Economic Impact of Two Wheel Tractor on Smallholder farming system in Ethiopia

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Abstract

Smallholder farmers in Ethiopia may not be able to afford buying tractors and their accessories due to their high cost and limited resources. Since buying and using machines on one's own farm is not profitable for small holder farmers, the most viable way of promoting agricultural mechanization in Ethiopia is through the hire service provision models. The benefits of hiring service providers are that there is no demand for an initial investment by the smallholder farmer and it does not require any operational skill as well as repair and maintenance cost to the farmer.

From the CIMMYT various mechanization project interventions and other actors' involvement, the number of two-wheel tractors (2WTs) is growing in Ethiopia. Two-wheel tractor-based technology service provision is also expanding in different parts of Amhara and Oromia regions. Most of the accessories/implements of 2WTs are new in Ethiopia and there are no studies that have quantitatively explored the economic viability of these technologies using field data. Accordingly, this study examined the economic viability of 2WT-based technologies in selected areas Ethiopia using field data collected from Service Providers (SPs), farmers and other actors. The analysis was conducted separately and in combination for each accessory to gauge the economic viability of single and, combined operations from both the farmers and service providers point of view. Three indicators were used to measure the profitability of 2WT mechanization investments over time: the Net Present Value (NPV); the Benefit-Cost Ratio (B/C) and the Internal Rate of Return (IRR).

From the point of view of the farmers who are the customers, the analysis showed that compared to conventional farming systems, they can generate a positive gross margin that is higher when they hire 2WT based technologies. The higher gross margin resulted from a reduction in the costs of ploughing, planting, fertilizer application, threshing and transportation. From the hire service provider point of view procurement of 2WTs and its accessories also proved to be viable and profitable generating a high and positive net present value.

Key words: Economic analysis. mechanization hire service. Agricultural mechanization.

Key highlights

- The advantages of 2WTs are their multifunctionality. They perform several farm operations, including ploughing/ ripping, planting/seeding, reaping/harvesting, threshing/shelling, water lifting and transport.
- Service provision model is the most viable way for smallholder farmers to reap the benefits of 2WTs.
- Average gross margin per ha increases significantly when farmers hire two-wheel tractors for planting, reaping, threshing and transportation operation, compared to conventional farming system.
- Service providers can select different combinations of machinery to maximize their profit. They can use threshing or transportation service as entry point for two-wheel tractor service provision with an investment cost of around $4,027 and $3,350 respectively.

1. Introduction

Agriculture has been the dominant sector of the Ethiopian economy, representing 42 percent of the GDP, 85 percent of the labor force and 90 percent of the total export earnings (CSA, 2018). Most of the agriculture sector consists of smallholder farmers who make their living from less than two hectares of land. Despite a significant increase in overall agriculture outputs in recent years, the sector is still dominated by subsistence modes of production. Efforts to expand agricultural productivity and enhance food security are chronically constrained by a shortage of quality agricultural inputs and farm machinery services in Ethiopia.

"Agricultural mechanization is broadly defined as the application of tools, implements and powered machinery and equipment to achieve agricultural production" (FAO and AUC. 2018). It covers all levels of farming and processing technologies, from simple and basic hand tools to more sophisticated and motorized equipment. Agricultural mechanization eases and reduces hard labor, relieves labor shortages, improves productivity and timeliness of agricultural operations, increases resource-use efficiency, enhances market access and contributes to mitigating climate-related hazards.

The productivity impact of agricultural mechanization is measured in terms of changes in crop yields, labor savings, area expansion, and improvement in quality of the marketed output. Even though productivity of farm operation depends on different inputs like fertilizer, seed, pesticides and others, FAO and UNIDO emphasized the key role of mechanization in realizing the full benefits of these inputs (FAO and UNIDO. 2011). The World Bank (2014) studies also suggested as the use of farm machinery is associated with agricultural modernization and productivity growth. According to the study, countries that perform best in terms of reducing hunger are also countries that manifest higher net investment rates per agricultural worker.

Various literature showed the impact of mechanization on reduction of labor hour required per hectare for all operations. Pingali et al (1987) reviewed 24 studies on labor use by operation on farms relying on animal draft power and farms relying on tractors in Asia. The study found reduction in labor use per hectare of crop production for tractor farms compared to animal draft farms. The greatest reduction in labor use was for land preparation, with all studies reporting reduction in labor input more than 75%. In addition to reduction in labor, study on the economic impact of agricultural mechanization adoption in Nigeria by Owombo et al. (2012), showed that mechanization increases gross margin of farmers.

Among the benefits of mechanization, expansion of farming area is also another key aspect Specially in areas where there is a shortage of farm power and unutilized arable lands. A study in Benin showed a strong correlation between the areas planted of paddy rice, millet, yams and the number of agricultural tractors (Ichaou, 2018). From total potential arable land in Ethiopia, 35,683, 000 hectares (World Bank, 2012), only 15,270,526 hectares (42%) is currently under production (CSA, 2018). Expansion of farming area and increase in production of the agriculture sector demands agricultural machineries/technologies.

The studies by the United Nations Industrial Development Organization (UNIDO) show that, African's agriculture heavily rely on human power. Out of the total farm power, 65 percent come from human labor, which is high compared to that of Asian, Latin American, and North American agriculture, which constitute 30%, 25% and 20% percent respectively. The dependence on human labor is the major factor contributing to low productivity and low rates of commercialization in Africa.

The number of tractors per 100 square kilometers of arable land in Ethiopia is only 4, which is low compared to Kenya (27) and Zambia (21). Comparing with other countries in Africa and other region, the number is much lower. The numbers of tractors per 100 square kilometers of arable land in Tunisia and Brazil are 143 and 129, respectively; the global average is about 200 (World Bank 2014). Studies on agricultural mechanization show that, increased power and better equipment contribute to increasing production, productivity and the profitability of farming. The benefits of mechanization must be seen in conjunction with other inputs, such as improved seed varieties, fertilizers, pesticides, and water availability (World Bank 2014). A study by Baudron et al. (2019) revealed that labor and other sources of farm power appear to be major limiting factors to the productivity of most farming systems in Africa.

The average horsepower per hectare in Ethiopia is very low (0.04) compared to Kenya (0.27), Zambia (0.21), 0.6 Zimbabwe, Tunisia (1.43) and even far lower than the continent average (0.13). The low-level power per ha in Ethiopia is contributing to lower production and productivity of the agricultural sector (Baudron et.al. 2015, FAO & UNIDO. 2011). With 0.04 horsepower per hectare (World Bank 2014), the country is a net importer of key staples, predominantly wheat. On average, about 24% of the wheat consumed in the country is imported from other countries (United States Department of Agriculture). Average production of wheat in Ethiopia is low with 2.65 tone/hectare, compared to the yields of 4 to 6 t/ha on well managed farms in the country. Increasing average wheat and other key staples production would reduce imports and save substantial foreign currency reserves as well as increase food security of the country.

Farm Power and Conservation Agriculture for Sustainable Intensification (FACASI) project was designed based on the fact that farm power in SSA countries is declining as a result of the collapse of most tractor hire schemes, the decline in number of draught animals and the decline in human labour (e.g. stemming from rural-urban migration and pandemics). The project believed that sustainable intensification in SSA will require an improvement of the farm power balance through increased power supply - via improved access to mechanization - and/or reduced power demand via energy saving technologies such as conservation agriculture. Therefore, the overall goal of the project was to improve access to mechanization, reduce labour drudgery, and minimize biomass trade-offs in Eastern and Southern Africa, through accelerated delivery and adoption of 2WT-based technologies by smallholders.

Most smallholder farmers in view of the meager resources at their disposal, may not afford to buy tractors and their accessories owing to their high costs. To address this problem, FACASI, GIZ, Africa RISING projects and other actors have been promoting mechanization hire service provision models. The major benefits of hiring service provision are that there is no demand for an initial investment by farmer and it does not require operational skill or repair and maintenance costs to the farmers.

Due to the various CIMMYT project interventions and other actors' involvement, the number of 2WTs and 2WT-based technology service provisions are growing in different areas of Amhara and Oromia regions of Ethiopia. Since most of the accessories/implements are new for Ethiopia and project intervention sites, there are no studies that have quantitatively explored economic viability of these technologies using field data. Accordingly, this study examined the economic viability of two-wheel tractor-based technologies in selected sites of Machakel and Tiyo district of Ethiopia under GIZ and ACIAR funded projects.

The Ministry of Agriculture and various national and international development organizations are working on the development of agricultural mechanization in Ethiopia. It was therefore hoped that the findings of this study would be found useful by stakeholders involved in this sector to consider 2WTs as one option of creating access to mechanization for smallholder farmers in Ethiopia. The major objective of this study is to assess economic viability of two-wheel tractor-based technology in the project area. Specifically, the study aimed at (1) Assessing profitability of 2WTs for smallholder farmers and (2) Conducting a cost-benefit analysis of two-wheel tractor hire service provision from the perspective of SPs.

2. Materials and methods

2.1. Study area

This study was carried out in two sites (Tiyo and Machakel), where FACASI and AMSISFE (Appropriate Mechanization for Sustainable Intensification of Smallholder Farming in Ethiopia) projects have been implemented (**Figure 1**).

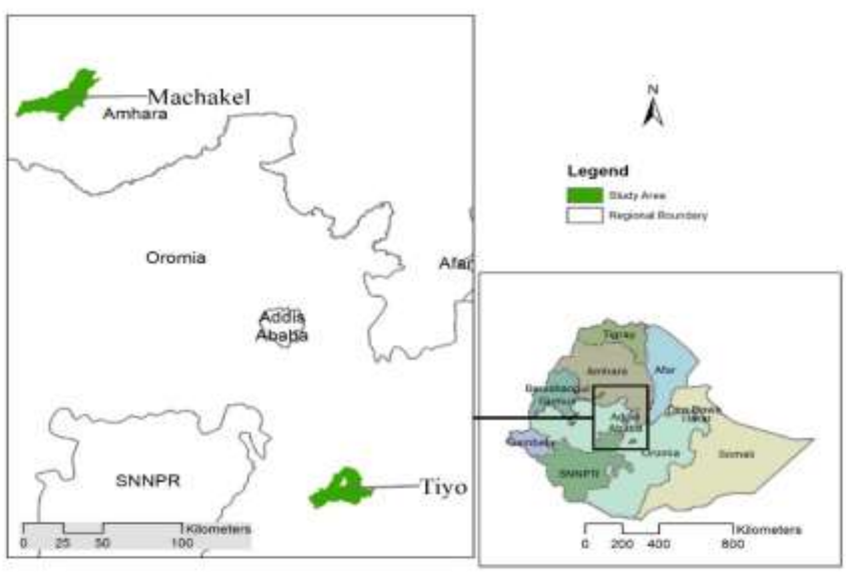

Figure 1: Location of project sites in Tiyo and Machakel areas of Ethiopia.

Machakel is a district in Amhara region located in East Gojam zone with an altitude range of 1200-3200 m above sea level, a 900-1800 mm rainfall and an annual temperature of 10-25 °C. The main crops are wheat, maize and teff. The main livestock species are cattle, poultry, sheep and goat.

The District has a total population of 118,097 (2007 national census by CSA) and 27,967 households with about 158.22 population density per square kilometer. Machakel district has a total area of 746.43 square kilometer and with one hectare average land holding size.

Tiyo district is in Arsi zone, Oromia region of Ethiopia at an average altitude of 2430 m above sea level and is characterized by a mean annual rainfall of 752 mm per year and a mean annual temperature of 17 °C. The main crops are teff, barley, wheat and maize and the main livestock species are cattle, poultry, sheep and goat. The 2007 national census reported a total population for this woreda is 86,761 with a population density of about 285 per square kilometer and 1.25 hectare average land holding size.

2.2. Nature and source of data

The study was conducted based on ex post data collected from SPs and user in both sites. The data were collected using structured questionnaires. In addition to SPs and users, machinery dealers, key informants and research institute (e.g. Ethiopian Institute of Agricultural Research) were also used as a source of data for this study. The data includes efficiency of machineries, hire charges, operation calendar, investment costs of 2WTs and implements, maintenance and running, method of land preparation, planting, weed control & harvesting, productivity, value of crop and cost of conventional and mechanized crop establishment system.

2.3. Data analysis

The viability of 2WT based mechanization was assessed from the perspective of the farmer and service provider using the following methods:

a. Profitability analysis for SPs

Owners of the machine or SPs need economic information to make investment decisions. Among the information SPs need to assess profitability include:

- Net Present Value,
- Internal Rate of Return and
- Benefit Cost Ratio are the most commonly used indicators.

Using these indicators, the study analyzed the cost benefit analysis of the mechanization investments from the perspective of service providers (individual or groups owning the machines and providing hiring services). To examine the profitability of a range of services, the study also investigated the viability of different implements in bundle and separately. The study also evaluated the payback period for single and combination of machineries and breakeven hour for each implement.

b. Gross margin analysis

Using farm budgetary techniques, the profitability of 2WT based technologies were also conducted from farmers or user perspective. The gross margin for a farm enterprise is one measure of profitability that helps farmers to plan effectively. A gross margin is the difference between the annual gross income of a farm enterprise and directly associated variable costs of the farm enterprise.

To examine profitability of hiring out of 2WT based technology for farmers, this study analyzed gross margin of representative farms with and without mechanization. Using major crops cultivated in the project area, variable costs of each operation, average yield and market value of crop, gross margin per hectare is evaluated and summarized in the result section. To examine the most impactful machinery or combination from the available technologies, the gross margin is calculated for each machinery and different combinations.

c. Breakeven hour

Mechanization hiring charge can be derived from the cost of providing service and the available hours of operation. There is not a specific charge level that assures service providers covered their costs. Because fixed costs need to be covered regardless of the number of hours served, SPs need to know the number of hours in a year which break their cost with the existing market hiring charges. This process requires classifying the costs into operations or variable and fixed costs.

Breakeven hour is the number of hours that SPs need to provide service in a year based on the market price. In other words, it is the number of hours that make profit zero or a point (hour) where total cost/hr. = contract charge/hr. This can be computed with the formula below:

TC/hr=CC/hr

FC/hr +VC/hr= CC/hr (Using average cost of service providers, this study will calculate VC/hr, CC/hr, and FC. Using range of available operation hours for each operation, the breakeven hour that makes total cost per hr. equal contract charge per hr. calculated for each technology). So, to get break-even hr.:

FC/hr = (CC/hr- VC/hr)

hr = FC/(CC/hr- VC/hr)

$$\text{Breakeven hour} = \frac{\text{Total Fixed Cost}}{\text{Hiring charge per hr. - Variable Cost per hr.}}$$

3. Results

3.1. Operation calendar and available time

Wheat production accounts for most of the crop pattern in Arsi and Machakele districts followed by barely and teff. The average land holding size is 1.25 and 1 hectare for Tiyo and Machakel districts, respectively. Based on major crops in both areas, the calendar for farm operations is shown in **Table 1** below. The table also summarizes the available potential hours for different mechanization operations.

Table 1: Calendar for mechanization operation and available time in Tiyo and Machakel districts.

Operations	**Site**	**Period**	**Total Hours available**
Ploughing	Assela	Mar 1 - June 30	976
	Machakel	Mar 15 - June 30	840
Planting/Seeding	Assela	July 15 – August 10	200
	Machakel	July 10 - July 30	160
Harvesting	Assela	December 1 – January 15	368
	Machakel	November 20 - January 10	408
Threshing	Assela	December 1 - March 31	920
	Machakel	December 21 - May 8	1104

Transport to market	Assela	January December	2112
	Machakel	January December	2112

3.2. Mechanization operations, cost of investment and efficiency of implements

Compared to different technologies, the advantage of a 2WT is its multifunctionality. It performs several farm operations including ploughing/ripping, planting/seeding, reaping/harvesting, threshing, water lifting and transport. From these operations, this study conducted on four technologies that are provided by service providers in the studied areas (seeder, reaper, thresher and trailer).

A survey was conducted among different local dealers to establish the current prices of the machinery. The **Table 2** provides a summary of purchase price, the average working life, utilization and work output for different implements.

Table 2: Average purchase price, working life, utilization and efficiency of implements.

Implement	2WT	2BFG seeder	Reaper	Thresher	Trailer	Water pump
Purchase price ($)	2,500	1000	1,100	1,600	1,500	600
Average working life (hrs.)	4,000	4,000	4,000	4,000	4,000	1,333
Crop	Multi use	Wheat	Wheat and Barely	Wheat, barely, teff	Multi-use	Multi-use
Work rate (hrs./ ha)		6.1	4	1.92 tons/ hr	1 ton per trip	6.25

3.3. Labor and operators' costs

Most of the farmers do not employ permanent laborers and they tend to rely on family labor to assist in farm operations. Casual laborers are employed during peak seasons for activities such as planting, weeding, harvesting and threshing. The number of casual laborers employed range from 1 to 10 people and the cost ranges between $3.5 and $5.4 per day.

3.4. Gross margin analysis

Budgetary analysis for adopters and non-Adopters

The budgetary analysis result (**Table 3**) summarised revenue and associated costs for conventional and mechanized farming systems. Using 2WT attached seeder, farmers plant wheat directly and reduced the costs associated with land preparation, planting and fertilizer application significantly. In addition to direct seeding, mechanized harvesting, threshing and transportation operations have also shown a significant reduction in cost compared to conventional farming. The result of the average total revenue for mechanized operation was $2,566.96 while that of conventional was $ 1,964.29. The average total variable cost for mechanized and conventional farming systems were $525.78 and $ 817.86, respectively. The gross margin for mechanized operations was significantly higher, reaching $2,041.18 which was 78% higher compared to the conventional farming which had $1146.43. The result revealed that 2WT mechanization option is more profitable than conventional farming system.

Table 3: Farm budget analysis.

No	Cost item	Value ($)	
		Conventional	Mechanized
1	Total Revenue	1,964.29	2,566.96
2	Variable cost		
	Land preparation	121.4	100
	Planting	35.7	
	Fertilizer	26.8	
	Weeding	77.14	103.93
	Harvesting	154.29	53.57
	Threshing	178.57	92.41
	Transport to homestead	31.43	30.8
	Seed	100	75
	Fertilizer	85.71	85.71
	Empty bags	15.71	20.54
3	Total variable cost	826.75	561.96
4	Gross margin (1-3)	1,137.54	2,005.00

Mechanizing operations option showed a reduction in the cost of planting, reaping and threshing by 46, 65 and 48%, respectively. **Figure 2** shows the reduction in cost as a result of mechanization for the different operations in studied areas.

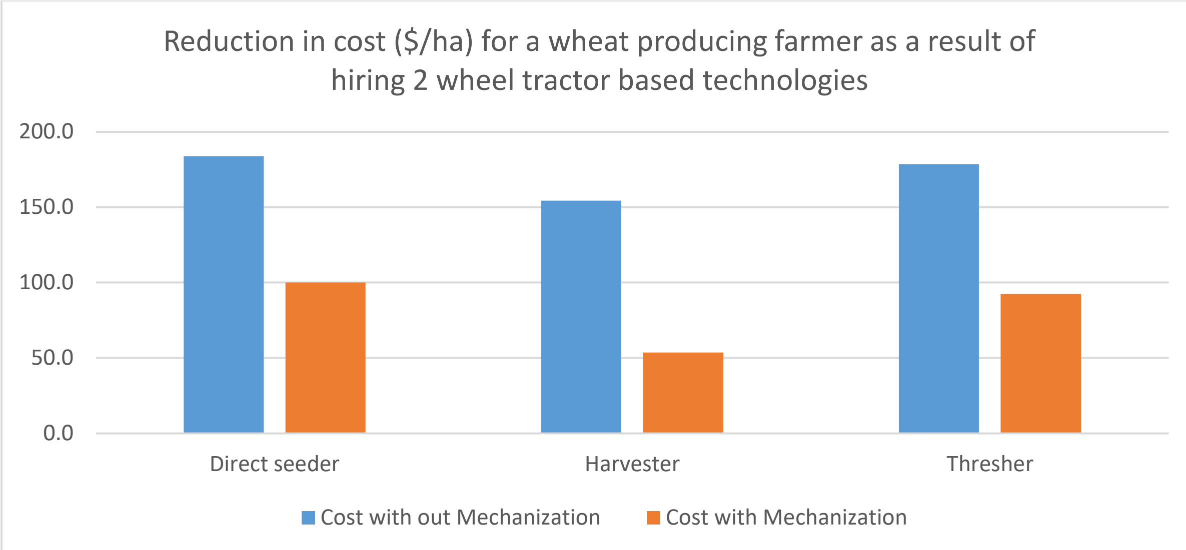

Figure 2: Cost comparison between conventional and mechanized operation

The farm budget analysis was conducted for farmers, who used combinations of four available machineries in their area; direct seeder, harvester, thresher and transportation service. To see the impact of each machinery and their combination on income of farmers, a gross margin analysis was conducted for a single machinery and in bundle and results are summarized in the **Table 4**.

The increase in gross margin varies based on the combination and number of machinery farmers used. The results from **Table 4**, show that the maximum gross margin of USD 2,005 can be achieved when farmers combine the four set of machineries (seeder, reaper, thresher and trailer). The gross margin increment gets lower as the number of machineries farmers hire reduced. For farmers, who hired only threshing service, they reduced their cost by 48% compared to conventional system and increased their gross margin by around 6%. Since the direct seeder reduced cost and increased yield, its impact on the gross margin is significant at 59%. The increase in gross margin for farmers as a result of mechanization is presented in **Figure 3.**

Table 4: Gross margins analysis with and without mechanization.

Increase in gross margin for farmers as a result of mechanization			
Without Mechanization	**With Mechanization**		
	Combination of accessory	Value	% increase as a result of Mech

1138	Direct seeder, Reaper, Thresher and Trailer	2005	76.3
	Direct seeder, Reaper and Thresher	1997	75.6
	Direct seeder and Reaper	1911	68.0
	Direct seeder and Thresher	1896	66.7
	Direct seeder	1810.3	59.1
	Reaper	1232	8.3
	Thresher	1210	6.4
	Reaper and Thresher	1311	15.2

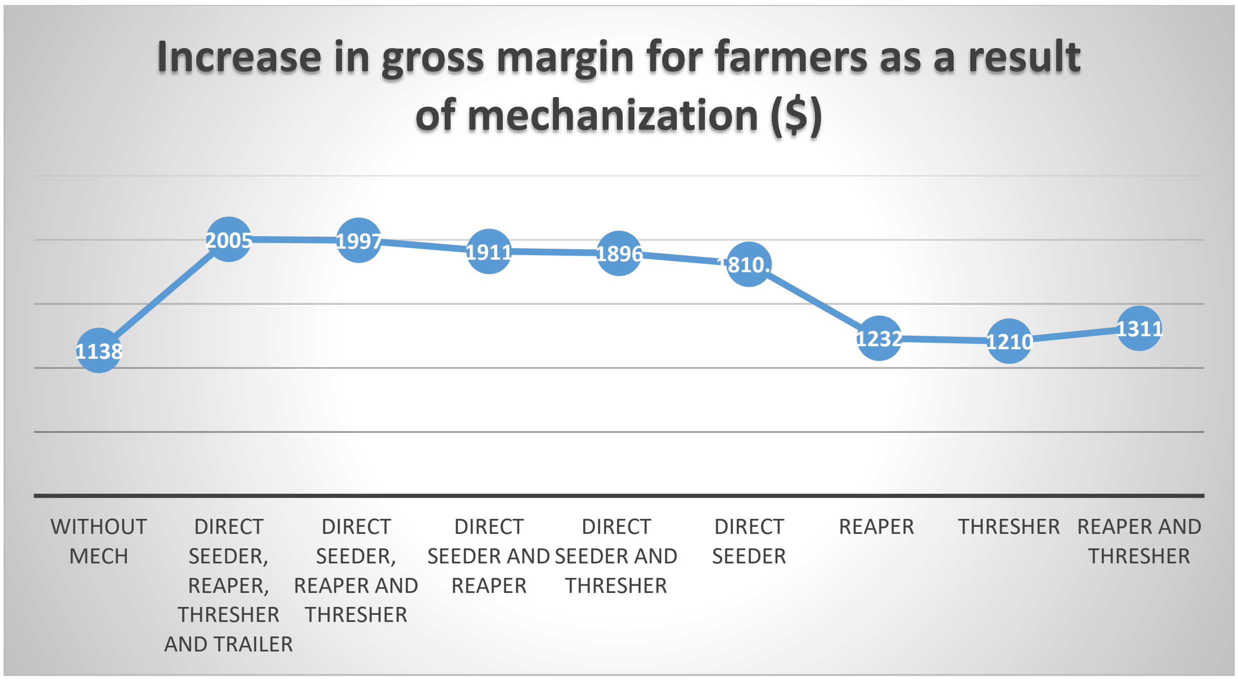

Figure 3: Increase in gross margin.

3.5. Cost-benefit analysis

Since most farmers (around 60%) in Ethiopia are smallholder farmers with less than 1 hectare, procuring and using 2WT on an individual farm is not profitable. Based on this fact CIMMYT projects in Ethiopia have been promoting service provision model. Therefore, this study examined profitability of 2WTs from a service provision perspective and results are presented in **Table 5** below. With an average investment cost of $7,700, SPs are generating a net present value (NPV) of $21,648 when they provide planting, reaping, threshing and transport service. The Internal rate of return (IRR) is 89%, which is positive and higher than the interest rate, which could be obtained through alternative investments. The benefit cost ration (B/C ratio) is also significant, which is 2.07. The Investment costs also seen not sensitive to cost variations, with a ten percent cost escalation, the NPV and IRR are $ 19,632 and 77%, respectively (**Table 5**). Based on the average market lending interest rate, the calculation is done at 15% discount rate. The payback period for this combination of investment is only about one year.

From the different combinations of implements, scenario 2 (thresher, trailer & harvester) is the second more profitable investment option. With an initial capital investment cost of $6,700 on average service providers generated an NPV of $17,205. Since trailers can be used for transportation throughout the year and threshers for longer period in a year, transportation and threshing operations are among the single operations that generate a higher profit for SPs. If farmers or service providers lack financial resource to buy full set of implements, threshing and/or transportation services can be used as an entry point for 2WT mechanization (**Figure 4**). On average, the payback period for most combination of machinery is less than two years except for single planting and harvesting operations.

Table 5: Cost-benefit analysis of 2WT based technology from service provider point of view.

Combination of technologies (scenarios)	**Investment cost ($)**	**Indicators**					
		With current price			Increase in cost (10%)		
		NPV ($)	IRR (%)	B/c ratio	NPV ($)	IRR (%)	Payback period (year)
Seeder, thresher, harvester & trailer (scenario 1)	7,700	21,648	89	2.07	19,632	77	1.08
Thresher, trailer & harvester (scenario 2)	6,700	17,205	83	2.04	15,419	72	1.15
Thresher & trailer (scenario 3)	5,600	12,354	75	1.87	10,808	64	1.27
Transportation (scenario 4)	4,000	4,345	47	1.45	3,248	37	1.85
Seeder, trailer & harvester (scenario 5)	6,100	13,639	76	1.87	12,073	65	1.26
Seeder, thresher & trailer (scenario 6)	6,600	16,797	83	1.95	15,021	72	1.16
Seeder & trailer (scenario 7)	5,000	8,788	64	1.66	7,462	54	1.45
Seeder & harvester (scenario 8)	4,600	6,039	52	1.76	5,244	45	1.71
Seeder (scenario 9)	3,500	1,189	26	1.21	633	20	2.72
Harvester (scenario 10)	3,600	1,596	29	1.28	1,031	23	2.57
Thresher (scenario 11)	4,100	4,754	48	1.61	3979.1	41	1.82

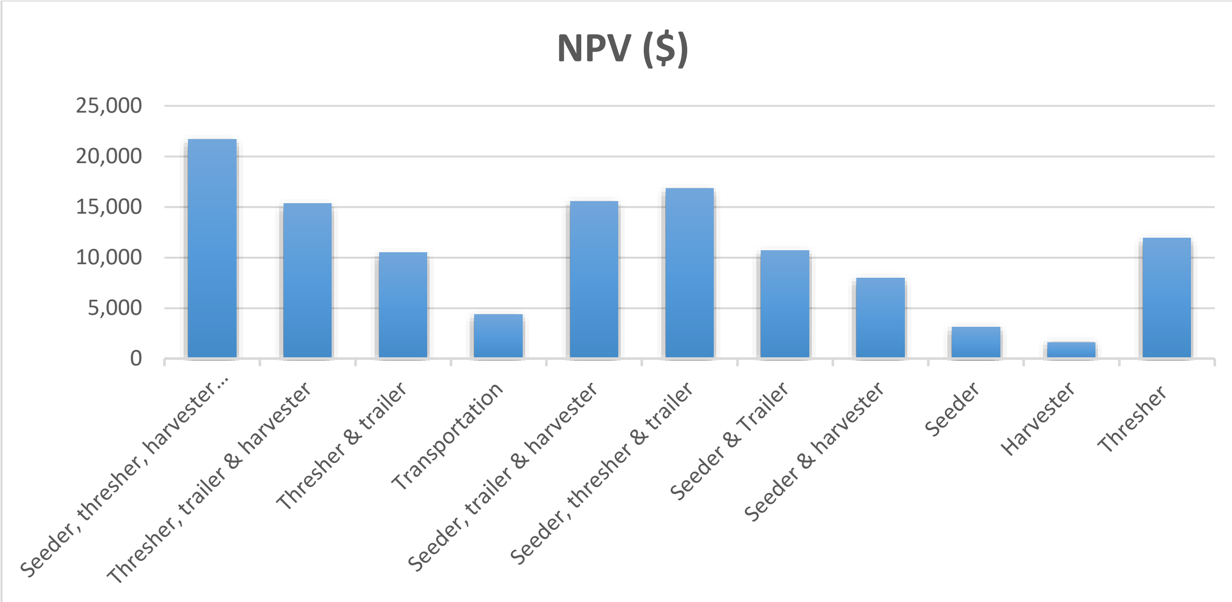

Figure 4: Service provision profitability analysis of 2WT based technologies with different combination implements.

3.6. Breakeven analysis

3.6.1. Breakeven point of seeder

Based on the planting window and efficiency of the seeder, SPs can work 200 hrs./year using the 2BFG seeder (wheat and teff planter). As per the calculation, the annual total fixed cost found by sum of interest, annual depreciation, insurance and storage cost is $ 426.56 and the variable cost per hour for the sum of labor, fuel, spare and repair is $2.03. Using a hiring charge of $14.27/hr, the breakeven hour of the seeder for Tiyo district is 34.9 hr. or 5 effective working days. To make profitable, the SPs are expected to work above the break-even hour or effective working days, and this is illustrated in **Table 6** and **Figure 5**.

From Table 6 and Figure 5, the break-even hour is a point, where profit is zero or total cost per hour of operation is equal to contract charge per hour. At a break-even point/hour (where annual hour is 34.9) a total cost per hour is equal to the contract charge per hour, which is $14.27. If the SPs provide services lower than the breakeven hour, he/she will have negative profit (loss). For example, if the SP provides planting service for only 24 hour or 3 days per year, he/she will end up with a of $ -5.54 per hour. However, if the SPs utilize all the potential working hours, they can make $10.10 profit per hour.

Table 6: Break-even point for 2BFG Seeder.

Annual use (hrs.)	8	16	24	34.9	128	160	176	200
FC/HR	53.32	26.66	17.77	12.23	3.33	2.67	2.42	2.13
VC/hr	2.03	2.03	2.03	2.03	2.03	2.03	2.03	2.03
Total costs/ hr	55.35	28.69	19.81	14.27	5.37	4.70	4.46	4.17
Contract charge/ hr	14.27	14.27	14.27	14.27	14.27	14.27	14.27	14.27
Profit or loss in providing services $/hr	-41.09	-14.43	-5.54	0.00	8.90	9.57	9.81	10.10

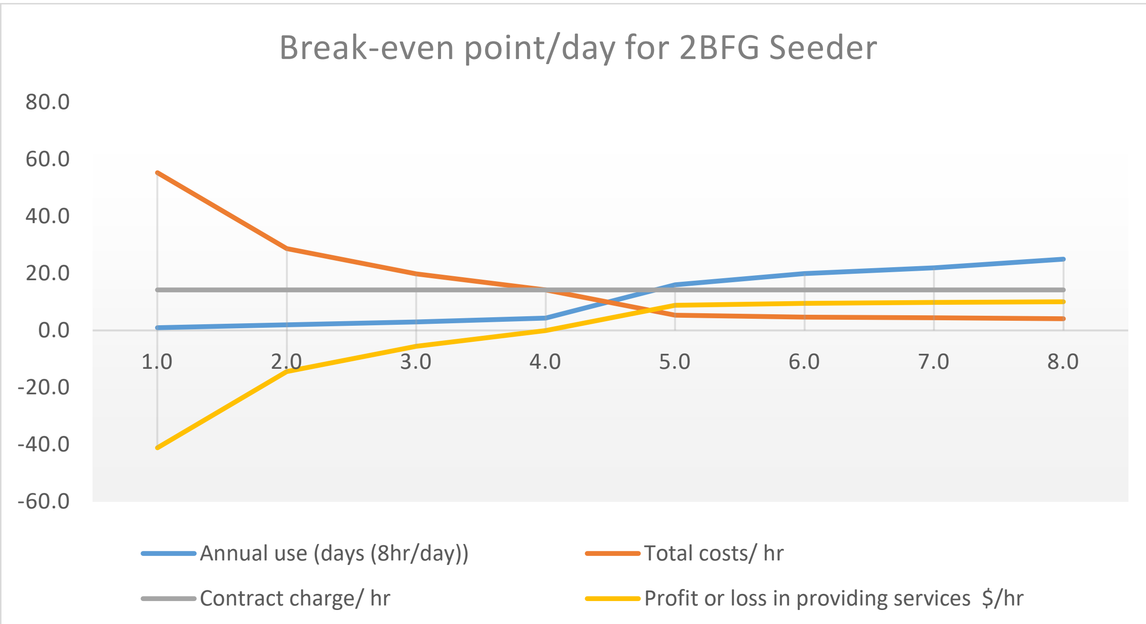

Figure 5: Break-even point for 2BFG wheat/teff Seeder.

3.6.2. Break-even point/hour and available potential hours for transportation, threshing, reaping and planting operation

The following **Table 7** and **Figure 6** summarize the break-even hour and potential available time for all operations. Transportation is the most demanded service among the 2WT based operations in rural areas. Unlike other operations, the demand and available hour for transportation is longer in a year. Based on the potential working hour (2,112) of the transportation service, associated fixed and variable costs, the breakeven hour of transportation using a trailer is around 207. To break their cost, SPs are expected to work above this hour in a year. Compared to the potential available hours for transportation, the breakeven hour is too low, which indicates a higher profitability of the service if SPs are committed and provide transportation service for a longer period.

Similarly, threshing operation in Assela area starts in December and ends by end of March. Within this period, SPs have 920 potential threshing hours. Since there is higher competition from large scale mechanization in the area, SPs are charging 450-500 birr/ton for threshing ($16-$18/ton). On average, the SPs thresh 0.5 ton per hour. With this rate and efficiency, the SPs are charging $8.04 per hr. As we can see from the **Table 7** and **Figure 6**, the breakeven hour for threshing business for Tiyo district is 132.3. Since the breakeven hour is significantly lower than the available potential hours, SPs are generating a higher profit with this service.

When we compare transportation and threshing, the difference between the breakeven and potential available hour for harvesting/reaping and planting is lower (**Figure 6**). Likewise, the result discussed in section 4, this also shows lower profitability of planting and harvesting compared to transportation and reaping service using 2WT as a result of short operation windows.

Table 7: Summary of break-even hour for all operations

	Trailer	Threshing	Harvesting	Planting
Potential available hour per year	2,112	920	368	200
Break-even hour	207.3	132.3	49.2	34.9

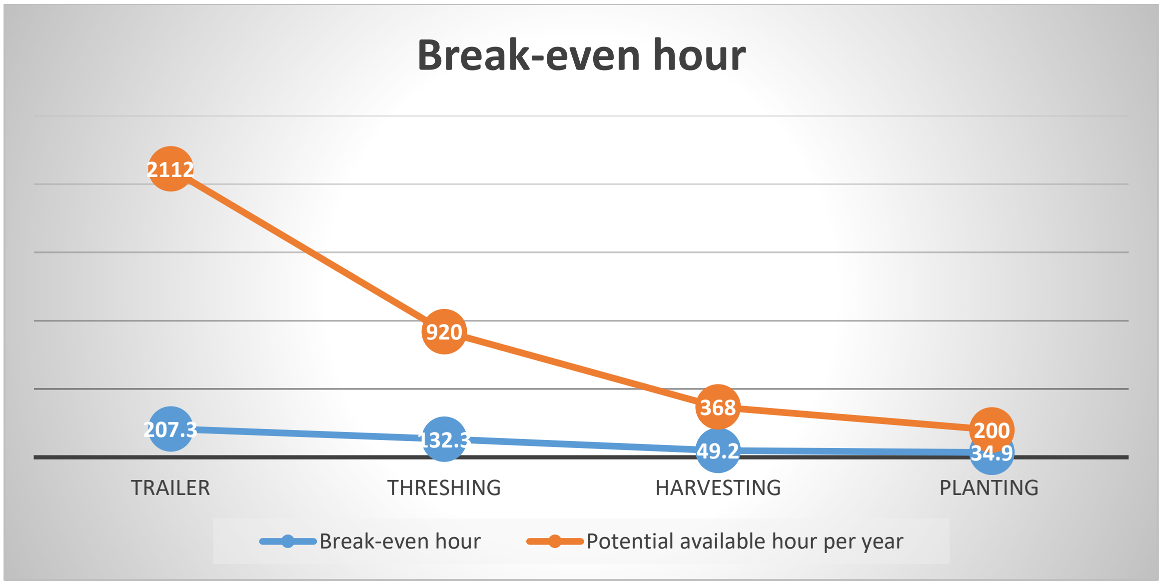

Figure 6: Comparison of breakeven hour and potential available hour for different operations.

4. Discussion

4.1. WTs can significantly increase gross margin of farmers

From the gross margin analysis (**Table 4**) we can see that farmers can indeed generate a higher and positive gross margin using the 2WT based technologies. The average gross margin per ha increased by 78% when farmers hire 2WTs for planting, reaping, threshing and transportation operations, compared to conventional farming system. The higher gross margin resulted from the reduction in the cost of ploughing, planting, fertilizer application, reaping, threshing and transportation. In addition to the reduction in cost, planting with 2WT attached seeders (2BFG) provided an increase in yield on farmers field. The result from EIAR showed 25-30% increase in yield when farmers plant with a direct seeder attached to a 2WT (Bisrat et al., 2019). The annual wheat production of Ethiopia is around 4,500,000 MT and domestic consumption is 6,150,000 MT. The country covers around 24% (1.500,000 MT) of domestic consumption of wheat by importing from abroad (United States Department of Agriculture, 2019). While there is an availability of yield improving technologies and inputs in the market, the country continued importing wheat despite the existing foreign currency shortage. For example, if wheat producing farmers in Ethiopia use such yield increasing appropriate technologies and other farm input, there is a big potential to increase the total wheat production in the country. If these farmers increase the current yield, at least by 35%, the country will fully cover the domestic consumption by locally produced wheat. These technologies will have also similar impact on other crops produced in the country. Therefore, these cost saving and yield increasing technologies will have a positive effect on the GDP of the country and also relieve the labor force engaged in the agriculture sector to be able to work in other off farm activities.

Since 2WTs can be used for different operations, knowing the machinery that gives the maximum gross margin helps farmers to decide or prioritize among the available list or their combination that will give them the highest profit. So, from the analysis we can deduce that using 2WT power-based technology can significantly increase the gross margin of farmers and reduce significantly the time required for crop establishment, harvest and postharvest operation.

4.2. Profitability of 2WT service provision increase as the number of implement increase

From the cost benefit analysis result we learned that the viability of 2WTs can be enhanced when service providers purchase the 2WT and implements as a combined package for multi-purpose use. Since the cost of the 2WT (the engine) can be shared among different operations, the more the set of the machineries the higher the NPV and IRR on the investment. Threshing and transportation are among the single operations that can generate a higher profit for SPs (Figure **4** and **Annex: 2**). If SPs lack the financial resource to procure the full set, they can select a combination of machinery (from different scenarios under **Table 5** and **Figure 4**) that can maximize their profit with the available resource on hand. Otherwise they can also use either threshing or transportation services as entry point for 2WT service provision with an investment cost of around $4,027 and $3,350, respectively.

The level of profit for single operations of planting or harvesting is lower for the average SPs and even negative for low performing SPs (**Annex:1**). Since the planting and harvesting window is too short, providing these services with 2WT engine is not a viable business for service provision model unless combined with other services. However, contrary to service provision, the most impactful technology for farmers was the seeder. Even though it is profitable for farmers, unless the service provision is profitable, adoption of mechanized planting (direct seeding) will be negatively affected. Therefore, this needs further interventions by different stakeholders to improve the efficiency of the planting machineries. To plant a hectare of a wheat farm, it takes on average around 6-7 hours with a good quality planter such as the one introduced by CIMMYT projects in Ethiopia. With a maximum of 20 available planting days, due to some down time of machineries and holidays in this period (which is more even in Amhara region), SPs will plant only 10-15 hectare per year. Therefore, one way of addressing this problem is improving the efficiency of the machineries and reduce the time spent per hectare and plant more farms in a season.

4.3. Service provision model is the most viable option

From the study, we learned that the costs of machinery and equipment could greatly be reduced by extending its use over a longer number of hours annually. The breakeven hour analysis showed that the profitability of mechanization increases as the number of operation hour increases. For example, the breakeven hour for harvesting operation is 49.2 hr. per a year. To make a profit the SPs or farmers have to use the machine for more hours. However, if they effectively work for 368 hours in a year, they can make USD 8.54 profit per hour, which is equal to $ 3,717.5 per year. This implies that the profitability of mechanization increases as the number of operation hour increases. If a smallholder farmer owns the machine and used it only on their farm, the result showed as it will not be profitable. For example, a farmer who has one hectare of wheat farm, can reap in 4 hours and the machine will be idle for the whole year. So, unless he/she provides services for others, it is not profitable.

4.4. Two-wheel tractor service provision is a viable product for financial service providers

For service provision, the package that rewards a higher return for SPs is 2WT, reaper, thresher, seeder and trailer (in bundle) with an average investment costs of $6,902. To reach more farmers with these technologies it might require access to credit as the required investment cost is not affordable for most SPS in rural areas. The Development Bank of Ethiopia has recently started a machinery leasing scheme. However, the Bank is providing credit for larger scale mechanization (for more than USD 36,000 value machineries). The Microfinance Institutions (MFIs) are also not providing credit for agricultural mechanization. With less than a year repayment period, 2WT based technology service provision can be a potential product for MFIs in Ethiopia. The maximum individual credit value of MFIs is less than 2,000 USD, which is not enough to buy the required set of machineries. It is important that MFIs start providing credit for agricultural mechanization and also increase the credit limit per individual.

5. Conclusions

Evidence from this study has revealed that small-scale mechanization (2WT based technologies) is a viable option for smallholder farmers in Ethiopia. The result showed that these technologies significantly increase the gross margin of famers and increase yield and create employment opportunities for service providers. When farm operations are mechanized, the labour engaged in the agriculture sector can be channelled to other off farm activities and more productive sectors, which will have a positive impact on the overall economy of the country.

Since the land size and fragmentation of holdings are critical factors for successful and sustainable mechanization, making more effective use of machinery is a necessary precondition. This suggests developing hiring out services and careful planning of machinery and equipment use. Although the impact of the direct planter is high on the gross margin of farmers, the most viable operations tend to be at the post-production stage– threshing and transportation. This suggests that the entry point for field planting rests with multi-purpose use of trailers as well as the wheat threshing operation. Improving the efficiency of the direct seeding machineries should also be considered as an option of sustaining planting service provision. To realize sustainable access to mechanization, attention needs to be given to local fabrication of 2WTs and accessories. With the existing and constant foreign currency shortage in Ethiopia, the 2WT and most of the implements are imported from abroad. To make the technologies affordable for smallholder farmers and to create access to spare parts, the local manufacturing sectors need to be strengthened. Since the cost of a set of the machine is not affordable for most service providers, access to small mechanization credit should also be created by public and private financial institutions.

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Annex: 1 Profitability of 2WT based technology for low performing SPs

Combination of technologies	Investment cost ($)	Indicators					
		With current price			Increase in cost (10%)		Payback period (year)
		NPV ($)	IRR (%)	B/c ratio	NPV ($)	IRR (%)	
Seeder, thresher, harvester & trailer (scenario 1)	7,700	10,721	55	1.63	9,006	46	1.65
Thresher, trailer & harvester (scenario 2)	6,700	8,193	50	1.59	6,674	42	1.76
Thresher & trailer (scenario 3)	5,600	5,472	44	1.47	4,165	35	1.95
Transportation **(scenario 4)**	4,000	1,161	24	1.17	256	17	2.78
Seeder, trailer & harvester (scenario 5)	6,100	6,409	46	1.49	5,097	38	1.89
Seeder, thresher & trailer (scenario 6)	6,600	8,000	50	1.53	6,496	42	1.77
Seeder & trailer (scenario 7)	5,000	3,689	37	1.33	2,588	30	2.18
Seeder & harvester (scenario 8)	4,600	1,994	28	1.27	1,261	23	2.58
Seeder (scenario 9)	3,500	-726	8	0.86	-1,249	3	4.08
Harvester (scenario 10)	3,600	-534	10	0.90	-1,071	6	3.89
Thresher (scenario 11)	4,100	1,057	23	1.15	328.6	17	2.86

Annex 2: Profitability of 2WT based technology for better performing SPs

Combination of technologies	Investment cost ($)	Indicators					
		With current price			Increase in cost (10%)		Payback period (year)
		NPV ($)	IRR (%)	B/c ratio	NPV ($)	IRR (%)	
Seeder, thresher, harvester & trailer (scenario 1)	7,700	32,575	122	2.41	30,258	107	0.81
Thresher, trailer & harvester (scenario 2)	6,700	26,217	115	2.38	24,163	100	0.86
Thresher & trailer (scenario 3)	5,600	19,235	104	2.17	17,450	90	0.94
Transportation **(scenario 4)**	4,000	7,529	67	1.66	6,240	55	1.39
Seeder, trailer & harvester (scenario 5)	6,100	20,869	104	2.15	19,048	90	0.94
Seeder, thresher & trailer (scenario 6)	6,600	25,594	114	2.25	23,546	100	0.86
Seeder & trailer (scenario 7)	5,000	13,887	89	1.90	12,336	76	1.09
Seeder & harvester (scenario 8)	4,600	10,085	74	2.18	9,228	65	1.28
Seeder (scenario 9)	3,500	3,104	41	1.53	2,515	35	2.04
Harvester (scenario 10)	3,600	3,726	45	1.63	3,132	38	1.92
Thresher (scenario 11)	4,100	8,452	71	2.03	7629.7	62	1.33