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Qualitative Study of Two and Four-Wheel Tractor Use in Timor-Leste's Five Districts

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ABSTRACT

Agricultural mechanization is increasingly promoted to address labor constraints and improve the timeliness of field operations in rice-based farming systems. This study qualitatively examines the use of two-wheel and four-wheel tractors in five districts of Timor-Leste (Manufahi, Covalima, Bobonaro, Manatuto, and Ainaro) and identifies key barriers and strategic implications for strengthening mechanization. Field data were collected through observation, questionnaires, and farmer interviews, and were synthesized using a SWOT (Strengths–Weaknesses–Opportunities–Threats) approach. Results indicate that tractor utilization remains limited across all districts, with most farmers reporting no tractor use (72.5–85.0%). A system-level assessment of four-wheel tractor (TR4) adequacy shows a substantial demand–availability gap: 124 units are available against an estimated requirement of 293 units (≈42.3% fulfillment), implying a shortfall of 169 units and potential bottlenecks during peak land preparation periods. District-level efficiency indications vary, suggesting different levels of operational pressure and the need for targeted interventions. The SWOT synthesis highlights productivity and efficiency gains as key strengths, while financial limitations, uneven distribution, and limited maintenance/spare-part access remain major weaknesses. Recommendations include strengthening operator and farmer training, improving maintenance and spare-part services (service centers and mobile repair), and enhancing access mechanisms such as managed hire services and context-appropriate financing to support reliable and timely tractor utilization.

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1. INTRODUCTION

Agriculture continues to be a pivotal sector for livelihoods in Timor-Leste, with enhancements in agricultural productivity widely acknowledged as crucial avenues for poverty alleviation. Recent evidence suggests that increased agricultural productivity reduces the likelihood of poverty among agricultural households and that productivity improvements are linked to facilitating factors such as enhanced access to extension services, credit, farmer organizations, and farm mechanization. These findings highlight the necessity of reinforcing practical interventions that can enhance farm performance and resilience in rural areas (Darko & Purnamasari, 2024; Van Loon & Rojas, 2024).

In this context, agricultural mechanization is frequently advocated as a suitable technology to enhance the timeliness of farm operations, alleviate laborious tasks, and improve the efficiency of crop production systems. Mechanization can lead to increased labor and land productivity when necessary conditions—such as skills, services, spare parts, and institutional support—are in place to ensure that machinery is utilized reliably and at optimal times. However, evidence from development interventions indicates that technocratic "leapfrogging" through the promotion of large tractors without adequate support systems often falls short, underscoring the importance of scale-appropriate solutions and service models that align with farmers' conditions and capacities

(Liao et al., 2022; Van Loon et al., 2020). This need is becoming increasingly pressing as the availability of and interest in agricultural labor decline and wages rise (Tahir et al., 2024).

The mechanization of agriculture in Timor-Leste, particularly through the use of tractors, exemplifies several persistent challenges. Analyses of the country's mechanization efforts reveal recurring issues, such as frequent equipment breakdowns, limited maintenance capabilities, inadequate supply of spare parts, and the necessity to reform mechanization hire schemes to ensure more sustainable service delivery. This suggests that the efficacy of utilizing two-wheel and four-wheel tractors is contingent not only on the availability of machinery, but also on the quality of service systems, the competence of operators, and the broader institutional and infrastructural context. (FAO, 2024; Van Loon & Rojas, 2024).

Owing to the substantial initial costs and limited financial options associated with machinery ownership, service-based access models, such as hiring or mechanization service provision, are frequently advocated as viable solutions for smallholders. Empirical research on mechanization services indicates that farmers' decisions to hire machinery are influenced by institutional support, labor constraints, cost perceptions, and weather-related risks. Conversely, the effectiveness of service provision may be compromised by challenges in finance, skill development, access to spare parts, fuel, and infrastructure. These findings underscore the necessity of comprehending farmers' lived experiences and constraints when formulating interventions aimed at enhancing tractor utilization and sustainability (Tesema et al., 2023; Yahaya et al., 2024).

Although there is a growing focus on mechanization in policy discussions, there remains a shortage of district-level data that elucidates the factors influencing farmers' choices to adopt or forgo the use of two-wheel and four-wheel tractors in Timor-Leste. This gap is particularly evident from a qualitative standpoint that considers practices, perceived advantages, and operational limitations. Consequently, this study undertakes a qualitative examination of tractor utilization across five districts in Timor-Leste: Manufahi, Covalima, Bobonaro, Manatuto, and Ainaro. The aim is to pinpoint barriers and opportunities unique to each context, thereby drawing practical conclusions to advance tractor-based mechanization as a suitable technology within local agricultural systems. (Van Loon et al., 2020; Van Loon & Rojas, 2024).

Accordingly, this study is guided by two primary research questions: (1) In what ways are two-wheel and four-wheel tractors employed in agricultural activities across the five districts of Timor-Leste (Manufahi, Covalima, Bobonaro, Manatuto, and Ainaro)? (2) What are the principal barriers and facilitating conditions that influence tractor use and the advancement of mechanization in these districts? To address these questions, the study aims to qualitatively (i) describe district-level patterns of tractor utilization, (ii) examine the current development and access pathways of two-wheel and four-wheel tractors, (iii) identify the perceived benefits and practical implications of tractor-based mechanization for farming operations, and (iv) document the main constraints that hinder effective and sustainable mechanization in the study area.

2 METHOD

2.1 Study Area and Period

This study was conducted in five districts of Timor-Leste: Manufahi, Covalima, Bobonaro, Manatuto, and Ainaro (Figure 1). This study commenced in January 2024. The selection of these districts was informed by considerations pertinent to the research objectives with the aim of obtaining representative and comprehensive field information.

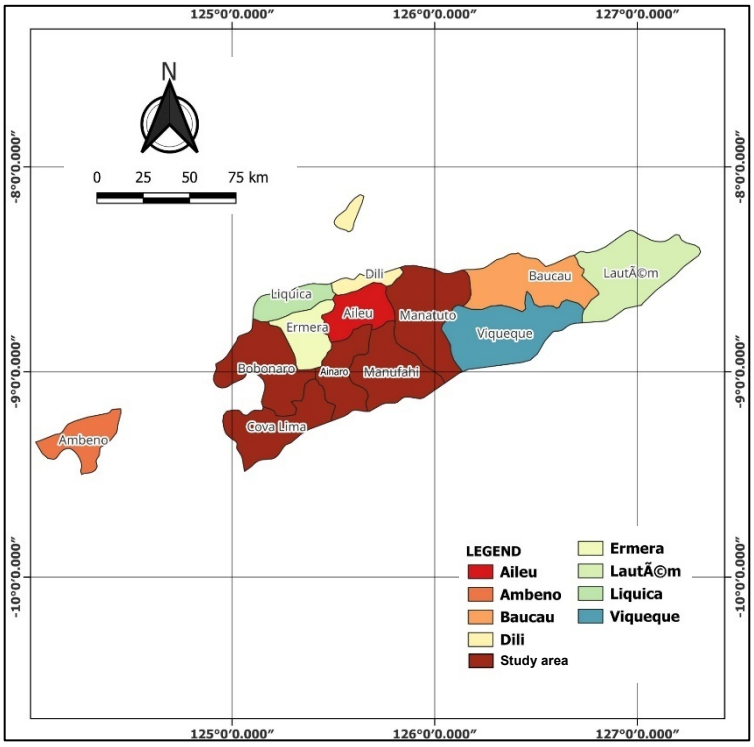

Figure 1. Study area (five districts) in Timor-Leste.

2.2 Research Design

This study utilized a qualitative descriptive methodology and was conducted as field research. The objective was to obtain a contextual understanding of how farmers employ two-wheel and four-wheel tractors, as well as the factors influencing tractor usage across the selected districts.

2.3 Data Types and Sources

This study used both primary and secondary data. Primary data were obtained directly from farmers through interviews guided by a questionnaire and supported by field observations. Secondary data were collected from local agricultural institutions and relevant documents, including previously published materials.

2.4 Research Object / Participants

The research object was farmers in Manufahi, Covalima, Bobonaro, Manatuto, and Ainaro districts

2.5 Data Collection

Data collection was carried out using (1) observations to document field conditions and tractor utilization practices, (2) a questionnaire as a guiding instrument for structured data collection, and (3) interviews to capture farmers' explanations, experiences, and constraints related to tractor use.

2.6 Data Analysis

Data were compiled and summarized descriptively to support district-level descriptions of tractor use. The main qualitative interpretation was conducted using SWOT analysis (Strengths, Weaknesses, Opportunities, and Threats) to identify internal and external factors influencing tractor utilization and derive strategic implications for improving agricultural mechanization in the study area.

3. RESULTS AND DISCUSSION

3.1 Tractor Utilization Across the Five Districts

This section analyses the patterns of tractor utilization based on feedback from farmers across the five districts, with each district comprising a sample size of 40. Overall, tractor usage was limited in all the areas examined, with a significant number of farmers reporting non-use of tractors. The highest percentage of non-use was observed in Ainaro at 85.0%, while the lowest percentages were recorded in Bobonaro and Covalima, both at 72.5%. These findings indicate that tractor-based mechanization has not been fully adopted across the five districts and that both access to and utilization of tractors are inconsistent.

Table 1 offers a comprehensive overview of tractor usage status across districts. Instead of presenting each district's data separately, this consolidated table underscores a key pattern: in every district, over two-thirds of the

respondents report not using tractors, highlighting the significant potential for improvement in adoption and service delivery.

Table 1. Summary of tractor utilization by district.

District	n	Using tractors (n)	Using tractors (%)	No tractors (n)	No tractors (%)
Ainaro	40	6	15	34	85
Bobonaro	40	10	27.5	30	72.5
Cavalia	40	11	27.5	29	72.5
Manatuto	40	9	22.5	31	77.5
Manufahi	40	10	25	30	75

Variations in tractor use at the district level can be attributed to differences in service access, affordability, infrastructure, operator skills, and maintenance support. These factors are frequently cited as major constraints in mechanization systems and are particularly pertinent in Timor-Leste, where evidence points to ongoing issues with maintenance capacity, spare-part supply, and the effectiveness of mechanization hire schemes (FAO, 2024; Van Loon & Rojas, 2024). Furthermore, research on mechanization service use indicates that institutional support, labor constraints, cost perceptions, and weather risks can influence farmers' decisions to hire mechanization services, underscoring the necessity for district-specific solutions rather than one-size-fits-all interventions (Tesema et al., 2023).

3.2 Adequacy of Four-Wheel Tractors (TR4) and Implications

Table 2 shows the estimated requirements and current availability of four-wheel tractors (TR4) in the five districts. Across all districts, availability is categorized as “not enough,” indicating a structural shortage of TR4 relative to the estimated needs. The total TR4 availability is 124 units compared with an estimated need of 293 units, corresponding to approximately 42.3% fulfillment and a shortfall of 169 units. This imbalance is likely to create operational bottlenecks during peak land preparation periods and may increase waiting time and production costs.

Table 2.TR4 requirements versus availability in the five districts.

District	Rice Field Area (ha)	TR4 Requirements	TR4 Availability	Category
Ainaro	6,076.00	35	14	Not enough
Bobonaro	7,662.00	48	24	Not enough
Covalima	12,167.00	69	27	Not enough
Manatuto	12,731.00	75	27	Not enough
Manufahi	9,942.00	58	32	Not enough
Total	48,578,00	293	124	

The district-level shortfalls also suggest that mechanization constraints are not only a question of adoption at the farmer level, but also of system-level capacity. When tractors are scarce, service provision is likely to become congested during peak demand, contributing to delays in land preparation and potential yield penalties from late planting. Such systemic challenges align with broader evidence from Timor-Leste, emphasizing that mechanization outcomes depend on functioning service systems, maintenance infrastructure, and appropriate business models, not merely on the presence of machines. (Van Loon et al., 2020; Van Loon & Rojas, 2024).

3.3 Workload and Efficiency Indications

The efficiency figures (Table 3) indicate variations among districts, with the lowest efficiency reported in Manatuto (36%) and the highest in Manufahi (55%). Although the table reports efficiency along working days, the key interpretation is consistent with the adequacy analysis: districts with lower efficiency face higher operational pressure, potentially increasing downtime risk and accelerating wear when tractors are intensively used without sufficient maintenance capacity.

Table 3. The efficiency of TR4 needs in relation to the rice field area and working days.

District	Rice Field Area (ha)	TR4 Need	Working days	Efficient
Ainaro	6.,076.00	35	31	40%
Bobonaro	7,662.00	48	31	54%
Covalima	12,167.00	69	31	39%
Manatuto	12,731.00	75	30	36%
Manufahi	9,942.00	58	30	55%
Total	4,578.00	281	153	

These findings support the argument that improving mechanization requires both increasing effective access (through additional units or better scheduling) and strengthening enabling services, such as operator training, repair facilities, and spare-part supply. Practical literature on sustainable agricultural mechanization emphasizes that choosing appropriate machinery sizes and ensuring after-sales support, training, and spare parts are essential for keeping equipment operational and reducing downtime (FAO, 2024; Van Loon et al., 2020).

3.4 SWOT Synthesis and Strategic Implications

The SWOT analysis (Table 4) outlines the internal and external factors influencing tractor mechanization across the five districts. Among the key strengths is the potential for tractors to enhance operational timeliness and boost productivity. However, significant weaknesses include financial constraints, limited access to spare parts and maintenance services, and uneven distribution of tractors. Opportunities lie in productivity improvements over larger land areas and the potential expansion of service-based access models. Conversely, threats encompass the ongoing reliance on traditional methods, which may lead to productivity stagnation and the risk of equipment breakdowns due to insufficient maintenance.

Based on this synthesis, strategic priorities should concentrate on (1) enhancing training for operators and farmers to ensure safe and efficient tractor operation, (2) boosting maintenance capabilities and improving access to spare parts through service centers and/or mobile repair services, (3) facilitating access mechanisms such as hire services and financing schemes to lower adoption barriers, and (4) optimizing coordination and scheduling to alleviate peak-season congestion. These priorities align with evidence from Timor-Leste, which underscores the need to reform mechanization hire schemes and establish sustainable service delivery. Additionally, broader mechanization research suggests that service models can broaden access when ownership is limited by costs and financial constraints (FAO, 2024; Van Loon et al., 2020; Van Loon & Rojas, 2024).

Table 4. SWOT analysis

Internal Factors / External Factors	Description
Strength (S)	Use of tractors increases agricultural productivity and work efficiency; government subsidies and international aid (e.g., FAO); tractors reduce dependence on manual labor.
Weakness (W)	Financial limitations prevent many farmers from purchasing or renting tractors; limited access to spare parts and maintenance services (especially in remote areas); uneven tractor distribution between districts.
Opportunities (O)	Tractor use can increase productivity on large land areas; government and international support for mechanization can be leveraged to expand capacity; potential market development for better farm outputs through efficiency.
Threats (T)	Reliance on traditional methods can lead to productivity stagnation; suboptimal land can hinder production increases; risk of mechanization equipment damage due to lack of maintenance.
WO Strategy	Create low-interest microcredit so farmers can buy or rent tractors; build maintenance service centers and spare-part distribution points in strategic locations; improve equitable distribution of tractors to remote areas; provide training on tractor use, land management, and modern agricultural technology; leverage international cooperation for subsidies/funding to improve access.
SO Strategy	Provide technical training to ensure optimal tractor utilization, especially on large land areas; use subsidies to encourage investment in machinery; collaborate with international organizations (e.g., FAO) for training, technical assistance, and additional funding; improve infrastructure (roads/logistics) to distribute products more efficiently and reach wider markets. .
ST Strategy	Gradually introduce mechanization to reduce dependence on traditional methods; use subsidies to train farmers in proper tractor use and maintenance to reduce damage risk; distribute tractors to areas with suboptimal land to improve productivity; establish maintenance and spare-part service centers; conduct land studies/optimization via partnerships to address land constraints.
WT Strategy	Prepare micro-financing and low-interest credit schemes to enable farmers to shift to mechanization; establish service centers and spare-part distribution points to keep equipment operational; provide maintenance training for farmer groups; leverage international cooperation to address financial constraints and expand access to modern technologies.

4. CONCLUSION

This qualitative study examined two-wheel and four-wheel tractor use in five districts of Timor-Leste (Manufahi, Covalima, Bobonaro, Manatuto, and Ainaro) and identified key constraints and strategic implications for improving mechanization. Overall, tractor utilization among the surveyed farmers remained limited across all districts, with non-use rates consistently dominating. This indicates that tractor-based mechanization has not yet become a mainstream practice, and that adoption and access barriers remain substantial.

At the system level, the analysis shows a persistent imbalance between the estimated needs and availability of four-wheel tractors (TR4) across the five districts. The overall fulfillment is far below the estimated requirement, implying that capacity constraints likely contribute to congestion during peak land preparation periods and may increase delays and operational pressure on existing machines. District-level efficiency indications further suggest that some districts experience higher operational pressure than others, reinforcing the need for targeted interventions rather than uniform distribution or generic programs.

The SWOT synthesis indicates that tractors offer clear potential benefits for improving operational timeliness and work efficiency, but major weaknesses and threats—particularly financial constraints, limited maintenance and spare-part access, and uneven distribution—can undermine sustainable utilization. Therefore, improving tractor mechanization in the study area requires a combined strategy: (1) strengthening operator and farmer capacity through practical technical training; (2) improving maintenance readiness and spare-part accessibility through service centers and/or mobile maintenance arrangements; (3) expanding feasible access mechanisms, such as sharing or hire-service management and context-appropriate financing; and (4) improving

distribution and scheduling to reduce peak-season bottlenecks, especially in high-pressure districts. These actions are expected to improve the reliability and utilization efficiency of existing equipment while increasing farmers' effective access to mechanization services.

In summary, tractor mechanization in the five districts shows positive potential but remains constrained by access and support system limitations. Addressing these constraints through service-oriented and capacity-building interventions is essential for achieving more effective, equitable, and sustainable mechanization outcomes.

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