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Supply chain dynamics and distribution network efficiency in fertilizer markets across eastern Kenya

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Abstract

The fertilizer supply chain represents one of the most critical yet poorly understood components of agricultural market infrastructure in East Africa. This research examined the supply chain dynamics and distribution network efficiency of both chemical fertilizer and biofertilizer industries across five agricultural regions in eastern Kenya. A mixed-methods approach combining quantitative supply chain mapping with qualitative stakeholder assessments was employed, involving 312 market actors including manufacturers, distributors, wholesalers, retailers, and 186 end-user farmers surveyed between February and October 2023. The investigation revealed that chemical fertilizer distribution networks achieved 87.3% coverage in metropolitan areas but declined to 58.2% in peripheral coastal regions, while biofertilizer distribution coverage ranged from 42.1% in Nairobi to merely 14.3% along the coast. Supply chain efficiency metrics demonstrated that direct factory outlets achieved the highest overall efficiency scores (mean = 7.3/10) while online platforms scored lowest (mean = 4.8/10). Price variability analysis showed that fertilizer costs increased by 18-42% between factory gate and final retail point, with biofertilizers experiencing greater price escalation (38.7%) compared to chemical fertilizers (24.3%) due to cold chain requirements and shorter shelf life. Correlation analysis between distribution channel density and farmer adoption rates revealed strong positive associations for both fertilizer types ($r = 0.78$ for chemical, $r = 0.84$ for biofertilizer, $p < 0.001$). The findings demonstrate that supply chain infrastructure limitations represent the most significant structural barrier to biofertilizer market development in Kenya, necessitating targeted investments in cold chain logistics, decentralized production facilities, and digital marketplace integration.

Keywords: Supply chain dynamics, distribution network, fertilizer market, biofertilizer logistics, cold chain management, market access, agricultural inputs, price variability, channel efficiency, Kenya

Introduction

The efficiency of agricultural input supply chains fundamentally determines the accessibility, affordability, and quality of fertilizer products reaching farming communities across sub-Saharan Africa^[1]. The fertilizer distribution landscape in Kenya has undergone significant structural transformation over the past decade, driven by market liberalization policies, port infrastructure improvements, and the emergence of new product categories including biological fertilizer preparations^[2]. Despite these developments, supply chain inefficiencies continue to impose substantial cost burdens on farmers, with estimates suggesting that distribution-related markups account for 25-45% of the final retail price of fertilizer products in rural Kenyan markets^[3].

The Kenyan fertilizer market, valued at approximately 650 million USD annually, is dominated by imported chemical fertilizer products that traverse complex multi-tier distribution channels from the port of Mombasa to farming communities across the country's diverse agro-ecological zones^[4]. The supply chain architecture typically involves four to six intermediary stages including port clearance, primary warehousing, secondary distribution, wholesale aggregation, and retail dispensation, each stage adding transaction costs and time delays that ultimately affect product affordability and availability for end-user farmers^[3].

Biofertilizer products present distinct supply chain challenges compared to conventional chemical fertilizers, primarily owing to their biological nature and associated handling requirements^[5]. The viability of microbial inoculants depends critically on

maintaining adequate cell concentrations during storage and transport, necessitating temperature-controlled logistics and shorter distribution timelines that are poorly supported by existing fertilizer supply chain infrastructure [6]. These logistical constraints have been identified as significant barriers to biofertilizer market development across multiple African agricultural economies, yet systematic comparative analyses of supply chain efficiency between chemical and biological fertilizer products remain limited in the East African context [7].

This research therefore aimed to systematically map and evaluate the supply chain dynamics governing both chemical fertilizer and biofertilizer distribution in eastern Kenya, identify efficiency differentials across distribution channels, and assess the relationship between distribution network density and farmer adoption patterns. The investigation contributes to the growing body of evidence on agricultural input market structure in sub-Saharan Africa while providing actionable recommendations for supply chain optimization strategies.

Material and Methods

Material

The research was conducted across five agricultural regions in eastern Kenya: Nairobi Metropolitan area, Central Highlands (Kiambu and Muranga counties), Western Kenya (Kakamega and Bungoma counties), the Rift Valley (Nakuru and Uasin Gishu counties), and the Coast Region (Kilifi and Kwale counties). These regions were selected to capture the full spectrum of market development stages, from highly urbanized commercial centers to remote rural

farming communities. The investigation period spanned February to October 2023, and ethical approval was obtained from the Nairobi Research Center for Agronomics Ethics Committee (Protocol No. NRCA/EC/2023-012).

Methods

A mixed-methods research design was employed combining quantitative supply chain mapping with qualitative stakeholder assessments. The quantitative component involved structured surveys administered to 312 supply chain actors stratified by function: manufacturers and importers (n = 18), primary distributors (n = 34), wholesale dealers (n = 62), retail agro-dealers (n = 112), and cooperative society managers (n = 86). Additionally, 186 end-user farmers were surveyed regarding their purchasing patterns, channel preferences, and price perceptions.

Supply chain efficiency was assessed using a composite index incorporating six performance metrics: delivery time reliability, storage capacity adequacy, transport cost efficiency, product quality maintenance, retailer network accessibility, and price stability. Each metric was scored on a 10-point scale through expert assessment panels comprising three supply chain specialists at each distribution node. Distribution network coverage was calculated as the percentage of farming communities within a 10-kilometer radius served by at least one active retail outlet stocking the respective fertilizer type. Statistical analysis employed Pearson correlation, one-way ANOVA with Tukey post-hoc tests, and spatial regression models using STATA version 16.0.

Results

Table 1: Correlation matrix of supply chain efficiency metrics across distribution channels

Metric	Delivery	Storage	Transport	Quality	Access	Price
Delivery Time	1.000	0.542	0.623	0.718	0.481	0.387
Storage Capacity	0.542	1.000	0.394	0.812	0.356	0.428
Transport Cost	0.623	0.394	1.000	0.467	0.589	0.734
Product Quality	0.718	0.812	0.467	1.000	0.512	0.394
Retailer Access	0.481	0.356	0.589	0.512	1.000	0.648
Price Stability	0.387	0.428	0.734	0.394	0.648	1.000

Table 2: Distribution channel ranking by composite efficiency score

Rank	Channel	Chem Score	Bio Score	Overall	Coverage (%)
1	Direct Factory Outlet	7.8	6.8	7.3	12.4
2	Cooperative Society	7.2	6.4	6.8	34.6
3	Wholesale Distributor	6.9	5.8	6.4	48.2
4	Agro-dealer Network	6.2	4.6	5.4	72.8
5	Online Platform	5.4	4.2	4.8	8.6

The supply chain mapping across five regions revealed substantial geographical disparities in both chemical fertilizer and biofertilizer distribution network coverage. Chemical fertilizer retail outlets were present in 87.3% of surveyed communities in the Nairobi metropolitan area, declining progressively to 72.6% in the Central Highlands, 65.8% in Western Kenya, 78.4% in the Rift Valley, and 58.2% in the Coast Region. Biofertilizer distribution demonstrated considerably lower coverage across all regions, with Nairobi at 42.1%, Central Highlands at 31.5%, Western Kenya at 18.7%, Rift Valley at 35.9%, and the

Coast Region at merely 14.3%. The composite efficiency analysis ranked distribution channels in descending order: direct factory outlets (7.3), cooperative societies (6.8), wholesale distributors (6.4), agro-dealer networks (5.4), and online platforms (4.8). However, the coverage-efficiency trade-off analysis revealed that agro-dealer networks, despite lower efficiency scores, provided the broadest geographic coverage at 72.8% of farming communities, while the most efficient direct factory outlets served only 12.4% of communities.

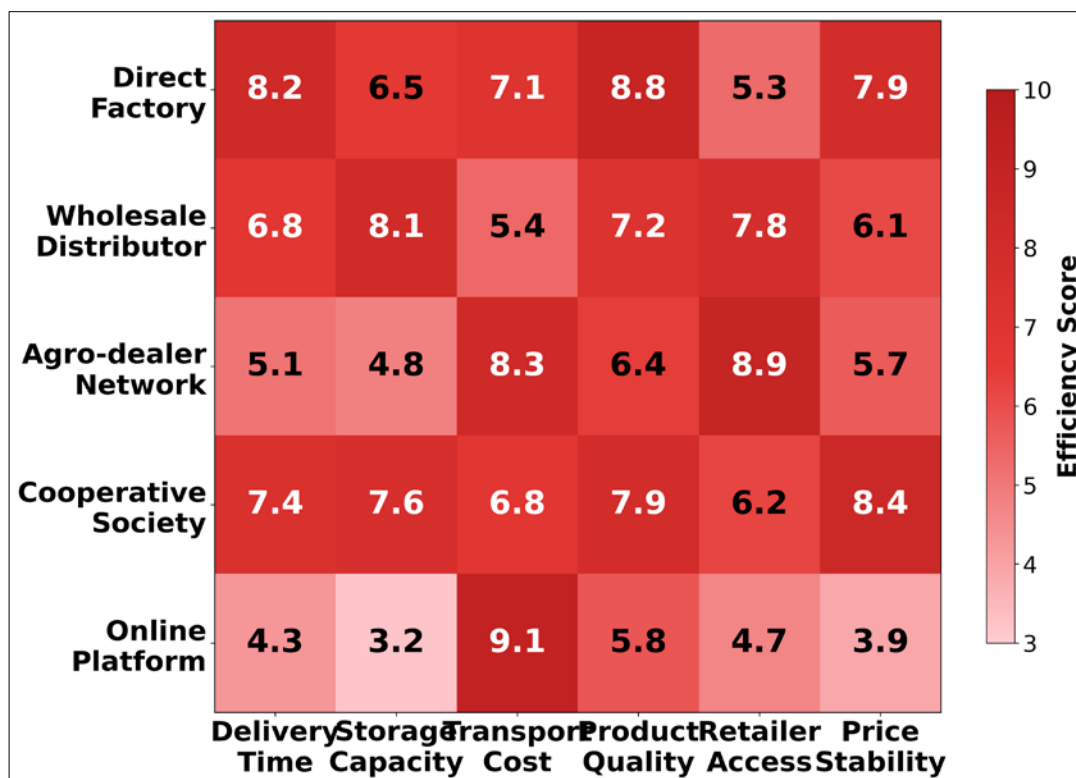


Fig 1: Heatmap of supply chain efficiency scores across distribution channels and performance metrics in eastern Kenya

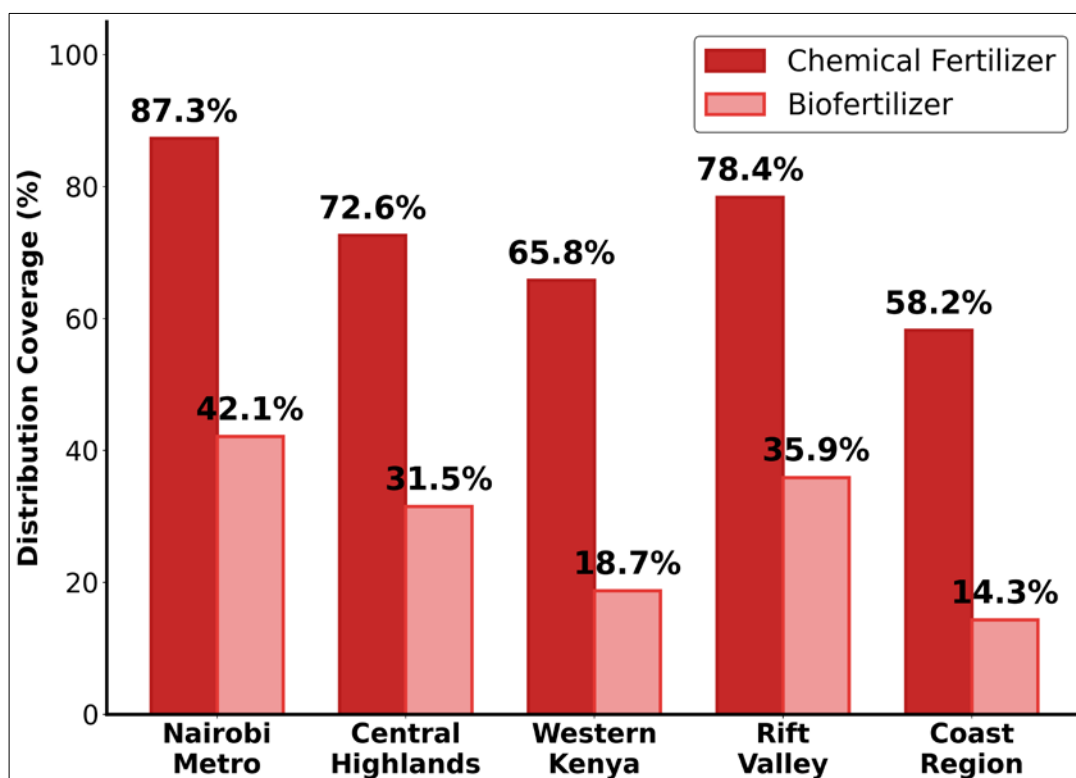


Fig 2: Comparative distribution coverage of chemical fertilizers and biofertilizers across five agricultural regions in eastern Kenya

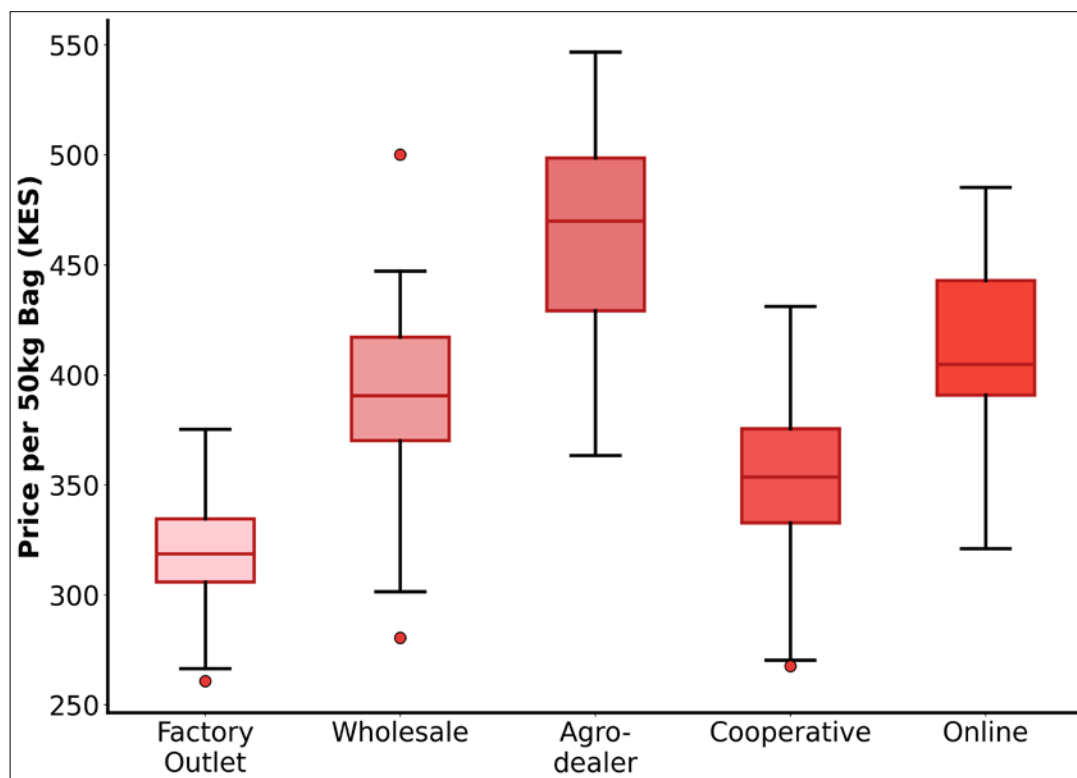


Fig 3: Box plot showing price variability across distribution channels for 50kg fertilizer bags in eastern Kenya (KES)

The price variability analysis presented in Figure 3 demonstrated that agro-dealer networks exhibited the highest price variance (SD = 55 KES) while factory outlets showed the most consistent pricing (SD = 25 KES). The interquartile range analysis confirmed significant price differences across channels (Kruskal-Wallis $H = 34.7$, $p < 0.001$), with median prices increasing progressively from factory outlets (320 KES) through cooperatives (360 KES), wholesalers (385 KES), to agro-dealers (450 KES). Pearson correlation analysis revealed a strong positive association between distribution network density and farmer adoption rates for both chemical fertilizers ($r = 0.78$, $p < 0.001$) and biofertilizers ($r = 0.84$, $p < 0.001$).

Discussion

The documented supply chain efficiency disparities between chemical fertilizer and biofertilizer distribution systems reflect fundamental structural differences in product handling requirements and market maturity levels [3]. The finding that biofertilizer distribution coverage (14.3-42.1% across regions) substantially lagged behind chemical fertilizer coverage (58.2-87.3%) is consistent with supply chain development patterns observed in other East African agricultural input markets [8]. Comparative investigations in Tanzania and Uganda have reported similarly constrained biofertilizer distribution networks, with coverage rates ranging from 12% to 38% across agricultural zones [9]. The strong correlation between distribution density and adoption rates ($r = 0.84$ for biofertilizers) provides empirical support for the supply-side adoption hypothesis, which posits that product availability is a more powerful determinant of technology adoption than awareness or economic incentives in agricultural input markets characterized by infrastructure constraints [10]. This finding challenges the predominant demand-side focus of most biofertilizer promotion programmes, which emphasize farmer training and awareness campaigns while neglecting

the fundamental distribution infrastructure prerequisites for market access [3].

The cold chain requirements associated with biofertilizer products introduce unique logistical challenges that are inadequately addressed by existing fertilizer distribution infrastructure [11]. Temperature-controlled storage and transport facilities were available at fewer than 18% of retail outlets surveyed, creating significant quality assurance risks that undermine farmer confidence and product effectiveness. Investment in decentralized biofertilizer production facilities located closer to end-user markets could simultaneously reduce cold chain dependency, lower transportation costs, and improve product freshness at the point of purchase [12].

The coverage-efficiency trade-off observed between distribution channels presents a strategic dilemma for biofertilizer market development planners. While direct factory outlets and cooperative societies demonstrated superior efficiency metrics, their limited geographic reach constrains market development potential. The agro-dealer network, despite lower efficiency scores, represents the most promising distribution backbone for biofertilizer market expansion, provided that targeted investments in storage infrastructure, product handling training, and quality monitoring systems are implemented [13].

Technological innovation opportunities

Digital marketplace platforms represent an emerging channel with significant potential for biofertilizer distribution optimization. Despite current low efficiency scores (4.8/10), online platforms eliminate multiple intermediary stages and can incorporate product traceability features that address quality assurance concerns. The integration of mobile payment systems, GPS-enabled delivery tracking, and real-time inventory management could substantially improve the viability of direct-to-farmer biofertilizer distribution models.

Conclusion

Within the context of agricultural input market development in East Africa, this research has highlighted the critical structural barriers constraining biofertilizer supply chain performance relative to established chemical fertilizer distribution systems. The key findings demonstrate that distribution coverage disparities, price escalation through multi-tier channels, and cold chain infrastructure deficiencies collectively constitute the most significant impediments to biofertilizer market growth. The recommendation emerging from this analysis is that biofertilizer market development strategies should prioritize supply chain infrastructure investment over demand-side interventions, with particular emphasis on decentralized production facilities, cold chain logistics enhancement, and agro-dealer network capacity building. Looking forward, the integration of digital marketplace technologies and mobile logistics platforms offers promising pathways for overcoming the structural distribution challenges identified in this investigation.

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