

# DETERMINANTS OF SMALL-SCALE MACADAMIA NUT PRODUCTIVITY IN ZIMBABWE: AN ORDINAL REGRESSION MODEL ANALYSIS

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**Abstract:** *This study determines the factors influencing macadamia nut productivity among smallholder farmers in Zimbabwe's Chipinge District. Despite favourable agro-ecological conditions, smallholder productivity (1.89t/ha) significantly lags behind commercial farmers (3.9t/ha) and global benchmarks (7.17t/ha). Using cross-sectional data from 284 registered smallholder farmers collected in 2023-2024, ordinal regression analysis identified critical productivity determinants. Results revealed that farming experience significantly increases productivity, with each additional year of experience raising the log odds of achieving higher productivity by 18.4% ( $p < 0.05$ ). Labour availability positively influences productivity ( $p < 0.05$ ), particularly during labour-intensive operations like pruning and harvesting. Farm resilience score, capturing innovations that reduce field losses and improve market access, exhibited a strong positive effect ( $p < 0.01$ ). Unexpectedly, financial management skills (FMS) and risk management skills (RMS) demonstrated significant negative effects ( $p < 0.05$ ), suggesting a "formalization penalty" where sophisticated management systems incur overhead costs that fail to yield proportional returns in contexts of pervasive market failure, price volatility, and liquidity constraints. The study concludes that while farm experience, labour capacity, and resilience-building investments enhance productivity, the effectiveness of formal management skills is constrained by fundamental market structure failures. Policy recommendations emphasize capacity building in experiential learning, labour skill development, resilience-enhancing technologies, and most critically the market structure reforms to enable formal management systems to function effectively. Addressing transaction costs, information asymmetry, and capital access constraints must precede investments in sophisticated farm management training.*

**Keywords:** *Macadamia nuts productivity, Farm management, Smallholder agriculture, Ordinal regression, Zimbabwe*  
(JEL code: Q02, Q13, Q18)

## INTRODUCTION

Agriculture contributes approximately 17% to Zimbabwe's GDP, supplies 60% of industrial raw materials, and supports 65% of the population (FAO, 2023). However, persistent low productivity among small-scale producers compromises competitive market participation and threatens rural livelihoods (Fortune, 2020). Macadamia nuts (*Macadamia integrifolia*), introduced around 2000 in Zimbabwe's Eastern Highlands, have emerged as a high-value export crop with significant poverty reduction potential. The global macadamia market is projected

to reach US\$4.5 billion by 2024, growing at a Compound Annual Growth Rate of 6% (Araya et al., 2023).

Chipinge District in Manicaland Province accounts for 45% of Zimbabwe's macadamia farmers and 47% of cultivated area. Despite favourable agro-ecological conditions including average annual rainfall of 1105mm and temperatures of 12°C, smallholder yields (1.89t/ha) fall hugely short of commercial farmers (3.9t/ha) and global benchmarks of 7.17t/ha achieved in Australia and South Africa (Bandason et al. 2022; Zuza et al. 2023). This 56% productivity gap represents a substantial economic loss for smallholder farmers and

threatens the sustainability of this emerging value chain.

Understanding the factors that influence productivity is critical for designing targeted interventions to close this gap. While technical knowledge exists among farmers (Bandason et al., 2021), productivity remains constrained by complex interactions between farm-level management capabilities, resource endowments, and external market conditions. This study addresses the research question: What factors significantly influence macadamia nut productivity among smallholder farmers in Zimbabwe?

### **The problem context, objective, and novelty**

Macadamia nut productivity among smallholder farmers in Zimbabwe has declined from approximately 54% in 2005 to 38% in 2020 (Agritex, 2023), threatening the viability of this poverty-alleviating cash crop. While farmers possess technical know-how in modern production techniques, productivity remains constrained by poorly understood factors related to farm management capabilities, resource availability, and market conditions. Farmers receive prices averaging only 50% of global benchmarks, with some receiving as low as US\$0.60/kg in 2023, making current returns insufficient to justify input investments.

Despite the crop's potential, comprehensive research on productivity determinants in Zimbabwe remains limited (Chikodzi, et al., 2021). Most existing studies have not adequately examined how farm management capabilities, labour dynamics, and resilience-building investments interact to influence productivity outcomes. This knowledge gap prevents policymakers and development practitioners from designing evidence-based interventions to enhance smallholder productivity and secure the sustainability of Zimbabwe's emerging macadamia value chain.

The objective of this study is to determine the factors influencing small-scale macadamia nut productivity in Zimbabwe, with specific focus on:

- o Farm and human capital factors (age, land size, experience, and labour availability).
- o Management capability factors (financial, technical, planning, risk management, and business management skills).
- o Farm resilience factors (innovations, market access, and climate adaptation).

This study makes several original contributions to the literature by being among the first to apply ordinal regression modelling to analyse macadamia productivity determinants among Zimbabwean smallholders. Unlike prior narrowly focused agronomic studies, it adopts a multidimensional framework examining human capital, farm management capabilities, labour dynamics, and farm resilience. A notable counter-intuitive finding, the "formalization penalty" associated with financial and risk management skills, challenges prevailing assumptions about formal farm management training in smallholder contexts. By situating these constraints within Zimbabwe's broader market failures, information asymmetry, and liquidity constraints, the study fills a critical knowledge gap (Chikodzi et al., 2021), generating actionable, evidence-based guidance for policymakers seeking to enhance the sustainability of Zimbabwe's emerging macadamia sector.

## **LITERATURE REVIEW**

### **Macadamia Production in Global and Regional Context**

Global macadamia production is dominated by Australia, South Africa, Kenya, and Hawaii, where technical efficiency exceeds 85% (Mokwite, 2022). In these regions, well-coordinated value chains support reliable supply to multiple markets, driven by increasing consumer demand for healthy foods. However, technical efficiency levels in most African countries remain below 40%, primarily due to low productivity levels, poor aggregate supply, and disconnected value chain functions (Mulo, 2022).

In Africa, Kenya provides lessons for value chain development, though challenges persist including lack of information on cultivars, inconsistent market data, and poor post-harvest handling (Maina, 2020; Materechera and Scholes, 2022). South Africa's macadamia market exhibits inefficiency, with demand progressively exceeding supply due to the gap between potential productivity (100kg/tree/annum) and actual productivity (34kg/tree/annum) (Materechera and Scholes, 2022).

### **Determinants of Agricultural Productivity**

Agricultural productivity is influenced by multiple interconnected factors. Farm and human capital including farmer age, education, experience, and labour availability provide the foundational capacity for production (Bouarakia et al., 2023). Management capabilities encompassing financial planning, risk management, and business acumen determine how effectively resources are deployed (Chingarande et al., 2020).

Farming experience enables farmers to navigate challenges including pest and disease management, input supply disruptions, and price fluctuations without compromising business operations (Bouarakia et al., 2023). However, the relationship between experience and productivity can be complex, as over-reliance on past practices may inhibit adoption of innovations (Weier et al., 2024).

Labour availability critically determines productivity in quality-sensitive crops like macadamia nuts, which require careful handling during pruning and harvesting to meet export market standards (Maina, 2020; Costa et al., 2020). The interaction between labour and technology adoption remains an important policy consideration, as inappropriate technology choices can displace labour without commensurate productivity gains (Fortune, 2020).

Farm resilience which is defined as the capacity to withstand shocks and adapt to changing conditions has emerged as a critical productivity determinant (Bhunu and Kwaramba, 2022). Resilience encompasses innovations that reduce field losses, climate adaptation strategies, and reliable market access (Zuza et al., 2023; Chingwaramusee, 2021). Large-scale farmers typically benefit more from resilience investments due to better access to ICT, finance, and early warning systems compared to smallholders (Mhlanga et al., 2020).

Financial and risk management skills theoretically enhance productivity by optimizing capital allocation and mitigating uncertainty (Chingarande et al., 2020). However, in contexts of severe market failure and liquidity constraints, the benefits

of sophisticated management systems may be undermined by structural barriers (Bouarakia et al., 2023).

Despite growing interest in macadamia production, significant research gaps persist in Zimbabwe's context. First, existing studies have not comprehensively examined how multiple farm management capabilities interact to influence productivity outcomes. Second, the relationship between formal management skills and productivity in resource-constrained, market-failure contexts remains poorly understood. Third, limited evidence exists on how farm resilience investments translate into measurable productivity gains for smallholder farmers. This study addresses these gaps through rigorous econometric analysis of productivity determinants.

**Theoretical Framework**

Transaction costs theory provides a lens for understanding how market inefficiencies constrain smallholder productivity. Transaction costs in Zimbabwe's macadamia value chain take the form of what Schaner (2016) describes as the "cost of inconvenience". This is the burden that farmers bear when participating in marketing activities. For small-scale macadamia nuts farmers in remote Manicaland province of Zimbabwe, these costs include:

- o Search and information costs: Farmers lacking real-time price data must physically travel to multiple collection points, incurring opportunity costs of lost farm labour and fuel expenditure to negotiate prices and verify buyer legitimacy.
- o Bargaining and contracting costs: The weak market power is as a result of being smallholder farmers with on average 5 hectares; thus, the production volume is low. Also, the cooperation between farmers towards one common product affects the production performance in the macadamia value chain. This also affects the high negotiation costs, resulting in not being able to retain bargaining power in value chains. Moreover, currently there is a lack of facilities such as certified drying facilities that can offer opportunities in contract farming.
- o Monitoring and enforcement costs: Selling to informal

middlemen carries high risk of delayed or defaulted payments. Farmers must expend effort monitoring transactions, which is a direct transaction cost that explains preferences for quick sales of lower-quality, undried nuts rather than investing in quality improvements.

Transaction costs constitute approximately 65% of total marketing costs among smallholder farmers in Zimbabwe (Mutami, 2015; Scoones et al., 2011). Middlemen exploit information asymmetry and farmers' lack of liquid capital, paying low prices that transfer all market uncertainty onto producers while extracting disproportionate profits through control of bulking and logistics functions. In this study, these transaction costs directly constrain productivity by:

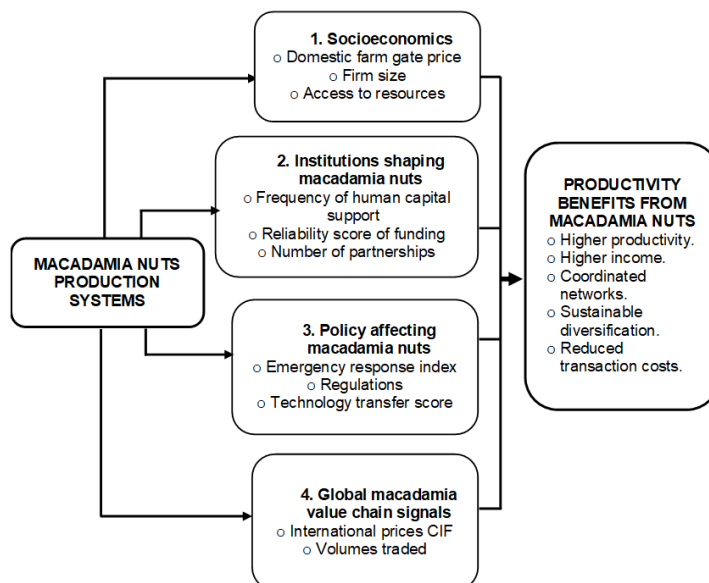
1. Reducing effective prices received, thereby lowering incentives for productivity-enhancing investments.
2. Creating liquidity constraints that prevent timely purchase of inputs.
3. Forcing farmers to prioritize quick sales over quality improvements.
4. Limiting access to information about improved production practices.

**Conceptual Framework**

Figure 1 presents the conceptual framework guiding this study. The framework posits that smallholder macadamia productivity is determined by the interaction of three key domains:

- Domain 1: Farm and Human Capital - Age, land size, farming experience, and labour availability provide the foundational capacity for production.
- Domain 2: Management Capabilities - Financial management, technical skills, planning capacity, risk management, and business acumen determine how effectively resources are deployed.
- Domain 3: Farm Resilience - Innovations that reduce losses, climate adaptation, and market access strategies enable farms to withstand shocks and capture opportunities.

**Figure 1. Conceptualizing macadamia nuts value chain functions and outcomes**



Source: Adapted from Aguiar de Medeiros et al. (2017).

These domains interact within a broader context shaped by transaction costs, market structures, and institutional arrangements. High transaction costs create a "formalization penalty" where sophisticated management systems incur overhead costs without yielding proportional returns due to market failures. This framework guided variable selection and hypothesis development for the empirical analysis.

## MATERIALS AND METHODS

### Study area, research design and sampling strategy

This 2024 study was conducted in Chipinge District, Manicaland Province, South-Eastern Zimbabwe (coordinates: 20.1938° S, 32.6206° E; elevation: 1132m). The area receives average annual rainfall of 1105mm with temperatures averaging 12°C, creating suitable conditions for macadamia cultivation alongside tea, coffee, and dairy farming. Chipinge accounts for over 43% of macadamia production in Manicaland Province and over 20% of national output.

The study adopted a pragmatic research philosophy, chosen for its flexibility in accommodating both quantitative and qualitative methods without ideological commitment to either paradigm. This enabled a more comprehensive understanding of macadamia productivity determinants than a single-method approach would allow. Mixed methods were employed to triangulate quantitative measurement of productivity determinants with qualitative insights into farm management challenges, thereby strengthening the validity and depth of findings. A cross-sectional survey design was selected for its cost-effectiveness and suitability for capturing farmer-level data at a single point in time across a geographically dispersed population. This design blended descriptive-exploratory and explanatory approaches:

the descriptive-exploratory strand served to characterize existing productivity patterns and surface emerging themes, while the explanatory strand established cause-effect relationships through rigorous econometric analysis. This provided both contextual understanding and statistically defensible conclusions.

Multi-stage sampling was employed with Manicaland Province and Chipinge District purposively selected based on macadamia nuts production dominance. The sample size was calculated using the formula suggested by Young (2016) with a known population (equation 1) and triangulated using the online sample size calculator (Calculator.net, 2026).

$$n = \frac{N}{\left[1 + N(e^2)\right]} \quad (1)$$

Where  $n$  = sample size,  $N$  = population (821 registered macadamia farmers), and  $e$  = precision level (0.05) for 95% confidence interval. A sample of 284 smallholder farmers was drawn through simple random sampling using random number generation. This is a technique chosen for its ability to eliminate selection bias and ensure every farmer in the sampling frame had an equal probability of inclusion, thereby enhancing the representativeness and generalizability of findings. Complementing this, 27 key informants were purposively selected, representing Agritex officers, buyers, processors, and farmer associations. Purposive sampling was deemed appropriate for this strand given the need to target individuals with specialized knowledge and institutional expertise in the macadamia value chain, whose insights would enrich the qualitative dimension of the study beyond what random selection could yield.

**Table 1. Population and sampling structure**

Sample cluster	Sampling technique	Research instrument to be used	Target population	Sample size
A1	Random	Questionnaire and Focus Group Discussion guide	530	228
A2	Random	Questionnaire and Focus Group Discussion guide	105	24
Estates	Purposive	Questionnaire and Key Informant Interview guide	5	5
Other stakeholders	Purposive	Questionnaire and Key Informant Interview guide	181	27
<b>Total</b>			<b>821</b>	<b>284</b>

Source: Survey analysis (2024)

### Data Collection

Primary data were collected in 2024 using a combination of approaches, with multiple data collection methods deliberately employed to capture the multifaceted nature of macadamia productivity determinants and reduce the limitations inherent in relying on any single instrument. Secondary data drawn from company records, farmer group reports, and policy documents complemented the primary data, providing historical context, institutional perspectives, and corroborating evidence that

strengthened the overall analytical framework and enhanced the credibility of the study's conclusions.

1. Structured questionnaires administered to farmers, covering: (A) socio-economic and demographic characteristics, land ownership, production patterns; (B) management capabilities across financial, technical, planning, risk management, and business domains; (C) farm resilience indicators including innovations, market access, and climate adaptation; (D) productivity outcomes measured in kg/ha.

2. Semi-structured key informant interviews with 27 stakeholders including Macadamia Growers Association representatives, Zimbabwe Farmers Union officials, Agritrex officers, middlemen, and processors to gain insights into value chain dynamics and productivity constraints.

3. Focus group discussions held during district and provincial development workshops enabled cross-stakeholder dialogue and triangulation of findings.

**Variable Selection and Measurement**

Variables were selected based on established agricultural economics literature and the study's conceptual framework,

ensuring theoretical grounding and relevance to the Zimbabwean macadamia context. The dependent variable, productivity, was deliberately categorized into three ordinal levels namely low, medium, and high based on kg/ha output relative to district averages. This categorization was adopted rather than treating productivity as a continuous variable, as it more accurately reflects the discrete, hierarchical nature of smallholder productivity outcomes and fulfils the distributional assumptions required for ordered logit regression. This made it the most statistically appropriate analytical technique for the data structure at hand.

**Table 2. Description of variables in the productivity model**

Variable	Description	Unit	Expected Effect
<b>Dependent Variable</b>			
Productivity	Categorical variable (1=low, 2=medium, 3=high)	Kg/ha	
<b>Explanatory Variables</b>			
Age	Age of principal decision maker	Years	+
Land size	Total land holdings	Hectare	+/-
Experience	Cumulative years farming macadamia	Number	+
Total labour	Total labour available (indexed by age)	Number	+/-
FRS	Farm Resilience Score (transformed from Likert scales)	Index	+
FMS	Financial Management Skills (transformed)	Index	+
BMS	Business Management Skills (transformed)	Index	+
PAS	Personal Attributes Score (transformed)	Index	+
TSS	Technical Skills Score (transformed)	Index	+
PSS	Planning Skills Score (transformed)	Index	+
RMS	Risk Management Skills (transformed)	Index	+

Source: Authors' own computation.

Management skill variables were constructed by transforming Likert scale responses measuring farmers' capabilities across multiple dimensions. The Farm Resilience Score captured innovations, climate adaptation, and market access strategies. The selected variables fall into two main categories: Farm and human capital (including age, land size, experience, and total labour, which measure the scale of operation and foundational knowledge), and Management skills (including variables for financial, technical, planning, risk management, and general business skills, all of which are transformed continuous variables designed to capture the quality and sophistication of the farmer's decision-making process). This comprehensive selection ensures the model tests how physical resources, experience, and the quality of farm management influence the farmer's likelihood of achieving a high, medium, or low productivity level.

**Analytical Framework**

Ordinal regression was employed to analyse productivity determinants. This technique allows examination of relationships between independent variables and a categorical dependent variable with natural ordering (low < medium <

high productivity). The model specification (Abid et al., 2020), follows:

$$P(Y \geq y_j | x) = \frac{1}{1 + \exp(\alpha_j + x' \beta)}, j = 1, 2, 3 \tag{1}$$

Transforming to logit form:

$$\log \left[ \frac{P(Y \geq y_j | x)}{1 - P(Y \geq y_j | x)} \right] = \alpha_j + x' \beta, \text{ for } j = 1, 2, 3. \tag{2}$$

Where  $P(Y \geq y_j | x)$  is the cumulative probability of an event ( $Y \geq y_j$ );  $\alpha_j$  is the respective constant term/intercepts and  $\beta$  is the vector of regression coefficients with the dimension of (p by 1) corresponding to the xi covariates.

Zeng et al. (2015) also noted that another critical interpretation of the ordinal logit regression model is the odds ratio which is the probability ratio of the sampled macadamia nuts farmers. The estimation of the logit model was done using the Maximum Likelihood (ML) method. In this research, the high

productivity cluster farmers were utilized as the reference group. As such, the form of odds ratios in natural logarithms (ln) for the farmers are as follows:

$$\ln \left[ \frac{P_{i1}}{P_{i2}} \right] = \alpha_{01} + \beta_{11} X_1 + \beta_{21} X_{21} + \beta_{31} X_3 + \dots + \beta_{n1} X_n + \mu_{i1}$$

(3)

$$\ln \left[ \frac{P_{i2}}{P_{i3}} \right] = \alpha_{02} + \beta_{12} X_1 + \beta_{22} X_2 + \beta_{32} X_3 + \dots + \beta_{n2} X_n + \mu_{i2}$$

(4)

Where Probability of Pi1 (P (Y = 1)) if the farm has low productivity, Pi2 Probability (P (Y = 2)) if the farm has medium productivity, Pi3 probability (P (Y = 3)) if the farm has high productivity.

Regression coefficients are interpreted as the predicted change in log odds of being in a higher productivity category per unit increase in the independent variable, controlling for other variables (Liu, 2008).

Pilot testing ensured instrument validity. Cronbach's Alpha test yielded 0.889 for the questionnaire (81 items), exceeding the 0.60 threshold for acceptable internal consistency (Majeed, 2019). The key informant interview guide achieved 0.894. Data quality was ensured through researcher-administered questionnaires, digital recording of interviews, and systematic coding of qualitative data.

## RESULTS AND DISCUSSION

### Sample Characteristics and Response Rate

The study achieved a 93.7% response rate, with data collected from 266 of the targeted 284 farmers (246 A1 smallholders, 15 A2 smallholders, and 5 Estates). This response rate exceeds the 83% regional average, attributed to effective collaboration with extension officers who ensured respondent availability during data collection.

Productivity distribution revealed significant underperformance: 62.74% of farmers fell into the low productivity category (<1.5t/ha), 23.53% achieved medium productivity (1.5-2.5t/ha), and only 13.73% attained high productivity (>2.5t/ha). This distribution aligns with findings by Materechera and Scholes (2022) in South Africa's macadamia sector, confirming widespread technical inefficiency among smallholder producers in the region.

The median age of principal decision makers was 48 years (range: 26-75 years), comparable to the 44-year median reported by Weier et al. (2024) in macadamia orchard management studies. This indicates that macadamia farming in Zimbabwe is dominated by middle-aged to older farmers, with limited youth participation in the sector. Zuza et al. (2023) reported varying age ranges among extension agents supporting macadamia development in Malawi, highlighting the policy need for context-specific farm management interventions to avoid one-size-fits-all approaches.

**Table 3. Summary of the variables used in the model**

Variables	Frequency	%	Valid %	Cumulative %
<b>Productivity:</b>				
	<b>Min.</b>	<b>Max.</b>	<b>Mean/Median</b>	<b>Std. Dev.</b>
Age of Respondent	26	75	48.00	12.98
Farming Experience	3	50	12.50	9.83
Total Land Size	2.60	40.00	3.47	6.24
Labour Reliability Index	2.00	11.00	2.93	2.49
Weighted Resilience	1.57	5.00	3.30	0.74
Financial Management Score	1.58	4.33	2.81	0.67
Business Management Score	2.10	4.70	3.19	0.69
Personal Attributes Score	2.38	5.00	3.69	0.57
Technical Skills Score	2.00	4.93	3.26	0.68
Planning Skills Score	1.00	5.00	3.65	0.91
Risk Management Index	1.63	4.88	2.58	0.56

Source: Survey analysis (2024)

Farming experience ranged widely up to 47 years (average 12.5 years), a pattern echoed globally (e.g., Bhunu and Kwaramba 2022 in Zimbabwe; Araya et al. 2023 in Malawi), urging policies that support all farmer levels while encouraging youth participation in agribusiness. Average land size was 3.47 hectares (range nearly 37 hectares), underscoring variability best addressed via ordinal regression models like this study's; transformed farm management skills averaged 1-5 on the Likert scale.

### Model diagnostics

Table 4 displays the model fit summary, goodness of fit statistics, parallel lines test outcomes, and ordinal logistic regression analysis results. A primary constraint of the ordinal regression approach is that unmeasured variables may affect macadamia nut productivity and introduce bias into the model's conclusions. Important unaccounted factors include farm-level specifics such as soil composition and tree condition, as well as comprehensive credit and capital access data. Excluding these influential variables means the reported impacts of measured

factors such as infrastructure and market linkages on productivity could be overestimated or underestimated due to omitted variable bias. Consequently, the analysis cannot provide a complete causal account of all productivity variations observed.

Testing the model's assumptions was crucial for establishing both its robustness and practical applicability to macadamia farmers in Zimbabwe's Chipinge District. The model fit information provides sufficient statistical evidence of good fit ( $p < 0.05$ ), demonstrating that the independent variables included in the ordinal regression are collectively meaningful and effectively capture the data's underlying patterns. These results indicate the model's predictions substantially outperform chance, enhancing confidence in the findings. Therefore, the estimated coefficients can be trusted to accurately represent genuine relationships between the measured value chain factors including infrastructure and market linkages and macadamia

nut productivity within this study context.

The parallel lines test reveals no violation of assumptions ( $p > 0.05$ ), confirming the statistical appropriateness of the model. The Nagelkerke statistic indicates that 43.9% of the variance in the dependent variable is explained by the model. In practical terms, this demonstrates that the model has identified significant, actionable intervention points, enabling policymakers and development organizations to confidently prioritize these factors when designing programs. This quantified relationship provides substantial justification for targeting investments toward the model's significant predictors, thereby minimizing investor risk while offering farmers clear direction on which structural and institutional factors to address for productivity improvement. The ordinal regression model analysis results appear in Table 4 below.

**Table 4. Results from the ordinal regression analysis with parameter estimates**

Variables		Estimate	Std. Error	Sig.	Odds Ratio (OR)	Sig.
<b>Threshold</b>	[Productivity = 1.00]	3.809	0.198	0.198	45.121	0.181
	[Productivity = 2.00]	5.855	0.059	0.059***	348.972	0.052
<b>Location</b>	Age	-0.039	0.339	0.339	0.962	0.370
	Total land size	-0.076	0.280	0.280	0.927	0.274
	Experience	0.184	0.029	0.029**	1.202	0.030**
	Labour index	0.417	0.029	0.029**	1.517	0.029**
	PSS	-0.172	0.792	0.792	0.842	0.792
	TSS	1.631	0.078	0.078***	0.377	0.258
	FRS	2.407	0.025	0.025**	11.102	0.023**
	RMS	-0.574	0.564	0.564	0.061	0.044**
	PAS	1.243	0.248	0.248	3.464	0.249
	FMS	-0.975	0.251	0.251	5.107	0.066***
BMS	-2.803	0.050	0.050**	0.563	0.565	
<b>Test of parallel lines</b>						
<b>Model</b>	-2 Log Likelihood		Chi-Square		df	Sig.
<b>Null Hypothesis</b>	61.102					
<b>General</b>	52.525		8.577		11	0.661
<b>Model fitting information</b>						
<b>Model</b>	-2 Log Likelihood		Chi-Square		df	Sig.
<b>Intercept only</b>	81.741					
<b>Final</b>	61.102		20.639		11	0.037
<b>Goodness-of-fit</b>						
			Chi-Square		df	Sig.
<b>Pearson</b>			70.409		77	0.689
<b>Deviance</b>			61.102		77	0.908
<b>Pseudo R-Square</b>						
<b>Cox and Snell</b>					0.368	
<b>Nagelkerke</b>					0.439	
<b>McFadden</b>					0.252	

Notes: Link function is the Logit; \*, \*\* and \*\*\* indicate p-values significant at 1%, 5%, and 10% levels, respectively; reference category is the high productivity class [Productivity = 3.00].

Source: Survey analysis (2024)

The ordinal regression model identified five statistically significant variables ( $p < 0.05$ ) that substantially affect macadamia nut productivity, indicating that performance depends on human capital, on-farm resources, and specific structural elements working in combination. The findings demonstrate that macadamia nut productivity is fundamentally shaped by three key positive drivers namely, farm resource score (FRS), labour index, and farmer experience. FRS emerges as the strongest predictor, with a substantial Odds Ratio (OR) of 11.102 ( $p < 0.05$ ), showing that access to enhanced farm resources and capital dramatically elevates the likelihood of attaining higher productivity levels. Both labour index (OR: 1.517,  $p < 0.05$ ) and farmer experience (OR: 1.202,  $p < 0.05$ ) also demonstrate significant positive effects on performance. In contrast, business management score (BMS) exhibited a significant inverse relationship (Estimate:  $-2.803$ ,  $p = 0.050$ ), implying that existing management practices, as currently applied or assessed, are actively undermining overall productivity. Meanwhile, the technical adoption score (TSS) presents a more nuanced picture. Together, these five significant variables confirm that investments in human and physical capital represent the highest-leverage intervention opportunities, although the effectiveness of technical adoption strategies and management systems warrants urgent reassessment.

Despite clear evidence supporting productivity enhancement through targeted investment, the existing value chain exhibits pronounced financial inequity and structural barriers. Farmers retain merely 0.16% of the domestic value, while processors and agents appropriate the overwhelming majority of profits illustrated by the processor's 34.97% gross margin. This imbalance persists due to absent local processing facilities in production areas and failure to achieve international certification requirements, which constrains export potential and diminishes investment interest in productive regions. Remedying this situation demands a two-pronged strategy involving offering fiscal incentives such as tax holidays to attract local agro-processing establishments, and encouraging formal association participation (notably, 56.5% of female respondents hold membership versus 48.1% of male respondents). This strengthens collective bargaining power and market accessibility, particularly benefiting women farmers.

### **Determinants of small-scale macadamia nut productivity in Zimbabwe**

The objective was to determine the factors influencing small-scale macadamia nut productivity and identify promising leverage points for sustainable development in Zimbabwe. The study shows the need for decision-makers to understand how the different farm management competencies factors affect productivity while acknowledging the need to continuously review the resilience and risk management issues. This helps the decision makers in macadamia nuts production to design practical interventions to tackle the farm management challenges related to their skills in sourcing for resources, reducing risks while harnessing the opportunities that exist in enhancing productivity in competitive macadamia nuts business (Mokwite, 2022). Decision makers must adopt diverse farm management skills suitable for their farm resource endowments, especially regard-

ing labour and the decision maker's experience in dealing with the aforementioned challenges and opportunities. Several factors are discussed in this subsection in relation to how they affect productivity.

### **Macadamia nuts farming experience**

Farming experience emerged as the strongest positive predictor of productivity. For every additional year of macadamia farming experience, the log odds of achieving higher productivity increase by 0.184 (18.4%), holding other factors constant. This translates to a 20.2% increase in the odds ratio of moving to a higher productivity category. Experienced farmers exhibit superior skills in pest and disease management by recognizing symptoms early and applying targeted interventions, as well as in optimizing input timing to apply fertilizers and chemicals during critical windows. They also excel in quality management through practices that boost kernel recovery and meet export standards, and in navigating markets by forging relationships with reliable buyers and strategically timing sales.

These findings align with Bouarakia et al. (2023) and Scheepers (2018), who observed that macadamia farmers with more experience effectively navigate production challenges without compromising business operations. However, the complexity of the experience variable emerges when farmers over-rely on past practices, potentially inhibiting innovation adoption (Weier et al., 2024). From a policy implication perspective, extension programs should emphasize experiential learning through farmer field schools, demonstration plots, and mentorship programs pairing experienced and novice farmers. However, continuous learning must be encouraged to prevent experience from becoming a barrier to innovation adoption.

### **Index labour availability**

Labour availability significantly increases productivity ( $p < 0.05$ ). As indexed effective labour increases by one unit, the log odds of achieving higher productivity increase by 0.143 (14.3%). The odds ratio of 1.154 indicates that farmers with adequate labour are 15.4% more likely to achieve higher productivity categories.

Macadamia production is labour-intensive during pruning (January-March), which requires skilled labour to maintain tree structure and optimize fruiting, and during harvesting (March-September), demanding timely collection to prevent quality deterioration. Post-harvest processing further intensifies labour needs, as dehusking and drying demand careful handling to meet quality standards.

The positive labour effect confirms findings by Maina (2020) and Costa et al. (2020) regarding the importance of adequate labour even in technology-intensive systems. However, the challenge remains balancing labour costs with productivity gains, particularly as rural wage rates increase. Policies should support labour-saving technologies appropriate for smallholder contexts while investing in labour skill development. Community-based labour-sharing arrangements and mechanization of non-skilled operations (like dehusking) could optimize labour deployment during critical periods.

### **Farm resilience score**

Farm Resilience Score demonstrates the second-strongest positive effect on productivity ( $p < 0.01$ ). For every unit increase in FRS, the log odds of achieving higher productivity increased by 0.267 (26.7%). The odds ratio of 1.306 indicates that farmers with higher resilience scores are 30.6% more likely to achieve higher productivity. The FRS captured three key dimensions in macadamia farming: innovations reducing field losses through improved pest and disease management, mulching, and irrigation. It also highlighted climate adaptation strategies like drought-resistant practices and shade management, alongside market access improvements via diversified buyers, contract arrangements, and quality premiums.

For smallholders producing macadamia nuts, building resilience involves direct sales to high-end markets like supermarkets and restaurants that offer competitive prices for quality nuts. It also requires contract farming arrangements for input access and price stability, plus cooperative membership to enable collective investments in processing and marketing infrastructure.

These findings align with Bhunu and Kwaramba (2022) and Zuza et al. (2023), who documented strong relationships between business resilience and productivity. However, scale matters as shown by Mhlanga et al. (2020) who observed that large-scale farmers benefit more from resilience investments due to better access to ICT, finance, and early warning systems.

Government and development partners should prioritize investments in farmer resilience (Chisoro et al. (2023)). This should be achieved through three interconnected pillars including subsidized access to climate-smart technologies, facilitation of contract farming arrangements with equitable terms, and development of domestic high-value markets to reduce transaction costs compared to export markets.

#### **Indexed financial management skills score**

Contrary to theoretical expectations, Financial Management Skills (FMS) exhibited a significant negative effect on productivity ( $p < 0.05$ ). For every unit increase in FMS, the log odds of achieving higher productivity decrease by 0.118 (11.8%). The odds ratio of 0.889 indicates that farmers with higher FMS are 11.1% less likely to achieve higher productivity.

This counterintuitive finding reveals a "formalization penalty" in Zimbabwe's macadamia value chain amid severe market failure, where theoretical benefits of robust financial management such as optimizing capital allocation, maintaining detailed records, strategic investment planning, and effective cash flow management are outweighed by harsh realities. Overhead costs from time-intensive record-keeping yield no proportional returns, sophisticated planning fails against price volatility, delayed payments, and credit scarcity, liquidity constraints expose capital gaps without solutions, and transaction cost barriers block profitable opportunities despite clear financial analysis.

The finding aligns with Bouarakia et al. (2023), who observed that financial management skills among smallholder macadamia farmers are too narrow to drive productivity in contexts of resource poverty. Chingarande et al. (2020) similarly noted that formal management systems require enabling market

structures to function effectively.

Critical interpretation shows that the FRS variable (which is highly significant and positive) represents access to hard capital which facilitates actual resources and market linkages. FMS represents management sophistication, which is the ability to plan and allocate resources. In this system, access to resources (FRS) is the binding constraint, rendering sophisticated management capabilities (FMS) ineffective until market structure and capital access are fundamentally improved.

Before investing in financial management training, policy-makers must address underlying market failures while focusing on reducing transaction costs through improved infrastructure and buyer aggregation, establishing reliable payment systems to reduce liquidity risk, and developing accessible agricultural credit products. Attention must also be paid to stabilize prices through market information systems and contract enforcement. Only after these structural reforms will financial management skills translate into productivity gains.

#### **Indexed risk management skills score**

Risk Management Skills (RMS) also exhibited a significant negative effect on productivity ( $p < 0.05$ ). For every unit increase in RMS, the log odds of achieving higher productivity decrease by 0.156 (15.6%). The odds ratio of 0.856 indicates that farmers with higher RMS are 14.4% less likely to achieve higher productivity. This finding suggests three important aspects:

- a) Current risk management strategies are misaligned with actual risk profiles: Farmers' risk management approaches may focus on diversification (reducing specialization in macadamia) or conservative input use (underinvesting in productivity-enhancing inputs) rather than strategies that directly enhance macadamia productivity (Araya et al., 2023).
- b) The dynamic risk environment exceeds management capacity: Macadamia production faces multidimensional risks (price volatility, pest outbreaks, climate variability, payment defaults) that overwhelm farmers' risk management capabilities, leading to risk-averse behaviors that constrain productivity (de Medeiros and Trebat (2017).
- c) Formal risk management creates overhead without proportional benefits: Similar to FMS, sophisticated risk assessment and mitigation planning incur time and cognitive costs without yielding productivity gains in the absence of actual risk management tools (insurance, forward contracts, stabilization mechanisms).

Araya et al. (2023) noted similar concerns about the adequacy of risk management strategies in dynamic agricultural systems. Abid et al. (2020) specifically warned that contract farming which is often promoted as a risk mitigation tool can lock farmers into unfavourable arrangements that increase vulnerability rather than reducing it.

From policy implication viewpoint, risk management capacity building must be paired with actual risk management instruments including index-based insurance products covering climate and price risks, enforceable forward contracts with price floors, collective risk-sharing mechanisms through

cooperatives, and price stabilization funds managed by farmer organizations. Additionally, risk management training should emphasize productive risk-taking (investing in quality improvements, forming buyer relationships) rather than defensive strategies (diversification away from macadamia, underinvestment in inputs).

## CONCLUSION

This study determined factors influencing macadamia nut productivity among smallholder farmers in Zimbabwe using ordinal regression analysis of data from 284 farmers. Five key conclusions emerge:

a) First, farming experience is the strongest positive productivity determinant, with each additional year of experience increasing the odds of achieving higher productivity by 20.2%. Experiential learning enables farmers to navigate production challenges, optimize input timing, manage quality, and build market relationships effectively.

b) Second, labour availability significantly enhances productivity, particularly during labour-intensive operations like pruning and harvesting. Adequate, skilled labour is essential even in technology-intensive production systems to maintain quality standards required by export markets.

c) Third, farm resilience capturing innovations that reduce losses, climate adaptation strategies, and market access improvements, strongly predicts productivity. Farmers who invest in resilience-building achieve 30.6% higher odds of reaching higher productivity categories.

d) Fourth, financial management skills exhibit an unexpected negative effect on productivity, suggesting a "formalization penalty" where sophisticated management systems incur overhead costs without yielding proportional returns in contexts of severe market failure, price volatility, and liquidity constraints. Access to actual resources (captured by Farm Resilience Score) is the binding constraint, rendering management sophistication ineffective until market structures are fundamentally improved.

e) Fifth, risk management skills similarly show negative effects, indicating that current risk management strategies are misaligned with actual risk profiles or that the dynamic risk environment exceeds farmers' management capacity without actual risk management instruments (insurance, forward contracts, stabilization mechanisms).

An overarching conclusion is also made showing that, while farm experience, labour capacity, and resilience-building investments enhance productivity, the effectiveness of formal management skills (financial, risk management) is fundamentally constrained by market structure failures. In the macadamia value chain, sophisticated management cannot overcome problems of information asymmetry, transaction costs, limited credit access, and weak governance in buyer-farmer relationships. This suggests that policy interventions must address underlying market failures before investing heavily in management capacity building.

### Policy Recommendations

Based on findings, the following policy recommendations

are proposed:

a) Strengthen experiential learning systems: Establish farmer field schools, demonstration plots, and mentorship programs pairing experienced macadamia farmers with novices to accelerate knowledge transfer, as experience boosts productivity by 18.4% annually and enables rapid mastery of production and marketing skills. Extension services should shift from workshops to hands-on, learning-by-doing methods using model farms as training centers.

b) Develop labour skills and optimize deployment: Invest in labour skill development via targeted training in pruning, harvesting, and post-harvest handling, while facilitating community-based labour-sharing arrangements. Labour availability boosts productivity odds by 15.4%, yet skilled labour shortages persist during peaks; implementation involves specialized short courses at agricultural institutes and cooperative labour registries to match needs with workers.

c) Scale up farm resilience investments: Provide subsidized access to resilience-enhancing technologies like irrigation, pest management, and climate-smart practices, while facilitating equitable contract farming arrangements. Farm resilience drives 30.6% higher productivity odds, so smallholders need support for innovations, climate adaptation, and market links; implementation includes a government-backed Farm Resilience Fund for matching grants and extension-promoted transparent contracts.

d) Address market structure failures before management training: Before financial and risk management training, prioritize market structure reforms to cut transaction costs via improved rural infrastructure (roads, storage), buyer aggregation points, and mobile money for swift payments. The farmers union should support the establishment of a multi-stakeholder Macadamia Market Development Task Force comprising government, private buyers, farmer organizations, and financial institutions to design and implement coordinated market structure reforms over a 3-5 year period.

e) Develop domestic high-value markets: Facilitate direct linkages between smallholder farmers and domestic high-value buyers like supermarkets, restaurants, and hotels that pay competitive prices for quality nuts. Domestic sales cut transaction costs versus exports while matching returns, offering smallholders value capture; implementation includes buyer-farmer matching events, fair contract support, quality certification, and marketing campaigns to boost consumption.

f) Promote cooperation and strengthening of networks: Support formation of professionally managed farmer cooperation platforms, building capacity in collective marketing, input procurement, and member services. Cooperatives shall be an effective model since they aggregate volume to lower transaction costs, secure better prices, access group credit, and fund shared infrastructure unaffordable for individuals. Further, their implementation offers technical assistance, seed funding, buyer/finance links, governance training, and peer exchanges with successful experiences drawn from Kenyan and South African models and adapted to the Zimbabwean context.

### Limitations and areas for further studies

Several limitations should be acknowledged. First, the study's cross-sectional design captures associations but cannot definitively establish causation. Longitudinal studies tracking farmers over multiple seasons could strengthen causal inference. Second, geographic scope is limited to Chipinge District. National surveys would enhance generalizability and enable regional comparisons. Third, productivity was farmer-reported rather than measured directly, introducing potential recall bias despite triangulation with secondary data. Future research should:

1. Conduct longitudinal studies tracking how productivity determinants evolve as farmers gain experience and as market conditions change.

2. Expand geographic scope through national surveys enabling regional comparisons and identification of context-specific productivity drivers.

3. Investigate mechanisms through which experience translates into higher productivity using detailed time-use studies and decision-making analysis.

4. Develop and test interventions addressing market structure failures, evaluating their impact on both market functioning and the effectiveness of management skills.

5. Examine gender dimensions of productivity determinants, particularly regarding labour availability, resource access, and decision-making authority.

6. Analyze the "formalization penalty" more deeply through comparative studies of farmers at different levels of management sophistication operating in varying market contexts.

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