



Service Accessibility and Technology Adoption in Smallholder Agriculture: Evidence from Mechanized Tillage Services in Mutasa District

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ABSTRACT

Background: Smallholder agriculture is central to Zimbabwe's food production, yet many farmers lack access to essential mechanised land preparation services. While government and private sector initiatives have promoted mechanised tillage, evidence remains scarce on how access, utilisation patterns and productivity outcomes vary among smallholders, particularly in districts like Mutasa. This study addresses that gap by examining the accessibility and use of mechanised tillage services, identifying factors influencing uptake and assessing their effects on agricultural productivity.

Methods: A descriptive cross sectional design was used, combining a structured questionnaire and semi structured interviews. Quantitative data were analysed with descriptive statistics and ordinal logistic regression in STATA; qualitative data were examined thematically.

Result: Mechanised tillage, mainly ploughing, is available to 72% of respondents, but provision is uneven. Remote farmers face major barriers due to poor roads and few service providers. Education, financial capacity and distance to providers significantly influence use. Econometric analysis confirms that access and use of mechanised tillage positively affect productivity: users achieve earlier land preparation and higher yields than those relying on manual or animal drawn methods. Nevertheless, adoption is constrained by high fees, limited machinery and weak rural infrastructure. Mechanised tillage can substantially improve smallholder output in Mutasa, but realising its potential requires policies that lower costs, expand service networks, upgrade rural roads and strengthen extension and awareness programmes to promote inclusive and sustainable adoption.

Key words: Accessibility, Agricultural productivity, Mechanization, Smallholder farmers, Tillage services, Utilization.

INTRODUCTION

Agriculture remains a cornerstone of Zimbabwe's economy, contributing approximately 15-20% of national GDP and employing over 60% of the labour force, most of whom reside in rural areas (ZIMSTAT, 2021). Within this sector, smallholder farmers, those cultivating less than five hectares, dominate staple crop production, including maize, sorghum, millet and legumes, while also managing livestock for household nutrition and income. Despite their central role, these farmers face persistent productivity constraints: limited access to quality inputs, deteriorating rural infrastructure, weak technical support and increasing climate variability (Mutenje *et al.*, 2019). These challenges collectively undermine food security and threaten the long term viability of smallholder farming systems.

Among the most critical barriers is the lack of timely and efficient land preparation. Proper tillage improves soil structure, enhances moisture retention and creates favourable conditions for crop establishment. Mechanized tillage, in particular, reduces labour drudgery, shortens turnaround times between operations and enables more precise input application, factors that can significantly boost yields (FAO, 2020; Mupakati and Chiputwa, 2021). In rain dependent systems like those in eastern Zimbabwe, a delay of even two weeks in planting can reduce maize yields

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by 30-50% (Cao *et al.*, 2019). Therefore, access to mechanized tillage is not merely a convenience but a productivity determinant.

However, mechanized tillage services remain unevenly accessible to smallholders. High service fees, sparse tractor availability, poor rural roads and weak institutional coordination have been documented as major adoption barriers across sub-Saharan Africa (Mudzonga, 2012; Madhuku and Makombe, 2014; Diao *et al.*, 2020). Evidence from custom-hiring models in other developing regions suggests that service accessibility determines adoption rates as much as machine availability (Mahal *et al.*, 2009). In Zimbabwe, private sector led custom hire models have emerged, but their reach is limited. For example, a national survey by ZIMSTAT, (2021) found that fewer than 25% of smallholders used any mechanized tillage service, with usage concentrated within 15 km of district towns. Remote areas face the most acute challenges: poor roads increase provider transport costs, which are passed on to farmers and low population density discourages private investment (FAO, 2016; Sakupwanya, 2018). Consequently, most farmers still rely on manual labour or animal traction, options increasingly undermined by rural urban migration (labour shortages) and livestock diseases such as January disease (Theileriosis) (Mupakati and Chiputwa, 2021).

Mutasa District, located in Manicaland Province, typifies these struggles. Although parts of the district receive favourable rainfall (800-1,200/ mm annually) and have relatively fertile soils, smallholder productivity remains low. Recent estimates place average maize yields at 0.8-1.2 t/ha, well below the national potential of 3-5 t/ha (Nyakudya *et al.*, 2019; FAO, 2020). Key reasons include soil degradation, climate-induced planting delays and, central to this study, inadequate access to mechanized tillage services. Farmers frequently report that even when tractors are available, high fees (often US\$30-50 per hectare) and long waiting times during peak seasons push planting beyond optimal windows (Mavesere and Dzawanda, 2022).

In response, the Zimbabwean government and development partners have launched several mechanization initiatives, including subsidized tractor hire schemes, conservation agriculture programmes and input support packages (Madhuku and Makombe, 2014; FAO, 2016a). Private providers have also entered the market. Yet, evidence on who actually accesses these services, what drives or limits their use and whether they translate into measurable productivity gains at the farm level remains scarce. Existing studies are either national in scope (lacking local specificity) or rely on small, non representative samples (Mudzonga, 2012; Mupakati and Chiputwa, 2021). Few have examined the interplay of distance, infrastructure and socio economic factors within a single district using mixed methods.

This study directly addresses that gap. Anchored in Agricultural Modernization Theory, which posits that technology adoption drives productivity gains but can also create exclusion risks (FAO, 2020; Mavesere and Dzawanda,

2022), the research evaluates the accessibility, utilisation patterns and productivity effects of mechanized tillage services in Mutasa District. By providing localized, empirically grounded evidence, the study aims to inform more equitable and sustainable mechanization policies that enhance food security and smallholder livelihoods.

MATERIALS AND METHODS

Study area and research design

This study was executed in Mutasa District, eastern Zimbabwe, a rural, agriculture-reliant region representative of countrywide smallholder areas. Focused on farmers cultivating under 5 hectares using manual or animal-powered techniques and key stakeholders, including extension officers and mechanization providers. Its representativeness and closeness to Mutare facilitated efficient data collection on mechanization barriers. A descriptive cross-sectional design assessed tillage service accessibility and usage, characterizing current availability, utilization patterns and influencing factors. The design captured a snapshot of conditions and farmer experiences regarding mechanized tillage services.

Sampling procedure and sample size

A multi-stage sampling strategy was employed. Mutasa District was divided into administrative wards, which were purposefully selected considering agricultural intensity, accessibility and presence of mechanized tillage providers. Within these wards, 50 smallholder farmers were randomly selected to represent variability in farm size, crops and socio-economic profiles. Additionally, 10 key informants (five mechanized service providers and five extension officers) were strategically chosen to share insights on service dynamics and constraints.

To determine an appropriate sample size from a finite population, Yamane's (1967) formula was applied:

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

Where:

n = Required sample size.

N = Total population size.

e = Desired level of precision (sampling error), usually 0.10 or 0.05.

Using an estimated population of 39,800 smallholder farming households in Mutasa District and a margin of error of 10%, the formula yielded an ideal sample size of approximately 100 farmers.

However, pragmatic fieldwork limitations; logistical, financial and temporal, necessitated a reduction to 50. The decision was justified by the district's homogeneity in landholding sizes, farming practices and resource access, ensuring the smaller sample captured critical patterns while maintaining feasibility.

Data collection methods

Quantitative data were obtained using structured questionnaires administered to smallholder farmers. The questionnaire captured

information on access to mechanized tillage services, utilisation patterns, affordability, distance to service providers, farm characteristics and perceived impacts on agricultural productivity.

Qualitative data were collected through semi-structured interviews with key informants, including extension officers and tillage service providers. These interviews explored institutional arrangements, operational challenges, seasonal demand patterns and opportunities for improving mechanized tillage service delivery.

Data analysis

Data analysis involved STATA for quantitative data, using descriptive and dispersion statistics to summarise farmer traits and mechanised tillage access. Frequencies, means, standard deviations, variance and interquartile ranges were computed; bar charts and histograms visualised key patterns. Bivariate analyses included chi-square and t-tests to examine associations between service use and socio-economic factors. Ordinal logistic regression assessed impacts on productivity. Qualitative interview data underwent thematic analysis. Recurring themes contextualised findings, with triangulation of both data types enhancing result robustness and interpretation (Kothari, 2004).

RESULTS AND DISCUSSION

Availability and accessibility of mechanized tillage services

This study examined the availability, accessibility and usage of mechanized tillage services among 50 smallholder farmers in Mutasa District. The findings show that 36 (72%) of respondents accessed such services (Fig 1), while the remaining 14 (28%) encountered barriers to access. Regarding service availability, 33 (66%) of farmers reported that mechanized tillage was available locally, yet 17 (34%) indicated it was not. This suggests progress in service provision but also highlights persistent challenges for nearly one third of farmers. Similar patterns have been observed elsewhere: Moyo and Salamu, (2018) noted that Zimbabwean farmers face limited access due to high costs and poor infrastructure, while Kansime and Harris, (2020) linked variations in access in Uganda to proximity to providers and transport availability.

Usage patterns (Fig 2) reveal that ploughing dominated at 45 (90%) of the farmers, reflecting its central role in mechanized land preparation. Ridging was moderately adopted by 19 (38%) farmers, whereas harrowing remained minimal with only 7 (14%) farmers, indicating a

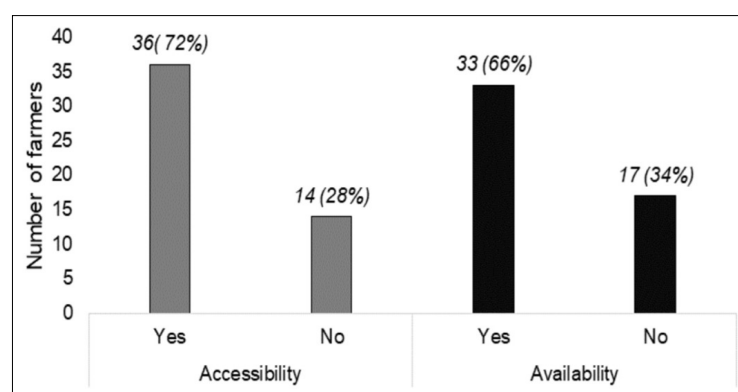


Fig 1: Responses for accessibility and availability of mechanized tillage services.

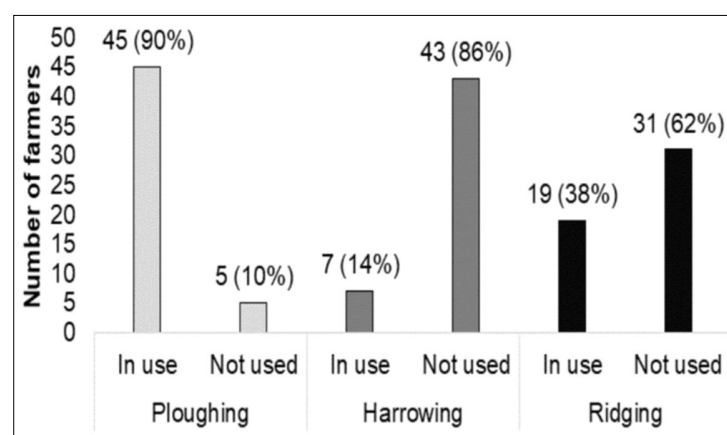


Fig 2: Farmers responses to usage of specific mechanized tillage services.

strong dependence on primary tillage. These trends align with the FAO, (2022), which prioritizes ploughing for its simplicity and yield gains. Ngwira *et al.* (2013) attribute the limited adoption of ridging to equipment shortages and high labour intensity, while Mupangwa *et al.* (2017) cite high costs and equipment scarcity as key reasons for the low uptake of harrowing.

Although basic mechanization, particularly ploughing, is emerging in Mutasa, service diversification remains limited. Nearly 30% of farmers still lack access to any form of mechanized tillage. This gap underscores the urgent need for expanded service coverage, rural infrastructure upgrades and targeted investments in secondary tillage operations to enhance both agricultural productivity and long term sustainability.

Factors associated with utilization of mechanized tillage services

This analysis employed Chi square and t tests to evaluate the demographic, institutional and spatial determinants of mechanized tillage adoption. Education level emerged as a critical driver ($p < 0.01$, Table 1); farmers with secondary or tertiary education were significantly more likely to adopt mechanized services. This finding is consistent with Taffese and Tadesse, (2024), who link education to improved technical understanding and decision making capacity. Affordability and equipment scarcity showed marginal relevance ($p < 0.10$), echoing Diao *et al.* (2020), who identified cost and supply constraints as major barriers across sub-Saharan Africa.

Somewhat unexpectedly, gender, awareness of service providers and infrastructure variables were not statistically significant. This suggests that expanded custom hire markets may help reduce gender disparities in access (Sims and Kienzie, 2017). Nevertheless, underlying gender inequities in resource access, such as land tenure and credit, likely persist (Doss, 2001).

Table 2 highlights proximity to service providers as the most pivotal factor ($p < 0.001$), with adopters living significantly closer to providers than non adopters. Age also trended toward significance ($p < 0.10$); older farmers (aged 51-60) adopted more frequently, likely due to greater farming experience and increasing labour constraints (Mengistu *et al.*, 2024). Farm size was not significant, reflecting that custom hire systems can offset scale limitations (Pingali, 2007).

Overall, education remained the strongest correlate, underscoring the importance of human capital. Although Table 3 suggests that perceived accessibility matters, the Chi square results prioritize physical proximity as the key

determinant. This aligns with Yeboah and Klerkx, (2024) and Ayalew *et al.* (2023), who emphasise distance driven transaction costs. In sum, the key determinants of adoption are education, proximity to providers and age, while affordability and provider density function as more indirect barriers.

Perceived drivers, affordability and challenges

Most farmers cited availability, cost, accessibility, timeliness, labour supply and awareness as key factors influencing their use of mechanized tillage. However, Chi square analysis revealed no significant link between these perceived factors and actual usage ($p > 0.1$), indicating a clear disconnect between farmers' beliefs and their behaviour. This finding aligns with prior research suggesting that even positive perceptions may not translate into adoption when structural barriers, such as high costs, equipment shortages, or logistical challenges, persist (Pingali, 2007; Diao *et al.*, 2020). In addition, intangible factors such as trust, access to credit and social norms may also shape adoption decisions (Baudron and Sims, 2016).

Affordability emerged as a critical factor (Table 3). All farmers who found the service cost effective used it and the association between cost effectiveness and usage approached statistical significance ($p < 0.10$). This supports findings by Katengeza *et al.* (2024) and Mulenje *et al.* (2023), who identify cost as a primary barrier to mechanization among smallholders. Government subsidy programs, such as the 50% subsidy on tillage equipment implemented in Punjab, India, have demonstrated effectiveness in improving adoption rates among smallholders (Mahal *et al.*, 2009).

On the supply side, variables such as high service fees, provider shortages, poor roads and unreliable delivery were not statistically significant constraints. However, equipment scarcity showed a trend toward significance ($p = 0.076$).

Table 1: Chi-square test results for factors associated with mechanized tillage service utilization.

Variable	Chi-square value (χ^2)	Df	P-value
Gender	0.63	1	0.43
Education level	20.35	3	0.000
Accessibility	0.14	1	0.704
Affordability	3.76	1	0.095
Availability of providers	0.00	1	0.962
Awareness of services	1.27	1	0.260
Inadequate equipment	3.14	1	0.076
Poor road infrastructure	1.08	1	0.297

Table 2: Independent samples t-test results for factors associated with mechanized tillage service utilization.

Variable	Mean (Users)	Mean (Non-users)	t-value	P-value
Age of farmer (years)	48.7	42.1	1.78	0.090
Farm size (ha)	3.8	2.9	1.56	0.124
Distance to service provider (km)	4.6	10.1	3.71	0.001

This suggests that limited machinery availability, particularly during peak planting seasons, hinders service provision, echoing reports of equipment bottlenecks across Africa (Diao *et al.*, 2020; Sims and Kienzie, 2017). Taken together, these findings indicate that overcoming adoption gaps requires addressing both economic accessibility (affordability) and supply side limitations (equipment availability) in an integrated manner.

The importance of timeliness in land preparation is reinforced by findings on soil moisture dynamics. Verma and Pradhan, (2024) demonstrated that proper soil management practices conserve moisture in rainfed systems, a benefit that mechanized tillage enables through timely field operations.

Contribution of mechanized tillage services to agricultural productivity

The ordered logistic regression (Table 4) shows that several variables significantly increase the odds of higher agricultural productivity. Age, access to village level services, ploughing, harrowing and farmers' perceived importance of tillage services all exhibit statistically significant positive

effects. In contrast, gender, education, farm size, actual use of tillage services, ridging, service affordability, poor road conditions, insufficient equipment and unreliable service delivery do not show significant impacts.

Older farmers display a modestly greater chance of productivity gains, likely because accumulated experience improves decision making, resource allocation and technical efficiency, a pattern documented by Mulema *et al.* (2021). Access to village level services emerges as a critical driver, as it enables timely land preparation. In rain fed systems, planting delays can sharply reduce yields (Cao *et al.*, 2019); prompt operations help synchronize fieldwork with optimal growth stages, thereby improving seedbed quality and overall output. The transformative impact of well-executed, timely tillage is further supported by recent reviews confirming that adequate tillage operations increase crop dry matter and yield compared to reduced or zero-tillage systems (Prasanna *et al.*, 2025).

Both ploughing and harrowing exhibit strong positive coefficients, underscoring their role in refining soil structure, conserving moisture and creating uniform seedbeds.

Table 3: Farmers' responses showing relationship between associated factor and use of mechanized tillage services.

Associated factor	Description	Using	Not using	N = 50
Age of farmer (years)	18-30	9	2	50
	31-40	10	2	
	41-50	8	0	
	51-60	11	0	
	≥ 61	6	0	
Gender	Male	27	3	50
	Female	19	1	
Farm size (ha)	0-4	21	3	50
	≥ 5	25	1	
Education level	No formal	1	3	50
	Primary	3	0	
	Secondary	32	1	
	Tertiary	10	0	
Access to mechanized tillage services	Yes	10	4	50
	No	36	0	
Distance to service provider (km)	0-5	29	0	50
	6-9	7	0	
	≥ 10	10	4	
Affordability of service	Affordable	25	0	50
	Not affordable	21	4	

Table 4: Ordered logistic regression results.

Variable	Coefficient	Std. error	z-value	P-value
Age	0.0834	0.0470	1.78	0.076
Access to tillage services.	3.7202	1.7647	2.11	0.035
Ploughing	6.6219	2.5838	2.56	0.01
Harrowing	4.2960	2.0897	2.06	0.04
Availability of services	-2.8181	1.5199	-1.85	0.064
Importance of tillage services	4.1108	1.4886	2.76	0.006

Table 5: Key themes from farmer suggestions.

Theme	Key suggestions	Frequency	% (N=50)
Road infrastructure Improvement	Improve roads, renovate roads, construct access roads	18	36
Cost reduction and affordability	Reduce prices, subsidies, affordable costs, credit facilities	16	32
Increased equipment and services	More service providers, mobile services, provide full equipment	10	20
Government and NGO support	Government/NGO provision, support schemes, intervention	7	14
Awareness and education	Educating farmers, extension services, awareness campaigns	6	12
Timeliness and reliability	Timely service, regular maintenance, reliable delivery	5	10
Conservation and modern practices	Promote conservation tillage, modern equipment	4	8

These findings align with Biswakarma *et al.* (2023), who reviewed CA-based tillage practices and confirmed that improved tillage enhances soil physico-chemical properties, leading to higher crop yields and resource use efficiency.

Farmers' suggestions: Thematic analysis

Thematic analysis of farmer recommendations (Table 5) reveals several key priorities for improving access to and efficiency of tillage services in the study area, highlighting interconnected challenges that require systemic solutions.

Inadequate road infrastructure was the most frequently cited issue, mentioned by 18 respondents (36%). Poor road conditions hinder machinery movement, delay service delivery, raise operational costs for providers and ultimately slow land preparation, negatively affecting farm output.

Cost and affordability ranked second, with 16 mentions (32%). Farmers called for lower service fees, government subsidies and improved access to credit, reflecting the financial burden of high mechanization costs on small scale farmers with limited resources. This finding aligns with Mottaleb *et al.* (2017), who showed that affordability is a stronger driver of service use than mere availability.

Shortage of machinery and service providers emerged as another critical concern, captured under 'increased equipment and service availability (10 mentions, 20%)'. Farmers recommended expanding the number of providers, introducing mobile tillage units and ensuring timely access to equipment. This unmet demand supports the regression results, which emphasize ploughing and harrowing as key to boosting productivity. Moreover, Mottaleb *et al.* (2017) observed that the use of service providers can increase the accessibility of tillage services to many farmers, including those who are starting up farming activities.

Government and NGO support was urged by seven respondents (14%), who advocated for policy interventions, direct assistance, or dedicated mechanization programmes.

Training and awareness were highlighted by six respondents (12%), who pointed to limited understanding

of mechanized tillage benefits and proper usage. Extension services were seen as vital to bridging this knowledge gap (Ntshangase *et al.*, 2018).

Service reliability was noted in five responses (10%), stressing the importance of timely and consistent delivery.

Additionally, four mentions (8%) emphasized adopting conservation and modern tillage techniques to improve efficiency and environmental sustainability, noting that delayed services and outdated methods reduce productivity. This point was echoed by Vergas, (2024), who highlighted that education, demonstration plots and supportive policies can help conservation tillage practices contribute to long term sustainability and resilience in agricultural systems. Collectively, these qualitative insights reinforce the quantitative outcomes: enhancing mechanization's impact requires systemic improvements. Key actions include upgrading rural infrastructure, reducing service costs, expanding service coverage and strengthening institutional and extension support. Together, these measures are essential for scaling up mechanized tillage and improving agricultural performance in Mutasa District.

CONCLUSION

This study addressed a critical evidence gap on smallholder access to mechanized tillage services in Mutasa District, Zimbabwe. The findings show that while mechanized tillage, mainly ploughing, is available to 72% of farmers, nearly 30% remain without access due to remoteness, poor roads and few local providers. Adoption is significantly shaped by education, proximity to service providers and age, with affordability and equipment scarcity acting as indirect barriers. Notably, gender was not a significant constraint, suggesting custom hire models can promote inclusive access. Crucially, access to ploughing and harrowing positively influences productivity by enabling earlier land preparation and higher yields, but gains depend on timeliness, reliability and farmers' positive perceptions, not merely service availability. To close the persistent access gap, priority actions include upgrading rural roads, subsidising service costs, expanding provider networks

and strengthening extension programmes. Without such systemic investments, nearly one third of farmers will remain excluded and productivity gains will stay uneven. This study provides the localized empirical evidence needed to guide equitable and sustainable mechanization policies in Zimbabwe.

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Disclaimers

The views and conclusions expressed in this article are solely those of the authors and do not necessarily represent the views of their affiliated institutions. The authors are responsible for the accuracy and completeness of the information provided, but do not accept any liability for any direct or indirect losses resulting from the use of this content.

Informed consent

All data collection procedures for this research were approved by the research ethics committee for Manicaland State University of Applied Sciences.

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this article. No funding or sponsorship influenced the design of the study, data collection, analysis, decision to publish, or preparation of the manuscript.

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