Towards inclusive mechanization? Two-wheel tractor-based service markets in Ethiopia, Burkina Faso, and Zimbabwe

Rabe Yahaya
International Maize and Wheat Improvement Center Ethiopia, Addis Ababa, Ethiopia

Thomas Daum
University of Hohenheim, Stuttgart, Germany

Ephrem Tadesse and Walter Mupangwa
International Maize and Wheat Improvement Center Ethiopia, Addis Ababa, Ethiopia

Albert Barro
L’Institut de l’Environnement et de Recherches Agricoles du Burkina Faso, Ouagadougou, Burkina Faso

Dorcas Matangi
International Maize and Wheat Improvement Center Zimbabwe, Harare, Zimbabwe

Michael Misiko
International Maize and Wheat Improvement Center Kenya, Nairobi, Kenya

Frédéric Baudron
International Maize and Wheat Improvement Center Zimbabwe, Harare, Zimbabwe

Bisrat Getnet Awoke
University of Hohenheim, Stuttgart, Germany and Ethiopian Institute of Agricultural Research, Addis Ababa, Ethiopia

Sylvanus Odjo
International Maize and Wheat Improvement Center, El Batan, Mexico

Daouda Sanogo
Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), Ouagadougou, Burkina Faso, and
Rahel Assefa and Abraham Kassa
International Maize and Wheat Improvement Center Ethiopia, Addis Ababa, Ethiopia

Abstract

Purpose - African agricultural mechanization could lead to a mechanization divide, where only large farms have access to machines. Technological solutions such as scale-appropriate machines and institutional solutions like service markets offer hope for more inclusive mechanization. Two-wheel tractor-based service markets combine both technological and institutional elements, but there is limited research on their economic viability and challenges.

Design/methodology/approach – We analyze the economic viability of two-wheel tractor-based service provision based on data from service providers in Ethiopia, Burkina Faso, and Zimbabwe. We also examine the institutional framework conditions for such service providers based on qualitative interviews with these service providers and stakeholders such as machinery dealers, spare parts providers, and banks.

Findings - Two-wheel tractor-based service provision is economically highly viable, largely due to multifunctionality. Post-production services such as threshing and transportation are particularly lucrative.
However, the emergence and economic sustainability of service providers can be undermined by bottlenecks such as access to finance, knowledge and skills development, access to fuel and spare parts, and infrastructure problems.

Originality/value – This is the first study on the economics of two-wheel tractor-based service provider models. Past studies have focused on large four-wheel tractors, but two-wheel tractors are different in many aspects, including regarding investment costs, repair and maintenance costs, capacity, and multifunctionality.

Keywords Agricultural mechanization, Smallholder farming, Inclusive development, Appropriate mechanization, Sharing economy

Paper type Research paper

1. Introduction
Farming systems in Sub-Saharan Africa are the least mechanized [1] in the world, with 80% of farms relying on manual labor (FAO and AUC, 2018). However, mechanization is now unfolding in some areas due to farming system evolution and rising rural wages (Diao et al., 2020), and it is high on the agenda of many governments (Benin, 2015; Daum and Birner, 2020; FAO and AUC, 2018). Studies suggest that labor is increasingly a major limiting factor for smallholder farmers (e.g. Baudron et al., 2019; Silva et al., 2019). Mechanization can reduce the labor burden associated with manual farming (FAO and AUC, 2018), which is particularly large for women and children (Daum and Birner, 2021; Takeshima and Vos, 2022), and raise labor and land productivity (Adu-Baffour et al., 2019; Mano et al., 2020; Silva et al., 2019; Yahaya et al., 2018). However, with the renewed focus on agricultural mechanization, concerns about mechanization have also resurfaced (Daum and Birner, 2020).

A major concern relates to a mechanization divide, where only large farms benefit from machinery such as tractors (Daum, 2023). Generally, large farms are more likely to adopt innovations, for example, as they have better access to markets, including credit markets (Feder et al., 1985). In the case of mechanization, large farms enjoy a further advantage since tractors are indivisible and associated with economies of scale, disadvantaging farms with small and spatially dispersed plots (Binswanger, 1986). This can lead to unequal land distribution (Wang et al., 2016; Yamauchi, 2016). When mechanization predominantly benefits large farms, small farms may face increased competition in land markets, or their prospects for future farmland expansion may be undermined (Pingali, 2007; Kansanga et al., 2018).

There are high hopes that technological and institutional solutions can make mechanization more accessible for smallholder farmers (Daum, 2023), which is key for inclusive value chain development (Devaux et al., 2018). A major technological solution is sometimes referred to as “appropriate” mechanization, involving smaller machinery such as two-wheel tractors. Two-wheel tractors play a major role in some farming systems in Asia, particularly in rice-growing regions, such as India and Bangladesh, but also mountainous regions in Nepal (Ahmed and Takeshima, 2020; Bhattarai et al., 2020; Diao et al., 2020; Justice and Biggs, 2020; Paudel et al., 2019, 2023; Win et al., 2020). Two-wheel tractors are less expensive, better suited to small plot sizes with field elements such as trees, and easier to run and repair (Baudron et al., 2015; Kahan et al., 2018; Van Loon et al., 2020). Another potential advantage is multifunctionality (Diao et al., 2014; Kahan et al., 2018). In some Asian countries, they are used to pull a range of implements such as ploughs and planters, to power stationary machinery such as shellers and pumps, and for transportation (Diao et al., 2020) [2].

A major institutional innovation is asset-sharing via service markets. Service markets have played a key role in smallholder mechanization in various countries in the Global North (Daum et al., 2018; Olmstead and Rhode, 1995), and more recently, in many Asian countries in the Global South (Belton et al., 2021; Diao et al., 2020; Yang et al., 2013). Service markets can help to spread the fixed costs of expensive machinery by increasing utilization rates and help farmers access machinery that they cannot afford or lack the knowledge and skills to operate, maintain,
and repair (Daum, 2023). These markets have emerged in some African countries (Diao et al., 2020), partly due to the rise of medium-scale farmers (Jayne et al., 2016) who can invest in tractors but need to offer services for repayment (Diao et al., 2014; Houssou et al., 2017).

While service markets can help make mechanization more inclusive, the emergence of such markets can be undermined by various challenges. In rain-fed agriculture, farmers typically demand services during the same period, often only for land preparation (Binswanger, 1986). In Northern Ghana, ploughing services are only demanded during 45 days (Houssou et al., 2013). Although service providers can offer services for other activities (e.g. planting, fertilizer spreading, pesticide spraying, harvesting, processing, and transportation), there is often no demand for such services as mechanization typically evolves stepwise, starting with the most labor-intensive farming steps (Binswanger, 1986). Service providers may increase utilization rates with seasonal migration; however, this option can be affected by various challenges (Berhane et al., 2020; Takeshima, 2015; Takeshima and Lawal, 2020; Tefera and Awoke, 2023).

The emergence of service markets is often undermined by transaction costs, which are particularly high where plots are small and scattered and infrastructure is poor (Daum, 2023; Takeshima, 2015; Tefera and Awoke, 2023). High transaction costs can prevent the emergence of service markets or make them exclude farms with small and scattered plots, disproportionately affecting female farmers (Daum and Birner, 2017). In Zambia, Adu-Baffour et al. (2019) found that only half of the tractor owners in a private scheme aimed at promoting smallholder mechanization via service provision offered any services to farmers. Digitalization options from the “Sharing Economy”, such as Uber-type solutions, may alleviate some challenges affecting service provision such as high transaction costs, however, such solutions are neither silver bullets nor widespread (Daum et al., 2021). Research has highlighted several other factors that can influence the development of service markets, including rural infrastructure, ease of border crossing, knowledge and skills of service providers and operators, including managerial knowledge and skills, and legal and business conditions (Daum and Birner, 2017; FAO and CIMMYT, 2018; Mrema et al., 2020).

There is a lack of understanding of the economics of mechanization service provision, particularly regarding two-wheel tractor-based models, as past studies have focused on four-wheel tractors (e.g. Adu-Baffour et al., 2019; Houssou et al., 2013; Houssou et al., 2017). The economics of four-wheel and two-wheel tractors differ regarding various aspects, for example, two-wheel tractors are less expensive and potentially better suited for multifunctionality, which can help to cover fixed costs throughout the season (however, they also have a lower capacity). Additionally, there is also a lack of empirical evidence on the potential and challenges facing emerging service providers using (two-wheel) tractors. This is problematic as the institutional framework conditions, such as knowledge and skills development and spare part and repair service markets, significantly shape the profitability of mechanization (Daum and Birner, 2017). Takeshima et al. (2015) and Onomu et al. (2020) do provide some insights into this question in Nigeria; however, they focus on four-wheel tractors.

This paper aims to fill these knowledge gaps by examining the economic viability of two-wheel tractor-based service provision and assessing the challenges faced by service providers, with a focus on Ethiopia, Burkina Faso, and Zimbabwe. Ethiopia has one of the highest rates of animal traction in Africa (Berhane et al., 2020; Sheahan and Barrett, 2017), but it is increasingly undermined by population growth, farming system evolution, and climate change (Baudron et al., 2015; Berhane et al., 2020; Kahan et al., 2018; Mrema et al., 2020; Takele and Selassie, 2018), allowing two-wheel tractors to “make inroads” (Kahan et al., 2018). In Burkina Faso, several projects are supporting two-wheel tractor-based service provision, and similar to Ethiopia, animal traction remains widespread. In Zimbabwe, land reforms, rural population growth, and land subdivision, have resulted in small-scale farmers owning land that is too small for four-wheel tractors yet too large for animal draft power (Kahan et al., 2018).
2. Study Sites and methods

2.1 Study countries and sites

2.1.1 Ethiopia. Agriculture is the dominant sector in Ethiopia, significantly contributing to the national GDP (42%) and employing the majority (85%) of the labor force (CSA, 2018). In recent years, labor has emerged as a key bottleneck for many farmers (Baudron et al., 2019; Silva et al., 2019). Over the last 2 decades, structural transformation has led to a more than 50% increase in real wages for unskilled laborers in rural areas (Berhane et al., 2020). Animal traction, in the form of the Maresha plough, has been common for 3,000 years (Takele and Selassie, 2018). 60–80% of farmers use draught animals, partially through service markets (Berhane et al., 2020; Sheahan and Barrett, 2017). However, animal traction is increasingly undermined by population growth, farming system evolution, and climate change, making it challenging to obtain fodder and water (Baudron et al., 2015; Berhane et al., 2020; Kahan et al., 2018; Mrema et al., 2020; Takele and Selassie, 2018). Animal traction also has a high labor demand, both during the farm and off-farm season, contributing to a doubling of prices for animal traction in the last 2 decades (Berhane et al., 2020; Takele and Selassie, 2018).

Around 1% of farms use tractors (Berhane et al., 2020), which is low compared to the African average (Daum, 2023; Kirui, 2019). However, tractors and two-wheel tractors are gaining popularity among smallholder farmers (Kahan et al., 2018). Most tractors are four-wheel tractors, but there is a significant share of two-wheel tractors (Berhane et al., 2020). In 2015/2016, 12% of all tractors sold by Ethiopia’s largest agricultural machinery dealer were two-wheel or other small tractors (Berhane et al., 2020). There are around 4,000 two-wheel tractors, many of which were procured as part of public programs (Baudron et al., 2015; Kahan et al., 2018).

This study was carried out in areas - the Machakel district of Amhara and the Tiyo district of Oromia regions - where the “Farm Power and Conservation Agriculture for Sustainable Intensification” (FACASI) and the “Innovative Financing for Sustainable Mechanization in Ethiopia” (IFFSMIE) projects were implemented. The projects promoted smallholder mechanization by supporting the adoption of two-wheel tractors by connecting importers, rural entrepreneurs, financial institutions, and by supporting private start-ups to catalyze mechanization entrepreneurship. The Machakel district is located at an altitude of 1,200–3,200 meters above sea level and receives 1,500–1,900 mm of rainfall per year (Demil et al., 2020). The district is dominated by smallholder farming and characterized by mixed farming systems, including rain-fed crops and livestock. The average landholding is 1.56 ha for female-headed- and 2.15 ha for male-headed households (Mengesha et al., 2022). The Tiyo district is 2,430 meters above sea level and receives an average of 752 mm of rainfall per year. The main crops grown are teff, barley, wheat, and maize, and the main livestock species are cattle, poultry, sheep, and goats. The average landholding is 1.25 hectares.

2.1.2 Burkina Faso. Agriculture is the main economic activity in Burkina Faso, engaging 80–90% of the population (FAO, 2014), who predominantly cultivate maize, sorghum, millet, and rice (Tomalka et al., 2020). Northern Burkina Faso is characterized by a semi-arid climate with limited rainfall, a short rainy season, and high climate variability, which will increase with climate change (Tomalka et al., 2020). Southern Burkina Faso has a more tropical climate, with an annual precipitation of up to 1,000 mm, mostly between June and September (Tomalka et al., 2020). In recent years, the government has implemented various policies and programs to increase farmers’ access to mechanization (Malabo Montpellier Panel, 2018). However, the adoption of mechanization remains low, which is due to challenges such as limited access to credits, a lack of technical knowledge and training, and poor infrastructure and transport networks (Malabo Montpellier Panel, 2018). Kirui (2019) has estimated that around 1% of farmers use tractors, however, up to 70% use animal traction.

The study focused on four regions in the South-West: Hauts-Bassins, Cascades, Boucle du Mouhoun, and South-West. The regions are at an altitude of 300–450 meters and receive 900–1,200 mm of rainfall per year, allowing farmers to cultivate 5–6 hectares of land on average,
mostly maize, sorghum, rice, cowpea, and sesame (Climate Voyages, 2023; MEDEV, 2005). The regions were selected because this is where the Green Innovation Centers Project of the German Development Cooperation (GIZ) has been implemented. The project supported service providers with access to mechanization kits, including a two-wheel tractor and implements.

2.1.3 Zimbabwe. Zimbabwe heavily relies on agriculture, which accounts for 9% of its GDP and employs 66% of its workforce (World Bank, 2023). Zimbabwe’s agriculture has faced various challenges in recent decades, including a contested land reform, declining infrastructure and agriculture support, economic instability, and frequent droughts (Runganga and Mhaka, 2021). Both large-scale commercial farming and small-scale farms coexist. Small-scale farmers occupy a larger land area overall but tend to farm in regions with relatively infertile land and less predictable rainfall patterns (Runganga and Mhaka, 2021).

Smallholder farmers mainly cultivate maize and groundnuts as well as cotton as a cash crop (Runganga and Mhaka, 2021). Historically, Zimbabwe’s commercial farming sector has relied on animal traction or four-wheel tractors, whereas smallholder farmers have mostly relied on manual labor, except for land preparation, which was often done using animal traction. Since the 2000s, the Zimbabwean government promotes mechanization with support from the Reserve Bank of Zimbabwe and concessional loans from countries such as Belarus, Brazil, China, Malaysia, and South Korea. These programs mostly focused on four-wheel tractors and were often characterized by political (e.g. corruption, elite capture) and technical challenges (e.g. inappropriate technologies, lack of spare parts and repair services) (Cabral and Amanor, 2022; Shonhe, 2022). At the same time, institutional support for animal traction has declined (Mudamburi and Starkey, 2022). It has been estimated that there are around 10,300 functional tractors (down from above 24,000 in 2000) whereas the government believes at least 40,000 are needed (ITA, 2022; Shonhe, 2022). Kirui (2019) has estimated that 65% of farmers use animal traction, whereas 1% use mechanical traction for land preparation.

The study focused on the Makonde district in the Mashonaland West Province, which lies at an altitude of 1,450 m above sea level and receives around 800 mm of rain per year (Baudron et al., 2019). Farming is dominated by maize, groundnuts, soybeans, and tobacco (Baudron et al., 2019). Makonde district is a typical resettlement area with large-scale commercial farms and small-scale farmers. It was selected because it was the project side of the “Farm Power and Conservation Agriculture for Sustainable Intensification” (FACASI) project, which promoted two-wheel-tractors based service provider models.

2.2 Data collection and analysis

This study relied on data collected from service providers in Ethiopia, Burkina Faso, and Zimbabwe, which were collected using structured questionnaires (Table 1). In Ethiopia, data were collected from 10 service providers. In addition, 26 key informant interviews were conducted, including 7 with manufacturers/importers/dealers, 5 with financial service providers, 4 with spare parts dealers, and 10 with the staff of research institutes and the

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<th>Source(s): Authors’ own creation/work</th>
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| Table 1. Sampling

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<table>
<thead>
<tr>
<th>Economics of service provision</th>
<th>Mechanization service providers</th>
<th>10</th>
<th>10</th>
<th>20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Institutional challenges of service provision</td>
<td>Key informants</td>
<td>26</td>
<td>30</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>Mechanization service providers</td>
<td>22</td>
<td>–</td>
<td>20</td>
</tr>
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</table>
ministry of agriculture to better understand the economics of service provision as well as institutional challenges of service provision. Moreover, 22 small mechanization entrepreneurs using two-wheel tractors were surveyed with the specific aim of better understanding the institutional factors influencing their business. In Burkina Faso, data from 10 service providers were collected and 30 key-informants such as machinery and spare parts dealers and financial service providers were interviewed to better understand both economic and institutional aspects of service provision. In Zimbabwe, data from 20 service providers were collected on both the economics and institutional challenges of service provision.

The viability of two-wheel-tractor based service provision was assessed using the following indicators: net present value, internal rate of return, and break-even hours.

1. **Net Present Value (NPV)** is the value of cash flows over the entire life of an investment discounted to the present (Žižlavský, 2014). It considers the difference between the present value of the cost and future benefit streams of investments. The net benefits are discounted at the appropriate rate of interest to obtain the present worth of the net benefits for each year. If the net present value is positive, the investment yields a higher rate of return than investing the money at the current rate of interest.

2. **Internal Rate of Return (IRR)** shows the profitability of an investment (Hartman and Schafrick, 2004). It is the discount rate at which the net present value of the costs of the investment equals the net present value of the benefits. The higher the IRR, the more desirable it is to invest. When the IRR is less than the discount rate, the NPV will be negative and when it is equal to the discount rate, the NPV will be zero. When the IRR is higher than the discount rate, the NPV of the investment will be positive. In this paper, a lending interest rate of 15% was used for Ethiopia and Burkina Faso, and of 20% for Zimbabwe.

3. **Breakeven hour:** Since fixed costs need to be covered regardless of the number of hours served, service providers need to know the number of hours in a year which breaks their cost with the existing market hiring charges. The breakeven hour is the minimum threshold hour a service provider should operate per year to break costs.

### 3. Results

#### 3.1 Is two-wheel tractor-based service provision economically viable?

#### 3.1.1 Insights from Ethiopia. In Ethiopia, the study analyzed the economic viability of investing in two-wheel tractors and combinations of four locally relevant implements (seeder, reaper, thresher, and trailer). Table 2 shows the purchase price, lifetime, suitable crop types, work rate, and operating costs of the different implements based on data from the service providers. Table 2 also shows the total number of hours that service providers could offer services based on cropping calendars for major crops grown (wheat, barley, and teff) in both areas.

Table 3 show the average economic viability of investing in different mechanization services. A key insight is that the viability of two-wheel tractors can be enhanced when service providers purchase tractors and a combination of implements, as the fixed costs of the tractor can be spread across different operations. Service providers investing US$7,700 in a two-wheel tractor plus a seeder, reaper, thresher, and trailer (Scenario 1) generate an average net present value (NPV) of US$16,801 in Machikel and US$20,607 in Tyko. This translates to an internal rate of return (IRR) of 74–86%, which is very high. Assuming a 10% cost increase, the IRR would still be 62–75%. The payback period for this combination of investments is 1–2 years.
Investing in single services is most profitable for transportation and threshing. Trailers can be used for transportation throughout the year, and threshers for an extended period (see Table 2). Potential service providers without enough resources to buy all implements may thus use transportation and/or threshing services as an entry point. The profits associated with investing only in reapers (Scenario 10) or seeders (Scenario 11) are more limited or even negative as the harvesting and planting windows are very short.

Figure 1 summarizes the break-even hours and the potential profits for all operations. Threshing and transport services have the highest break-even points, however, since they are
demanded throughout the year (or a major part of it in the case of threshing), they are associated with high potential annual profits. The breakeven hour of transportation is around 207 h, a fraction of the potential working hours (1,410–1,752) (see Table 2). The breakeven hour for the threshing is 132 h, again a fraction of the 968–1,104 potential working hours. While the breakeven points are low for reaping (49 h) and planting (35 h), these farm steps are also associated with short operating windows. For example, there is a maximum of 160–200 h for planting, which may further decline due to potential breakdowns and public (religious) holidays during the planting season in Ethiopia. Typically, service providers can only plant 10–15 hectares per year unless providing migratory services. Given the challenges to make planting services profitable, service providers may refrain from offering such services, even though they could be profitable for farmers.

3.1.2 Insights from Burkina Faso. The study also analyzed the economic viability of investing in two-wheel tractors and combinations of different implements in Burkina Faso. Table 4 shows that two-wheel tractors and threshers are considerably more expensive compared to Ethiopia. Trailers have a similar price. All the other implements are considerably less expensive. The work rates of the equipment are similar to the Ethiopian case. Most services are less expensive, but threshing and transportation services are significantly more expensive in Burkina Faso.

Table 5 shows the NPV and IRR for different investment scenarios. Consistent with the findings from Ethiopia, threshing and transportation services are highly profitable. Investing in both the thresher and trailer results an IRR of 185%, which is remarkably high. Scenarios that include other implements also result in very high IRRs. IRRs are significantly lower in

![Break-even hours and profits](image)

**Figure 1.** Break-even hours and profits under scenario 1 in Tiyo, Ethiopia

**Note(s):** Assumption: Service providers purchased the full set of technologies (two-wheel tractor, seeder, reaper, thresher, and trailer) and the fixed costs of the tractor are equally shared among the four types of services. Otherwise, the same assumptions are used as described in Table 2. The maximum potential hours reflect the lower bounds in Table 2, reflecting the situation in Tiyo

**Source(s):** Authors’ own creation/work
scenarios without thresher or trailer. Investing only in land preparation services (ploughs, rotary tiller, and harrow) or only in seeding or mechanical weeding services results in negative NPVs and IRRs. While land preparation and planting services are less lucrative for service providers, they may nevertheless offer such services if they expect farmers to use their threshing and transportation services after the harvest. In the climatic conditions of the
In the Zimbabwean case study, only two-wheel tractors, planters, and threshers (shellers) were assessed, all of which entail comparable costs to those in Ethiopia. However, service charges and operating costs are around five times higher. The actual hours of annual service provision are significantly lower than the potential hours: below 10% for planting and below 20% for shelling.

In Zimbabwe, all business models exhibit positive NPVs and high IRRs (Table 7). The maximum NPV is achieved when combining planting and threshing (shelling) services, while the highest IRR is attained when only providing threshing (shelling) services. Threshing (shelling) also has the lowest break-even hour (not shown), making it an interesting entry point into service provision since shellers are inexpensive (explaining their high adoption in recent years). Similar to Ethiopia and Burkina Faso, planting is less profitable; however, unlike in Ethiopia and Burkina Faso, it remains highly profitable to offer this service.

### 3.2 What are the challenges for two-wheel tractor-based service providers?

Section 3.1 has shown that the economic viability of two-wheel tractor-based service provision is high in principle. However, our qualitative insights from Ethiopia and Burkina

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**Table 6.** Economic and technological characteristics of mechanization options in Zimbabwe

<table>
<thead>
<tr>
<th>Implement</th>
<th>2WT</th>
<th>Planter</th>
<th>Sheller</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price (US$)</td>
<td>2000</td>
<td>4,500</td>
<td>1,000</td>
</tr>
<tr>
<td>Lifetime (years)</td>
<td>5 years</td>
<td>5 years</td>
<td>5 years</td>
</tr>
<tr>
<td>Crops</td>
<td>Multi-use</td>
<td>Maize</td>
<td></td>
</tr>
<tr>
<td>Work rate</td>
<td>2 h/ha</td>
<td>4 tons/h</td>
<td></td>
</tr>
<tr>
<td>Service charge (US$/hr)</td>
<td>28</td>
<td>58,50</td>
<td></td>
</tr>
<tr>
<td>Operating costs (US$/hr)*</td>
<td>5,80</td>
<td>4,62</td>
<td></td>
</tr>
<tr>
<td>Maximum annual hours#</td>
<td>896</td>
<td>976</td>
<td></td>
</tr>
<tr>
<td>Actual annual hours</td>
<td>110</td>
<td>186</td>
<td></td>
</tr>
</tbody>
</table>

* Operating costs include costs for labor, fuel, spare parts, and repairs, and traveling costs. 
# Based on crop calendars. Additional technical remarks: Fitarelli double-row planter, self-propelled sheller. In Zimbabwe, service providers also obtained a trailer, costing 500US$, however, only for the transportation of the planter and sheller.

**Source(s):** Authors’ own creation/work

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**Table 7.** 10-year cost-benefit analysis of 2WT-based service provision in Zimbabwe

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Technologies</th>
<th>Investment cost (US$)</th>
<th>NPV (US$)</th>
<th>IRR (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Thresher</td>
<td>3,000</td>
<td>17,909</td>
<td>169</td>
</tr>
<tr>
<td>2</td>
<td>Seeder, thresher</td>
<td>7,500</td>
<td>27,401</td>
<td>124</td>
</tr>
<tr>
<td>3</td>
<td>Seeder</td>
<td>6,500</td>
<td>7,155</td>
<td>53</td>
</tr>
</tbody>
</table>

**Note(s):** Assumptions: Based on the average market lending interest rate, the calculation is done at a 20% discount rate. Machinery lifetime: 5 years. Insurance: 10% of investment costs. Annual repair and maintenance costs: 10% of investment costs.

**Source(s):** Authors’ own creation/work
Faso revealed that various factors related to the enabling environment can undermine the emergence of two-wheel tractor-based service providers and their long-term success:

3.2.1 Access to finance, market stability, exchange rates, and foreign currency. The interviews with the service providers suggest that limited access to finance can be a key constraint to starting mechanization businesses. While they may use cash, savings, or financial services to purchase machinery, access to loans is often hindered by a lack of collateral, tedious application procedures, and high interest rates. The qualitative insights from Ethiopia suggest that credit is inaccessible or unaffordable for many potential service providers. While the Development Bank of Ethiopia has started a machinery leasing scheme in 2018, it only provides credit for larger-scale mechanization (above US$36,000) (DBE, 2022).

At microfinance institutions, the maximum credit is below US$2,000, which is not enough to buy a two-wheel tractor set, which costed US$7,700 in Ethiopia. 13 of the 22 service providers interviewed did not even try to get a loan from a formal bank. 9 applied for finance from microfinance institutions, of which 3 succeeded. In Zimbabwe, service providers noted that threshers (shellers), costing around US$1,000, are typically purchased without formal financial assistance, explaining their rapid adoption - with suppliers running short of supplies at the beginning of each shelling season. For other small-scale machinery (e.g. two-wheel tractors), financial products are reportedly readily available, at least to salaried farmers. In principle, service providers can overcome capital constraints by purchasing machinery collectively. In Ethiopia, 9 businesses were owned by groups of about three individuals; however, only two preferred to maintain this arrangement, citing difficulties in necessary and speedy consensus building, shared financial responsibilities, confidentiality requirements, and unequal skills for machinery maintenance as reasons. A unique problem in Zimbabwe is the shortage of foreign currency for machinery imports. Some service providers reported high demand for services but an inability to access foreign currency to procure equipment.

3.2.2 Knowledge and skills. Lack of knowledge and skills on how to manage, operate, maintain, and repair tractors and implements can undermine the economic viability and sustainability of service provision. In Ethiopia, the qualitative interviews revealed that there are few long-term and regular capacity-enhancing opportunities for service providers - beyond initial short-term training upon machinery purchase (often only a few hours) and sporadic courses by the government (e.g. Ethiopian Institute of Agricultural Research) or development partners (e.g. CIMMYT). Consequently, 16 out of 22 service providers identified a lack of technical training as a business constraint. Knowledge and skills are also important for operators and mechanics. However, only 14 of 22 service providers in Ethiopia have access to trained and experienced mechanics. Similarly, in Burkina Faso, service providers complained about the insufficiency of after-sales and repair service and a lack of mechanics proficient in agricultural equipment.

3.2.3 Fuel and spare parts. Fuel accessibility is also a concern. In Ethiopia, the average distance to a fuel station was 16 km, making it costly to access fuel in addition to the actual fuel costs. In Zimbabwe, fuel costs and access were also noted as key problems. Spare parts shortages are another pressing issue. In Ethiopia, 10 of 22 service providers identified spare part shortages as a significant constraint. In Zimbabwe, service providers reported challenges getting spare parts such as Fitarelli planter plates, which are reportedly only available in Harare, nearly 200 km from Makonde, translating to a considerable amount of time and money spent on fixing broken machinery. In this context, it is important to point out that the economic viability calculations (see 3.1.) were based on service providers who had recently received tractors and implements, hence they witnessed only a few breakdowns. Table 8 illustrates the internal rates of return in Ethiopia under the assumption of increased machinery downtime (operations reduced by 20%). Prolonged downtime significantly reduces economic viability, although internal rates of return remain high.
3.2.4 Infrastructure and transaction costs. As noted in the introduction, poor infrastructure and high transaction costs can prevent the emergence of service markets or make them exclude farms with small and scattered plots. The fact that production-related services are less lucrative than post-harvest-related services (i.e. threshing and transportation) suggests that infrastructure and transaction costs are problematic in both Ethiopia and Burkina Faso. In Ethiopia, 16 of 22 service providers identified poor rural infrastructure, such as poor feeder roads, as a major business constraint. Poor infrastructure limits the number of farmers that can be reached within the short time windows for planting and harvesting and confines service providers to small operating areas. It also hinders migratory service provision, which could help to increase utilization rates, which is particularly important regarding planting and harvesting services. Stakeholders in Ethiopia reported that migratory service provision following the harvest season is still uncommon except for threshers, which can easily be transported with trucks.

4. Discussion
Mechanization is key for agricultural development in Africa; however, it may exacerbate disparities between small and large farms. There are high hopes that technological and institutional solutions can make mechanization more inclusive to smallholder farmers, which is key for inclusive value chain development (Devaux et al., 2018) and women empowerment (Daum, 2023). This paper suggests that two-wheel tractor-based service markets may be one such solution. However, the study also shows that the emergence and economic sustainability of service providers can be undermined by various bottlenecks in the enabling environment such as access to finance, knowledge and skills development for owners, operators, and mechanics, access to fuel and spare parts, and infrastructure problems, calling for strengthened public efforts to support private mechanization efforts with conducive institutions.

Across all three case study countries, the results suggest that the economic viability of two-wheel tractor-based service provision is high, largely due to the multifunctionality of the two-wheel tractors, which allows to spread the fixed costs of the two-wheel tractor itself (Kahan et al., 2018). In all countries, post-harvest services such as threshing and transportation are particularly attractive for service providers, resonating with research on the economic viability of four-wheel tractor-based services from Ghana (Daum and Birner, 2017; Houssou et al., 2013). In contrast, land preparation and planting services are less

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Technologies</th>
<th>Original IRR (%)</th>
<th>Tiyo 20% downtime IRR (%)</th>
<th>Machakel 20% downtime IRR (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Seeder, thresher, harvester, trailer</td>
<td>86</td>
<td>66</td>
<td>74</td>
</tr>
<tr>
<td>2</td>
<td>Thresher, harvester, trailer</td>
<td>80</td>
<td>61</td>
<td>73</td>
</tr>
<tr>
<td>3</td>
<td>Seeder, thresher, trailer</td>
<td>79</td>
<td>60</td>
<td>65</td>
</tr>
<tr>
<td>4</td>
<td>Seeder, harvester, trailer</td>
<td>76</td>
<td>58</td>
<td>68</td>
</tr>
<tr>
<td>5</td>
<td>Thresher, trailer</td>
<td>70</td>
<td>53</td>
<td>62</td>
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<td>6</td>
<td>Seeder, trailer</td>
<td>64</td>
<td>48</td>
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<tr>
<td>7</td>
<td>Seeder, harvester</td>
<td>52</td>
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<td>41</td>
</tr>
<tr>
<td>8</td>
<td>Trailer</td>
<td>47</td>
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<td>9</td>
<td>Thresher</td>
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<td>29</td>
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<tr>
<td>10</td>
<td>Harvester</td>
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<tr>
<td>11</td>
<td>Seeder</td>
<td>26</td>
<td>15</td>
<td>8</td>
</tr>
</tbody>
</table>

Source(s): Authors’ own creation/work

Table 8. Internal rate of return (IRR) of 2WT-based service provision in Ethiopia with 20% downtime

3.2.4 Infrastructure and transaction costs. As noted in the introduction, poor infrastructure and high transaction costs can prevent the emergence of service markets or make them exclude farms with small and scattered plots. The fact that production-related services are less lucrative than post-harvest-related services (i.e. threshing and transportation) suggests that infrastructure and transaction costs are problematic in both Ethiopia and Burkina Faso. In Ethiopia, 16 of 22 service providers identified poor rural infrastructure, such as poor feeder roads, as a major business constraint. Poor infrastructure limits the number of farmers that can be reached within the short time windows for planting and harvesting and confines service providers to small operating areas. It also hinders migratory service provision, which could help to increase utilization rates, which is particularly important regarding planting and harvesting services. Stakeholders in Ethiopia reported that migratory service provision following the harvest season is still uncommon except for threshers, which can easily be transported with trucks.
lucrative as they are associated with high transaction costs - as service providers need to travel to small and scattered farms (Daum, 2023) - and are demanded only during a very short time window. The lower profitability of land preparation and planting services can deter service providers from investing in such services, which is problematic as they can help farmers to increase their labor and land productivity (Adu-Baffour et al., 2019; Mano et al., 2020). In Zimbabwe, the profitability of planting (seeding) services is higher than in Burkina Faso and Ethiopia, mainly due to much higher service prices.

There are different ways to make the provision for land preparation and planting services more attractive. One way is to improve rural infrastructure and reduce transaction costs, for example, by organizing farmers in groups or using digital “Uber-type” solutions (Daum et al., 2021). This could also facilitate migratory service provision to areas with different rainfall patterns, thereby increasing utilization rates (Berhane et al., 2020; Daum, 2023; Takeshima, 2015; Takeshima and Lawal, 2020). Another way would involve improving machinery efficiency, thereby reducing the time required per hectare, necessitating applied research in this area. Governments could also subsidize such services, which may be justified if positive externalities arise from higher yields, such as improved food security and economic development. It is important to point out that such services for land preparation and planting may be less profitable but can still yield decent IRRs, depending on management and contextual factors (Adu-Baffour et al., 2019). Also, despite their lower profitability, service providers may nevertheless want to offer such services to ensure sufficient demand for post-harvest services (Daum and Birner, 2017; Houssou et al., 2013). Offering service bundles that combine less profitable services with more profitable services (e.g. threshing services), could be a viable strategy to bind customers.

The results highlight that the emergence and economic sustainability of service providers can be enhanced with efforts to create better enabling environments. While two-wheel tractors are easier to operate, maintain and repair than four wheels tractors (Baudron et al., 2015; Kahan et al., 2018; Mrema et al., 2020; Van Loon et al., 2020), owners, operators, and mechanics still require adequate knowledge and skills. Previous studies have shown that inadequate maintenance, poor handling, and a shortage of skilled mechanics can result in frequent and prolonged breakdowns (Daum and Birner, 2017; Houssou et al., 2013; Thoelen and Daum, 2019). Our analysis is based on a sample of service providers that were supported with knowledge and skills development, including technical (e.g. on operations and maintenance) and management aspects (e.g. on business plans and accounting). Assuming prolonged downtimes would reduce their profits but net present values and internal rates of return would remain high. Knowledge and skills development initiatives could include driving and operating training and licenses for operators, along with vocational training options for mechanics. A role model could be the Kulumsa Agricultural Mechanization Research and Training Center in Ethiopia, which trains and provides licenses to two-wheel tractor operators in collaboration with the Ministry of Transport and Logistics. Experiences from other world regions such as Europe and Asia highlight the pivotal role of public efforts in fostering knowledge and skills - not only in technical aspects but also managerial ones (Daum et al., 2018; Diao et al., 2020), mirroring recent findings on the importance of entrepreneurial competency for agricultural development (i.e. Abawa, 2024).

The emergence and economic sustainability of service providers also depend on other factors within the enabling environment. Access to finance is key; however, finance poses less of a constraint compared to four-wheel tractors. Moreover, some technology options are characterized by low investments and high profitability (e.g. shellers/threshers), which could serve as an entry point into mechanization service provision even without access to finance. As mentioned above, improving transportation infrastructure can help to reduce the (transaction) costs for service providers and the costs of accessing spare parts, repairs, and fuel, all of which would improve profitability (Daum and Birner, 2017; FAO and AUC, 2018; Tefera and Awoke, 2023).
While the findings suggest a significant potential to make agricultural mechanization in Africa more inclusive, two-wheel tractors may not be the best choice for all agro-ecological contexts (Baudron et al., 2015; Daum et al., 2023). For example, two-wheel tractors struggle where soils are stony and heavy and where it is too hot and humid for operators (Baudron et al., 2015; Daum et al., 2023). Power-saving farming practices such as conservation agriculture may expand the niche of two-wheel tractors (Awoke et al., 2020; Baudron et al., 2015, 2019b), however, four-wheel tractors are better suited in many areas within Africa (Daum et al., 2023), and efforts are also needed to enable affordable and reliable four-wheel tractor based asset-sharing arrangements.

5. Conclusions
The rise of agricultural mechanization in Africa presents both opportunities and challenges. A major concern is the potential for a mechanization divide, where only large farms have access to machinery. Leveraging technological solutions such as two-wheel tractors and institutional solutions such as service markets can make mechanization more inclusive for smallholder farmers. Our study, which analyzed data from Ethiopia, Burkina Faso, and Zimbabwe, revealed that the economic viability of two-wheel tractor-based service provision is high, largely due to the multifunctionality of these tractors. However, the emergence and economic sustainability of service markets can be hindered by various bottlenecks such as limited access to finance, insufficient knowledge and skills development, challenges with accessing fuel and spare parts, and infrastructure problems. To fully exploit the potential of two-wheel tractor-based service markets for inclusive agricultural mechanization in Africa, it is necessary to strengthen public efforts to support private mechanization efforts with enabling environments.

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Notes
1. Agricultural mechanization involves substituting human power with mechanical or animal power in agricultural value chains (Daum and Kirui, 2021; FAO and AUC, 2018). Tractors are an important element of farm mechanization, as they can pull various tools and power stationary machinery (Valle and Kienzle, 2020).
2. Some critics argue that (walk-behind) two-wheel tractors have a limited capacity, still require heavy physical work, and may lack the power required for rain-fed agriculture (Daum and Birner, 2020). Power demands are lower under mechanized conservation agriculture (Baudron et al., 2015), which could help to preserve soils; however, its adoption remains limited in Africa (Kassam et al., 2019).

References


**Corresponding author**

Thomas Daum can be contacted at: thomas.daum@uni-hohenheim.de