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Sustainability in Agricultural Value Chains: Evidence from the Pineapple Sector in Ghana

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ABSTRACT

The pineapple sector in Ghana plays an important role in the country's economy, providing a livelihood for actors along the value chain. This study aims to understand the factors influencing the sustainability of the major actors along the pineapple value chain in Ghana, addressing the challenges such as changing market prices, environmental degradation, and socio-economic inequalities. The study surveyed 320 smallholder pineapple farmers, 66 processors, and 169 marketers from three districts in Ghana's Central Region: Abura-Asebu-Kwamankese, Komenda-Edina-Eguafo-Abirem, and Ekumfi using snowball sampling. The sustainability levels among the actors were high, with average index scores of 0.62 for farmers, 0.82 for processors, and 0.69 for marketers. Key findings from the fractional logit model analysis revealed that socio-economic factors such as marital status (particularly married and divorced individuals), household size, age, education level, number of pineapple farms, occupation (e.g., civil servants), farming experience, and farm size play a critical role in driving sustainability among farmers in the pineapple value chain. For processors, sustainability was significantly influenced by the number of workers, age, education level (primary and tertiary), business ownership, and marital status. Among marketers, sustainability hinged on the source of pineapples, age,

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and type of education. The findings highlight the need for policymakers to target interventions that address these socio-economic factors to strengthen sustainability across the pineapple value chain.

Keywords: Sustainability; Value Chain; Fractional Logit and Agricultural Policy

1. Introduction

When it comes to the worldwide endeavor to maintain food security, environmental preservation, and economic stability, sustainability in agricultural value chains has emerged as a major problem. Pineapples are a key export item for many tropical nations, including Ghana, and are among the various farming goods produced [1]. Along the value chain, the pineapple sector in Ghana not only makes a significant contribution to the country's economy but also provides a means of subsistence for many smallholder farmers, processors, and marketers [2]. Thus, it is necessary to understand the factors that determine sustainability within this value chain to promote behaviors that have the potential to improve productivity, environmental stewardship, and socio-economic well-being [2].

The GDP and the standard of living for most Ghanaians is influenced by the agriculture sector, which is a major contributor to the country's economy [3]. Regarding livelihoods, more than 60% of Ghana's working population depends on agriculture for jobs and income, and it also helps to satisfy food demands [4]. The industry currently plays a key part in Ghana's development plan because of the industry’s contribution to economic growth and development. To promote the growth and development of the economy, Ghana has been developing agricultural policies since 2002. These policies aim to improve access to market and financial services, improve infrastructure, increase institutional capacity and human resources, and decrease unsustainable land and agricultural resource management [5].

According to Boakye's [2] research from 2019, the idea of sustainability in agricultural value chains involves many different characteristics, including viability from an economic standpoint, environmental health, and social equality. According to Kwasi Bannor et al. [6], the pineapple value chain in Ghana has several issues that are related to sustainability. These challenges include changing market prices, environmental degradation caused by using chemicals, and socio-economic inequities among the players in the value chain. To address these difficulties, it is necessary to do a thorough examination of the aspects that influence sustainability, beginning with manufacturing and continuing through marketing.

A high-value crop grown commercially around the world is the pineapple (Ananus comosus), a tropical fruit. Cayenne, Queen, Sugarloaf, Pernambuco, Variegated, Baby, Red Spanish, and the most recent variation, MD2, are among the native pineapple varieties found in Central and South America [7]. Ghana started producing pineapples in the 17th century or before. Through the Basel Missions and Governments, agriculture quickly expanded throughout this period. However, over time, pineapple production spread to other cities and villages in the Greater Accra area, and then to other parts of the country. Notably, pineapple is grown in Ghana's Eastern, Central, and Greater Accra regions. Pineapple contains minerals including calcium, potassium, magnesium, iron, and vitamins A, B, and C, and has a very high food content. Additionally, it is a good source of the enzyme bromelain [7]. Both fresh and processed forms of the fruit are consumed. It may be used to make a wide range of value-added products, including juice, jam, and jelly-blended jam, which would pay the agricultural community well and offer rural locals work.

Although the pineapple sector in Ghana plays a crucial role in the economy, it also faces significant sustainability challenges, including environmental degradation, market volatility, and socio-economic inequalities [8]. Over 65% of smallholder farmers rely on synthetic fertilizers and pesticides, leading to soil depletion and water contamination, while deforestation for pineapple farming contributes to a 3.2% annual forest cover loss [2]. Additionally, annual rainfall in key production regions has declined by 15% over the past two decades, increasing reliance on irrigation and raising production costs [2]. Market volatility further threatens the sector, with Ghana’s pineapple exports declining by 35% between 2004 and 2014 due to competition from Costa Rica’s MD2 variety, and farm-gate prices fluctuating by up to 40% per harvest season [8]. Compliance with international standards is another hurdle, as 15% of Ghana’s fresh pineapple exports were rejected in 2021 due to pesticide residue concerns [8]. Socio-economic constraints exacerbate these issues, with only 25% of smallholder farmers having access to formal financing and only 12% of female farmers owning land [3], limiting their ability to implement sustainable practices.

In Ghana's pineapple business, smallholder farmers constitute the backbone of the industry. However, these farmers frequently face challenges such as restricted access to cash, technology, and markets, which can make it difficult for them to engage in sustainable practices [8]. Processors and marketers also play important roles in the value chain, as the activities they engage in have an impact on the overall efficiency, quality, and marketability of pineapples. One of the most important steps in the process of planning targeted interventions that can improve the resilience and sustainability of the whole value chain is to understand the factors that are responsible for driving sustainable practices among these main actors [2].

Moreover, the sector faces the challenge of local pineapple growers being unable to quickly transition between different varieties, even though farmers and marketers require adaptability to meet the frequent changes in demand for specific types of pineapple fruits. Further, the pineapple value chain actors cannot incorporate sustainable agricultural practices into their line of activity. This study therefore investigates the determinants of sustainability among the major actors along the pineapple value chain in Ghana. Unlike other studies [7,9–10], this study provides a new contribution by looking at the impact of sustainability on the activities of the major actors along the pineapple value chain and thereby exploring sustainability as an impact pathway for agricultural development in a country like Ghana.

Sustainability in agricultural value chains can be analyzed through multiple theoretical lenses [11]. This study integrates the Sustainable Livelihoods Framework (SLF), the Triple Bottom Line (TBL) Theory, and Institutional Theory to understand the factors influencing sustainability among pineapple farmers, processors, and marketers in Ghana. The SLF framework is relevant as it explains how agricultural actors utilize natural, human, social, and financial capital to sustain their operations [11]. Farmers with greater access to credit, training, and productive land are more likely to adopt sustainable practices. The TBL theory provides a multidimensional view of sustainability, emphasizing economic viability, social well-being, and environmental responsibility [11]. This aligns with the study's approach of measuring sustainability beyond profitability. Institutional Theory further contextualizes how government policies, market incentives, and regulations shape sustainability outcomes [11]. Applications of these theoretical perspectives, this study provides a robust framework for analyzing sustainability determinants across different actors in the pineapple value chain.

Research Gap and Purpose Statement

Existing studies on sustainability in agricultural value chains [7,9,12-15] have primarily examined broad aspects such as economic viability, environmental impact, and social inclusion [16,17]. While these studies provide valuable insights, they often fail to offer sector-specific and actor-focused empirical analyses that account for the unique sustainability challenges faced by different participants in the agricultural value chain. According to Latino et al. [18], sustainability in food supply chains has been widely explored through a macro-level lens, with an emphasis on generalized models and management practices rather than a deep investigation into actor-specific sustainability determinants [19]. This lack of disaggregated analysis limits the ability to develop targeted strategies that address the distinct roles, constraints, and contributions of farmers, processors, and marketers in achieving sustainability goals.

Furthermore, agricultural sustainability research in Ghana has largely focused on broad farming practices without adequately addressing the sectoral and actor-specific challenges that influence sustainability outcomes in high-value crop sectors such as the pineapple industry. Studies tend to examine economic, environmental, and social sustainability in isolation rather than adopting a holistic, value chain-wide perspective that captures the interdependencies across the chain. Latino et al. [18] highlights that while environmental and economic sustainability factors are frequently included in assessments, social sustainability remains underexplored, particularly in developing countries where labor conditions, social equity, and community resilience play a crucial role in overall sustainability [19]. Additionally, while research in agricultural sustainability increasingly acknowledges the importance of food traceability and monitoring frameworks, the adoption and impact of such technologies within Ghana's pineapple sector remain insufficiently examined. Given the rising global demand for sustainable agricultural practices and the increasing pressure on agribusinesses to demonstrate compliance with sustainability standards, there is a critical need to understand how different actors in the pineapple value chain contribute to and are affected by sustainability dynamics.

This study addresses these critical gaps by providing empirical evidence on the determinants of sustainability across key actors, including farmers, processors, and marketers, within Ghana's pineapple value chain. By utilizing a fractional logit model and cluster analysis, it identifies the socio-economic, demographic, and business-related factors that influence sustainability outcomes at different stages of the value chain. Furthermore, the study incorporates insights from food traceability research by Radogna et al. [20] to examine how monitoring frameworks can strengthen sustainability efforts, particularly in terms of environmental impact mitigation and supply chain transparency. Beyond merely discussing sustainability at a broad conceptual level, this study offers policy-relevant insights tailored to specific value chain actors, facilitating practical, data-driven interventions. By adopting a sector-specific and actor-focused approach, the research provides a more nuanced and actionable understanding of sustainability in the pineapple industry. The findings offer practical implications for policymakers, agribusiness leaders, and researchers aiming to enhance sustainability performance, resilience, and competitiveness in high-value agricultural value chains.

2. Literature Review

2.1. Sustainability in Agricultural Value Chains

Sustainability in agricultural value chains has emerged as a critical focus, motivated by the need to strike a balance between economic growth, environmental protection, and social well-being. A sustainable agricultural value chain includes practices that reduce environmental impact, promote social equity, and ensure long-term profitability for all stakeholders, such as farmers, processors, distributors, and consumers. The concept of sustainability in these chains is based on the idea that each link should strive to reduce waste, optimize resource use, and promote fair labor practices. This approach is consistent with global efforts to achieve the Sustainable Development Goals (SDGs), particularly those related to food security, poverty reduction, and climate action [21, 22].

Environmental sustainability is a major challenge in agricultural value chains because the industry relies heavily on natural resources like land, water, and energy. Precision agriculture, increased water efficiency, and the incorporation of renewable energy sources into production processes are examples of sustainable practices. These efforts are required to combat deforestation, soil degradation, and biodiversity loss. Muller et al. [23] found that organic farming systems play an important role in promoting ecological balance, reducing greenhouse gas emissions, and improving soil health, all of which are essential components of sustainable value chains. However, the transition to sustainable practices frequently necessitates significant investment and training, which can be prohibitive for smallholder farmers.

Another important component is social sustainability, which focuses on improving people's livelihoods and working conditions across the value chain. Building resilient agricultural communities requires ensuring fair wages, protecting labor rights, and providing access to education and training. According to Diao et al. [24], inclusive value chains that provide smallholder farmers with access to markets, credit, and technology increase productivity while also improving community welfare. Furthermore, gender inclusion in agricultural value chains can result in a more equitable distribution of resources and decision-making power, which promotes long-term social sustainability.

Economic sustainability entails producing value for all stakeholders in the agricultural value chain while protecting natural and human resources for future generations. Gereffi et al. [25] posited that value chain models that stress shared value in which firms and communities benefit mutually are critical to establishing long-term sustainability. Such tactics encourage innovation, increase competitiveness, and lower costs via resource efficiency. Nonetheless, attaining economic sustainability in agricultural value chains necessitates comprehensive legislative frameworks and market incentives that promote sustainable practices while protecting the interests of smaller actors [25]. A visual representation of the three dimensions of sustainability is presented in **Figure 1** below:

Figure 1. Visual representation of the three dimensions of sustainability.
Source: Author's design.

The diagram illustrates the interconnected nature of sustainability's three key dimensions: economic, environmental, and social. These dimensions overlap, indicating that sustainability is achieved when all three are balanced. Key influencing factors such as market prices, education, access to finance, and regulations interact with these dimensions by shaping decision-making and sustainability outcomes [25]. For example, market prices influence the economic sustainability of farmers, processors, and marketers, while education enhances social sustainability by fostering knowledge and adoption of sustainable practices. Access to finance supports investment in eco-friendly technologies, linking both the economic and environmental aspects. Regulations, such as environmental laws and fair labor policies, play a role in ensuring sustainability across all three dimensions. The diagram simplifies these relationships, showing how different actors and factors contribute to a sustainable agricultural value chain.

2.2. Overview of the Pineapple Value Chain in Ghana

The pineapple value chain in Ghana encompasses a series of stages from production to export, involving various actors including farmers, processors, marketers, and exporters. The profitability analysis of these actors reveals that while production and processing are profitable, marketing is not, with different factors influencing the profit margins of each group [1]. Supply chain integration practices, such as internal, supplier, and consumer integration, have been shown to positively impact value chain performance, especially when coupled with information sharing [11].

The value chain is influenced by the implementation of risk mitigation strategies, which generally enhance performance. Strategies such as avoidance, control, and coordination are effective in mitigating risks, except for political and weather-related risks [26, 27]. However, the dynamics are complicated by climate variations, which significantly affect pineapple production and, by extension, the value chain. Temperature increases and variable rainfall patterns have been shown to influence yield variability, posing a challenge to the sustainability of the pineapple industry in Ghana [27].

The economic importance of the pineapple sector to Ghana is multifaceted. The sector contributes to Ghana's trade through its responsiveness to production, trade openness, and competitiveness indices. However, some studies indicate that pineapple exports hurt economic growth, which contrasts with the positive impact of cocoa exports [26]. The socioeconomic significance of pineapple production is underscored but also points to the vulnerability of the sector to climate variations, which can affect yields and, by extension, economic outcomes [26].

2.3. Determinants of Sustainability for Pineapple Farmers

The determinants of sustainability for pineapple farmers are influenced by various factors, including agricultural practices and their environmental impact. Farmers face climatic challenges, soil quality issues, and pest management concerns, which necessitate the adoption of sustainable practices to ensure optimal growth and yields [28]. The environmental sustainability of agricultural products, such as those from organic farming systems, is also a critical consideration, as it involves the assessment of environmental impact per product unit and the delivery of ecosystem services [29].

Economic factors such as access to credit, market information, and technology are significant determinants of sustainability for pineapple farmers. Access to formal credit enables farmers to invest in their agricultural practices and improve productivity. Market insights, such as consumer trends and demand fluctuations, can inform sustainable farming techniques, aligning practices with market demands and enhancing economic viability. However, there are complexities within these determinants, such as the distance to credit sources and annual household income negatively influencing credit access [28].

Social factors, including labor conditions, gender dynamics, and community relations, also play a crucial role in determining the sustainability of pineapple farming. The socio-demography and working conditions of pineapple farmers are associated with musculoskeletal symptoms, which are prevalent among these farmers [12]. Gender dynamics could influence sustainability in agricultural contexts, potentially affecting the environmental dimension of sustainability for pineapple farmers. Community involvement has a robust positive correlation with agricultural productivity, implying that strong community ties and participation may be important determinants of sustainable practices among pineapple farmers [28].

A growing body of literature highlights the critical role of socioeconomic and structural factors in shaping the adoption of sustainable agricultural practices across different regions. According to Akaba [30], farmers in Ghana exhibit a generally positive attitude toward sustainable agriculture, with production sustainability emerging as a key influencing factor. This suggests that in regions such as the Volta Region, promoting sustainability in farm businesses could significantly enhance food security levels by ensuring long-term productivity and resource conservation. However, while attitudes towards sustainability are favorable, the extent to which farmers implement sustainable practices depends on several external factors.

Evidence from Iran further underscores the importance of socioeconomic determinants in driving sustainability outcomes. As revealed by Sharifzadeh et al. [31], variables such as farm income, access to agricultural extension services, and education significantly influence the sustainability of agricultural production among rural farmers. This aligns with broader findings from the Southern African Development Community (SADC), where Guo et al. [13] identified age, farmland size, education, gender, household size, income, and access to credit as crucial factors shaping sustainability adoption. These determinants not only affect farmers' willingness to implement sustainable practices but also influence their ability to overcome financial and technical barriers associated with transitioning to more sustainable production methods.

Similarly, studies from Vietnam reinforce the idea that sustainability adoption is deeply embedded in the broader economic and institutional environment. According to Dung et al. [14], farmers' uptake of sustainable agricultural practices is shaped by human capital, farm size, social capital, extension services, and access to markets. These findings suggest that a well-developed support system including targeted extension services, financial incentives, and market linkages is essential to drive widespread adoption of sustainability initiatives.

Taken together, these studies highlight the interconnectedness of socioeconomic, institutional, and demographic factors in influencing agricultural sustainability. While positive farmer attitudes are a necessary foundation, enabling environments such as access to credit, extension services, and education are crucial for translating these attitudes into actionable sustainability practices. Therefore, policies aimed at improving agricultural sustainability should adopt a holistic approach that integrates financial support mechanisms, targeted education and training, and enhanced market access to ensure that farmers can successfully implement sustainable practices.

2.4. Determinants of Sustainability for Processors

The determinants of sustainability for pineapple processors are multifaceted, with processing technologies and waste management being critical components. Advanced processing technologies can enhance efficiency and reduce waste generation, while effective waste management practices ensure the responsible disposal or repurposing of by-products. The adoption of the 3R approach (reduce, reuse, recycle) and circular economy principles within the processing industry can lead to more sustainable operations by minimizing waste and maximizing resource utilization [26].

Quality standards and certification requirements play a crucial role in enhancing firm revenue and household welfare by improving yields; however, the proliferation of competing and overlapping global sustainability standards creates uncertainties for firms, particularly in emerging economies, reducing their propensity to adopt any standard due to the diversity, dynamism, and unpredictability of customer requirements. While certification can be a key determinant of sustainability, it may also have unintended consequences on the inclusivity of small-scale farmers [29]. Additionally, market access and international trade dynamics significantly influence the sustainability of pineapple processors and exporters by enabling firms to engage with foreign buyers and navigate the complexities of global business. Trade costs play a vital role in determining the size and survival of exporters, making access to market intelligence and strategies such as international trade fairs essential for minimizing barriers and expanding into new markets, particularly for smaller firms seeking growth opportunities [26].

In addition to the above, the determinants of corporate sustainability in agro-processing industries vary across regions and sectors, with existing studies highlighting a range of economic, institutional, and social factors that influence sustainability outcomes. For instance, Setthasakko [12] found that government regulations, management decisions, and local community engagement were the primary sustainability drivers among seafood processors in Thailand, contrasting with the present study's findings and underscoring the context-specific nature of sustainability determinants. Similarly, Kiende [15] revealed that tea processing in Kenya is ecologically and environmentally unsustainable, emphasizing the need for sustainable resource management and regulatory oversight. Other studies highlight the role of socioeconomic factors, such as Khoza et al. [32] identified age, access to training, education, and household size as key influencers of sustainability among agro-processors, while Adekunle et al. [33] found that age, gender, household size, and experience played significant roles in Sub-Saharan Africa.

Additionally, Hernández-Rubio et al. [34] reported that quality control and safety inspections were the primary sustainability determinants for agro-food marketers, contradicting studies that emphasize socioeconomic or institutional factors. These varying findings suggest that sustainability in agro-processing is a multidimensional issue shaped by regulatory frameworks, economic viability, social capital, and business management strategies. Therefore, policies aimed at improving sustainability should adopt a sector-specific and regionally tailored approach, integrating government incentives, capacity-building initiatives, and market-driven sustainability standards to address the unique challenges of agro-processors. Future research should explore the dynamic interactions between these factors across different value chains to ensure that sustainability strategies are both practical and adaptable to local conditions.

2.5. Determinants of Sustainability for Marketers

Consumer preferences for sustainable products are increasingly influencing the retail market. Attributes such as taste, size, and color are crucial for market demand and sales strategies. Marketers'/Retailers' sustainability efforts can lead to improved consumer responses, particularly when aligned with personal and social norms favoring environmentally friendly practices. The demographic profile of consumers, particularly younger and more educated individuals, appears to be an important factor in the demand for sustainable products [2, 29].

Retail strategies for promoting sustainable pineapples encompass a variety of approaches, including communication of environmental policies, corporate social responsibility (CSR) initiatives, and the adoption of sustainable practices. Retailers can leverage CSR strategies to align with sustainability goals, such as introducing local initiatives and "social stores" to support sustainable products. However, effective communication strategies are crucial to correct misconceptions and promote the sustainability of products like pineapples [26].

Labeling and certification significantly influence consumer choices towards sustainable pineapples, as they indicate the product's environmental and health impacts. However, the complexity of consumer behavior and the broader CSR context must also be considered. Retailers should ensure that their sustainability efforts are comprehensive, encompassing both clear labeling and a commitment to broader ethical practices to effectively guide consumer decisions towards sustainability [29].

3. Methodology

3.1. Sampling and Sample Procedure

This study focused on three districts in Ghana's Central Region: Abura-Asebu-Kwamankese, Komenda-Edina-Eguafo-Abirem, and Ekumfi. The sample frame consisted of smallholder pineapple growers, processors, and marketers from these districts. According to the Department of Agriculture (2018), the sample frame for farmers included 1,051 farmers from Ekumfi, 875 farmers from Komenda-Edina-Eguafo-Abirem, and 15 farmers from Abura-Asebu-Kwamankese. Since the sample frame for processors and marketers was unknown, the snowball sampling method was used to identify as many individuals from these groups as possible within the study area. This method yielded 10 processors from the Abura-Asebu-Kwamankese district, 25 processors from the Komenda-Edina-Eguafo-Abirem district, and 45 processors from the Ekumfi district. For the marketers, the sample frame included 55 marketers from the Abura-Asebu-Kwamankese district, 152 marketers from the Komenda-Edina-Eguafo-Abirem district, and 93 marketers from the Ekumfi district.

The study's sample size was determined using the sample size determination technique outlined in paper [35], based on the sample frames provided. This resulted in the inclusion of 320 smallholder pineapple farmers, 66 pineapple processors, and 169 pineapple marketers. To account for potential non-responses and errors during data collection, Elliott et al. [36] and Boakye et al. [37] recommended increasing the sample size by an additional 10%.

Prior to data collection, ethical clearance was secured from the Institutional Review Board (IRB) of the University of Cape Coast and the Department of Agriculture in the selected districts. Participants were informed both verbally and in writing that their participation was entirely voluntary and that they could withdraw from the study at any time before or during the interview. Verbal consent was emphasized to accommodate participants who were unable to read or write. This approach received approval from the University of Cape Coast IRB, the Department of Agricultural Economics and Extension at the University of Cape Coast, and the Department of Agriculture in the selected districts.

3.2. Clarification of Cluster Analysis and Determination of the Number of Clusters

The cluster analysis was conducted to classify farmers, processors, and marketers based on their sustainability index scores, allowing for the identification of distinct groups with similar sustainability characteristics. The K-means clustering method was used due to its efficiency in segmenting observations based on numerical sustainability index values. We plotted the within-cluster sum of squares (WCSS) against the number of clusters, identifying the point where adding more clusters yielded diminishing improvements. This helped assess the cohesion within clusters and separation between clusters, ensuring that the chosen number of clusters maximized interpretability and statistical validity. The clusters were chosen based on distinct sustainability patterns among the actors, ensuring that each cluster represented meaningful differences in sustainability practices.

3.3. Practical Implications of Clustering

Clustering the farmers will help policymakers design targeted interventions for groups with lower sustainability scores, such as providing training or financial support. For processors, distinguishing between sustainability levels allows for the development of customized business support programs to enhance resource efficiency and compliance with international standards. Finally, identifying marketers using clusters helped in formulating strategies to improve supply chain sustainability and reduce market inefficiencies.

3.4. Measurement of Variables

The dependent variable, sustainability, is measured using a sustainability index that ranges from 0 to 1, where higher values indicate higher levels of sustainability. This index is constructed based on key sustainability indicators related to economic, environmental, and social dimensions. The classification of sustainability levels (very low, low, high, and very high) is adapted from prior studies and detailed in Appendices (A–C). For the independent variables, we have clarified the unit of measurement for each factor:

- Age (measured in years)
- Household size (number of individuals)
- Farm size (measured in acres)
- Number of pineapple farms (count of separate farm plots)
- Education level (categorical: No education, Primary, JHS, SHS/Technical/Vocational, Tertiary)
- Marital status (categorical: Single, Married, Divorced, Widowed)
- Number of workers (for processors) (count of employees)
- Source of pineapples (for marketers) (categorical: own production, other producers, intermediaries)

3.5. Model Selection

For a continuous dependent variable that ranges from 0–1, several models can be applied but the most common ones are the OLS with transformation, Generalized Additive Models (GAMs), Betta regression, fractional logit, or probit. Although all the models listed above are good, the fractional logit model fits best as far as the distribution of the data is concerned [38]. Thus, the other models, although advantageous, the fractional logit model provides the best results for the data. Aside from this, the fractional logit model ensures any predictions from the model stay within the [0,1] range, making it more advantageous. Thus, the model provides a robust and interpretable framework for modeling continuous dependent variables within the [0,1] range [38].

3.6. Specification of the Fractional Logit Model

The fractional logit model is another approach to modeling dependent variables with proportions or probabilities bounded between 0 and 1 [38]. Unlike the fractional probit model which uses the probit link function, the fractional logit model uses the logit link function [39]. The fractional logit model is specified in **Table 1** as follows:

Table 1. Summary of key equations in the methodology section.

Equation No.	Formula	Description
1.	Y_i	The dependent variable y_i is a continuous variable that lies within the interval [0,1]
2.	X_i	Is a vector of independent or control variables: $X_i = (X_{i1}, X_{i2}, \dots, X_{ik})$
3.	$logit(y_i) = \log\left(\frac{y_i}{1-y_i}\right)$	The logit link function which is used to transform the dependent variable into the linear predictor
4.	$logit(y_i) = \beta_0 + \beta_1 X_{i1} + \beta_2 X_{i2} + \cdots + \beta_k X_{ik}$	The linear function for the fractional logit model
5.	$L(\beta) = \pi_{i=1}^{n}\left[\frac{e^{\beta_0+\sum_{j=1}^{k}\beta_j X_{ij}}}{1+e^{\beta_0+\sum_{j=1}^{k}\beta_j X_{ij}}}\right]^{y_i}\left[1 - \frac{e^{\beta_0+\sum_{j=1}^{k}\beta_j X_{ij}}}{1+e^{\beta_0+\sum_{j=1}^{k}\beta_j X_{ij}}}\right]^{1-y_i}$	Maximum Likelihood Estimation (MLE) function for parameter estimation according to Misango et al. [39].

3.7. Empirical Model

Applying the theoretical model to the dataset for the smallholder pineapple farmers gives us the following equation: thus,

$$logit(y_i) = \beta_0 + \beta_1 Age + \beta_2 Marital\ Status + \beta_3 Education + \beta_4 Other\ Occupation + \beta_5 Farming\ years + \beta_6 Household\ size + \beta_7 Acres\ of\ pineapple\ farm + \beta_8 Number\ of\ Pineapple\ farms + \varepsilon_i \quad (6)$$

where y_i: is the log transformation of the dependent variable (Sustainability index of the ith farmer).

By fitting the model to the processor data, we have:

$$logit(y_i) = \beta_0 + \beta_1 Age + \beta_2 Marital\ Status + \beta_3 Education + \beta_4 Years\ of\ Processing + \beta_5 Business\ Ownership + \beta_6 Number\ of\ Workers + \varepsilon_i \quad (7)$$

where y_i: is the log transformation of the dependent variable (Sustainability index of the i[th] processor).

Finally, the empirical model for the marketers is specified as follows:

$$logit(y_i) = \beta_0 + \beta_1 Age + \beta_2 Education + \beta_3 Household\ Size + \beta_4 Pineapple\ Source + \varepsilon_i \quad (8)$$

4. Results

Sustainability of the Activities by the Major Actors Along the Pineapple Value Chain (*Classification of the Actors Based on Their Sustainability Practices)*

The study began by assessing the level of sustainability in the participants' operations, with sustainability measured on a scale from 0 to 1. Similarly, sustainability practices among the actors were evaluated within the same range. The farmers had an average sustainability index of 0.62, ranging from 0.12 to 1. Processors demonstrated a higher average sustainability index of 0.82, with a range of 0.46 to 1, while marketers averaged 0.69, ranging from 0.13 to 0.93. To evaluate sustainability, the study adopted and modified the sustainability scale from Dadzie et al. [40] (see **Appendices A–C**) as a benchmark for comparing groups or clusters. The scale was divided into four equal intervals: very low sustainability (0–0.25), low sustainability (0.26–0.50), high sustainability (0.51–0.75), and very high sustainability (0.76–1.0). The sustainability index scale was further used as a baseline to classify farming activities as low, very low, high, or very highly sustainable.

Classification of Farmers Based on the Computed Sustainability Index Scores

Cluster analysis was employed to categorize farm households' agricultural activities based on their sustainability index scores. The results of the analysis are presented in **Table 2**. Using the sustainability index scores, the farmers were grouped into three clusters: Cluster 1, Cluster 2, and Cluster 3, with mean scores of 0.86, 0.60, and 0.41, respectively. The distance between the cluster centers was calculated to be 0.412.

Table 2. Classification of farmers based on their sustainability index scores.

Clusters	Frequency	Percent	$\bar{X}$
Cluster 1	81	24.8	0.86
Cluster 2	178	54.4	0.60
Cluster 3	68	20.8	0.41
ANOVA			
Df	324		
F	872.67		
P-value	0.000		

Source: Field survey, Boakye (2019).

Additionally, the ANOVA results from the cluster analysis were statistically significant, with an F-value of 872.67 and p = 0.000. This indicates that the mean for one cluster (Cluster 1) is statistically different from the means of the other clusters (Clusters 2 and 3). The cluster groupings revealed that farm households within each cluster share similar characteristics regarding sustainable agricultural practices.

Additionally, most farmers (54.4%) were grouped in Cluster 2, while 24.8% were in Cluster 1, and 20.8% were placed in Cluster 3. Based on the sustainability scale benchmark, the cluster mean of 0.41 for Cluster 3 indicates that the agricultural practices of its members were classified as lowly sustainable. The mean of 0.60 for Cluster 2 suggests that their practices were highly sustainable, while the mean of 0.86 for Cluster 1 reflects that the agricultural activities of farm households in this cluster were very highly sustainable.

Classification of Pineapple Processors Based on the Computed Sustainability Index Scores

The cluster analysis for pineapple processors was conducted using their sustainability index scores is presented in **Table 3.** The processors were divided into two main clusters: Cluster 1 and Cluster 2, with mean scores of 0.87 and 0.61, respectively. These groupings indicate that processors within the same cluster exhibit similar characteristics regarding their sustainable practices. The analysis also revealed that the distance between the final cluster centers was 0.358. Furthermore, the ANOVA results showed a statistically significant difference between the clusters, with F = 130.77 and p = 0.000, indicating that the mean of Cluster 1 is statistically distinct from that of Cluster 2.

Table 3. Classification of processors based on their sustainability index scores.

Clusters	Frequency	Percent	$\bar{X}$
Cluster 1	56	82.4	0.87
Cluster 2	12	17.6	0.61
ANOVA			
Df	66		
F	130.77		
P-value	0.000		

Source: Field survey, Boakye (2019).

Additionally, most processors (82.4%) were grouped in Cluster 1, while 17.6% were in Cluster 2. Based on the sustainability scale benchmark, the mean score of 0.61 for Cluster 2 suggests that the practices of processors in this group were highly sustainable. Meanwhile, the mean score of 0.87 for Cluster 1 indicates that the practices of processors in this cluster were very highly sustainable.

Classification of Pineapple Marketers Based on the **Computed Sustainability Index Scores**

Table 4 presents cluster analysis for marketers was conducted using their sustainability index scores. The marketers were categorized into two main clusters: Cluster 1 and Cluster 2, with mean scores of 0.74 and 0.38, respectively. These clusters indicate that marketers within the same group share similar characteristics in terms of sustainable practices. Most marketers (86.9%) were grouped in Cluster 1, while 13.1% were in Cluster 2.

Table 4. Classification of marketers based on their sustainability index scores.

Clusters	Frequency	Percent	$\bar{X}$
Cluster 1	152	86.9	0.74
Cluster 2	23	13.1	0.38
ANOVA			
Df	173		
F	241.83		
P-value	0.000		

Source: Field survey, Boakye (2019).

Based on the sustainability scale benchmark, the mean score of 0.38 for Cluster 2 indicates that the activities of marketers in this group were classified as lowly sustainable. Conversely, the mean score of 0.74 for Cluster 1 reflects that the practices of marketers in this cluster were highly sustainable. Further analysis revealed that the minimum distance between the final cluster centers was 0.80. The ANOVA results showed a statistically significant difference between the clusters, with F = 241.83 and p = 0.000, confirming that the mean of Cluster 1 is statistically distinct from that of Cluster 2.

The sustainability index scores indicate that the activities of pineapple farmers, marketers, and processors are largely sustainable, with mean scores of 0.62 for farmers, 0.69 for marketers, and 0.82 for processors. These findings suggest that while all actors demonstrate a high degree of sustainability, processors exhibit the highest sustainability levels, likely due to better resource utilization, compliance with standards, and efficiency in processing techniques.

The result is in line with the findings in a research conducted by Gamboa et al. [41] and Dadzie et al. [40] concluded that the activities of farm households were moderately sustainable, indicating some level of adherence to sustainable agricultural practices, though with room for improvement. Their findings highlight a balance between economic viability, environmental conservation, and social responsibility within the agricultural practices of these households, though not at an optimal level.

Additionally, the study by Akaba [30], which focused on climate change responses, food security, and the production sustainability of maize farmers in Ghana's Volta Region, revealed that farmers exhibit positive attitudes toward sustainable agriculture. This positive outlook suggests a willingness among farmers to adopt practices that mitigate climate change impacts while enhancing productivity and food security. The study emphasized that these attitudes are essential for transitioning to more sustainable farming systems, especially in regions vulnerable to climate change. Together, these studies underline the importance of fostering sustainable practices among farmers to ensure long-term agricultural productivity and resilience.

Table 5 presents results from the fractional logit model examining the determinants of sustainability among pineapple farmers, with sustainability index as the dependent variable. From the results, age has a negative and statistically significant effect on sustainability index with a coefficient of -0.0159 and $p < 0.01$. This shows that older farmers are associated with lower sustainability levels. Thus, older farmers are less likely to adopt new sustainable agricultural practices or technologies. The results further revealed that a farmer being married or divorced has a significant positive effect on sustainability whereas being widowed has no considerable impact. The positive effect for a farmer being married or divorced could be due to the farmer having a more support system or resources related to a single farmer.

Table 5. Fractional logit model of the determinants of sustainability among pineapple farmers.

Variables	Sustainability index
Age (Years)	−0.0159*** (0.00319)
Marital Status (ref - Single)	
Married	0.275** (0.118)
Divorced	0.483** (0.215)
Widowed	−0.0718 (0.142)
Type of Education (ref – No Education)	
Primary	0.0381 (0.111)
JHS/Middle School	−0.180 (0.176)
SHS/Technical/Vocational	−0.830*** (0.102)
Tertiary	−0.233* (0.139)
Other Occupation (ref - Only farming)	
Civil Servant	0.582*** (0.0619)
Private business	0.116 (0.1000)
Farming experience	0.00679** (0.00333)
Household size	0.0128*** (0.00454)
Size of pineapple farmland (Acres)	0.0547*** (0.00677)
Number of Pineapple farms	−0.250*** (0.0352)
Constant	0.790*** (0.203)
Observations	327
Pseudo R^2	0.208

Source: Field survey, Boakye (2019); Robust standard errors in parentheses.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Further, primary education has a positive but not significant effect on sustainability. Junior High School or Middle School education on the other hand has a negative but not significant effect on sustainability. Secondary, technical, or vocational education has a strong negative effect on the sustainability index of the farmer and thus decreases it by 0.830 units. Similarly, tertiary education showed a significant negative effect on the sustainability index with a coefficient of 0.233 and a $p < 0.1$ and thus reduces the sustainability index by 0.233 units.

It is revealed that some farmers have other occupations other than farming and thus, a farmer who doubles as a civil servant positively and significantly influences sustainability. Thus, being a civil servant has a sustainability index which is 0.582 units higher. Owning a private business on the other hand does not affect the sustainability of the farmer.

The results further revealed that the farming experience positively impacts the sustainability of the farmer which suggests that experienced farmers are more likely to have better knowledge or practices that enhance sustainability. Similarly, farmers with larger household sizes have higher sustainability levels because there is more available family labor or decision-making processes.

Additionally, the findings show that the size of pineapple farmland positively influences the sustainability of the farmer. This may be because farmers with larger farmlands enjoy economies of scale or may have greater access to resources. Also, the number of pineapple farms has a significant negative (coef. = -0.250, $p < 0.01$) effect on sustainability. Thus, a unit change in the number of farms a farmer has changes the sustainability index by 0.250 in the opposite direction. The negative effect of the number of farms is due to the divided attention of the farmer and resources.

From the findings, it can be concluded that some demographic, socioeconomic, and farming-related factors significantly influence sustainability among pineapple farmers in Ghana.

Table 6 presents results from the fractional logit model looking at the determinants of sustainability among pineapple processors in Ghana. The sustainability index of pineapple processors is used as a dependent variable with some socioeconomic and business-related factors and independent variables. The results revealed that the age of pineapple processors significantly positively affects the sustainability index. This shows that older processors are more likely to adopt more sustainable practices, due to accumulated experience and knowledge over the years. The finding aligns with the concept that experience in an industry can lead to better sustainability practices as older processors may adopt more efficient and environmentally friendly processing techniques.

Table 6. Fractional logit model of the determinants of sustainability among pineapple processors.

Variables	Sustainability index
Age (Years)	0.0417*** (0.0161)
Marital Status (ref – Single)	
Married	−0.831*** (0.241)
Divorced	−0.785** (0.306)
Widowed	−0.726** (0.348)
Type of Education (ref – No education)	
Primary	0.617** (0.252)
JHS/Middle School	0.375 (0.256)
SHS/Technical/Vocational	0.228 (0.279)
Tertiary	15.14*** (0.751)
Business ownership (ref - No)	−1.553*** (0.507)
Number of workers	−0.781*** (0.232)
Constant	2.748*** (0.803)
Observations	68
Pseudo R^2	0.531

Source: Field survey, Boakye (2019); Robust standard errors in parentheses.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

The results further revealed that being married significantly and negatively affects sustainability. Thus, married processors have a lower sustainability index of 0.831 units compared to single processors. This is because married processors face additional responsibilities and financial pressures that limit their ability to invest in sustainable practices. Also, being divorced negatively and significantly impacts sustainability. This may be due to stress and financial constraints associated with being divorced. The results further revealed that being widowed significantly negatively affects sustainability, reducing the sustainability index by 0.726 units.

Also, the results revealed that Junior High School or Middle School and Senior High School, Technical, or vocational school both showed positive but not significant effects. Further, primary education positively and significantly affects sustainability. Thus, processors with primary education have a higher sustainability index, which shows that some basic education can contribute to better sustainability practices by providing foundational knowledge and skills. Additionally, tertiary education was statistically significant with a coefficient of 15.14 and $p < 0.1$ and thus increases the sustainability index by 25.14 units. This points to the critical role of higher education in promoting advanced sustainability practices due to better access to knowledge, resources, and technology.

From the results, it was revealed that not owning a business has a strong negative effect on sustainability. This suggests that business owners are more likely to implement sustainable practices because they have greater control over business decisions and resources to invest in sustainability. Finally, the number of workers in a business has a significant negative impact on sustainability. This implies larger workforces might create management challenges that impede the implementation of sustainable practices.

The findings from this study contribute to the literature on agricultural sustainability by highlighting the importance of socioeconomic factors and education in promoting sustainable practices among processors.

Results from the fractional logit regression model on the determinants of sustainability among pineapple marketers in Ghana is presented in **Table 7**. The dependent variable used in this model is the sustainability index of pineapple marketers and several socioeconomic and operational factors as independent variables. The results show that age has a positive and significant impact on the sustainability index. Specifically, with each additional year in age, the sustainability index increases. This suggests that older marketers are more likely to engage in sustainable practices, which could be attributed to the experience and accumulated knowledge they have gained over time. Thus, older marketers might be aware of the long-term benefits of sustainability, such as maintaining product quality and securing repeat customers, which could contribute to their willingness to adopt more sustainable practices.

Table 7. Fractional logit model of the determinants of sustainability among pineapple marketers.

	(1)
Variables	**Sustainability Index**
Age	0.0176***
	(0.00554)
Type of Education (Ref – no education)	
Primary	−0.296**
	(0.128)
JHS/Middle School	−0.293
	(0.181)
SHS/Technical/Vocational	−0.817**
	(0.343)
Tertiary	−0.204
	(0.142)
Household size	0.00575
	(0.00664)
Source of pineapple (Ref – own production)	
Other producers	1.099*
	(0.627)
Other (eg. Intermediaries, processors, etc.)	1.109*
	(0.640)
Constant	−0.760
	(0.689)
Observations	175
Pseudo R^2	0.169

Source: Field survey, Boakye (2019); Robust standard errors in parentheses.
*** $p< 0.01$, ** $p < 0.05$, * $p < 0.1$.

Further, the results revealed that Junior High School or Middle School and tertiary education do not significantly influence the sustainability of the marketer. Also, primary education has a negative and significant impact on sustainability. This might suggest that individuals with primary education may lack advanced knowledge, or resources to implement sustainability practices effectively. Again, senior high school, technical, or vocational education significantly negatively affects sustainability. This is because, even with more advanced education, marketers may not receive the specific training needed to prioritize and implement sustainable practices due to a focus on technical skills rather than sustainability issues.

From the findings, sourcing pineapple from other producers has a positive impact on sustainability. This is because marketers who rely on other producers may have more stringent requirements for product quality and sustainability, or they may collaborate with producers who prioritize sustainable practices. Similarly, sourcing pineapples from market intermediaries also has a positive effect on sustainability.

5. Discussion

The common determinants for sustainability among the actors along the pineapple value chain in Ghana include but are not limited to socioeconomic, farm, business, and education factors. One possible explanation to the counterintuitive finding regarding is that higher education increases access to non-agricultural employment, leading individuals to shift away from farming and agribusiness. Additionally, formal education in Ghana often lacks practical agricultural training, limiting the adoption of sustainable farming techniques. Educated individuals may also prioritize short-term profitability over long-term sustainability, relying on chemical inputs rather than eco-friendly practices. Furthermore, limited landownership among educated individuals, particularly younger farmers, reduces incentives for investing in sustainability measures such as soil conservation and agroforestry. There is also a potential disconnect between formal education and indigenous agricultural knowledge, where educated actors may favor modern, technology-driven approaches that are not always suitable for smallholder farmers.

Another unexpected result was the counterintuitive effect of age on sustainability among processors and marketers. While younger individuals are often assumed to be more adaptable to innovation, our findings indicate that older processors and marketers exhibit higher sustainability levels. This may be due to accumulated experience, financial stability, and stronger business networks, which allow them to adopt sustainable practices more effectively than younger counterparts who may face financial or knowledge barriers.

Our findings on sustainability determinants in Ghana's pineapple value chain align with research conducted in other Sub-Saharan African countries. An example is a study by Sharifzadeh et al. [31] on the socioeconomic determinants of sustainability in rural areas. The study found that technology usage, farm income, access to agricultural extension and education services, satisfaction with farming jobs, and land fragmentation influence the sustainable practices of farmers in rural areas. In a study by Guo et al. [13], it was revealed that sustainability is determined by age, size of farmland, education, gender, extension services, household size, and access to credit. Similarly, Dung et al. [14] found that farmers' adoption of sustainable practices in Vietnam is determined human capital, farm size, social capital, extension, and access to market.

Globally, our results on the negative impact of higher education on sustainability adoption contrast with findings in European and North American contexts. Studies in the Netherlands [19] and the United States [42] indicate that higher education correlates positively with sustainability adoption, largely due to the integration of sustainable agriculture training in formal education systems. In contrast, our study suggests that in Ghana, higher education does not necessarily translate into better sustainability outcomes, likely due to curriculum gaps and the lure of non-agricultural employment opportunities for highly educated individuals. Another study by Bro et al. [43] found that only cooperative membership significantly influences sustainability. The study revealed that field management practices, soil and plant health practices do not significantly influence sustainability among farmers in Nicaragua.

Setthasakko [12] studied the determinants of corporate sustainability among seafood processors in Thailand and found that government, management, and the local community are the main determinants of sustainability which is contradictory to the results in this study. Similarly, a study by Kiende [15] revealed that tea processing in Kenya is ecologically or environmentally unsustainable. In a different study, it was revealed that sustainability among agro-processors is determined by socioeconomic factors such as age, access to training, education, and household size [32]. Also, the results of a study by Adekunle et al. [33] revealed that sustainability among agro-processors in sub-Sahara Africa is determined by age, gender, household size, and experience. Also, the findings in the study contradict the findings in the study by Hernández-Rubio et al. [34] which revealed that quality control and safety inspection are the key determinants of sustainability among agro-food marketers.

Furthermore, our results on older processors and marketers exhibiting higher sustainability levels are consistent with research in India [44] and Brazil [45], which found that experience and financial stability among older actors enable them to implement long-term sustainability measures. This supports our interpretation that age-related sustainability outcomes may be influenced by experience, accumulated capital, and risk management strategies rather than purely by willingness to adopt new technologies.

6. Limitations of the Study

The study focused on three districts in Ghana's Central Region (Abura-Asebu-Kwamankese, Komenda-Edina-Eguafo-Abirem, and Ekumfi), which may limit the generalizability of the findings to other regions with different agricultural conditions, market structures, or policy environments. Future studies could adopt a broader geographical scope to improve applicability. Also, the sustainability index was constructed based on specific indicators, but the choice and weighting of these indicators can introduce subjectivity. Different approaches to measuring sustainability such as incorporating more qualitative data or multi-criteria decision analysis (MCDA) might provide a more comprehensive assessment.

In a similar dimension, while the fractional logit model is appropriate for analyzing sustainability scores constrained between 0 and 1, it may not fully capture nonlinear relationships between explanatory variables and sustainability outcomes. Alternative models, such as generalized additive models (GAMs) or machine learning approaches, could offer more flexibility in capturing complex interactions.

Finally, the analysis primarily focuses on individual and business-level factors, but external variables such as government policies, climate change effects, and global market fluctuations were not fully integrated into the model. Incorporating macroeconomic and environmental variables in future research could provide a more holistic view of sustainability determinants.

By addressing these limitations, the robustness and applicability of sustainability assessments in agricultural value chains can be significantly enhanced.

7. Conclusions and Policy Implications

The sustainability of Ghana's pineapple value chain is critical for enhancing productivity, improving livelihoods, and ensuring long-term environmental and economic stability. This study examined the factors influencing sustainability among farmers, processors, and marketers within the pineapple sector. By employing the fractional logit model, we identified key socio-economic and business-related determinants affecting sustainability across the value chain. Our findings indicate that farmers' sustainability is influenced by land size, farming experience, marital status, and access to financial and technical resources. Processors' sustainability is significantly shaped by age, level of education, business ownership, and workforce size, while marketers' sustainability is largely dependent on sourcing strategies and education level. These insights underscore the need for tailored interventions to enhance sustainability at different stages of the value chain.

7.1. Policy and Practical Implications

Land and Resource Access: Given that larger farmland size correlates with higher sustainability among farmers, policymakers should prioritize land access programs. This could include implementing community land trusts, encouraging land-sharing agreements, and offering subsidies for land acquisition to smallholder farmers.

Youth Engagement in Agriculture: Sustainability levels among younger farmers and processors tend to be lower due to limited experience and financial constraints. To address this, government and agricultural institutions should develop mentorship programs and financial incentives for young entrepreneurs in the pineapple sector. Training in sustainable farming and processing techniques should be integrated into agricultural education programs.

Education and Skill Development: The study found that formal education significantly influences sustainability, especially among processors. As such, adult education and vocational training programs should incorporate financial literacy, sustainable business management, and technical training tailored to actors in the pineapple sector. This will enhance decision-making and the adoption of sustainable practices.

Strengthening Market Linkages and Infrastructure: Sustainability among marketers is largely influenced by their sources of supply. Ensuring a stable and sustainable pineapple supply chain requires investment in rural infrastructure, improved logistics, and cooperative-based supply networks. The government should facilitate direct partnerships between producers, processors, and exporters to enhance supply chain efficiency.

Financial and Institutional Support: Limited access to capital and financial services restricts sustainability for all actors. Policymakers should work with financial institutions to expand access to low-interest loans, grants, and insurance schemes specifically tailored for smallholder farmers and agribusinesses. Additionally, tax incentives and subsidies should be provided to encourage sustainable agricultural and processing practices.

Environmental Sustainability and Climate Adaptation: To reduce environmental degradation within the pineapple value chain, policies should promote eco-friendly farming techniques, organic certification programs, and climate-smart agriculture. Encouraging waste recycling and energy-efficient processing methods will also improve sustainability among processors.

Gender-Sensitive Policies: Given that marital status influences sustainability, particularly for women in the value chain, policies should promote gender-inclusive agricultural programs that provide equal access to land, credit, and training. This would help bridge socio-economic inequalities affecting sustainability.

7.2. Future Research Directions

While this study provides valuable insights, further research is needed to assess the long-term effects of sustainability policies, explore the role of technology and innovation in sustainability, and examine sustainability dynamics in other high-value agricultural value chains in Ghana. Future studies could also conduct comparative analyses with other Sub-Saharan African countries to identify best practices for improving sustainability in agricultural value chains. By implementing these recommendations, Ghana's pineapple sector can achieve greater resilience, productivity, and sustainability, ultimately contributing to national food security, rural employment, and economic growth.

Author Contributions

Conceptualization: K.B., S.A. and S.M.; Literature review: H.D., S.K.A. and K.B.; Methodology: K.B. and S.M.; Formal analysis: K.B., S.A., S.M., and H.D.; Resources: K.B. and H.D.; writing – original draft preparation: K.B., S.A., H.D., S.K.A. and S.M.; writing, review, and editing: K.B., S.A., H.D., S.K.A. and S.M.

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Institutional Review Board Statement

Not Applicable.

Informed Consent Statement

Not Applicable.

Data Availability Statement

Data for the study will be available on request.

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Conflicts of Interest

The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results

Ethical Approval and Consent to Participate

The consent of all individuals included in the study was obtained before their inclusion.

Consent for Publication

The authors' consent to the publication was sought.

Appendix A

Sustainability Index Scale for Pineapple Farmers

Classification of Farmers based on the Sustainability Practices in the Farming Business

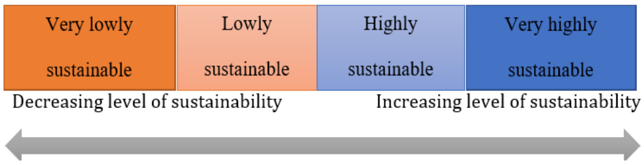

Figure A1. Interpretation of sustainability scale for farmers (0 – to – 1). Adapted from Dadzie et al., (2021).

Appendix B

Sustainability Index Scale for Pineapple Processors

Classification of Processors based on the Sustainability Practices in the Pineapple Processing Business

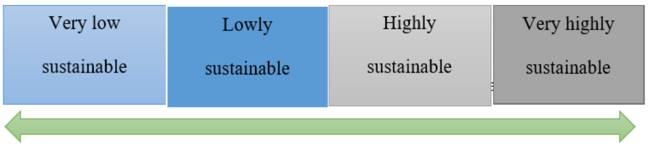

Figure A2. Interpretation of sustainability scale for processors (0 – to – 1). Adapted from Dadzie et al., (2021).

Appendix C

Sustainability Index Scale for Pineapple Marketers

Classification of Marketers Based on the Sustainability Practices in the Pineapple Marketing Business

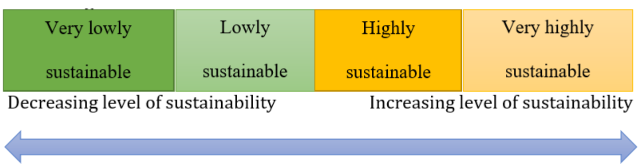

Figure A3. Interpretation of sustainability scale for marketers (0 – to – 1). Adapted from Dadzie et al., (2021).

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