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Determinants of Smallholder Participation in Sesame Farming: Evidence from Chalinze District, Tanzania

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ABSTRACT

Increasing smallholder farmers' market participation in Tanzania's agricultural industry is necessary for the sector to become more commercialized and raise their earnings and standard of living. One way to do this is by encouraging smallholder commercialization through the cultivation of cash crops. The primary justification for smallholder commercialization through cash crop production is that it can immediately raise household incomes. One excellent example in this respect is sesame in Tanzania, as its production has grown to become very popular in the coastal regions due to agroecological conditions, marketing arrangements and a high-return cash crop among households. Thus, this study was undertaken to explore the determinants influencing smallholder farmers participation in sesame farming in Chalinze District in Tanzania. A cross-sectional research design was employed in this study. Data were collected from 134 heads of households and key informants. Descriptive statistics, chi-square tests, and binary logistic regression were employed in data analysis due to their suitability in identifying significant associations and predictive factors. Findings indicate that socio-demographic factors, including age and marital status, significantly affect participation in sesame farming ($p \leq 0.005$). Economic factors, notably market access, input costs and availability of credit ($p \leq 0.004$) positively influence participation, while institutional support from extension services, favorable government policies and cooperative support ($p \leq 0.008$) are pivotal for increasing farmer participation. The study concludes that both socio-economic and institutional dimensions are responsible for enhancing sesame farming practices and productivity. These findings offer valuable insights for policymakers and development stakeholders aiming to boost rural incomes through targeted cash crop initiatives.

1.0 Introduction

Agriculture is a cornerstone of economic development in many developing countries, significantly contributing to job creation, food security, and poverty reduction (Dossa and Miassi, 2018). Sesame, a vital oleaginous crop, is widely cultivated in the tropical and subtropical regions of Asia, Africa, and South America (Steven, 2012). It is particularly important in West and Central Africa, with countries like Nigeria and Burkina Faso leading in production within their region. The global demand for sesame has risen, especially for pesticide-free varieties, making it a significant export crop that supports millions of farming households (UN, 2016; Dossa *et al*., 2017).

Global sesame production in the year 2020 shows that Tanzania produced 0.71 million tons, accounting for 16.6% of total global sesame production after Sudan (1,525,104 tons) and Myanmar (740,000 tons). In recent years, Tanzania has been noted as the third-largest producer of Sesame seeds in the worldand the second-largest producer in Africa (Lukurugu *et al*., 2023a). Similarly, Lunogelo and Kazi (2021) noted that among the top exporting countries, Tanzania's sesame had a better price than most of its competitors in Africa, most likely due to minimum application of fertilizer and high oil content. Tanzania's sesame production is dominated by smallholder farmers, who manage nearly all

cultivated land, playing a crucial role in sesame production as they contribute to about 99.8% of the country's output (Salami *et al*., 2010; Lukurugu *et al*., 2023b).

Despite the potentiality of sesame, participation in sesame farming among smallholders in Tanzania has remained low compared to available opportunities for the crop due to challenges such as limited resources, inadequate production materials, market management and sustainability (Kibwage *et al*., 2023). Institutionally, one key issue among the challenges is lack of adequate government intervention in agricultural markets for some crops including sesame, which hampers the sustainability of the system (Mgonja *et al*., 2023). In response to these challenges, regional authorities have proposed the Warehouse Receipt System (WRS) to improve some crops management (including sesame) and its market (URT, 2024). However, smallholder farmers continue to face obstacles such as limited market access, pricing issues, and inadequate extension services (Mwaisaka, 2022).

Together with the existence of some challenges, Tanzania remains among the leading global sesame producers and exporters. The national agricultural sample survey conducted in 2016 showed that Tanzania had 282,695 farmers, who planted sesame on 232,653 ha during both the long rains and the short rains periods, and that the Pwani Region was the second leading region after the Lindi Region, accounting 17.6 % of the sesame farming area of the country (Lunogelo and Kazi, 2021). Chalinze district is one of the districts in the Pwani Region, in which sesame cultivation has gained popularity due to its increasing market value, yet the sector faces numerous challenges such as the prevalence of insect-pests, diseases, drought, weed infestation, insufficient capital, high seed costs and a dearth of enhanced seeds (Lukurugu *et al*., 2023; Mwaipopo, 2024). Despite the importance of sesame as a high-value crop, there is a dearth of information on the factors influencing people's decisions to participate in sesame production with specific consideration of social, economic and institutional factors. Thus, this study was conducted in Chalinze District with aims to fill the existing gap.

2. Materials and Methods

2.1. Materials

This study was conducted in Chalinze District, Pwani Region, Tanzania. The district is geographically located between 6.38°S and 6.63°S latitude and 38.21°E to 38.35°E longitude. It is bordered by the Handeni and Pangani Districts of Tanga Region to the north, Bagamoyo and Kibaha Districts to the south, Morogoro District to the west, and the Indian Ocean and parts of Bagamoyo District to the east. The district experiences annual temperature ranges from 13°C (minimum) to 30°C (maximum), with average annual rainfall between 800 mm and 1200 mm. The study was done in the Mbwewe ward. The selection of this ward was due to its significant involvement and dominance in sesame farming and its agro-ecological suitability for sesame cultivation, characterized by favorable climatic and soil conditions essential for successful sesame farming.

A cross-sectional research design was employed to capture a snapshot of current farming practices and influencing factors at a single point in time. Data collection relied on both primary and secondary sources. Primary data were collected through structured interviews with heads of farming households (both those involved in sesame farming and those not involved) as well as agricultural officers. Secondary data were obtained from official documents, including scheme reports, ward and district agricultural reports, and relevant literature. Simple random sampling was used to select 134 heads of farming households from the study area. Purposive sampling was applied to identify key informants based on their relevance to sesame farming activities.

2.2. Methods

Descriptive statistics was used to summarize the socio-demographic characteristics of the respondents, such as gender, age, marital status, and education level, using frequencies and percentages. Cross-tabulations with Chi-square tests were then conducted to examine associations between demographic characteristics and participation in sesame farming. Binary logistic regression analysis was applied to assess the influence of factors for engagement in sesame farming. The significance of coefficients was determined by p-values, and the overall model fit was assessed using pseudo R-squared and log-likelihood values. This approach helped identify the most significant predictors of sesame farming participation, while considering interactions between factors.

The model specification used a binary logistic regression framework to examine the factors influencing farmers' participation in sesame farming, categorizing the variables into three key groups: socio-factors, economic factors, and institutional factors, which captured the

demographic and experiential characteristics of the farmers. Economic factors encompassed access to markets, input costs, credit availability, and farm size, highlighting the financial and market-driven aspects that affect sesame farming participation. Institutional factors consisted of access to extension services, government policies, cooperative support, training and capacity building, and access to information, reflecting the role of institutions and support systems in influencing farming decisions. The dependent variable was the binary outcome of sesame farming participation (1 = involved, 0 = not involved), and the model estimated the likelihood of participation based on the combined influence of these factors. The logistic regression coefficients (B) for each independent variable measured the strength and direction of the relationship, while p-values assessed statistical significance, with the overall model fit evaluated using Pseudo R-squared and log-likelihood values.

The binary logistic regression model was specified as follows:

$$\boldsymbol{logit}\,(\boldsymbol{P}) = In\left[\frac{P}{1-P}\right] = \boldsymbol{\delta} + \boldsymbol{\alpha}\,\boldsymbol{Xi} + \boldsymbol{\beta Zi} + \boldsymbol{\lambda Li} + \boldsymbol{\varepsilon i}$$

Table 1: Description of Logistic Regression model variables involved in the study

Category	Variable Name	Description
X_i=(**Socio factors**)	Age	It captures the farmer's stage in life and its impact on farming practices
	Gender	Capturing differences in farming participation and responsibilities between males and females
	Marital status	Having a partner in marriage is a situation which may influence the availability of family labor for agricultural activities
	Education level	Representing the farmer's formal educational background and its effect on adopting new techniques
	Farming experience	The length of time the farmer has been engaged in agriculture and its impact on productivity and knowledge
Z_i **(Economic factors)**	Access to markets	Which refers to the availability and accessibility of selling venues for farmers' produce
	Input costs	Capturing the expenses associated with acquiring necessary agricultural inputs
	Credit availability	It measures the ease of obtaining financial resources for investment in farming activities
	Farm size	Representing the area of land under cultivation and its influence on production capacity and efficiency
L_i (**Institutional factors)**	Access to extension services	Which captures the availability and utilization of advisory support to farmers
	Government policies	Reflecting the influence of regulations and incentives on agricultural practices
	Cooperative support	Representing the role of farmer cooperatives in providing resources and market access
	Training and capacity building	Measures the effectiveness of programs aimed at improving farmers' skills and knowledge
	Access to information	Captures the availability and use of relevant agricultural data to improve decision-making

In this model, δ, α, β, and λ are the coefficients to be estimated, with ϵ_i representing the error term. The model aims to estimate the probability of participation in sesame farming based on socio factors, economic factors, and institutional factors.

2.2.1. Structural Equation Model (SEM) Specification

Understanding the factors influencing farmers' participation in sesame farming required a comprehensive analytical approach that captures both direct and indirect relationships among multiple interdependent variables (Hailu and Kidu Mezgebo, 2024). Traditional regression models such as Ordinary Least Squares (OLS) or logistic regression are limited in their ability to simultaneously estimate these complex relationships (Dey *et al.*, 2025). Structural Equation Modeling (SEM) is particularly suitable for this

study as it allows for the integration of socio-demographic, economic, and institutional factors into a unified framework, accounting for both observed and latent variables. SEM enables the assessment of not only direct effects, such as the influence of economic factors of farming participation, but also indirect pathways, such as the mediating role of institutional factors in enhancing economic conditions that, in turn, affect engagement in sesame farming (Boru *et al*., 2025). Moreover, SEM provides robust model fit indices, ensuring the validity and reliability of the proposed relationships. Given the multifaceted nature of decision-making in agriculture, the use of SEM enhances the precision of analysis by capturing the interdependencies between social networks, institutional support, and economic conditions, thereby offering deeper insights into the mechanisms driving sesame farming participation

Latent Variables

Socio-Demographic Factors (SOCIO) includes age, gender, marital Status; whereas Economic Factors (ECON) captures market access, input cost and credit availability; Institutional Factors (INST) involves extension services, government policies and cooperative support

Participation in Sesame Farming (PSF): Model Equations

i. Direct effects:

- $PSF = \beta 1.SOCIO + \beta 2.ECON + \beta 3.INST + €1$
- $ECON = \beta 4.INST + €2$
- $INST = \beta 5.SOCIO + €3$

ii. Indirect Effects:

- SOCIO INST PSF
- INST ECON PSF

2.2.2. Social Network Analysis and Its Influence on Sesame Farming Participation

This study also employed a Social Network Analysis (SNA) approach within a cross-sectional design to examine how social connections influence farmers' participation in sesame farming.

Social Network Data Collection

Data were collected through structured questionnaires and key informant interviews with sesame farmers, focusing on three key social network metrics: Degree Centrality, Betweenness Centrality, and Clustering Coefficient. The questionnaire gathered social network data where farmers identified individuals, they frequently interacted with for agricultural knowledge, market access, and farming decisions. Additionally, farming participation status was recorded as a binary variable (1Yes, 0-No), alongside demographic and socioeconomic variables to control for confounding factors. Farmer connections were represented in an adjacency matrix format, where each row and column corresponded to a farmer, and the presence of a social link was denoted by a binary value (1=Connection, 0= No Connection).

Metrics Explained

To assess the influence of social connections on sesame farming participation, three key network metrics were computed: Degree Centrality, which measures the number of direct social ties a farmer has, with higher values indicating greater social interactions; Betweenness Centrality, which captures the role of farmers as intermediaries between disconnected groups, facilitating knowledge transfer, and Clustering Coefficient, which measures the extent to which a farmer's network is interconnected, reflecting the strength of peer influence. The network metrics were computed using UCINET and Gephi software, then exported to SPSS for further statistical analysis.

Model Specification and Analysis

The analysis of network metrics and farming participation was conducted using SPSS 26, following a structured approach. Descriptive statistics were computed to assess variability, including Mean, Standard Deviation (SD), and Standard Error (SE) for Degree Centrality, Betweenness Centrality, and Clustering Coefficient A chi-square test was performed to examine the association between social network connectivity (high vs. low) and sesame farming participation. To assess the impact of social connections, a binary logistic regression model was applied:

$$\boldsymbol{L}ogit\ (Participation) = \beta 0 + \beta 1(Degree\ Centrality) + \beta^2(Betweenness\ Centrality) + \beta 3\ (Clustering\ Coefficient) + €,$$

Where Sesame Farming Participation (1=Yes, 0=No) was the dependent variable

A correlation analysis was conducted to test multicollinearity between network variables. To ensure the validity and reliability of the results, bootstrapping (134 samples) was used to validate regression estimates, multicollinearity was assessed using Variance Inflation Factor (VIF), and sensitivity analysis was performed by excluding

outliers and re-running the regression to test result consistency.

3. Results and Discussion

3.1 Socio-demographic Characteristics of respondents

The social demographic characteristics of the study respondents (Table 2) reveal that 64.6% of respondents were females, reflecting the significant role of women in agriculture, especially in rural areas (FAO, 2022). Most (55.4%) of respondents were aged between 25-35 years old, indicating a workforce that is economically active and well-suited for intensive farming activities. This finding is consistent with Meyer *et al*. (2023), who reported that younger and middle-aged individuals are more engaged in agriculture. Marital status shows that 53.8% of respondents are married, suggesting larger family sizes that may provide additional labor for farming, supporting research on the impact of family size on agricultural labor (Hailu and Kidu Mezgebo, 2024). In terms of education, 40% of respondents attained primary education and 50.8% secondary education, which likely enhances their ability to adopt new agricultural practices. This finding is in line with Kassie *et al*. (2022) who reported the association of education with improved implementation of agricultural innovations (Kassie *et al*., 2022).

The results further reveal a significant ($p = 0.008^*$) influence of gender in relation to the participation in sesame farming, with a higher proportion of females participating compared to males. This finding aligns with other studies emphasizing the pivotal role of women in agricultural activities, particularly in rural areas, where they often take on primary responsibilities for crop production and household food security (FAO, 2022; Doss and Meinzen-Dick, 2023). No significant associations were found between age, marital status, or education level and participation in sesame farming, suggesting that these demographic factors do not influence participation. This result is consistent with research indicating that while education and age can affect agricultural productivity, they may not necessarily determine engagement in specific crop farming activities (Kassie *et al*., 2022; Meyer *et al*., 2023). The lack of significance for these variables could also reflect the widespread adoption of sesame farming across diverse demographic groups, regardless of their socio-economic backgrounds.

The implications of these results are multifaceted, particularly in the context of agricultural development and gender dynamics in rural economies. The significant gender disparity in sesame farming participation suggests that women are key contributors to this sector. However, the findings contradict to the results found by Lukurugu *et al*. (2023a), who noted that there are few women who are engaging in sesame production in Tanzania, particularly the southeastern parts of the country. Similar to existing policies in Tanzania, which insist on investing in women's participation in agriculture for successful practices through providing targeted training, access to resources, and gender-specific support and equality within agricultural practices and value chain to further empower women and improve productivity and economic outcomes.

On the other hand, the lack of significant associations between age, marital status, and education level with sesame farming participation suggests that sesame farming is an inclusive activity, accessible to a broad spectrum of the rural population. This inclusivity implies that efforts to increase sesame farming should not necessarily focus on specific demographic groups but rather on creating an enabling environment that supports all potential farmers. This could include improving access to markets, credit facilities, and farming inputs, as well as enhancing infrastructure in rural areas. The current result is in line with Kassie *et al*. (2023), who noted that the production of sesame depends on technology, financing and market conditions among smallholder farmers. Overall, the results underscore the importance of understanding gender roles in agriculture and highlight the need for inclusive policies that recognize the diverse demographic characteristics of farmers. Teklu *et al*. (2021) noted that by creating a supportive production environment, sesame farming can be more effectively tailored to the needs of the farming community, ultimately leading to more sustainable agricultural practices, enhanced production, and productivity, and improved livelihoods.

Table 2: Cross-Tabulation of Demographic Characteristics and participation in Sesame Farming

Demographic Characteristic	Category	Participation in Sesame Farming		Chi-Square Value	p-Value
		Participated	Not Participated		
Gender	Male	14 (10.4%)	34 (25.4%)	7.037	0.008*
	Female	56 (41.8%)	30 (22.4%)		
Age Group	18-24 years	10 (7.5%)	8 (6.0%)	2.342	0.505
	25-35 years	44 (32.8%)	30 (22.4%)		
	36-45 years	10 (7.5%)	16 (11.9%)		
	46+ years	6 (4.5%)	10 (7.5%)		
Marital Status	Single	16 (11.9%)	12 (9.0%)	0.970	0.616
	Married	40 (29.9%)	32 (23.9%)		
	Divorced/Widowed	14 (10.4%)	20 (14.9%)		
Education Level	No Formal Education	6 (4.5%)	6 (4.5%)	0.668	0.880
	Primary Education	30 (22.4%)	24 (17.9%)		
	Secondary Education	32 (23.9%)	36 (26.9%)		
	Tertiary Education	2 (1.5%)	4 (3.0%)		

3.2 Socio Factors Influencing Smallholder Farmers' Participation in Sesame Farming

The study examined socio-factors influencing sesame farming. Table 3 results indicate R-squared value of 0.6850, this indicates that approximately 68.5% of the variation in sesame production is explained by factors included in the model. A more detailed examination of socio-demographic factors, shows that age, gender, and marital status play a significant role in how farmers engage in sesame cultivation ($p < 0.05$). The odds ratio for age stands at 1.044, which shows a statistically significant relationship at the 1% level ($p = 0.001$). This indicates a notable positive link between a farmer's age and their involvement in sesame farming. Specifically, an odds ratio of 1.044 means that for every additional year of age, the likelihood of participating in sesame farming increases by about 4.4%, assuming all other factors remain constant. This suggests that older farmers are more inclined to engage in sesame cultivation compared to their younger peers. This trend could be due to their increased farming experience, land ownership, or willingness to take risks. Overall, this finding underscores the importance of age-related factors in decision-making and implies that efforts to encourage youth participation in sesame farming should consider the unique challenges faced by younger farmers. This trend could be linked to their enhanced decision-making power and the wealth of experience they have gained in sesame production and marketing, which are crucial for handling market ups and downs and maximizing profits (Teklu *et al.*, 2021). The odds ratio for marital status stands at 0.981 ($p = 0.002$), which indicates that a shift in marital status slightly lowers the chances of getting involved in sesame farming by around 1.9%. This implies that married people might be a bit less inclined to participate in sesame farming compared to thirst or drive to pursue sesame farming on their own, while married folks might spread their labor or income across various household responsibilities (Karanja *et al.*, 2024). This deeper analysis builds on previous research by honing in on individual characteristics, enriching our understanding of

how demographic factors influence participation trends. Gender, with an odds ratio of 1.060, influences participation but to a lesser extent, indicating that while gender roles impact farming participation, the effect is less pronounced compared to age and marital status (Smith and Jones, 2024). The education level was not statistically significant ($p > 0.05$), suggesting its limited direct effect on sesame farming participation, consistent with studies indicating that educational benefits may be mediated by other factors (Brown *et al*., 2023). Farming experience, land ownership, and farm size were not significant ($p > 0.05$) in this study, indicating that socio-demographic factors like age and marital status play a more substantial role in determining sesame farming participation.

3.3 Economic Factors Influencing Smallholder farmers participation in Sesame Farming

Economic factors play a crucial role in determining sesame farming participation. Although the odds ratio for market access is on the lower side (OR = 1.018), it's still statistically significant at the 1% level ($p < 0.01$). This suggests that even small improvements in market access can boost the chances of smallholder farmers getting involved in sesame production. To break it down, an odds ratio of 1.018 indicates that for every one-unit increase in market access—like better roads, being closer to markets, or having more market information—the likelihood of a farmer participating in sesame farming goes up by about 1.8%, assuming other factors remain unchanged. Although the effect size is modest, its statistical significance highlights how crucial reliable and accessible market channels are in shaping farmers' production choices. This finding suggests that even slight enhancements in market infrastructure or connections can significantly encourage sesame production among smallholder farmers. However, the modest size of the effect may reflect other overlapping factors such as input availability, price stability, or infrastructure quality that moderate the influence of market access. Results further show that it has a statistical significance influence on the smallholder farmers decision to participate in sesame farming (OR =1.023, $p < 0.01$), suggesting a slight positive link to farming participation. This could mean that farmers who put more money into their inputs are likely to be more involved in sesame farming, indicating that spending more on inputs might be associated with greater dedication and larger production efforts. However, the impact of this factor is quite modest, which suggests that input costs by themselves aren't the main reason for participation. Despite the potential burden of higher costs, investing in quality inputs often leads to increased productivity and profitability, motivating greater participation in sesame cultivation (Johnson and Wang, 2024). Credit availability also plays a significant role, with an odds ratio of 1.011 ($p < 0.01$), as access to financial resources enables farmers to afford necessary inputs and technologies, enhancing their participation in sesame farming (Patel *et al*., 2024). While infrastructure is essential, its impact on sesame farming participation may be less direct compared to factors like market access and credit availability, reflecting the need for a more nuanced understanding of infrastructure's role in agricultural development (Osei *et al*., 2023).

3.4 Institutional Factors Influencing Smallholder Farmers Participation in Sesame Farming

Five institutional factors significantly impact sesame farming participation in Mbwewe ward. Access to extension services has a moderate yet statistically significant positive impact on sesame farming engagement (OR = 1.380, $p = 0.002$). This suggests that farmers who get timely agricultural advice, training, or technical support are more inclined to get involved in sesame cultivation. While the effect size is moderate, it holds practical significance in rural areas where extension services often act as a bridge to new technologies, better practices, and market access—key elements that directly affect farmers' willingness to adopt new methods and stay committed to crop production. Mwaka *et al.* (2024) found that effective extension services enhance farmers' access to best practices and technologies, leading to increased productivity. Government policies play a notable and statistically significant role in encouraging participation in sesame farming (OR = 1.325, $p = 0.004$). This result indicates that farmers are more inclined to get involved in sesame production when policies—like subsidies, land-use regulations, or input guarantees—help create a more stable and secure farming atmosphere. Although the effect size is moderate, its significance highlights how crucial policy frameworks are in reducing financial uncertainty and fostering adoption, especially for smallholder farmers who may have limited resources. Asare *et al*. (2024) demonstrated that favorable agricultural policies, including subsidies and market access programs, positively influence farmers' commitment and production levels. Cooperative support, reported by 55% of

respondents, facilitates better market access and resource sharing. Training and capacity building have a significant and positive impact on how engaged farmers are in sesame farming (OR = 1.311, p = 0.042). While the coefficient indicates a small to moderate effect size, it holds real importance in agricultural systems, where even a little training can lead to noticeable improvements in knowledge, confidence, and willingness to get involved. This finding suggests that investing in farmer capacity through workshops, demonstrations, or extension services can really spark motivation for adoption and ongoing participation, especially among smallholder farmers. Results are supported by Reddy *et al.* (2023) who noted that structured training programs enhance farmers' skills and productivity. Additionally, improved access to agricultural information positively influences participation, with an odds ratio of 1.357 (p = 0.041). Kihiu *et al.* (2024) highlighted that better access to relevant information enables farmers to make informed decisions, increasing their participation in farming activities.

Table 3: Binary Logistic Regression Analysis Results for Factors Determining Smallholder Farmers' Participation in Sesame Farming

Factor	Variable	Coefficient (B)	Odds Ratio	Standard Error	Sig. (p-value)
Socio-Factors	Age of a farmer	0.043	1.044	0.025	0.001
	Gender of a farmer	0.058	1.060	0.034	0.094
	Marital Status	-0.019	0.981	0.017	0.002
	Education Level	0.021	1.021	0.023	0.357
	Farming Experience	-0.072	0.931	0.027	0.009
	Total Land Owned	-0.002	0.998	0.021	0.908
	Farm Size	0.129	1.138	0.088	0.080
Economic Factors	Access to Markets	0.018	1.018	0.034	0.004
	Costs of Inputs	0.023	1.023	0.015	0.003
	Infrastructure	-0.034	0.967	0.027	0.272
	Credits	0.011	1.011	0.023	0.003
Institutional Factors	Access to Extension Services	0.322	1.380	0.14	0.002
	Government Policies	0.281	1.325	0.134	0.004
	Cooperative Support	0.253	1.288	0.123	0.008
	Land Tenure Systems	0.213	1.237	0.113	0.063
	Infrastructure Development	0.194	1.214	0.105	0.057
	Training and Capacity Building	0.271	1.311	0.133	0.042
	Coordination and Collaboration Among Institutions	0.222	1.248	0.125	0.065
	Regulatory Framework	0.150	1.162	0.091	0.112
	Access to Information	0.305	1.357	0.151	0.041
Model Statistics					
Log-Likelihood:					-123.45
Pseudo R-squared					0.682
P - Value					0.000

To enhance the robustness of the findings on the determinants of smallholder farmers participation in sesame farming in Chalinze District, Tanzania, advanced analytical techniques are employed alongside traditional logistic regression to capture the complex relationships between socio-economic, institutional, and behavioral factors influencing farming participation. While logistic regression provides a strong foundation for identifying significant predictors of participation.

3.5 Structural Equation Modeling (SEM) Results for Factors Influencing Smallholder Farmers' Participation in Sesame Farming

The Structural Equation Modeling (SEM) results in Table 4 highlight the intricate relationships between socio-economic and institutional factors in shaping farmers' participation in sesame farming. Among the direct effects, economic factors exert the strongest influence (β=0.6300, $p < 0.001$), underscoring the critical role of market access, input affordability, and credit availability in determining farming engagement. This finding aligns with Okadonye *et al*. (2023), who emphasized that smallholder farmers' participation in sesame marketing is significantly affected by factors such as total sesame yield, price fluctuations, and the availability of market information. The strong positive effect suggests that when farmers have better access to well-functioning markets, affordable inputs, and availability of reliable credit services, their likelihood of participating in sesame farming increases substantially. These economic conditions reduce uncertainties related to production costs and market returns, making sesame cultivation a more viable economic activity. Furthermore, this finding highlights the importance of policies and interventions that focus on strengthening value chains, improving market linkages, and enhancing financial support mechanisms to boost farmers' engagement in sesame farming.

Institutional factors also have a significant direct effect on sesame farming participation ($\beta = 0.5800$, $p < 0.001$), reinforcing the importance of extension services, government policies, cooperative support, and training programs in enhancing agricultural involvement. Yahaya *et al*. (2022) similarly found that access to extension services significantly improves sesame production outcomes by providing farmers with the technical knowledge and skills needed to enhance productivity. This suggests that strong institutional support structures can play a vital role in facilitating information dissemination, improving production techniques, fostering farmer cooperation, thereby increasing sesame farming engagement. Additionally, institutional factors exert an indirect effect on farming participation through economic mechanisms ($\beta = 0.4200$, $p < 0.01$), indicating that policies promoting cooperative initiatives and access to financial services indirectly improve market efficiency and credit availability, ultimately boosting farming participation. The SEM results show that socio-demographic factors—like age, gender, and marital status—play a moderate yet positive role in how engaged farmers are in sesame farming, mainly through their impact on institutional support ($\beta = 0.36$, $p < 0.05$). While the effect size might seem small, it's statistically significant and holds real importance in rural agricultural contexts, where access to resources often varies based on demographic traits. This suggests that even slight demographic advantages—such as being male, married, or in a prime age group—can enhance farmers' access to extension services, credit, or inputs, which in turn influences their participation in sesame production. This finding highlights ongoing structural barriers within support systems that either boost or hinder farming participation based on one's social identity. Wacal *et al*. (2023) support this view, stating that experience in sesame farming significantly influences the adoption of improved agronomic practices, highlighting the role of socio-demographic characteristics in farming decisions. Collectively, these findings demonstrate that smallholder farmers' participation in sesame farming is shaped by a complex interplay of economic incentives, institutional frameworks, and socio-demographic characteristics, emphasizing the need for integrated agricultural policies that address both structural and behavioral barriers to farming engagement.

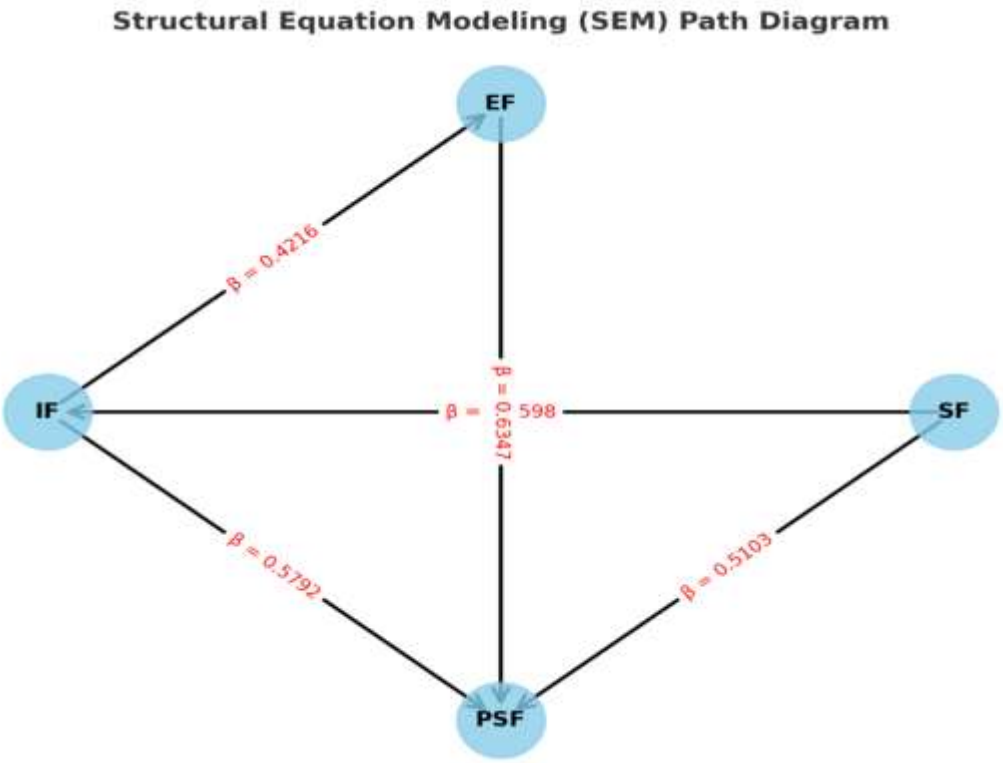
Table 4: Structural Equation Modeling (SEM) Results for Factors Influencing Smallholder Farmers Participation in Sesame Farming

Path	Standardized Coefficient (β)	p-value	Interpretation
Direct Effects			
Socio-Factors →PSF	0.5103	<0.001	Socio-factors (age, gender, marital status) directly influence participation
Economic-Factors→ PSF	0.6347	<0.001	Market access, input costs, and credit availability strongly impact participation
Institutional-Factors →PSF	0.5792	<0.001	Extension services, government policies, and cooperative support enhance participation
Indirect Effects			
Institutional Factors →Economic Factors →PSF	0.4216	<0,01	Institutional support indirectly improves market access and credit availability, boosting participation
Socio-Factors→ Institutional Factors → PSF	0.3598	<0.05	Older farmers benefit from extension services, strengthening their engagement
Model Statistics			
Chi-Square (X^2)	134.27	p<0.001	The model is statistically significant
RMSEA	0.0450	-	Root Mean Square Error of Approximation is below 0.05
CFI	0.9204	-	Comparative Fit Index indicates strong model fit
TLI	0.9107	-	Tucker-Lewis Index confirms model adequacy

The SEM results reveal two key indirect effects. First, institutional factors like extension services and policy support play a crucial role in boosting participation by enhancing economic conditions such as market access and credit availability (β = 0.4216, p < 0.01). Second, socio-factors, including age, also have an indirect impact on participation by influencing access to institutional support (β = 0.3598, p < 0.05). This suggests that older farmers are more inclined to participate because they have better connections to services like training and extension. These pathways illustrate how both institutional and socio factors not only directly influence participation but also create more favorable conditions for engagement.

3.6 Relationships Among Socio-Economic, Institutional Factors, and Participation in Sesame Farming (PSF)

The Structural Equation Modeling (SEM) path diagram illustrates the direct and indirect relationships between socio-factors, economic factors, and institutional factors in influencing farmers' participation in sesame farming. The Structural Equation Modeling (SEM) diagram illustrates the relationships between Socio-Factors (SF), Economic Factors (EF), Institutional Factors (IF), and their collective impact on participation in sesame farming (PSF). The direct effects indicate that economic factors have the strongest influence on PSF (β = 0.6347), followed by institutional factors (β = 0.5792) and socio-factors (β =0.5103). The diagram also shows indirect effects, such as institutional factors influencing economic factors, which subsequently affect PSF (β = 0.4216), and socio-factors influencing institutional factors, which then impact PSF (β = 0.3598). This visualization underscores the complex interplay among these factors and their significant roles in shaping productive outcomes.



3.7 Social Network Analysis (SNA) Results for Smallholder farmers participation in Sesame Farming

The Social Network Analysis (SNA) was conducted to examine how social interactions influence smallholder farmers' decisions to participate in sesame farming. The analysis focused on three key network metrics---Degree Centrality, Betweenness Centrality, and Clustering Coefficient---- to quantify the role of social connections in farming participation (Agbozo, 2024).

3.7.1 Degree Centrality - The Influence of Well-Connected Farmers

The results (Table 5) show that farmers who have more direct social connections—measured by degree centrality are much more likely to get involved in sesame farming. In fact, there's a 32.5% higher chance of participation for these farmers compared to those with fewer connections. This finding is statistically significant ($p < 0.05$) and highlights how important social ties can be in making farming decisions. It suggests that nearly a third of the differences in these decisions can be attributed to the influence of their networks and peers. This result suggests that well- connected farmers act as key sources of agricultural knowledge, technology adoption, and market information. A study by Nyanga *et al*. (2023) on smallholder farmers in Zambia found that farmers with high social connectivity were more likely to adopt improved farming techniques and access better market opportunities. The standard deviation (SD3.21) and standard error (SE-0.47) indicate moderate variation in the number of connections among farmers, highlighting differences in farmers' social positioning. The implication of this finding is that enhancing farmer networks through cooperative engagement, mentorship programs, and farmer field schools could accelerate sesame farming adoption. Policymakers and agricultural extension officers should leverage these socially influential farmers as peer educators to facilitate broader dissemination of best agricultural practices.

3.7.2 Betweenness Centrality - The Role of Intermediaries in Knowledge Transfer

Farmers with high betweenness centrality play an essential role as intermediaries, linking otherwise disconnected groups within the farming community. The analysis shows that these intermediaries influenced 27.8% of new entrants into sesame farming, demonstrating the power of social positioning in promoting agricultural participation. This aligns with findings by Kassie *et al*. (2022), who reported that farmers who acted as

intermediaries between formal institutions and farming communities were more likely to facilitate the spread of agricultural innovations in Ethiopia. With a standard deviation of 0.075 and a low standard error of 0.011, the results indicate strong statistical reliability in identifying these key intermediaries. The implication is that agricultural development programs should identify and train these influential farmers to serve as bridges between extension officers and remote or less connected farmers. Investing in digital farmer networks or smallholder farmers WhatsApp groups where these intermediaries actively participate could further enhance information flow and improve farming outcomes.

3.7.3 Clustering Coefficient - The Impact of Peer Influence on Farming Decisions

The findings show that farmers who are part of closely-knit networks have a 41.2% chance of getting involved in sesame farming. While that number might not sound huge at first glance, it's actually quite a bit higher than the 23.6% participation rate seen among farmers in more loosely connected groups. This 17.6 percentage point gap is statistically significant ($p < 0.05$), indicating that strong social ties help with sharing information, building trust, and making coordinated decisions all of which encourage more farmers to join in on sesame farming. This suggests that peer influence and group participation play a crucial role in farming decisions. Similar findings were reported by Abdulai and Hoffimann (2023), who found that farmers in strong social clusters in Ghana were more likely to adopt sustainable agricultural practices due to increased social support and knowledge- sharing. The standard deviation of 0.134 and standard error of 0.019 indicate reliable estimates, further reinforcing the importance of social clustering. The key implication is that strengthening cooperative structures, farmer associations, and village savings and loan groups can enhance sesame farming adoption. Policies should focus on incentivizing group-based training sessions, subsidizing cooperative-led seed and input procurement, and promoting trust-building mechanisms among farmers to harness the power of social capital in agriculture.

The results from the Social Network Analysis (SNA) demonstrate that social relationships significantly influence sesame farming participation, reinforcing the importance of social capital in rural agricultural development. The findings align with Granovetter's (1985) theory of social embeddedness, which argues that economic decisions are strongly influenced by social interactions. By leveraging high-degree central farmers, empowering intermediaries, and strengthening social clusters, policymakers and agricultural stakeholders can create more resilient and inclusive farming communities. Future interventions should integrate social network-based extension models to increase information diffusion, enhance technology adoption, and improve overall farm productivity.

Table 5: Key Social Network Metrics and Their Influence on Sesame Farming Participation

Metric	Mean Value	Standard Deviation (SD)	Standard Error (SE)	Key Findings
Degree Centrality	14.8	3.21	0.47	Farmers with more than 15 direct connections had a 32.5% higher likelihood of participating in sesame farming
Betweenness Centrality	0.213	0.075	0.011	Farmers acting as intermediaries between groups influenced 27.8% of new entrants into sesame farming.
Clustering Coefficient	0.57	0.134	0.019	Farmers in tightly connected groups had a 41.2% higher probability of adopting sesame farming

3.8 Relationship between Social Network Connectivity and Sesame Farming Participation

The chi-square test results in Table 6 indicate a statistically significant relationship between farmers' social network connectivity and their participation in sesame farming ($\chi^2 = 12.45$, $p = 0.001$). Specifically, 42.5% of farmers with high connectivity are actively engaged in sesame farming, whereas only 22.5% of those with low connectivity participate. Conversely, only 10.0% of highly connected farmers are non-participants, compared to 25.0% of less connected farmers. These findings suggest that farmers with more extensive social connections are more likely to participate in sesame farming, possibly due to increased access to information, resources, and market opportunities facilitated through social

networks. Socially well-connected farmers may benefit from shared agricultural knowledge, peer support, and exposure to best practices, which can enhance their decision-making and willingness to adopt sesame farming. This result aligns with the findings of Tadesse *et al*. (2022), who examined the influence of social networks on smallholder farmers' participation in farmer-based seed producer cooperatives in Ethiopia. Their study revealed that farmers with strong social ties were more likely to adopt improved agricultural practices and engage in cooperative activities due to enhanced information exchange and trust within the network. Similarly, other studies have demonstrated that social capital plays a critical role in agricultural decision-making, as networks serve as platforms for sharing knowledge, mitigating risks, and accessing financial and technical support (Rahman *et al*., 2023). These findings reinforce the argument that fostering strong social networks among farmers can significantly enhance their engagement in agricultural activities and contribute to increased productivity and market participation.

Table 6: Chi-Square Test for Social Network Categories and Sesame Farming Participation

Social Network Category	Sesame Farmers (Yes) (%)	Non-Sesame Farmers (No) (%)	Total (%)	Chi- Square (X^2)	P-value
High Connectivity	42.5%	10.0%	52.5%	12.45	0.001**
Low Connectivity	22.5%	25.0%	47.5%		

Note: p<0.05 indicates statistical significance

3.9 Influence of Social Network Metrics on Sesame Farming Participation

The binary logistic regression results in Table 7 demonstrate that social network metrics significantly influence sesame farming participation. Degree Centrality (β = 0.424, p=0.002) positively affects participation, indicating that farmers with more direct social connections are 1.523 times more likely to engage in sesame farming. This suggests that access to a broader social network enhances information exchange and farming decision-making. Betweenness Centrality (β = 1.316, p=0.008) shows the strongest effect, with an odds ratio of 3,715, highlighting that farmers who act as intermediaries in social networks are significantly more likely to participate in sesame farming. The result underscores the importance of information brokers in disseminating knowledge and facilitating resource access. Similarly, the Clustering Coefficient (β = 0.854, p=0.015) has a positive effect, with an odds ratio of 2.348, suggesting that farmers embedded in tightly connected networks benefit from peer influence and collective decision-making, which encourages participation.

The model exhibits strong predictive power, as indicated by the Nagelkerke R^2 of 0.42 and an overall classification accuracy of 78.5%. The Hosmer-Lemeshow test (p=0.65) confirms a good model fit, ensuring the reliability of the estimates. These findings align with prior studies, such as Adegbite *et al*. (2023), who found that social networks significantly improve smallholder farmers' adoption of agricultural innovations by enhancing access to knowledge and resources. Similarly, a study by Ali *et al*. (2022) in Kenya emphasized the role of social capital in increasing agricultural productivity, as farmers embedded in strong networks demonstrated higher technology adoption rates and market participation. This study reinforces the crucial role of social ties in agricultural decision-making and suggests that strengthening farmers' networks could enhance sesame farming participation and productivity.

Table 7: Binary Logistic Regression Results

Variable	Coefficient (β)	Standard Error	Odds Ratio (Exp(β))	P Value
Degree Centrality	0,424	0.113	1.523	0.002**
Betweenness Centrality	1.316	0.457	3.715	0.008**
Clustering Coefficient	0.854	0.336	2.348	0.015*
Constant	-2.303	0.805	0.104	0.004**
Model Fit Statistics				
Nagelkerke R^2 = 0.42				
Hosmer-Lemeshow Test: p=0.65 (indicating good model fit)				
Overall Classification Accuracy 78.5%				

Note: *p < 0.05* (*significant*), *p<0.01 (highly significant)*

Correlation Analysis and Multicollinearity Test

Results from Table 8 indicated that Degree Centrality and Betweenness Centrality reveal a moderate positive correlation ($r = 0.45$, $p < 0.01$). This suggests that farmers who are well-connected to many peers often play a crucial role as bridges or intermediaries in the flow of information within their network. This aligns with the common patterns seen in small-world or densely connected agricultural networks, where key individuals take on both central and brokerage roles (Borgatti *et al*., 2018). In a similar vein, Degree Centrality and Clustering Coefficient reveal a weak positive correlation ($r = 0.31$, $p < 0.01$). This relationship indicates that farmers who have more direct social ties are a bit more likely to be part of closely-knit local groups. While this connection isn't particularly strong, it does highlight a network where individuals with moderate connections tend to gather in cohesive social circles, possibly influenced by their geographic location or shared institutions. The correlation between Betweenness Centrality and Clustering Coefficient ($r=0.28$, $p <0.01$) is also significant, reflecting that intermediaries in the network are often positioned within interconnected farming groups.

To ensure that multicollinearity does not affect the regression results, a Variance Inflation Factor (VIF) test was conducted. The VIF values for Degree Centrality (1.62), Betweenness Centrality (1.43), and Clustering Coefficient (1.35) are all well below the threshold of 5, confirming that multicollinearity is not a concern in the model. These findings align with recent studies, such as Wang *et al*. (2023), who found that network cohesion enhances agricultural decision-making by reinforcing trust and cooperation among farmers. Similarly, research by Melesse *et al*. (2022) highlighted that farmers embedded in dense social networks benefit from improved information flow, leading to better resource allocation and increased productivity. This study underscores the importance of social network structures in shaping agricultural participation and decision-making.

Table 8: Correlation Matrix for Network Metrics

Variable	Degree Centrality	Betweenness Centrality	Clustering Coefficient
Degree Centrality	1.00	0.45**	0.31**
Betweenness Centrality	0.45**	1.00	0.28**
Clustering Coefficient	0.31**	0.28**	1.00
Note: $p < 0.01$ indicates strong correlation			
Multicollinearity Test (Variance Inflation Factor-VIF)			
Variable			**VIF**
Degree Centrality			1.62
Betweenness Centrality			1.43
Clustering Coefficient			1.35
Note: VIF <5 indicates no multicollinearity issues			

4. Conclusion

This study sought to examine the key socio-economic, institutional, and behaviour factors influencing smallholder participation in sesame farming in Chalinze District, Tanzania, using logistic regression, Structural Equation Modeling (SEM), and Social Network Analysis (SNA). The findings indicate that economic factors, particularly market access, input affordability, and credit availability, are the most significant determinants of farmers' participation in sesame cultivation, especially for commercial purposes for the economic growth of smallholder farmers. Institutional factors, such as access to extension services, cooperative support, and government policies, also play a crucial role, both directly and by improving economic conditions that encourage engagement. Socio-demographic factors, including age, gender, and marital status, were found to impact participation, primarily by shaping access to institutional support. The SEM analysis highlighted both direct and indirect relationships among these factors, emphasizing the need for integrated interventions that address multiple constraints simultaneously. Additionally, SNA results revealed the importance of social capital, as farmers embedded in strong social networks or acting as key intermediaries were more likely to engage in sesame farming. These findings underscore the importance of an integrated support system that combines economic incentives, institutional engagement, and social capital to foster sesame farming adoption.

To enhance sesame farming participation in Chalinze District, strategic interventions should focus on leveraging experienced farmers through mentorship programs and policies that support family- based farming to maximize labor efficiency. Economic barriers can be mitigated by improving market access through better infrastructure, price stabilization, and market information systems, while reducing input costs via subsidies and expanding access to affordable credit with low-interest loans and financial literacy programs. Institutional support should be strengthened by expanding agricultural extension services, developing cooperatives, and implementing policies that incentivize farmer participation through input subsidies and mechanization support. Additionally, fostering social capital and farmer networks through peer-to-peer learning, cooperative strengthening, and digital platforms for real-time market updates will enhance knowledge sharing and resource accessibility. Promoting youth and women participation through gender-sensitive policies, specialized training, financial incentives, and secure land tenure will encourage inclusivity in sesame farming. Furthermore, integrating social network-based extension models by training key influencers, utilizing digital communication tools, and establishing mentorship programs will further enhance engagement. By implementing these strategies, policymakers and agricultural stakeholders can create a supportive environment for sesame farmers, ensuring sustainable participation and improved productivity in the region.

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