Initial conceptualization based on Araújo et al,2021 and Osterwalder & Pigneur, 2010

3.7 Summary of Literature

The research underscores a critical gap in understanding vertical farming business model feasibility in Sub-Saharan Africa, notably Cameroon. It identifies a significant shortfall in comprehensive studies addressing specific challenges and prospects for vertical farming in Cameroon, highlighting overlooked aspects like market demand, climate adaptability, stakeholder expectations, profitability, and regulatory impact. This gap suggests a need for targeted research to unlock vertical farming's potential in enhancing food security and agricultural sustainability in the region.

4 METHODOLOGY

The study adopts a qualitative research methodology, underpinned by an interpretivist philosophy, to explore the feasibility of vertical farming business models in Cameroon. It combines deductive and inductive approaches, drawing on existing theories and allowing new insights to emerge from the data collected through interviews and observations. This mixed-method approach facilitates a comprehensive understanding of vertical farming technologies and models suitable for Cameroon, emphasizing the subjective nature of research findings as influenced by the researcher's interpretations (Nur, 2020; Byrd, 2020; Cuthbertson et al., 2020; Mayring, 2004; Tyagi et al., 2021).

Data collection centered on interviews, with 15 carefully crafted questions informed by recent literature and expert feedback, ensuring content validity. The study engaged with individuals knowledgeable about Cameroon's agricultural sector, including farmers and investors, employing non-probability and purposive sampling techniques complemented by snowballing. Online interviews conducted via Zoom and WhatsApp from January 6th to 16th, 2024, facilitated participation from respondents both within and outside Cameroon, leveraging technology that is online software and websites for efficient transcription and documentation of the data collected.

For data analysis, the study utilized MAXQDA software to perform qualitative content analysis, applying both concept-driven and data-driven coding strategies. This methodology enabled the identification of key themes and insights pertinent to vertical farming business in Cameroon, drawing on initial codes derived from research goals and allowing for the emergence of new categories. The use of MAXQDA enhanced the analytical rigor of the study, providing a structured framework for coding, quantification, and mapping relationships between codes, thus effectively addressing the research questions posed (Van der Walt, 2020)

4.1 Ethical Considerations

The research adhered to ethical standards by obtaining informed consent from all participants, ensuring they understood the study's procedures. Participant identity and personal information were kept confidential, with only the researcher accessing the data to maintain privacy and security throughout the study.

5 PRESENTATION OF FINDINGS

5.1 Benefits, Challenges, and Barriers of Vertical Farming Business in Cameroon

5.1.1 Benefits of Vertical Farming

The respondents provided insights into the advantages of vertical farming in Cameroon. Many of them highlighted many potentials which include increased production and yields, efficient water management, and year-round cultivation in controlled environments. Operating in this way reduces reliance on variations and promotes crop diversity. Additionally, it minimizes transportation costs encourages community involvement drives advancements, and supports eco-friendly practices. These findings emphasize the potential of vertical farming businesses to address challenges related to urban space, water scarcity, and food security in Cameroon. Therefore, implementing vertical farming businesses can contribute to sustainability efforts(agriculture, food security, environmental, etc..) as well as technological innovation in the agricultural sector.

Vertical Farming benefits extend beyond considerations such as water management and conservation. It also serves as an alternative to farming methods by mitigating issues like deforestation, soil erosion, land disputes, and greenhouse gas emissions. In addition to conserving resources, it optimizes land usage which addresses land scarcity while promoting sustainability, within urban areas (R1, R2, R3, R5, R7, R8&R12).

The respondents also highlighted how vertical farming can help overcome challenges faced by agriculture practices in Cameroon. Specifically mentioned is the shorter distribution chain offered by vertical farming which reduces transportation needs while improving produce quality. This approach is considered a solution for areas addressing the challenges of logistics and ensuring a supply of fresh produce. Additionally, vertical farming is recognized for its ability to save time and financial resources while reducing reliance on inputs such as herbicides and pesticides. This has been particularly highlighted during COVID-19. These findings indicate that vertical farming offers an alternative to overcome the obstacles faced by farming methods in terms of logistics and yield.

Respondents further emphasized the importance of distribution and partnerships with retailers to ensure the financial sustainability of vertical farming businesses in Cameroon. They highlighted how customer demand impacts the market and expressed views on the increasing popularity of vertical farming. They also acknowledged its benefits, including access to sources of fresh produce, and improved financial sustainability through continuous production. These insights highlight the significance of relationships and market responsiveness, for vertical farming ventures.

5.1.2 Challenges and Barriers

Respondents highlighted both the benefits and challenges of vertical farming businesses in Cameroon, noting skepticism due to traditional farming loyalty and market dynamics issues like customer demand and high costs leading to higher cost prices for vertical farming products. Concerns were raised about competition affecting profitability and the lack of regulatory frameworks. Emphasizing the balance between vertical farming's advantages, and market and legal challenges is deemed crucial for its successful integration and financial sustainability in Cameroon.

Respondents identified key financial, technological, and infrastructural challenges for vertical farming in Cameroon, including high initial costs, especially for artificial lighting and energy use, and issues with technology access, funding, and resource availability. The need for specific expertise and stable infrastructure such as electricity and water supply was also highlighted since it is unstable and unreliable, underscoring the complexities of implementing vertical farming in the region. These insights stress the importance of addressing these barriers to harness vertical farming's potential for sustainable agriculture in Cameroon.

The challenges for vertical farming in Cameroon are diverse, including financial, technological, and infrastructural issues. Solutions like outsourcing alternative power sources, as suggested by one of the respondents, could mitigate the barriers and ensure the implementation of vertical farming business models in Cameroon and it is essential to address various challenges. Vertical farming holds potential in terms of enhancing food security and sustainability in Cameroon.

During the interviews respondents further pointed out several regulatory and policy obstacles that vertical farming faces in Cameroon. These include unfavorable taxes, the absence of frameworks and financial supports, incentives as well as a lack of clear regulations. Additionally, concerns were raised about resistance from farming communities. The complex landscape of these challenges must be navigated effectively to foster the success of farming in the region.

Lastly, one major challenge identified by respondents across interviews is the knowledge and skill gap associated with vertical farming in comparison to traditional farming practices in Cameroon. This gap arises due to its novelty and technological demands. Bridging this gap is crucial for the adoption and implementation of vertical farming technologies and models in Cameroon. It requires training programs, education initiatives, and adjustments within the educational curriculum to incorporate vertical farming.

The challenges faced by vertical farming businesses in Cameroon include knowledge gaps, lack of awareness, insufficient educational support, unclear policies, and financial constraints. All these obstacles could hinder the adoption and success of vertical farming practices in Cameroon. Comprehensive strategies must be developed promptly to address these issues effectively.

Even though, t these obstacles could be addressed soon, the local farmers and investors will smoothly adopt vertical farming businesses as an alternative for more sustainable agricultural practices for some crops for higher profits and food security. However, Vertical farming cannot replace traditional farming 100 percent in Cameroon anytime soon, especially as Cameroon's staple crops like maize, cocoa, plantains, and bananas haven't been investigated thoroughly to know if they can do well in vertical farming technology now.

5.2 Optimal Vertical Farming Technologies and Vertical Farming Business Models

5.2.1 Vertical Farming Technologies and Adoption

Here the respondents were asked about the technologies they are familiar with and how well the technologies have been adopted and accepted.

Vertical Farming Technologies

Respondents across the study demonstrated a strong familiarity with vertical farming technologies, particularly favoring aquaponics also for its traditional practices in Cameroon, cost-effectiveness, and suitability in Cameroon's climate. Aquaponics was noted for its year-round profitability despite dry season challenges and stands out as a sustainable method for fish and vegetable cultivation. Hydroponics also gained attention for its resource efficiency and adaptability to local conditions. The need for alternative water sources during dry seasons and considerations for regional characteristics underline the importance of

tailored approaches. Greenhouse farming was mentioned as another prevalent method, indicating a diverse technological landscape in Cameroon's vertical farming sector.

Conclusively, aquaponics stands out as the favorable vertical farming technology in Cameroon, reflecting the emphasis on sustainable practices suited to local conditions. This method demonstrates the importance of adapting farming techniques to regional needs and efficient resource utilization.

Acceptance and Adoption

The adoption of vertical farming technologies in Cameroon varies, with enthusiasm and acceptance among several farmers for its potential to reduce costs and improve efficiency, particularly through integrated systems like aquaponics. However, overall acceptance is slow, attributed to the novelty of the technology and challenges such as energy costs and a lack of familiarity. Skepticism also exists due to loyalty to traditional farming practices and a general reluctance to adopt new methods without proven benefits, others also mentioned lack of awareness is the cause of the slow acceptance, underscoring the need for increased awareness and education to foster wider acceptance and implementation of vertical farming technologies.

Vertical Farming Business Models

The Aquaponics business model is widely favored among respondents as a cost-effective vertical farming model in Cameroon, noted for reducing production and transportation costs, enhancing resource accessibility, and supporting climate resilience. It combines fish and crop production, promoting water recycling and integration with local practices. Some respondents also recognize the potential of aeroponics and hydroponics for their space efficiency and resource utilization. Emphasis is placed on renewable energy to lower operational costs, with aquaponics praised for its environmental benefits and alignment with local materials and practices for long-term scalability.

5.3 Stakeholders Expectation

5.3.1 Expected support for a vertical farming investment.

The insights emphasize the necessity for government support, partnerships, and educational initiatives to advance vertical farming in Cameroon. Key areas include policy development, financial incentives, infrastructure improvement, and raising public awareness. Stakeholders stress the importance of government flexibility & support, community involvement, and access to finance. The consensus underlines the need for a collaborative approach, incorporating government, private sector, and educational institutions to create a conducive environment for vertical farming businesses, highlighting the crucial roles of sensitization, supportive policies, and resource availability in driving adoption and success.

5.3.2 Opportunities and uncertainties of the vertical farming business

Experts expressed optimism about the potential of vertical farming business in Cameroon to boost food production. They highlighted benefits, such as year-round cultivation, water conservation, job creation, and increased profits. The experts also emphasize the opportunities for market differentiation, growth, sustainable food production, and addressing food shortages. They believe that cultivating high-value diverse crops and reducing distribution chains are vital for ensuring the success and sustainability of farming in the region. In summary, they see a range of opportunities in vertical farming in Cameroon including maximizing production all year providing fresh and high-quality produce, shortening distribution chains for better availability of fresh produce making efficient use of land and water resources while being environmentally friendly.

While vertical farming business models offer promising prospects in Cameroon it is not without challenges and uncertainties. Respondents raised concerns about costs, market dynamics, the unreliability of resources needed for vertical farming operations as well as regulatory complexities. They also acknowledge the novelty of this approach which brings some unpredictability to the market as well as potential pollution risks and demands on resources. Additionally noted were energy costs and political instability that could pose barriers to its success. Addressing these issues will be crucial to unlock the potential of vertical farming business models in Cameroon. It will require efforts to increase market acceptance through regulations and support mechanisms.

5.3.3 Financial Feasibility

Respondents offered insights into evaluating the financial feasibility of vertical farming in Cameroon, emphasizing market analysis, financial support, government involvement, crop selection, and social and environmental considerations. Key points include the importance of understanding market demand, consumer preferences, and climate suitability, alongside the necessity for comprehensive feasibility studies. Financial challenges, the need for collaboration, and the potential for profitability with the right strategies were also discussed, indicating a positive outlook for vertical farming's financial viability compared to traditional methods.

5.3.4 Policies and Regulatory Changes

Respondents emphasized the need for supportive policies for vertical farming in Cameroon, focusing on financial support, resource management, education & training, market dynamics, and partnerships. They advocate for tax breaks, incentives, grants, low-interest loans, infrastructure improvements, educational programs, market access facilitation, and collaborative initiatives between government, industry, and communities to foster vertical farming businesses' adoption. These strategies aim to address challenges like high initial costs, market acceptance, unreliability of resources, lack of awareness, and knowledge gaps, highlighting a holistic approach to promoting sustainable agriculture through vertical farming.

6 DISCUSSION AND CONCLUSION

6.1 Discussion

The study effectively addresses gaps in research on vertical farming business models in Cameroon, highlighting its potential benefits and challenges through expert insights that close the gap which was identified as the lack of research specifically examining the potential benefits, challenges, and barriers associated with adopting vertical farming in Cameroon (Jeh Mkong, 2018; Sonwa et al., 2019). The respondents' feedback (R1-R12) has been synthesized, revealing key benefits such as increased production, water efficiency, and year-round crop availability, alongside challenges including high initial costs and energy requirements, which align with literature findings (Kalantari et al., 2018; Ntsama et al., 2018). Notably, respondents emphasized the barriers of high startup expenses, particularly for infrastructure and energy-intensive systems required for controlled environment agriculture, mirroring concerns highlighted by Tambi et al. (2017). It offers solutions to land-use conflicts, potentially easing tribal tensions by reducing reliance on traditional farming spaces (R12), and can boost Cameroon's economy and food self-sufficiency through shorter supply chains and enhanced crop diversity (R3, R9, R1, R4, R5, & R12). However, it faces significant challenges including political instability, regulatory uncertainties (R1 & R9), and environmental concerns like urban pollution and infrastructure deficits (R4, R1, R4, R5, & R7), which were not extensively addressed in existing literature. These findings highlight both the transformative potential of vertical farming in Cameroon and the critical need for supportive policies and infrastructure to realize its benefits fully by enhancing food security, environmental sustainability, and economic growth.

Respondents emphasize the suitability of aquaponics and hydroponics as the favorable model and technology. The need for supportive policies, education and training, financial incentives, government support, and the importance of stakeholder collaboration for the successful adoption of vertical farming. However, this indicates a thorough emphasis on education and training to be carried out for local farmers and investors in vertical farming businesses to gain skills and knowledge on vertical farming and also increase experts in vertical farming.

The study proposes a tailored vertical farming business model for Cameroon, considering the unique socio-economic and environmental context, aiming to guide future implementations and policy formulations. See Figure 9. The final model which is the "Vertical Farming Business Model for Cameroon" presents the combined and condensed findings. This model also closes the gap that was noted by Nchu et al., & Sneyd which was earlier discussed in the literature

The final model integrates insights from expert interviews on vertical farming business in Cameroon, aligning innovative findings that is the inductive findings that were not discussed in the literature (coded in blue) with literature review insights that is the deductive findings (in black) for localized context adaptation. It emphasized stakeholder involvement, government support, sensitization & campaigns, education &

training, and financial incentives as pivotal for adoption and profitability. Technological adaptation through HR management emphasizes education and training. Operational resources focus on aquaponics as the preferred technology, the model also highlighted the urgent need for comprehensive stakeholder cooperation(cooperation of all key partners) to ensure fast adoption and higher profit margins compared to traditional farming methods in Cameroon.

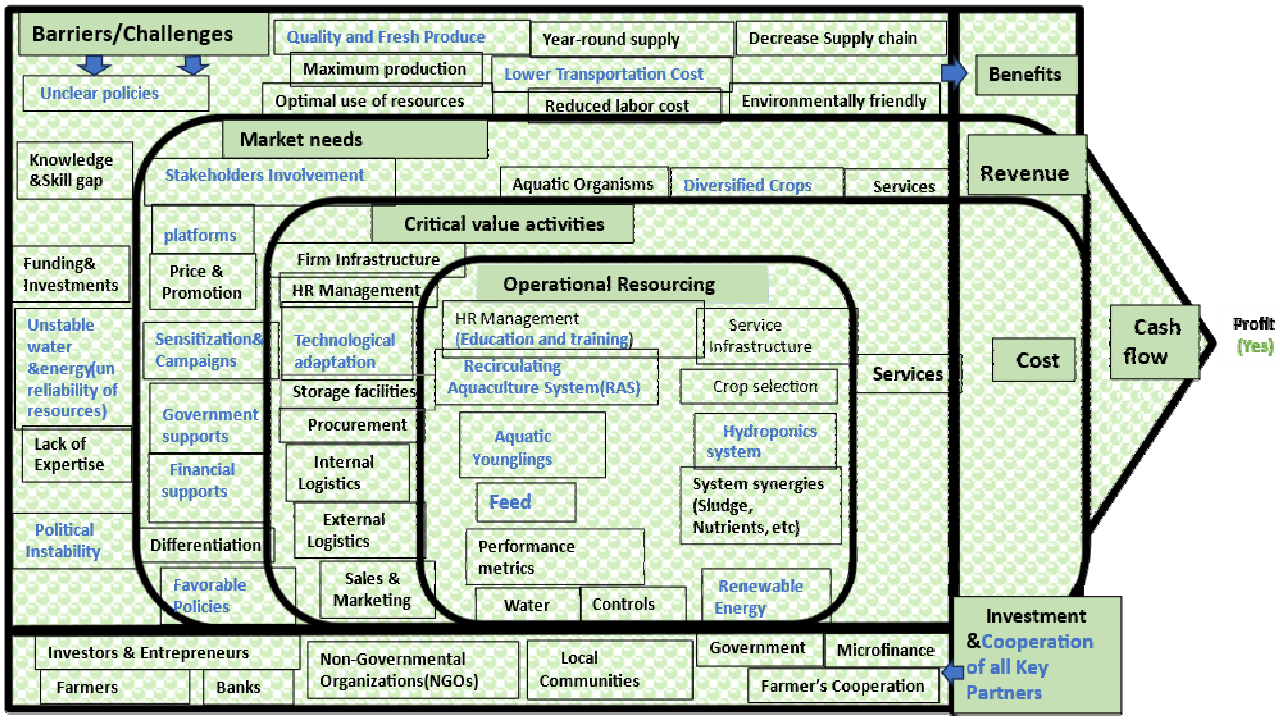

Figure 7: Vertical farming business model for Cameroon

6.2 Conclusion

The paper explores the viability of vertical farming business models in Cameroon, focusing on integrating such business models with local practices and addressing food security and sustainability. It emphasizes the need for sociocultural integration, financial support, governmental support, clear and favorable policies, and skill development for successful implementation. Despite potential benefits, challenges like infrastructural deficits and technological gaps must be overcome with stakeholder engagement, education & training, and supportive policies. This work contributes to sustainable agriculture research, offering insights for policymakers, practitioners, and researchers on adopting vertical farming in developing contexts.

7 LIMITATIONS AND SUGGESTIONS

The study faces limitations, including conducting only online interviews due to budget constraints, potentially affecting the depth of insights compared to face-to-face interactions. Technical issues with online connections impacted the clarity of transcriptions. Additionally, there was limited access to key government officials, particularly from the Ministry of Agriculture, which could have enriched the findings with more diverse perspectives and insights into regulatory and support frameworks.

To enhance the study of vertical farming business models in Cameroon, future research should include on-the-ground fieldwork for broader insights, incorporate both qualitative and quantitative methods for greater validity, delve into specific crop and fish types suitable for vertical farming business models, a delve study on the socio-cultural integration of vertical farming business that is a vertical farming culture needs to be created. A further discussion with farmers and other stakeholders to get their perspective on whether vertical farming will replace traditional practices and what role are they going to play especially the traditional farmers, also let them discuss, if they would have priority in the needed skill training of vertical farming, will they accept socially and culturally the change from rural to urban life?. Additionally, developing a financial model specific to Cameroon's context would significantly benefit local farmers and how staple crops like maize, wheat, etc… can be done using vertical farming techniques.

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