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Investigation of Supply Chain Processes Affecting Adoption of Maize Post-Harvest Loss Reduction Practices among Smallholder Farmers in Chipata District, Zambia

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Abstract

Persistent maize post-harvest losses continue to undermine household food security and smallholder livelihoods in Chipata District, Zambia, despite the availability of improved post-harvest technologies. This study examined the influence of supply chain processes on the adoption of maize post-harvest loss reduction practices among smallholder farmers, focusing on warehousing, transportation, evidence-based recommendations, and market access. A cross-sectional mixed-methods design was employed, involving 77 smallholder farmers and 16 key informants. Quantitative data were analysed using descriptive statistics, correlation, ANOVA, and multiple regression, while qualitative data were analysed thematically. The findings revealed that warehousing significantly influenced the adoption of post-harvest loss reduction practices ($\beta = 0.438$, $p < 0.05$), with improved storage facilities, storage training, and the ability to delay sales encouraging greater uptake. Market access emerged as the strongest determinant, with cooperative marketing, aggregation centres, reliable buyers, and improved price opportunities promoting investment in post-harvest management. Although transportation mode was not statistically significant ($p > 0.05$), qualitative findings identified poor road infrastructure and high transport costs as major constraints. Overall, the study demonstrates that effective post-harvest loss reduction depends not only on technological interventions but also on an enabling supply chain environment. The study recommends strengthening warehousing systems, market infrastructure, extension services, cooperative marketing, rural road networks, affordable transport, and market information systems to enhance the adoption of post-harvest loss reduction practices and improve food security among smallholder maize farmers.

Keywords: Maize; post-harvest loss reduction; supply chain processes; smallholder farmers; warehousing; market access; Zambia.

Background

The complexities inherent in smallholder maize production within the agricultural supply chain landscape necessitate a context-sensitive understanding of the interplay between supply chain processes and the adoption of post-harvest loss reduction practices. The effectiveness of post-harvest loss reduction practices is closely linked to the performance of the supply chain (Nsefu et at.,2020). Efficient storage,

transportation, handling, and marketing systems improve farmers' access to post-harvest technologies, strengthen the flow of market information, and increase the economic incentives to invest in better grain management. Where these systems are poorly developed, adoption becomes more difficult, often leading to higher post-harvest losses and lower farm returns(Nsefu,2021). Examining the influence of supply chain processes is therefore essential for identifying practical interventions that can encourage wider adoption of post-harvest loss reduction practices among smallholder maize farmers.

Agriculture continues to underpin food security, economic development, and rural livelihoods across much of the world, with maize remaining a principal staple crop for millions of people, particularly in developing countries (FAO, 2022; World Bank, 2023; Padhan et al., 2024). Despite notable gains in maize production driven by improved agronomic practices, high-yielding varieties, and sustained agricultural research, post-harvest losses remain persistently high. Estimates indicate that 30–40 percent of harvested maize is lost because of inadequate storage, poor handling, inefficient transport systems, and limited market infrastructure (FAO, 2022; UN, 2021). Such losses erode food supplies, reduce farm incomes, and weaken the gains achieved through increased production, underscoring the need to strengthen agricultural supply chains alongside advances in production technology.

Across sub-Saharan Africa, maize remains indispensable to food security and rural livelihoods, yet post-harvest losses continue to undermine agricultural productivity. Grain is frequently lost during drying, storage, handling, and transportation as a result of inadequate infrastructure, pest infestations, and weak quality management systems (FAO, 2022). Similar constraints are reflected in the African Development Bank's assessment, which identifies limited rural storage capacity, inefficient transport networks, and poorly developed aggregation systems as major barriers to profitable market participation by smallholder farmers (AfDB, 2021). Recognising these challenges, the African Union has placed value chain development and post-harvest loss reduction at the centre of the Comprehensive Africa Agriculture Development Programme (CAADP) as part of its broader agricultural transformation agenda (African Union, 2020). Even so, the continued scale of post-harvest losses indicates that technological innovations achieve greater impact when supported by efficient and well-coordinated supply chain systems.

A comparable trend is observed across Southern Africa, where an estimated 15–30 percent of maize production is lost after harvest because of pest damage, poor handling practices, inadequate storage, and weak transport infrastructure (Affognon et al., 2015; World Bank, 2021). In response, governments and development agencies have promoted hermetic storage technologies, improved drying methods, and stronger value chain coordination to curb these losses (Amjath-Babu et al., 2016; Kihara et al., 2017). Progress, however, has been uneven. High investment costs, limited extension services, restricted market access, and fragmented marketing systems continue to constrain adoption among many smallholder farmers. These conditions suggest that lasting reductions in post-harvest losses depend not only on the availability of improved technologies but also on coordinated supply chain processes and effective institutional support.

In Zambia, agriculture contributes about 10–12 percent of gross domestic product and supports the livelihoods of more than 70 percent of the rural population, the majority of whom are smallholder farmers (Malesu et al., 2024; World Bank, 2024; FAO, 2023; Zambia Statistics Agency, 2023). Maize occupies a dominant position within this sector as the country's principal staple crop and a major source of household income, making effective post-harvest management central to national food security. This priority is reflected in public policy, where programmes such as the Farmer Input Support Programme (FISP) allocate a substantial share of subsidised seed and fertiliser to maize production (Ndhlovu & Muchapondwa, 2025;

Kuntashula & Mwelwa-Zgambo, 2022). Likewise, national production targets, procurement by the Food Reserve Agency, and agricultural financing initiatives continue to place considerable emphasis on maize (Mweene & Mwange, 2025). Even so, significant post-harvest losses persist, suggesting that production gains alone cannot deliver sustainable food security without stronger supply chain systems to support the storage, movement, and marketing of harvested maize.

Table 1 FISP Seed Distribution by Crop (2024/25) – Percentage Share

Crop Type	Seed Delivered (Metric Tonnes)	Share of Total Seed Support (%)
Maize	2,851.68	38.6%
Groundnuts	2,088.73	28.3%
Soybeans	1,485.78	20.1%
Other Crops (Beans, Sunflower, Sorghum, Rice, Cowpeas)	~1,070	~14.9%
Total	~7,496	100%

Source: National Assembly of Zambia 2025 Ministerial statement

Although Zambia does not have legislation that specifically addresses post-harvest loss reduction as a separate legal requirement, several national laws and policies promote practices that contribute to reducing these losses. The Ministry of Agriculture and national agricultural policy framework provide legislative support for agricultural production, storage, and marketing systems that contribute to post-harvest loss reduction. Key instruments include the Food Reserve Act No. 6 of 2020, which establishes the legal framework for strategic grain reserves and storage management through the Food Reserve Agency, and the Warehouse Receipt System Act No. 8 of 2019, which regulates licensed warehouses and promotes secure commodity storage. Complementing these statutes, the National Agricultural Policy (2016–2020) prioritises improved post-harvest handling technologies and value chain development, while the National Planning and Budgeting Act No. 1 of 2020 provides the framework for allocating public resources to agricultural development programmes. Collectively, these policy and legislative instruments recognise that reducing post-harvest losses requires coordinated investments in storage, marketing, and broader agricultural support systems.

Smallholder maize farmers form the backbone of Zambia's food production system and make a substantial contribution to both household and national food security. Despite this role, their integration into agricultural supply chains remains constrained by persistent structural and institutional barriers. Most cultivate relatively small landholdings and rely primarily on family labour for production activities. Access to improved storage technologies, agricultural extension services, reliable market information, and affordable credit is often limited, reducing their capacity to adopt improved post-harvest practices and participate effectively in formal markets. These constraints increase their exposure to post-harvest losses and reduce their ability to adopt improved post-harvest management practices. In addition, weak market linkages and low bargaining power discourage investment in better post-harvest technologies because the expected financial returns are often uncertain. As a result, many farmers continue to rely on traditional handling and storage methods that are less effective in reducing losses. Recent evidence suggests that targeted interventions can strengthen smallholder farmers' participation in agricultural supply chains and improve the uptake of post-harvest loss reduction practices. Farmer training, investments in rural

infrastructure, improved access to financial services, and stronger market support have all been associated with higher adoption of improved post-harvest technologies and management practices (Zhang et al., 2025; Arulmanikanda et al., 2023; Zahiduzzaman et al., 2025). Viewed from this perspective, supply chain processes and post-harvest loss reduction cannot be separated from the realities of smallholder farming. They are shaped by institutional support, access to productive resources, and prevailing market conditions, all of which influence farmers' adoption decisions and the overall performance of the maize value chain.

Statement of the Problem

Post-harvest losses remain a persistent challenge to food security and rural livelihoods in Eastern Province, Zambia, where maize production is largely undertaken by smallholder farmers. A substantial share of harvested grain is lost during handling, drying, storage, and marketing, reducing both the quantity and quality of maize reaching consumers. Recent estimates indicate that these losses may account for as much as 30 percent of total production (Mwamba, 2025; Chiliboyi & Bwalya, 2026; MAFF, 2021). The consequences extend beyond the farm, reducing household food supplies, lowering marketable surplus and farm income, and diminishing the broader economic contribution of maize production within the province.

Despite continued efforts to promote post-harvest loss reduction practices, adoption among maize farmers in rural Zambia remains uneven (Ng'andu & Chibomba, 2025; Silwimba & Chileshe, 2025; AGRA, 2025). Existing studies have largely examined individual supply chain factors or reported findings at national and regional scales, providing limited insight into how these processes interact to shape farmers' adoption decisions at the district level. This gap is particularly relevant in Chipata District, where infrastructure, market access, and institutional support operate within a distinct local context. Consequently, the influence of interconnected supply chain processes on the adoption of post-harvest loss reduction practices remains insufficiently documented, underscoring the need for district-specific empirical evidence.

This study investigates how supply chain processes influence the adoption of post-harvest loss reduction practices among smallholder maize farmers in Chipata District, Zambia. By generating district-level empirical evidence, it aims to deepen understanding of the ways in which warehousing, transportation, and market access shape farmers' adoption decisions and, in turn, inform interventions that strengthen post-harvest management within the maize value chain. The findings are expected to inform context-specific interventions and contribute to the growing body of knowledge on agricultural innovation and supply chain management.

Research Objectives

The research objectives focused on the supply chain factors influencing the adoption of post-harvest loss (PHL) reduction practices among smallholder maize farmers in Chipata District. They include one general objective and specific objectives that guide the study.

General Objective

To investigate supply chain processes influencing the adoption of post-harvest loss reduction practices among smallholder maize farmers in Chipata District, Zambia.

Specific Objectives

1. To examine the influence of warehousing facility on the adoption of PHL reduction practices among

smallholder maize farmers in Chipata District, Zambia
2. To assess the role of transportation mode in shaping the adoption of post-harvest loss reduction technologies among smallholder farmers in Chipata District, Zambia.
3. To analyze the impact of market access on farmers' adoption of PHL reduction practices in Chipata district Zambia.
4. To provide supply chain evidence-based recommendations for policymakers, extension services, and stakeholders to enhance adoption rates so as to reduce post-harvest losses in Chipata District of Zambia.

Research Questions

1. To what extent does warehousing facility significantly predict the adoption of post-harvest loss reduction practices among smallholder maize farmers in Chipata District, Zambia?
2. What is the effect of transportation mode on the likelihood of adopting post-harvest loss reduction practices among smallholder maize farmers in Chipata District, Zambia?
3. How does market access impact smallholder maize farmers' decisions to adopt or not adopt post-harvest loss reduction practices in Chipata District Zambia?
4. How are supply chain evidence-based recommendations made for policymakers, extension officers and smallholder farmers to enhance adoption rate so as to reduce post-harvest losses in Chipata district, Zambia?

Significance of the Study

Smallholder maize farmers are expected to benefit from the findings of this study. By identifying the supply chain factors that influence the adoption of post-harvest loss reduction practices, the study is expected to provide a better understanding of the challenges and opportunities that affect adoption at the farm level. The findings are also expected to inform extension services and other support programmes aimed at reducing post-harvest losses, improving farm incomes, strengthening food security, and enhancing household resilience.

At the theoretical level, this study is expected to contribute to existing knowledge on the adoption of agricultural practices by examining supply chain factors within a single analytical framework. While previous studies in Sub-Saharan Africa have largely considered these factors separately, this study provides a broader understanding of how they interact within the maize supply chain.

The findings are also expected to provide context-specific evidence that can inform the design of post-harvest programmes by the Ministry of Agriculture, extension services, development partners, and farmer organisations.

Literature Review

Supply chain process in maize post-harvest management

Supply chain processes are a critical aspect of maize production and post-harvest management, particularly in smallholder farming systems, which are often vulnerable to high post-harvest losses. Evidence from Latin America points to persistent deficiencies in post-harvest supply chains as a major source of maize losses. In Peru, Díaz Valderrama et al. (2020) estimated losses of between 15 and 27 percent, attributing them to inadequate drying, limited storage capacity, and inefficient transport arrangements. The implication is clear: technical improvements, when implemented in isolation, rarely

deliver substantial reductions in post-harvest losses because weak logistics and storage systems continue to undermine their effectiveness. Similar conclusions emerge from Mexico, where Odjo et al. (2022) examined the adoption of hermetic storage technologies and observed that uptake was considerably stronger when storage innovations were reinforced by farmer training, dependable input supply, and improved market access. Access to technology, therefore, represented only one element of a much broader support system. Working in Peru, Baributsa et al. (2024) likewise contend that investments in storage and distribution infrastructure yield greater benefits when accompanied by continuous farmer education and routine monitoring of storage practices. Taken together, these studies portray supply chain management as an interconnected system rather than a sequence of separate activities, where production, storage, transport, and marketing function as mutually reinforcing components. Although the evidence originates outside Zambia, its implications remain relevant for maize-producing regions such as Chipata District, where many smallholder farmers continue to face comparable logistical, institutional, and market-related constraints that shape the adoption of post-harvest loss reduction practices.

Recent evidence suggests that the influence of supply chain processes on post-harvest technology adoption extends well beyond the physical movement of agricultural products. Nakoma-Ngoma et al. (2025) identify fragmented distribution networks, the limited availability of input suppliers, and insufficient farmer training as interconnected constraints that suppress technology uptake among smallholder farmers. Their findings suggest that wider adoption is unlikely to occur through technology dissemination alone; coordinated improvements in input access, distribution systems, and farmer capacity are equally necessary. Similar conclusions have been reported elsewhere in Africa. In Tanzania, Zacharia et al. (2024) found that farmers who had easier access to hermetic storage vendors and received training on the proper use of the technology were more likely to adopt improved storage practices and achieve better maize storage outcomes. This suggests that the availability of technologies is only one part of the adoption process; farmers also require practical knowledge and timely access to suppliers before they can use these innovations effectively. Comparable evidence is reported by Mutungi et al. (2023), whose multi-country study across East Africa found that the adoption of hermetic bags and other airtight storage technologies was associated with improved household food availability, better access to food, and higher farm incomes. These outcomes, however, were not attributed to storage technologies alone. Rather, the authors emphasise the importance of supply chains capable of delivering technologies, technical information, and support services consistently to farming communities. Viewed collectively, the evidence suggests that effective supply chain processes involve far more than transporting maize; they also include reliable input distribution, accessible vendors, farmer capacity development, and continuous information exchange that supports adoption decisions. Although these studies were undertaken in different African settings, their findings remain relevant to Zambia, where stronger supply chain systems could accelerate the adoption of post-harvest loss reduction technologies, improve food security, and strengthen rural livelihoods.

In Zambia, supply chain processes underpin the functioning of the maize value chain by determining how production inputs, post-harvest technologies, and market information reach smallholder farmers. The Ministry of Agriculture (2023) identifies these processes as encompassing input procurement and distribution, transportation, storage management, and extension services, each supporting farmers from production through the post-harvest period. Physical infrastructure alone, however, is insufficient. The World Food Programme (2022) argues that coordinated supply chains also improve market access while reducing losses during handling, storage, and transportation, highlighting the importance of reliable logistics alongside institutional support. Farmers require consistent access to hermetic bags and other

storage technologies, responsive extension services, and distribution networks capable of delivering these resources when they are needed. Reflecting this broader perspective, the Ministry of Agriculture (2023) and United Nations Zambia (2022) contend that integrating technology distribution with farmer support services strengthens the adoption of improved drying and storage practices, thereby reducing avoidable post-harvest losses. Although the scale of these benefits differs across farming communities, the available evidence consistently associates stronger supply chain systems with lower post-harvest losses, wider adoption of improved storage technologies, and greater participation in agricultural markets (World Food Programme, 2022). Such improvements carry particular significance for Zambia, where maize remains the principal staple crop and a major source of rural livelihoods, making efficient supply chain systems integral to food security, farm productivity, and sustainable household incomes.

The reviewed literature consistently shows that supply chain processes shape the adoption of post-harvest loss reduction practices among smallholder farmers. Within the Zambian context, better access to production inputs, more efficient transportation and storage systems, and stronger extension services collectively create an environment that supports the uptake of improved post-harvest technologies. Adoption rarely depends on technology alone. As coordination across these supply chain functions improves, farmers are better positioned to minimise post-harvest losses, maintain grain quality, and engage more effectively in maize markets. For this reason, strengthening supply chain systems should remain a central consideration in policies and programmes designed to improve food security and enhance the livelihoods of smallholder maize farmers.

Maize post-harvest loss reduction practices adoption

Evidence from Asia and Latin America indicates that the adoption of maize post-harvest loss (PHL) reduction practices is shaped by an interaction of technological, economic, and institutional conditions rather than by the availability of improved technologies in isolation. In Nepal, Nepali and Maharjan (2025) found that subsidised hermetic storage bags increased adoption among smallholder farmers by lowering acquisition costs and making improved storage practices more accessible. Affordability mattered. Mexico and several Central American countries present a complementary pattern. Verhulst et al. (2022) demonstrated that hermetic bags and metal silos outperformed conventional storage methods in limiting insect damage and preserving grain quality, yet their effectiveness depended heavily on local farming conditions and farmers' capacity to use them correctly. Stathers, Onumah and Lamboll (2024), together with Abrol et al. (2025), extend this argument by showing that improved technologies generate stronger and more sustained outcomes when accompanied by farmer training, institutional support, and policies that expand access to post-harvest services. Technology, therefore, represents only one component of the adoption process. Lasting improvements emerge when technical innovations are reinforced by supportive institutions, accessible information, and enabling policy environments. Although these studies were undertaken in settings that differ from Zambia, they converge on a common conclusion: farmers are more inclined to adopt post-harvest loss reduction practices when technologies are affordable, knowledge is accessible, and institutional support is dependable. These insights provide a useful basis for strengthening interventions aimed at increasing adoption among smallholder maize farmers in Zambia.

Research across East and Southern Africa indicates that the adoption of post-harvest loss reduction practices is shaped by an interplay of socioeconomic, institutional, and informational conditions rather than by technology availability alone. Access to improved technologies remains important, but it is rarely sufficient on its own. Farmers are more likely to adopt new post-harvest practices when financial capacity, technical knowledge, and institutional support converge. Evidence from Tanzania illustrates this

relationship. Mutungi et al. (2023) found that the adoption of mechanised shelling, drying tarpaulins, and airtight storage technologies increased among farmers with larger farm sizes, access to credit, off-farm income, and opportunities to exchange knowledge through community groups. These factors were also associated with improved household food security and welfare, underscoring the contribution of both economic resources and social learning to technology adoption. Comparable evidence is reported by Zacharia et al. (2024), who observed that training, proximity to input suppliers, and access to credit significantly increased the uptake of hermetic storage technologies among Tanzanian farmers. Despite examining different dimensions of adoption, both studies emphasise the importance of an enabling environment in which farmers can secure the knowledge, financial resources, and production inputs needed to implement improved storage practices. Similar patterns emerge across the wider sub-Saharan African region. Nakoma-Ngoma et al. (2025) identify inadequate training, fragmented distribution networks, and weak policy support as persistent barriers to the uptake of post-harvest technologies. Yami et al. (2025), by contrast, demonstrate that stronger integration into agricultural markets and value chains creates incentives for adoption by improving access to market information and expanding economic opportunities. Abass et al. (2022) likewise report that effective extension services and farmer training contribute to lower post-harvest losses, particularly where institutional support and market linkages are well developed. Viewed collectively, these studies suggest that widespread adoption is unlikely to result from technology provision alone. More durable outcomes emerge when affordable technologies are complemented by responsive extension services, accessible finance, efficient markets, and institutions capable of supporting farmers throughout the adoption process. Although generated in different national contexts, these findings offer important lessons for Zambia, where strengthening these interconnected factors could accelerate the adoption of post-harvest loss reduction practices among smallholder maize farmers.

Evidence from Zambia indicates that the adoption of post-harvest loss reduction practices among smallholder maize farmers remains below the level required to substantially reduce storage losses, despite the availability of improved storage technologies. Technology alone has not resolved the problem. The literature instead points to a broader set of constraints embedded within agricultural supply chains and rural support systems. Across many farming communities, traditional storage structures such as granaries and cribs remain the dominant option, yet they provide only limited protection against insect infestation and moisture, allowing both grain quantity and quality to deteriorate before marketing. De Groote, Gitonga and Sonder (2023) estimate that post-harvest losses reach as much as 25 percent in some districts, highlighting the continuing need for more effective storage and post-harvest management practices. Although hermetic bags and related storage technologies have proven effective in limiting insect and fungal damage while preserving grain quality, adoption has remained uneven (Ng'andu & Chibomba, 2025). Chekenya et al. (2024) attribute this pattern to a combination of high acquisition costs, weak local distribution networks, and limited farmer awareness, suggesting that economic, institutional, and informational barriers are more influential than technological limitations themselves. Effective post-harvest management therefore depends on more than introducing improved storage technologies. Reliable extension services, accessible input supply systems, stronger market linkages, and sustained farmer training are equally important if adoption is to increase. Strengthening these interconnected supply chain functions would not only encourage wider use of post-harvest loss reduction practices but also improve grain quality, enhance household food security, and support more resilient livelihoods among smallholder maize farmers in Zambia.

Across the reviewed literature, a consistent pattern emerges: farmers who adopt maize post-harvest loss reduction practices are more likely to strengthen household food security while improving farm income and overall livelihood resilience.They also indicate that coordinated support through technology, extension services, and efficient supply chains is important for increasing adoption and reducing post-harvest losses.

Theoretical Review

Supply Chain Management Theory Perspective

Supply Chain Management (SCM) theory has emerged as a critical framework for understanding the coordination, integration, and management of processes within supply chains, particularly in agricultural systems (Christopher, 2016). This theory explains how the flow of goods, information, and resources is coordinated across the supply chain to create value and improve overall system performance. It provides a useful lens for examining how warehousing, transportation, market access, and other interconnected supply chain activities shape the adoption of post-harvest loss reduction practices among smallholder maize farmers by influencing product availability, transaction costs, and market efficiency.

Lambert and Cooper (2000) conceptualise Supply Chain Management (SCM) Theory as the coordinated management of interdependent functions, including warehousing, inventory management, and logistics, to improve the efficiency and continuity of product flows while reducing avoidable operational costs. Coordination is indispensable. Within agricultural supply chains, warehousing extends well beyond the simple storage of grain because storage conditions directly influence post-harvest losses, product quality, and market value. Even minor deficiencies matter. Consequently, reliable storage infrastructure, supported by disciplined inventory management and appropriate handling practices, strengthens the preservation, marketability, and overall supply chain performance of agricultural commodities.

Management decisions have tangible consequences. Supply Chain Management (SCM) Theory provides a robust analytical lens for examining how warehouse facilities shape the adoption of maize post-harvest loss reduction practices. From this perspective, the condition of storage infrastructure, its accessibility, and the quality of warehouse management collectively influence farmers' ability to preserve maize after harvest and their readiness to adopt improved post-harvest practices. Its relevance is evident. Well-functioning warehouse systems reduce grain deterioration, protect product quality, and improve the operational efficiency of the wider supply chain. Consistent with this reasoning, Abebe and Zeleke (2018) argue that applying SCM principles strengthens the relationship between storage capacity and the successful uptake of post-harvest innovations among smallholder farmers.

Transaction Cost Theory Perspective

Developed from the pioneering work of Coase (1937) and subsequently refined by Williamson (1981), Transaction Cost Theory (TCT) explains that economic exchanges entail costs extending beyond the purchase price of a product or service. These costs matter. Information search, contract negotiation, and agreement monitoring all require resources that influence economic decision-making. As transaction costs decline, coordination becomes more efficient, exchanges proceed more smoothly, and resources are allocated more effectively. Applied to agricultural supply chains, TCT provides a valuable analytical framework for explaining how transportation, access to market information, and institutional arrangements shape farmers' decisions to adopt post-harvest loss reduction practices.

The main idea of Transaction Cost Theory (TCT) is that the way transactions are organised influences the costs of exchanging goods and services, which in turn affects efficiency and decision-making (Coase, 1937; Williamson, 1981). In agricultural supply chains, transportation and market access play an important

role in determining these costs. Poor roads, long distances, and high transport or handling costs can discourage farmers from adopting improved post-harvest loss reduction practices, while reliable transport and better access to markets lower transaction costs and make investment in these practices more worthwhile.

Lower costs alter incentives. Transaction Cost Theory is directly applicable to this study because it explains how transportation and market access shape farmers' decisions to adopt maize post-harvest loss reduction practices. High transport costs, lengthy travel distances, and restricted access to output markets increase transaction costs, thereby reducing the expected returns from investing in improved post-harvest technologies. More efficient transport systems and stronger market linkages shift this balance by improving market participation and making the adoption of post-harvest practices more economically attractive. Viewed through this theoretical lens, reducing transaction costs provides a practical pathway for strengthening market access and encouraging technology adoption. Consistent with this argument, Abebe and Zeleke (2018) and Yusuph and Guohua (2017) contend that lower transaction costs increase the uptake of post-harvest innovations among smallholder farmers.

Diffusion of Innovations Theory Perspective

The core idea of DOI theory is that the adoption of an innovation is influenced by five characteristics: relative advantage, compatibility, complexity, trialability, and observability. According to the theory, farmers are more likely to adopt an innovation when it offers clear advantages, fits well with their existing practices, is easy to use, can be tested on a small scale, and produces visible results. The theory also recognizes that communication, social networks, and trusted community members play an important role in shaping adoption decisions. As Rogers (2003) explains, understanding these factors is important for designing interventions that encourage the successful uptake of new technologies

First introduced by communication scholar Everett Rogers in 1962 and subsequently refined by Rogers (2003), it explains how new ideas, technologies, and practices are communicated, accepted, and gradually disseminated across social systems over time. Adoption seldom occurs uniformly. Although individuals may be exposed to the same innovation, differences in perception, experience, and social influence often result in markedly different rates of acceptance. Communication remains central. Information exchanged through interpersonal networks, extension services, and other social interactions shapes farmers' awareness, influences their evaluation of new practices, and ultimately informs their adoption decisions.

The theory is particularly relevant to this study because it explains how supply chain processes influence the adoption of maize post-harvest loss reduction practices. Adoption depends on more than perceived benefits. Farmers' decisions to use improved storage technologies, hermetic bags, enhanced drying methods, and other post-harvest practices are also shaped by the accessibility of support embedded within the supply chain. Warehouse facilities, reliable transport networks, market opportunities, and related supply chain services expand farmers' access to information, technologies, and practical experience, thereby reducing barriers to adoption. As these support systems become more accessible, the likelihood that farmers will adopt improved post-harvest practices correspondingly increases.

Institutional Theory Perspective

Institutional Theory (IT), advanced by W. Richard Scott, explains how rules, policies, social norms, and shared expectations shape organisational and individual decision-making (Scott, 2004). Rather than acting independently, organisations operate within institutional environments that influence their actions, strategic choices, and behaviour. It further argues that regulatory requirements, professional standards, and

social expectations often encourage the adoption of particular practices in order to gain legitimacy, support, and access to resources.

The behaviour of individuals and organisations is shaped by the rules, policies, and support systems within their operating environment (DiMaggio & Powell, 1983). Institutional Theory provides the conceptual basis for understanding these influences. Within agricultural supply chains, government agencies, extension services, farmer cooperatives, and development programmes shape farmers' decisions to adopt maize post-harvest loss reduction practices by improving access to knowledge, institutional support, and productive resources. Their contribution is substantial. Through training, policy implementation, and resource provision, these institutions help reduce knowledge gaps, infrastructure limitations, and financial constraints that frequently impede adoption.

Relevant to this study is Institutional Theory because it supports explain how policies, institutions, and support programmes influence farmers' adoption of post-harvest loss reduction practices. Government agencies, extension services, farmer cooperatives, and development programmes can shape farmers' decisions by providing training, improving access to credit, and strengthening storage and marketing support. These institutional arrangements create conditions that make it easier for smallholder maize farmers to adopt improved post-harvest practices and reduce maize losses. As noted by Abebe and Zeleke (2018) and Yusuph and Guohua (2017), strong institutional support plays an important role in sustaining the adoption of post-harvest innovations among smallholder farmers.

Empirical Review

Access to improved storage can influence how smallholder farmers manage maize after harvest. Studies in Rwanda and Tanzania found that hermetic and other improved storage systems reduced grain losses, preserved quality, and improved market returns (Benimana, Ritho & Irungu, 2023; Zacharia et al., 2024; Mlay et al., 2025). In Brazil and India, warehouse receipt systems also allowed farmers to delay sales while improving access to credit and market information (Kumar et al., 2022; Souza et al., 2023). Yet high costs, limited credit, and weak extension support continue to restrict adoption. Similar constraints are reported in Zambia, particularly inadequate storage facilities and limited financial and extension support (Muntanga, 2023; Chavula et al., 2022). Improved warehousing is therefore more useful when farmers can afford and access the services needed to use it effectively.

Transportation can shape farmers' adoption of post-harvest loss reduction practices. Studies across Asia, Latin America, and Africa link poor transport to grain damage, moisture exposure, longer travel times, and greater losses (Affognon et al., 2022; Kumar et al., 2023; Abass et al., 2022). Poor roads and distant markets can also force farmers to sell maize soon after harvest rather than wait for better prices (Mapfumo et al., 2022; Nhamo et al., 2023). Similar constraints occur in Zambia, where high costs, delays, and limited transport capacity affect maize movement (Chisanga et al., 2022; Mofya-Mukuka et al., 2023). Thus, adoption depends not only on transport mode, but also on its cost, reliability, and connection to markets.

Market access can influence farmers' willingness to invest in post-harvest loss reduction practices. Studies from India and China link fragmented markets and weak price incentives with lower adoption of improved storage and drying technologies, while stronger market infrastructure and information have supported adoption in Brazil (Kumar et al., 2023; Stathers et al., 2025; Silva et al., 2024). Across sub-Saharan Africa, poor market information constrains adoption, whereas credit and farmer organisations can improve farmers' capacity to invest (Bisheko & Rejikumar, 2023; Mutungi et al., 2023). Similar constraints occur in Zambia, where weak market coordination has affected maize losses and farmers' bargaining power (De

Groote et al., 2023; Chiliboyi, 2026). Farmers therefore have greater incentive to adopt improved practices when markets offer reliable buyers, useful information, and better returns.

Adoption of post-harvest loss reduction practices tends to improve when storage, transport, markets, finance, and extension support work together. Studies link higher adoption with extension services, market access, training, credit, and coordinated institutional support (Stathers et al., 2025; Nakoma-Ngoma et al., 2025). In Africa, cooperatives and aggregation centres also provide shared transport, credit, and collective marketing opportunities (Abate et al., 2023). Similar evidence from Zambia shows that combining cooperative marketing with extension services can improve market information and technology uptake (Tembo, 2023). These findings show that warehousing, transportation, and market access are closely related, yet their influence on adoption among smallholder maize farmers in Chipata District remains less understood.

Research Gap

The literature consistently demonstrates that the adoption of post-harvest loss (PHL) reduction practices among smallholder farmers is shaped by several interrelated supply chain factors, notably warehousing, transportation, and market access. Effective warehousing preserves grain quality and reduces storage losses. Reliable transportation facilitates timely movement to storage facilities and markets, while improved market access strengthens the economic incentives for farmers to invest in better drying, storage, and grain-handling practices. Viewed collectively, these supply chain functions create conditions that support wider adoption by lowering transaction costs, reducing post-harvest risks, and improving the expected returns from post-harvest investments. Although these factors have been widely studied, they are often examined separately. There is limited evidence on how they interact to influence adoption among smallholder maize farmers in Zambia. As a result, there is still a need for research that considers these supply chain factors together. The goal being to provide practical recommendations for improving adoption of PHL reduction practices and reducing post-harvest losses in districts such as Chipata.

Conceptual Framework

In this study, a hybrid conceptual framework is developed to examine the relationship between supply chain processes, adoption of post-harvest loss reduction practices, and improved maize quality in the context of smallholder maize farmers in Zambia.

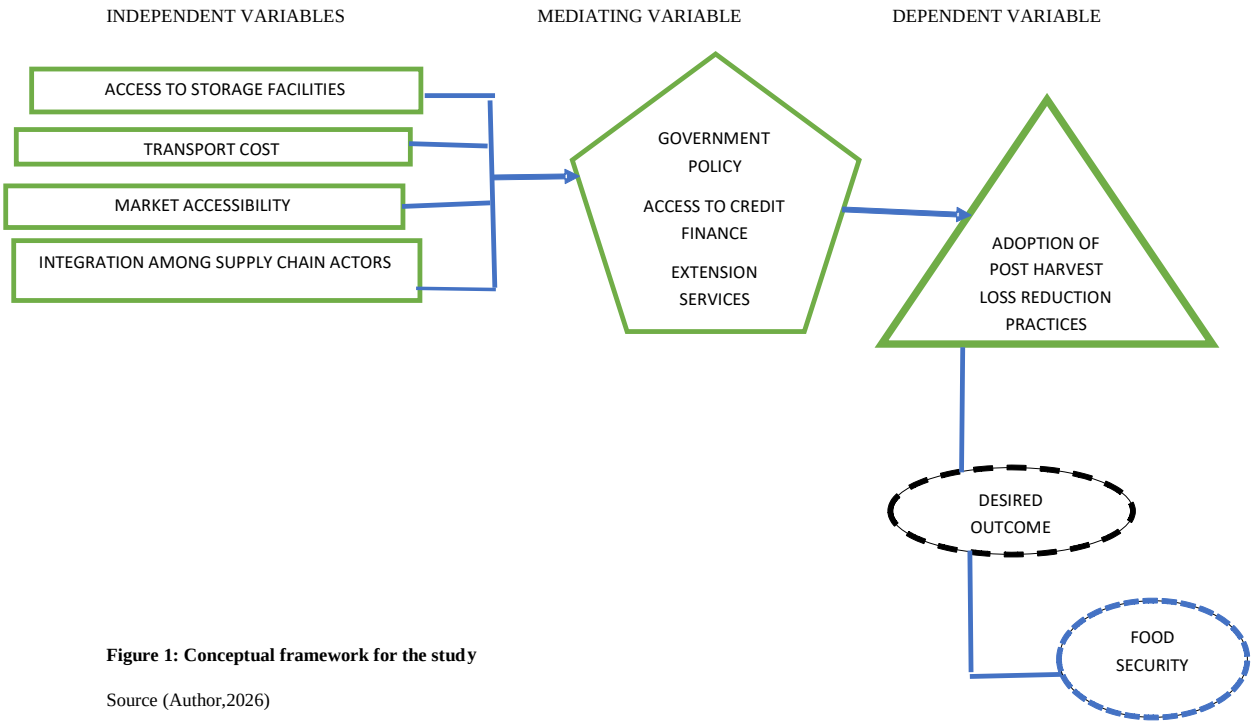

Figure 1: Conceptual framework for the study

Source (Author,2026)

Research Methodology

Research Design

As noted by Othman et al. (2020), research design provides a strategic framework that links research questions with data collection and analysis procedures. Research design can be understood as a structured plan that guides the overall conduct of a study by specifying how data will be collected, measured, and analysed within qualitative, quantitative, or mixed methods approaches (Punch, 2014; Yin, 2018; Silverman, 2020). It ensures that the data generated is relevant to the research objectives while maintaining coherence and methodological efficiency throughout the study (Akhtar, 2016). By applying a well-structured research design, the study ensured that the data collected was both valid and reliable, and that it directly contributes to addressing the research objectives.

However, mixed methods research designs are commonly categorised into three main types: sequential, concurrent, and transformative designs (Creswell& Plano Clark, 2022; Saunders et al., 2023). In sequential designs, data collection occurs in phases, where one form of data either precedes or follows the other, such as in sequential explanatory or sequential exploratory approaches, allowing one dataset to build on the results of the other. Concurrent designs, on the other hand, involve the simultaneous collection of qualitative and quantitative data within the same phase of the study, enabling direct comparison and integration of findings. Transformative designs are guided by specific theoretical or philosophical perspectives and are often used to address issues of social change or marginalised groups (Mertens, 2020). In this study, a concurrent mixed methods design was adopted, allowing for the simultaneous collection and analysis of both quantitative and qualitative data. The chosen research design was well suited to the study because it examined both the relationship between supply chain factors and the adoption of post-harvest loss reduction practices, and the experiences of smallholder maize farmers. Quantitative data was collected through structured questionnaires with closed-ended questions, while qualitative data was obtained through semi-structured interviews with open-ended questions.

Philosophy of the Study

The philosophical approach of this study on the influence of supply chain processes on the adoption of post-harvest loss reduction practices among smallholder maize farmers is grounded in pragmatism. As noted by Morgan (2020), research philosophy significantly shapes methodological choices, explaining why a particular approach qualitative, quantitative, or mixed methods is adopted. Research philosophy encompasses epistemological assumptions about the nature and acquisition of knowledge, ontological assumptions about the realities being studied, and axiological considerations regarding the influence of the researcher's values on the research process (Saunders et al., 2022). A pragmatic research philosophy was well suited to this study. It integrated qualitative and quantitative methods to examine how supply chain processes influence smallholder farmers' adoption of post-harvest loss reduction practices.

Study Area

Selecting the study area ensured that the findings reflected the local conditions under which farmers produce, store, and market maize. In this way, the study area becomes more than just a location; it becomes part of how the research problem is understood. Smallholder maize farming is the main source of livelihood for many rural households in Chipata District in Eastern Province, Zambia.

Study Population

The study population refers to the entire group of individuals who meet the criteria for inclusion in a research study (Leedy & Ormrod, 2019) The study primarily focuses on smallholder maize farmers as the main unit of analysis, as they are directly involved in the adoption of post-harvest loss reduction practices. Key informants included agricultural extension officers, market actors, transporters, and storage facility operators because of their day-to-day involvement in the maize supply chain. Their experiences offered practical insight into how storage, transportation, and market access influence farmers' decisions to adopt post-harvest loss reduction practices. These contributions complemented the views of smallholder farmers and helped build a clearer picture of the supply chain factors influencing adoption.

Sample Size and Sampling Techniques

A total of 77 respodents participated in the quantitative component of the study through structured questionnaires. For the qualitative component, 16 key informants were purposively selected based on their experience and involvement in procurement decision-making, who successfully participated in the interviews. Stratified random sampling was used to select respondents for the quantitative survey to ensure equal chances of participation, while purposive sampling was employed to identify key informants with extensive knowledge and experience in e-procurement implementation.

Data Collection Methods

Secondary data were obtained from published books, journal articles, reports, and other scholarly literature related to supply chain processes and post-harvest loss reduction practices. Primary data were collected using structured questionnaires and interview guides administered to the selected participants. Quantitative data were gathered through self-administered closed-ended questionnaires, which incorporated a 5-point Likert scale to measure respondents' perceptions and levels of adoption. Participants shared their experiences of storage, transportation, market access, and the factors influencing their adoption of post-harvest loss reduction practices. These insights were gathered through open-ended questionnaire items and interviews, complementing the quantitative findings

Data Analysis

In this study, both quantitative and qualitative data analysis techniques were employed to examine the data collected from various supply chain stakeholders. For the quantitative component, which consisted of

responses from structured questionnaires with multiple items under each variable, inferential statistical methods were applied. Likert-scale responses were numerically coded, and mean scores were calculated for each variable by averaging responses across all respondents. This conversion of ordinal data into continuous measures allowed the application of inferential statistics, including correlation and regression analysis, to examine relationships between supply chain processes and the adoption of post-harvest loss reduction practices.

For the qualitative data collected through interviews and open-ended questionnaire responses, thematic analysis was employed. Thematic analysis is a method used to identify, analyze, and report patterns (themes) within qualitative data. In this study, Microsoft Excel was utilized to organize and code the qualitative data, providing a structured platform for identifying and interpreting key themes related to supply chain processes and the adoption of post-harvest loss reduction practices. This approach enabled a deeper understanding of participants' experiences, perceptions, and challenges within the maize supply chain, thereby complementing and enriching the findings obtained from the quantitative analysis.

Ethical Considerations

Ethical considerations are fundamental in research, as they ensure that participants are treated with respect and that their rights are protected throughout the research process (Israel & Hay, 2006). In this study, several ethical principles were observed to uphold the integrity and credibility of the research. To begin with, informed consent was obtained from all participants involved in the study. Participants were provided with clear and detailed information regarding the purpose of the study, their role in the research, and how the data would be collected, used, and stored. Additionally, participants were assured of confidentiality and anonymity, and all information provided was treated with strict privacy. Participation in the study was entirely voluntary, and respondents were informed of their right to withdraw at any stage without any consequences. Following these procedures also supported the integrity of the research process and strengthened confidence in the way the study was conducted.

Result and Discussions

Response Rate

The quantitative findings were derived from 77 completed questionnaires administered to smallholder maize farmers in Chipata District, with every questionnaire returned and included in the analysis, resulting in a 100.0% response rate. The qualitative component consisted of 16 key informant interviews involving agricultural extension officers, transporters, storage or warehouse operators, and market traders or buyers. Questionnaire responses were recorded on a five-point Likert scale, where 1 indicated Strongly Disagree and 5 indicated Strongly Agree.

Demographic Characteristics of Respondents

This section presents the background characteristics of the smallholder maize farmers who participated in the questionnaire survey. Following the presentation style of the guide document, the demographic results are separated into individual tables. This makes it easier to observe the composition of respondents and to relate the findings to the farmer profile covered by the study.

Influence of Warehousing Facility on Adoption of PHL Reduction Practices

The influence of warehousing facilities on the adoption of post-harvest loss reduction practices among smallholder maize farmers in Chipata District is examined through the first study objective, drawing on evidence from both the questionnaire survey and the key informant interviews. Quantitative findings are

considered before the interview evidence is introduced to extend and explain the statistical results. Together, they provide a fuller understanding of the findings.

Table 2: Descriptive statistics for warehousing facility items

Statement	N	Mean	Std. Deviation	Disagree %	Neutral %	Agree %
Facilities physically available within reasonable distance	77	3.532	1.154	22.1	22.1	55.8
Facilities affordable for smallholder farmers	77	3.130	1.116	28.6	33.8	37.7
Facilities easy to access during storage/marketing season	77	3.442	1.019	15.6	40.3	44.2
Facilities have enough safe storage capacity	77	3.208	1.080	23.4	39.0	37.7
Facilities protect maize from moisture, pests and spoilage	77	3.182	1.085	28.6	31.2	40.3
Facilities provide security against theft and damage	77	3.195	0.960	22.1	40.3	37.7
Shared warehousing encourages adoption	77	3.481	1.096	19.5	28.6	51.9
Access to facilities helps delay sale until better prices	77	3.597	1.042	14.3	27.3	58.4
Improved storage technologies encourage adoption	77	3.805	0.828	2.6	37.7	59.7
Training on storage	77	3.792	0.784	3.9	31.2	64.9

technologies encourages adoption						

Source:(Author,2026)

Table 2 shows moderate to strong agreement on warehousing-related items. The highest mean was recorded for improved storage technologies encouraging adoption (M = 3.805), followed by training on storage technologies (M = 3.792) and the ability to delay sale until favourable prices (M = 3.597). Lower scores were recorded for affordability, storage capacity and protection from moisture or pests, indicating that warehousing influenced adoption but remained constrained by cost, distance and quality concerns.

Role of Transportation Mode in Shaping Adoption of PHL Reduction Technologies

The second objective assessed the role of transportation mode in shaping adoption of post-harvest loss reduction technologies. Transport was measured through reliability, timeliness, carrying capacity, road accessibility, transport cost and the availability of motorised or cooperative transport.

Table 3: Descriptive statistics for transportation mode items

Statement	N	Mean	Std. Deviation	Disagree %	Neutral %	Agree %
Main transport mode reliable for moving maize	77	3.364	1.025	23.4	29.9	46.8
Transport allows maize to reach storage/markets on time	77	3.286	1.110	28.6	32.5	39.0
Transport protects maize from spillage and damage	77	2.948	1.012	32.5	37.7	29.9
Transport has enough carrying capacity	77	3.078	1.554	40.3	9.1	50.6
Roads and paths accessible during harvest/marketing	77	2.896	0.867	37.7	32.5	29.9
Poor road conditions reduce safe transportation	77	3.987	0.925	7.8	19.5	72.7
High transport costs discourage adoption	77	3.649	0.855	11.7	24.7	63.6

Poor transport limits access to storage and markets	77	3.519	0.940	14.3	36.4	49.4
Motorised or group transport would encourage adoption	77	4.351	0.721	0.0	14.3	85.7

Source:(Author,2026)

As shown in Table 3, respondents expressed the strongest agreement that motorised or cooperative transport would encourage the adoption of post-harvest loss reduction practices (M = 4.351). Even so, transportation mode was not a statistically significant predictor of adoption in the regression analysis. Farmers nevertheless described poor roads and high transport costs as persistent obstacles to moving maize. Proposition that these constraints affected day-to-day post-harvest operations without showing a direct statistical relationship with adoption in this study.

Table 4: Adoption index by main mode of transport

Main transport mode	N	Mean adoption	Std. Deviation
Bicycle	10	3.60	0.52
Cooperative/group transport	13	3.34	0.41
Head-load/manual carrying	4	3.10	0.35
Hired vehicle/pick-up	15	3.48	0.73
Motorbike	10	3.58	0.47
Ox-cart/animal-drawn cart	19	3.54	0.67
Public transport	1	3.80	
Truck/larger vehicle	5	3.28	0.58

Source:(Author,2026)

Table 4 shows variation in adoption by transport mode, although the one-way comparison was not statistically significant (F = 0.599, p = 0.754). The lowest mean adoption was among farmers using head-load or manual carrying, while farmers using bicycles, motorbikes and hired vehicles recorded slightly higher means. The difference should therefore be interpreted cautiously.

The third objective centred on market access. To understand its role in the adoption of post-harvest loss reduction practices, the study examined several practical aspects of farmers' market participation. These included access to reliable markets and buyers, price fairness, availability of market information and opportunities to delay sales until market conditions became more favorable Chipata District.

Table 5: Descriptive statistics for market access items

Statement	N	Mean	Std. Deviation	Disagree %	Neutral %	Agree %
Reliable maize markets easy to access	77	3.390	1.090	22.1	29.9	48.1
Enough buyers available when selling maize	77	3.688	1.079	15.6	23.4	61.0
Prices encourage investment in PHL reduction	77	3.000	1.203	33.8	31.2	35.1
Price information helps sale decisions	77	3.351	1.316	31.2	22.1	46.8
Reliable buyers encourage careful handling	77	3.442	1.118	18.2	35.1	46.8
Difficult market access forces quick sale	77	2.896	1.209	39.0	28.6	32.5
Delayed sale at better prices encourages improved storage	77	3.753	1.090	15.6	23.4	61.0
Cooperatives/aggregation centres support adoption	77	3.935	0.833	3.9	26.0	70.1

Source:(Author,2026)

Respondents gave the highest ratings to cooperatives, aggregation centres and other structured markets (M = 3.935). This was followed by the opportunity to delay sales until prices became more favourable (M = 3.753) and the availability of buyers (M = 3.688). Price fairness received the lowest mean score (M = 3.000). Overall, the findings suggest that farmers placed greater value on having dependable market opportunities and timely market information than on price fairness alone.

Correlation and Regression Analysis of Supply Chain Processes and Adoption

This section presents the overall statistical relationship between the main supply chain processes and adoption of maize PHL reduction practices. Pearson correlation was used to examine the strength and direction of associations, while multiple regression was used to determine the predictive effect of warehousing facility, transportation mode and market access on adoption.

Table 6: Pearson correlation matrix for key study variables

Variable	Warehousing facility	Transportation mode	Market access	Adoption
Warehousing facility	1.000	0.012	0.129	0.391**
Transportation mode	0.012	1.000	-0.096	-0.149
Market access	0.129	-0.096	1.000	0.601**
Adoption	0.391**	-0.149	0.601**	1.000

** Correlation is significant at the 0.01 level.

Source:(Author,2026)

Table 6 shows that warehousing facility had a positive and statistically significant relationship with adoption ($r = .391$, $p < .001$), while market access had a stronger positive and statistically significant relationship with adoption ($r = .601$, $p < .001$). Transportation mode had a negative but non-significant relationship with adoption ($r = -.149$, $p = .195$).

Table 7: Model summary for regression predicting adoption of PHL reduction practices

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.687	0.471	0.450	0.426

Source:(Author,2026)

The regression model indicated that, when considered together, warehousing facilities, transportation mode and market access accounted for 47.1% of the variation in farmers' adoption of post-harvest loss reduction practices. Taken together, the results indicated that the supply chain processes accounted for a substantial share of the variation in the adoption of post-harvest loss reduction practices among the smallholder maize farmers included in this study. Even after adjusting for the number of predictors, the model retained an adjusted R^2 of 0.450. This indicates that the supply chain factors continued to explain differences in farmers' adoption behavour.

Table 8: ANOVA for regression predicting adoption of PHL reduction practices

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	11.830	3	3.943	21.691	<.001
Residual	13.271	73	0.182		
Total	25.101	76			

Source:(Author,2026)

The regression model was significant ($F(3, 73) = 21.691$, $p < .001$), suggesting that the supply chain processes explained a substantial proportion of the differences in the adoption of post-harvest loss reduction practices among the smallholder maize farmers included in this study. In other words, variation in adoption was closely linked to the combined influence of these supply chain processes within the study area.

Table 9: Coefficients for regression predicting adoption of PHL reduction practices

Model	Unstandardized B	Std. Error	Standardized Beta	t	Sig.
(Constant)	1.673	0.371		4.514	<.001
Warehousing facility	0.240	0.064	0.321	3.744	<.001
Transportation mode	-0.091	0.078	-0.100	-1.175	0.244
Market access	0.359	0.056	0.550	6.379	<.001

Source:(Author,2026)

Table 9 shows that market access was the strongest predictor of adoption (Beta = .550, $p < .001$), followed by warehousing facility (Beta = .321, $p < .001$). Transportation mode was not statistically significant (Beta = -.100, $p = .244$). The regression output therefore indicates that adoption was mainly strengthened by

market incentives and warehousing conditions, while transport constraints were more clearly expressed in the qualitative findings.

Integrated Presentation of Findings by Objective

Table 10: Integrated summary of quantitative findings

Objective	Main quantitative finding
Objective 1: Warehousing facility	Warehousing facility had a positive and statistically significant relationship with adoption ($r = .391$, $p < .001$) and significantly predicted adoption in the regression model (Beta = .321, $p < .001$).
Objective 2: Transportation mode	Transportation mode had a negative but non-significant relationship with adoption ($r = -.149$, $p = .195$) and was not a significant regression predictor (Beta = -.100, $p = .244$).
Objective 3: Market access	Market access had the strongest positive relationship with adoption ($r = .601$, $p < .001$) and was the strongest regression predictor (Beta = .550, $p < .001$).
Objective 4: Recommendations	Nearly half of the observed variation in the adoption of post-harvest loss reduction practices (47.1%) was explained by the supply chain processes examined in this study. This shows that differences in farmers' access to key supply chain conditions were closely associated with how widely improved post-harvest practices were adopted in Chipata District.

Source:(Author,2026)

Taken together, the survey and interview findings reinforced the importance of supply chain conditions in shaping the adoption of post-harvest loss reduction practices. Safe storage facilities and reliable market access emerged as the strongest influences, while the qualitative evidence showed that transport constraints continued to affect farmers' access to these services despite their limited statistical effect.

Qualitative Findings

Influence of Warehousing Facility on Adoption of PHL Reduction Practices

Theme 1: Limited Storage Access, Affordability and Capacity Constrain Adoption

The Access to usable warehousing differed across Chipata District. Participants explained that storage facilities were generally easier to access near trading centres and cooperatives, while farmers in more remote villages often depended on home granaries or less durable storage structures.

> *"Facilities exist around trading points,but distance and fees discourage many smallholders"(KII-01),*

"Access is better for cooperative members; isolated villages have no usable store nearby,"((KII-03)

"Most farmers store at home because community warehouses are few and seasonal capacity is limited. "(KII-08)

The interview responses suggest that access to warehousing depends not only on the availability of storage facilities but also on their distance, cost and capacity. Where these barriers existed, farmers found it more difficult to store maize for longer periods, delay sales and make use of improved storage practices.

Theme 2: Storage Quality Risks Influence Farmers' Willingness to Adopt Improved Practices

Participants consistently linked the quality of storage facilities to farmers' willingness to adopt post-harvest loss reduction practices. They explained that poor storage conditions exposed maize to moisture, pests, rodents, mould and theft, making farmers less willing to store grain for longer periods or invest in improved post-harvest practices.

"Moisture, rodents and weevils are common, so farmers sell early or keep maize in weak structures." (KII-01)

"When pallets are inadequate and warehouse roofs leak, maize spoils more easily. As a result, many farmers see improved storage practices as too costly to maintain." (KII-03)

"When there isn't enough space to dry maize properly and the storage bags are torn, mould and pests become a bigger problem. That makes farmers less confident about storing their grain." (KII-06)

The interview evidence helps explain the positive relationship between warehousing facilities and the adoption of post-harvest loss reduction practices observed in the quantitative analysis. When storage facilities were secure and well maintained, farmers faced fewer risks of grain spoilage and were better able to dry, sort, protect, and store maize until favourable market opportunities became available.

Role of Transportation Mode in Shaping Adoption of PHL Reduction Technologies

Theme 3: Low-Capacity Transport Modes Expose Maize to Handling and Quality Risks

The first transportation theme showed that many farmers relied on head-loads, bicycles, ox-carts, motorbikes and occasional hired vehicles. Participants described these modes as affordable but often unsuitable for bulk maize movement, especially when maize had to be moved over long distances.

"Common modes are head-loads, bicycles, ox-carts and hired pick-ups; small loads are exposed." (KII-01)

"Manual carrying and bicycles are cheap but unsuitable for bulk maize and long distances." (KII-06)

"Hired vehicles and group transport are better, but many farmers only access them occasionally." (KII-10)

Storage and marketing opportunities were closely linked to local transport conditions. While the regression analysis did not identify transportation mode as a significant predictor of adoption, interview participants described transport as a practical constraint that influenced farmers' ability to reach storage facilities and markets, providing context for the quantitative findings.

Theme 4: Road Condition, Cost and Vehicle Availability Reduce the Practical Benefits of Adoption

Participants consistently described transport as an important challenge during the post-harvest period. Poor feeder roads, limited vehicle availability and high transport costs made it difficult for farmers to move maize safely, often resulting in delays, spillage and exposure to rain or dust.

"Vehicle shortages during peak harvest raise costs and reduce timely movement to storage." (KII-02)

"Bad feeder roads and high fares cause delays, spillage and exposure to rain or dust." (KII-05)

"High transport costs reduce farmers' profits, making it difficult for them to invest in improved storage." (KII-07)

Reliable transport was viewed as an important part of effective post-harvest management. Interview participants explained that when transport was costly or unreliable, moving maize to storage facilities or markets became more difficult. Investment in improved storage and other post-harvest practices incentives consequently being reduced.

Impact of Market Access on Farmers' Adoption of PHL Reduction Practices

Theme 5: Prices, Payment Terms and Buyer Reliability Shape Investment in PHL Reduction Market conditions featured prominently in participants' accounts. Fair prices, dependable buyers, and timely payments gave farmers greater confidence that investments in improved drying, storage, and pest management would be worthwhile. Low prices and delayed payments created the opposite effect, making farmers more cautious about committing resources to post-harvest loss reduction practices.

"When maize prices are low and payments are delayed, many farmers cannot afford to buy hermetic bags or other pest control materials." (KII-01)

"Farmers are more likely to take good care of their maize after harvest when buyers pay better prices for grain that is clean and properly dried." (KII-04)

"Quality handling is easier to encourage when reliable buyers are available, but unstable prices make many farmers reluctant to invest in improved post-harvest practices." (KII-10)

The interview evidence points to the importance of market incentives in shaping farmers' post-harvest decisions. Participants repeatedly described reliable buyers, fair prices, and timely payments as conditions that made investment in improved post-harvest practices worthwhile, while unstable prices and delayed payments discouraged such investments. This pattern reflects the quantitative findings, where market access emerged as the strongest predictor of the adoption of post-harvest loss reduction practices.

Theme 6: Market Distance, Weak Bargaining Power and Limited Information Encourage Early Selling

Long distances to markets, a shortage of reliable buyers, weak bargaining power and limited access to market information often left farmers with little choice but to sell maize soon after harvest instead of storing it for better prices.

"Lack of structured markets leads to roadside sales and little reward for quality." (KII-01)

"Challenges include distance, few buyers, weak bargaining power and limited market shelters." (KII-03)

"Transport to reliable buyers is costly, pushing farmers toward local briefcase buyers." (KII-05)

The interview responses suggest that market access involved more than the distance to a marketplace. Farmers also emphasised the importance of having dependable buyers, fair prices and reliable market information. When these conditions were lacking, many preferred to sell quickly through local buyers rather than invest in improved storage and other post-harvest management practices.

Supply Chain Evidence-Based Recommendations for Enhancing Adoption

Theme 7: Integrated Storage, Transport and Market Improvements Are Needed

Participants recommended expanding access to drying facilities, secure storage, affordable transport and

stronger market linkages to help farmers protect maize after harvest and sell it under better conditions.

> *"Provide drying slabs, secure warehouses, affordable transport and structured buyer linkages." (KII-01)*
>
> *"Increase access to hermetic bags, promote cooperative transport and provide current market prices." (KII-09)*
>
> *"Build shared storage points, improve feeder roads and support village aggregation centres." (KII-10)*

The recommendations point to the need for coordinated support that addresses the main challenges farmers face after harvest. Improving storage facilities, transport services and access to reliable markets was seen as an effective way of encouraging farmers to adopt better post-harvest management practices.

Theme 8: Policy and Institutional Support Should Make Adoption Affordable and Coordinated

Informants highlighted the role of government, extension services, cooperatives and other stakeholders in improving farmers' access to finance, storage technologies, marketing opportunities and technical support.

> *"Stakeholders should finance community storage, road maintenance and market information systems." (KII-01)*
>
> *"Government should expand extension staffing, subsidise storage technologies and support cooperative marketing." (KII-04)*
>
> *"Farmers need policies that connect them with warehouse receipt systems, make credit easier to obtain, and link them to buyers who pay for quality maize." (KII-09)*

Participants consistently described adoption as depending on more than farmers' own efforts. Their accounts pointed to the need for better extension services, affordable storage technologies, easier access to credit, cooperative marketing, warehouse receipt systems, reliable buyers, and timely market information. Together, these measures were viewed as important for improving post-harvest management and creating conditions that encourage farmers to invest in better post-harvest practices.

Discussion of Findings

The findings indicate that warehousing facilities played an important role in encouraging the adoption of maize post-harvest loss reduction practices among smallholder maize farmers. Although transport was not a statistically significant predictor of adoption, it remained an important enabling factor. Farmers identified poor roads, high transport costs and limited transport options as barriers that reduced the benefits of improved storage and market access. Rather than directly influencing adoption, transport shaped how effectively farmers could use these opportunities. the findings point to the importance of an effective market system in influencing the adoption of post-harvest loss reduction practices among smallholder maize farmers in Chipata District. When farmers could rely on organised marketing channels, dependable buyers, and better market coordination, they had stronger reasons to adopt improved post-harvest management practices. The situation was different where these conditions were absent. Uncertain markets, weak coordination, and limited buyer reliability increased marketing risks and reduced the expected returns from investing in post-harvest loss reduction practices

Conclusion

the study highlights the need for coordinated improvements in both supply chain systems and institutional support to increase the adoption of maize post-harvest loss reduction practices among smallholder farmers in Chipata District. Achieving this requires investment in storage facilities, transportation, market access,

extension services, and access to finance, supported by effective collaboration among government, farmer cooperatives, extension agencies, and development partners. Through these coordinated efforts, smallholder farmers will be better positioned to reduce post-harvest losses, improve their livelihoods, and strengthen food security.

Recommendations

Based on the study findings, the following recommendations are intended to support the adoption of maize post-harvest loss (PHL) reduction practices among smallholder farmers in Chipata District. They are directed at policymakers, extension services, cooperatives, the private sector, and development partners. These recommendations are based on the study findings and are intended to address the key supply chain and institutional factors influencing adoption. Their implementation is expected to strengthen storage infrastructure, improve transportation and market access, expand farmer support services, and create an enabling environment that promotes sustainable adoption of post-harvest loss reduction practices.

Establish and Upgrade community-based Warehousing Facilities

The Ministry of Agriculture, local authorities, cooperatives and development partners should invest in the establishment and upgrading of community-based warehousing facilities to address storage-related challenges that contribute to maize post-harvest losses. Investment should prioritise secure storage structures, drying facilities, and improved technologies such as hermetic storage systems. Regular maintenance is equally important to keep these facilities functional over time. Affordable and accessible warehousing would help smallholder farmers protect grain quality, reduce post-harvest losses, and encourage wider adoption of recommended post-harvest practices, while improving household incomes.

Investment in Rural Transport Infrastructure

Enhanced farm income and food security can be achieved if the Ministry of Transport and Logistics, local authorities, cooperatives and development partners improve transportation systems supporting smallholder farmers. This should include rehabilitating and maintaining feeder roads, expanding access to affordable and reliable rural transport services, and encouraging cooperative transport arrangements to improve the movement of maize from farms to storage facilities and markets. Poor rural roads and unreliable transport continue to make it difficult for many smallholder farmers to move maize efficiently after harvest. Upgrading rural transport infrastructure would ease these constraints by improving year-round access to storage facilities and markets. As a result, grain can be moved more quickly, handling losses reduced, and farmers placed in a stronger position to adopt recommended post-harvest loss reduction practices while contributing to improved food security.

Strengthen Market Information Systems and Aggregation Centres

Reliable markets give smallholder farmers a stronger incentive to invest in improved post-harvest practices because they increase the likelihood of securing better returns for quality grain. To strengthen these opportunities, government agencies, local authorities, farmer cooperatives, and private sector actors should expand access to timely market information, organised marketing channels, and dependable buyers. A more responsive market system would improve farmers' confidence in storing maize, reduce unnecessary post-harvest losses, and encourage wider adoption of recommended post-harvest loss reduction practices. This should include the establishment of structured marketing arrangements,

aggregation centres and reliable market information systems to improve price transparency and bargaining power. In addition, the promotion of warehouse receipt systems, contract farming arrangements and strengthened cooperative marketing should be prioritized to directly link farmers with credible and stable buyers. Furthermore, improved coordination among value chain actors should be enhanced to ensure efficient and predictable grain trading systems.

Strengthen Coordination Across the Maize Supply Chain

Government agencies, local authorities, farmer cooperatives, private sector actors, and development partners need to coordinate efforts to strengthen supply chain systems that support the adoption of maize post-harvest loss reduction practices. Better conditions for farmers to adopt maize post-harvest loss (PHL) reduction practices thus be created. This should include investment in modern and secure storage facilities, rehabilitation of rural road networks and promotion of affordable transport services, as well as the establishment of structured and reliable market channels. In addition, the development of aggregation centres, warehouse receipt systems and timely market information platforms should be prioritized to enhance efficiency and coordination across the value chain. Better coordination among farmers, cooperatives, extension services and other supply chain actors can help reduce post-harvest losses. Wider adoption of improved post-harvest practices, and support better incomes and food security is likely to be encouraged.

Future Areas of Research

A number of future research areas are suggested based on the findings of this study, including the following:

1. Future research should conduct comparative studies across multiple districts to examine variations in the adoption of maize post-harvest loss (PHL) reduction practices and identify common constraints and best-performing supply chain and institutional arrangements. A clearer understanding of how local conditions influence the adoption of post-harvest practices across different contexts would emerge by including farmers from different agro-ecological zones and market settings. This broader representation would also make the findings more applicable beyond the study area.
2. To assess the long-term impact of maize post-harvest loss reduction interventions, future research should adopt longitudinal study designs to evaluate changes in adoption behaviour, farm incomes and food security outcomes over time. This will provide deeper insights into the sustainability of supply chain and institutional support strategies and their effectiveness in reducing post-harvest losses under evolving market and environmental conditions.

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