Investigating the Cattle Supply Chain in the Northern Communal Areas of Namibia: A Case Study Paper of the Oshikoto and Zambezi Regions

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ABSTRACT

This paper examines cattle marketing behaviour and supply chain performance in Namibia's Northern Communal Areas, focusing on the Oshikoto and Zambezi regions. Although the NCAs hold a substantial share of the national cattle herd, formal market offtake remains low, limiting rural incomes, value addition, and abattoir utilisation. Using survey data from 116 communal cattle farmers, the study applies descriptive statistics, Principal Component Analysis, cluster analysis, and Random Forest modelling to identify marketing channels, assess drivers of channel choice, and map key supply chain bottlenecks. The findings show that farmers rely strongly on informal marketing channels, particularly in Zambezi, where poor transport infrastructure, high logistics costs, seasonal road challenges, animal health risks, and limited price information constrain formal market participation. The Oshikoto region shows comparatively higher engagement with auctions and abattoirs, reflecting better infrastructure and market access conditions. Transportation cost per head emerges as the strongest determinant of marketing channel choice, followed by herd dynamics, price uncertainty, cattle age, disease outbreaks, and access to market information. Cluster results further reveal that communal cattle farmers face different combinations of constraints, indicating that the NCAs should not be treated as a homogeneous production system. The study concludes that improving formal offtake requires reducing transport and transaction costs, strengthening price information systems, improving veterinary and production support, simplifying formal market procedures, and designing region-specific interventions instead of using an umbrella approach. These measures are essential for improving supply chain efficiency, increasing abattoir utilisation, supporting rural livelihoods, strengthening producer participation, and promoting more inclusive cattle commercialisation in Namibia's communal areas.

Keywords: Communal Cattle Farming; market access; transaction costs; supply chains; Namibia

INTRODUCTION

In Namibia, it is estimated that approximately 70% of the population relies on agriculture directly (Namibia Statistics Agency, 2019) or indirectly for their livelihoods, and that the sector employs about 23% of the population (Namibia Statistics Agency, 2018). Livestock contributes significantly (over 50%) to the agricultural GDP (Namibia Statistics Agency, 2024). Namibia is divided into two livestock production systems: the Northern Communal Areas (NCAs), located north of the Veterinary Cordon Fence (VCF), and the commercial areas, south of the VCF (Behnke, 1998). The NCAs hold approximately 46% of Namibia's total cattle population, which is about 1,157,584 out of 2.5 million (Directorate of Veterinary Services, 2021). The region has a large cattle population but experiences low formal market offtake rates (Werner, 2021). Abattoirs in the NCAs, such as Oshakati-Eloolo, Otavi, and Rundu, ceased operations in 2015, with only Katima Abattoir (an export abattoir) operating under Meatco as of 2022 (Livestock and Livestock Products Board of Namibia, 2023). Katima Abattoir has low utilization rate representing about 30% in 2022 and 25% in 2023 (Livestock and Livestock Products Board of Namibia, 2023).The combined slaughtering capacity of registered abattoirs in the NCAs is 88,820 head of cattle (Meatco, 2021), yet in 2022, only 8,007 cattle were sourced and slaughtered, resulting in a formal market offtake of around 1% (Livestock and Livestock Products Board of Namibia, 2023). The low production implies that the NCAs' beef supply is insufficient for its population, leading to increased imports from south of

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the VCF. Table 1 shows the slaughtering capacity of registered abattoirs in the NCAs, as well as the actual versus potential beef production in the NCA.

Table 1. NCA Abattoir Capacity versus Actual Slaughter 2024

NCAs Abattoir	**Slaughter Capacity – Cattle (n)**		
Oshakati Abattoir	42 420		
Rundu Abattoir	20 000		
Katima Export Abattoir	12 500	**Actual Formal Beef Production Quantity – 2024 (kgs)**	**Potential Beef Production Quantity of NCA (kgs)**
Eenhana Abattoir	6 000		
Opuwo Abattoir	6 000		
Outapi Abattoir	6 000		
Meatco Mobile Slaughter Unit	5 500		
Oshakati Municipal Abattoir	2 400		
Total capacity	**88 820**	**1,647,941.75**	**18 637 100.60**

Source: Livestock and Livestock Products Board of Namibia, 2024.

Taken together, these trends highlight a clear mismatch between production potential and formal market performance in the Northern Communal Areas. Despite substantial cattle numbers and available slaughter infrastructure, formal offtake remains low while informal channels continue to dominate. This suggests that the central challenge is not simply cattle production, however, the broader set of logistical, informational, and institutional constraints that shape farmers' marketing decisions and limit the effectiveness of existing supply chains.

According to previous studies in the NCAs, the Oshikoto and Zambezi regions represent contrasting contexts on remoteness and weak infrastructure. Shiimi et al., (2012) and Werner, (2021) point out that Zambezi region is particularly constrained by poor transport access, high transaction costs, and limited access to market information, which collectively reinforce farmers' dependence on informal sales. In contrast, some parts of the Northern Communal Areas show relatively stronger engagement with formal markets, reflecting local differences in infrastructure and market access conditions. For example, better-developed road networks and proximity to quarantine and auction facilities improve formal marketing opportunities in parts of Oshikoto compared to more remote areas in the Zambezi Region (Enkono et al., 2013; Venter, 2011).

This is consistent with broader evidence that regional infrastructure and institutional access influence formal market participation in communal cattle systems in Namibia. These regional differences, documented in recent empirical work, provide a valuable basis for comparing how infrastructural conditions and farmer-level characteristics shape market participation in communal cattle systems. Despite these insights, much of the existing literature examines barriers individually or treats the NCAs as a relatively homogeneous production system. This risks obscuring how constraints interact across locations and among different categories of farmers.

This study addresses this gap in two ways. First, it examines how multiple constraints jointly shape cattle marketing behaviour, rather than focusing on single explanatory factors. Second, it compares two contrasting regions within the NCAs, Oshikoto and Zambezi, to identify how regional conditions influence channel choice

and supply chain performance. The Oshikoto region represents a relatively better-connected north-central production area, while Zambezi faces greater remoteness, transport challenges, and animal health risks. Comparing these settings provides a clearer basis for understanding intra-regional heterogeneity in communal cattle markets.

Guided by Transaction Cost Economics as an interpretive framework, this paper analyses cattle marketing behaviour using survey data from communal cattle farmers. Descriptive analysis is used to identify dominant marketing channels, cluster analysis is used to explore farmer segments facing similar combinations of constraints, and Random Forest modelling is used to rank the relative importance of factors associated with observed channel choice. These methods are applied as exploratory tools to better understand complex decision environments rather than to estimate causal behavioural parameters. This paper provides new evidence on how logistical, informational, herd-related, and regional factors jointly shape market participation in Namibia's communal cattle sector. The findings have practical relevance for designing regionally differentiated interventions aimed at improving formal offtake, strengthening abattoir utilisation, and increasing the efficiency and inclusiveness of cattle supply chains in the NCAs.

The remainder of the paper is structured as follows. The next section reviews relevant literature. Description of the study area, data, and methods. Presentation of the results and discussion and the final section conclude and offers policy recommendations.

LITERATURE REVIEW

We provide empirical literature arguments under the following headings to conceptualise the research problem of cattle supply chain in the northern communal areas of Namibia.

Informal Livestock Marketing and Farmer Behaviour

Livestock supply chains in sub-Saharan Africa operate under persistent constraints such as high transaction costs, weak infrastructure, and limited access to formal markets. These factors contribute to the dominance of informal marketing systems, where flexible negotiations, lower compliance requirements, and immediate cash payments make them attractive to smallholder farmers (Pingali et al., 2005). Therefore, farmer decisions are shaped not only by price incentives but also by access conditions, social relationships, and risk management strategies (Chaudhuri et al., 2021).

Market Segmentation in Namibia

The livestock sector in Namibia presents a structural divide created by the VCF has long influenced livestock marketing outcomes. Early work by Behnke (1998) highlighted how the VCF restricts market integration between the Northern Communal Areas and the commercial farming sector. Although several policy reforms have been introduced since 1998 to reduce these disparities, including investments in abattoir infrastructure and efforts to expand animal health certification systems, recent studies show that the divide remains intact. Farmers north of the fence continue to face higher transaction costs, lower prices, and limited access to formal markets (Institute for Public Policy Research (IPPR, 2019a; Werner, 2021). These challenges continue to reinforce reliance on informal marketing channels.

Informal Cattle Markets and Price Formation in Communal Areas

Evidence from Namibia shows that informal markets serve as the primary outlet for cattle sales in many communal areas. The Millennium Challenge Account (2014) documented extensive farmer-to-farmer and roadside trading, highlighting the importance of informal exchange for local livelihoods despite limited regulation and quality control. Kalundu & Meyer (2017) further showed that prices in informal cattle markets are shaped by cattle condition, seasonality, and negotiation-based transactions. Collectively, these findings suggest that informal markets persist not simply because of tradition, but because they provide accessible, flexible, and locally embedded alternatives where formal market participation is costly or uncertain.

Transaction Costs in Livestock Marketing

Transaction Cost Economics offers an additional lens for understanding why formal market participation remains low. Shiimi et al. (2012) reported that transport expenses, limited access to market information, and delays in the formal system reduce the attractiveness of abattoirs and auctions. These constraints are more severe in remote areas such as Zambezi, where poor roads and long travel distances significantly increase the cost of accessing formal buyers.

Value Chain Constraints and Abattoir Underutilisation

Value chain studies reinforce these observations. Institute for Public Policy Research value chain analysis (IPPR 2019a) noted that abattoir facilities within the NCAs operate far below capacity, due to irregular supply, high compliance requirements, and logistical bottlenecks. These constraints reduce producer incentives to participate in the formal sector and weaken the efficiency of the entire supply chain.

Empirical Approaches to Analysing Livestock Marketing Decisions

Recent studies have begun to apply multivariate and machine learning techniques to analyse livestock marketing decisions. Approaches such as clustering and Random Forest models can be particularly useful for exploring heterogeneity among farmers and ranking the relative importance of multiple interacting factors (Grzesiak et al., 2025). These approaches are particularly relevant in settings where farmers face overlapping structural and behavioural constraints that cannot be captured by linear models alone.

Research Gap

Existing literature provides important evidence on the role of transport costs, price incentives, information asymmetries, and institutional barriers in shaping livestock market participation. However, three gaps remain. First, many studies examine these constraints individually rather than as interacting bundles of conditions that jointly influence farmer behaviour. Second, limited attention has been given to empirically segmenting farmers who face different combinations of constraints.

Third, the Northern Communal Areas are often treated as a relatively homogeneous system, with insufficient focus on intra-regional variation. This study addresses these gaps by comparing Oshikoto and Zambezi, two regions with contrasting market environments, and by applying exploratory multivariate methods to identify farmer segments and the relative importance of key constraints. In doing so, the paper provides a more differentiated understanding of cattle marketing behaviour and generates evidence for more targeted policy design.

METHODOLOGY

Study Area

The study was conducted in two regions of Namibia's NCAs, Oshikoto and Zambezi. These regions were purposively selected because of their sizeable cattle populations and contrasting infrastructural and market access conditions. Oshikoto, located in north-central Namibia, has a semi-arid climate and contains areas such as the Mangetti block where formal marketing activity is more established. In contrast, Zambezi receives higher rainfall but faces pronounced transport challenges and dispersed formal market infrastructure. These differences provide a useful comparative context for analysing region-specific constraints shaping cattle marketing behaviour.

Sampling Methods

A multi-stage sampling strategy was adopted. First, constituencies with relatively high cattle density and active marketing potential were purposively selected. Within these constituencies, communal cattle farmers were identified with the assistance of local facilitators.

The final sample consisted of $n = 116$ farmers from the Oshikoto and Zambezi Regions. Yamane's (1967) sample size formula was used as a reference point for determining a sufficient sample size for the targeted study population. The formula is:

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

where in equation 1, n = required sample size, N= estimates population of cattle farmers in the target constituencies and e= margin of error (set at 0.09).

Because complete farmer lists were not available and field access constraints were present, the survey was implemented using purposive and convenience procedures rather than probability sampling. Accordingly, the Yamane calculation is interpreted as a guide to sample size adequacy rather than evidence of statistical representativeness. The findings should therefore be interpreted as indicative of patterns within the sampled population, with caution regarding broader generalisation. Data were collected through structured face-to-face questionnaires, capturing information on demographics, herd management, marketing behaviour, transportation costs, market information access, and perceived challenges across channels.

Data Reliability and Ethical Considerations

To ensure data reliability and quality, the questionnaire was pre-tested to evaluate clarity, sequencing, and respondent understanding. Feedback from the pre-test informed refinements to wording, response options, and question flow. Enumerators received training on survey administration, probing techniques, and consistency checks, which helped minimize interviewer bias and missing values during fieldwork.

All participants were fully informed about the purpose of the study, assured of confidentiality, and gave voluntary informed consent prior to participation. No personal identifiers were recorded, and all data were stored securely to protect respondent privacy.

Analytical Approach

The paper combined descriptive and exploratory multivariate techniques using R Statistical Software to analyse cattle marketing behaviour in the Northern Communal Areas. This mixed analytical approach was selected because farmers' marketing channel choices are shaped by multiple interrelated factors, including transport costs, herd characteristics, market access conditions, and information constraints. In such settings, single-variable or purely linear approaches may not adequately capture heterogeneity in farmer behaviour. The analysis was guided by Transaction Cost Economics as an interpretive framework. In this context, farmers are assumed to choose marketing channels based on the expected net benefits associated with available alternatives, where monetary and non-monetary transaction costs influence observed behaviour. The framework is used here as a heuristic for variable selection and interpretation rather than as a structural model estimated for causal inference. To improve comparability across variables measured on different scales, survey responses were coded numerically where required and standardised prior to multivariate analysis. Continuous and ordinal variables were transformed into comparable numeric formats for inclusion in the exploratory analysis. Farmer i's latent utility from choosing marketing channel j is specified as:

$$U_{ij} = \beta_0 + \beta_1 TC_i + \beta_2 MA_i + \beta_3 HC_i + \beta_4 IC_I + \varepsilon_{IJ} \quad (2)$$

Where in equation 2, TC_i= denotes transaction costs, MA_i=denotes market access conditions, HC_i= captures herd characteristics, IC_I= reflects information constraints, and ε_{IJ}= margin of error.

Principal Component Analysis (PCA)

Principal Component Analysis was first applied to reduce collinearity among explanatory variables and summarise correlated dimensions of market constraints. Components explaining a substantial share of cumulative variance were retained for subsequent clustering. In this study, 24 principal components explained

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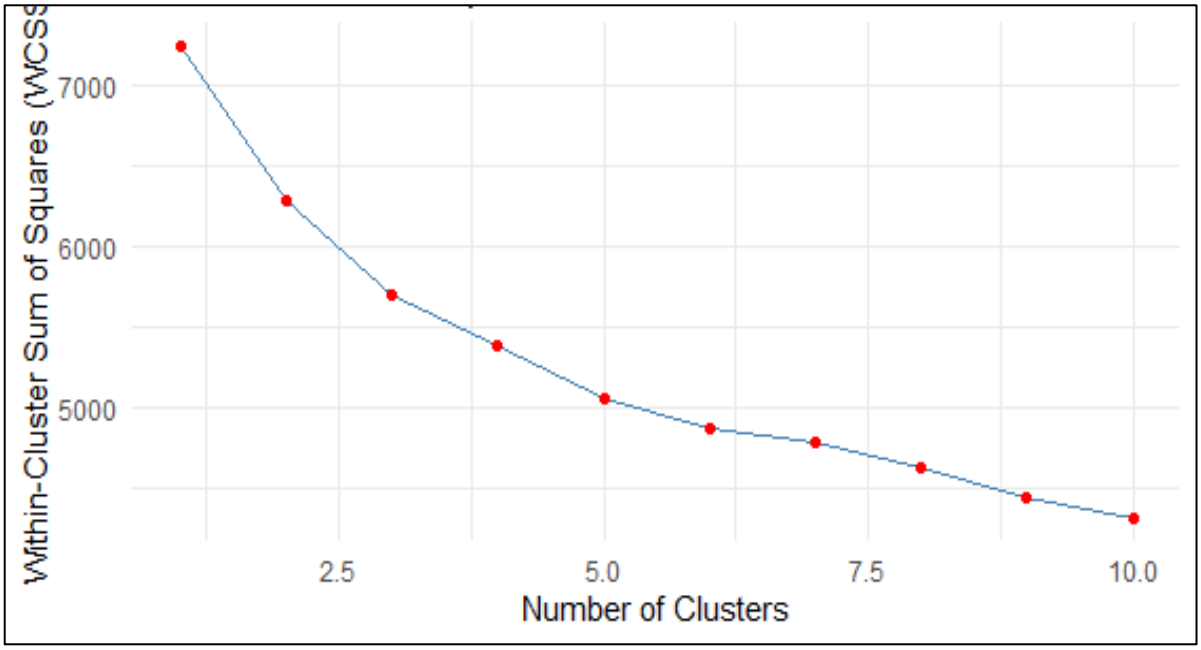
about 80.76% of total variance. While this represents modest dimensionality reduction, it reflects the dispersed and multidimensional nature of cattle marketing decisions, where no small set of variables fully captures observed variation. The retained components were used as composite inputs for clustering rather than interpreted as latent causal constructs.

Cluster Analysis

Farmer segmentation was undertaken using a two-stage clustering procedure. Hierarchical clustering was first used to explore the underlying structure of the data and identify a plausible range of cluster solutions. Thereafter, k-means clustering was applied to assign farmers into distinct groups based on similar combinations of constraints and behavioural characteristics.

The number of clusters was informed primarily by the Elbow Method, where changes in within-cluster sum of squares were assessed across alternative solutions. Visual inspection of this plot as seen in Figure 1 above suggested that 3 clusters represented a reasonable compromise, as the rate of decrease in the Within-Cluster Sum of Squares (WCSS) began to diminish significantly at this point, resulting in a distinct "elbow" bend in the curve. This elbow point indicates the optimal balance between minimizing WCSS (gaining information) and avoiding the diminishing returns of adding more clusters (overfitting). Cluster results were interpreted as exploratory typologies rather than fixed farmer categories.

Figure 1. Elbow Method for Optimal Number of Clusters
Source: Author's own compilation, 2025



Random Forest

A Random Forest classifier with 100 trees (ntree = 100) was applied to assess the relative importance of variables associated with observed marketing channel choice. Random Forest was appropriate for this study because cattle marketing channel choice is influenced by multiple interacting logistical, informational, herd-related, and institutional factors. Unlike simpler linear models, Random Forest can accommodate non-linear relationships and interaction effects among predictors without requiring strict parametric assumptions.

The model was used primarily for variable ranking rather than causal explanation or prediction. Variable importance was evaluated using mean decreases in classification accuracy. Results are therefore interpreted as associative indicators of influence, recognising that correlated predictors may affect rankings.

Model performance was assessed using a confusion matrix and classification metrics. The model achieved an overall accuracy of 50.0%, which exceeded the no-information rate of 40.9%, and produced a Cohen's Kappa

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statistic of 0.3615, indicating moderate agreement beyond chance. However, the accuracy level also shows that the model's predictive performance was moderate rather than strong.

This limitation is likely related to the relatively small sample size, the multi-class nature of the marketing channel outcome, and possible class imbalance. Therefore, the Random Forest results are interpreted mainly as exploratory evidence of the relative importance of variables associated with marketing channel choice, rather than as precise predictions of individual farmers' decisions.

Descriptive Analysis

Descriptive statistics, cross-tabulations, and regional comparisons were used throughout the analysis to contextualise multivariate findings and link statistical patterns to observed differences between Oshikoto and Zambezi.

RESULTS AND DISCUSSION

Marketing Channel Use in the Northern Communal Areas

The results indicate that communal cattle farmers in the Northern Communal Areas rely predominantly on informal marketing channels, with only a minority participating directly in formal markets such as auctions and abattoirs. Overall, fewer than one-third of surveyed farmers sold cattle through formal channels, confirming the persistence of low formal market off-take in the NCAs.

Clear regional differences emerge as seen in Figure 2 below. Farmers in Zambezi show a substantially higher reliance on informal and alternative channels compared to those in Oshikoto. This pattern reflects differences in market accessibility rather than differences in cattle ownership or production potential. While Oshikoto farmers benefit from relatively better road infrastructure and closer proximity to auctions and quarantine facilities, Zambezi farmers face longer travel distances, poorer road conditions, and higher fuel costs. These factors significantly increase the cost and risk of formal market participation, making informal sales a more rational choice.

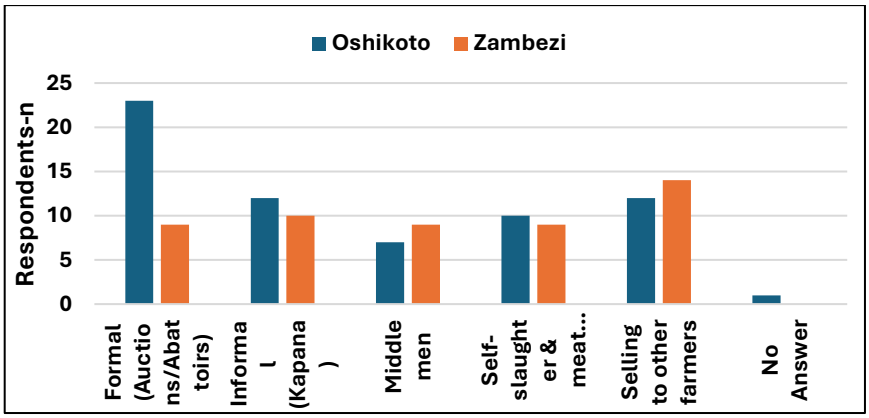

Figure 2. Preferred Marketing Channel by Region

Source: Author's own compilation, 2025.

These findings are consistent with earlier evidence from Namibia showing that transport expenses, weak market information, and logistical barriers significantly reduce participation in formal cattle markets (Shiimi et al., 2012). They also align with broader evidence that informal cattle and beef trade remains an important livelihood and marketing outlet in the NCAs, particularly where formal systems are less accessible. From a Transaction Cost Economics perspective, farmers are likely to select channels that minimise the total monetary and non-monetary costs of exchange. In higher-cost environments such as Zambezi, informal markets offer faster

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transactions, flexible negotiation, and greater certainty of payment, even when formal prices may be comparatively higher.

Drivers of Marketing Channel Choice

Multivariate analysis reveals that marketing channel choice is shaped by a combination of logistical, informational, and herd-related factors. Across all analytical approaches, transportation cost per head emerges as the most influential driver of channel selection. Farmers facing high transport costs are significantly less likely to participate in formal markets, particularly where reliable transport services are unavailable. This finding is consistent with earlier evidence from Namibia, which identified transport expenses and market access barriers as major constraints to formal cattle sales(Shiimi et al., 2012). It also reinforces the central prediction of Transaction Cost Economics that states that producers tend to select channels that minimise the total costs of exchange rather than simply those offering the highest nominal prices.

Livestock Herd Dynamics

Herd dynamics also play a key role. Farmers with larger or growing herds are more likely to engage with formal channels, reflecting greater capacity to absorb transaction costs and meet quality requirements. In contrast, farmers managing smaller herds tend to rely on informal channels or farmer-to-farmer sales, where entry barriers are lower and transactions can be tailored to immediate household cash or consumption needs. These patterns suggest that participation in formal markets depends not only on access conditions, but also on production scale and asset capacity.

Price Uncertainty and Market Information

Price uncertainty and limited access to market information further reduce the attractiveness of formal markets. A substantial proportion of farmers reported not knowing the price they would receive prior to selling at auctions or abattoirs. This lack of transparency increases perceived risk and discourages participation in formal channels, particularly for farmers with limited cash reserves. By contrast, informal markets allow prices to be negotiated directly and payments to be received immediately. This reduces uncertainty and may be especially valuable for liquidity-constrained households. These findings are consistent with earlier evidence from Namibia. Shiimi et al. (2012) identified limited market information and weak access to pricing knowledge as important barriers to formal cattle marketing, while Kalundu & Meyer (2017) showed that formal and informal beef markets are characterised by weak price information linkages and different speeds of price adjustment across market segments. Together, these studies suggest that incomplete market information and weak price discovery continue to undermine confidence in formal marketing channels. From a behavioural perspective, farmers may rationally prioritise certainty of payment over potentially higher but uncertain returns, especially where household cash flow needs are immediate.

Animal Health and Welfare

Animal health and cattle characteristics also influence marketing outcomes. Disease outbreaks, cattle age, and condition affect both eligibility for formal markets and the prices offered. Animals in poorer condition or those failing to meet market standards are less likely to enter formal channels and may instead be sold through informal outlets. Previous studies of Namibia's Northern Communal Areas have similarly highlighted the importance of animal health controls, quarantine requirements, veterinary service delivery, and institutional barriers in shaping livestock market participation (IPPR, 2019a, 2019b; Shiimi et al., 2012). In addition, seasonal feed shortages and weak production support systems can reduce body condition, carcass quality, and market readiness, lowering producer returns even when market demand exists. Evidence from Namibia further shows that cattle quality, seasonality, and animal condition are important determinants of price variability in informal and segmented livestock markets (Kalundu & Meyer, 2017). Taken together, these findings suggest that expanding formal market participation requires more than price incentives alone. Strengthening veterinary services, disease surveillance, extension support, producer training, and on-farm husbandry practices may be equally important in improving market access, animal quality, and overall supply chain performance. These factors are especially

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important in regions such as Zambezi, where disease risk and limited veterinary service coverage further constrain formal market participation.

Farmer Segmentation and Market Behaviour – PCA and Cluster Results

To better understand heterogeneity in cattle marketing behaviour, Principal Component Analysis (PCA) and cluster analysis were used to identify underlying dimensions of variation and group farmers with similar combinations of constraints. Rather than treating communal cattle producers as a homogeneous population, this approach recognises that marketing decisions are shaped by multiple overlapping logistical, informational, production, and institutional factors. The PCA results as shown in Table 2 below indicate that no single factor fully explains observed behaviour. Instead, the first components capture broad dimensions of market participation. The leading components can be interpreted as reflecting: (i) production capacity and resource constraints, including herd size, feed access, water availability, and disease pressures; (ii) market access and transport costs, including transport cost per head, fuel costs, transport organisation, and infrastructure conditions; (iii) institutional support and production investment, including training, programme participation, and input use; (iv) seasonal stress and regulatory constraints; and (v) farmer experience and information networks. This confirms that channel choice is multidimensional and influenced by interacting constraints rather than a single dominant variable.

Table 2: Summary of Principal Components, Variance Explained, and Interpretations

Principal Component	Variance Explained (%)	Cumulative Variance (%)	Interpretation
PC1	14.7	14.7	Production Capacity and Resource Constraints
PC2	10.9	25.6	Market Access and Transport Costs
PC3	5.3	30.9	Institutional Support and Production Investment
PC4	4.9	35.8	Seasonal Stress and Regulatory Constraints
PC5	3.8	39.6	Experience and Information Networks

Source: Author's own compilation, 2025.

The retained components were subsequently used in cluster analysis to identify farmer segments with distinct marketing behaviour. These clusters, as shown in Figure 3 below, should not be interpreted as fixed farmer types, but rather as observable behavioural patterns shaped by differences in costs, opportunities, and constraints. The clustering results reinforce earlier evidence from Namibia showing that transport barriers, information gaps, veterinary controls, and infrastructure limitations affect producers unevenly across regions and farming systems (IPPR, 2019a, 2019b; Shiimi et al., 2012). The cluster analysis was conducted on 115 valid **observations** after data pre-processing, as one respondent had incomplete values for the variables included in the clustering procedure.

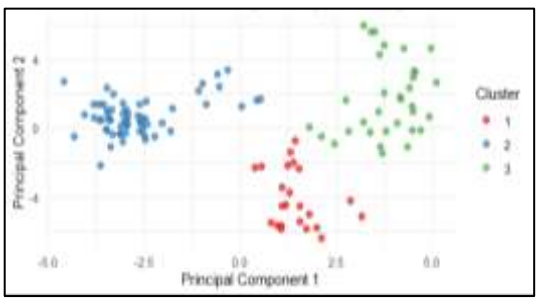

Figure 3. Cluster Visualisation based on first two principal components

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Source: Author's own compilation, 2025

Cluster One: The Diverse & Challenged Group (n = 50 Farmers)

This is the largest cluster, representing a highly diverse group of farmers who utilise a balanced mix of all five marketing channels. While no single channel dominates, selling to other farmers (26%) is slightly more prevalent, suggesting a reliance on direct farmer-to-farmer transactions. A considerable proportion (40%) reported not knowing cattle prices before selling, and 50% cited unknown prices at auctions or abattoirs as a problem. Overall, half (50%) experienced selling difficulties.

These findings suggest that farmers in Cluster One operate under multiple overlapping constraints and respond by diversifying their marketing behaviour rather than specialising in a single channel. Channel diversification may therefore function as a risk-management strategy where price certainty, buyer availability, and market access remain unpredictable.

Cluster Two: Formal Channel Users with Price Information Gaps (n = 31 Farmers)

This cluster exhibits a strong inclination towards formal markets (Auctions/Abattoirs) channels (35.48%) and frequently uses 'Selling to other farmers' (22.58%). Farmers in this group face high average transport costs (approximately N$3,070 per head), indicating that participation in formal markets can persist even under substantial logistical costs. However, severe information constraints are evident. Most farmers (83.87%) reported not knowing cattle prices before selling, and 61.29% experienced general selling difficulties. Despite utilizing formal channels, these farmers struggle with market transparency and information access, particularly on pricing. Half of cluster two farmers (51.61%) are farming with smaller herd sizes which might push these farmers towards formal channels or direct farmer sales, despite the challenges. This may suggest that some farmers use formal channels out of necessity, limited alternatives, or periodic distress sales rather than because these channels are consistently more attractive.

The behaviour of this cluster demonstrates that formal market participation does not necessarily imply favourable market conditions. Producers may still face high costs, weak bargaining positions, and limited transparency within formal systems.

Cluster Three: Lower Transport Cost but High Selling Difficulty (n = 34 Farmers)

Farmers in this cluster experience lower average transport costs (N$301- N$600 per head), suggesting better logistical positioning. This cluster exhibits moderate use of both Formal (Auctions/Abattoirs) (35.29%) and other channels (Kapana- grilled cuts or pieces of beef) and Middlemen channels (both at 17.65%), indicating diversified engagement across outlets.

Despite relatively lower transport costs, farmers in this cluster continue to experience high selling difficulty, indicating that improved physical access alone is insufficient to ensure smooth participation in formal markets. This pattern suggests that non-transport constraints, including limited access to reliable price information, procedural barriers within formal markets, and animal health considerations, continue to shape marketing outcomes. The behaviour of this cluster highlights the interaction between logistical and institutional constraints, where reduced transport costs do not automatically translate into lower overall transaction costs or greater formal market participation.

Synthesis of the Results

Overall, the segmentation results show that communal cattle farmers are not a homogeneous group responding to a single incentive. Instead, farmers face different combinations of costs, risks, and institutional barriers that produce distinct marketing behaviours. Policies aimed at increasing formal market participation should therefore be more targeted, with interventions tailored to the specific constraints faced by different farmer groups and regions.

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Random Forest Analysis of Marketing Channel Choice

The Random Forest model was applied to assess the relative importance of factors associated with communal farmers' choice of cattle marketing channels. Variable importance rankings reported in Table 3 are based on the Mean Decrease in Gini index and indicate the relative contribution of each predictor to observed channel choice. Although the model achieved moderate classification performance (accuracy = 50.0%; Kappa = 0.3615), the results are interpreted primarily as exploratory associations rather than causal effects.

Table 3. Key determinants of cattle marketing channel choice in the NCAs: Random Forest results

Rank	Variable	Importance
1	How much do you typically spend on the transportation of cattle to the nearest abattoir or auction? Per Head	2.163893
2	In the past year, how would you describe your herd numbers?	1.469752
3	Is it a problem if you do not know how much you will get for cattle sold at an auction/abattoir?	1.281727
4	Has age of your cattle influenced the price you received at abattoirs?	1.239751
5	Do you always know the price you will receive for the cattle you sell?	1.206027
6	Over the past 5 years, have there been health issues/disease outbreaks recorded in your area (50km radius)?	1.134171
7	In your opinion, how easy or difficult is it to sell cattle in your area?	1.048415
8	What is your primary source of feed? / Concentrates	1.030316
9	How do you stay informed about market prices for cattle in the NCAs? /Agricultural Extension Services	1.008426
10	How well do you think different people and organizations in the livestock sector work together and share information in your area?	1.005967

Source: Author's own compilation, 2025

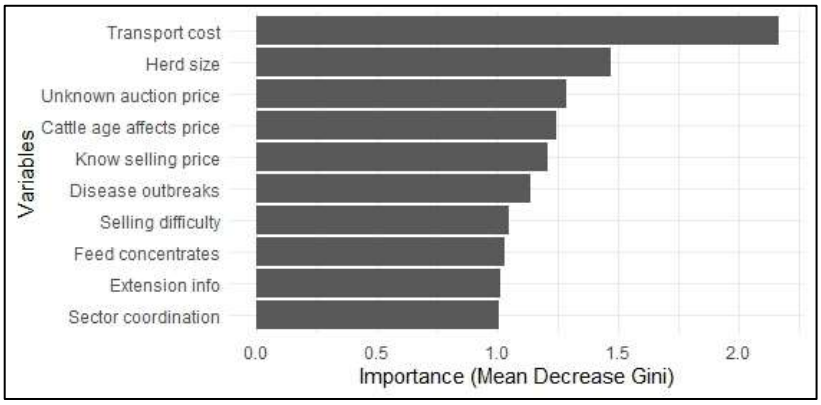

Figure 4. Top 10 Determinants of Marketing Channel Choice

Source: Author's own compilation, 2025

As shown in Table 3 and Figure 4, transportation cost per head is the single most influential determinant of marketing channel choice. High transport costs significantly reduce the likelihood of participation in formal markets, particularly auctions and abattoirs, where participation often requires longer travel distances, organised transport, and higher cash outlays. This finding reinforces earlier descriptive, PCA, and cluster-based results and confirms that logistical constraints remain the dominant barrier to formal market participation. It also supports earlier evidence from Namibia that transport expenses remain a major constraint to formal cattle sales (Shiimi et al., 2012).

Herd dynamics emerge as the second most important factor. Farmers reporting stable or increasing herd sizes are more likely to participate in formal markets, reflecting greater capacity to absorb transaction costs and

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comply with formal market requirements. In contrast, farmers with declining or small herds tend to favour informal channels, where sales can be adjusted to immediate household needs and lower volumes.

Price uncertainty and limited access to market information also play a central role. Variables capturing uncertainty about auction or abattoir prices, and lack of prior knowledge of expected sale prices, rank among the most influential predictors. This highlights the continued importance of information asymmetry in shaping marketing behaviour. Where producers cannot anticipate prices or trust formal pricing mechanisms, informal markets may offer greater certainty through direct negotiation and immediate payment. These findings are consistent with previous evidence of weak price linkages and uneven price transmission between formal and informal beef markets in Namibia (Kalundu & Meyer, 2017).

Animal-related factors further influence channel choice. Cattle age, disease outbreaks, and general market readiness affect both eligibility for formal markets and the prices offered. This suggests that marketing outcomes depend not only on access to buyers, but also on animal quality and production conditions. The inclusion of feed sources, veterinary conditions, and sector coordination variables among the top predictors further indicates that supply-side support systems remain relevant to commercialisation pathways.

Overall, the Random Forest results confirm that marketing channel choice is shaped by a combination of logistical costs, herd characteristics, information constraints, and production conditions rather than price incentives alone. The prominence of transportation costs and price uncertainty helps explain the persistent reliance on informal markets, particularly in regions such as Zambezi where infrastructure and market access remain weakest. Policies aimed at increasing formal market participation should therefore prioritise reducing transaction costs, improving price transparency, strengthening animal health systems, and addressing region-specific logistical barriers.

Supply Chain Bottlenecks and Regional Implications

The combined results from the descriptive analysis, farmer segmentation, PCA, and Random Forest model reveal several interrelated bottlenecks that constrain the performance of the cattle supply chain in Namibia's Northern Communal Areas. These bottlenecks operate at multiple points along the supply chain and collectively discourage participation in formal markets, thereby limiting overall supply chain efficiency. Figure 5 below provides a conceptual representation of the cattle supply chain in the Northern Communal Areas and summarises the key bottlenecks identified in the analysis, including transportation costs, market information asymmetry, animal health constraints, and procedural barriers within formal markets.

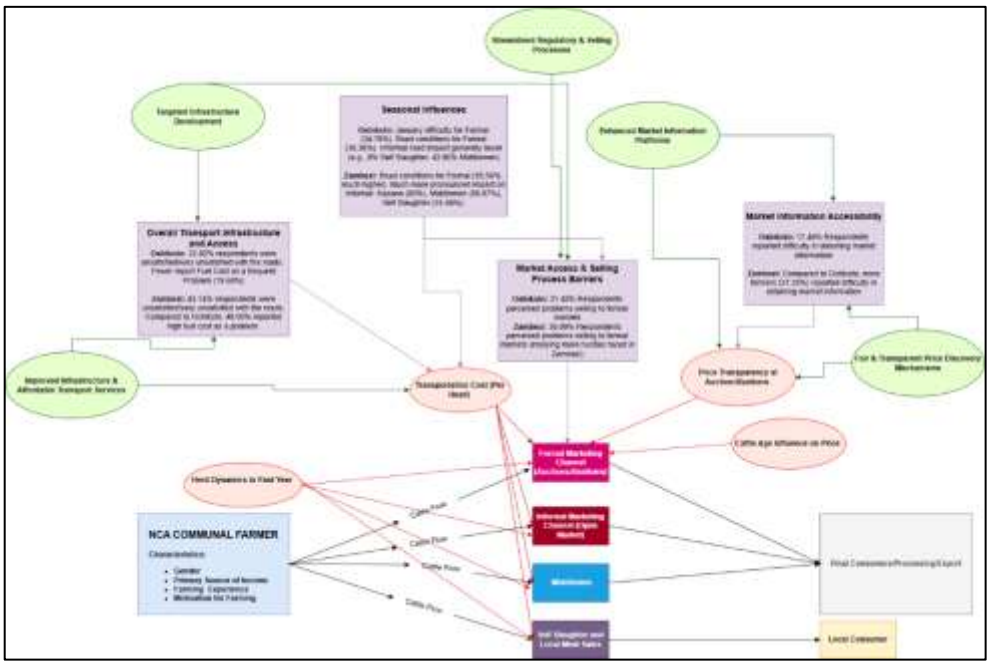

Figure 5. Conceptual Model: Cattle Supply Chain in the NCA, Oshikoto and Zambezi.

Source: Author's Own Compilation, 2025

The most binding constraint is the excessive cost of transportation, which consistently emerges as the dominant determinant of marketing channel choice. Poor road infrastructure, long travel distances, and limited availability of affordable transport services increase the per-head cost of moving cattle to auctions and abattoirs. For many communal farmers, particularly those in rural locations, these costs outweigh potential price advantages offered by formal markets. As a result, informal channels that require limited transport and offer immediate payment become more attractive. This finding is consistent with earlier evidence from Namibia showing that transport costs remain a major barrier to formal cattle sales (Shiimi et al., 2012).

Closely linked to logistical constraints is market information asymmetry. Many farmers lack reliable and timely information regarding prices, quality requirements, and selling procedures at formal markets. Uncertainty about expected prices at auctions or abattoirs increases perceived risk and discourages formal market participation. Informal markets, by contrast, allow direct negotiation and provide price certainty at the point of sale, even if prices are lower on average. This information gap reinforces the persistence of informal trade and weakens incentives for quality upgrading, planned offtake, and market-oriented production. These patterns align with previous findings of weak price linkages and uneven price transmission between formal and informal beef markets in Namibia (Kalundu & Meyer, 2017).

Institutional and procedural barriers within formal markets further compound these challenges. Quality inspections, regulatory compliance requirements, and delayed payments increase transaction costs and reduce trust in formal marketing systems. These barriers are particularly restrictive for farmers with limited liquidity or small herd sizes, who are less able to absorb delays and compliance costs. Consequently, even farmers who have physical access to formal markets may still opt for informal channels. Animal health and herd characteristics also affect supply chain participation. Disease outbreaks, cattle age, and condition influence eligibility for formal markets and the prices offered. In regions with higher disease risk and weaker veterinary service coverage, these factors further reduce formal market participation and contribute to irregular supply to abattoirs. The severity of these bottlenecks, as summarised in Table 5 below, varies markedly across regions. In Zambezi, transport infrastructure constraints, higher fuel costs, and limited market information are more pronounced, resulting in a heavy reliance on informal channels. Seasonal road deterioration further exacerbates access challenges, particularly during the rainy season, making formal market participation costly and uncertain. In Oshikoto, while similar constraints exist, better road networks, higher market density, and more consistent access to auctions and quarantine facilities reduce transaction costs and support comparatively higher engagement with formal markets. These regional differences demonstrate that the cattle supply chain in the NCAs cannot be treated no as a uniform system. Bottlenecks arise from the interaction of logistical, informational, and institutional constraints that vary spatially. Addressing only one constraint in isolation is therefore unlikely to yield sustained improvements in formal market participation.

Overall, the findings indicate that current supply chains in the Northern Communal Areas fail to meet producer needs and operate inefficiently. Low formal offtake undermines abattoir utilisation, reduces value addition, and weakens incentives for investment in herd quality and animal health. Improving supply chain performance requires region-specific interventions that reduce transportation costs, improve access to market information, and simplify formal market procedures in ways that reflect local conditions and farmer capabilities.

Table 4. Regional Distinctions - NCA Cattle Supply Chain

Factor / Characteristic	**Oshikoto Region Perspective**	**Zambezi Region Perspective**
Overall Channel Preference	- Higher formal sector participation (28% of overall respondents). - Auctions perceived as an easier way to make money.	- Significantly higher reliance on Informal/Other channels (82.36% overall preference).

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Transportation & Logistics	- Lower proportion reporting fuel cost as a frequent problem (19.6%). - Lower dissatisfaction with transport infrastructure (32.82% unsatisfied/very unsatisfied).	- Higher proportion reporting fuel cost as a frequent problem (48%). - Higher dissatisfaction with transport infrastructure (43.14% unsatisfied/very unsatisfied) - Higher proportion finding transport "Very Easy" suggesting disparity in access/methods.
Market Information Access	- Lower challenge in obtaining information (17.46% difficult/very difficult).	- Greater challenge in obtaining information (37.25% difficult/very - Information asymmetry is a more significant barrier.
Perceived Selling Problems (Formal)	- Slightly lower incidence of perceived problems (31.48%).	- Slightly higher incidence of perceived problems (36%). - Implies more hurdles (e.g., quality inspection, payment delays).
Seasonal Difficulties / Road Conditions	- January difficulty for Formal users (34.78%). - Road conditions for Formal users (36.36%) - Informal road impact lower.	- Much more pronounced road impact across all channels (e.g., Formal: 55.56%, Informal: 60%, Middlemen: 66.67%, Self Slaughter: 55.56%).
Gender & Channel Choice	- Formal channels more male-dominated (65.22% male). - Informal (Kapana, selling to other farmers) show stronger female participation (58.33% female).	- Formal channels still male-leaning (55.56% male) but less pronounced. - Middlemen overwhelmingly utilised by female farmers (88.89%). - Informal (Kapana) more male-dominated (60% male).
Income Source & Channel Choice	- "Mixed Farming" strong inclination to Formal (65.22% of formal users). - "Old age pension" to Informal (50% of Kapana users).	- "Off-Farm Income" notable preference for Formal (44.44% of formal users). - "Livestock" farmers to "Selling to other farmers" (50%). - "Old age pension" to Informal (40% of Kapana users).
Farming Experience & Channel Choice	- Farmers with >10 years' experience stronger inclination to Formal (56.52% of formal users) and dominate Informal.	- Farmers with >10 years' experience notably lower representation in Formal (33.33%). - "6-10 years" experience group dominates among Middlemen users (55.56%).

Source: Author's Own Compilation, 2025.

CONCLUSION

This paper examined cattle marketing behaviour and supply chain performance in Namibia's Northern Communal Areas, with a comparative focus on the Oshikoto and Zambezi regions. Despite holding a substantial share of the national cattle herd, the NCAs continue to experience persistently low formal market offtake, undermining rural incomes, abattoir utilisation, and overall supply chain efficiency. By combining descriptive analysis, farmer segmentation, and machine learning methods, the paper provides new empirical evidence on the

drivers of marketing channel choice and the structural bottlenecks shaping market participation. The results show that communal cattle farmers rely on informal marketing channels, with only limited engagement in formal markets such as auctions and abattoirs. Transportation costs, herd dynamics, and price uncertainty emerge as the most influential determinants of channel choice.

High transaction costs, weak access to market information, and procedural barriers within formal markets discourage participation, even where formal prices may be higher. Informal markets persist not merely because of preference, but because they offer flexibility, immediacy of payment, and lower perceived risk. A key contribution of the paper is the demonstration of substantial intra-regional heterogeneity within the NCAs. Farmers in Zambezi face more severe transport, infrastructure, and information constraints, resulting in a heavier reliance on informal channels.

In contrast, Oshikoto exhibits comparatively higher, though still limited, formal market participation, reflecting better road infrastructure, higher market density, and more consistent access to formal marketing facilities. These findings show that treating the NCAs as a homogeneous production system obscures critical spatial differences that matter for policy design. Overall, the paper finds that current cattle supply chains in the Northern Communal Areas do not adequately meet producer needs and operate inefficiently. Low formal offtake constrains value addition, weakens incentives for investment in herd quality and animal health, and perpetuates underutilisation of abattoir capacity. Addressing these challenges requires interventions that directly target the transaction costs and information constraints shaping farmer behaviour, rather than relying solely on price incentives.

RECOMMENDATIONS

Based on the findings, several policy-relevant recommendations emerge to improve cattle supply chain performance and formal market participation in the Northern Communal Areas. Reducing transport and logistics costs should be a primary policy priority, as transportation costs emerged as the strongest determinant of marketing channel choice across the study. Investments in rural road maintenance and feeder road upgrades are particularly important in remote production areas such as Zambezi, where poor accessibility raises the cost and risk of reaching formal buyers. Support for collective livestock transport arrangements, scheduled transport services, and stronger producer coordination could further lower per-head transport costs and improve access to auctions and abattoirs.

Market information systems also need to be strengthened. Reliable and timely dissemination of cattle prices, quality requirements, auction schedules, and payment procedures would reduce uncertainty and improve farmer confidence in formal channels. Low-cost communication tools such as SMS alerts, radio programmes, mobile platforms, and strengthened agricultural extension services could play an important role, particularly in underserved areas. Formal market procedures should be simplified and made more farmer-friendly. Streamlining regulatory processes, improving transparency in grading systems, simplifying documentation requirements, and ensuring faster payment turnaround times would reduce transaction costs and build trust in formal marketing systems. Attention should be given to small-scale and liquidity-constrained producers who may otherwise remain excluded from formal channels. Animal health and production support services should also be strengthened. Disease outbreaks, cattle quality, and market readiness were shown to influence both eligibility for formal markets and prices received. Expanding veterinary outreach, disease surveillance, vaccination programmes, and producer training in herd management would improve supply consistency and support greater participation in higher-value markets. The findings further indicate that region-specific strategies are required. In Zambezi, policy should prioritise transport reliability, seasonal road access, market information delivery, and animal health support. In Oshikoto, where infrastructure constraints are relatively less severe, greater emphasis should be placed on strengthening existing formal market linkages, improving auction efficiency, and expanding market opportunities. Uniform policy approaches across the NCAs are therefore unlikely to be effective.

Finally, stronger coordination across the value chain is essential. Greater collaboration between government institutions, veterinary services, farmer organisations, transport providers, auctions, abattoirs, and private buyers is needed to address bottlenecks in an integrated manner. Shared market information systems, regular coordination platforms, and aligned infrastructure planning would help create a more efficient and inclusive

cattle marketing system. Overall, improving formal market participation in the Northern Communal Areas will depend less on raising prices alone and more on reducing the costs, risks, and institutional barriers that currently limit farmer participation.

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