Drivers for Adoption of Mechanization in Smallholder Farming Systems

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FOREWORD & LITERATURE REVIEW

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1. Background

Agricultural mechanization is broadly defined to include the application of tools, implements and powered machinery and equipment to achieve agricultural production, comprising both crop and livestock production as well as aquaculture and apiculture (Kormawa et al., 2018). These tools, implements and machinery may use either human, animal or motorized power, or a combination of these (B Sims & Kenzle, 2006). Mechanization applies to agricultural land development, crop production, harvesting, and preparation for storage, on-farm processing, and rural transport (Houmy, Clarke, Ashburner, & Kienzle, 2013).

Agricultural mechanization is promoted as one of the essential components in agricultural development. Essentially, it represents technological change through the adoption of nonhuman sources of power to undertake agricultural operations (Diao, Silver, & Takeshima, 2016). In fact, it enables farm family members not only to increase farm productivity via production intensification and/or expansion, but also to seek off-farm employment opportunities because of the increased time made available to look for and be engaged in such employment (Brian Sims, Hilmi, & Kienzle, 2016). Although agricultural mechanization is an essential input for agricultural production, it is difficult to place it alongside other inputs because it is not a single input like seed and fertilizer, but rather a series of production tools which are used in almost all phases of production (Houmy et al., 2013).

Agricultural mechanization is often used alongside other terms such as farm mechanization and agricultural machinery. Farm mechanization is technically equivalent to agricultural mechanization but refers only to those activities occurring inside the boundaries of the farm unit covering production of crops, livestock, and aquaculture (Kormawa et al., 2018). On the other hand, agricultural machinery is a general term that refers to tractors, combines, implements and devices more sophisticated than hand tools and which are animal- or mechanically powered and utilized in agricultural production (Kormawa et al., 2018)

2. Agricultural mechanization development trend

Globally, agricultural mechanization is often associated with increased application of advanced technology in farming and agricultural development. Mechanization is credited as one of the factors contributed to agricultural revolution in Europe, America, and Asia. According to Kormawa et al. (2018) the usage of tractors contributed to the economic growth of the United States of America in the twentieth century, as it replaced 24 million draft animals from 1925 to 1955 and significantly transformed agricultural productivity and land-use patterns. Similar developments took place in Europe between 1945 and 1965, facilitated in large part by the US-funded Marshall Plan.

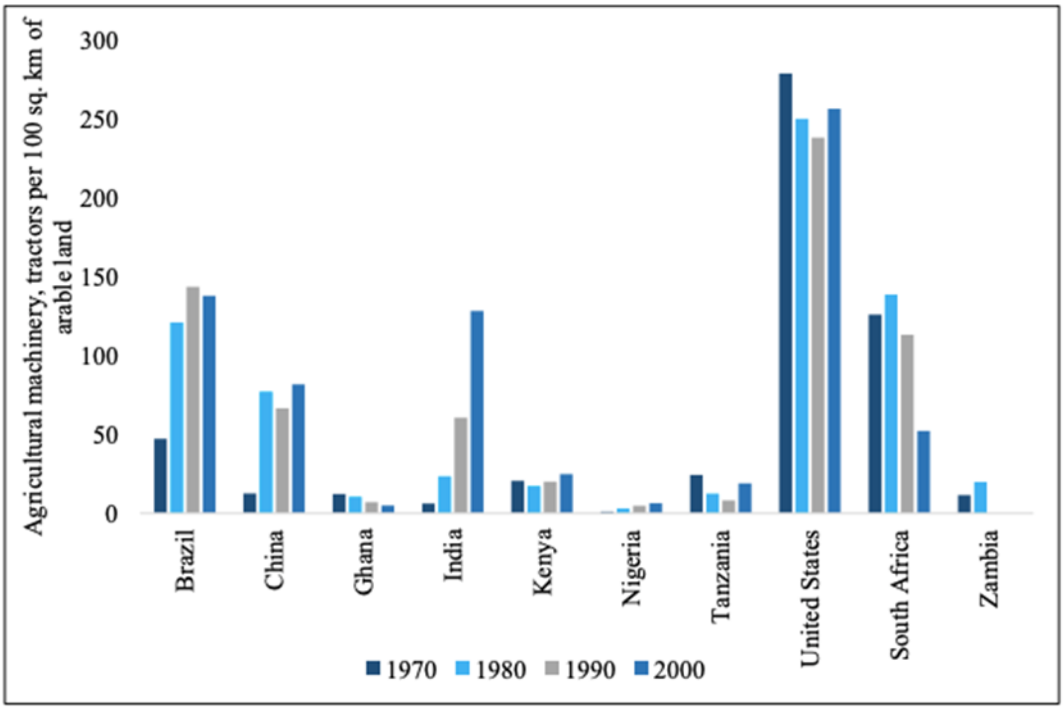
Developing countries have also experienced moderate development to agricultural mechanization. The move away from muscle power towards tractors and engines for pumping and post-harvest operations has been much more rapid in Asia and Latin America (Brian Sims et al., 2016). Draught animal numbers in India and China are falling dramatically and are being replaced with 4-wheel tractor power; whereas in Bangladesh, for example, draught animals have been replaced by 2-wheel tractors, which now perform 80% of land preparation (Brian Sims et al., 2016).

While investment in agricultural mechanization in Asia and Latin America are growing rapidly, they are stagnating or declining in most African countries (Kormawa et al., 2018). Mechanization use in Sub-Saharan Africa (SSA) has been substantially lower than in other developing regions (Westhuizen, Jayne, & Meyer, 2019).

First attempts to bring motorized implements to medium and small-scale farmers in SSA were in 1950s and 1960s, when public hiring schemes were launched, mainly for tractor-based services (Mrema et al., 2008). However, these programs faced many constraints including unsuitable farm sizes, unaffordable hiring fees for most smallholders, dependence on public subsidies, inefficient administration, and a weak supporting infrastructure for transportation and repairs (Fischer et al., 2018).

Since then, the majority of sub-Saharan African countries have not made much progress at all in agricultural mechanization, and in some instances even the achievements obtained in earlier years are being lost (Houmy et al., 2013). For example, in 1961, numbers of tractors in use was higher than in both Asia and the Near East (172,000 vs 120,000 and 126,000 units respectively), but it increased very slowly thereafter, peaking at just 275,000 in 1990 before declining to 221,000 units in 2000 (Kormawa et al., 2018). Actually, in 1961, Africa had more tractors in use than Brazil, India and the People's Republic of China respectively, but by 2000 the reverse was the case: there were more tractors in use in India, the People's Republic of China and Brazil respectively, than in the entire Africa region (Kormawa et al., 2018).

Figure 1: Agricultural machinery (Tractors) in selected countries



Source: Westhuizen et al (2019)

In general, number of tractors and even draught animal technology have both declined in African agriculture in the past few years, making agriculture more reliant on manual farming methods in a continent where constraints such as severe health problems and demographic shifts make manual labour a scarce and weak resource (FAO & UNIDO, 2008). The productivity is generally low because of the limited availability of physical energy and range of hand tools because human muscles still contribute about 65% of the power for land preparation in SSA (B Sims & Kenzle, 2006). There is a severe constraint on the area that can be prepared by hoe; more than 60 person-days per hectare are generally required for the job (B Sims & Kenzle, 2006).

In Tanzania, local manufacturing of agricultural machinery is very low, which contributes to the low level of mechanization in the country. Tanzania started its local manufacturing in the 1970-80's, however the capacity dropped after the collapse of the country's two main farm implements and tools factories - Ubungo Farm Implements (UFI) and Zana Za Kilimo, Mbeya (ZZK) (Kahan, Sariah, & Titus, 2014). Currently, most of the machinery and other agricultural implements used in Tanzania are imported.

3. A Case Study of Agricultural Mechanization in Tanzania

3.1 Types of agriculture mechanization

Types of agriculture mechanization can be grouped according to the source of power. Hence, based on the source of power, the technological levels of mechanization can be broadly classified as hand-tool technology, draught animal technology and mechanical power technology (B Sims & Kenzle, 2006).

i) Hand-tool technology is the mechanization based on human power sources. It consists of the tools and implements that use human muscles as the main power source ie. hand tools and manually powered machines (Houmy et al., 2013; Kormawa et al., 2018). They are technologically simple and can be designed and made locally in small quantities by artisans and small workshops or can be mass produced and sold through shops (Houmy et al., 2013). Hand tools are the main implements for smallholder farmers throughout SSA as they are used everywhere for land clearing, tillage, weeding and harvesting (B Sims & Kenzle, 2006). In Tanzania, hand-tool technology is the most common type of agricultural mechanization (National Bureau of Statistics, 2014; URT, 2016).

ii) Draught animal power technology (DAP) is the animal-power based mechanization. It consist of machines, implements and equipment powered by animals (Kormawa et al., 2018). The potential draught power of animals varies greatly according to the type of animal. The main animals used for work purposes are horses, oxen, mules, donkeys and camels (Houmy et al., 2013). Draught animal power is generally considered to be an affordable and sustainable source of power for small scale-farmers (B Sims & Kenzle, 2006). The DAP has been promoted in Tanzania for more than a century; however, its adoption has largely been confined to six drier regions in the northwest of the country where farmers have a tradition of both livestock and crop husbandry: Shinyanga, Mara, Singida, Manyara, Tabora, and Mwanza (Mrema, Kahan, & Agyei-Holmes, 2020).

iii) Mechanical-power technology is the mechanical-power based mechanization. It consists of mechanization powered by engines and or motors e.g. tractors and/or motors using petrol/diesel or electricity to power threshers, mills, centrifuges, harvesters, pumps etc. (Kormawa et al., 2018). Engine powered machines represent the highest level of mechanical technology in agricultural mechanization (Houmy et al., 2013). In Tanzania, various types of mechanical technologies have been adopted, based on regional heterogeneity. These include tractors, motorized pumps and other water lifting devices, motorized harvesting and postharvest processing equipment such as combine harvesters and threshers, and grain milling equipment (Mrema et al., 2020).

3.2 Trends in Agricultural Mechanization in Tanzania

As it is in other SSA countries, the utilization of farm machinery and implements is very low in Tanzania. There is strong reliance of hand hoe as the main cultivation tool, as 98% of the households own a hand hoe: (National Bureau of Statistics, 2014; URT, 2016). According to the Agricultural Policy of Tanzania, only about 12% of farmers use tractors, the rest use draught animal power (24%) and hand hoes (64%) (URT, 2013). However, the use of animal traction (ox plough, ox seed planter, ox cart) has been steadily increasing over the years. The National Panel Survey (NPS) of 2012/13 indicated that 10% of farmers possess ox ploughs and 23% of farmers can afford to rent an ox plough or an ox seed planter when they needed to use them (National Bureau of Statistics, 2014). According to NPS of 2012/13, 2.5% of the farmers owned tractors, however, those who use them through owning and renting were 6.3%.

Table1: Percentage of people using various agricultural machines in the country

	NPS 2008/09		NPS 2010/11		NPS 2012/13	
	Own item	Used item	Own item	Used item	Own item	Used item
Hand hoe	98.0	95.8	96.6	91.6	97.9	95.7
Hand powered sprayer	7.0	12.8	5.9	8.5	6.3	9.7
Ox plough	8.7	18.2	9.4	17.8	10.3	22.8
Ox seed planter	9.9	19.4	10.5	18.7	11.1	23.3
Ox cart	0.1	0.4	0.0	0.1	0.0	0.0
Tractor	2.4	7.7	2.4	5.1	2.5	6.3
Tractor plough	0.1	2.8	0.2	2.9	0.1	5.0
Tractor harrow	0.3	1.4	0.1	2.3	0.1	3.9
Sheller/thresher	0.1	0.1	0.0	0.0	0.1	0.2
Hand mill	0.5	1.1	0.1	0.1	0.1	0.2
Watering can	2.0	1.8	1.2	1.1	0.8	0.9
Farm buildings	7.5	7.2	6.8	6.6	5.6	5.1
Geri cans/drums	12.7	10.8	3.8	2.3	2.4	2.1
Power tiller	-	-	-	-	0.2	0.4
Other	-	-	10.5	10.0	31.7	31.3

Source: National Bureau of Statistics (2014)

Large tractors

The number of tractors in use in a country is commonly used as the main indicator of mechanization level in most of the main databases (Kormawa et al., 2018). The types of tractors in use in Tanzania include traditional two-axle four-wheel tactors (4WTs) and low-horsepower 4WTs. About 65% of 4WT ownership is concentrated in six regions; Morogoro, Arusha, Kilimanjaro, Manyara, Dodoma, and Shinyanga.

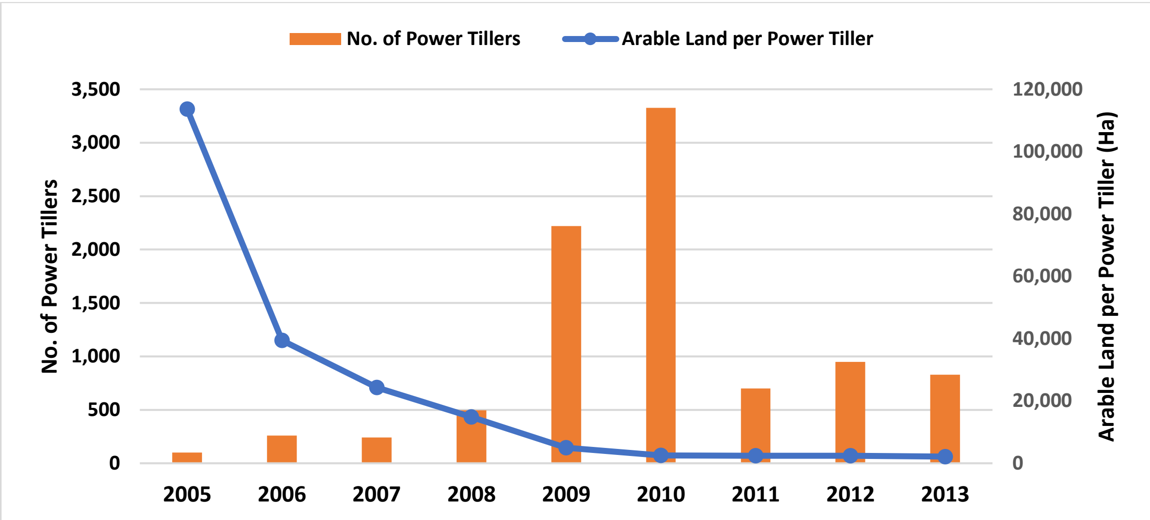
Most of these tractors are used for own farms and for hiring services. Thus, they appear also to be concentrated in the regions that are well connected with roads, such as Arusha, Iringa, Manyara, Kilimanjaro, Dodoma, and Morogoro (Mrema et al., 2020).

The usage of tractors has been increasing in Tanzania. The composition of the users is also changing. Currently, the increase in the number of households making use of tractors is not limited to larger-scale producers, but is also observed among small-scale agricultural households (Westhuizen et al., 2019). The purchase of Tractors increased in 2010 when the government provided loans to farmers for 569 two-axle tractors and 193 single-axle through provision of affordable loans through the Agricultural Inputs Trust Fund (AGITF) (Kahan et al., 2014). Typically, 4WTs were used for plowing and transportation, and about 62 percent of the owners hired out their tractors, mainly for transportation, (Mrema et al., 2020).

Power tillers

The use of power tiller two-wheel tractors (2WT) has also grown in recent years. Importation of 2WTs increased in 2009 when the government supported the import of more than 2,000 units (Mrema et al., 2020). The importation peaked in 2010 (Kahan et al., 2014).

Figure 2: Growth in the number of 2WTs in Tanzania



Source: Kahan et al (2014)l; own calculations

** Note: The Arable Land per Power Tiller takes the total arable area for Tanzania divided by the cumulative total of Power Tillers over the time period, but assuming a 20% year-on-year redundancy rate after 2005 as machines break and are not repaired. .*

Even before the government initiative in 2009, the number of Power Tillers was increasing, but the import scheme sought to significantly increase the amount of land in which Power Tillers were used. On average, after 2009, there was one Power Tiller for every <2,500 hectares.

The increased use of tractor rental services by smallholder farmers in Tanzania is significantly associated with the concentration of medium-scale farms in the district; where there is a high concentration of medium-scale farms (eg. Arusha, Morogoro and Manyara) over 20% of small-scale farmers were also able to make use of tractor rental services (Westhuizen et al., 2019)

Combine harvesters

Combine harvesters and other postharvest processing equipment (ie. threshers and shellers) are commonly used in the large-scale commercial farms. There is, however, evidence of increasing smallholder use of small combines and other equipment from Japan, China, and India, (Mrema et al., 2020).

3.3 Models of access agricultural machines by smallholder farmers in Tanzania

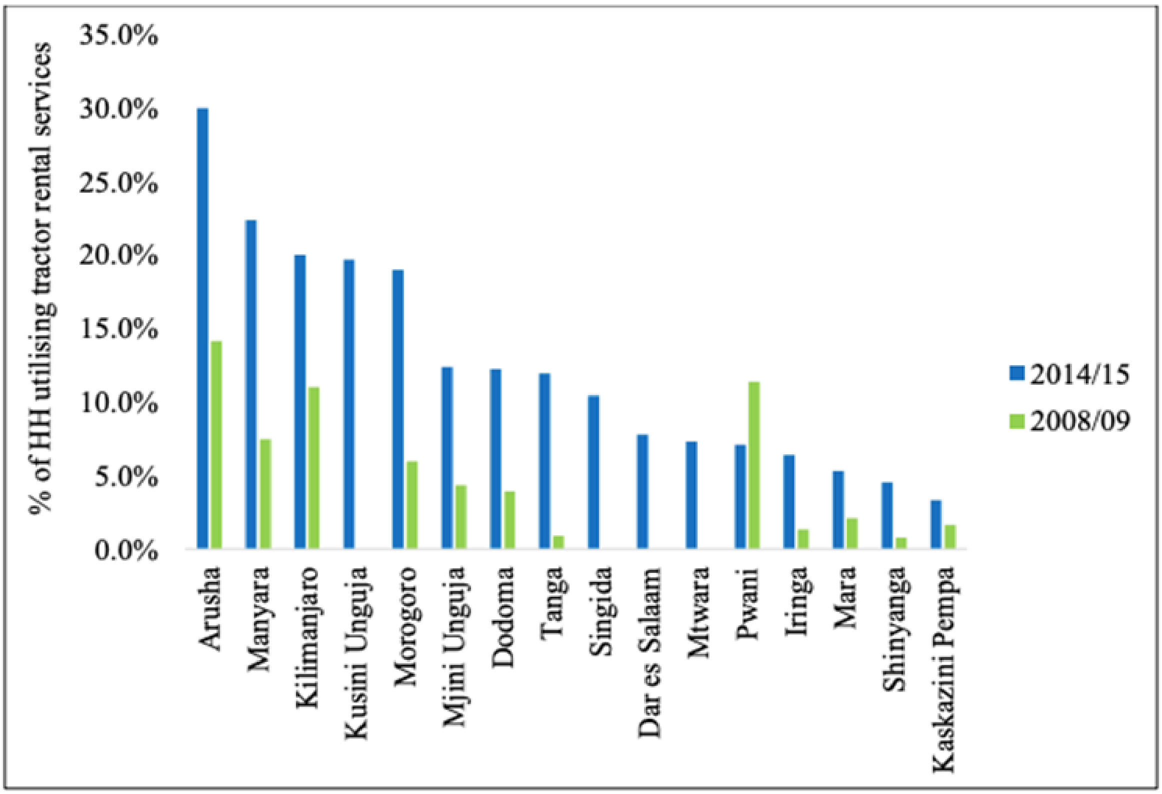
Individual ownership

Individual ownership of large tractors is often common to large-scale farms (LSF) in Tanzania. LSFs normally procure new 4WTs and use them for 5–10 years before depreciating them for tax purposes and selling them to either medium-scale farmers and small-scale farmers (Mrema et al., 2020). In Tanzania, farm size is categorized as follows; small-scale farmers are those farmers with holdings of 0 – 5 ha, medium size farmers have holdings of 5 – 100ha and large-scale farmers have holdings of over 100 ha.

Tractor hiring services (THSs)

The Tractor hiring services (THSs) model has been predominantly operated by the private sector, whereby more than 90% of tractor-owning farmers now provide THSs (Mrema et al., 2020). A study by (Westhuizen et al., 2019) showed that by 2008/09 and 2014/15 the regions with high percentages of tractors that are under THSs in Tanzania were Arusha, Manyara, Kilimanjaro, Kusini Unguja and Morogoro.

Figure 3: Regions with Tractors that provide hiring services*



Source: Westhuizen et al (2019)

** Note: Figure 3 shows the top 16 regions for where tractor use and hiring services are adopted. This is somewhat different from the national picture, as detailed in Table 1 above, which shows the national average across all regions (6.3% of farmers nationally use tractors in 2014/15)*

The government of Tanzania is trying to promote ownership of tractors by small scale and medium scale farmers. There is also an exemption of taxes on most agricultural machinery to encourage farmers to purchase tractors and other farm implements at affordable prices (FANRPAN & GACSA, 2016; Word Bank, 2012).

Mrema et al (2020) divided the THS into three categories; Individual ownership—Farmer-tractor-owner hiring service providers, Cooperative/group farmer model and Enterprise ownership of the hiring service.

(i) Individual ownership—Farmer-tractor-owner hiring service providers

Medium-scale farmers and large-scale farmers that own 4WTs provide custom hiring services to other farmers in their locality and sometimes outside their districts. According to Westhuizen et al (2019), the increasing tractor use is driven by the development of rental markets and not through the acquisition of their own tractors. According to the URT (2016), the government is trying to promote agricultural mechanization by offering public finance through AGITF and Tanzania Investment Bank (TIB), and through other commercial banks, so as to extending loans for purchase of tractors, power-tillers, and combine-harvesters. For example, in 2011, 1,800 Farmtrac tractors and 400 power-tillers were imported by the Government of Tanzania with a soft loan financed by the Government of India with the aim of selling to farmers (Word Bank, 2012).

(ii) Cooperative/group farmer model

Cooperative/group farmer models help to increase the use of tractors in the country. In this case, a group owns a tractor and members hire it for a specific period of time. Group members contribute to the running and maintenance costs of the tractor as well as fees for servicing the loan used to procure the machine. On the other hand, there are active Savings and Credit Co-Operative Societies (SACCOS) that provide loans to its members for purchasing agricultural machinery (URT, 2016). Also, farmers have been purchasing tractors from SACCOS and other farmer groups that have access to subsidized financing from public banks or donor financed programs (Word Bank, 2012).

(iii) Enterprise ownership of the hiring service

These include contract farming, commercial farming, and machinery dealer hiring services; however, compared with the other THS types, these enterprise models are generally less common.

3.4 Economic and agronomic benefits of mechanization

Farm mechanization has the potential to transform rural families' livelihoods by facilitating increased output of agricultural related products (Brian Sims et al., 2016). Studies show that tractor use on farms has been found to correlate with higher yields of maize, beans, and paddy rice in Tanzania (Mrema et al., 2020).

In addition, mechanization is known to eliminate the drudgery associated with human muscle-powered agricultural production (Brian Sims et al., 2016; Houmy et al., 2013). By reducing drudgery, farm machinery facilitates the timely implementation of various agronomic activities (FANRPAN & GACSA, 2016). Where the conditions for the use of tractors and large machinery are suitable, investment in agricultural mechanization has proven to be profitable (Houmy et al., 2013). According to FANRPAN & GACSA (2016) tractors, power tillers and trailers have enabled farmers to plough large areas in a very short time period, and to transport manure and crop produce conveniently and efficiently. In the study by (Fischer et al., 2018), farmers used machine for chopping livestock feeds reported to productivity gain after shifting from manually chopped feed practice to machine-chopped feed.

Mechanization plays a critical role in agriculture commercialization (Word Bank, 2012). This would lead to improved land use, increased food production, enhanced rural prosperity and, on a national scale, greater export potential and less reliance on imports (FAO & UNIDO, 2008). The farming activities that Tanzanian women commonly participate in include weeding, tillage and land preparation, postharvest management, and transportation of agricultural produce. Mechanization is considered as one of the options that might reduce the workload to women and children. Men's appropriation of mechanized implements may relieve women of these tasks (Fischer et al., 2018).

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1. INTRODUCTION TO THE ADOPTION OF MECHANIZATION STUDY

Estimates suggest that there are over 500 million smallholder farmers in the world, with approximately 98% of the world's agricultural holdings being smaller than 10 hectares in size.

Lack of access to mechanization is often cited as a key reason for low labor and land productivity on smallholder farms, but amongst developing countries and regions there are significant differences in adoption of mechanization, and the reasons behind this.

According to the Food and Agriculture Organization, Africa has less than two tractors per 1000 ha of cropland, whilst the number has sharply increased in other parts of the developing world, reaching ten tractors per 1000 ha in South Asia.

Within the *agri benchmark* network, we have formed a smallholder working group to enable the comparison and analysis of smallholder production systems and facilitate peer-to-peer exchange and understanding between *agri benchmark* scientific partners, and the wider network generally. This representation covers countries in Africa and Asia where smallholders form the majority of farmers.

As a first output of the working group, *agri benchmark* initiated a project between 2020 and 2021 to gain a greater understanding of mechanization adoption within our smallholder network, what socio-economic drivers exist that influence the reasons for adoption, and what strategies are currently employed to allow smallholder farmers to mechanize operations in crop production.

This interim paper considers the results from this first phase of study, looking at labor availability, and the level of mechanization adoption for key operations. We also consider the next steps the working group will take to further investigate the strategies towards mechanization.

2. METHODOLOGY FOR DATA COLLECTION

A questionnaire was distributed to partners, into two parts. Part A asked partners to select one or more of the key agricultural regions producing nationally important food or cash crops. Table 1 provides a list of the countries and regions where data was provided.

The questionnaire asked a series of questions relating to the population of the region, the number of people working in agriculture in 2010 and 2020, and the agricultural wage rates in those two years. This information will enable us to assess and describe the different framework conditions for labor supply in agriculture.

To understand what push or pull factors may influence labor use, the questionnaire also asked partners to give their opinion on the availability of labor for key agricultural operations (see table 2), and what other activities a laborer could do besides farm work. The latter will be used as an indicator for opportunity cost for family labor usage.

Partners were asked for estimates on the use of mechanization, how this was typically done, and the level of uptake amongst smallholders for key tasks of ploughing, planting/seeding and harvesting. The rational for this selection is that these activities are rather labor intensive when done manually and a replacement with machinery can be achieved relatively easily.

Part B of the questionnaire then asked partners to identify a specific cash crop production system, and how the three key operations were carried out. Table 1 lists the chosen cash crops in each region. In particular, we sought to understand what mechanized or manual resources were typically used, along with the man hours and costs associated with the operation.

Where different from a typical system, and known to be available in the region, partners were also asked to compare this with a contractor hired to undertake the operation with machines instead, the hypothesis being that a smallholder farmer would be most likely to hire a contractor with mechanized equipment as a first means of accessing mechanization.

Table 1. Countries and regions contributing to the study, crops studied and region abbreviations

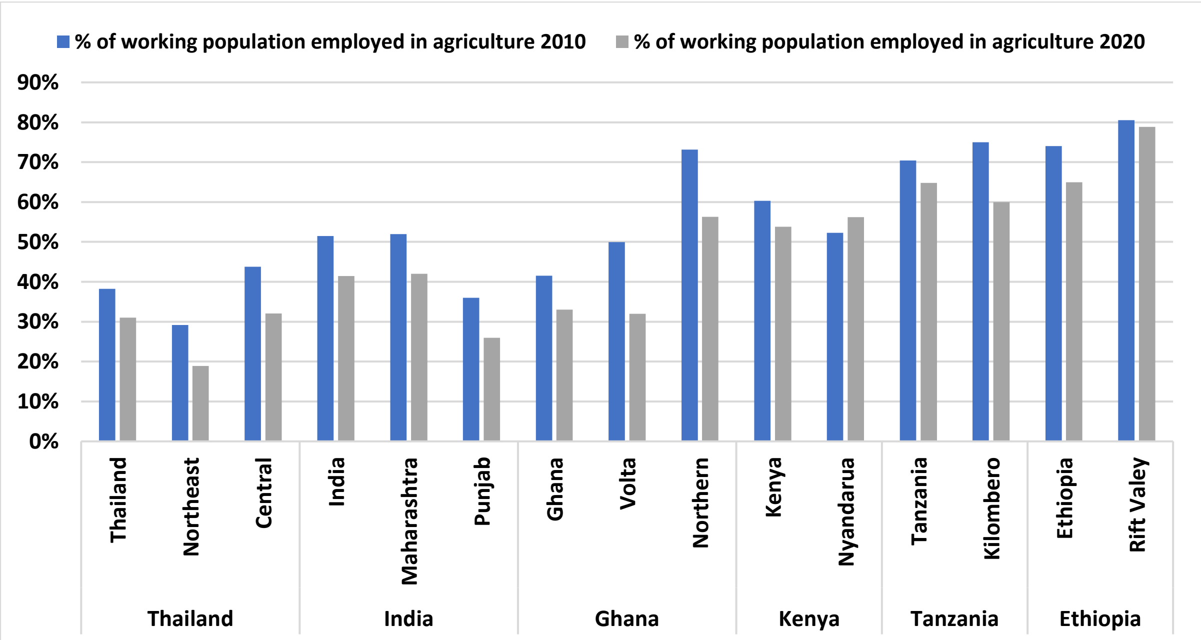
Country	Region	Cropped Area of Typical Farm	Crop Selected	Abbreviation
Thailand	Northeast	3	Rice	NE, TH
	Central	24	Sugarcane	CN, TH
India	Maharashtra	6	Sugarcane	MH, IN
	Punjab	3	Rice	PJ, IN
Ghana	Volta	1	Rice	VT, GH
	Northern	1	No data section B	No data section B
Kenya	Nyandarua	2	Potatoes	ND, KE
Tanzania	Kilombero	1	Rice	KB, TZ
Ethiopia	Rift Valley	2	Maize	RV, ET

The crops selected in all African countries are grown as staple foods for domestic consumption. In Thailand and India, rice is the largest crop by acreage, grown for both domestic and export. Sugarcane is a cash crop and mostly produced commercially for export on larger farms. In this respect, those farms are more likely to have access to mechanization.

3. AGRICULTURAL LABOR

Regarding the overall framework conditions for labor supply the questionnaire revealed that in 2020 the two Asian countries (Thailand and India), and Ghana had less than 45% of the population classed as employed in agriculture.

Figure 1. Percentage of working population employed in agriculture (2010, 2020)



Source: world bank; various regional statistics

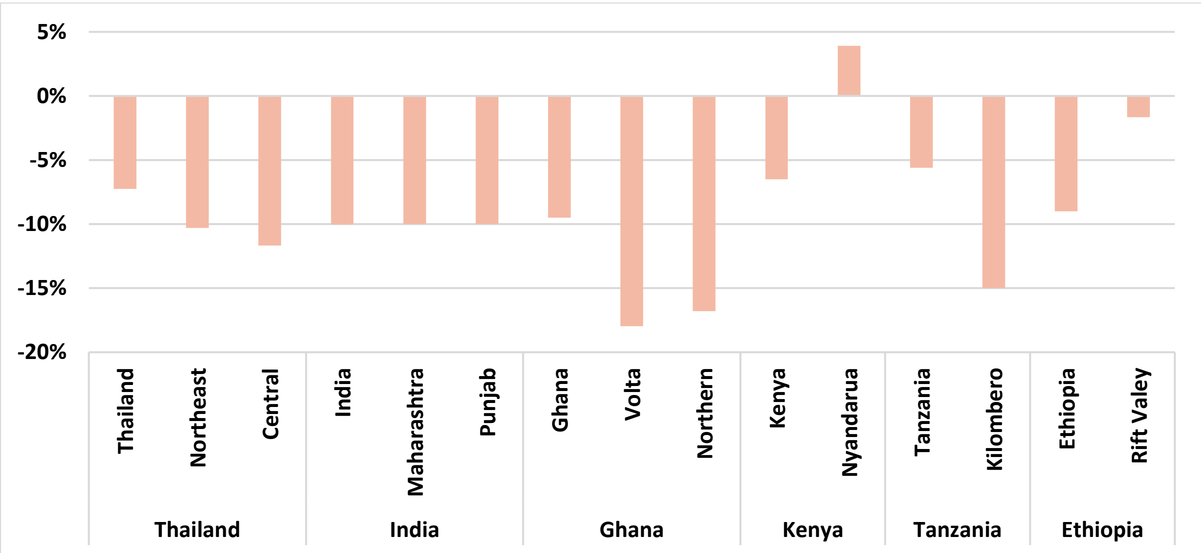
This contrasts with the populations of all the other participating African countries, which still have more than 50% of the working population employed in agricultural work. Indeed, Ghana's agricultural employment rate nationally is at a similar level to that of Thailand and India.

Whilst Ghana has seen an urbanization of the population in the past decade, this has been particularly coupled with a rise of the formal and informal service economy, particularly in the southern regions closest to major urban centres. Even in rural areas, non-farm employment now makes up the majority of household income, so whilst many people may still do work on their own smallholdings, they would not class themselves as being employed in and deriving their main income from agriculture. We would therefore caution that these figures may not fully capture the extent of agricultural work overall.

When looking at the two regions included in the study for Ghana, agriculture is still the majority employer in the more rural and remote Northern region (>50% of working population), but the Volta region, closer to urban areas of Accra in the south, has seen a fall from 50% of the working population to 32% in the past decade. The fall in the working population employed in agriculture in both regions is, however, well above the national level as seen in Figure 2 below.

In India and Thailand, the drop in agricultural employment both nationally and within the selected regions over the past decade is believed to be because of a migration of younger people from rural areas towards manufacturing, construction, tourism, and service employment in urban centers.

Figure 2. Change in amount of working population employed in agriculture between 2010 – 2020 (%)



Source: world bank; various regional statistics

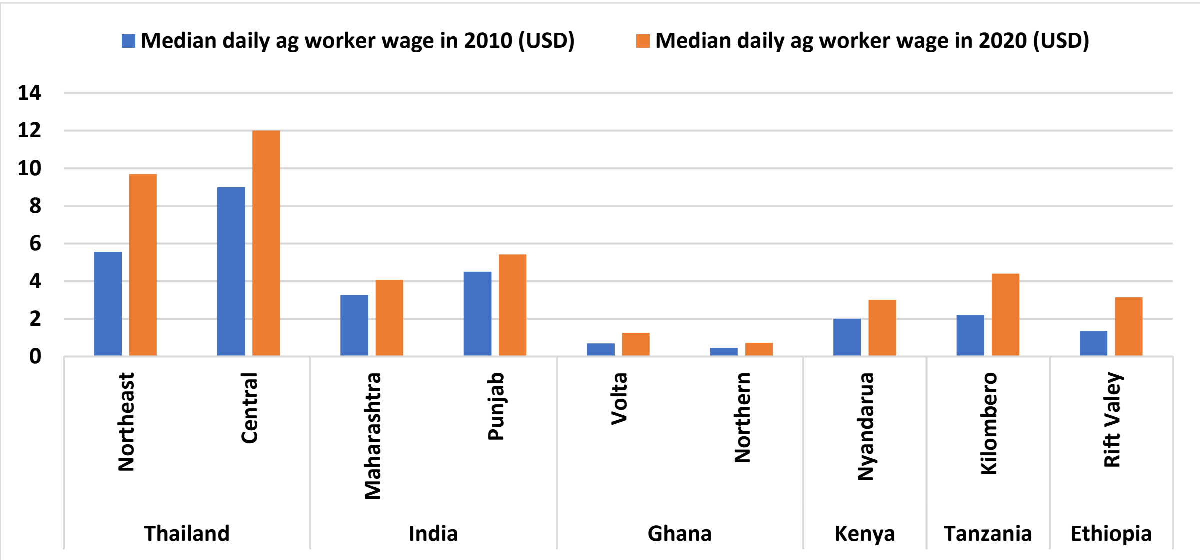
The rate of the move away from agricultural employment has been generally slower in the other African countries in the study, although regional differences exist. In the Nyandarua region of Kenya, the percentage of population employed in agriculture was recorded to have increased, despite a decline of 7% nationally. In the Kilombero region of Tanzania, however, employment in agriculture has reduced by 15%, despite a national reduction of just 5.5%. This is again likely to be due to a move into informal service sector work.

Although these countries have also experienced population growth over this time period, this has not been at a stronger rate than the reduction in agricultural worker population, and therefore the labor supply in agriculture as a % of population has also gone down. This lower labor supply translates into increasing wages, although to a varying degree depending on the country. This is particularly true in Asia where workforce competition from other sectors for low-skilled and manual work is stronger than in Africa.

When looking at the wage rates of agricultural workers, there is significant discrepancy between the countries and regions. Thailand has substantially higher wage rates than the other countries, driven by relative labor shortage and higher wage rates in manufacturing, tourism and service sector jobs that compete for low-skill workers.

Agricultural worker wages in the Ghana regions are lowest of all, perhaps explaining why there has been a rapid move away from agricultural to non-farm work over the same timeframe.

Figure 3. Median daily agricultural worker wage 2010 and 2020 (USD/day)

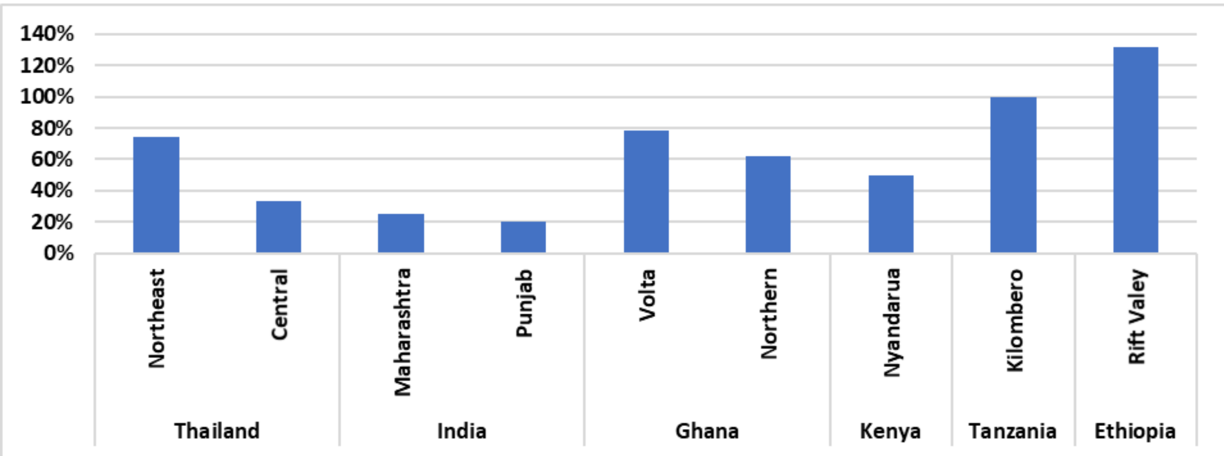


Source: world bank; various regional statistics

USD figures calculated against exchange rate in 2010 and 2020 to take account of depreciation over the period

While Thai ag wage rates are obviously much higher than the rest of the group, Indian and African values are relatively similar when considering 2020 data and excluding Ghana data.

Figure 4. Percent change in agricultural worker wage rates 2010 to 2020 (%)



Source: world bank; various regional statistics

Whilst the percentage change in wage rates is proportionately highest in the African countries, this is from a lower base than Thailand. However, the strong increase in agricultural wages suggest that African growers should face a challenge to increase economic labor productivity.

In terms of availability of agricultural labor, our respondents noted that this was very much dependent on the operation and time of year. Generally, however, the regions in Thailand, India and Ghana reported medium or low availability of agricultural labor, whilst Kenya, Tanzania and Ethiopian reported either medium or high availability, as can be seen from table 2 below.

4. ADOPTION OF MECHANIZATION

The adoption of mechanization differs between countries, regions, and crop types.

Table 2. Worker availability and adoption rate of mechanization amongst smallholder farmers

Country	Region	Study Crop used in survey	Availability of Agricultural Workers	% of smallholders adopting mechanization		
				Ploughing/Cultivations	Seeding	Harvesting
Thailand	Northeast	Rice	Medium	100%	20%	95%
	Central	Sugarcane	Low	90%	80%	10%
India	Maharashtra	Sugarcane	Medium	85%	40%	20%
	Punjab	Rice	Medium	95%	20%	95%
Ghana	Volta	Rice	Medium	<15%	0%	5%
	Northern	Rice	Low	<10%	0%	1%
Kenya	Nyandarua	Potato	High	40%	1%	1%
Tanzania	Kilombero	Rice	High	80%	3%	20%
Ethiopia	Rift Valley	Maize	Medium	7%	0%	7%

In both the Thailand and India regions, ploughing and/or other heavy cultivation operations are mostly carried out mechanically. This is by using either small tractor and ploughs, hand operated rotavators/Power Tillers, and in India, also draught animals. For the majority of smallholder farmers, this is carried out by contractor service providers working from farm to farm, on a piece-work basis.

The use of mechanical power in ploughing and other heavy cultivation work is not as prevalent in Africa, but differs considerably between countries, regions, and crops. For smallholders in the Volta and Northern regions of Ghana, and the Rift Valley in Ethiopia, the data suggests that over 85% of farmers in those regions still use manual labor for cultivation work.

That contrasts with farmers in Nyandarua, Kenya, where 40% of farmers are estimated to use mechanical ploughing, and in Kilombero region of Tanzania the figure is even higher at 80% of smallholders. Mechanized operations are mainly contracted on a piece-work basis here as well. This implies that (a) risks of difficult field conditions are with the contractor and (b) depending on the competition, the incentive for contractors to perform well might be low.

The story was somewhat different for seeding operations, with significant differences between crops and regions. For farmers in central Thailand, the majority use mechanical seeding technology, whereas uptake is considerably less in the northeast region. In Maharashtra, India, 40% of farmers were estimated to be using mechanized planting methods, but for smallholder farmers in the Punjab region, this was only at 20%. In both Asian countries, where mechanized seeding is carried out, this is also done mostly by contractors.

In all African countries, more than 95% of farmers still use manual labor for seeding. This is carried out either by family members or contract hired laborers.

For harvest operations, the level of mechanization adoption differs depending on both the region and the type of crop.

In rice production in the northeast region of Thailand, there was more than 95% adoption of mechanization in harvest, but less than 10% in cassava production for example. In the Punjab region of India, 95% of farmers use mechanical harvest, whereas less than 20% of smallholders do so in the Maharashtra region.

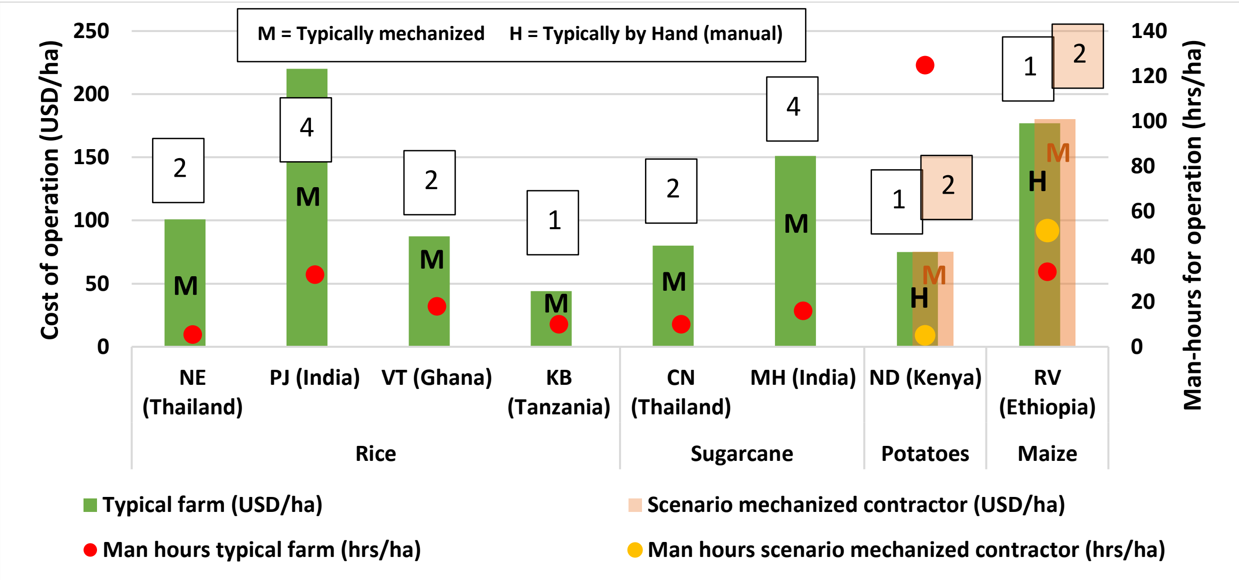
In the African countries, there was generally low-level use of mechanical harvesters, although 20% of farmers are now estimated to use mechanized harvesting equipment in Kilombero, Tanzania.

5. CROP CASE STUDIES ON TYPICAL FARMS

The second part of the questionnaire looked in more detail at what manual or mechanized resources are used in certain cash crops grown on the typical farms in those regions.

In all the typical farms growing rice**, heavy cultivation work** (such as ploughing and seedbed preparation) is mostly a mechanized process (green column and left axis). The red dots represent the man-hours spent per operation, as numbered on the right axis. “M” is for mechanized, “H” is for mostly hand operated tools (manual power). The numbered box in the below graph also indicates the typical number of passes that are required to prepare a seedbed before seeding.

Figure 5. Cost and Man hours in heavy cultivation operations



Source: *agri benchmark* questionnaire data

The data revealed that farmers tend to use hired contractors for mechanized cultivation of their land in India and the African countries studied. In Thailand, many farmers own small tractors themselves, but where this is not the case, hiring the machine off a neighboring farmer is a common alternative over hiring a contractor to do the work as a service.

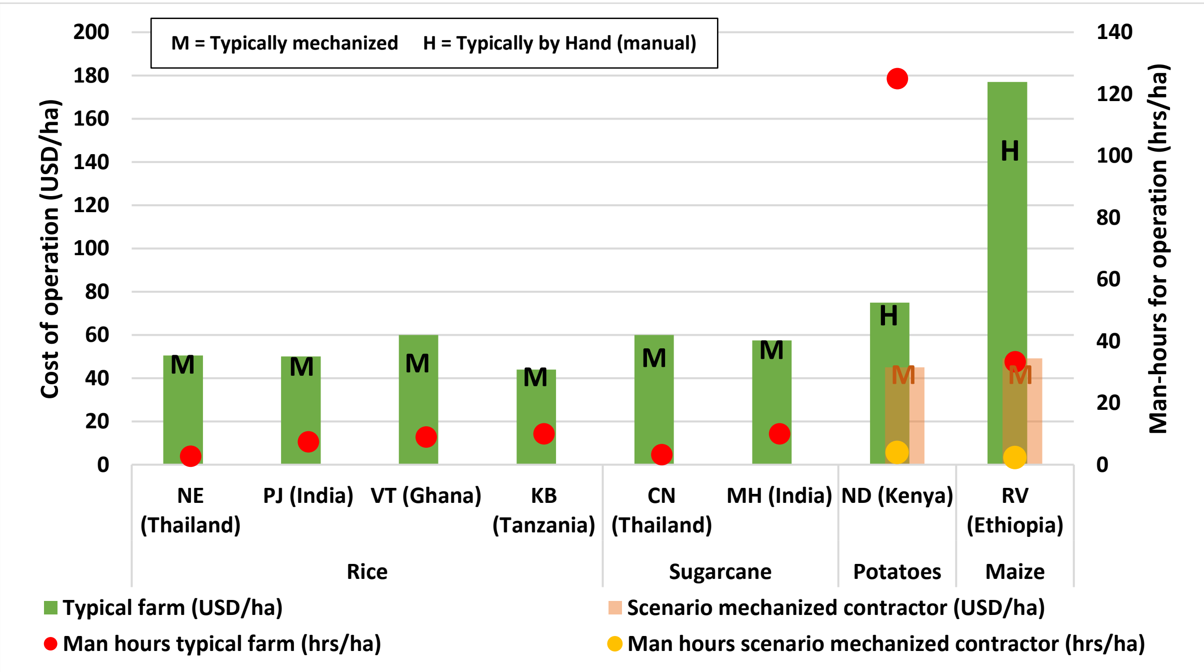
Of the sugarcane farms in Thailand and India, ploughing and cultivation work was also a mechanized process using contractors.

Ploughing and cultivation work for bed-forming in potato cropping in Nyandarua, Kenya, is mechanized for 40% of farmers, whilst 60% of farmers still use manual labor. The data showed that using contracted mechanized operations (orange column) was similar in cost to manual cultivations but required just a fraction of the man hours (yellow dot). Given that mechanical cultivation is efficient and considered to produce a better-quality seedbed, and the chance of a higher yield, it is surprising that contractor services for this operation are not at a higher charge than manual.

Our Kenyan partners explained that this is due to multiple factors influencing demand, with mechanized contractors being price takers rather than price makers. Firstly, the high availability of cheap labor in the region means that the price mechanized contractors can charge is heavily linked to the manual alternative. This is because the decisions smallholder farmers make around their cultivation strategy is strongly driven by what they can afford to pay at that point in time, even despite the likely agronomic and yield benefits that mechanized cultivation brings further down the line in improved timing and quality of seedbed preparation. Secondly, the highly fragmented nature of land ownership and associated issues of accessibility by machine mean that, for many smallholder farmers, tractor-mechanized cultivation is not really a practical option either for the farmer or the contractor to entertain. The result of this is that demand for mechanized contractor services does not significantly outweigh the supply and availability of those services.

In maize in the Rift Valley, Ethiopia, the operation is typically undertaken by draught animal powered plough in combination with manual labor assistance following behind to break up the soil and prepare the seedbed in one overall pass. Where a farmer can hire a contractor with a tractor, the time taken to undertake the ploughing is reduced, and the cost element for this operation is lower, but there is still a requirement for an additional manual operational pass to break clods in the soil and prepare the seedbed. This requires a similar amount of manual time and therefore there does not appear to be a particular advantage to using mechanization, at least from a cost perspective. There may, however, be an agronomic benefit to doing so in terms of better soil preparation and timing leading to improved crop resilience, but this has not been investigated in this study.

Figure 6. Cost and Man hours of One Pass of heavy cultivation operations



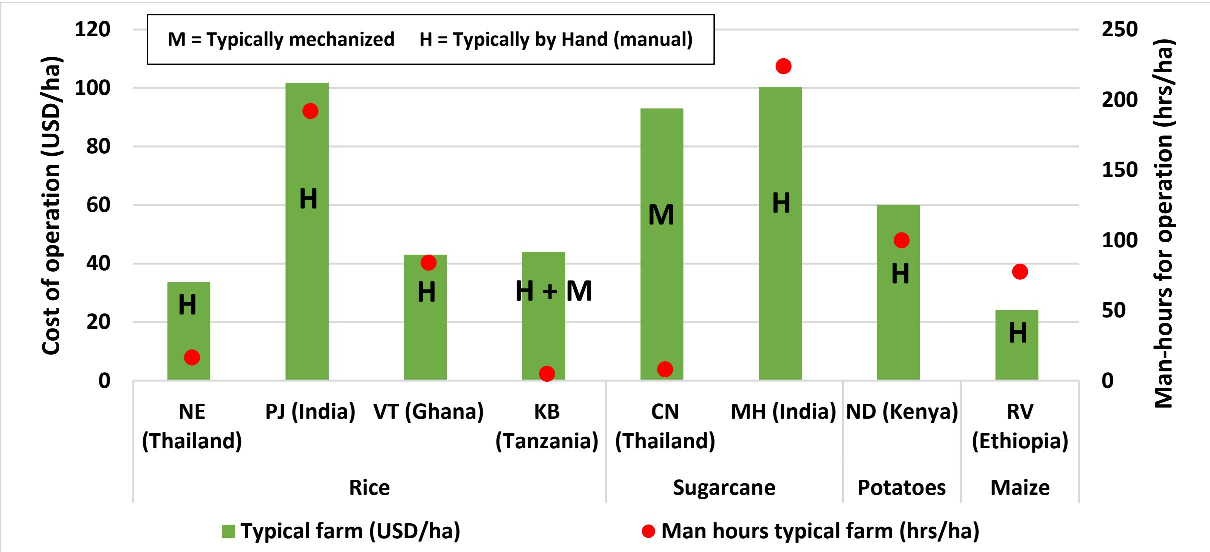
Source: *agri benchmark* questionnaire data

Figure 6 above shows that if we were to look at just one pass of heavy cultivations (e.g. ploughing), the costs for mechanized operations are actually very similar in all countries and across all crops.

One pass of mechanized heavy cultivation for the mechanized contractor scenario in Kenya and Ethiopia (orange column) are actually lower cost than the manual operation, but keep in mind that following this mechanized pass there is still an additional manual operation that needs to be conducted in the subsequent seedbed preparations, such as breaking clods and bed-forming (in the case of Kenya Potatoes). The manual cultivation takes substantially more man-hours, and is more expensive per pass, but this activity includes all tasks in cultivation and seed bed preparation at the same time, rather than in two distinct operations, which may be days or weeks apart. Therefore, the cost saving on heavy cultivations by machine is also partially offset by the need to still hire manual labor on a piece-work basis to still finish the seedbed preparations before planting.

Seeding and planting data showed that there is a low adoption of mechanization on typical farms, regardless of the crop. It is still mainly a manual operation carried out using contract piece-work labor.

Figure 7. Cost and Man hours in seeding/planting operations



Source: *agri benchmark* questionnaire data

Only the sugarcane farm in central Thailand was a mechanized planting operation. It is important to consider, however, that the farm size is 24 hectares, which is at the higher range for smallholders. The same service may not be available to smaller farmers.

Manual transplanting of rice plants is preferred in Punjab, India, which is more time intensive and costly, although generally producing higher yields. The Thai, Ghanaian and Tanzanian rice farms all use manual broadcast of seed. This is lower cost with a smaller man-hours requirement, but there is increased risk to poor crop establishment and uneven spread of seeds, which generally results in lower yields or a requirement to do some further passes of re-fill broadcasting where the crop has not taken and needs to be re-seeded. This is commonly the case in the Ghana rice typical farm in Volta, explaining the higher number of man hours.

The rice farm in the Kilombero region of Tanzania includes a mechanized discing in of the broadcast seed (hence the H + M label), but the actual process of broadcasting the seed is a manual one. Essentially the second cultivation pass that is undertaken prior to seed broadcast in both the Thai and Ghana typical farms is actually undertaken as part of the seeding process in the Tanzania case. Whether this alternative timing and method has a positive or negative effect on the crop yield has not formed part of this initial study, but understanding the agronomic benefits of mechanizing certain operations, at what time and in what system, is certainly an important dimension that requires further investigation.

Further to that, it is also important to understand what actions can have the biggest impact, especially on crop yield, productivity, and profitability, within the context of the local framework conditions. What works in one country, or one region, may not be appropriate or realistic in another due to limiting factors such as availability of labor, machinery, or other resources.

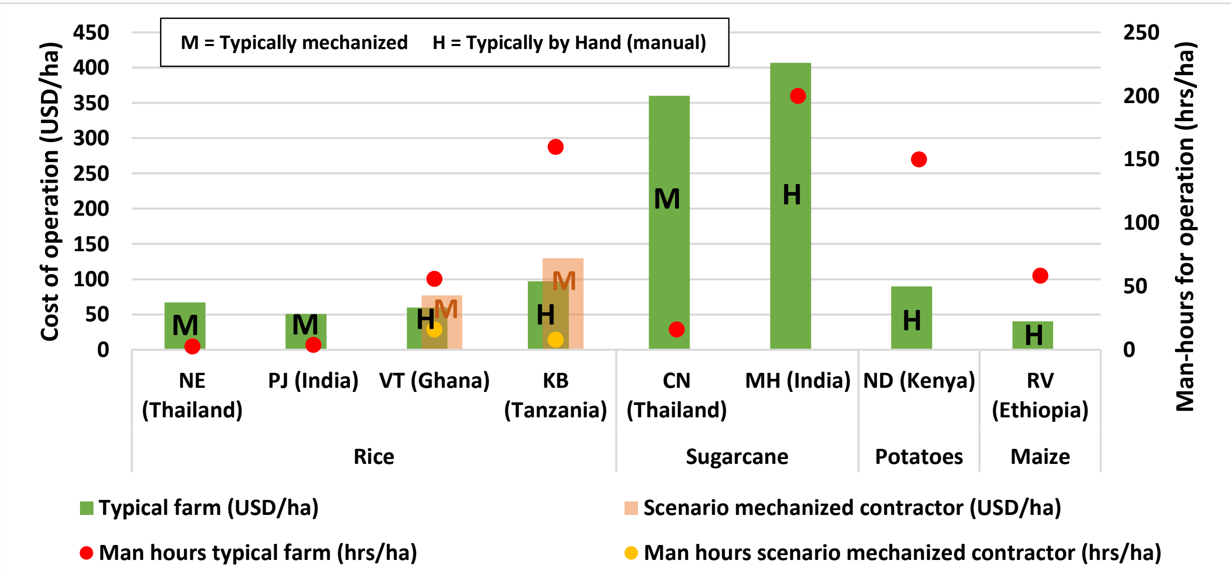
Planting sugarcane is costly and time consuming due to the type of operation requiring the planting of canes in prepared rows. In Maharashtra in India, this is carried out manually, and is similar in cost to the transplanting operation of rice in Punjab. Mechanical planting of sugarcane in central Thailand is quicker and somewhat cheaper by comparison.

Planting of potatoes in Nyandarua, Kenya, requires a high number of workers but is done relatively quickly as a result. Since timing is critical in crop establishment, laborers are in high demand, and this poses a significant risk should manual labor become scarcer.

In Rift Valley, Ethiopia, farmers manual plant behind draught animal and plough. This is manual row planting rather than broadcast.

Harvesting has become a mechanized process for smallholders in some crops, but it is not easily accessed in all regions. Whilst harvest of rice is a mechanized operation in north-east Thailand, and Punjab in India, it is still a manual operation for most rice farmers in Ghana and Tanzania. With that said, mechanized technology is starting to become more accessible as some larger farmers are able to acquire harvesters and offer to smallholders as a contractor service. The practical issues of small farm sizes and land fragmentation, along with poor infrastructure and remote and inaccessible locations do, however, pose a significant barrier to widespread adoption at present, quite apart from the aspects of affordability of the service.

Figure 8. Cost and Man hours in harvesting operations



Source: *agri benchmark* questionnaire data

The cost of mechanical harvest of rice in Thailand and India is similar to manual harvest in Ghana and Tanzania. This shows that, despite the higher capital costs of machines, the greater efficiency in labor use – which is significantly more costly in Thailand compared to African countries - and competition amongst contractors, keeps the cost of the operation comparable to manual harvest in the African countries.

In sugarcane, the harvest on the typical farm in Thailand is undertaken mechanically by contractors. The contracts are often linked to the sugarcane mills, providing this service to out-growers in exchange for the delivery of the raw product to the mill. The man-hours required to harvest is 8.33% of the time taken per hectare for manual harvest in the India sugarcane typical farm example, and is more cost effective. We do need to consider that the farm is quite large by smallholding standards at 24 ha and such services may not be available to all smaller-scale sugarcane farmers.

For smallholders in Maharashtra in India, the sugarcane harvest is typically done manually by contracted laborers, given that the cost of mechanical harvesters, even on a contract hire basis, would appear to be prohibitively expensive. Because of the high number of workers required to harvest the sugarcane (20 laborers in this case), there is a high number of man-hours per hectare, and the cost exceeds that of mechanized harvest in Thailand, despite wage rates being lower.

In potato harvest in Nyandarua, Kenya, and maize harvest in Rift Valley, Ethiopia, the operation is also undertaken manually. The cost and man-hours are comparable to manual rice harvest.

This initial study has not investigated how mechanized harvest compares to manual in terms of crop quality and losses. Foor example, the data in Figure 8 suggests that mechanical harvest in rice in Ghana and Tanzania is 40 – 50% more costly than manual harvest, but is that translated into value for money in terms of the improvements in the amount of the crop harvested, the quality and ultimately the earnings that the smallholder obtains for the crop?

Mechanical harvest is considered to result in fewer in-field losses, especially since the timing in harvest is greatly reduced, but whether the crop losses that are saved by adopting mechanization are enough to cover the additional cost of using mechanized harvest should also be subject of further investigation.

The type of crop also plays a big role in this. For some crops, such as root crops like potatoes, timeliness of harvest may be less critical than in others like rice of maize, which are more susceptible to weather, pests and disease risks if left ripe in the field for too long. Therefore, the value to a smallholder of a quicker harvest period by mechanized operation is more pronounced where the risks of losses are highest.

A further dimension to mechanized harvest is that not much is known about the impact that the mechanized technology has on the quality of the harvested crop, or what amount of the crop is damaged and/or lost by comparison during the mechanized harvest process. This potentially leads to an additional “cost” to the smallholder for using mechanized harvesting technology over manual labor that should be further explored.

Again, depending on the sophistication of the technology employed and the type of crop being harvested, these losses or risks to quality may be more pronounced in some crops than others. Issues of greater bruising or damage to the crop caused by machine harvest may lead to quicker deterioration and lowering of quality that is reflected in the price received by the farmer, or a greater amount of the crop being rejected post-harvest. These dimensions also need to be considered given the impact this may have on what the farmer earns for the crop.

6. CONCLUSIONS

From the first phase of our study, availability of labor and associated labor wage rates has been a key driver towards mechanization adoption, especially in Thailand and India, where the agricultural labor supply is under pressure due to competition from the manufacturing sector.

However, adoption of mechanization for smallholders is still largely influenced by the type of operation, region and infrastructure, and the suitability of the crop to cost-effective means of mechanized processes.

In Africa, labor supply is generally higher, but with regional pressures driven mostly by the informal and formal service sector. Mechanization is not so widespread, but it is being adopted for certain operations in certain crops and regions. Ploughing and heavy cultivations, which require relatively similar techniques for most crops, are the most likely to be mechanized, whereas tasks that require more complex and specialized machines, such as planting and harvesting, are not as accessible or widespread.

The favored way for smallholders in both Asia and Africa to access mechanization is via contractor services. The price a contractor can charge for a mechanized ploughing service would appear to be influenced by competition, whether that be from other mechanized contractors, as is increasingly the case in most of the countries and crops studied, or the readily available manual alternative, as is the case in Kenya and Ethiopia. On a per-pass basis, the more standard heavy cultivation tasks like ploughing are also rather similar between countries and crops.

This is not the case in the operation of rice harvest, where availability of mechanized harvesters is not as common. Higher availability of mechanized harvesters means that the cost in Thailand and India is similar to manual harvest in Ghana and Tanzania, but contractor charges for mechanical harvest in Ghana or Tanzania is 40 – 50% more expensive than the manual alternative.

In crops such as sugarcane and potatoes, where mechanized planting and harvesting operations require specialist and expensive equipment, the majority of smallholder farmers use manual labor instead, even where labor costs are higher, such as in India. There is some adoption of mechanization within these operations in Thailand on larger farms, and especially where linked to out-grower programs with processors, although not yet a widespread and typical method for all smallholder farms.

7. NEXT STEPS

In all countries, it was clear that mechanized operations on smallholder farms were mostly carried out by contract service providers. We do not, however, have a detailed understanding of the profile of contractors in different regions.

Further study should therefore be undertaken to gain a better understanding of the profile of a typical contract service provider in each country. The following questions should be addressed:

- Are contractors larger farmers utilizing spare capacity in machines, or specialist operators?
- Is there a typical pathway or enabling environment that leads to becoming a contractor?
- How do contractors fund machinery purchases in each country?
- How competitive is the service and what are the risks?
- How profitable is it to offer contracting services?

At the same time, we should gain a greater understanding of the economic benefits for smallholders in using mechanical operations over manual ones, measured in terms of additional productivity and profit generation against the additional cost of using mechanized contractor services.

In particular, we should better understand the potential for increased yields, crop quality and crop resilience through timeliness of crop establishment operations, and what tasks have the biggest impact on those parameters.

In the case of mechanized harvesting technology, we should also consider a cost versus benefit analysis.

This should include not just the known costs implications for hiring these mechanized contractor services, but also a greater understanding of how utilization of the available technology might impact the quality and quantity of the harvested crop positively or negatively, when compared against the manual alternative, and whether that ultimately impacts on the price and/or income the smallholder receives.

In that way, we are able to provide quantitative judgement on the level of benefit to smallholders of mechanized adoption within each of the countries represented within the smallholder group.