Moving to Mechanisation

Mechanisation in maize farming systems in Kenya, Tanzania and Ethiopia

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Introduction

The need for sustainable intensification in sub-Saharan Africa (SSA) is widely recognized. Considerable emphasis is being placed on increasing the efficiency with which land, water and nutrients are being used, however farm power appears to be a 'forgotten resource'. A consequence of low farm mechanization is high labour drudgery throughout the production cycle. Sustainable intensification in SSA will require an increase in power supply via improved access to mechanization and/or a decrease in power demand via energy saving technologies such as conservation agriculture (CA).

This has led to increasing calls for research and interventions that will contribute to the growth of more productive and sustainable maize-based systems, which in turn will contribute to the livelihoods of rural producers. Agriculture in developing countries has traditionally relied on physical labour, limiting its productivity. However, increased mechanisation in agriculture can help reduce the dependency on physical labour, and give higher yields and food security (Sims & Kienzle 2006).

Over the past 50 years or so there has been phenomenal growth in the number of tractors in use in Asia, Latin America and the Caribbean (Mrmema et al 2008). However, the current state of mechanisation in SSA is one of underutilisation. SSA has the lowest uptake of mechanisation out of all the world regions and remains heavily dependent on manual labour.

The current state of mechanisation differs between the Sub-Saharan countries of Kenya, Tanzania and Ethiopia – the focal countries of this research. While large scale farms in these countries are often fully mechanised, millions of smallholders are non-mechanised, affecting their efficiency, production capacity, profits and food security. This lack of utilisation is not for lack of understanding the machines, but more the collapse of most government run tractor hire schemes and the loss of draught animals to disease or drought (Vergnani 2013).

Whilst in past decades promotion of mechanization in SSA has not been successful, there seem to be promising opportunities for mechanization at present (Sims & Kienzle 2006). Challenges in the past include (1) weak supportive infrastructure, (2) issues incorporating four-wheel tractors with small-scale farming, (3) a public sector focus and neglect of private sector engagement, and (4) supply rather than demand-driven introduction of mechanization. Improvements in infrastructure as well as increased viability of small scale mechanization, combined with more commercial orientation of smallholder farming, offer opportunities for renewed and innovative farming mechanization initiatives in the region.

Mechanisation is the term used to describe tools, implements and machines applied to improving the productivity of farm labour and land. It may be a combination of human, animal or motorised power utilised to do so (Sims et al 2006). Depending on 'what' is doing the powering, the technological levels of mechanisation can be either hand-tool, draught animal or mechanically powered technology.

With human power productivity is lower as the physical constraints can be limiting and the low range of tools hampers efficiency. It is also susceptible to health epidemics harming the pool of workers, or migration of workers away from farm work. Draught animals (oxen and horses being the most common) have traditionally been the most common form of mechanisation used by small scale farmers in Sub-Saharan Africa. However, animals remain vulnerable to famine or drought in the same way as human power. Mechanically powered technology can apply to any tool or machine which is powered by non-human or animal. It is most common in two wheel or four wheel tractor form, but applies also to grinding, pumping or any variety of farm work.

CIMMYT is involved in mechanisation projects aiming to promote the adoption of two wheel tractor (2WT) technology in Eastern and Southern Africa. By focussing on tasks which urgently need mechanisation, excess labour will be freed up to involve themselves in other agricultural practices. The FACASI project aims to test commercial two wheel tractors, with an estimated 35,000 farmers set to benefit from the project (Vergnani 2013). FACASI aims to contribute to sustainable agricultural intensification to meet the demand for increased agricultural production and improved food security, with minimum negative environmental and social consequences. Increased efficiency of using resources is key in this, and the FACASI project focuses on the 'forgotten resource': farm power. The rationale for the FACASI project is based on a recognition of (a) increasing labour shortages, (b) declining numbers of draft animals, and (c) high labour drudgery, with strong gender and youth dimensions.

The research presented in this paper should be considered as separate from the FACASI project, although many of the findings are likely to prove directly relevant to the project.

Outline of the paper

This paper first describes the prevailing maize farming system in the research areas in Kenya, Tanzania and Ethiopia. This includes a description of land availability and crop choices in each area, the use of fertilizer and expenditure on seed and other inputs, the availability and rates for labour per activity and a description of maize yields. This data is brought together in a maize crop budget which presents the profitability per acre for a smallholder in each of the research countries. This is followed by a description

of group organisation in the research areas, access to credit for smallholder farmers, and maize marketing channels.

The paper then focuses on mechanisation more specifically and describes current hiring behaviour in the research areas, costs of hiring mechanised services and farmer's reasons for hiring or not hiring these services. A regression analysis is also presented to show the factors most influencing hiring behaviour. This section leads into a discussion on the enabling environment for mechanisation in each of the three countries. Farmer challenges are then discussed in relation to mechanisation and conservation agriculture. We then present and discuss mechanisation models by which services could be supported and better extended to smallholder farmers. Finally, the paper offers key conclusions for policy makers, research institutes and practitioners looking to support the adoption of mechanisation in (maize-based) smallholder farming systems.

Methodology

The research was carried out by Roger Bymolt and Fred Zaal from the Royal Tropical Institute (KIT) in late 2014. Three countries were targeted for the research: Kenya, Tanzania and Ethiopia, as these are focal countries for CIMMYT, and countries where complementary research was also being conducted for the FACASI project[1].

The researchers first conducted a desk study, reviewing available literature on agricultural mechanisation in Sub-Saharan Africa, with a focus on the target countries.

Over the course of the fieldwork, 491 surveys were conducted across the three countries, with 163 conducted in Kenya, 154 in Tanzania and 174 in Ethiopia (Table 1, Figure 2). Whilst this is not a large sample size due to the resources available for the study, it was deemed to be satisfactory for describing smallholder maize farming and mechanisation adoption in the research areas. The sample was a purposive selection of farmers from areas where the FACASI project has started (or intends to start) activities. Surveys were conducted using digital tablets running ODK[2] to ensure enumerators collect data of high quality.

To complement the survey data, KIT conducted 20 focus group discussions across the countries in order to gather farmer perceptions around key issues in maize farming systems and mechanisation. Focus group discussions allowed the researchers to probe on the 'why' and 'how' questions and understanding the processes around mechanisation uptake. KIT also conducted 25 key informant interviews across the three countries (Table 2).

This research paper offers a detailed analysis of the smallholder maize farming system and factors that shape the articulation of demand for and adoption of mechanization.

[1] See http://facasi.act-africa.org/
[2] https://opendatakit.org/

Figure 1 Survey locations

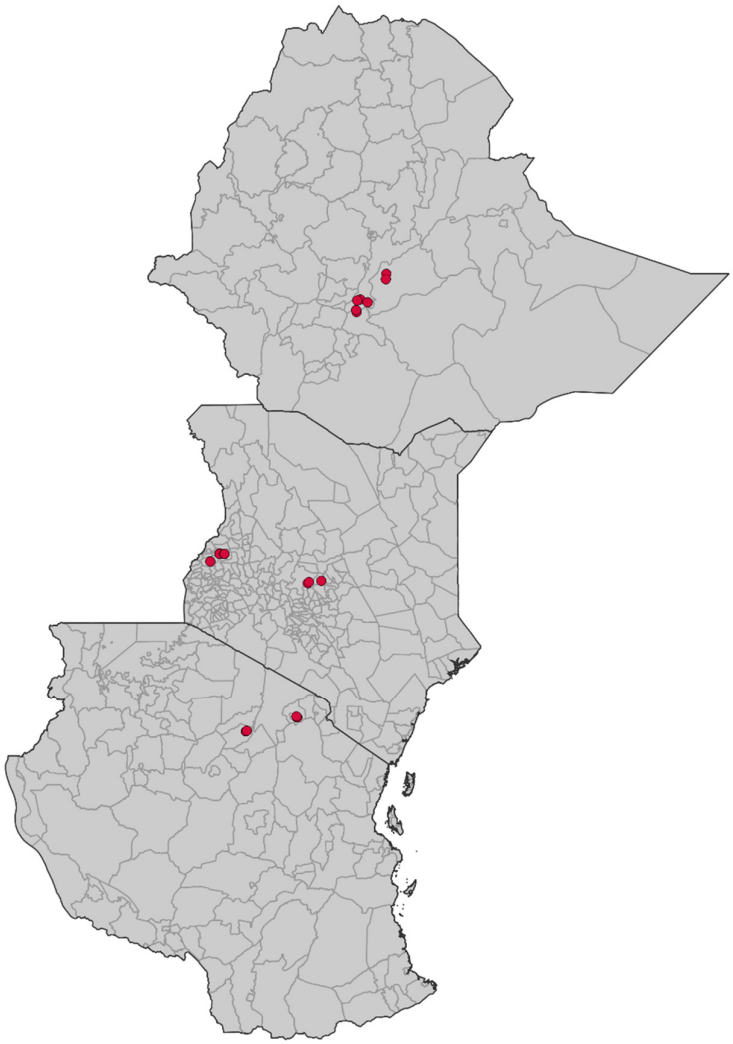

Table 1 Countries and districts surveys

Country	N	District	N
Kenya	163	Bungoma	85
		Meru	57
		Laikipia	21
Tanzania	154	Arumeru	75
		Mbulu	79
Ethiopia	174	Shashamane	18
		Hawassa_Zuriya	28
		Shala	44
		Tiyo	84
		Total	**491**

Table 2 List of interviews conducted

Organisation name	Type	Country
Tuuti Community Driven Development Training Centre	CBO	Kenya
Agricultural Technology Development. Centre (ATDC)	NGO	Kenya
Farm mechanisation and conservation agriculture for sustainable intensification (FACASI)	ACIAR project	Kenya
Kenya Network for Dissemination of Agricultural Technologies (KENDAT)	NGO network	Kenya
Car & General (C&G)	Agricultural machinery dealers	Kenya
Hollman brothers	Agricultural machinery dealers	Kenya
Selian Agricultural Research Institute (SARI)	Government research centre	Tanzania
Centre for Agricultural Mechanization and Rural Technologies (CAMARTEC)	Government research centre and extension	Tanzania
Ministry of Agriculture, Mbulu district	Government research centre and extension	Tanzania
PASS-TRUST	Private sector	Tanzania
Arsi Rural Development Unit (ARDU)	Core Process Owner	Ethiopia
Agricultural Transformation Agency (ATA) and METEC	Public enterprise	Ethiopia
Adama Agricultural Machinery Industry (METEC – AAMI)	Public enterprise	Ethiopia
ATC Ethio-German training centre	Irrigation case team, Seed multiplication specialist	Ethiopia
Melkassa Agricultural Research Center	Government research centre	Ethiopia
Center for Development Initiatives (CDI)	NGO	Ethiopia
International Maize and Wheat Improvement Center (CIMMYT)	International research institute	Ethiopia
Farm mechanisation and conservation agriculture for sustainable intensification (FACASI)	ACIAR project	Ethiopia
Woreda Agricultural Expert	Government research centre and extension	Ethiopia
Abosara Seed Cooperative	Seed cooperative, also providing hire services	Ethiopia
Oromiya Saving and Credit Association	Saving and Credit Association	Ethiopia
Ethiopian Institute of Agricultural Research, Wondo Genet Agricultural Research Center	Government research centre and extension	Ethiopia
TGT Enterprises	Machinery importer and dealer	Ethiopia
Solomon Garage	Local agricultural machinery maintenance	Ethiopia
Omega Automotive Engineering Service	Local agricultural machinery maintenance	Ethiopia
Hitossa Farmers' Cooperative Union	Union/Primary cooperative	Ethiopia
Bekelcha primary cooperative	Union/Primary cooperative	Ethiopia

The prevailing maize farming system

This section describes the prevailing smallholder maize farming system for respondents in our sample in Kenya, Tanzania and Ethiopia. It begins by presenting smallholder land holdings and land under maize, as well as predominant crops in each area. It then moves into a discussion on seed and chemical inputs, before describing and quantifying labour inputs. This is brought together at the end of the section with a cost/benefit analysis of producing maize per acre of land for smallholders in our sample. This serves to illustrate which activities farmers are currently investing in, and the resources available from maize profits to reinvest in subsequent seasons (including in mechanisation). The section concludes with a brief discussion on farmer organisation, access to credit and marketing realities.

Land and crops

The vast majority of respondents in the sample reported growing maize last season, as can be expected in a study focusing on maize farming households. This was followed by beans as the second most frequently grown crop. The frequency of reporting other crops grown was mostly due to district specificities. For example, among maize producing households, potato is common in the Kenyan and Ethiopian highlands, pigeon peas in Mbulu, Tanzania, fodder is common in Ethiopia (not just for dairy, but also for oxen), enset is widely grown in Hawassa Zuriya and Shashamane and wheat is the most common in Tiyo.

Last season, most households grew 4-7 crops in each of the three researched countries (Figure 2). Maize only accounts for 33% of total land size in the Kenya sample, 59% in Tanzania and 28% in Ethiopia (Table 4). This has obvious implications for policymakers and researchers considering interventions on maize mechanisation: cropping systems are relatively diverse and when mechanisation is suitable to more than one crop type then farmers are more likely to see it as a worthwhile investment option. For example, farmers would likely be interested in 2 wheel tractors equipped with implements for ploughing both maize and ridging for potatoes. Another example would be threshing machines that have sufficient horsepower to thresh not only maize but also teff in appropriate agro-ecological zones in Ethiopia. Policymakers should thus think about the prevailing farming systems in each context when considering how to increase mechanisation.

Table 3 Percentage of farmers growing each crop last season, per district

	Kenya				Tanzania		Ethiopia				
	Bungoma	Meru	Laikipia	Buuri	Arumeru	Mbulu	Hawassa Zuriya	Shala	Shashamane	Tiyo	Total %
Maize	76	84	90	100	96	95	96	93	89	81	88
Beans	84	61	76	63	77	82	25	18	17	92	69
Potatoes	2	90	81	100	3	0	64	27	72	83	38
Cabbages	8	35	19	25	1	0	61	30	56	54	24
Fodder	7	18	14	0	0	0	32	18	17	56	17
Enset	0	0	0	0	0	0	96	5	67	48	16
Millet	28	0	0	0	1	6	32	68	39	2	16
Peas	2	4	38	0	0	3	4	0	0	73	15
Pigeon peas	0	2	0	0	3	89	7	0	0	1	15
Teff	1	0	0	0	0	0	0	34	72	54	15
Bananas	49	20	0	0	1	4	21	0	0	2	13
Sweet potato	49	0	5	0	0	5	46	0	6	0	12
Tomatoes	5	2	0	0	53	0	7	2	17	10	12
Carrots	1	31	0	13	1	0	43	14	11	20	11
Kale	15	29	10	13	11	0	7	0	11	12	11
Onions	4	2	0	0	0	0	29	5	17	36	10
Wheat	0	0	0	0	0	0	0	0	0	100	8
Sugarcane	28	0	0	0	0	0	46	0	0	0	8
Cassava	28	0	0	0	1	0	0	0	0	0	5
Cowpea	2	2	0	0	0	0	32	11	0	4	4
Coffee	1	0	0	0	0	0	14	0	17	8	3
Groundnuts	13	0	0	13	0	1	0	0	0	0	3
Chickpea	0	0	0	0	0	0	4	0	0	12	2
Spinach	2	6	0	13	4	0	0	0	0	0	2

Note: cut-off is 2% of total farmers growing

Figure 2 Frequency, number of crops grown per household

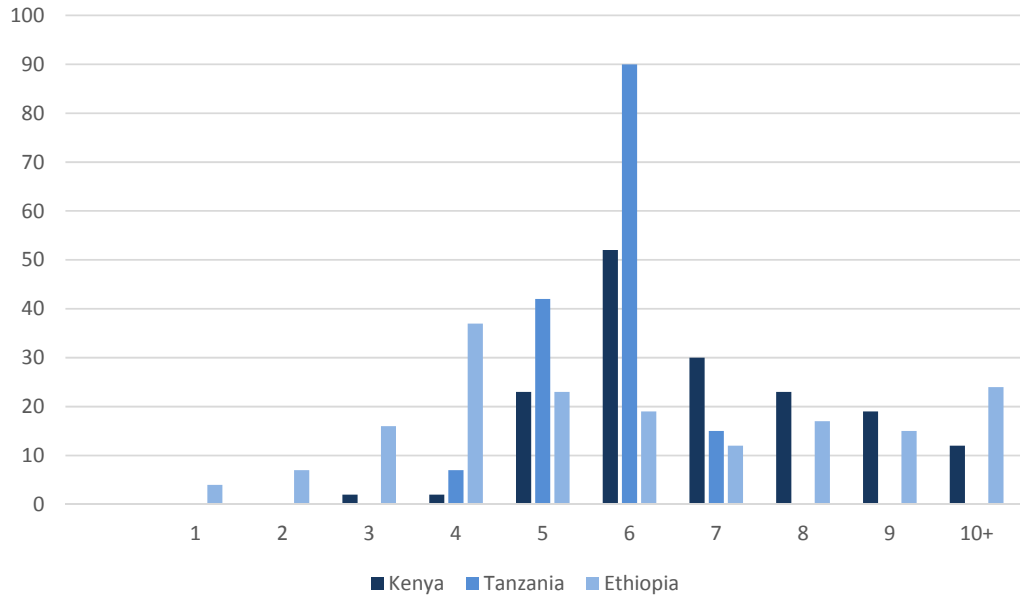

Table 4 Mean land sizes (ac)

	Kenya	Tanzania	Ethiopia	Ethiopia (ha)
Total land	6.07	3.66	7.44	3.01
Total land owned	5.19	3.01	5.44	2.20
Total land leased	0.87	0.65	2.00	0.81
Land under maize	1.98	2.16	2.05	0.83
% of total land under maize	33%	59%	28%	28%
Maize land owned	1.48	1.96	1.69	0.68
Maize land leased	0.57	0.37	0.42	0.17
Land under maize (calculated owned + leased)	2.05	2.33	2.11	0.85
% respondents leasing some land for maize	30%	25%	23%	23%

Kenya

In Kenya the study areas are relatively densely populated, and the population is growing fast. With an increasing population and smaller fields (mean ~6 acres) farmers are increasingly looking to shift to other, more rewarding farm enterprises (for example in Bungoma bananas, sweet potato, and sugarcane are popular). With land availability in decline and improvements in road infrastructure better linking markets, maize is 'competing' with other crops which may in fact be more profitable. This is reflected in our analysis with, on average, only around 2 acres (33%) of farmer's total land being allocated to maize. On average Kenyan farmers in our sample grew nearly 7 different crops last season (Figure 2).

Tanzania

In Tanzania, the study focussed on relatively densely populated areas. Population increases and subsequent land subdivision into smaller sized plots (mean 3.7 acres) has affected the availability of land and was reported as a problematic issue in focus group discussions. For this reason land under maize (mean 2.2 acres) is said to be in decline. Furthermore, with smaller land parcels farmers say they are increasingly looking to put more of their land under higher value crops, such as horticultural crops. Households report growing nearly 6 crops per season (5.73). Maize is not perceived as a very lucrative crop per acre (in terms of earnings/ costs). As land becomes more scarce due to population pressures, focus group participants say that land owning farmers are less willing to lease out some of it out to others. Large, or even medium scale operations (even those with more than 10 acres) have become less prevalent because of that.

Ethiopia

The land and crop situation in Ethiopia varies between geographical areas. Overall in our sample land sizes averaged 7.47 acres (3 hectares), and land under maize last season averaged about 2 acres (0.8 hectares). However around Tiyo woreda wheat is the dominant crop and land under maize only accounts for 0.29 hectares (0.72 acres), dragging down this average slightly. In some other areas maize is looked upon favourably because it is important for home consumption as well as a cash crop. Furthermore it suits most climates, is short cycle, resists diseases well and the work is said to be easy compared with other crops. Even the by-product is very often used; for example stems are feed for oxen. In saying this, farmers averaged growing about 6 different crops last season, again showing farm diversity.

Soils and fertilizer

Table 5 Percent of farmers purchasing fertilizer, seed, herbicides and pesticides for maize production last season

	Kenya	Tanzania	Ethiopia
Fertilizer	87%	38%	68%
Seed	83%	75%	63%
Herbicides	20%	4%	9%
Pesticides	40%	31%	13%

Table 6 Mean spend on fertilizer per acre for maize production last season

	Kenya		Tanzania		Ethiopia		Ethiopia (ha)	
	KSH	$US	TSH	$US	ETB	$US	ETB	$US
Mean (all farmers)	3951	43.23	18443	10.19	801	39.36	1977	97.23
Mean (of those buying fertilizer)	4203	45.99	47699	26.36	881	43.33	2177	107.03

Kenya

In Kenya, all focus groups complained about the decline in soil fertility. Lack of knowledge of appropriate fertilizer for respective farms, continuous cultivation, soil erosion and poor soil aeration are the major contributing factors to decline in soil fertility. The use of only one type of fertiliser (DAP) is said not to have improved the situation much (although a hidden issue may be correct volumes applied or application methods). Soil analysis services are scarce in the area and so are hardly used by farmers to understand the soil fertility situation on their farms. Farmers also interestingly mention the fact that the type of tillage they do often doesn't crack the hard pan that has developed: they would appreciate deeper ploughing to avoid this problem. In Kenya fertilizer is available to small farmers from the government through the National Accelerated Agricultural Input Program (NAAIP) at subsidized prices, sufficient for 1 acre of land per farmer. For example, 50kg of Diammonium Phosphate (DAP) is available at KSH 2,500 subsidized. If purchased from private traders without subsidies, it would cost around KSH 4000. NAAIP was initiated by the government of Kenya in 2007 and aims to promote food security, agricultural input use, input market development, and agricultural productivity. Previously subsidised fertilizer was only available via National Cereal Produce Board (NCPB) warehouses, but now vouchers are issued to target disadvantaged households with land, and subsequent redemption through private input sellers who would also be eligible for trade credit guarantees[3]. Three out of five groups (Kibiricha, Laikipia East and Ontulili) mentioned that there has been an increase in the number of farm

[3] See more: Druilhe, Z., Barreiro-Hurlé, J. (2012) Fertilizer subsidies in sub-Saharan Africa. FAO available from http://www.fao.org/3/a-ap077e.pdf and Recommendations to the African Union Commission, Regional Economic Communities, and Country Decision-Makers from an Expert Technical Convening, Addis Ababa,2013i, available from http://agrilinks.org/sites/default/files/resource/files/Document%201%20DAtwood%20post%20Summary%20Note.pdf

inputs stockists and that they believe this to have come about due to the subsidy and an increase in fertilizer availability (94% reported buying at least some fertilizer last season). The negative side of this increase in availability is that it is reported to have led to an increase in the supply of fake inputs. There have been delays in the delivery of subsidized fertilizer as well, which hampered farmers in the use of them and reduced the impact of fertilizer on yields. The researchers initially suspected that 87% of Kenyan farmers reporting buying fertilizer is on the high side, largely because farmers were sampled from farmer organisations who might be interested in mechanisation, and hence may be of slightly higher capacity than the average Kenyan farmer. However, recent research by Sheahan, Black & Jayne (2012)[4] found that in their nationwide sample over 90 percent of smallholder farmers in western Kenya use fertilizer on fields containing maize.

Tanzania

In Tanzania, as elsewhere, the continuous cultivation of agricultural lands is said to have caused a decline in the fertility of the soil and thus the yields of maize. Soil erosion and lack of training on soil fertility management have also been contributing factors to a general decline in soil fertility. In focus groups farmers did say they tried to apply animal manure 'once in a while'[5], although this does not appear to be systematic. Tanzania groups did however note that there has been a recent positive change in input availability. This, despite the percentage of farmers spending money on fertilizer for maize in Tanzania (38%) being considerably lower than for the Kenya and Ethiopia samples. Participants attributed this to efforts by government (noted by all groups) and other development agencies promoting capacity building and good agricultural practices. The government is said to have provided subsidized inputs to farmers through local stockists for the past three seasons. This has attracted Agrovets to invest in shops and improved provision of various inputs.

Ethiopia

Soils varied across the research area – in Shala the land was described as 'soft' or 'medium' whereas in Assella and Tiyo the land was described as very heavy. Heavy land was said to have implications for tractorisation as farmers didn't want to rent out tractors to plough heavy land that could break implements and cause undue stress to the machines. This has obvious implications for governments, development agencies or private investors looking to expand mechanisation – if implements are easily damaged then this a serious risk to mechanisation investment and uptake. In Ethiopia the majority of farmers said they were using fertilizers as part of a 'full package' of 1 quintal of DAP (1240 ETB) and 1 quintal of urea (960 ETB) per hectare. The 'full package' also includes a basic set of trainings on row planting and ploughing. The package is supplied to farmers from the government, through unions, and

[4] Sheahan. M., Black. R., Jayne, T (2012) *Are farmers under-utilizing fertilizer? Evidence from Kenya.* Available from http://ageconsearch.umn.edu/bitstream/126739/2/SheahanEtAl.pdf

[5] Detailed data on manure not available.

down through farmer cooperatives. In Ethiopia, virtually all respondents described in focus groups big changes in maize production in the past 10 years. Yields were reported to have greatly improved due to increased training and knowledge, better provision of fertilizer and supply of improved seeds. Maize farmers are broadly positive about these changes and last season 68% of farmers reported buying fertilizer. There are of course challenges – timeliness of delivery was occasionally mentioned, as was a need for further training on optimal application. However these challenges were not ranked particularly high by focus group respondents, perhaps indicating that the present strategy is on track, provided ongoing training and backstopping is available.

Maize seed

Table 7 Mean expenditure of farmers on maize seed, last season

	Kenya		Tanzania		Ethiopia		Ethiopia (ha)	
	KSH	$US	TSH	$US	ETB	$US	ETB	$US
Mean (all farmers)	1325	14.50	23078	12.76	261	12.81	644	31.65
Mean (of those buying seed)	1461	15.99	30102	16.64	311	15.28	768	37.75

Kenya

Most Kenyan farmers bought seed last season (83%) rather than recycling from their own farms. Several seed companies are active in the market including Pannar seed, Monsanto and Seedco. Agrodealers have also been increasing in number, bringing new varieties closer to farmers. This has led to greater availability of seed throughout the year and the more widespread introduction of drought resistant varieties. However, there has also been an increase in several varieties of counterfeit maize seed, which has resulted in poor yields for some farmers. In the flow of new company names and varieties, counterfeit seeds can maintain a niche and disappoint farmers. Farmers in Kenya say they need time to get to know the behaviour of these new seeds: innovations cannot just be adopted overnight. In the Laikipia area for example, farmer's experience is that new early maturing varieties cannot be stored for a long time compared to late maturing varieties. These farmers still prefer H614D which is not very suitable for prevailing conditions since the area is a dry highland and is on the leeward side of Mt. Kenya. The end result is that low yields are harvested. Some of the new varieties on the market do poorly compared to others while some are bitter when roasted. So while all groups have stated that seeds and new varieties are increasingly available, there are all kinds of issues around their introduction, and adapting farming systems to seed innovations takes a certain amount of time.

Tanzania

The percentage of Tanzanian farmers buying seed last season was 75%, suggesting the majority are using improved varieties promoted by the government. In Tanzania farmers mentioned an increased number of seed companies present in the area. Seed companies from a number of countries (Kenya, Mozambique, Uganda) were now operating in Tanzania including Monsanto, SeedCo, Pannar and Kibo Seed Company. The Serian Research Institute also distributed seeds mainly used for demonstrations. In the recent past, the majority of farmers used their own saved seed, which is typically less resistant to droughts, maize borer and other pests. The use of improved seed varieties is anecdotally said to have increased yields, and most groups reported up to a doubling of yields when improved seeds were used compared with recycling unimproved varieties. However, not everyone in Tanzania can afford to buy and use those improved seeds. Most groups state that farmers often struggle to buy seeds during planting season affecting uptake. Prices of maize seed were TZS 7,500 (per 2 kg bags) but are currently TZS 9,000 on the open market. Though the government supplies subsidized seeds for TZS 2,000 per 2 kilogrammes, availability is limited and delivery said to be frequently late. Some farmers thus resort to saved seed which goes for around TZS 2,000 per 4 kilogrammes, but has lower yields.

Ethiopia

In Ethiopia, improved maize seed is relatively common for those who are members of farmer cooperatives. Last season 63% of respondents reported purchasing seed, which was lower than buying rates in Kenya and Tanzania. Improved seed is sourced through the cooperatives via either the unions or from government owned companies such as Oromia Seed Enterprises (OSE). In Shala, Raya is most common followed by BH543. Other common varieties are BH540, Pioneer, Shone and Limu. According to farmers the varieties available are frequently changing. In Hawassa Zuria, Shonee and Limu are the main varieties and cost 465ETB/12.5kgs. BH540 costs 288ETB/12.5 kgs however farmers in this area say BH540 is not sufficiently disease resistant. At Kebele level administrators identify farmer needs and collect money for the seed through the farmer cooperative. OSE provides farmers with C1 seed which is later delivered to the village, in what is said to be a reasonably efficient process. Farmers report satisfactory germination rates of 85% or more. Their only reservation is that volumes of seed supplied are occasionally inadequate. In Shala the main variety is Raya. A major change in most of the Ethiopian research areas compared with 10 or even 5 years ago is that farmers say they are now planting in rows (80cm between rows, 40cm between plants), whereas before they were broadcasting. This is due to training received from government extension in cooperation with the farmer organisations. However, in one village in Sheshamane, there appears to be an isolated case whereby previously excellent seed (Baco660, yielding ~40 quintal/hect) has been replaced with a much poorer performing later generation of the same variety. Apparently the authorities are aware, and have done some soil testing for the past 2 seasons, but no one seems sure of the problem. Either way, the result is that farmers in the village of

Ilala Korke have said that they were forced to reduce their land under maize from around 2 hectares to 0.5 or so and have moved into wheat, threatening the farmers organisation that previously engaged in group marketing of maize and has had to shift into wheat marketing.

Other inputs

Pesticide use was highest in Kenya among the researched countries (40%), as was herbicide use, despite overall low adoption rates (20%). Tanzania reported 31% of farmers using pesticides, but only 4% using herbicides. Pesticide use in Ethiopia was the lowest of any of the studied countries (9%), and only 9% of herbicide uptake (see Table 5). The low uptake of herbicides in particular is an important issue for the successful promotion of conservation agriculture (CA). This point will be expanded on in the CA section (Table 5).

Labour

Labour availability

The availability of labour, or lack thereof, is sometimes cited as a reason emphasising the need for increasing mechanisation. However, in our survey data we find that in the Kenyan and Tanzanian samples, that the majority of respondents feel that labour is 'easily available'. In Kenya, only 9% of respondents say that labour is difficult to find, and 3% in Tanzania. In Ethiopia the perception among respondents was different – only 26% said that labour was easily available, with 31% saying that it was difficult to find (Table 8).

Table 8 Perceptions on availability of labour

	Kenya	Tanzania	Ethiopia
Difficult to find	9%	3%	31%
Sometimes difficult to find	25%	26%	43%
Easily available	66%	71%	26%
n	152	148	159

The survey question was: How easy is it to find the hired and shared labour you need, when you need it, for your MAIZE crop?

Hired labour rates

In Kenya and Tanzania the majority of households (67% and 68%) used at least some hired labour for maize. In both of these countries, focus group participants mentioned that a large rural population and high unemployment means that labour availability is good, triangulating with our survey data (Table

8). Also participants said that it is not uncommon for labourers to temporarily migrate for seasonal work from other parts of the country.

In Ethiopia, considerably fewer households (44%) hired labour for maize last season. One reason for this difference with Kenya and Tanzania is that the Ethiopian research areas in Tiyo were predominantly wheat areas with small maize plots (0.29 hectares, 0.7 acres) that can mostly be tended by the household. In Tiyo (80%) said that they did not hire labour for maize last season, distorting this picture for Ethiopia. In saying this, when we filter for land sizes larger than 3 acres/ 1.2 ha, Ethiopia still exhibits a much lower prevalence of households paying for hired labour for maize (54%) than in Kenya (82%) and Tanzania (83%). In focus groups, Ethiopian respondents indicated that most households can manage 1 hectare (2.47 acres) without hiring additional labour at any one time in the season. One reason that hired labour rates are lower in Ethiopia may be that hired labour is somewhat more difficult to find, as discussed earlier (Table 8). Another is the cost of hiring labour (Table 12 and Table 13).

Table 9 Percentage of households paying for hired labour for maize last season

	Kenya	Tanzania	Ethiopia
Yes	67%	68%	44%
No	33%	32%	56%
n	*163*	*154*	*174*

Table 10 Percentage of households paying for hired labour for maize last season (minimum 3 acres, 1.2 ha)

	Kenya	Tanzania	Ethiopia
Yes	82%	83%	54%
No	18%	17%	46%
n	*28*	*18*	*50*

Table 11 Percentage of households hiring at least some labour last season, per maize activity

	Kenya	Tanzania	Ethiopia	Total
Land preparation	59%	58%	32%	54%
Planting	66%	58%	40%	58%
Weeding	65%	64%	58%	63%
Harvesting & Transport	69%	72%	67%	70%
Shelling	n/a	n/a	n/a	n/a

Hired labour costs

Hired labour costs were reported to be the same for male and female labourers (i.e. within the standard error) in both Kenya and Tanzania. In Ethiopia, female labourers were found to be paid about 10% less

than male labourers. The reason for this difference is not clear but may reflect the more heavy work that male labourers are perceived to do, or simply discrimination.

Table 12 Labour costs per day (male)

	Mean (local currency)	Mean US$	Std. Err.	LCI	UCI
Kenya (KES)	277	3.02	34	210	345
Tanzania (TZS)	5950	3.37	228	5501	6398
Ethiopia (ETB)	50	2.46	1	48	52

Table 13 Labour costs per day (female)

	Mean (local currency)	Mean US$	Std. Err.	LCI	UCI
Kenya (KES)	269	2.94	34	203	335
Tanzania (TZS)	6058	3.43	234	5597	6520
Ethiopia (ETB)	45	2.21	1	42	47

US$ rate as of 1 January 2015

Labour per activity

Labour inputs can be analysed per activity, and separated by household and hired labour. Table 14 shows that total labour inputs per acre for Kenya (41 days) and Tanzania (43 days) are rather similar (and within the standard error), whereas the reported labour inputs per Ethiopia are slightly higher (53 days). There are several possible explanations for this difference such as different climates and a longer growing season in Ethiopia. The main difference is in the harvesting & transport days. One reason may be that the enumerator team conducting surveys in Kenya and Tanzania did not clearly ask about harvesting *and* transport to storage, whereas in Ethiopia this distinction was more clearly made. In hindsight, these activities should have been listed separately for clarity, even though respondents often prefer to discuss them together. Regardless, this data is interesting for seeing where the main labour inputs are in the maize cycle. This of course has implications for where mechanisation, or other technologies, can ease labour burden. Table 15 is also important for understanding the mean division between household and hired labour. This clearly shows that land preparation has a higher household-hired labour ratio for all countries than, say, harvesting for which the ratio is approaching 1-1.

Table 14 Crop budget for maize - mean total labour days per activity (hired + household labour) per acre

	Kenya	Tanzania	Ethiopia	Ethiopia (ha)
Land preparation	8.00	7.16	9.91	24.49
Planting	5.52	5.35	6.31	15.58
Fertilizer application	1.00	1.00	1.00	2.47
Weeding	11.51	13.12	13.93	34.40
Harvesting and transport	7.14	8.24	13.76	33.98
Threshing	8.00	8.00	8.00	20.00
Totals	**41.16**	**42.88**	**53.00**	**130.92**

The above table shows data from the household survey on the amount of labour days used for various maize production activities (hired + household labour). For example, 2 persons doing an activity for 3 days would be 6 labour days. Notes: 'Land preparation' (ie clearing, ploughing) usually includes multiple ploughs, with the labourer either doing manual ploughing or managing oxen. 'Planting' includes the last pass of discing the soil and planting at the same time. Fertilizer application data is taken from the focus group dataset. Weeding data is the sum of several weeding moments. Harvesting *should include transport to the homestead but may be under-estimated for Kenya and Tanzania due to the way enumerators asked the question. In hindsight harvesting and transport categories should have been separated. Threshing data is taken from the focus group dataset. Herbicide and pesticide application is not included due to low prevalence of use.

Table 15 Farm budget - breakdown of household and hired labour days per activity per acre

	Kenya			Tanzania			Ethiopia			Ethiopia (ha)	
	hh	hired	ratio	hh	hired	ratio	hh	hired	ratio	hh	hired
Land preparation	6.09	1.95	3.12	5.71	2.64	2.16	6.38	1.87	3.42	15.77	4.61
Planting	3.26	2.51	1.30	3.52	2.37	1.48	5.05	1.56	3.23	12.47	3.86
Fertilizer app.	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Weeding	7.68	4.70	1.64	8.65	5.18	1.67	7.23	5.06	1.43	17.85	12.51
Harvesting	3.78	3.38	1.12	4.99	3.65	1.37	7.26	7.21	1.01	17.94	17.81
Threshing	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

Fertilizer and threshing household and hired labour breakdown not available, see totals given in Table 14. Mean days include '0's', i.e. those farmers who purchased no hired labour last season.

Knowledge and record keeping

Farmers in our sample generally had a positive self-perception of their knowledge on maize production (Table 16). This is perhaps unsurprising as our sample largely consisted of farmers who were organised into groups or cooperatives, and were not extremely remote. Kenyan farmers had the most positive self-perceptions of knowledge and Ethiopian farmers the lowest. In saying this, the farmers in the Ethiopian sample frequently reflected in focus group discussions that they have been getting more support in the past 10 or so years and that they feel that they have been making improvements in farming practices. Few farmers kept detailed records and the big majority keep no records whatsoever (Table 17). This lack of records is a potential issue when smallholders seek finance and wish to make a strong business case to lenders. Access to credit is usually an issue for smallholders, even when borrowing as a group

and paying a deposit. Reliable records helps to show a client is credit worthy, and that the investments that they intend to make will generate a return that will allow the lender to make the repayment.

Table 16 Farmer self-perception of maize production knowledge

Perceptions of knowledge	Kenya	Tanzania	Ethiopia
Poor	1%	6%	20%
Not sufficient	13%	10%	17%
Adequate	24%	39%	25%
Good	28%	38%	26%
Very good	34%	6%	12%
n	163	154	150

Table 17 Percent of farmers keeping records

	Kenya	Tanzania	Ethiopia
No records kept	63%	75%	68%
Yes basic records	26%	18%	30%
Yes detailed records	10%	8%	2%
n	163	154	166

Maize yields

Table 18 Maize yields last season (2014) (kg/acre)

Last season	Mean	Std. Err.	[95% Conf. Interval]	
Kenya	852	51	751	953
Tanzania	882	44	797	968
Ethiopia	1713	87	1543	1883
Ethiopia (ha)	4231	214	3811	4652

Table 19 Maize yields in a recent good season (kg/acre)

Good season	Mean	Std. Err.	[95% Conf. Interval]	
Kenya	1795	70	1656	1933
Tanzania	1630	61	1511	1749
Ethiopia	2341	85	2173	2509
Ethiopia (ha)	5782	211	5366	6197

Table 20 Maize yields in a recent bad season (kg/acre)

Bad season	Mean	Std. Err.	[95% Conf.	Interval]
Kenya	519	34	452	586
Tanzania	553	31	493	614
Ethiopia	1023	70	886	1159
Ethiopia (ha)	2526	172	2188	2864

Table 21 Maize yields - bad season, last season, good season (kg/acre)

Country	Bad season	Last season 2014	Good season
Kenya	519	852	1795
Tanzania	553	882	1630
Ethiopia	1023	1713	2341
Ethiopia (ha)	2526	4231	5782

Kenya

In Kenya, all groups except the Tongaren group reported a decline in maize production over recent seasons (in Tongaren a poverty eradication programme supported farmers in maize growing). Factors that have contributed include an increase in population resulting in smaller farmers and smaller maize fields but also a shift to other crops. The Ministry of Agriculture was also said to have advised farmers to diversify from maize for the next few seasons until maize lethal necrosis disease (MLN) is under control[6]. Other farm enterprises such as livestock production have also led to reduced land under maize. Yields are also said to have declined due to various factors such as frequently erratic rainfall patterns, decline in soil fertility, as well as the high cost of inputs forcing some farmers to use saved seed and less fertilizer. Apart from this, an increase in the prevalence of fake inputs in the market is said to have stunted growth of maize crops and resulted in low yields. Unverified reports by the Laikipia East group mentioned deforestation as having led to less pollination (fewer bees and birds are currently seen) and thus lower yields for some crops. Other issues mentioned were labour shortages for some farmers and diseases affecting maize. Last season (2014) Kenyan maize yields were reported among our sample as 852kg/acre. This compares with 519kg/acre in recent 'bad seasons' and 1795kg/acre in a 'good season'.

Tanzania

Tanzanian farmers gave sometimes conflicting reports on recent production levels and yields. On the one hand, some farmer maintained that yields had recently fallen, with the causes variously being attributed to changing weather patterns, Maize Lethal Necrosis Disease (MLND), increases in prices of inputs (forcing some to use saved seed and not using fertilizers thereby getting low yields), and floods water logging maize fields. However some Kenyan farmers mentioned an increase in recent yields due

[6] See news reports such as http://www.bloomberg.com/news/articles/2014-10-22/kenyan-corn-disease-outbreak-may-cut-production-by-30-this-year and http://www.standardmedia.co.ke/article/2000152411/researchers-work-round-the-clock-to-control-maize-disease

to the use of improved seed and training on Good Agricultural Practices (GAP) although some of the improved varieties are said to have had poorer germination rates than expected. Last season (2014) Tanzanian maize yields were reported among our sample as 882kg/acre. This compares with 553kg/acre in recent 'bad seasons' and 1630kg/acre in a 'good season'.

Ethiopia

In Ethiopia, maize was not the main crop around Assella, which is in the wheat belt. Maize was included in the sample because it is in the FACASI[7] project implementation area. Apparently around 10 years ago there was no maize here due to the altitude but with the introduction of BH660 seed and changing weather patterns maize is now grown here in small plots (0.25-0.5 hectares) for household consumption. In the other research areas maize is the dominant crop. Around Aje, farmers report very large increases in maize yields (around three times higher) over the past 10 years or so. Similar increases are also reported around Hawassa Zuria and Sheshemene. The reasons for this are widely reported to be due to abandoning poor practices, such as broadcasting seed. Instead there have been clearly described improvements in government extension and support from NGOs, particularly around *regular* training on good agricultural practices, and sharing this knowledge via model farmers (1 model farmer to 5 'normal' farmers). Farmer cooperatives seems to be playing a role here as model farmers are cooperative members, and government extension gives training at cooperative facilities. Farmers reported in some detail the dimensions of row planting (80x40cm), the number of times recommended to plough (3-4), crop rotation with haricot bean, seasonal timing of activities and preferred seed varieties. Last season (2014) Ethiopian maize yields were reported among our sample as 1713kg/acre (4231/ha), which is considerably higher those that reported in Kenya and Tanzania. This compares with 1023 kg/acre (2526 kg/ha) in recent 'bad seasons' and 2341 kg/acre (5782 kg/ha) in a 'good season'.

Maize crop budget

The following describes the *average* maize crop budget for each of the studied countries. This provides an approximation of maize farm costs (input costs and labour), revenues (yield * price, + additions), and overall profitability per acre. Such a model gives an insight into the available financial resources that a farmer may wish to invest in maize mechanisation or other inputs. The model comes with several caveats (see notes under the table).

[7] http://aciar.gov.au/aifsc/projects/farm-mechanisation-and-conservation-agriculture-sustainable-intensification-facasi

Table 22 Profit model for maize farming in Kenya, Tanzania and Ethiopia, per acre

	Kenya		Tanzania		Ethiopia	
	KSH	**$US**	**TZS**	**$US**	**ETB**	**$US**
Labour: land preparation (3 ploughs)	2215	24.24	42589	23.54	496	24.37
Labour: Planting	1530	16.74	31860	17.61	315	15.51
Labour: Fertilizer application	277	3.03	5950	3.29	50	2.46
Labour: Weeding	3187	34.88	78071	43.15	696	34.24
Labour: Harvesting	1977	21.63	49046	27.11	688	33.82
Labour: Threshing	2216	24.25	47600	26.31	405	19.91
Subtotal labour costs	***11402***	***124.76***	***255116***	***141.01***	***2650***	***130.30***
Input: Oxen plough	3000	32.83	30000	16.58	800	39.33
Input: Seed	1325	14.50	23078	12.76	261	12.81
Input: Fertilizers (DAP + urea)	3951	43.23	18443	10.19	607	29.86
Input: Pesticides	394	4.31	4036	2.23	36	1.76
Input: Herbicides	184	2.01	611	0.34	24	1.20
Transport to threshing point/homestead	800	8.75	15000	8.29	101	4.98
Sacks	1200	13.13	15000	8.29	162	7.96
Subtotal input costs	***10854***	***118.77***	***106168***	***58.68***	***1991***	***97.91***
Total costs	**22256**	**243.53**	**361284**	**199.68**	**4641**	**228.21**
Yield/acre	852	852	882	882	1713	1713
Average price kg	31	0.34	350	0.19	5	0.22
Additional: Cobs, stems, ears	3107	34.00	61515	34.00	700	34.42
Total revenue (yield*price)+additional	**29783**	**325.89**	**370215**	**204.62**	**8528**	**419.32**
Profit	**7527**	**82.36**	**8931**	**4.94**	**3887**	**191.11**
Profit ex labour costs	**18929**	**207.13**	**264048**	**145.94**	**6537**	**321.42**

Costs are separated in two groups – labour costs and input costs. For labour costs we use mean labour days per acre (Table 14) * mean hired labour daily rate (Table 12) for each country. In reality households use a range of labour strategies – for example all hired, all household, or a mix. The hired labour rate is used as a convenient proxy for all labour, since household labour is also an opportunity cost (for example, one could work exclusively as a farm labourer instead). The end profit calculations are given both with and without labour included.

For input costs, the means are taken from the survey data, but were also cross checked with the qualitative focus group farm budget data to ensure they are within a realistic range. Where few households paid for certain inputs last season, these means are dragged down. For those households which did buy all of the recommended inputs however (such as clean seed and fertilizer) their actual costs will be higher, which should be reflected in higher yields also. Data on oxen ploughs, transport (e.g. donkeys), and sacks (gunny bags) has been taken from the participatory budgeting exercise in the focus group discussions. The oxen plough hire rates have been used for all farmers, even though the majority of farmers in our Ethiopian sample owned their oxen. For Ethiopian farmers, this oxen hire rate is a proxy for the investment capital required and the year round running costs (particularly feed) which were reported at around 200 ETB/month ($US10).

Revenue is calculated from yield per acre (Table 18, Table 21) * common price paid to farmers per kg (Table 31). Additional revenue from cobs, stems, and ears is also included, which is usually sold or utilized at home for animal feed. Unfortunately this additional revenue calculation was only available for the Ethiopia dataset, and this value was extrapolated as a rough proxy for the Kenya and Tanzania cases.

Return to labour

Another way to look at profitability for smallholders who use considerable household labour, is to calculate the return to labour. This is essentially (revenue – non-labour input costs) / labour days. In all cases the return to labour (Table 23) is higher than the mean daily hired labour rate per country (Table 12, Table 13), as one would expect, although it was only marginally higher in Tanzania. (If the return to labour was lower than the daily hired labour rate then technically it would be more profitable to be a hired labourer provided sufficient work was available).

This suggests that the cost of plough hire services would need to be in the region of *return to labour rate * land preparation days,* to make it cost competitive in relation to manual labour or animal traction. This means competitive rates for three ploughs per acre would be around: Kenya 3680 KSH; Tanzania 44091 TZS; Ethiopia 1218.93 ETB. (If we instead use *hired labour rate * land preparation days* then the competitive rate would be even lower). In reality, these calculated competitive rates per acre are about the cost of hiring a tractor for only a single plough: Kenya 3070 KSH; Tanzania 44590 TZS; Ethiopia 1161 ETB. Additional ploughs are still required after one tractor pass (Table 36).

Of course there are also other factors influencing farmer's desires to mechanise such as ploughing quality, or easier subsequent ploughs using manual labour or animal traction. This calculation simply gives an indication of what farmers consider to be competitive pricing between different means of ploughing.

Table 23 Return to labour, value per day of labour

	Kenya		Tanzania		Ethiopia	
	KSH	$US	TZS	$US	ETB	$US
Profit ex labour costs	18929	207.13	264048	145.94	6537	321.42
Labour days	41.16	41.16	42.88	42.88	53	53
Return to labour	460	5.03	6158	3.40	123	6.06

Unions, cooperatives and farmer groups

Table 24 Percent of respondents in a registered cooperative

	Kenya	Tanzania	Ethiopia
Percent	41%	29%	78%
n	163	154	174

Tanzania

Among the Tanzania sample there was little reference to farmer groups, other than credit groups, however it was inferred that there has been an increase in farmer cooperative membership in recent years in the research areas. In our sample Tanzania had the lowest membership of respondents in registered cooperatives (29%). No groups in our sample were reported to offer tractor hiring services.

Kenya

In Kenya farmers reported that 'challenges in life' have led to the formation of more groups to help one another. This is despite reluctance to join these groups because of membership costs. A few reasons were offered for this, the most important of which being that training and capacity building from government and other organizations is often channelled through farmers groups. Groups are also formed as a means to obtain credit from SACCO's are a popular type of group formed. Finally, a desire for the acquisition of knowledge from one another has motivated people to join these groups. 41% of Kenyan respondents in the study reported being a member of a registered cooperative. This is lower than expected given that the purposive sampling used in the study meant that respondents were largely called by the cooperatives. This actually shows how farmers can be non-members (especially non-paying members) but still affiliated with the cooperative and its members, and can glean knowledge from this. No groups in our sample were reported to offer tractor hiring services.

Ethiopia

In Ethiopia, group organisation appears to be stronger than in Kenya and Tanzania. There are many established cooperatives in each kebele, and these usually come under the umbrella of a large union. Unions can have tens of thousands of members, dozens of cooperatives under them and have a high capacity to distribute inputs and other services from the government to cooperatives. In Ethiopia, around Assella the cooperatives are wheat cooperatives as there is little maize grown in these areas. In the kebele around Hawassa, we found fairly low capacity maize cooperatives, which speaks of the relative remoteness of the areas visited, the relatively poor road infrastructure linking to the towns, and the small size of land plots. In the kebele around Sheshamene, we found some strong cooperatives who

have been supported by the NGO CDI for 5 to 10 years, although one cooperative appears to have suffered from government interference and is now considerably weaker.

The function of most of the Ethiopian cooperatives is to provide seed and fertilizer to farmer members, as well as being a conduit for government extension or NGO support. In some cases farm inputs can be bought on credit, however none of the cooperatives have a savings and loans function. Around Hawassa farmers spoke of how they used to be able to buy inputs on credit but now the union asks for payment up front. In general most cooperative members said that the timeliness, volumes supplied and quality of inputs was sufficient, even if there was some discontent with rising prices. Farmers say that it is necessary to buy clean seed each year as recycled seed was said to perform poorly, with around 20-30% lower yields. Two of the three cooperatives around Sheshamene had grown in strength so that they could successfully do group marketing, buying from their members and selling on through the larger unions.

Only one of the cooperatives visited in Ethiopia own or have preferential access to mechanisation. While there is demand from farmers for mechanisation, there must be serious doubts whether most cooperatives could manage this efficiently or equitably, as farmers themselves recognised. The idea of cooperatives maintaining tractors was dismissed by some: 'the cooperative cannot even look after an oxen!'.

There were exceptions – two of the cooperatives in the Sheshamene area appeared to be of sufficient capacity, built up through the years with intensive support from CDI (NGO) and the government. They have built up a track record, performing well with input supply to members, engage in successful group marketing, and have an impressive block store (although not sufficiently large to keep tractors as well). It would seem that if cooperatives are going to manage mechanisation then they would need such a proven track record, including experience in financial management (see more: Mechanisation models p.65).

In Ethiopia, cooperatives and unions can experience quite some challenges affecting their membership. The most frequently (and obliquely) referred to challenge is 'government interference'. According to cooperatives but also other value chain actors (names withheld) the government on the one hand wants cooperatives to succeed in better supporting farmers to boost yields and profitability. But on the other hand are seen as political entities, and government wants to retain control over them by, for example, embedding their own people within the leadership. The point is that if increased mechanisation is to be advanced via cooperatives, government at various levels needs to be on board.

Box 1 Case study: Abosara Seed Cooperative

The following case study of the Abosara Seed Cooperative in the kabele 'Abosara Alko' in Ethiopia is illustrative of the challenges and opportunities for secondary cooperatives to invest in mechanisation. The case study has been developed from an in-depth interview with the chairman of the cooperative.

Abosara began as a seed cooperative only two years ago in 2012. The cooperative was kick started with only 15 close knit members comprising family and friends. Members agreed to each invest 15000 ETB (US$745) into the cooperatives accounts as membership and start-up capital for the cooperative. This start-up investment totalled 225,000 ETB (US$11,160). The original idea was for the cooperative to multiply basic seed supplied by the Ethiopian Seed Enterprise with an agreement to sell this back as C1 seed (generation 1), with the intention of turning a profit for the cooperative, whilst supporting the provision of quality seed to the area. This has been a successful enterprise and continues to this day.

In 2014, the cooperative decided to diversify and looked into investing in a 4 wheel tractor. Having made their own plans and projections, the small cooperative visited the Woreda seeking a letter of support from the Head Administrator, which was given. Together, the Woreda representatives and the cooperative leader visited METEC[8], a state-owned enterprise to select an appropriate tractor and plough. The cooperative contributed 225,000 ETB (US$10,800) from its own money and were granted by a loan from METEC for a further 500,000 ETB to be repaid within 2 years. The full cost of the tractor was 735,000 ETB (US$35,300). The Woreda provided a written guarantee to METEC that if the cooperative cannot pay back the loan then the Woreda will step in and cover the difference. The Woreda agreed to guarantee the loan because they had a lot of belief in this cooperative, and possibly because Woreda and Kabele compete with each other for national recognition of development progress. The cooperative make deposit repayments of just over 100,000 ETB every six months for two years. To date, the first loan repayment has been made on time and the cooperative is confident in meeting their obligations.

The cooperative generates revenue leasing out the tractor to both the 15 cooperative members and to many non-members. Demand is said to be high for this service. Members pay per 1200 ETB per hectare for the service, whereas non-members pay anywhere from 1500-1700 ETB per hectare depending on the 'strength' of the soils. For the season from April to June 2014 (a 3 month period) the cooperative brought in revenues of 335,000 ETB (US$16,100) from the tractor hiring service - easily covering their 6 month loan repayment obligations of 100,360 ETB.

The cooperative says that last season the cooperative provided tractor ploughing services to about 200 individual farmers and 225 hectares were ploughed – although there were many applicants the cooperative couldn't service due to high demand. Due to the relatively high cost of tractor hire services and low availability of tractors in the area generally, most farmers only hire the tractor for the first plough (which is the most difficult), and subsequently utilize oxen for subsequent ploughs.

The tractor is 82 horsepower, and can do 7 to 8 hectares per day, working from morning and sometimes up to midnight. The number of hectares ploughed per day partly depends on the distances the operator needs to travel as well as the strength of the soil. Given that 225 hectares was ploughed last season and that a tractor can do around 7 hectares per day, this means that the tractor ploughed the equivalent of 32 days last season. It should be noted that the cooperative experienced several tractor breakdowns, and the tractor has to travel to farms around the Woreda, so it is unrealistic to plan for 7-8 hectares of ploughing every day of a season. The tractor is operational for two seasons every year.

Two operators are employed to do shift work. Each tractor operator earns a fixed retainer of 2000 ETB per month, and earns an additional 100-150 ETB per shift. Therefore, a tractor operator who works 30 days in a month will earn 5000 to 6500 ETB per month. In a working day from 8 to 6pm the tractor consumes around 30 litres of petrol at 19 ETB per litre, which equates to around 570 ETB (US$27) in fuel costs per day. The total profit per day, season and year is shown in Table 25.

Table 25 Tractor hire service budget for Abosara cooperative

	Assumptions	ETB	US$
Fuel	30 litres of petrol at 19 ETB per litre	570	27.40
Operator	1 operator, 1 shift	217	10.41
Total operation costs/day	Fuel + operator	787	37.81
Revenue per day	7 hectares ploughed at 1500 ETB/hectare	10500	504.69

Profit per day		9713	466.87
Revenue per season	225 hectares reported at ~1500 ETB/hectare (cooperative quoted revenue reported)	335,000	16,100
Profit per season (exc. loan repayment)	Conservatively using costs per day * 30 days per month, over 3 months = 70,830	264,170	12,700
Profit per season after loan repayment	Loan repayment of 100,360 ETB per 6 months	163,810	7,873
Profit per year after loan repayment	2 seasons	327,620	15,746

Note: excludes repair costs and labour for managing hire operations

Spare parts are difficult to acquire. The cooperative had to travel to Adama (~300km away) for labour and parts three times in the first 3 months of operation. Sometimes these parts are pulled off other tractors in Adama. Each time it took a week to get the repairs made. The cooperative estimates that breakdowns resulted in the tractor being out of action for 20 days in the 3 months of the season.

To be profitable outside of the ploughing season, the cooperative needs to continue to hire out the tractor in other Woreda. However, a problem for Abosara is that they don't yet have registered licence plates for the tractor, making it impossible to take the tractor across Woreda lines. This is said to be a complicated process, requiring 4 separate documents and considerable time and effort. Another opportunity for the cooperative is to buy tractor attachments for transporting harvested cereals, thereby continuing to accrue some revenue. Profit from transport services is expected to depend on distances, although revenues estimates are in the range of 2-10 ETB per quintal (100kg). A tractor can feasibly transport 200 quintal per day. Offering transport services is untried as yet, although the cooperative expressed confidence that this could be successful.

The cooperative says they have no fear about repaying the tractor loan and they are certain that it is profitable. In fact, they are considering buying another tractor in the not so distant future. The 15 original members who each invested 15000 ETB in the establishment of the cooperative get preferential use of the tractor. Once the loan is repaid members will be able to receive back the 15000 ETB they invested if they want to leave the cooperative. Otherwise, dividends are paid annually to cooperative members based on yearly profits. As per the by-law, members can share up to 50% of the total annual profit of the cooperative at the end of the year.

The tractor purchase has worked well for the cooperative thus far. In the opinion of the chairman, the most important thing before they started was that members all knew each other well. This was not an artificial construction put together by someone else. He believes that the success of the cooperative depends on identifying the right people. It took a long time to convince these 15 members to each invest 15,000 ETB and believe in the idea. The chairman suggests that 15 is an ideal number of members, and if the cooperative expands beyond this number of members then it could become difficult to manage. Even now, there are some existing members who put in less effort and perform their roles in supporting the tractor hire operations less well, preferring to focus on their own farms. The chairman's advice to other aspiring cooperatives is to start with between 5 and 15 members who are all of a similar awareness level and capacity and who know each other well.

Trust and transparency is very important as a success factor: *"If we bring someone from outside, they could collapse the group. You cannot just put people into a group based on whether they live close to each other, or their socio-economic status. Family ties are good, as there is more trust and no corruption. Cheating and corruption are the problems of other groups. You have to share something together beforehand. Buying a tractor is not the end, it's the start, the start of managing a business. This needs the strength of the group. We established a committee of 7 members who meet every week to report, planning and do budgeting. Then every fortnight we call all the members together to approve the latest plan. Everyone needs to understand each other and the business. This is the hard part of the work. If this is not done then the level of service will drop off and with it profitability".*

As well knowing each other first, the cooperative proved that members could work well with each other in their seed business before buying a tractor. In the view of the chairman, if cooperatives can successfully work with unions, research centres and government extension to address other fundamental needs for farmers (such as input provision) then they can build their capacity to manage a business and graduate to bigger investments. *"In the case of our cooperative, we started with improved seed supply and multiplication for the research centre. We demonstrated to ourselves and others that we could run a business. Maybe other cooperatives should start like this - supplying needed things to members before jumping into big investments which are more difficult to manage".*

[8] http://www.metec.gov.et/

Abosara Seed cooperative tractor, Ethiopia

Access to credit

Table 26 Percentage of respondents borrowing money last season for maize production and marketing related activities

	Kenya	Tanzania	Ethiopia
Percent	12%	18%	20%

Table 27 Reasons for not borrowing money last season

	Kenya	Tanzania	Ethiopia
Not available in the village	7%	18%	22%
Interest rate too high	10%	6%	33%
Repayment period too short	1%	2%	8%
I was refused because I didn't have collateral	6%	4%	1%
I was refused (for another reason)	3%	2%	5%
I didn't need any credit	49%	50%	58%
I don't want to be in debt	31%	31%	22%
Other	5%	9%	28%

N=388 of those not taking credit last season. Percentages do not add up to 100% because respondents could give more than one reason.

Table 28 Percent of farmers reporting that they would consider borrowing money to hire a tractor

	Kenya	Tanzania	Ethiopia
Percent	58%	62%	48%
n	163	154	174

N=491

Kenya

In Kenya money lending organizations like Equity Bank, Kenya Women Finance Trust (KWFT), K-REP, Meru capital SACCO and others are said to have improved the availability of credit in most of the research areas although only 12% of respondents borrowed money last season. An increase in the number of financial institutions and the activities of these institutions was said to be slowly sensitising more members of these community towards a 'savings culture' and entrepreneurship outlook. Accessing of a loan is said to be now simpler, although there is still a high interest rate, and often short repayment periods. Improved availability appears to be reflected in the survey data, in which only 7% mentioned lack of availability of credit facilities as a reason for not taking credit last season (the lowest among the researched countries). Farmers also admit to sometimes diverting loans to other uses, making it difficult for them to repay their loans. Only in Tongaren did the situation not improve. Agricultural Finance Corporation (AFC) has withdrawn from the area, and credit services in the villages are far away for most farmers and have tough conditions to get loans. In saying this, the survey data shows that the biggest reasons for not taking credit is that farmers don't think they need any (49%) or that they don't want to be in debt (31%). As was the case in Kenya, the majority of farmers (58%) said that they would be willing to borrow money to pay for tractor hire services.

Tanzania

In Tanzania, credit in most rural areas is often a challenge. In the case of Tanzania, all groups mentioned that farmers are increasingly able to access loans through the use of the SACCOs (small Savings and Credit Cooperative organisations), although only 18% of respondents said they took credit last season. Agricultural loans obtained through the SACCO are payable after harvest, and is flexible enough to allow farmers to repay. However, the Bargesh group mentioned a limitation to the success of the SACCOs: very few of these groups have received adequate training or start-up funds. The reliability and sustainability of these groups is always a challenge. Groups have few members and table banking is a challenge when people are not trained properly. And lastly, one still has to have a certain amount of savings to be able to participate: the SACCO can provide three times the amount of savings that one has, which limits the amount for quite a number of farmers. Microcredit organizations have not invested heavily in the research areas because farmers lack collateral and there is the risk that farmers may fail to service the loan. The only bank available in the area is the National Microcredit Bank. With the risks involved (a drought can easily cause a total crop failure) many farmers are also reluctant to

take credit and invest in their agricultural activities. This is reflected in the survey data where 31% of respondents said that they reason they didn't take credit was that they don't want to be in debt. 50% of respondent said they simply didn't need credit. However, interestingly when asked directly whether farmers would consider borrowing money to pay for tractor hire, 62% responded positively. This could be interpreted in a variety of ways, however the researchers suggest that it shows that if tractors are easily available at a reasonable hire rate then farmers would have few qualms about borrowing money for this service.

Ethiopia

In Ethiopia, 20% of respondents reported taking credit last season. There was a wider array of reasons for people not taking credit in Ethiopia than in other countries, but again the most common reason was that farmers either didn't need any credit (58%). High interest rates were mentioned very strongly as the second biggest reason affecting the decision to take credit (33%). Availability appears to be a greater issue in Ethiopia than in Kenya in particular. Still, nearly a quarter of respondents choose not to take credit because they do not want to bear the risk.

Interestingly 48% of respondents said would consider borrowing money to use for tractor hire. Of those who said they wouldn't borrow for tractor hire, many reasons were given. The main reasons were that there was a lack of tractors available to hire regardless, that interest rates were too high, that they would rather use credit for inputs, that they have oxen so no tractor is needed, that their land is too small for a tractor, or that their religion does not allow borrowing money (Muslim).

Microfinance can be a useful option for farmers to lend small amounts of money for inputs, or perhaps to hire a tractor. However microfinance is not at all sufficient to buy a tractor, even as a group. Participants described how microfinance institutes would usually start by lending 700ETB ($35) and over time this could increase up to a maximum of 6000 ETB ($300). Lending is also usually done as a group, for security to the lender. One group of borrowers discussed the challenge of this when someone passes away – it needs to be reported within 24 hours or the group has to pay back that persons loan to the lender, which is what happened in their case.

To borrow money to buy even a two wheel tractor would require most farmers to pool resources. As the participants rightly observed, to buy a tractor for oneself is not worthwhile, and the farmer would need to spend a lot of time and energy going around promoting his tractor service to help pay back the loan. This is possible for very organised farmers, and was observed with one small cooperative in Ethiopia - Abosara seed cooperative (see Box 1).

Maize marketing

Table 29 Maize marketing by respondents last season

	Kenya	Tanzania	Ethiopia
Local market	10%	18%	34%
Traders / brokers	48%	45%	33%
Through a group/ cooperative	3%	1%	19%
I did not sell any maize	36%	36%	10%
Other	3%	1%	5%
n	151	145	197

Table 30 Number of traders sold to last season

	Kenya	Tanzania	Ethiopia
0	3%	0%	33%
1	73%	65%	54%
2	18%	20%	21%
3	2%	9%	12%
4+	4%	7%	12%

For those farmers who marketed at least some maize last season

Table 31 Mean maize prices per kg received by farmers last season (2014)

	Kenya		Tanzania		Ethiopia	
	KSH	$US	TZS	$US	ETB	$US
Lowest	28.22	0.31	292.58	0.16	3.86	0.19
Common	31.31	0.34	350.00	0.19	4.57	0.22
Highest	31.89	0.35	377.82	0.21	5.4	0.27

The prices presented here are the mean prices which were actually received by farmers in our sample. The lows and highs are not the extremes of the market price spread but represent the extremes experienced by farmers in relation to when they actually market their maize. The common price is the price the farmers said the sold most of their maize for.

Kenya

In Kenya, farmers state that the number of traders has increased. High demand for maize has led to competition from maize dealers, and perhaps this is one reason why maize prices in Kenya (31 KSH/kg, US$0.34/kg) are considerably higher than in Tanzania and Ethiopia. The number of maize millers has increased and more traders are working with these millers to provide them with the maize. The use of mobile phones was said to have made it easy to contact maize dealers, although this is difficult to quantify. Traders prefer to buy immediately after or even before harvest (in the field) when prices are at their lowest, and this explains why there is little difference between the mean common prices farmers receive and the mean highest prices. It seems that either few farmers can afford to wait for better prices,

or farmers are not sufficiently organised to group bulk and call in traders (or other buyers) a few months later when prices have risen again. With liberalisation, the government no longer plays any role in setting minimum (maize) or maximum (inputs) prices. Grain marketing is currently fully liberalized in Kenya allowing producers to dispose their produce to willing buyers at market driven prices for different regions depending on supply and demand[9]. Just as in Tanzania, the vast majority of farmers sold their maize to traders, and usually this was to a single trader (73% of respondents), suggesting that most maize is typically sold in a single moment, rather than throughout the year.

Tanzania

In Tanzania, most groups reported an increase in maize trader activity in their area in recent years. This, despite apparent diversification by many smallholders, reducing their maize production levels and shifting part of their land holdings into other cash crops. Perhaps a reason for this is that demand on the market for maize remains high, and traders need to work harder to source quantities of maize to meet this demand. Another reason is surely that rural infrastructure has improved. Participants described how improvements mainly in roads and communication have played a significant role. Massive road construction has allowed lower cost and faster transport of commodities, and maize has certainly benefitted from the lowering of transaction costs. Improvements have also come about by the government investment in feeder roads and communications have improved mainly through the use of cell phones. There is still a challenge during rainy season as the roads become unpassable. The increased competition for maize produce however hasn't apparently led to producers being able to negotiate for better prices: the traders still dictate the price (according to farmers). This may partly depend on the fact that farmers quite often have to sell right after harvest, when the prices are low due to market glut and household needs for cash. During and immediately after harvest the prices are depressed (TZS 30,000 per 100/kg bag), while during off season the prices are as high as TZS 60,000 per 100 kg bag. This obviously presents an opportunity for those who can store harvested maize and wait for market prices to change, but the fact is most farmers are not in the this position. Furthermore, there is generally much less maize trader activity months after the harvest so the onus is on the farmer to find alternative marketing outlets. The majority of farmers sold at least some maize (36% did not sell any) with the main marketing channel clearly being through traders. The common price was 350 TZS/kg ($0.19/kg).

Ethiopia

In Ethiopia, the maize marketing situation varies through the country. In Assella in the wheat belt, maize was ranked by respondents as the fourth most common crop, after wheat, legumes and barley, as such was mostly grown for household consumption. Despite this, maize was marketed by virtually all farmers in other research areas, with only 10% of Ethiopian farmers in the sample not selling any maize

[9] http://www.ncpb.co.ke/index.php?option=com_content&task=view&id=33&Itemid=49

last season. Maize prices in Ethiopia were similar to those cited in Tanzania when converted to dollars ($0.22/kg). However, what really stands out in comparison with the Kenyan and Tanzanian respondents is the variety of ways that farmers are marketing their maize. 34% said that the sold directly in local markets and 19% marketed maize through farmers cooperatives - percentages which are far higher than reported in Kenya and Tanzania. 33% still marketed directly through traders with the majority of farmers selling to traders selling to a single trader. Farmer cooperatives were generally of higher capacity in our sample, reflected in their capacity to supply inputs fairly reliably to members. However, the capacity of maize cooperatives, particularly around Shashemene to successfully engage in group marketing over a number of years is something not found in other areas. This functions because cooperatives are able to access capital to pay farmers on delivery at market rates, removing the usual advantage that traders have over other formal buyers. The interest rate to the cooperative is in the region of a hefty 10% *per month,* however this is still perceived to be worthwhile as the maize is not held long and is on sold to the umbrella union for around 10-14 ETB ($0.49 – $0.69) commission per quintal (100kg bag). For example, one cooperative described the process of selling on to Mira Cooperative Union near Shashemene (Oromiya region), which in turn sells to the World Food Programme (WFP). The fact that some cooperatives are engaging in group marketing with substantial revenues flowing through them is relevant for mechanisation discussions – if a cooperative has this level of governance capacity and understands financial management it may be a candidate to manage tractor rental services.

Maize mechanisation

The following section focuses on maize mechanisation and reports on findings from our survey and focus group discussions. We begin by presenting ownership and hire experiences per country for animal ploughs, 2 wheel tractors and 4 wheel tractors. We look at the reasons given for hiring and not hiring tractors, as well as a breakdown of costs. We briefly discuss work rates of 4 wheel tractors, as well as experiences with planters and threshers. We conclude the chapter by presenting a regression analysis of factors determining tractor hire last season.

Tractor hire experience and land sizes

Most farmers prepare their land with an animal plough, or animal plough with some manual labour (Table 32, Table 34). In Ethiopia the percentage of farmers owning an animal plough was found to be very high in the research areas (93%), and subsequently few Ethiopian maize farmers lease animal ploughs (1%). Animal plough ownership in Kenya (36%) and Tanzania (49%) is much lower, although hiring of animal ploughs is much more prevalent (Kenya 40%, Tanzania 27%).

The frequency of smallholder farmers owning tractors is much lower – only 5% in Kenya, 0% in Tanzania and 1% in Ethiopia. Virtually all of the tractors owned in the sample across all three countries (25) were 4 wheel tractors (23), with only 2 cases of 2 wheel tractor ownership reported.

Table 32 Percentage of households owning an animal plough, 2W and 4W tractor

	Kenya	Tanzania	Ethiopia	Total
Animal plough	36%	49%	93%	60%
2 wheeled tractor	0%	0%	0%	0%
4 wheeled tractor	5%	0%	1%	5%
N	163	154	174	491

Table 33 Percentage of households who have ever hired a tractor

	Kenya	Tanzania	Ethiopia	Total
2 wheeled tractor	0%	4%	1%	2%
4 wheeled tractor	69%	39%	17%	41%
N	163	154	174	491

Table 34 Percentage of households who hired an animal plough or tractor last season

	Kenya	Tanzania	Ethiopia	Total
Animal plough	40%	27%	1%	22%
2 wheeled tractor	1%	2%	1%	1%
4 wheeled tractor	35%	14%	11%	20%
Total	163	154	174	491

Table 35 Mean land size under maize of those hiring and not hiring a tractor last season (acres)

	Kenya	Tanzania	Ethiopia	Ethiopia (hectares)
Hired last season	2.51	3.05	5.63	2.28
Did not hire last season	1.67	2.02	1.56	0.63
P value	0.0264**	0.0186**	0.0000***	0.0000***

Note P value is significance of Two-sample t test with equal variances, Pr(|T| > |t|). ** significant at 5%, *** highly significant at 1%

For those using 4W tractors, mean land sizes are commonly thought to be significant to their uptake. Farmers themselves generally expressed in focus groups that smaller land sizes are less suitable for several reasons: the cost of hiring and the effort involved to organise hiring, the availability of manual labour and oxen to do a similar job, fragmented land parcels makes tractor usage inefficient, and small land may difficult to access with tractors and cause difficulty with turn arcs. These expressed issues were found to be common across the Kenya, Tanzania and Ethiopia research areas. Indeed there is a significant correlation between the mean size of land and farmers hiring a tractor last season when running a two-sample t test with equal variances. The mean land size is considerably bigger (in percentage terms) than those who didn't rent a tractor last season (Table 35).

In saying this, land size did not come out as a statistically significant factor in our regression (Table 42), although it did move in a positive direction (farmers with larger land sizes had a slightly higher probability of using a tractor). This finding suggests that there are additional factors at play than just land size, which determines whether a farmer hires a tractor or not (see more in the regressions section p.49).

Kenya

In Kenya there is greater availability of four wheel tractors than in the other countries studied. However, this is not to say that there is sufficient availability, just more experience. However, the cost of tractor hire services for ploughing is said to have sharply increased sharply in recent seasons (reported by most groups). Survey data in Kenya puts the average cost per acre as 3070 KES, which fits closely with indications in focus groups that ploughing land which had previously been cultivated cost around KES 3,500 per acre. In most study areas, farmers said there are few tractors for hire in the community. So while 35% of households did manage to hire a tractor last season, the demand was much higher than this. Insufficient supply and delayed availability can result in late land preparation and planting, which in turn can lead to lower yields if timing is not optimal. Tractors are of course expensive to buy and the majority of the farmers cannot afford to buy them (5% of respondents own a tractor in Kenya). Maintenance costs are also high and most tractor owners do not have the required skills for tractor repair and maintenance. The soil in the area is heavy and tractors also fear ploughing land in the area. When it comes to tractor owners renting them out, it is said that there are greater rewards in renting these out to the forest industry and for transport. Tractor owners also prefer providing tractor services to larger farms close to their own homes rather than piecemeal hiring services. In Kenya respondents indicated that overall the use of 4W tractors is in decline, which perhaps makes sense intuitively if one considers greater population densities and smaller or more fragmented land parcels. Animal traction is an option but some respondents stressed that in areas with heavy soils that oxen struggle, and that cattle rustling can be a problem. The bigger problem with oxen however is that while they are an asset, there is also a considerable cost in keeping them. For many with small plots there is not enough space to grow sufficient fodder. For these reasons, many small farmers reported that using only manual labour was an option. This may suggest an opening for the promotion of 2W tractors, however as discussed later there are various challenges in this also (see Mechanisation challenges p.58).

Tanzania

In Tanzania, the average cost of tractor hire services for ploughing is TZS 44500 per acre ($24.65). This compares with TZS 30,000 for animal traction. Farmers want to hire tractors as they are obviously faster and more efficient in ploughing sizeable areas of land which would otherwise take several days with oxen. However, in areas where tractors are scarce, seeking out a tractor and waiting for it to appear can take as long or longer. Animal ploughing is anecdotally on the increase in the research areas in Tanzania

as a result. However, keeping and feeding oxen is also expensive for owners. Keeping land available for oxen takes space, and additional land for growing fodder (Napier grass) is also not always possible. For these reasons, in this area it is stated that only around 25% of the farmers in the area own oxen. As a consequence, ox-ploughing hiring issues may lead to additional delays in land preparation and possibly lower yields as the optimal farming cycle is not followed.

Ethiopia

Mechanisation uptake in Ethiopia was the lowest of the three countries studied, with very few households (<1%) owning a 4W tractor in our sample, and only 11% hiring a tractor for ploughing last season. Hire costs average 1161 ETB per hectare (470 ETB per acre equivalent), and in fact this 1100-1200 ETB/hectare was commonly reported as the rate in all areas. It also stands out that those farmers who hired a tractor last season had considerably larger plots of land (2.28 ha, 5.63 ac) under maize than those who didn't (0.63 ha, 1.56 ac). We suggest this is illustrative of the extent of the challenges and costs of hiring tractors in Ethiopia, making it only worthwhile for smallholders with 'larger' plots to pursue in the current climate. Tractor hiring is usually done through either unions or private owners. While cooperative members who belong to the umbrella union can theoretically register to rent one of the union tractors, in practice the availability is extremely limited. Unions might only have one or two tractors available for thousands of members. While tractor hiring is a reasonable source of revenue for the union, it is not its core business. Private tractor owners often come from different areas where different crops (eg wheat) are grown on a different calendar. Farmers, during focus group discussions, discussed how it was only possible for them to hire a tractor for their small farms when doing so as a group. This can be an informal group (perhaps a group of interested farmers who are also cooperative members). In focus group discussions farmers explained how private owners or the union were only interested providing tractor hire services for ploughing when there was a sufficiently large amount of land to be ploughed at one time (e.g a day or two). For this, farmers said, there usually needs to be 10 or so farmers who together have 10-20 hectares (25-50 acres) and whose farms are in close proximity. Several focus groups agreed that tractor operators will not service less than 10 hectares (25 acres). This acreage makes it worthwhile for the owner, and this land can be ploughed over one or two days. Some farmer owners require an advance payment of perhaps 3000 ETB to secure the booking. There is anecdotal evidence that tractor hire services are becoming a little more common. 'Big investors' are said to have brokers working for them who seek out groups of farmers to rent to. Farmers in groups around Sheshamane say they put their names on informal registers with tractor owners. Repeat customers who inform the owners early have the best chance to secure tractor services that season. Most households however own an animal plough (93%), rather than hiring them. The rate of oxen plough ownership is considerably higher than Tanzania (49%) and Kenya (36%) respondents. Those who have hired tractors in the past season stress that they only hire tractors for the first plough (typically there are about 3

ploughing/discing/harrowing moments for maize). This is because the first land break is the most difficult and heavy for oxen, and the 4WT tractor can plough a depth that oxen cannot. However, the effort involved in sourcing and coordinating tractor hire, not to mention the additional cost, means that farmers are rarely bothering with hiring multiple times.

Oxen ploughing, Ethiopia

Tractor hiring costs

Table 36 Actual tractor hiring costs per plough, per acre, compared with perceptions of fair and reasonable costs

	Actual		Fair and reasonable		Difference	
	Mean	US$	Mean	US$	Mean	US$
Kenya	3070	33.55	2310	25.25	760	8.30
Tanzania	44590	24.65	36423	20.62	8167	4.03
Ethiopia (ha)	1161	57.24	848	41.63	313	15.61
Ethiopia	470	23.15	343	16.85	127	6.30

In all countries studied, respondents all believed that hiring costs are higher than what is 'fair and reasonable'. It is not uncommon to hear from farmers that certain inputs are too expensive, but it is still interesting to see here how actual tractor hiring costs compare with what is considered by farmers to be 'fair and reasonable'. The differences between actual and perceived fair costs (Table 36) are 28% in Kenya, 17% in Tanzania and 31% in Ethiopia.

In all countries studied, manual labour for 3 ploughs costs less than one plough with a 4 wheel tractor. Likewise, hiring an ox plough for several passes is cheaper than hiring a tractor for one plough (Table 22). Taking into account that when ploughing with a tractor at least 2 passes are required (or one pass plus manual/animal ploughing on subsequent passes) it is clear that hiring a tractor is at least twice as expensive as other ploughing options. This doesn't factor in the time and cost of sourcing and negotiating for tractor services in the first place. Thus, saving costs would appear not to be the main motivation for hiring a tractor for most farmers. Saving household labour drudgery is not a convincing argument either, because if a household has the money to hire a tractor then they would also have the money to hire manual labourers who are available (Table 8) at less than half the price (Table 22). In focus group discussions the main advantages expressed were speed of ploughing and the depth/quality of the plough which was said to achieve better yields.

Reasons for hiring a tractor

All respondents were also asked in the survey why they would consider hiring a tractor. Many expected responses came out on top – such as tractors being faster, assisting in better yields[10], and increasing the ability to cultivate more land. Interestingly, a not inconsiderable number of respondents perceived that tractor hiring *was* in fact cheaper than other options (27%) and that it can save household labour (37%). However, on the whole farmers in our sample did perceive tractor hire to be slightly more expensive that other options (Table 38).

[10] The researchers suggest this is a perception, and not easily tested due to a small sample of farmers hiring 4W tractors for ploughing, and ploughing with tractors being done in conjunction with animal traction or manual labour. There are stronger predictors of yields, including fertilizer use, quality seed, timeliness of weeding, soil quality etc.

Table 37 Reasons for considering hiring tractors (all respondents)

	Kenya	Tanzania	Ethiopia	Total
Faster	70%	70%	82%	74%
Better yield	29%	44%	83%	53%
Cultivate more	31%	41%	64%	46%
Save household labour	26%	29%	53%	37%
More reliable	25%	22%	37%	29%
Cheaper	31%	29%	21%	27%
Wouldn't consider hiring	3%	4%	17%	8%

Percentages do not add up to 100% because respondents can give multiple responses

Table 38 Tractor hire perceptions

		Kenya	Tanzania	Ethiopia
Is the cost of hiring a tractor compared to using hired manual labour for your land…	1) Much more expensive 2) A little more expensive 3) About the same 4) A little cheaper 5) Much cheaper	2.56	1.92	2.37
Are there many tractors in your area to hire, if you wanted to and you had the money?	1)Very few - almost no tractors available to hire 2) Few - few tractors available to hire 3) Some - but can be difficult in times of high demand 4) many - good availability if you want to hire one	1.78	1.33	1.43
How suitable is your land to tractor use, in terms of land SIZE?	1) size is much too small 2) size is a little too small 3) size is good for a tractor	2.73	2.93	2.15
How suitable is your land to tractor use, in terms of land SLOPE?	1) slope is much too big 2) slope is a little too big 3) slope is ok / good	2.90	2.93	2.86

Reasons for not hiring a tractor

Table 39 Reasons for not hiring a tractor

	Kenya	Tanzania	Ethiopia	Total
Availability	40%	24%	44%	36%
Cost	39%	31%	21%	30%
Distance to access	6%	3%	40%	17%
Fuel costs	0%	0%	2%	1%
Total	163	154	174	491

Table 40 Mean distance to nearest tractor hire place

	Kenya	Tanzania	Ethiopia
Mean	5.66	12.48	29.96
Std. Err.	0.89	1.35	1.19
LCI	3.91	9.83	27.63
UCI	7.4	15.12	32.29

Note: distance outliers were capped at 50km

Many reasons were given for not hiring tractors in all researched countries (Table 39) with the most common being availability and cost followed by distance. In focus group discussions, participants elaborated on these reasons. Cost involves a few dimensions – farmers need to make up front payment deposits as a group, and then pay cash for the service. In Ethiopia they are also expected to pay the operator (who is not the owner) an additional ~10% if they want the job done properly. By way of example, a hiring a tractor for the first plough costs around 1200 ETB/hectare, whereas hiring oxen and labourers costs approximately 600-800 ETB/hectare[11]

Work rates

Respondents who had experience with tractors were asked of their experience in estimating work rates of tractors. These work rates were only described for 4 wheel tractors, as 2 wheel tractors were virtually non-existent in our sample (Table 41). Also, these work rates were for ploughing, not for other services (eg transport) as no farmers in our sample had ever hired a tractor for any operations other than ploughing.

Table 41 Work rate of a typical 4 wheel tractor per country, acres ploughed per day

	Mean	Std. Err.	LCI	UCI
Kenya	8.95	0.41	8.15	9.76
Tanzania	9.61	0.44	8.74	10.47
Ethiopia	15.56	1.47	12.66	18.46
Ethiopia (ha)	6.3	0.59	5.13	7.47

Planters

No cases were found of farmers using tractors for planting. Obviously utilizing tractors reduces labour and further use of mechanisation would reduce household labour burden and hired labour costs. But as described earlier, tractor hire is generally more expensive than other options and availability is limited. That is why the majority of farmers using tractors only did so for the first plough. Smallholders are

[11] The first plough with oxen takes 5-6 days per hectare as oxen can only work the land for half the day at a time. Oxen hire is 80birr per day, labourer 40-50 birr per day.

thought to be more tolerant of uncertainty when it comes to a slightly delayed first plough. However, when it comes to planting timing few farmers would tolerate uncertainty in accessing a tractor just to save a few labour days (Table 15).

Threshing and shelling

Another issue is threshing/shelling, for which there was much expressed demand for mechanisation. There was virtually no mechanisation for taking the grain from the cob in Ethiopia. Maize is almost exclusively threshed manually – essentially beating maize with sticks. In Ethiopia, labourers are paid 60 ETB/quintal (US$3) to thresh manually. This is very labour intensive and physical work –only men were observed doing this task during the course of the research. Furthermore threshing in this way can damage the maize seeds and best done when the maize is very dry. There was only one other cooperative using different methods in Sheshamane. An NGO (CDI) and the World Food Programme (WFP) had supported the farmer cooperative for more than 5 years, and lately have supplied simply manual shellers (a hand turning device) which can do about 1 quintal an hour, but which is still relatively hard work. Cooperative members can buy these for the subsidized price of 30 ETB ($1.50).

At the same cooperative CDI and WFP have helped the cooperative access a mechanised sheller, which was currently broken and sent for repairs at the time of the site visit. The cooperative invested 20,000 ETB ($985) which is believed by the cooperative leadership to be 50% of the real cost. This diesel run sheller can shell about 20 quintal per hour. It is rented to cooperative members at 10 ETB per 1.5 quintal of maize threshed. The machine gets hot after a time, so it runs for 6 hours, followed by a 2 hour rest, and then another 2 hours. In the three years it has been running it has broken down 3 times, which usually takes 2-3 days and 1000 ETB to repair in the nearby town. There is an extremely high demand for the sheller and can be a source of conflict to use it as it's the only one in the area, servicing thousands of households. The cooperative leadership highlighted that it would be more profitable if it could also thresh teff after the maize season. They have done some experimentation with this and find that their 5hp engine needs to be 7-9hp for teff. This multi-functionality should be kept in mind for any organisations looking to introduce mechanisation.

In the Kenyan research areas, maize shellers are more common than in Ethiopia. They are either powered by 4 wheel tractors or movable engines. Service providers move from village to village offering providing the service. Some shellers are transported on motorbikes or on trailers attached to 4 wheel tractors. In fact, motorbike engines powering shellers may provide the biggest competition to 2 wheel tractor powered threshing services.

Manual maize threshing, Ethiopia

Gender

This research explored issues relating to gender and mechanisation, and these have been comprehensively covered in a complementary study for CIMMYT, *Gender Matters in Farm Power* (van Eerdewijk & Danielsen (2015). This research did not focus on gender in detail, however this was explored to some extent in the focus group discussions with both men and women. Male respondents dominated the research[12] as most respondents were identified through their respective cooperatives. This hints at both the dominant position of men within the cooperative and within the farming economy more generally.

Of note, ploughing is by far the most common application of on-farm mechanisation, and other types of mechanisation were rare or non-existent in our sample. Ploughing is most often performed by men whether by way of operating animal traction or through household or hired labour. In this regard, increased mechanisation for ploughing would have relatively little direct impact on women's labour

[12] Kenya 67%; Tanzania 63%; Ethiopia 87%; Total 73%

burden. Women's on-farm labour contribution is greatest in weeding and harvesting and if mechanisation is to reduce their on-farm labour burden then these activities would require focus.

Regressions

Factors determining whether a tractor was used last season

The following regression looked at factors determining whether a tractor was used last season (either owned or hired)[13]. There were found to be several statistically significant predictors of this across countries. District was used as a control variable for environmental differences.

Where a respondent in Kenya reported earning more than US$3000 per year there was a 29% higher probability of using a tractor compared with a respondent earning less than this. In Ethiopia there was a 22% higher probability. (Figures for Tanzania were deemed unreliable for wealth).

However, the strongest predictor of tractor use last season (significant for all countries) was if an animal plough was hired last season. If an animal plough was hired last season there was a 36% higher probability of a respondent also using a tractor in Kenya, 15% in Tanzania and 65% higher probability in Tanzania. At first glance this may seem counter intuitive, but it confirms what was often heard in focus group discussions.

Farmers are often using mixed ploughing practices (mechanisation plus animal traction) because tractors are difficult and expensive to access on multiple occasions and the main perceived advantage of a tractor is a thorough and deep first plough. It also points to investment attitudes in the farming system – if farmers are already willing to hire animal ploughs then it stands to reason that they will also hire a tractor if available.

On the other hand, if an animal plough is already owned and no hiring is required then there is no significant correlation with hiring a tractor (although the direction is a weak negative correlation). Hired labour was also included when running the regression for all countries but was found not to be significant for any of the studied countries. Hired labour is not included in the regression outputs reported below because there were too many missing values which reduced the number of observations in the regression, and hence its power to report other variables. However, the researchers are confident that the number of hired labour days is not a significant predictor of whether respondent would hire a tractor. Distance to travel to hire a tractor is also not significant, although this may say more about the

[13] reg tractor_used_tractor land_all_owned_acres land_maize_use_acres distances_tractorhire i.district_coded i.income_cat passets_hiredlastseason_animalpl passets_owned_animalplough fertilizer_yn seed_yn land_maize_leased_yn i.country

sample frame – respondents were surveyed from village clusters so those who did and did not hire a tractor were a similar distance from a tractor hire source. Land size and land under maize were also found to be non-significant predictors. This possibly says more about the fact that these is little variation in smallholder land size in the sample (Table 4).

Table 42 Regression, tractor use, Kenya

	Coef.	Std. Err.	t	P>t	[95% Conf.	Interval]
Total land owned (ac)	**0.010**	0.006	1.880	0.062*	-0.001	0.021
Land used for maize (ac)	0.028	0.020	1.440	0.151	-0.011	0.067
Distance to hire a tractor (km)	0.000	0.003	0.040	0.972	-0.006	0.007
District (control var)						
2	0.004	0.160	0.020	0.982	-0.313	0.320
4	-0.148	0.108	-1.370	0.173	-0.363	0.066
6	-0.086	0.086	-1.000	0.319	-0.257	0.084
Income (> US$3000 pa)	**0.288**	0.111	2.590	0.011***	0.068	0.507
Animal plough hired last season	**0.360**	0.078	4.600	0.000***	0.205	0.515
Animal plough owned	-0.005	0.080	-0.070	0.947	-0.163	0.152
Fertilizer used (y/n)	0.081	0.146	0.550	0.580	-0.208	0.371
Seed bought (y/n)	0.056	0.125	0.440	0.659	-0.192	0.303
Land leased for maize (y/n)	-0.171	0.082	-2.080	0.039**	-0.334	-0.009
Country (control)	0.000	(omitted)				
_cons	0.052	0.132	0.400	0.691	-0.208	0.312

N=153; * significant at 10%; ** significant at 5%; *** significant at 1%

Table 43 Regression, tractor use, Tanzania

	Coef.	Std. Err.	t	P>t	[95% Conf.	Interval]
Total land owned (ac)	0.013	0.009	1.390	0.167	-0.006	0.032
Land used for maize (ac)	0.027	0.017	1.550	0.123	-0.007	0.061
Distance to hire a tractor (km)	0.000	0.002	-0.260	0.798	-0.004	0.003
District (control var)	0.090	0.056	1.620	0.109	-0.020	0.200
Animal plough hired last season	**0.154**	0.061	2.530	0.012**	0.034	0.274
Animal plough owned	**-0.113**	0.053	-2.120	0.036**	-0.219	-0.008
Fertilizer used (y/n)	**0.175**	0.057	3.060	0.003***	0.062	0.287
Seed bought (y/n)	0.061	0.063	0.970	0.333	-0.063	0.186
Land leased for maize (y/n)	0.026	0.063	0.410	0.681	-0.098	0.150
Country (control)	0.000	(omitted)				
_cons	-0.098	0.075	-1.310	0.191	-0.246	0.050

N=152; * significant at 10%; ** significant at 5%; *** significant at 1%

Table 44 Regression, tractor use, Ethiopia

	Coef.	Std. Err.	t	P>t	[95% Conf.	Interval]
Total land owned (ac)	0.006	0.007	0.880	0.378	-0.007	0.019
Land used for maize (ac)	0.019	0.014	1.400	0.165	-0.008	0.046
Distance to hire a tractor (km)	-0.001	0.002	-0.470	0.638	-0.004	0.002
District (control var)						
7	0.180	0.074	2.430	0.016**	0.034	0.326
8	-0.002	0.096	-0.020	0.985	-0.191	0.188
9	0.019	0.080	0.240	0.813	-0.138	0.176
Income (> US$3000 pa)	**0.222**	0.088	2.530	0.013**	0.048	0.396
Animal plough hired last season	**0.655**	0.279	2.350	0.020**	0.103	1.207
Animal plough owned	-0.071	0.087	-0.810	0.420	-0.244	0.102
Fertilizer used (y/n)	-0.040	0.087	-0.460	0.648	-0.212	0.132
Seed bought (y/n)	-0.015	0.080	-0.180	0.855	-0.173	0.144
Land leased for maize (y/n)	0.058	0.064	0.910	0.365	-0.068	0.185
Country (control)	0.000	(omitted)				
_cons	0.071	0.147	0.480	0.631	-0.220	0.362

N=152; * significant at 10%; ** significant at 5%; *** significant at 1%

Maize mechanisation - from left, trailor, 2 wheel tractor, sheller

Supporting environment and policy context

In focus group discussions and key informant interviews participants were also asked about the supporting environment (other projects/interventions and actors) and policies which have contributed to recent changes in their area. This helps to establish some of the local context, which is important for present and future interventions such as FACASI.

It should be noted that the level of agricultural mechanisation is directly influenced by government policy. Tariffs are often levied on tractors or tractor parts in sub-Saharan countries (including Kenya, Tanzania and Ethiopia). While such tariffs are usually used to boost these government's revenues directly (rather than protection of local industry), it also increases the final cost to consumers. This depresses the market for tractors and the volume of tractors in the country, which in turn potentially affects agricultural production levels. Such policies are in contrast to countries such as China and India who *subsidize* farmers procuring tractors and other forms of farm mechanisation. The Chinese government began to subsidize farmers who purchased tractors and combine harvesters in 2004 in order to promote agricultural mechanization. At present the agricultural machinery subsidy rate is 30% (the farmer pay 70%, the remaining 30% is paid by the government)[14]. In India, tractors are currently subsidized at a rate of 25% (up to 30,000 rupees)[15]. The argument here is not for Kenya, Tanzania and Ethiopia to introduce subsidies on mechanisation, but for these countries to at least re-evaluate whether such tax generating tariffs are really worth the drag they put on the agricultural sector.

Kenya

Perhaps the most up to date discussion on mechanisation policy in Kenya can be found in Mutua, Kaubutho & Mung'oo (2015)[16], which confirms the low uptake of mechanisation in Kenya generally, as well as the very low availability of 2 wheel tractors specifically.

The National Agricultural Mechanization Strategy – MAMS (1995) and Strategy for Revitalizing Agriculture (2004-2014) identifies low levels of mechanization as one of the main causes of low agricultural productivity in the country and further states that the three main causes of low utilization of mechanization to be: a) Inadequate mechanization extension services b) Inadequate access to mechanization technologies, and c) Lack of finance available to farmers.

In the Strategy for Revitalizing Agriculture (SRA), the following measures are stipulated:

[14] UN-CSAM. (2011). *Research report from China.* Available from http://www.unapcaem.org/Activities%20Files/A1205_AS/PPT/cn_temp.pdf

[15] Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India. (n.d.) *The manner of execution of subsidy programmes, including the amounts allocated and the details of beneficiaries of such programmes.* Available from http://agricoop.nic.in/RTIfiles/Manual%20No.%20xii.pdf

[16] Mutua, J., Kaubutho, P., Mung'oo, J. (2015). *Market analysis for small mechanization- Kenya*. Available at http://facasi.act-africa.org/file/20150130_market_analysis_for_small_mechanization_kenya.pdf

- Accord the private sector incentives to set up mechanization centers to provide machinery and equipment hire services to both small and medium-scale farmers
- Provide financial incentives to local institutions of technology; public and private institutions to research, design and develop appropriate technologies for different categories of farmers and farming systems
- Provide tax incentives to manufacturers to set up local assembly or manufacturing of machinery suitable for smallholder farming.

The Ministry of Agriculture has 23 Agricultural Machinery Service (AMS) stations spread across Kenya, with a fleet of 40 operational earth moving equipment (in 2007). There was an intention to increase the fleet to 120 units and 150 farm tractors in subsequent years. This has happened haphazardly as the Government Tractor Hire Services Scheme that used to provide farmers with subsidized farm services collapsed. In 2007, there was a Government plan to spend KSh. 1.5 billion over the following five years to revamp Agricultural Mechanization Services. Observations on the ground show that this did not happen. Inevitably farm mechanization services have been scant for the majority smallholder farmers and services have been left to the private sector hirers (Mutua, Kaubutho & Mung'oo 2015).

From 2003 the government zero rated the importation of agricultural machinery in Kenya. However, from September 2013 all agricultural machinery now attracts a VAT of 16%, making it more expensive for farmers and service providers to buy tractors (Mutua, Kaubutho & Mung'oo 2015). Tax policies can depress consumer spending in mechanisation and by inhibiting supply work against the Strategy for Revitalizing Agriculture objectives.

Mutua, Kaubutho & Mung'oo (2015) also provide a detailed list of tractor importers and dealers. Further reading about Kenyan policy and context regarding mechanisation can be found in Sims & Kienzle (2009)[17].

Focus group participants recalled a long list of supporting agencies. Farmers mentioned the National Accelerated Agricultural Inputs Access Programme (NAAIAP) which provides subsidized planting fertilizer at KES 2,000 and subsidized top dressing at KES 1,600 per 50 kg bag. Planting fertilizers provided in the project are DAP, 20:20:0, 23:23:0 and 17:17:17. Top dressing fertilizer provided is CAN. Farmers stated that this programme had helped to boost yields, as should be expected.

As in the case of Tanzania, alternative crops can be expected to compete with maize in the coming years. Several organisations are working with the authorities on various crops. The development of rural road

[17] Sims, B., Kienzle, J. (2009) Farm equipment supply chains - Guidelines for policy-makers and service providers: experiences from Kenya, Pakistan and Brazil. Available from http://www.fao.org/3/a-i1209e.pdf

infrastructure also brings regional markets closer and reduces transaction costs, making other crops increasingly marketable. In Laikipia east, the government through Ministry of Agriculture made an effort to construct the Maili Saba agricultural dam (2009). The dam was constructed for irrigation and livestock production. It mainly focused on horticultural crops and individual farmers must have his/her own pump to irrigate his/her own farm.

In Tongaren the Kenya Maize Development Programme (2009-2012) provided capacity building, training on maize production, promoted value addition, post-harvest management and marketing(through market linkages). Improved maize productivity and saving culture, took farmers to exhibitions. In Inyokha, the Ministry of Agriculture together with Equity bank (since 2009) provided loans for farm size from 1 to 10 acres. The loan for one acre is KES 10,000.About 90 farmers in the community has benefited from the project. Ministry of Agriculture together with equity bank officials visit farmers and provide training on maize production.

Tanzania

In Tanzania, most agricultural machineries are imported from abroad. But the government has been supporting mechanization workshop at the Center for Agricultural Mechanization and Rural Technology (CAMARTEC) that does some re-designing and modifications to adapt farm implements to local conditions. Most farm machineries used in Tanzania are imported from abroad, and the Tanzanian government has waived import tariffs on most agricultural machineries to reduce machinery costs and make them affordable to the final buyers. However, there are still taxes on machinery spare parts and fuel used for operations.

With the aim of supporting smallholder agriculture, the government of Tanzania subsidized importation of power tillers (two wheel tractors) to make them affordable for those owning and providing farm operation services. Subsidy initiative carried out under Agricultural Sector Development Strategy (ASDS, 2001) created profitable market for the dealers, and distributors of farm machinery especially power tiller sub-sector. It also encouraged establishment of farm machinery hiring services at region level, district and farm levels. Through this program, groups and individual farmers at farm level especially smallholder farmers managed to own power tillers and its implements. The strategy also helped in enhancing farm machinery supply chain from dealers to individual farmers at farm level[18].

[18] Facasi draft paper (forthcoming). *Review of National Policies Affecting the Expansion and Development of Agricultural Mechanization in Tanzania.* Available from http://facasi.act-africa.org/file/20150130_review_of_national_policies_affecting_the_expansion_and_br_development_of_agricultural_mechanization_in_tanzania.pdf

In 2007-2008 a new Crop Mechanization Department was created within the Ministry of Agriculture and Food Security (MOAFS) to foster new investment in agri-business and crop diversification. This new initiative to empower farmers/SME is called "Kilimo Kwanza" (Swahili word) meaning "Agriculture comes First". This initiative invites private companies to work with government to unleash the potential for growing cash and food crops. The mechanization initiative covers a wider spectrum that accommodates small-scale mechanization using two-wheel power tillers to medium and large-scale four-wheel tractor based mechanizations.

In focus groups, a number of recent projects were recalled by participants which support the improvement of maize (and other crops and livestock) in the research areas.

PADEP (Participatory Agricultural Development Empowerment Programme, 2005-2007, all areas), a government supported project, was mentioned as an important one. The project aimed at promoting crop and livestock production in the area. It specifically targeted poultry and pigs production and beans, pigeon peas and maize production and included free provision of improved seeds and fertilizers to farmers. The farmers were arranged in group of forty households whereby each household was given inputs for one acre each for free. The project also championed for agro forestry and constructed water troughs. Farmers were trained on good crop and animal husbandry. Each household was given inputs for one acre each. The government provided assistance to community owned projects such as agrovets and renting out of farm implements (ploughs and ox carts). Especially the latter part of this project may be expected to influence the success of the introduction of 2 wheel tractors: if animal ploughing is supported, one might expect challenges in adoption levels of more expensive forms of farm mechanisation.

Another project of interest is the Sustainable Intensification of Maize Legume in Southern Africa (SIMLESA, in Bargesh and Antsi areas), active since 2010 and supported by the government. The project seeks to improve productivity and production of maize and legumes as a source of food security. It trained farmers in our sample on maize and legume production and provided seeds (from Seedco company), fertilizer and pesticides.

Another frequently recalled project was the Tanzania Social Action Fund (TASAF). The project tries to improve infrastructure in the community. It has constructed feeder roads, school classes and staff quarters. The project also encourages the local people to plant trees as well as production of fruits specifically avocados. The project rehabilitated water canals in all areas. It did by improving distribution channels and chambers. More channels were directed to specific farms. The irrigation development seems to have had a major impact, as it was mentioned repeatedly that irrigation is attracting investments and people from around to work on the farms. Maize under irrigation is a reality for a few,

but has more broadly meant that some farmers can have two seasons of crop production per year (although not necessarily two maize seasons). However many farmers lack access to the water, due to the wide geographical spread and sheer numbers of smallholder farmers.

The subsidised provision of fertiliser and other inputs mentioned by farmers appears to be related to a voucher system implemented by the government since 2010. The government of Tanzania provides subsidized inputs to vulnerable groups in the society. The identified farmers are supposed to pay 50% of the market price of the inputs, who which they receive an input kits including DAP fertilizer, top dressing and seeds for one acre. The total cost of inputs is TZS 90,000(urea TZS 40,000,DAP TSZ 30,000 and seeds TZS 20,000). The voucher system has promoted use of improved seeds and chemical fertilizers, however a recent drought was said to have negatively affected the impact of the voucher system.

Ethiopia

Government control of tractor importation is stronger than in either Kenya or Tanzania, and the researchers suggest this as an important reason why mechanised farming among smallholders is particularly low in Ethiopia. Tractor importation is limited to commercial entities who must apply for and receive an investment license. In an interview with the ATA (Agricultural Transformation Agency)/Ministry of Agriculture it was conceded that importing tractors is a long and bureaucratic process.

A number of private importers and dealers are in business[19]. However policy has been such that until recently dealers were not allowed to import and stock machinery. Instead they are dealers of specific manufacturers and import on behalf the investors, such as to state sugar farms, unions, and commercial investors. Recent reports suggest that tractor imports may now be stocked at bonded warehouses for 3 months. A 35% duty is levied for all those that do not have the investment license, including small farmers (interviews with one importer suggested this figure was 58%). This policy puts smallholder farmers at a serious disadvantage in the market – even for procuring 2 wheel tractors. Such a policy surely contributes to depressing the smallholder farm economy, however the government is clearly of the view that the tax revenue resulting from these tariffs is worth the trade-off in lower farm productivity.

An interview was granted with Metals and Engineering Corporation (METEC) of the Ethiopian Government. METEC was previously Adama Agricultural Machinery Industry (AAMI) until 2010 and before 1992 was the Nazareth Tractor Assembly Plant (NTAP), established in 1984.

[19] See FACASI. (2014). *Agricultural mechanization performance, constraints and recommendations on strategies to enhance market and service delivery*

Its main products are:

- Assembly of different size and brands of tractors
- Manufacturing of various construction equipments such as trailers, loaders, water tankers etc.
- Assembly of various tractor combines including disc ploughs and harrows
- Assembly of water pumps that have various ranges

Its main services are:

- Maintenance and service of tractors , implements, pumps, irrigation equipments both at client sites as well as on company premises
- Sales of tractor, tractor implement, water pumps & irrigation equipment spare parts
- Training operators of tractor & tractor implements

The users of METEC products are mainly regional governments, farmers' unions, and state owned enterprises for agriculture, water irrigation, construction, and transportation projects.

The company has been importing different types of tractors, both (4 wheel and 2 wheel) for several years. It has about 3 years' experience of working with 2 wheel tractors. In total it says it has imported 3,025 walking tractors from China (8 and 15hp) and Turkey (12hp). Most of them are ready to be sold to the regional governments for demonstrations. So far more than 1,300 have been sold to the regional governments. The remaining ones will also be sold to government related organizations. In some cases, if the regional governments write some support letters/guarantee letters, they are ready to sell to farmer groups, unions and cooperatives.

The main intention of the government is to promote multipurpose models of tractors which can plough, harrow, seed, pump water, thresh and transport depending on the accessory attached to them. However, the current ones only have a transport function other than ploughing implements.

The company sells its products both on cash and credit basis. In some cases, an advance payment of 10-20% settlement of the remaining sum in two years is accepted. To get credit services, official letters of guarantee is required from appropriate government office. The price of walking tractors ranges from 23,000-33,000 depending on the brand type and accessories.

Challenges

Farming challenges

In focus group discussions, farmers were asked what the biggest challenges were that they faced in maize farming. It was notable that lack of mechanisation or labour burden was rarely, if ever, mentioned by respondents despite earlier probing on mechanisation issues through the course of the focus group. This calls into question the real demand articulation for mechanisation, at least as far as it is high priority compared with other issues. This could be interpreted in several ways: farmers have more immediate and pressing issues (see below); farmers feel that mechanisation is so far out of reach in terms of cost or availability so don't consider including it; farmers lack awareness of how mechanised technology could improve their farming practices; or that maize typically has lower labour demands than other crops so relatively speaking this is not such an important issue.

This is not to say that there is *not* demand articulation for mechanisation, but that this articulation very much depends on the question being asked (and by whom). If farmers are asked if they would like to mechanise most will answer positively; if they are asked whether they would hire tractor services if available at present hire rates a substantial number, but fewer, would answer positively (Table 39). But the real test is not just expressed preferences but actual hiring behaviour, and there is a gap here. This gap can be visibly seen between those who have ever hired a tractor (Table 33) and those who did so last season (Table 34). For while some farmers have been able to regularly mobilise as a group to hire tractors, most do not do so.

In Kenya and Tanzania the most frequently mentioned issues were weather patterns becoming less predictable, as well as constraints around the availability and costs of inputs such as seed and fertilizer.

The question of challenges was addressed more systematically in the Ethiopia research. Focus group participants were asked to recall and describe their biggest challenges and then rank them. These rankings were converted to a score and from all focus groups exercises a sum total was made[20] (Table 45).

[20] Rank 1=10points, rank 2=9 points… rank 5=6 points.

Table 45 Challenges in Ethiopia with maize farming

Challenge	Challenge score
Chemical inputs	26
Storage	19
Rain	18
Pests	15
Disease	14
Labour	12
Marketing	10
Weeds	8
Seed	8
Soil	7
Communications	7

In Ethiopia, **inputs** were reported as the biggest problem with maize production. This referred to fertilizer costs in particular, and also knowledge on proper application methods. Timeliness of delivery was also mentioned by one group. **Storage** was the next most frequent challenge, as "to get a better price you need to keep it in storage, where it can be affected by weevils and losses. Shortages and untimely **rains** are mentioned by several groups as it affects timing, yields and diseases. Intensive **labour** was mentioned as a necessity to get good productivity. Also the 'long maturing' varieties grown in the research areas mean more labour attention for longer, compared with say haricot bean. **Marketing** was mentioned by only one group, as during harvest time there is a high supply depressing prices, which farmers says affects their ability to re-invest in their farms. Weeding was also mentioned by only one group, as it is manual, without chemicals.

It is notable that none of the unprompted challenges mentioned by Ethiopian respondents directly referred to mechanisation, either in land preparation, threshing or transport. When prompted, one group responded that "mechanisation comes below the other challenges", and another said "we don't know enough about mechanisation to really talk about it as a challenge".

Mechanisation challenges

Lack of confidence in small-scale farm market

Most manufacturing and importation of agricultural machinery is in response to orders rather than for stock in the expectation of future sales. Up to now few companies have looked to promote mechanisation for small holder farmers due to uncertainty whether this is a profitable option. There are several dimensions to this, such as government import policies and tariffs (p.50), lack of smallholder

awareness of suitable mechanisation options (e.g. 2 wheel tractors), and lack of chain supporters (hiring businesses, repairers and parts etc.).

Poor infrastructure, especially in rural areas

Poor infrastructure increases delivery costs of machinery and services. Rural roads (and often main trunk roads) are frequently in a state of poor repair, which adds to distribution costs. Furthermore, registration can be an issue if the owner wishes to transport a tractor across district lines to deliver hire services.

Lack of product testing, especially for smaller-scale entrepreneurs

This particularly refers to 2 wheels tractors in the research countries. There is a general lack of awareness about the tractors themselves, and the various ways they can be configured with different implements. Furthermore, a general lack of competition in the marketplace contributes to the difficulty in distinguishing value between machines.

Hire service providers

There were found to be very few hire service providers indeed. Those who did provide services tended to be larger farmers hiring out their tractor and operator after they had finished with it. Farmers often mentioned in focus groups that they had to seek out these larger farmers themselves, who they heard about through word of mouth, and sometimes came from other districts. The only other provider type encountered were unions, however they also tended to have relatively few tractors for a membership that could run to several thousand members. Unions in Ethiopia were also more focussed on input supply services to cooperatives under their umbrella. Large distances between smallholders wishing to hire services puts off providers due to the transaction costs and fuel. Most will only deliver services when a group of nearby farmers pool together to hire a tractor service for around 20-30 acres. Hire service providers for 2 wheel tractors are virtually non-existent and were said to only make an appearance from time to time at a field day.

There is also a lack of capacity among other potential actors to manage tractor services as a profitable business. This includes unions, cooperatives, and small businesses. Buying a tractor is just the beginning. Operating the services in a way to optimise work rates and promoting and coordinating the delivery of services to achieve profitable results (and pay back loans) is imperative. The researchers suggest that there is a lack of entrepreneurial activity around mechanisation. While some reasons for this are obvious (high costs of raising finance, tariffs, high cost of tractor investments generally, lack of supporting actors, land fragmentation etc.) The few cases identified during the research who have entered the business of offering tractor services have been able to pay off loans and generate good profits

in around 3 years (see Box 1). Therefore the challenge is broader than just buying tractors, but in building entrepreneurial capacity to manage the business.

This is not so much of an issue for large scale commercial farmers who primarily own tractors for working their own land, and only provide rental services as a secondary income stream.

Repair services

During in depth interviews with individuals owning tractors it was clear that the capacity of repairers is constrained by a number of factors: lack of availability of parts, distance to travel for repairs, and waiting time for repairs to be made. For tractor hire providers the adage 'time is money' rings true. Ploughing season is the time when tractor hire service providers need to be working non-stop in order to turn a profit and repay debts and in case of a breakdown this not only disadvantages smallholder farmers who are booked in for a ploughing service, but also threatens small hiring businesses if repairs extend to several weeks. This is compounded by the fact that few tractor owners (whether cooperatives or individuals) have more than one tractor. The general capacity of repairers to maintain machinery is unknown even to those who own the tractors. For the introduction of any new tractor types (and implements) the capacity of repairers to maintain these machines and access parts should be assessed.

Small-scale farmers have severely limited purchasing power and access to finance

As discussed throughout this paper, small-scale farmers have limited purchasing power and often purchasing quality inputs (seed, fertiliser etc.) is a significant investment for them. Most farmers have a diversified cropping system to hedge against price fluctuations and to bring in income throughout the season, as well as for household consumption. Maize farming is not particularly profitable (Table 22), at least as far as making sufficient profits for acquiring even a 2 wheel tractor. This means that small-scale farmers need to be hiring tractors through different models, rather than procuring tractors themselves. Another issue is access to finance for smallholders for tractors. Most microfinance (even offered by banks) is between US$50-$300 per lender even for those with a positive credit history. This means that finance for 4 wheel tractors is all but out of the question for smallholders. 4 wheel tractor purchasing would then be only in the domain of unions, cooperatives, businesses, and medium-large scale farmers. 2 wheel tractors are within reach of smallholders pooling together, or small-medium farmers who have additional financial capacity, say, from other income generating activities.

Tractors and conservation agriculture

Conservation Agriculture (CA) is an approach to managing agro-ecosystems for improved and sustained productivity, increased profits and food security while preserving and enhancing the resource base and the environment. According to FAO, CA is characterized by three linked principles, namely:

- Continuous minimum mechanical soil disturbance
- Permanent organic soil cover
- Diversification of crop species grown in sequences and/or associations[21]

This paper does not attempt to discuss the merits or otherwise of CA, although interested readers will find a summary of the main issues on the website of Wageningen University[22]. Instead we offer some analysis around conservation agriculture and mechanisation based on observations in the field.

CA, as promoted by CIMMYT, was rarely found to be practiced in any of the research areas. In focus groups most farmers could not explain what CA was, and general awareness of CA among key informants was also found to be low (except among CIMMYT employees). In rare cases, a farmer mentioned that they had heard about CA on the radio and could list some of the CA principles. There were only two cases of participants claiming to have received CA training. In one case a female farmer said she received a few trainings in CA in one season but remained unconvinced and didn't apply the training. In another case in Ethiopia the deputy administrator of the Kebele was trained in conservation agriculture, and given seeds and herbicides. The results were reported to be satisfactory, however he did not try again for two reasons –herbicides were not readily available the following year (even though he was prepared to pay for them), but furthermore, he experienced a kind of social exclusion when using the herbicides – they killed all the weeds on his plot but other villagers were said to be very scared that "such strange things" would affect their livestock and kill their children.

Another interesting challenge for CA proponents was that in all three research countries most focus group participants mentioned big positive changes with regards to maize production over the past 10 years or so. In areas where maize was already established, yields were reported to have greatly improved due to increased training and knowledge, better provision of fertilizer and supply of improved seeds. In some cases this was through intensive support by NGOs, but just as frequently mentioned was government extension trainings delivered through cooperatives. In areas where previously there were no highland maize varieties (e.g. Assella, Ethiopia), these have been introduced successfully, and

[21] See http://www.fao.org/ag/ca/1a.html

[22] See http://www.wageningenur.nl/en/Expertise-Services/Chair-groups/Plant-Sciences/Plant-Production-Systems-Group/Conservation-Agriculture.htm

adoption has been aided by a reported warming climate. The implication is that promoting CA at scale would involve encouraging farmers away from a production system that most farmers feel is delivering improvements. This also raises the stakes for any introduction of CA to generate additional benefits in terms of labour costs and yields from the outset, less farmers become discouraged and revert. The authors are not certain how realistic this would be given that it takes several seasons for crop residues to produce a layer of mulch that stabilizes soil moisture and temperature in the surface layers. It is also worth recalling that by definition smallholders have small plots of land (Table 4) and are generally risk adverse to experimentation without early adopters demonstrating proof of concept.

Herbicide availability and use is another issue. Very few respondents reported buying herbicides last season (Table 5). This is partly due to low demand, as participants in focus group discussions noted that weeding can be done with conventional hoeing and weeding. But also low availability of herbicides were reported in most areas. Therefore, if CA is to be promoted along with mechanisation then supply linkages to herbicide suppliers must developed.

Maize stems, ears and cobs are also often overlooked as by-products with significant value for farmers, both as animal feed and fuel (Table 22). Thus, leaving residues on the field constitutes an immediate loss of around US$34 in the eyes of farmers (regardless of future gains in soil quality). This additional income helps to push maize production from a marginally profitable enterprise to a more worthwhile one. Thus farmers would need to be assured that there is a sound value proposition for leaving residues on the field.

These anecdotes serve as a reminder that knowledge of CA is presently very low and that in itself CA is an entirely new set of practices compared with present norms. Adoption of CA at scale would require quite intensive training as it involves farming *system* change.

2 wheel tractor use is particularly interesting for integrating with CA. The opportunities and constraints are well described in Johansen et al. (2012)[23]. Smallholder farmers in rain fed agriculture believe that soil tillage is needed to maximize crop yields. However, with increased tillage intensity organic soil matter declines, oxidation is accelerated and above-ground biomass is not returned due to crop residues being used for other purposes. This cycle limits crop yield. Johansen et al. (2012) note that over the previous decade planter attachments to two-wheel tractors have been developed which permit seed and fertilizer placement with minimum to zero tillage in a single-pass. “Recent tests have demonstrated that use of these implements can produce crop yields equal to or better than conventional tillage and that

[23] Johansena, C., Haqueb, M., Bell R., Thierfelderd, C., Esdailee, R. (2012*) Conservation agriculture for small holder rainfed farming: Opportunities and constraints of new mechanized seeding systems*. Field Crops Research 132 (2012) 18–32

fuel, labour costs, seed and fertilizer inputs and turnaround time between crops can be reduced" (Johansen et al. 2012).

Nevertheless, Johansen et al. discuss how movement towards minimum tillage with two-wheel tractor mounted planters and animal-drawn direct seeding equipment is constrained by weed management issues. Interviews and focus groups in the research areas confirmed the same issues regarding the availability and of safe and effective use of herbicides by resource-poor farmers and there is a need to develop more integrated weed management strategies that can be combined with small-scale planters.

Johansen et al. (2012) argue that more adaptive research and on-farm evaluation is needed across a diverse range of soils, cropping systems and agro-ecological regions to bring conservation agriculture to more small holders.

The researchers would go further by arguing that in addition to technical analysis of 2 wheel tractor performance in CA, researchers, policy makers and implementing agencies need to understand cost/benefit models of small scale farming, attitudes of smallholders towards risk and technology adoption, existing levels of farming knowledge/capacity and support through cooperatives and partners, and value chain characteristics particularly regarding tractor availability and chemical inputs. Understanding these rather complex factors, as we have tried to present in this paper, will help predict initial farmer adoption and the incentives needed to stimulate and mainstream CA with tractors. For example, we would suggest that implementing agencies consider targeting higher capacity and better linked smallholders and smallholder cooperatives initially. This profile of smallholder is more likely to have the resources available to make the necessary investments, experiment with the technology and demonstrate to other smallholders the benefits of CA and small tractor integration.

2 wheel tractors can slit the soil and plant in a single pass, rather than ploughing the soil 3 or 4 times using oxen. The 2 wheel tractor thus potentially saves the farmer time and money, but this depends on many variables – such as the costs of hiring a 2 wheel tractor and the additional costs of herbicides, compared with existing household labour availability and present ownership of oxen.

No respondent in our sample was found to own a 2 wheel tractor and only one reported ever hiring one. This naturally makes it difficult to assess their suitability, which is something that Melkasa research centre is presently researching. It is reasonable to say that 2 wheel tractors would only be suitable for applying with conservation agriculture practices, at least within the research areas. This is because in some areas (eg around Assella) the soils were described as heavy, and 4 wheel tractor operators even shy away from working these soils given the damage they can cause to ploughing implements and the tractors themselves. This calls into question the power of 2 wheel tractors on such soils.

Another factor is land slope. While 46% of respondents described their land as flat, 40% described theirs as either mostly medium or steep sloping. Respondents expressed concerns about using 2 wheel tractors on land that is medium or steeply sloped.

Mechanisation models

Identifying 'best' models for delivering mechanised services is a difficult task. In the research countries there were found to be low levels of mechanised services currently active in rural areas, which means, from a research point of view, that one needs to be very careful in generalising from so few examples. On the positive side our research suggests that several models in each country *may* be suitable to deliver tractor and other services, but that the real issue is not the model but the capacity to run tractor hire and other mechanised services *as a business*. By capacity we mean a number of things: Financial literacy, record keeping and basic business planning, the ability to promote services to customers, ability to efficiently deliver those services with qualified staff, ability to maintain and securely store the machines, and the ability to invest their own money and raise further capital. As has been reiterated throughout this paper, actors with such capacity were found to be rather limited and we strongly suggest that any intervention or investment promoting the delivery of mechanised services should include training on business management.

Farmer Unions

The farmer unions[24] interviewed in Ethiopia already provide 4 wheel tractor services (usually ploughing) to members, making them a viable service provider. In saying this, unions typically operated these as a side service, and their main focus was providing other inputs (mainly seed and fertilizer) to cooperatives under their umbrella, as well as marketing. Thus unions typically only had a couple of tractors for tens of thousands of farmer members. This is the reason why no farmers in our sample hired a tractor from a union last season. Unions would in theory be an option for expanding tractor services (even into 2 wheel tractors), however unions need to be sounded out about this and express a motivation to do so. Equally unions may decide to stick with developing their core services rather than expanding mechanised services.

Farmer cooperatives

The advantage for cooperatives[25] as a tractor service providers is that they are close to their potential customers (their members) and that profits made by the cooperative will indirectly benefit their farmer members. Cooperatives could be suitable to deliver either 4 wheel or 2 wheel tractor services, as well as other services such as threshing. However, much depends on the existing cooperative capacity, and what is required to bring the cooperative up to speed to run tractor services as a profitable enterprise. For if a cooperative cannot run tractor services as a profitable enterprise – including making margins to be used for repairs, to repay loans, and to reinvest in new tractors in the future as the existing ones come

[24] Also known as secondary cooperatives
[25] Also known as primary cooperatives

to the end of their useful life – then a particular cooperative should not be invested in. As a guidance, implementing organisations and partners should look at what the cooperative currently does successfully and ask several questions: How many members are in the cooperative and how many are active (i.e. assessing a reliable customer base)? For how many years has the cooperative been operating at its present capacity (many exist in name only, especially after initial support to become established), is the cooperative leadership and governance structure fit for purpose? Does the cooperative efficiently and cost-effectively bulk and distribute inputs to members? Does the cooperative bulk member's produce and engage in group marketing? If the answer to such questions is initially positive then the cooperative may be suitable for further capacity building to provide tractor services. Only one cooperative in our sample in Ethiopia was currently providing mechanisation services (see Box 1)

Farmer groups

Farmer groups are a possible option for 2 wheel tractor ownership. This could possibly involve 5-10 smallholders who are together able to raise the finance required for a 2 wheel tractor and additional implements. In some cases farmers who own oxen may choose to sell them and save on the costs of maintaining them if they are sufficiently convinced that 2 wheel tractor ownership can wholly replace animal traction.

While group ownership may sound like an attractive model for smallholder ownership there are several caveats. Smallholders would need to raise US$2000-3000 which is more than most smallholder have saved and more than most microfinance institutions would be willing to loan. Banks would possibly lend this money with the conditions, including a viable business plan, group lending guarantee (if a member of the group defaults then the other members pickup that members obligations), an initial deposit in the region of 20% (if farmers cannot show they can lay down a deposit then this does not reflect well for the profitability of the smallholder's farms), an interest rate in the region of 25-40% p/a and likely land title as collateral. Such conditions mean that trust among farmers is imperative and they must carefully choose their own group members (perhaps from extended family members or close knit neighbours), as they will need to cooperate for many years together.

Furthermore, group management is another issue, with regards to the capacity of this group to profitably hire out the machine, and to coordinate operations efficiently among co-owners. With up to 10 members pooling together to finance a 2 wheel tractor, there will be less opportunity to rent it out than with a 4 wheel tractor. For example, a 2 wheel tractor has a ploughing work rate of around 2-3 hours per acre. Investing smallholders would likely have larger land sizes than the average farmer (Table 4) which would mean only one farmer could have his land ploughed per day, at most. This suggests that it would take 10 days to plough each investor smallholder's land one time. If conservation agriculture (P.61) is being practiced and only a single pass is required there would be an opportunity to rent it out

to neighbouring farmers, but if not then the several ploughs farmers would perform on their own lands would leave few additional days for renting out after 3 ploughs each.

As there were no 2 wheel tractor services found operating in our research sample, this remains a research gap. However, if smallholder 2 wheel tractor owners wish to make the most of their investment then the 2 wheel tractor will need to be equipped to deal with other crop systems (Table 3) and have implements for other on farm activities such as planting, water pumping, threshing, transport etc. While this might seem obvious in order for the 2 wheel tractor not to lie idle for much of the year, additional implements incur substantial additional costs. Furthermore, in the course of this research it was found to be extremely rare for 4 wheel tractors services to offer anything more than ploughing (discing and harrowing) and occasionally transport.

Large and medium scale farmers

At present large (and sometimes medium scale) farmers are the dominant source of 4 wheel tractors in Kenya, Tanzania and Ethiopia. Tractor ownership is primarily geared towards managing their own farm land and tractors may be hired out year round while not required on the large farm. Services are delivered by a tractor operator who usually will only come to plough smallholder farms when there is at least a full day of work available to make the journey worthwhile, as it is not uncommon for tractors to come from other districts. This typically means that smallholders need to have 20-30 acres of land between them, and be willing to pay a deposit in advance to secure the service. Smallholders sometimes complain that above the agreed price, they must pay an additional amount to the operator to ensure a quality job is done. We would expect that medium and large scale farmers would be less interested in developing their tractor services by expanding their fleet, as this is typically a side business. However, it is for these large and medium scale farmers where policy changes, such as an elimination of tariffs, shorter import periods and less bureaucracy, should stimulate increased tractor ownership. This would have a positive spinoff for smallholders, for whom there would be increased availability of tractors for hire, and likely lower hire prices due to an increase in competition.

Private businesses (agribusiness, private dealer)

Private businesses would seem to be an attractive option in Kenya and Tanzania, though perhaps less so in Ethiopia given that the business environment is not as liberalised. Some private businesses who are already involved in the delivery of agro inputs (seeds, fertilizer, other chemical inputs) may be interested in expanding and diversifying their business to provide hiring services. In saying this many will be risk adverse to making the investment, especially in 2 wheel tractors for which there is little experience. A clear business case would need to be put to such businesses to stimulate interest, else more would already be offering such services. This model may require a subsidy (or co-investment) as well as

training in managing a hire business. Furthermore, storage for the machines would be to be appropriately addressed.

Public company

Public companies in Ethiopia could be invested in to offer tractor services (either 2 or 4 wheel tractors), much as described above for private businesses in Kenya or Tanzania. METEC, the largest parastatal, owned by the Ministry of Defence and already importing tractors is one example. There has been some discussions on METEC transferring responsibilities to the private sector, but if and when this will happen is unclear.

Contract farming

Contract farming would appear to be an unlikely model to successfully promote mechanisation. Firstly, maize contract farming is relatively uncommon. Rarer still are maize offtakers who have tractors and would be willing to invest further in mechanisation for supplying smallholder farmers. Furthermore, while contract farming arrangements sometimes include the provision of seed or fertilizer on credit, investments in tractors are more substantial, while at the same time seen as less essential by the off-taker for smallholders to deliver required volumes or quality.

Conclusions

On average, maize is only a marginally profitable crop choice with current practices (Table 22). Limited profits from maize mean that farmers are financially constrained and need to make choices about whether or not, and the extent to which, they reinvest in maize each season. Furthermore, low profitability may discourage farmers from making additional investment in maize production, unless they are sure that it will have a direct effect on yields and profits. To this end, most farmers would make investments in fertilizer and clean seed before considering tractor hire services.

Mechanisation can reduce farm drudgery to some degree but this should not be overstated in the smallholder maize farming system. Mechanisation is often framed in terms of relieving farm drudgery. For smallholders, mechanisation almost always takes the form of 4 wheel tractor use for a first plough in *combination* with animal traction or manual labour for subsequent ploughs. This means that actual labour savings from tractor use is only a proportion of the 7-10 labour days typically used for ploughing (Table 14). Also, in Kenya and Tanzania farmers do not believe labour availability to be such an issue (Table 8).

Farmers prefer tractor ploughing mainly because it is a faster and better quality plough. A further reason is that it enables smallholders to cultivate more land (Table 37). However, saving household labour and costs are not the main reasons for hiring a tractor (although they are sometimes mentioned).

Lack of availability and high costs are the main reasons for farmers not hiring a tractor (Table 39). Hiring a tractor plough is more expensive than either hiring animal ploughs or hiring manual labour. The fact that tractors provide a better quality plough (deeper, better at removing weeds) is cited as a major reason for farmers to put in considerable time looking for and organising tractor hire services to come to their farms.

In our sample, **smallholders in Kenya had a higher prevalence of hiring a 4W tractor last season (35%) than those in Tanzania (14%) or Ethiopia (11%)**. Very few farmers in our survey had ever hired a 2W tractor (around 1%) (Table 34).

Land size under maize was positively correlated with tractor hiring behaviour (statistically significant, Table 35). In our sample, Kenyan farmers who hired a tractor last season had on average 2.51 acres under maize, whereas those who did not hire a tractor had 1.67 acres under maize. In Tanzania, hiring farmers had 3.05 acres under maize and non-hiring farmers 2.02 acres under maize. In Ethiopia, farmers who hired tractors for their maize plots had 5.63 acres under maize last season, compared with a mean of only 0.63 acres under maize for those who didn't hire a tractor.

Better-off smallholders and those who also hire animal ploughs are more likely to hire tractors. This is the finding from our regression analysis and is consistent with findings across the three countries (Table 42) and suggests that agencies should focus on somewhat wealthier smallholders to promote tractor services in order to stimulate a business environment. If the promotion of tractor services is not profitable then it will not be sustainable. Promoting tractors to poorer farmers who struggle to purchase clean seed and fertilizer is not a winning strategy for promoting tractors. Agencies should have a different strategy for working with this profile of smallholder (see Farming challenges p.57). Distance to access a tractor was described in focus groups as a factor constraining tractor hiring, as farmers need to mobilise and track down a large farmer to deliver a service. However distance didn't show up as a factor in our regression, possibly because everyone had to travel a more or less equal distance to hire a tractor. Mean land under maize was larger for those hiring a tractor last season than for those not hiring a tractor (Table 35), suggesting a positive relationship between land size and tractor hiring behaviour. However mean land size under maize was not a statistically significant predictor in our regression, suggesting other factors (e.g. wealth) are more important.

Smallholders are not all the same. We stress this point because there are certainly a subset of smallholder farmers who have comparatively higher capacity for (maize) farming than others. These farmers tend to have larger land sizes (~5+ acres), have had prior training on production methods (e.g. row planting, timeliness of weeding etc.), are using improved inputs (improved varieties of seed, quality fertilizers etc.), are achieving above average yields, and have access to storage facilities (for bulking, delayed marketing etc.). Such farmers are generally on their way to farming as a business, rather than maize farming as a way of life, or for subsistence with the intention of selling limited surplus. These higher capacity farmers are ready to invest in 'new' technologies (whether to hire or buy). We suggest that agencies looking to expand mechanisation to smallholders should look for those higher capacity smallholders who are prepared to invest and make a step up. For this subset of smallholders there is likely to be a good prospect for successful adoption.

Demand for mechanised threshing (shelling) was articulated however there was very little availability of shelling (for maize) or threshing (for teff) machines in any of our research areas. Given the relatively high number of labour days (often hired labour) spent on threshing and the damage and losses that are typically incurred during manual threshing (Table 15), this would be one aspect of mechanisation that agencies could give more attention, particularly if the thresher is also able to be configured for other grains (e.g. wheat and teff in Ethiopia).

There are many opportunities to extend mechanised services to smallholders, especially in planting, water pumping, threshing and transport. However, at present these additional services are rarely delivered because tractor availability is frequently limited as well as being a more expensive option. For

example, planters are not common and planting does not take so many labour days to do manually, maize is rarely irrigated (although horticultural crops could be), threshers are rarely available, and tractor hire for transport is a more expensive option than using donkey carts[26]. We expect few farmers to hire mechanisation for these other activities due to availability and cost constraints. On the other hand, multi-purpose functionality would seem to be important for smallholders considering *buying* tractors (especially 2 wheel tractors). Multi-functionality would ensure that the tractor does not stay idle for much of the year and reduces labour in other (maize) farming activities. Due to a lack of experience in the research countries with multi-purpose functionality, sensitisation and training support would be needed, as well as help in identifying best-bet products which are fully costed so smallholders can know the expected return on their investment. So while demand is articulated, in that farmers wish to mechanise various operations, it is by no means clear whether farmers would pay market rates to hire these additional services, since there is very little present supply of these services. Therefore some 'safe to fail' pilots could be implemented which would need to be closely monitored to learn more about hire behaviour, models and outcomes.

The promotion of tractors and other forms of mechanisation must be considered in the context of the dominant cropping system of the area. Last season, most households grew 4-7 crops in each of the three researched countries (Figure 2). Maize only accounts for 33% of total land size in the Kenya sample, 59% in Tanzania and 28% in Ethiopia (Table 4). This means that a strategy for increasing mechanisation only around maize is missing the broader picture of the smallholder farming system. When it comes to the promotion of 2 wheel tractors to smallholders, or delivering tractor hire services through other models, mechanisation needs to be adapted to a range of activities for all the predominant crops of an area. This will help increase profitability for service providers, or encourage individuals or small groups to make the investment because of its increased usefulness.

Smallholder farmer's biggest challenges were not said to be mechanisation. During focus group discussions, farmers were asked what their main challenges were around maize production and marketing. The most commonly cited challenges were accessing quality inputs, storage, roads and markets, diseases and pests and various others (Table 45). While there is certainly demand for mechanisation if one asks about it, it is still not high on the priority list of most smallholder farmers. This can be interpreted as a reflection of several things: Most smallholders have, by definition, small plots of land which don't urgently require the efficiency of mechanisation, even if it would be an advantage. Furthermore, we also interpret this in terms of an unfortunate reflection of the low farming capacity (knowledge, skills, ability to invest, access to inputs etc.) of most smallholder farmers. In other

[26] Tractor hire for transporting an acre of maize is approximately 1200 Birr compared with 400-500 Birr for donkey and cart hire. Source: focus group discussions.

words, there is much 'low hanging fruit' in terms of capacity building that a large proportion of smallholders would benefit from before mechanisation becomes a priority issue. A final way of looking at the issue would be to say that smallholder farmers are simply not sufficiently sensitised to the advantages of mechanisation. However, in Kenya and Tanzania at least, a reasonable percentage of farmers have hired a tractor at least once before (Table 33).

A compelling business case needs to be put to potential investors in mechanisation as to the return on investment. To motivate actors to invest in mechanisation (whatever the model, and whatever the subsidy or tariff rate) there must be a compelling financial incentive that far outweighs the risk of the investment, and sufficiently favourable lending terms. Most actors, whether individual smallholders, cooperatives, or agribusinesses, have hardly considered making such a substantial investment because the financial case is not sufficiently clear to them. Agencies wishing to promote mechanisation would need to work with these actors to sensitise them on the financial side, including projecting returns on investment and financing options.

Most smallholders know little about 2 wheel tractors. 2 wheel tractors, also known as walking tractors or power tillers were found to be even less common than we had presumed in the research areas. Some farmers had of course heard about these on the radio, or occasionally at a field day, however very few had ever used or even seen one. Experiences in Asian countries suggest that promoting 2 wheel tractors can be a successful strategy. This lack of experience with 2 wheel tractors up to now suggests that some combination of advertising/sensitisation, subsidies, training, and linking with financial institutions is required to initially stimulate 2 wheel tractor use, otherwise use can be expected to continue to languish among smallholders.

Research institutes, public extension and other agencies have an important role to play to demonstrate and promote smallholder appropriate technologies. Farmers need guidance to know what machinery they should invest in and which makes and models are cost effective, robust and relatively easy to service. Such knowledge is very much lacking among most smallholders. There is a role for private sector dealers too, however at present few businesses provide hiring services. After awareness has been raised and there is greater uptake in hiring the private sector should be supported to drive the transformation to mechanised farming.

Present demand for tractor services is partly based on the desire for deeper ploughing. Farmers believe that deeper ploughing with a tractor achieves better yields because it brings up 'fresh' soil. Such ploughing is then usually followed by animal traction and/or manual labour for subsequent ploughs. While 2 wheel tractors have their advantages, we are unsure of the extent to which 2 wheel tractors are strong enough to satisfy demands for deep ploughing in difficult soils and slopes. Some smallholders

spoke of how their soils were too 'heavy' and that tractor owners were reluctant to plough land in their area because their machines were prone to break under undue stress. It might be expected that such issues would only be more extreme in the case of 2 wheel tractors.

2 wheel tractors can be incorporated with conservation agriculture, driving rippers rather than deep ploughing. However, **conservation agriculture was rarely practiced in any of the research areas** (see Tractors and conservation agriculture p.61). Introducing conservation agriculture will require considerable sensitisation and capacity building to change production practices. If this is to happen, better linkages with herbicide suppliers will be necessary, given the low level of herbicide use at present. We also note that many smallholders expressed positive opinions that yields have been increasing with better practices under conventional farming practices. This may dampen smallholder enthusiasm for taking up conservation agriculture.

There is no 'best model' as such, however the capacity to manage a tractor service as a business is paramount. A range of models were discussed in this paper, and we argue that more important than the model is the characteristics and capacity of the group or small business to actually manage the tractor hire service as a *profitable business*. We directly asked smallholders which model they thought might be best for delivering tractor services and why, however focus group participants usually struggled with this question. Many expressed serious doubts that their cooperative could efficiently manage the service. On the other hand, two cooperatives demonstrated that this was possible and profitable, highlighting the fact that cooperatives range substantially in their capacity. A few would appear to be capable while many are certainly not. Cooperatives should be able to demonstrate competent and efficient delivery of other services in addition to good financial management before they enter into tractor hire services. Tractor hiring from large (or medium) farmers found to be the dominant model in all research areas, with other models rarely found to be operating.

Repair services and parts for tractors are under developed and may therefore be a threat to adoption levels. We suggest that any agency promoting mechanisation should consider having one component of a programme focussing on capacity building of repair service providers. We would also suggest that pilot programmes promoting mechanisation should not be too far from towns with repairers and parts. Machines break down regularly and delays in either sourcing parts or working on repairs will result in lost days, and will very likely have negative implications for loan repayments. It should be noted too that 2 wheel tractors require a vehicle and trailer to travel long distances for repairs. Failure to address this part of the value chain would risk smallholders becoming frustrated with mechanisation and either returning to animal traction or opting against making the investments in the first place.

Government trade policies can either support or stymie mechanisation. The research countries variously apply import tariffs on assembled tractors, import tariffs on parts, VAT, or other forms of import restriction and licensing on smallholder mechanisation. Usually the purpose of such trade policy is to generate revenue rather than to protect domestic industries. However the effect is to stymie the growth of smallholder mechanisation as such trade and tax policies increase the final cost to smallholders and/or reduce import volumes. In some cases investor licenses can be obtained to waive tariffs, however this is not realistic for smallholders. There has been some movement towards more liberalised trade policy for mechanisation in Kenya and Tanzania over the past 10 years, however less so in Ethiopia. Trade policies are thought to be a contributing factor in the observed differences in tractor use between Kenya, Tanzania and Ethiopia (Table 33). The private sector is an important driver for increased mechanisation at scale.

Microfinance is probably not the answer for financing mechanisation and formal banking institutions will need to be brought along. The amounts the farmers can borrow from a microfinance institute are probably insufficient for buying even a 2 wheel tractor as a group. The amount that can be borrowed from a microfinance institute starts at around US$30 for first time lenders, and may increase up to $300 for a lender with an established credit history. The normal conditions for microfinance apply, such as group lending and short repayment periods (usually within 6 months but sometimes up to 1 year). Some serious thinking and piloting is required to see how formal lenders can be brought on board, and how loans can be structured, and how they can be securitised with terms that can be realistically met by smallholders. This is no small challenge and one that will need to be overcome if mechanisation is to increase at scale. Creative ideas could be piloted, such as co-investments, subsidies, insurance structures, or a fund that guarantees banks against losses incurred from tractor loans.

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