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Assessing Factors Influencing Cassava Yield in Salayea, Liberia: A Study Using the Analytical Hierarchy Process

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Abstract

This study examines the factors influencing cassava yield among farmers in Salayea, Lofa County, Liberia. As cassava is a vital staple in Liberia, providing food security and economic benefits, understanding the decline in its productivity is paramount. This research employs the Analytical Hierarchy Process (AHP) to assess three main themes: Climate and Temporal Factors, Production and Yield Factors, and Financial and Economic Factors. Data were collected from 60 cassava farmers through surveys, which were then analyzed to determine the relative importance of various sub-factors within these themes. The findings revealed that Financial and Economic Factors, particularly access to loans and low soil fertility, had the most significant impact on cassava yields. In contrast, Climate and Temporal Factors, such as rising temperatures, increased soil acidity, late planting, as well as production and yield factors, including damage caused by livestock and Improper spacing, were ranked lowest overall. This research provides policymakers, development organizations, and agricultural institutions with valuable insights to enhance cassava productivity.

Keywords: cassava yield; agricultural productivity; Salayea; Liberia; AHP; Sustainability

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Introduction

Cassava (Manihot esculenta) is a vital staple in Liberia, playing a crucial role in the country's food security and economy. Known for its drought resistance and ability to grow in various agroecological zones, cassava is a resilient crop widely cultivated by farmers in Liberia. It serves as a primary source of carbohydrates, providing sustenance to a significant portion of the population. Cassava also contributes to rural households' livelihoods, forming an essential part of the agricultural economy (Awoyale et al., 2020). Given its adaptability and importance, cassava has become a vital asset for many Liberian communities.

The crop has deep historical roots in Liberia, having been introduced from other parts of Africa and steadily becoming a staple in local diets. Its versatility enables it to be processed into products such as fufu and gari, both integral to Liberian culinary traditions (Awoyale et al., 2020). Besides being a key component of daily meals, cassava products hold economic value, with potential for trade across regional markets, contributing to both food security and economic development.

However, cassava production in Liberia faces several significant challenges, mainly due to pest and disease pressures. Diseases such as cassava mosaic disease (CMD) and cassava brown streak disease (CBSD) pose tremendous threats to cassava yields, resulting in considerable losses (Ano et al., 2021; Torkpo, 2024; Yadav et al., 2011). These problems are compounded by the resurgence of pests and multiple viruses, which necessitate the adoption of integrated pest management strategies and disease-resistant cassava varieties (Bisimwa et al., 2019). Current research into genetically modified cassava varieties that are more resistant to these diseases aims to mitigate yield losses and strengthen Liberia's food security (Adenle et al., 2012; Yadav et al., 2011).

In light of these challenges, this study seeks to investigate the underlying causes of the observed decline in cassava yields in Salayea District. The research specifically aims to identify the major biotic and abiotic factors, such as diseases, pests, soil conditions, and climatic influences, that may be driving yield reductions. It also examines the role of agronomic practices, particularly those related to pest and disease control, and how variations in farming methods influence overall productivity. Furthermore, the study examines the extent to which socio-economic variables, including farmers' access to improved inputs, extension services, and market infrastructure, impact cassava production.

Guiding this investigation are several key hypotheses. It is assumed that the prevalence of CMD, CBSD, and other pest infestations is significantly associated with the yield decline observed in Salayea. Additionally, the study hypothesizes that farmers who adopt improved cassava varieties and integrated pest management strategies experience higher productivity than those who rely on traditional practices. Another assumption is that limited access to inputs, advisory support, and marketing channels is a significant constraint on cassava productivity. It is also hypothesized that adopting disease-resistant varieties and modern agronomic practices can lead to measurable yield improvements.

To support this analysis, the paper is structured into five main chapters. The first chapter introduces the study, providing background information, stating the research objectives, and presenting the questions and hypotheses that drive the investigation. Chapter Two reviews the existing literature on cassava production. Chapter Three details the methodological approach, including the study area, data collection methods, and analytical tools. Chapter Four presents and discusses the results. Finally, Chapter Five concludes the study and proposes actionable recommendations to improve cassava productivity and support food security in Salayea and similar agroecological zones in Liberia.

Literature Review

Cassava is an essential staple crop in many tropical regions, including Africa, Asia, and Latin America. Its significance lies in its role as a primary food source for millions and in its potential for economic development in rural areas. However, the efficiency of cassava farming remains a critical concern, particularly in the context of resource allocation and productivity (Burns et al., 2010; Mohidin et al., 2023; Plucknett et al., 1998).

The selection of suitable sites and soil types plays a significant role in the efficiency of cassava yield. Although cassava is considered undemanding and adaptable to a variety of soils (Burns et al., 2010; Martin & Ejike, 2018), specific soil properties enhance productivity. Ideal soils for cassava are characterized by dense vegetation, rich in decomposing organic matter, and light, well-drained textures. While sandy and clay soils are less suitable, soils rich in organic matter, such as plant and animal remains, provide the nutrients needed for growth (Munyahali et al., 2023; Pypers et al., 2011). These residues enhance topsoil fertility, thereby increasing yields (Diacono & Montemurro, 2011).

The preparation of the soil and the timing of planting also affect yield. Farmers plant cassava either just before or immediately after the first rain, with recommended planting densities ranging from 6,000 to 10,000 plants per hectare. For intercropping, which improves soil quality and agricultural profitability, cassava is often paired with legumes such as cowpeas, beans, and peanuts, or with crops such as maize and plantain. Legumes are particularly valuable as they enrich the soil with nutrients. The proper placement of cuttings, whether horizontally, diagonally, or vertically, also affects the harvest (Chintu et al., 2004; Crews & Peoples, 2004; Kebede, 2021). Healthy cassava cuttings are essential for optimal production. Cuttings are typically 20-30 cm in length, taken from mature, disease-free stems, and planted shortly after harvest (Sungthongw et al., 2016). Proper storage in cool, well-ventilated areas ensures the viability of the cuttings (de Oliveira et al., 2020; Krakowska-Sieprawska et al., 2022).

Fertilization practices vary depending on the field's previous usage. According to the FAO (1981) and Kiba et al. (2012), new or long-fallow land may not require fertilizer, whereas intensively cultivated land benefits from the application of mineral fertilizers, such as NPK, dolomite lime, and urea, to replenish depleted nutrients. For tuber production, organic fertilizers, including chicken litter or manure, are preferable (Diacono & Montemurro, 2010). Maintaining soil fertility through these practices can yield up to 30 tonnes per hectare (Munyahali et al., 2023; Pypers et al., 2011).

Weed control and pest management are also crucial for maximizing cassava yields. Manual weeding at specific intervals, 3 to 4 weeks after planting, followed by another weeding 1 to 2 months later, helps prevent nutrient competition. Moreover, proper husbandry practices, such as clean field maintenance, reduce the risk of pests and diseases (Kiba et al., 2012; Weerarathne et al., 2017). Termites, cassava mealybugs, and whiteflies pose significant threats to cassava by damaging tubers, stems, and leaves (Chikoti et al., 2019). Whiteflies, for example, transmit the African cassava mosaic virus, which stunts plant growth and reduces productivity. Cassava is also susceptible to diseases such as anthracnose and bacterial blight, which hinder growth and reduce yields. Anthracnose, caused by Colletotrichum gloeosporioides, leads to stem cankers and leaf necrosis, while bacterial blight (Xanthomonas axonopodis pv manihotis) causes foliage burn and wilting (Kalyebi et al., 2018). Both diseases can reduce harvests if not adequately managed.

In West Africa, land tenure systems further complicate cassava farming. Traditionally, land ownership is communal, with individual farmers gaining access through their membership in the community (Daudu et al., 2022). This system can limit large-scale farming efforts due to restrictions on land use and ownership. While national governments have attempted to shift toward private ownership to promote agricultural and industrial growth, communal land ownership remains prevalent (Gao et al., 2022; Gyapong, 2020; Jayne et al., 2014). This ongoing struggle between traditional and modern land tenure systems presents challenges to expanding cassava production in the region.

Fuzzy Logic and Analytical Hierarchy Process

Multi-criteria decision-making (MCDM) involves making decisions based on criteria or goals in a hierarchical manner. They are generally based on some criterion or sub-criterion that impacts decision-making. In an MCDM context, AHP converts psychological judgments into mathematical reasoning by assigning relative priorities through hierarchical structures. It creates a quantitative framework based on pairwise comparisons to lead the criteria and options toward the desired aim. The relative importance or weight of each criterion is assessed and scored for comparison (Lin et al., 2020; Navarro et al., 2020).

The Analytical Hierarchy Process (AHP) is a powerful MCDM technique with widespread acceptance and application across many research domains due to its methodological simplicity and flexibility in collecting input data in a hierarchical structure (Kaya et al., 2019). The AHP method, on the other hand, cannot account for the uncertainty in the preference ratings used to score the criterion. Fuzzy logic, developed by Zadeh (1965), is paired with AHP to form a fuzzy AHP. Combining fuzzy logic with AHP addresses the complexity of imprecision by enabling decision-makers to express their opinions using a range of values on a fuzzy scale, rather than the AHP scale. This integrated technique maintains the advantages of AHP and has been extensively used (Mardani et al., 2015).

A detailed review of Fuzzy logic and AHP, along with some of their applications, can be found in Baumann et al. (2019), Guersola et al. (2018), Kramar & Topolšek (2018), Sitorus et al. (2019), and Yap et al. (2019).

Analytical Hierarchy Process

The Analytical Hierarchy Process (AHP), developed by Professor Thomas L. Saaty in the 1970s, is an MCDM tool (Patil & Kumthekar, 2016). Hierarchical decision-making criteria or objectives characterize MCDM problems, enabling the identification of an ultimate goal. They are typically based on specific criteria or sub-criteria that influence the decision-making process to varying degrees of importance. Many MCDM problems are psychological, and selecting multiple criteria without carefully vetting the alternatives is detrimental to project management. Applying an AHP approach to an MCDM problem transforms psychological attributes into mathematical reasoning by using relative importance within hierarchical structures (Lin et al., 2020). It employs pairwise comparisons to develop a quantitative framework that informs the criteria and alternatives for achieving the required objective. The relative importance or weight of each criterion is evaluated and scored for comparison across levels.

The mathematical nature, methodological convenience, and flexibility in hierarchical input data collection make AHP a versatile MCDM tool with widespread adoption across various research fields (Kaya et al., 2019), including the agricultural industry. Their model enabled decision-makers to select subcontractors, providing companies with the benefits of quality products and on-time delivery.

Several studies have applied fuzzy logic and AHP to cassava farming to enhance decision-making. Fuzzy logic has been used to manage uncertainties in soil conditions, weather patterns, and pest management, providing farmers with flexible guidelines for optimizing yields [see Rafiuzzaman & Cil (2016); Roussel et al. (2000); Sharma et al. (2923). AHP has complemented these models by allowing the prioritization of various factors such as soil type, planting time, and crop variety. For instance, Okafor and Chikalipah (2021) combined fuzzy logic and AHP to develop a decision-support system that helps cassava farmers select the most appropriate planting strategies based on multiple criteria, including climate conditions and soil fertility. These integrated approaches have proven effective in improving the accuracy and efficiency of decision-making in cassava farming.

Thus, in this study, fuzzy logic and AHP are also utilized to assess factors affecting yield among cassava farmers in Salayea. By applying fuzzy logic, uncertainties and variability in key farming conditions, such as soil quality, rainfall patterns, and pest presence, were managed. As in previous studies, AHP is used here to prioritize these factors, enabling a structured comparison of their relative importance in influencing cassava yield.

Methodology

Location

Participants and data for this study were collected in Salayea, located in Lofa, Liberia. Liberia is transitioning from a post-conflict society to a developing nation with long-term economic objectives and rising investments in infrastructure and the utilization of natural resources. The country is recovering from the effects of a 14-year civil war. There are indications that the agricultural, energy, mining, information and communications technology, and transportation industries are expanding due to progressive investment and political activity supporting long-term objectives. Although the civil war severely impacted the agricultural sector, it is now recovering rapidly and offers tremendous growth potential.

More than 60% of Liberia's population relies on agriculture and related industries as their primary source of income. Additionally, agriculture accounted for more than 31% of Liberia's real gross domestic product (GDP) in 2021. It is a source of income for many families who produce cassava, rubber, rice, oil palm, cocoa, or sugarcane. Rice and cassava are the most essential primary food crops in this country; more families cultivate cassava than any other crop. However, the vast majority of farms are smaller, and agricultural production is poor, mainly due to low-technology practices and a lack of quality farm inputs. Consequently, Liberia imports more than 80% of its basic food, including rice, making the nation vulnerable to fluctuations in food prices. The agricultural industry is poorly integrated and lacks basic infrastructure, including machinery, farm-to-market roads, fertilizers, pesticides, and food storage capacity.

Data Collection

A structured questionnaire incorporating the AHP pairwise comparison mechanism was developed to guide data collection. The questionnaire was initially pilot-tested with a small group of local cassava farmers to evaluate its clarity, relevance, and usability. Feedback from the pilot phase informed necessary modifications before the full rollout.

The target population for this study comprised cassava farmers in Salayea District, Lofa County, Liberia, specifically individuals actively cultivating cassava for subsistence or commercial purposes. For this study, cassava farmers are defined as adults who are directly engaged in cassava production and involved in decision-making regarding farm management. Although the exact number of cassava farmers in the district is not officially documented, local agricultural officers and community leaders confirmed that cassava cultivation is widespread across all communities.

Given the absence of a complete farmer registry, a purposive sampling approach was adopted. Participants were selected in consultation with local agricultural agents and community representatives to ensure representation across villages, age groups, and farm sizes. A total of 60 cassava farmers were selected and invited to participate in the study. All invited participants completed and returned the questionnaire, resulting in a 100% response rate.

The questionnaire collected data on demographic characteristics, yield-related challenges, pest and disease pressures, processing capacity, and value-added cassava activities. Based on recorded administration times, the average time to complete the questionnaire was 6 minutes. However, surveying more than 60 farmers in the study area proved difficult due to several practical constraints. Many cassava farmers are dispersed across remote and hard-to-reach villages, making access challenging due to limited transportation and poor road conditions. Additionally, many potential participants declined to participate, expressing frustration that similar surveys had previously raised their hopes for government support that never materialized. This study also did not receive external funding, limiting its ability to engage more enumerators or reach a broader pool of respondents, thereby further restricting the sample size.

Data were entered and cleaned using Microsoft Excel 2016. The dataset was then exported to SPSS version 26 for analysis. Descriptive statistics were used to summarize key variables, and cross-tabulation was employed to explore relationships between selected variables. Reliability analysis using Cronbach's Alpha yielded an α of 0.885, indicating strong internal consistency.

The Analytical Hierarchy Process Model

Hierarchical decision-making criteria or goals characterize MCDM challenges and are based on criteria or sub-criteria that substantially influence the decision-making process. AHP ensures that psychological attributes are transformed into relative importance judgments using hierarchical structures when applied to MCDM problems (Lin et al., 2019). It does this by using pairwise comparisons to generate criteria and alternatives that guide the evaluation of the required objective. Therefore, to provide a fair comparison, the relative significance or weight assigned to each criterion is evaluated and scored at each level.

With these advantages, AHP is employed in this research to quantitatively assess the relative importance of several variables affecting cassava farmers in Salayea, Liberia. As explained in the literature section, all influencing factors and the sub-factors for this study were sourced from existing studies and presented in Table 1. Pairwise comparisons were made between the individual levels of the hierarchy. These comparisons were then fed into the AHP model developed in Microsoft Excel using the questionnaire.

Table 1
The factors affecting yield among cassava farmers in Salayea

Factors	Name	Sub-factors	Details
Climate & Temporal Factors (CTF)	CTF1	Climate change	Climate extremes and natural climatic variations have a statistical impact on cassava yields. As temperatures rise, certain cassava types become more productive. Unfortunately, the crop is vulnerable to various diseases, such as cassava mosaic disease and brown streak disease, which are hastened by climate change.
	CTF 2	Inadequate rainfall	There are very few drought-tolerant cassava varieties for farmers to cultivate. However, farmers will likely experience yield losses if these varieties are unavailable, as the increased capital required to procure them is likely beyond their means. As a result, inadequate rainfall becomes a problem for farmers cultivating non-drought-resistant varieties.
	CTF3	Rise in temperatures	Cassava grows best in areas with a mean temperature of 25-29°C and a soil temperature of about 30°C; below 10°C, the plant stops growing. Therefore, if there is any rise in the temperature at the time the cassava is in the field, this will undoubtedly reduce the yields and productivity of the cultivated cassava.
	CTF4	Increased soil acidity	High soil acidity reduced plant height and root yields in most cassava cultivars. Farmers should plant cassava in soils with lower soil acidity. However, failing to do this results in reduced yields.
	CTF5	Late planting	Early planting produces greater marketable yields. Cassava can be profitably grown from March to October in the area studied. If larger roots are preferred, early planting is recommended. However, if a farmer fails to plant on time, this reduces cassava yield and productivity.
Production & Yielding Factors (PYF)	PYF1	Low soil fertility	Crop yields are significantly reduced by low soil fertility. An inadequate supply of nutrients causes yield reduction in growing plants. In addition to limiting yields, low soil fertility also affects the nutritional composition of crops, thereby altering their nutritional quality. Low soil fertility also reduces yields of hardy crops such as cassava (Manihot esculenta). The cyanogenic glucoside content of cassava is also negatively affected by low soil fertility.
	PYF2	Poor site selection	Cassava cultivation begins with selecting a suitable site. The selection of a good site for cultivation is essential to yields and productivity. Therefore, incorrect site selection can significantly affect cassava yield. Farmers who select an unsuitable site for cassava cultivation are most likely to experience yield reduction.

	PYF3	Improper fertilizer application	Cassava does well when fertilizer is applied in the field. However, inefficient use of chemical fertilizer can significantly reduce yields. Farmers should apply fertilizer to increase yields. Cassava does best with both organic and mineral fertilizers, but how the fertilizer is applied can affect yield, especially with chemical fertilizers.
	PYF4	Improper disease and pest control	The cultivation of cassava is hampered by several Biotic constraints, which can cause yield losses of up to 100% in susceptible cassava varieties. Therefore, the lack of effective disease management and migration strategies can adversely affect cassava yields, resulting in economic losses for farmers. Like other significant crops, cassava is vulnerable to pests and diseases that can cause heavy yield losses. The impact of pests on cassava is severe in Africa. However, improper pest management and control lead to damage, resulting in low yields and high economic losses for cassava farmers.
	PYF5	Poor husbandry practices	Cassava, like other crops, is subject to many diseases and pests in the field. One primary reason diseases attack cassava is poor husbandry practices. Inadequate husbandry practices lead to diseases and pest infestations of cassava, reducing yields and causing economic losses for farmers.
	PYF6	Use of low-yielding varieties	Using low-yielding varieties can lead to significant reductions in cassava yields. Farmers who use low-yielding cassava cultivars will likely experience reduced yields, posing a significant economic challenge.
	PYF7	Damages caused by livestock	Like other crops, cassava is fed to livestock. Animals such as squirrels, groundhogs, goats, and cattle directly affect cassava yields by damaging the crop in the field. The lack of proper management to mitigate the impact of this livestock on field-cultivated cassava may result in reduced yields and economic losses.
	PYF8	Improper spacing	For maximum root production, cassava is usually planted at 10,000 plants/ha in fertile soil and 16,000 plants/ha in infertile soil, where plant growth is less vigorous. However, planting cassava at higher or lower densities can reduce yield. Therefore, farmers should follow proper spacing methods to avoid low yields.
Financial & Economic Factors (FEF)	FEF1	Lack of access to loans	Access to credit is an essential factor in increasing agricultural productivity. Therefore, if cassava farmers lack access to loans or credit to procure inputs and meet farm workers' needs, this can affect cassava yields.
	FEF2	Lack of capital to procure cassava cuttings	Cassava farming requires financing, as with all other crops. The acquisition of land, inputs, and cassava cuttings requires capital. The lack of capital adversely affects cassava yields when farmers lack the funds to

			acquire everything necessary for production. This can affect the yield and productivity of cassava cultivation.
	FEF3	Lack of subsidies and other investment support from the government	The lack of government subsidies can affect cassava yields. If farmers lack government subsidies, yields will decline. Therefore, farmers need government support through subsidies and other investments to continue cassava production and achieve the highest yields.
	FEF4	Increments in the procurement of inputs	The appropriate cost of inputs can effectively increase cassava yields if farmers can acquire agricultural inputs at affordable prices. However, if input costs increase and farmers lack the capital to purchase them, this becomes a problem that reduces cassava yields.
	FEF5	Lack of training infrastructure for farmers	To achieve the best yields and productivity in cassava cultivation, farmers need hands-on training and access to extension officers to understand the importance of cassava production, what to do, and what not to do during cultivation. The lack of training and proper information dissemination leads to reduced yield.

Source: Author's work

The following steps were taken in the AHP analysis.

Step 1: Since the AHP analysis requires only one value per pairwise comparison, the results of each participant's comparisons have been consolidated into a single value. These aggregated pairwise comparisons were generated using the geometric mean method (Krejčí & Stoklasa, 2018; Yadav & Jayswal, 2013) from the judgments of 60 farmers. As seen in Equation (1), the geometric mean is widely used in AHP analysis.

$$\mu_{ij} = \sqrt[n]{a_{ij1} a_{ij2} \dots a_{ijn}} \quad (1)$$

Where:
μ_{ij}= geometry mean row-*i* column-*j*
n =number of experts (participants)

Step 2: From Table 2, the weight of importance with respect to the n^{th} criteria is indicated as w_n. Thus, the relative importance between the i^{th} and j^{th} criteria can be expressed as $a_{ij}=w_i/w_j$ (Lin et al., 2019).

Table 2
Pairwise comparison matrix

	A_1	**A_2**	**A_j**	**A_n**
A_1	w_1/w_1	w_1/w_2	w_1/w_j	w_1/w_n
A_2	w_2/w_1	w_2/w_2	w_2/w_j	w_2/w_n
A_i	w_i/w_1	w_i/w_2	w_i/w_j	w_i/w_n
A_n	w_n/w_1	w_n/w_2	w_n/w_j	w_n/w_n

Source: Author's work

Given the relative importance of each nth factor (criterion), Saaty's scale (Table 3) was used to compare these criteria at the same hierarchical level. If decision criteria have rank values listed in column 1 of Table 3, the rating values are considered; otherwise, the reciprocal values in column 2 of Table 3 are considered. Thus, a pairwise comparison of matrix A (Equation 2) was achieved.

Table 3
Saaty's AHP and fuzzy pairwise comparing scale

AHP Rating	Inverse	Linguistic Scale
1	1	Equally important (EI)
2	1/2	Intermediate value (IV)
3	1/3	Moderately important
4	1/4	Intermediate value (IV)
5	1/5	Strongly more important (SMI)
6	1/6	Intermediate value (IV)
7	1/7	Very strongly important (VSI)
8	1/8	Intermediate value (IV)
9	1/9	Extremely more important (EMI)

Source: Authors' work

$$A = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & a_{ij} & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix} \quad where\ i, j = 1, \dots n \tag{2}$$

Step 3: Using equations 3 and 4, we obtained a normalized pairwise comparison matrix by dividing each element by its column total.

$$X_{ij}^{*} = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}} \ for\ all\ j = 1, 2, \dots, n \tag{3}$$

$$X = \begin{bmatrix} X_{11} & X_{12} & \cdots & X_{1n} \\ X_{21} & X_{22} & \cdots & X_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ X_{n1} & X_{n2} & \cdots & X_{nn} \end{bmatrix} \tag{4}$$

Where
X_{ij}^{*} = the value of the division of the i^{th} row j^{th} column with a total value of j^{th} column; and
$\sum_{i=1}^{n} a_{ij}$= total value of all pairwise comparisons of column *j*.

Step 4: To obtain the weighted matrix, the average of the row elements in the normalized matrix is computed (see equations 5 & 6). In the weighted matrix, the elements represent the relative weights of the different criteria compared to one another. A higher value indicates a greater preference for each criterion.

$$\boldsymbol{W_i = \frac{\sum_{j=1}^{n} X_{ij}}{n} = \begin{bmatrix} W_1 \\ W_2 \\ \vdots \\ \vdots \\ W_n \end{bmatrix} \; for\; all\; i = 1, 2, \dots, n} \quad (5)$$

$$\boldsymbol{W = \begin{bmatrix} W_1 \\ W_2 \\ \vdots \\ \vdots \\ W_n \end{bmatrix}} \quad (6)$$

Step 5: Due to the potential for various inconsistencies in respondents' views, a consistency analysis is performed on all preferences expressed by the participants. The consistency vector was obtained by summing the column elements of the pairwise comparison of the matrix (C) multiplied by the appropriate weight (W_i) (see Equation 7).

$$\boldsymbol{Cv_1 = [C_{1i} + C_{2i} \dots C_{ni}] \times W_i} \quad (7)$$

Where $i = 1,2, \dots n$

Step 6: Summing all elements of the consistency vector (Cv) in equation 8, a principal eigenvalue (λ_{max}) is obtained using equation 9.

$$\boldsymbol{Consistency\; Vector \quad Cv = \begin{bmatrix} Cv_1 \\ Cv_2 \\ \cdot \\ Cv_i \\ \cdot \\ Cv_n \end{bmatrix}} \quad (8)$$

$$\boldsymbol{\lambda_{max} = \sum_{i=1}^{n} Cv_i} \quad (9)$$

Step 7: The Consistency Index (CI) (see equation 10) is used to determine the degree to which respondents' perspectives are consistent with one another. CI, defined as the difference between the lowest eigenvalue and the size of the comparison matrix (n), reflects the variation in respondents' views on consistency. To determine the Random Consistency Index, a comparison is made between the values computed based on the random index formulated by Saaty (Table 4). This index is dependent upon the number of criteria used.

$$\boldsymbol{CI = \frac{\lambda_{max} - n}{n - 1}} \quad (10)$$

Table 4:
Random index values

Matrix	1	2	3	4	5	6	7	8	9	10	11	12
Random index (RI)	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.58

Source: Authors' work

Step 8: Lastly, using equation 11, the consistency ratio between the CI and the RI is calculated.

$$\boldsymbol{CR} = \frac{\boldsymbol{CI}}{\boldsymbol{RI}} \tag{11}$$

To proceed with the AHP analysis, the consistency ratio must be 0.10 or lower. Otherwise, a rerun of the pairwise comparison is required (Saaty, 1988; Sumo et al., 2023).

Results and Discussion

Survey Results

As mentioned in the methodology section, a questionnaire was built with an AHP pairwise comparison mechanism embedded. Cassava farmers in Salayea participated in a survey conducted using a comprehensive questionnaire delivered through a participatory learning approach. A total of 60 questionnaires were distributed to various cassava growers in the region under investigation. To enhance the quality of the research data, respondents were selected as cassava farmers who were willing and available to complete the questionnaire. The survey tally reported 60 participants.

Additionally, the survey results revealed a gender imbalance, with males comprising 45 (75%) and females 15 (25%) (see Table 5). These gender disparities are also evident in other studies, such as those by Amadi et al. (2019) and Teeken et al. (2018). Although the percentage of female participants in this survey is substantially lower than that of male participants (Onyemauwa, 2012), this statistic remains relatively positive. It indicates that progress is being made toward greater female involvement in all aspects of society.

Table 5
Summary of respondents' demographics (n=60)

Variable	Category	Frequency	Percent (%)
Gender	Male	45	**75**
	Female	15	**25**
Marital Status	Single	30	**50**
	Married	20	**33.3**
	Engaged	10	**16.6**
Age	18-25	2	**3.3**
	26-33	5	**8.3**
	34-41	10	**16.6**
	42-50	25	**41.6**
	>50	18	**30**
Education Level	No formal education	15	**25**
	Elementary education	20	**33.3**
	Junior secondary education	15	**25**
	Senior secondary education	10	**16.6**
Employment	Employed	10	**16.6**
	Unemployed	50	**83.3**
Religion	Christianity	50	**83.3**
	Islam	2	**3.3**
	Traditional African Religion	**8**	**13.3**

Source: Author's work

The participants' marital statuses are also presented in Table 5. Participants who reported as single were 30 (50%). Those who were married were 20 (33.3%), while those who were engaged were 10 (16.6%). The age distribution of participants showed that those aged 41-50 (41.6%) have the highest engagement in cassava farming in Salayea. They were followed by those aged 50+ (30%) and those aged 34-41 (16.6%). Those aged 18 to 33 accounted for 11.6% of the total respondents. This figure shows that young people in Salayea are less involved in cassava farming than their older counterparts. These age disparities correspond with other studies on cassava farming in Thailand and Kenya (Mutuku et al., 2013).

The study participants' educational levels also revealed a significant finding. Fifteen respondents, constituting 25% of the total, reported having no formal education. Those with elementary education were 20 (33.3%), junior secondary education respondents were 15 (25%), and senior secondary education respondents were 10 (16.6%). Low educational levels have also been reported among cassava farmers in other countries, such as Indonesia (Zakaria et al., 2019) and Nigeria (Babatunde et al., 2016). Interestingly, the study found no farmers with an education level above senior secondary. Although education was found to have a less substantial impact on cassava farming, it still plays a favorable and essential role in addressing cassava farmers' technical and economic inefficiencies (Ogundari & Ojo, 2006).

Employment-wise, only 10 farmers reported employment. This means they are engaged in cassava farming while also serving in other sectors, such as teaching in elementary and kindergarten schools or working as nighttime security guards. Most respondents reported engaging only in cassava farming, with no other compensatory positions attached (83.3%). A further result of the survey revealed that Christians (50, 83.3%) are more engaged in cassava farming in Salayea compared to Muslims (2, 3.3%) and followers of Traditional African Religion (8, 13.3%).

Result of the Analytical Hierarchy Process

The study analyzes the variables influencing yields among cassava growers in Salayea as a multi-criteria decision problem that must be computed at three levels. The objective of Level 1 is to identify the factors affecting cassava yields for farmers. The results of a review of the relevant literature revealed three primary motives that advance the aim (level 2). Each of the three main themes was then broken down even further into sub-themes: CTF had 5, PYF had 8, and FEF had 5. Level 3 presents the 18 sub-factors that span the three themes identified in Level 2. These ancillary elements impact the amount of cassava that farmers in Salayea harvest. Therefore, this section will describe the findings derived from the AHP analysis of the 60 respondents. The researcher began by calculating the weights of the factors and the subfactors. Lastly, we developed the global weight by multiplying the factor and subfactor weights.

Results of the Three Themes (CTF, PYF, & FEF)

The questionnaire consisted of three main parts, each with an appropriate heading. In the first part of the survey, participants were asked to provide their demographic information. An AHP pairwise comparison of the three components was provided in the second part. These factors were Climate and Temporal Factors (CTF), Production and Yielding Factors (PYF), and Financial and Economic Factors (FEF). The level 2 analysis was built on these three underlying components or themes. The aggregated pairwise comparisons for all 60 respondents on the level-2 criteria are shown in Table 6, along with their respective weights and rankings. Upon examining the responses, consistency (CR = 0.03) was found.

Table 6

AHP pairwise comparison of the three criteria of Level 2

	CTF	PYF	FEF	Weight	Rank
CTF	1	1	0.20	0.158	3
PYF	1	1	0.33	0.187	2
FEF	5	3	1	**0.655**	**1**
CR = 0.03		λ_{max} = 3.04		**CI = 0.02**	

Source: Author's work

The findings presented in Table 6 suggest that Financial and Economic Factors (FEF), with a score of 0.655 and a rank of 1, are considered by farmers in Salayea to be the primary Level 2 factor affecting their cassava yields. Farmers believe that FEF has the most significant potential to affect their yields. It was followed by Production & Yielding Factors (PYF), which scored 0.187. Climate & Temporal Factors (CTF) received the lowest rank, with a score of 0.158. The variances in these scores are fascinating to examine, as they align with findings from other studies in a similar vein. For instance, agricultural production is mainly dependent on factors such as access to loans (Awotide et al., 2019). These results also align with those of Mupakati and Tanyanyiwa (2017), who found that 78% of respondents believed cassava production is unaffected by climate change variables, including changes in weather, heatwaves, and severe heat.

In the third and final section of the questionnaire, respondents were also asked to conduct a pairwise comparison of the 18 sub-factors identified in the literature (level 3). Table 2 has an explanation of each of the 12 sub-factors. The pairwise comparisons are presented below, organized by theme.

Results from the 18 Sub-factors

Pairwise comparisons among sub-factors of the Climate & Temporal Factors (CTF) group (Table 7) reveal that farmers attach great importance to Climate Change (CTF1), with a score of 0.465. Climate extremes and natural climatic variability affect cassava yields. As temperatures rise, certain cassava types become more productive. Unfortunately, the crop is vulnerable to various diseases, such as cassava mosaic disease and brown streak disease, which are hastened by climate change (Boansi, 2017; Brown et al., 2016; Burns et al., 2010).

Table 7
Pairwise comparison of CTF sub-factors

	CTF1	CTF2	CTF3	CTF4	CTF5	Weight	Rank
CTF1	1	3	3	7	7	**0.465**	**1**
CTF2	0.33	1	3	3	9	0.274	2
CTF3	0.33	0.33	1	3	3	0.142	3
CTF4	0.14	0.33	0.33	1	3	0.077	4
CTF5	0.14	0.11	0.33	0.33	1	0.041	5
CR =	0.08		$\lambda max = 5.36$			CI = 0.09	

Source: Author's work

It was followed by Inadequate rainfall (CTF2) with a weight of 0.274. Drought-resistant cassava varieties are rare for farmers to find. However, suppose these varieties are not readily accessible. In that case, farmers are likely to experience lower crop yields, making it more difficult for them to compensate for the increased capital required to acquire these varieties. Therefore, low rainfall becomes a concern for farmers planting drought-unresponsive varieties (Boansi, 2017; El-Sharkawy & De Tafur, 2010; Emaziye, 2015; Okogbenin et al., 2013; Pingali, 2012; Santisopasri et al., 2001). Rise in temperatures (CTF3), increased soil acidity (CTF4), and Late planting (CTF5) received scores of 0.142, 0.077, and 0.041, respectively. Thus, the importance order for all Climate & Temporal Factors sub-factors can be summarized as CTF1 > CTF2 > CTF3 > CTF4 > CTF5.

Respondents' grading of sub-factors in the Production & Yielding Factors (PYF) group, presented in Table 8, reveals that Low soil fertility (PYF1), with a score of 0.341, is the most significant factor affecting cassava yields in Salayea.

Table 8
Pairwise comparison of PYF sub-factors

	PYF1	PYF2	PYF3	PYF4	PYF5	PYF6	PYF7	PYF8	Weight	Rank
PYF1	1	3	3	3	5	9	9	9	0.341	1
PYF2	0.33	1	3	3	3	3	7	9	0.207	2
PYF3	0.33	0.33	1	5	3	3	7	9	0.181	3
PYF4	0.33	0.33	0.20	1	3	3	3	3	0.097	4
PYF5	0.20	0.33	0.33	0.33	1	3	3	3	0.071	5
PYF6	0.11	0.33	0.33	0.33	0.33	1	3	3	0.050	6
PYF7	0.11	0.14	0.14	0.33	0.33	0.33	1	3	0.032	7
PYF8	0.11	0.11	0.11	0.33	0.33	0.33	0.33	1	0.022	8
CR = 0.09				λ_{max}8.96				CI = 0.13		

Source: Author's work

Low soil fertility significantly reduces crop yields (Adams et al., 2016; Amoah et al., 2012; Di Falco & Zoupanidou, 2017; Zhang et al., 2018). An inadequate supply of nutrients causes yield reduction in growing plants (Schjoerring et al., 2019). In addition to reducing yields, low soil fertility further affects the nutritional composition of crops, thereby altering their nutritional quality (Imakumbili et al., 2019). Low soil fertility also reduces yields of hardy crops, such as cassava (Manihot esculenta). The cyanogenic glucoside content of cassava is also negatively affected by low soil fertility (White et al., 1998). Poor site selection (PYF2), with a score of 0.207, was ranked the second most significant factor influencing cassava yields in Salayea. Cassava cultivation begins with selecting a suitable site. The selection of a good site for cultivation is essential to yields and productivity. Therefore, the site selection can significantly affect cassava yield if done incorrectly. Farmers who select unsuitable sites for cassava cultivation are most likely to experience yield reduction (Edgerton, 2009; Gerssen-Gondelach et al., 2015; McDougall et al., 2019).

Improper fertilizer application (PYF3) was ranked third with a score of 0.181. Cassava does well when fertilizer is applied in the field. However, the inefficient use of chemical fertilizers can significantly affect yields. Cassava responds best to organic and mineral fertilizers; however, the method of application can significantly affect yield, particularly with chemical fertilizers (Biratu et al., 2018; Ezui et al., 2017). Improper disease and pest control (PYF4) was ranked fourth. The cultivation of cassava is hampered by several Biotic constraints, which can cause yield losses of up to 100% in susceptible cassava varieties. Therefore, inadequate disease management and migration strategies can adversely affect cassava yields, resulting in economic losses for farmers.

Like other major crops, cassava is susceptible to pests and diseases that can result in significant yield losses. The impact of pests on cassava is severe in Africa. However, improper pest management and control cause damage, resulting in low yields and significant economic losses for cassava farmers. Poor husbandry practices (PYF5) were also reported to influence cassava yields. Cassava, like other crops, is susceptible to various diseases and pests in the field. One primary reason diseases attack cassava is poor husbandry practices. Inadequate husbandry practices lead to disease and pest infestations in cassava, reducing yields and causing economic losses for farmers. Low-yielding varieties (PYF6) can result in significant yield losses in cassava. Farmers who use low-yielding cassava cultivars will likely experience reduced yields, posing a significant economic challenge. Like other crops, cassava is fed to livestock (PYF7). Animals such as squirrels, groundhogs, goats, and cattle directly affect cassava yield by damaging the crop in the field. The lack of proper management to mitigate the impact of this livestock on field-cultivated cassava may result in reduced yields and economic losses.

Improper spacing (PYF8) was ranked the least. For maximum root production, cassava is typically planted at 10,000 plants per hectare in fertile soil and 16,000 plants per hectare in infertile soil, where plant growth is less vigorous. However, planting cassava at higher or lower densities can reduce yield. Hence, the importance order for all PYF group sub-factors can be summarized as follows: PYF1> PYF2 > PYF3 > PYF4 > PYF5 > PYF6 > PYF7 > PYF8.

In the Financial & Economic Factors (FEF) group, a comparison of sub-factors presented in Table 9 reveals that lack of access to loans (FEF1), with a score of 0.473, is the most significant factor influencing cassava yields, as reported by the 60 farmers.

Table 9
Pairwise comparison of FEF sub-factors

	FEF1	FEF2	FEF3	FEF4	FEF5	Weight	Rank
FEF1	1	3	3	7	7	**0.473**	**1**
FEF2	0.33	1	3	3	3	0.227	2
FEF3	0.33	0.33	1	3	5	0.169	3
FEF4	0.14	0.33	0.33	1	3	0.082	4
FEF5	0.14	0.33	0.20	0.33	1	0.048	5
CR = 0.09			$\lambda_{max} = 5.43$			CI = 0.10	

Source: Author's work

Access to credit is a crucial factor in achieving increased agricultural productivity (Awotide et al., 2019). Therefore, if cassava farmers lack access to loans or credit to procure inputs and meet farm workers' needs, this can affect cassava yields

(Okpukpara, 2010). Lack of capital to procure cassava cuttings (FEF2) was ranked second with a score of 0.227. Cassava farming requires finance, like all other crops. The acquisition of land, inputs, and cassava cuttings requires capital. The lack of capital can adversely affect cassava yields if farmers do not have the funds to acquire everything needed for production. This can affect the yield and productivity of cassava cultivation (Shackelford et al., 2018). The lack of government subsidies and other investment supports (FEF3) is also a significant factor influencing cassava yields. The lack of government subsidies can affect cassava yields (Mahul & Stutley, 2010). If farmers lack government subsidies, yields will decline. Therefore, farmers need government support, including subsidies and other investments, to produce cassava and achieve sustainable, optimal yields. Incremental increases in input procurement (FEF4) were ranked fourth. The appropriate cost of inputs can effectively increase cassava yields if farmers can acquire agricultural inputs at affordable prices. However, if the cost of inputs increases and farmers have the capital to purchase them, this becomes a problem, reducing cassava yields. The lack of training infrastructure for farmers (FEF5) in this sub-group received the lowest score. To achieve the best yields and productivity in cassava cultivation, farmers need hands-on training and access to extension officers to understand the importance of cassava production, what to do, and what not to do during cultivation. The lack of training and proper information distribution reduces yield (Gerssen-Gondelach et al., 2015; Zambrano et al., 2019). Hence, the importance order for all FEF group sub-factors can be summarized as FEF1>FEF2>FEF3>FEF4>FEF5.

Global Weights Computation

Table 10 presents the global weights for each subfactor. The global weight for the subfactors was derived by multiplying the local and group weights. Additionally, the global rank column values were calculated using Microsoft Excel's RANK function, based on the global weights.

Table 10
Global weights for each of the subfactors

Factors	Factor Level Weight	Rank	Sub-factors	Sub-factors Level weight	Local Rank	Global Weight	Global Rank
CTF	0.158	3	CTF1	0.465	1	0.073	4
			CTF2	0.274	2	0.043	7
			CTF3	0.142	3	0.022	11
			CTF4	0.077	4	0.012	14
			CTF5	0.041	5	0.006	16
PYF	0.187	2	PYF1	0.341	1	0.064	5
			PYF2	0.207	2	0.039	8
			PYF3	0.181	3	0.034	9
			PYF4	0.097	4	0.018	12
			PYF5	0.071	5	0.013	13
			PYF6	0.050	6	0.009	15

			PYF7	0.032	7	0.006	17
			PYF8	0.022	8	0.004	18
FEF	0.655	1	FEF1	0.473	1	**0.310**	**1**
			FEF2	0.227	2	**0.149**	**2**
			FEF3	0.169	3	**0.111**	**3**
			FEF4	0.082	4	0.054	6
			FEF5	0.048	5	0.031	10

Based on the sub-factor results from the combined sub-factors group, the three most outstanding sub-factors that influence cassava yields in Salayea were Lack of access to loans (FEF1), Lack of capital to procure cassava cuttings (FEF2), and Lack of subsidies and other investment support from the government (FEF3), with global weights of 0.310, 0.149 and 0.111, respectively. Climate change (CTF1) ranked 4th, followed by PYF1 (Low soil fertility) with weights of 0.073 and 0.064, respectively. Even though Inadequate rainfall (CTF2) from the Climate & Temporal Factors group and Poor site selection (PYF2) from the Production & Yielding Factors group received the second-highest local ranks, they did not perform well globally (ranked 7th and 8th, respectively).

Conclusion and Recommendation

This research employs the Analytic Hierarchy Process to gain a deeper understanding of the relative impact of three main themes – climate and temporal factors, production and yield, and financial and economic factors – on cassava yields among farmers in Salayea District. The study further explored the influence of several sub-factors within each theme. Among the major groups, Financial and Economic Factors were the most significant, with a weight of 0.655.

At the sub-factor level, the three most influential elements affecting cassava yields were identified as Lack of access to loans (FEF1), Lack of capital to procure cassava cuttings (FEF2), and Lack of subsidies and other investment support from the government (FEF3). These were followed by Climate change (CTF1), ranked 4th, and PYF1 (Low soil fertility), ranked fifth. Although Climate change (CTF1) was the highest-ranking sub-factor within its group, it ranked much lower when all 18 sub-factors were evaluated globally. Other Climate and Temporal Factors, such as rising temperatures, increased soil acidity, and late planting, and production and yield factors, including damages caused by livestock and Improper spacing, were ranked lowest overall, suggesting a limited perceived influence by farmers in Salayea.

The findings of this study have practical implications for policymakers, agricultural extension agencies, and development organizations seeking to improve cassava productivity. They offer a localized perspective on the challenges faced by cassava farmers and provide a quantitative basis for prioritizing interventions. Given the applicability of these findings to rural agricultural contexts in other developing nations, this study makes a meaningful contribution to the discourse on cassava yield improvement strategies.

However, several limitations should be acknowledged. The study's sample size of 60, drawn through purposive sampling in the absence of an official farmer register, limits the generalizability of the findings. The reliance on self-reported data may introduce bias, as key variables such as soil fertility and climatic impact were not objectively measured. The gender imbalance in the sample (75% male, 25% female) may also have excluded essential perspectives.

Thus, future research should aim to overcome these limitations by incorporating larger, more representative samples, balancing gender participation, and employing longitudinal designs that capture changes over time. Combining objective field data with farmers' perceptions and using complementary decision-making tools alongside AHP would also enhance the depth, reliability, and applicability of future studies.

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