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Final report

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1 Acknowledgments

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2 Executive summary

The Farm Mechanisation and Conservation Agriculture for Sustainable Intensification (FACASI) project was implemented from 2013 to 2017 in Kenya and in Tanzania, and from 2014 to 2019 in Ethiopia and Zimbabwe. The aim of the project was to identify appropriate small-scale machines (in particular two-wheel tractors and their ancillary equipment) to improve farming practices (in particular crop establishment through direct seeding), and the commercial mechanisms needed to deliver these to smallholder farmers. The project identified opportunities to create new markets for equipment and services, as well as supporting policies and networks.

The project demonstrated that small-scale mechanization could stimulate intensification of African smallholder farming systems, in particular through better timeliness of operations and greater precision. However, technologies from other regions often needed adaptation to perform well in Eastern and Southern Africa, because of the specificities of African smallholder farming systems (e.g., uneven fields, hard soils due to e.g., limited use of irrigation, long distances between farms, etc), warning against direct South-South transfers.

The project demonstrated that commercialization – and in particular the provision of mechanization services through specialized rural service providers – can be a viable approach to scale technology adoption, in a way that is inclusive. After an initial investment by the project in promotion, information, capacity development and coordination, local market actors (including public sector) appear eager to take over these functions. Finance remains the biggest bottleneck, but the development of a machinery leasing scheme in Ethiopia is a source of hope.

Supporting market system(s) for small-scale mechanization led to adoption beyond what was initially projected, both in terms of the number of rural service providers and their clients. Rural service providers where able to generate substantial annual gross profits (e.g., on average US$4,130 for planting, US$6,400 for transport, and US$1,080 for shelling in Zimbabwe). Similarly, a recent cost-benefit analysis has demonstrated that adoption of small-scale mechanization services increases the gross margin of wheat producing farmers on average by 76% in Ethiopia, and the gross margin of maize producing farmers on average by 12% in Zimbabwe.

There is evidence that the project contributed to 'revitalize' agricultural engineering and mechanization research in Eastern and Southern Africa, as can be seen by the increase in budget and staff of mechanization departments in some countries (e.g., Ethiopia) and the increase in the number of local dealers and local manufacturers selling small-scale mechanization equipment.

3 Background

Per capita food production in sub-Saharan Africa (SSA) has declined dramatically in all regions except West Africa over the last half-century (Pretty, Toulmin, and Williams 2011), highlighting the need for intensification in the region. In addition, the need to foster a new form of intensification – often coined 'sustainable intensification' (SI) – one that increases agricultural production and productivity while minimizing detrimental economic, social and environmental outcomes – is widely recognized (Vanlauwe et al. 2014). By definition, intensification (whether conventional or sustainable), is a process of increasing agricultural output. This increase is generally accompanied by an increase in farm power demand, to handle greater volumes during harvest, transport and processing (Clarke and Bishop 2002). In addition, the implementation of SI technologies tends to result in increased labour demand in a context of low mechanization (Dahlin and Rusinamhodzi 2019). For example, precise application of fertilizer manually (as in the case of micro-dosing) increases labour demand compared with fertilizer banding (Babiker et al. 2017). Similarly, timely weeding is often conditioned by labour availability (Orr, Mwale, and Saiti 2002). Management practices intended to improve the quantity and quality of manure also tend to be highly labour-intensive (Harris 2002). In manual conservation agriculture (CA) production systems, labour demand for land preparation and weeding is much higher than for conventional production systems (Rusinamhodzi 2015). Finally, the adoption of agroforestry technologies - such as alley cropping - has been found to be limited by high labour demand for e.g., pruning (Hoekstra 1987). The positive impact on productivity of precise fertilizer application, timely weeding, CA, agroforestry and many other SI technologies is well known, but their impact on labour demand, which may limit their adoption in the context of SSA where mechanization levels are low, is rarely acknowledged. This lack of consideration for labour issues emanates from the perception that labour in smallholder systems of SSA is abundant, and thus non-limiting. This view is also fuelled by macroeconomic analyses (of e.g., land/labour ratio; Headey and Jayne, 2014), which are based on national data that may be too aggregated to reveal farm-level dynamics.

Several lines of evidence point to the fact that labour and farm power are increasingly becoming major limiting factor to the productivity of smallholder systems in SSA, and most likely a significant constraint to the adoption of SI technologies (which are labour-intensive, as demonstrated above). In areas of low population density, farming is often limited more by labour and draught power than by land (Baudron et al. 2012). For example, the quantity of cereals produced by farming households in the Ethiopian Rift Valley increases with increasing numbers of draught animals owned by these households (Baudron et al. 2014). Farm production may be affected by power constraints in more subtle ways, including low nutrient input and delayed planting. Manure is often the main source of nutrients applied to fields in SSA. However, manure is a bulky material that requires labour and/or draught power for its transport and application (Tittonell et al. 2005). As most farming households experience constraints in their available farm power, they tend to apply most of the manure available to the fields closest to the homestead (Zingore et al. 2007). As a result of negative nutrient balances, fields further away may become degraded and unproductive (Tittonell and Giller 2013). Constraints in farm power may also result in delayed land preparation and delayed planting, which often result in severe yield penalties in SSA (Roxburgh and Rodriguez 2016).

Labour and farm power becoming increasingly limiting, associated with the growing scarcity (and cost) of rural labour – in particular because of rural-urban migration (Collier 2017) – points to the need for mechanization to increase the productivity of smallholder agriculture in SSA. Mechanization is also expected to reduce the post-harvest losses currently experienced by smallholders in the region (Tefera 2012) and reduce drudgery, which is disproportionately placed on women (Doss 2001). However, the form mechanization should take in the smallholder farming systems of SSA is the subject of much debate. Smallholder farms in the region tend to be small and fragmented (Masters et al. 2013). The use of (relatively) large (two axle) tractors would thus require land consolidation. Some authors have argued that consolidation is a prerequisite to mechanization, to use large tractors efficiently (e.g., Asiama et al., 2017). In contrast, others have argued for a concept of 'appropriate mechanization', whereby machines are adapted to farm size, and not the opposite. This is because of the negative social (e.g., labour displacement; Binswanger et al., 1995) and environmental (e.g., loss of landscape heterogeneity; Benton et al. 2003) consequences of land consolidation, and because of negative farm size productivity relationship often reported in smallholder farming systems in Africa (Ali and Deininger 2015). The use of animal traction is part of appropriate mechanization. However, draught animals are uncommon in large parts of SSA, with most oxen concentrated in the central plateau of Zimbabwe, Southern Zambia and the highlands of Malawi (http://www.fao.org/waicent/FAOINFO/AGRICULT/againfo/programmes/documents/livatl2/draftoxenmap.htm). Elsewhere, diseases such as trypanosomiasis restrict the presence of oxen. Even in regions where draught animals are commonly used, their numbers tend to decline because of the combined effect of epidemics (in particular tick-borne diseases such as the East Coast fever), recurring droughts and feed shortages (Moyo et al. 2017; Mapiye, Chimonyo, and Dzama 2009). Thus, it could be argued that the need for smallholder mechanization in SSA combined with the presence of small and fragmented fields and the diminishing availability of animal traction calls for small (less than 25 horsepower) motorized solutions. Such mechanization pathways successfully took place in countries like Bangladesh. Despite very small and fragmented fields, Bangladesh agriculture is highly mechanized, but power is delivered by hundreds of thousands of small (single axle) tractors and other small engines, not large (two axle) tractors (Biggs, Justice, and Lewis 2011).

Land preparation is the most power-intensive farming operation in rainfed agriculture (Lal 2004). It is also one of the most critical operation in Southern Africa, as delayed land preparation and delayed planting often result in severe yield penalties in the region (Roxburgh and Rodriguez 2016). Two-wheel tractors can be used to plough light (e.g., sandy) soils (Kebede and Getnet 2016), but do not produce traction to plough heavier soils in rainfed conditions (Holtkamp and Lorenz 1990; Singh 2006). However, two-wheel tractors could be used to establish a crop in these soils providing energy requirements for tillage are reduced. This can be achieved by simplifying land preparation i.e., using reduced or no tillage, which cuts energy requirements by about half compared to conventional (i.e., mouldboard or disc ploughing) land preparation (Lal 2004). Therefore, it could be argued that reduced or no tillage could make the use of two-wheel tractors for crop establishment viable in most of Southern Africa. Several direct seeders (i.e., placing seed and fertilizer without prior tillage) for two-wheel tractors are now commercially available, from countries such as China and Brazil, and can be used to seed most large grain (e.g., maize, cotton) and small grain crops (e.g., wheat, rice).

The collapse of virtually all the government-run tractor schemes – which were popular up to the 1990s in most of SSA – demonstrates the need for a new approach to mechanization that involves the private sector. The experience of International Development Enterprises (iDE) in Bangladesh has demonstrated the possibility of harnessing the power of the market to drive technology adoption among the rural poor, by involving the private sector in the development and promotion of agricultural technologies (Magistro et al. 2007). Similarly, a market-oriented approach to business development may be used in SSA to foster the adoption of two-wheel tractors and their ancillary equipment. This approach could be guided by the lessons learned from previous experiences in market development, which can be distilled into a set of six principles: (1) facilitating the emergence of private rural service providers; (2) considering the need for a broker; (3) linking mechanization and other input business models to output business models; (4) broadening the range of services offered; (5) bundling hiring services; and (6) providing kick-start subsidies for private sector investment in mechanization service provision.

Building on this background, the project aimed to answer the following research questions:

- What are the context-specific two-wheel tractor-based technologies that could represent economically, energetically and environmentally competitive options to reduce farm power shortage and labour drudgery, and minimize biomass trade-offs in Eastern and Southern Africa?
- What are the site-specific unsubsidized competitive business models that can effectively, profitably, equitably and sustainably deliver these site-specific two-wheel tractor-based technologies for CA to smallholder farmers in Eastern and Southern Africa?
- What are the institutional and policy gaps, impediments and/or opportunities to the adoption of two-wheel tractor-based technologies in Eastern and Southern Africa, and how can they best be addressed?

Among the main mandate countries of CIMMYT in sub-Saharan Africa, Tanzania and Kenya were selected as priority countries to answer these questions: Tanzania because it was the only SSA country where the number of two-wheel tractors in use was substantial at the time the project was developed, and Kenya because of its high credit coverage, commercially-oriented agriculture, high industrialization level, large and growing fleet of four-wheel tractors, and extensive experience with small-scale mechanization in the sector of transport (large fleet of motorbikes and auto-rickshaws). Ethiopia and Zimbabwe were selected as secondary countries with implementation starting a year later: Ethiopia because of its affordable fuel price, its fast increase in agricultural productivity, and its growing expertise in small-scale mechanization (large fleet of auto-rickshaws), and Zimbabwe because of its excellent supporting infrastructure for mechanization (very large fleet of transport vehicles), affordable fuel price, a business-friendly environment (at the time of proposal development, despite recent turmoil), and an agriculture limited by labour more than by land.

In these four target countries, eight sites (two per country) were selected based on the potential for mechanization, the comparative advantage of small-scale mechanization (two-wheel tractor-based) compared to large-scale mechanization (four-wheel tractor-based), and early adoption of conservation agriculture.

After four years of implementation, the following three research questions were added to a two-year project variation:

- What are the adaptive business models to generate sustainable commercial benefits for investors in two-wheel tractor-based service provision, and equitable broad merits for different categories of adopters under varied contexts?
- What is the value of programs that integrate training among trainers, service providers, and other actors in the market system?
- What are the second generation engineering and agronomic improvements (e.g., increased field capacity, improved mobility) needed by the service provision business?

To answer these research questions, activities were implemented in the sites of Ethiopia and Zimbabwe only (Kenya and Tanzania were not included in the variation).

4 Objectives

4.1 Objective 1: To evaluate and demonstrate two-wheel tractor-based technologies to support CA systems, using expertise and implements from Africa, South Asia and Australia.

This objective aimed at understanding the demand for mechanization, importing commercially available 'best bet' machines to meet this demand, adapting these machines to local conditions if and where need be, and assessing the potential impact on farming systems of adoption at scale of these machines. Considering the initial focus of the project on mechanized conservation agriculture, most of the testing and adaptation efforts have been placed on direct seeders. However, considerable work also took place on transport and post-harvest equipment due the high demand for these operations. Similarly, single-axle two-wheel tractors were initially the sole source of power considered. However, self-powered shellers/threshers and motorized pumps were later considered, particularly in Zimbabwe.

The outputs of this objective include:

- Most promising two-wheel tractor-based technologies identified and acquired
- Best bet two-wheel tractor-based technologies evaluated on-station and on-station component technology research
- Best bet two-wheel tractor-based technologies evaluated on-farm and continuously refined
- Exploration of short-term incentives and long-term impact of two-wheel tractor-based technologies on farmer livelihoods through farm bio-economic models.
- Second generation technological improvement to increase the performance of service provision

4.2 Objective 2: To test site-specific commercial systems to deliver two-wheel tractor-based mechanization.

This objective aimed at developing innovative unsubsidized business models to deliver mechanization to smallholder farmers, based on the collapse of virtually all the government-run tractor hire schemes which were popular up to the 1990s in most of sub-Saharan Africa. This was centred on intensive training of private rural service providers and market linkages between these service providers and local importers, manufacturers, financial organizations, etc with the goal of delivering the most promising two-wheel tractor-based technologies in an efficient and equitable way (i.e., affordable to the poor and women-headed households).

The outputs of this objective include:

- Country- and site-specific market analysis of small-scale mechanization
- New or upgraded business models designed and re-designed
- New or upgraded business models supported
- Performance of the new or upgraded models assessed
- Mechanization frame of reference developed

4.3 Objective 3: To identify improvements in national institutions and policies for wide adoption of two-wheel tractor-based mechanization.

This objective aimed at examining the institutional and policy constraints and opportunities that may affect the adoption of two-wheel tractor-based technologies in the various target countries, motivated in part by the Bangladesh case (where removal of duties, sales tax, and standardization restrictions in 1988 resulted in an exponential adoption of two-wheel tractors in the following years) and the Tanzania case which appeared as a success at the time the proposal was developed (large imports of two-wheel tractors were being stimulated by generous Government subsidies).

The outputs of this objective include:

- Review of policies affecting two-wheel tractor-based mechanization
- Policy options for wider delivery of two-wheel tractor-based mechanization

4.4 Objective 4: To improve capacity and create awareness of two-wheel tractor-based technologies in the sub-region, and share knowledge and information with other regions.

This objective aimed to facilitate and accelerate exchange of mechanization related knowledge within the region and between the region and others. This objective is centred around repositories of knowledge products produced by the project (including a knowledge platform hosted by the private company Hello Tractor), communication products targeting difference audiences, and an international mentoring platform aiming at building capacity of the NARS in the target countries to engage in research related to the multiple dimensions of mechanization.

The outputs of this objective include:

- Outputs from the project available to project partners and partly available to the public
- Awareness on two-wheel tractor-based technologies created at various levels
- International mentoring platform created

5 Methodology

5.1 Understanding the demand for mechanization and the impact of different mechanization scenarios on local farming systems (Outputs 1.1 and 1.4)

Results from the baseline survey and from focus group discussions related to drudgery in farming were used to understand farmers' needs and likely demands and, compiled with key characteristics of each site (local manufacturing and maintenance capacity, demand for local rural transport) were used to identify the most promising two-wheel tractor-based technologies. In parallel, an inventory of the most promising two-wheel tractor-based technologies available regionally and globally was conducted, through country-specific desk studies and consultations of all available options. The focus was on conservation agriculture seeders, but threshers, shellers, and trailers were also considered. From this inventory, best bet two-wheel tractor-based technologies that were most likely to meet farmers' needs and demand were selected and acquired.

To assess the impact of different mechanization scenarios on local farming systems, the baseline survey dataset was analysed through multivariate methods (generalized linear models, boundary line analysis, and binary classification and regression trees) in one hand, and through yield gap analysis.

5.2 Performance of commercially available machines and local adaptations (Outputs 1.2, 1.3 and 1.5)

Selected technologies were then continuously (over the first four year of the project) evaluated through two parallel processes: on-station evaluation and on-farm evaluation. The selected technologies were commercially available 'best bet' tow- behind seeders and rotary strip-tillage seeders. Two-behind seeders included the Brazilian Fitarelli single row seeder (http://www.fitarelli.com.br/site/produto/45/plantadeira-e-adubadeira-para-micro-trator-1-linha), the Brazilian Fitarelli double row seeder (http://www.fitarelli.com.br/site/produto/27/plantadeira-e-adubadeira-para-micro-trator-2-linhas), and the Indian National Agro four row seeder (https://www.nationalagro.com/product/national-zero-till-multi-crop-planter-for-2-wheel-tractor). The single row Morrison seeder (http://www.morrisonseeders.com/) was later added in the evaluation in all countries, thanks to a donation from the World Help Through Technology (WHT). In Kenya and Tanzania, a modified version of the Gongli seeder – developed by the project itself – was also added (https://www.cimmyt.org/news/two-wheel-tractor-seed-drill-modified-for-african-smallholder-maize-farmers/). Rotary strip-tillage seeders included the Chinese 2BFG 100 (http://www.chinalyjx.com/en/Rotary-tillage-fertilizing-seeder/155.html) and the Bangladeshi Versatile Multicrop Planter (https://www.mdpi.com/2076-3298/3/1/1). On-station evaluation was researcher-managed but also involved other important stakeholders. This evaluation was key in the first year, as it enabled project staff to familiarize themselves with the details of field operation and adjustments. In the subsequent year, on-station research aimed mainly at adapting equipment to local conditions (e.g., seed metering, soil engagement parts). On-farm evaluation was a participatory process, where the perception of farmers, manufacturers, service providers and other relevant stakeholders was recorded during planting and before harvest, in addition to planter performance data (e.g., field capacity, fuel consumption) and yield data. In the first year, field data collected during on-station and on-farm evaluation was analysed to select a subset of technologies to be delivered to smallholders through business models.

During the two years of the variation, second generation technological improvements based on the demand from service providers and their clients were made through several iterations of consultation of service providers and their clients (focus group discussions to identify improvements in the equipment used in order to improve the quality and efficiency of the service they deliver/receive), design (based on the consultation process), and participatory testing (field testing involving a group of service providers and their clients/farmers) in Ethiopia and Zimbabwe. For seeders, the work focused on transportability (lower demography in SSA compared to Asia, implying that seeders need to be transported easily or ridden off-road at a decent speed), soil engagement parts (limited irrigation compared to Asia), ground-following ability of planting units (limited levelling and widespread grazing making fields uneven) and seed metering devices (to allow for crops such as teff to be seeded). Engineering research on threshers and shellers adapted to the local farming systems also took place.

5.3 Market analysis (Output 2.1)

In each target country, a sector profile and a sector organization (description of key actors, size of the market, recent and anticipated growth, geographic spread, etc.) for two-wheel tractors, their ancillary equipment, and corresponding spare parts were produced through a literature review and a quick appraisal using key informants.

Key market actors identified during the sector profile and sector organization (both national and local, private and government entities, local importers, manufacturers, financial organizations, mechanics, workshops, etc.) were then interviewed to collect data on performance and constraints of the sector in each country. Particular attention was placed on constraints, both generic and actor-specific.

Finally, key services and interventions necessary to establish sustainable market systems based on the analysis above were discussed in country-specific multi-stakeholder roundtables.

5.4 Development of business models (Outputs 2.2 and 2.3)

Focus group discussion and multi-stakeholder round tables were organized to prioritize interventions, with a focus on linkages between market players (i.e., competitiveness of the market) rather than the agenda of a particular market player. A business study looking at the way these interventions were projected to affect each actor was conducted and presented to each actor to ‘demonstrate incentive’. Annual multi-stakeholder roundtables took place throughout the project duration to evaluate the performance of these interventions and continuously refine them.

The business model approach used by the project focused on strengthening the main supporting functions of two-wheel tractor-based markets: promotion (including the creation of initial demand for mechanization services by farmers), capacity building (of service providers), coordination, information, and finance.

Demand creation (of mechanization services by farmers) is key for technologies that are relatively new (two-wheel tractor, conservation agriculture seeders, etc) and is a prerequisite for private sector investment (to jumpstart the virtuous cycle of demand creation, transmission of market demand, and response to market demand). As such, the creation of farmer demand was a strong focus of the project, particularly during the first years. Early service providers were selected, trained, mentored and provided with machines on a grant basis. These service providers were linked to local microfinance institutes for repayment of the equipment and were required to establish demonstration plots (between 5 and 10) in strategic locations and participate in field days to create demand amongst farmers, in addition to providing services on a commercial basis. Farmers have been invited regularly during the season to observe operations on farmer's land. Field days have also played a major role in creating awareness on small-scale mechanization, not only for farmers but also for local government officers, local NGOs, etc.

Continuous training of the growing number of service providers – both on technical issues and on business and financial management – was a key in strengthening small-scale mechanization markets. During the variation, to ensure the sustainability of training capacity in Ethiopia and Zimbabwe, the project built the capacity (as well as curricula within these organizations) of the Institute of Agricultural Engineering and Gwebi College in Zimbabwe, and of Selam Vocation Training Center in Ethiopia.

The project stimulated market interlinkages through multi-stakeholder meetings and by inviting manufacturers and dealers to field days. Finally, the project engaged microfinance institutions in each country from the onset, and the project lobbied for the development of financial products adapted to the need of emerging service providers (and poor farmers keen to benefit from mechanization services).

It should be noted that none of the collaborating private sector actors benefited from subsidies (from the project or other sources). However, early service providers were assisted through equipment provided on a grant basis, and through capacity development. The R&D of manufacturers was supported for equipment improvement (although most of it is funded by other initiatives than FACASI). Manufacturers and importers were also supported by the project through promotion of their equipment (field days and 'live demonstration' through the early service providers equipped by the project) and better coordination amongst market actors during multi-stakeholder meetings.

However, reaching a trigger requires investment (developing unsubsidised business models is a myth!). Incentive schemes (matching grants, soft loans, guarantee funds, etc.) are necessary to set up supply chain stakeholders in business. It may also take several years (and resources during all these years)

5.5 Performance of business models and cognitive process of adopting mechanization (Outputs 2.4 and 2.5)

The profitability of the hire service business models was analysed through the application of economic analyses (ex post) for each of the hire services offered. The analysis examined profitability from the perspective of the rural service provider and from the user (farmer hiring a service). The benefits and costs of the different machineries and equipment – separately and in combination – was assessed through selected indicators of profitability. Risk analysis was conducted to examine the robustness of the different business services offered. From the user perspective, simple gross margin analyses and whole farm analyses were used to assess profitability.

The performance of the business models for different actors along the supply chain was evaluated to understand the incentives and trade-off for adoption of small-scale mechanization. The evaluation drew on a business model conceptual framework developed by the project which included the following dimensions: the business infrastructure (business organization and resources), the business environment (policies, regulations, laws), the services and products offered (value proposition, flow of services), the customer segment and relations, the market attractiveness/share, the profitability, the customer satisfaction, the business growth, the linkages and partnerships (suppliers, finance, research and extension) and the sustainability (innovativeness, management capacity, risk mitigation, competitiveness). The methodology identified critical success factors from the perspective of the hire service provider and user.

To complement the performance assessment, cognitive process of knowing, perceiving and therefore adopting (and expanding) mechanization were studied. The focus was on farmers and rural entrepreneurs' knowledge, attitudes, perceptions, and how these are shaped by social networks. Four factors influencing decision processes regarding mechanization were studied: perceived readiness (i.e., whether farmers and rural entrepreneurs regard themselves inclined/fit for mechanization), perceived risks or consequences (i.e., whether mechanization has serious personal perils), perceived benefits (i.e., whether specific mechanization actions can improve readiness, or reduce the risks) and perceived obstacles (i.e., whether the perceived benefits of mechanization outweigh subjective costs and other barriers to taking action; and whether institutional, social, policy or infrastructural contexts and arrangements eliminate obstacles of mechanization).

5.6 Review of policy options and policy recommendations (Outputs 3.1 and 3.2)

A global review was conducted to understand the policies, markets and institutions necessary to the expansion of mechanized conservation agriculture. The findings were used to benchmark the review of national policies likely to affect the adoption of mechanization in the target countries. From this review, and guided by the inbuilt learning in Objective 2, policy gaps, constraints and opportunities were identified and discussed during national policy workshops. Alternative policy options for a wider and more inclusive adoption of two-wheel tractor-based mechanization were then proposed and discussed during a second round of national policy workshops.

5.7 Knowledge exchange and awareness creation (Outputs 4.1 and 4.2)

During the first four years of the project, a knowledge platform focusing on mechanized conservation agriculture for smallholder farmers was established and hosted by the African Conservation Tillage (ACT) network, a pan-African network dedicated to knowledge sharing on all issues related to conservation agriculture. ACT issued a project newsletter and published project news and success stories via social media platforms (e.g., Twitter). All communication products produced by the project are (and will continue to be) hosted on a specific page of the ACT website (http://facasi.act-africa.org/). In order to broaden the project audience, the project also collaborated with the world acclaimed company Hello Tractor to create a knowledge platform hosting the best products of the first four years of the project as well as the communication products of the variation (http://knowledgeplatform.hellotractor.com/) including drawings of the machines produced by the project.

In each country, existing national conservation agriculture task forces were used to share lessons learnt by the project. Training materials targeting emerging service providers were developed in each country. Project outputs were also published in various formats including fact sheets, bulletins, photobooks, videos, and cartoon books. During the variation, a short video targeting policy makers was produced in Zimbabwe and videos in local languages for national and regional TVs in Ethiopia. In addition, annual advisory and scaling meetings were organized during the variation in Ethiopia and Zimbabwe.

5.8 Capacity building (Output 4.3)

Exposure visits to India and Bangladesh – who have successfully mechanized their smallholder sector – as well as to Australia for key members of the project research team were organized. The capacity of the National Agricultural Research System to engage in research related to mechanization, conservation agriculture and business models was built through an international mentoring platform co-managed by CIMMYT and Charles Sturt University. The platform funded practical trainings in engineering, gender, and communication, amongst others. It also funded research for MSc students.

6 Achievements against activities and outputs/milestones

Publications mentioned in the table correspond to publications in the list of section 10.2 (page 49). These publications are available in the project data repository: https://simlesa.cimmyt.org/facasi/resources/.

Objective 1: To evaluate and demonstrate two-wheel tractor-based technologies to support CA systems, using expertise and implements from Africa, South Asia and Australia

no.	activity	outputs/ milestones	completion date	Comments
1.1.1	Biophysical and socio-economic site characterization (desk study)	Site-specific report detailing biophysical (e.g. major soil types, main crops) and socioeconomic (e.g. labour availability, cultural setting, proportion of women-headed households) context	TAN, KEN, ETH: May 2014	Completed (as reported in the annual report of May 2014)
			ZIM: May 2015	Completed (as reported in the annual report of May 2015)
1.1.2	Focus group discussion in each innovation platform on the current knowledge and skills on 2WT-based technologies	Report on the current knowledge and skills on 2WT-based technologies in each innovation platform	TAN, KEN: May 2014	Completed (as reported in the annual report of May 2014; see Publication 8)
			ETH: May 2015	Completed (as reported in the annual report of May 2015; see Publication 10)
			ZIM: May 2015	Completed (as reported in the annual report of May 2015; see Publication 9)
1.1.3	Farm survey with focus on farm power and drudgery, disaggregated by gender	Baseline report for each site Cross-site database available through the knowledge platform	TAN, ETH, ZIM: Dec 2016	Data available: https://dataverse.harvard.edu/dataset.xhtml?persistentId=doi:10.7910/DVN/61PWTB
			KEN: June 2013	
1.1.4	Inventory and characterization of most promising 2WT-based technologies available in each country	Country-specific report	TAN, KEN: Nov 2014	Completed (as reported in the semi-annual report of November 2014)
			ETH May 2014	Completed (as reported in the annual report of May 2014)
			ZIM: Nov 2015	Completed (as reported in the semi-annual report of November 2015)

no.	activity	outputs/ milestones	completion date	Comments
1.1.5	Import of most promising 2WT and ancillary equipment (including transport trailers and herbicide sprayers), based on inventory, site characterization and likely farm demand.	2WT and ancillary equipment available in each site for testing	TAN May 2015	Import of seeders (2 Fitarelli double row, 2 Fitarelli single row, 2 Versatile Multicrop Planter, and 2 National Agro) complete (as reported in the annual report of May 2014). One modified Gongli seeder and one trailer/sheller/thresher/chopper were later fabricated through the International Mentoring Platform fund (as reported in the annual report of May 2015). Moreover, 2 Morrison seeders were donated by World Help Through Technology (WHT) in April 2014. See section 5.2 for a description of seeders.
			KEN: May 2015	Import of seeders (2 Fitarelli double row, 2 Fitarelli single row, 2 VMP, 2 National Agro, and 2 2BFG-100) completed (as reported in the annual report of May 2014). One modified Gongli seeder and one trailer/sheller/thresher/chopper were later fabricated through the International Mentoring Platform fund (as reported in the annual report of May 2015).
			ETH: Nov 2014	Import of seeders (2 Fitarelli double row, 2 Fitarelli single row, 2 VMP, 2 National Agro, and 2 2BFG-100) completed (as reported in the semi-annual report of November 2014). Moreover, 2 Morrison seeders were donated by World Help Through Technology (WHT) in April 2014.
			ZIM: June 2017	Import of seeders (2 Fitarelli double row, 2 Fitarelli single row, 2 VMP, 2 National Agro, and 2 2BFG-100) (as reported in the semi-annual report of November 2014). Moreover, 2 Morrison seeders were donated by World Help Through Technology (WHT) in April 2014. An additional Chinese two row planter was procured in 2017 through CRP MAIZE funding.
1.2.1	Training of researcher teams in the calibration, operation, repair and maintenance of 2WT and ancillary equipment	Research teams trained	TAN May 2014	Completed in February 2014 (as reported in the annual report of May 2014)
			KEN: May 2014	Completed in January 2014 (as reported in the annual report of May 2014)
			ETH, ZIM: Nov 2014	Completed in November 2014 (as reported in the semi-annual report of November 2014).
1.2.2	Adaptation of seeders (seed metering and soil engagement parts)	Seeders adapted to the local seeds and the local soils	TAN, KEN, ETH, ZIM: May 2015	A common protocol has been developed and adopted during the Mid-Term Review in Hawassa and has been applied during the trials of 2015.

no.	activity	outputs/ milestones	completion date	Comments
1.2.3	Researcher-managed field evaluation of most promising 2WT-based technologies	Technical report on the comparative performance of the equipment and on their adaptation to suit local circumstances; and recommendations for on-farm evaluation	TAN: Dec 2016	Data from 4 seasons (2013, 2014, 201(, 2016) and 4 locations (Mbulu, Arumeru, SARI)
			KEN: Dec 2016	Data from 4 seasons (LR 2014, SR 2014, LR 2015, SR 2015) and 2 locations (Laikipia, Bungoma)
			ETH: Dec 2018	Data from 3 seasons (2014, 2015, 2016) and 2 stations (Hawassa and Kulumsa)
			ZIM: Dec 2019	Data from 2 seasons (2015, 2019) and one station (UZ farm)
1.3.1	Identification of at least five farm-sites per innovation platforms for participatory evaluation of 2WT-based technologies	Farm-sites identified and characterized	TAN, KEN: May 2014	Completed (as reported in the annual report of May 2014)
			ETH: May 2015	Completed (as reported in the annual report of May 2015)
			ZIM: Nov 2014	Completed (as reported in the semi-annual report of November 2014)
1.3.2	Development of protocols for on-station testing	On-farm evaluation protocols	TAN, KEN, ETH, ZIM: May 2015	Completed in May 2015 (as reported in the annual report of May 2015)
1.3.3	Training of innovation platform members on basic calibration, operations and maintenance of tractors and ancillary equipment	Innovation platform members trained	TAN: May 2015	14 trainees (as reported in the annual report of May 2015)
			KEN: Nov 2014	12 trainees (as reported in the semi-annual report of November 2014)
			ETH: May 2015	40 trainees (as reported in the annual report of May 2015)
			ZIM: May 2015	23 trainees (as reported in the annual report of May 2015)
1.3.4	Participatory evaluation and adoption of best bet 2WT based technologies	Participants identification Activity facilitation Data collection	TAN: Dec 2016	Between 3 and 8 on-farm trails planted each season for 4 seasons (2013, 2014, 2015, 2016) in two locations (Mbulu, Arumeru)
			KEN: Dec 2016	Between 6 and 11 on-farm trials established each season for 4 seasons (LR 2014, SR 2014, LR 2015, SR 2015) in two locations (Laikipia, Bungoma)
			ETH: Dec 2016	Between 11 and 12 on-farm trials established each season for 2 seasons (2016, 2017) in two sites (Hawassa, Assela)
			ZIM: Dec 2016	Between 6 and 8 on-farm trials established each season for 2 seasons (2014, 2015) in two sites (Makonde, Domboshawa)
1.4.1	Development of farm typology, based on farm power availability and constraints	Prototype farms for simulation	TAN, KEN: Dec 2016 ETH, ZIM: Dec 2016	Farm-level assessment of labour and mechanization in the 4 project countries (Publication 2) translated into a factsheet (Publication 81). In depth

no.	activity	outputs/ milestones	completion date	Comments
1.4.2	Selection (or development) of a farm scale model, calibration and validation	Model ready for simulation for each farm type	TAN, KEN: Dec 2016 ETH, ZIM: Dec 2016	yield gap analysis in Ethiopia (Publication 4).
1.4.3	Identification of realistic scenarios of change in available farm power and simulation of these scenarios	Outputs of simulation runs (e.g. expected labour input, cash flow) of various realistic modelling scenarios (incorporating adoption rate of different 2WT-based technologies)	TAN, KEN: Jul 2014; ETH, ZIM: Jul 2015	
1.4.4	Participatory workshops discussing simulation outputs within each innovation platform	Workshop report for each innovation platform	Apr 2019	Result from the analyses discussed during national advisory meeting and review and planning meetings.
1.5.1	Improvement of 2BFG wheat seeders (seed metering devices, blades, transportability) and exploration of the possibility to produce local strip till seeders based on conventional rotovators	Drawings and testing reports. At least 10 improved seeders in use.	Dec 2019	Fabrication drawings of a two-wheel tractor operated four-row strip tillage wheat seeder from a conventional rotovator (Publication 63) Drawings for two-wheel tractor attached wheat metering unit (Publication 61) Fabrication drawings for trailer modifications (Publication 62). Fabrication drawings of a two-wheel tractor operated wheat thresher (Publication 64)
1.5.2	Improvement of the Zimplow maize seeders (transportability and soil engagement parts)	Production of machine Drawings Test Reports Development of operators training manuals.	Dec 2019	Drawings for the Zimplow and Grownet planters developed in collaboration with FACASI have not been made available for distribution given the potential IP conflicts with the private sector partners. The partner's contribution in the development process was significant. Fabrication drawings of two-wheel tractor operation boom sprayer, double cob sheller, and cutter miller (Publications 65, 66 and 67) MSc theses for the development of a two-wheel tractor operation boom sprayer and a monitoring system for two-wheel tractor based planters (Publications 55 and 56) Double cob sheller manual and starwheel planter manual (Publications 68 and 69)

Objective 2: To test site-specific commercial systems to deliver two-wheel tractor-based mechanization

no.	Activity	outputs/ milestones	completion date	Comments
2.1.1	Demonstration trials seeded by rural service providers	Technical report on the performance of mechanical seeding using a two-wheel tractor compared with conventional methods	KEN, TAN, ETH, ZIM: May 2015	Completed (as reported in the annual report of May 2015, see Publication 11, 12, 13 and 14)
2.1.2	Regular mentoring/backstop visits from CIMMYT	Trip report	KEN, TAN, ETH, ZIM: May 2015	Completed (as reported in the annual report of May 2015, Publication 15, 16, 17 and 18)
2.1.3	Multi-stakeholder roundtable discussions in each IP to identify underlying causes for market systems weakness	Report on the identification of key services and interventions necessary to establish sustainable market systems Recommendations on strategies enhancing markets and service deliveries	KEN, TAN, ETH, ZIM: May 2015	Completed (as reported in the annual report of May 2015, Publication 15, 16, 17 and 18)
2.2.1	Focus group discussions with each actor group to prioritize critical success factors related to actor linkages and supporting services	Prioritized list of interventions	KEN, TAN, ETH, ZIM: May 2015	Completed (as reported in the annual report of May 2015, Publication 19, 20, 21 and 22)
2.2.2	Multi-stakeholder roundtables to secure agreement on an action plan for the design of new business models or the upgrading of existing ones	Draft agreements with identified stakeholder/market actor	TAN: May 2015	Some agreements (formal and informal) have been drawn up (as reported in the annual report of May 2015). Roundtable meetings have been conducted during the reporting period in Mbulu, Arumeru, Babati, Karatu and Arusha. See Publication 21
			KEN: May 2015	Some agreements (formal and informal) have been drawn up (as reported in the annual report of May 2015). See Publication 20
			ETH: May 2015	Some agreements (formal and informal) have been drawn up (as reported in the annual report of May 2015). Roundtable Minutes reported). See Publication 19.

no.	Activity	outputs/ milestones	completion date	Comments
			ZIM: Nov 2019	Roundtable meetings conducted in collaboration with Ministry of Agriculture Mechanization and Irrigation Development, Agritex, UZ, Domboshava and Makonde farmers on the basis of which project sites were selected and preliminary agreements reached. An additional two round table meetings involving the same parties but funded by a sister project were convened in 2018, and 2019. See Publication 22
2.2.3	*Ex ante* business study to assess the potential impact of new/upgraded business models (considering the size of the market, profit along the market chain, etc.)	-benefit analysis for farmers, net present value and breakeven point of investment for rural service providers, for local importers and manufacturers, and for financial and credit institutions	KEN, TAN, ETH, ZIM: May 2015	Ex-ante economic analyses completed (as reported in the annual report of May 2015). Publication 23, 24, 25 and 26.
2.2.4	Focus group discussions to 'demonstrate incentive' (cost-benefit analysis, net present value, breakeven point) to each group of market actor (including financial institution)	Reports on the focus group discussion	KEN, TAN, ETH, ZIM: May 2015	Completed (as reported in the annual report of May 2015). See Publications 23, 24, 25 and 26.
2.2.5	Annual multi-stakeholder roundtable in each IP to evaluate and refine (if need be) the new/upgraded business models	Minutes of the roundtable	KEN, TAN, ETH, ZIM: May 2015	Completed (as reported in the annual report of May 2015)

no.	Activity	outputs/ milestones	completion date	Comments
2.3.1	Lobbying for greater market integration of local importers and manufacturers, workshops/mechanics and rural service providers	Signed deals between local importers/manufacturers and (a) selected rural service providers and (b) maintenance workshop owners/mechanics to be dealers/commission agents Development of rural service providers as sales agent/after sales service agent for the manufacturer/dealer/importer Development of pricing structure so that after sales service costs are embedded in the machinery costs	TAN: May 2016	The project linked market actors with rural service providers in different areas for the purpose of establishing two-wheel tractor leasing schemes among competent rural entrepreneurs for promotion and market creation. ✓ 3 rural service providers were selected (one from each district-Mbulu, Arumeru and Babati) ✓ 3 meetings were conducted between the project and Farm Equip to conduct second on-farm demonstration in Mbulu, Arumeru and Babati districts that would create better environment for leasing of two-wheel tractors and accessories to one service providers in each district. These 3 service providers were connected to financial institutions (EFTA equipment loan and Equity bank for equipment loans)
			KEN: Dec 2016	Focus has been placed on developing and refining the hub model which primarily aims at providing mechanization services from a central one-stop shop where farmers can access mechanization, information, inputs among other services. It is intended to be a centre of excellence replicable all over the country and beyond. The hub, located at Mwireri in Laikipia, is fully operational with both two- and four-wheel tractor technologies. It was officially launched on 18th November 2016. At the time of launch, the hub had served over 250 farmers in various farm operations covering an area of about 300 acres of land. It employs 7 people – hub manager, hub client manger, hub administration assistant, two machine operators and two assistants.
			ETH: May 2016	Completed (as reported in the annual report of May 2016)

no.	Activity	outputs/ milestones	completion date	Comments
			ZIM: Dec 2019	There was a submission made by the project in collaboration with the University of Zimbabwe to the national cabinet on efforts being made to support the local manufacture of small-scale mechanization and the status of progress for each of the 4 private sector partners. The FACASI project in Zimbabwe made a presentation to the Minister of Youth and his senior staff on the opportunities to engage young people in two-wheel based mechanization kits. A MoU is to be signed between the UZ and the Ministry, which would allow project staff to advise and train young entrepreneurs. Empower bank has been processing at least one known application for a planter purchase by a service provider in December 2019. Lease agreements were signed between the 20 shelling service providers and the 4 planting service providers in Makonde, Domboshawa and Kasoko
2.3.2	Training of local importers/manufacturers/dealers in 2WT-based CA (including machinery operation, machinery maintenance, rotational requirements, agronomy, mulch conservation, fertilizer management, weed control)	Local importers/manufacturers/dealers become trainers in 2WT-based CA Training report Training modules translated and adapted, and published as public resource for each IP	KEN, TAN: Nov 2014	Completed (as reported in the semi-annual report of November 2014)
			ETH: May 2016	Completed (as reported in the annual report of May 2016)
			ZIM: May 2015	Completed (as reported in the annual report of May 2015)
2.3.3	Training of local importers/ manufacturers/dealers for them to become trainers of rural service providers in business and financial management and marketing	Training reports	KEN, TAN: Nov 2014	Completed (as reported in the semi-annual report of November 2014)
			ETH: Feb 2016	Completed (as reported in the annual report of May 2016)
			ZIM: Oct 2019	Training manuals were developed. Training was targeted at Gwebi and Hatcliffe Centres as opposed to manufacturers and dealers. The two centres would cascade training to the target groups. Both centres were equipped to run courses for artisans, mechanics and service providers.
2.3.4	Backstopping training of rural		ETH: May 2016	Completed (as reported in the annual report of May 2016.

no.	Activity	outputs/ milestones	completion date	Comments
	service providers in 2WT- based CA and business and financial management and marketing by the importers/manufac turers/dealers and workshop owners/mechanics	Training reports	TAN: Feb 2017	One business mentoring training to service providers was conducted in each district (15 services providers mentored in business management skills including record keeping) - 5 from each district. Technical trainings have been on-going and provided by district councils.
			KEN: Feb 2017	The hub provides training services to clients on two- and four-wheel tractor technology as well as Climate Smart Agriculture. In 2016, trainings were commissioned by ADRA in Kitui County and CARITAS in Makueni County in which over 50 farmers, among the service providers were trained on CA and equipment use. Additional training trainings were conducted for the 4 cluster members in Laikipia and Meru in support of establishing a SACCO.
			ZIM: May 2016	The backstopping has been done by the project staff in collaboration with district extension staff and people from the national mechanization training centre (IAE). This was done for those in the shelling, transport and planting business.
2.3.5	Development of appropriate financial products targeting (1) rural service providers (2) farmers seeking 2WTbased services	Financial products are available and advertised	TAN: May 2016	Completed (as reported in the annual report of May 2016, Publication 28). 5 service providers connected to financial institutions with equipment loan packages (two-wheel tractor, trailers, ploughs)
			KEN	This activity did not take place in Kenya
			ETH: April 2016	Completed (as reported in the annual report of May 2016, Publication 27)
			ZIM: April 2016	Completed (as reported in the annual report of May 2016, Publication 29).
2.3.6	Development of promotional materials targeting (1) rural service providers to support and raise awareness on importers/dealers and (2) targeting farmers to support service providers	e.g. DVDs, manuals, flyers, posters, village plays, push-sales media.	KEN, TAN: May 2016 ETH, ZIM: Nov 2019	Various products. See Activity 4.4 and 4.1.5
2.3.7	Quarterly IP meetings on 2WT-Based market systems	Minutes of the IP	KEN, TAN: May 2016	These were on-going
			ETH, ZIM: Dec 2019	These were on-going.

no.	Activity	outputs/ milestones	completion date	Comments
2.3.8	Twice yearly training of Ethiopian rural service providers, mechanics, and trainers in wheat-based systems	Training reports. At least 50 men and women trained during each training.	Oct 2019 SVTC (lead) CIMMYT, EIAR	Two technical trainings on calibration, operations and maintenance of tractors and ancillary equipment provided to 13 members (4 females) of youth group management committee. Two training sessions on hire service business management provided to the same 13 youth. Production of manuals (Publications 70 and 71)
2.3.9	Twice yearly training of Zimbabwean rural service providers, mechanics, and trainers in maize-based systems	Training reports. At least 50 men and women trained during each training.	Oct 2019 IAE (lead) CIMMYT, UZ	Week-long training on technical and business issues related to planting services provided to 20 service providers from Makonde District, at the Institute of Agricultural Engineering. Another week-long training on technical and business issues related to shelling services provided to 17 service providers from Makonde District, at Gwebi college. Additionally, 38 service providers and extension staff from Eastern Zimbabwe (Nyanga district) underwent a 2-day training on operations and business for shelling services.
2.4.1	Actor-specific financial analysis (local importers, manufacturers, dealers, financial organization, mechanics and workshops)	Reports on the way incentives structure work in small mechanization business	KEN: May 2016	Completed (see Publication 32).
			ETH: April 2016	Completed (see Publication 31).
			ZIM: Oct 2015	Completed (see Publication 34)
			TAN: May 2016	Completed (see Publications 33, 57 and 58).
2.4.2	Adoption and impact survey, disaggregated by gender	Country-specific reports on the adoption and impact potential of small mechanization	May 2015	Surveys were conducted in all the four project target countries and data were collected from service providers on the feasibility of the services provided and from users on the satisfaction of the services made available to them. In these surveys 31 machinery service providers and 225 service users were interviewed to assess the above-mentioned research objectives. Data has been analysed and reports published (see Publication 35).

no.	Activity	outputs/ milestones	completion date	Comments
2.4.3	Socio-economic analysis of the mechanisation service packages offered by hire service business models	Report on the costs and benefits of small mechanisation service packages for rural service providers and users At least 30 service providers assessed in each country	Feb 2019 iDE, UZ, CIMMYT (lead)	Report on cost and benefit analysis of small-scale mechanisation in Ethiopia finalised for Ethiopia and Zimbabwe (see Publications 36, 37, and 38).
2.4.4	Assessment of the performance of business models along the supply chain (local importers, manufacturers, hire services providers)	Report on the incentive structure and supply chain in small mechanization business At least 30 service provision business models assessed in each country	Feb 2018 iDE, UZ, CIMMYT (lead)	Report on performance of selected mechanization hire service business models finalized in Ethiopia and in Zimbabwe (see Publications 39, 40, 41, and 42).
2.5.1	Analysis of structural and cognitive drivers of mechanization, especially related to costs and benefits, and the way they influence 2WT adoption decision-making	Report on the relationship among structural factors and cognitive drivers of mechanization (i.e. their influence on 2WT adoption decision-making) Policy brief on structural factors of 2WT entrenchment At least 30 service providers assessed in each country	March 2018 CIMMYT (lead) June 2018 CIMMYT (lead)	Completed (see Publications 43, 44 and 59).

no.	Activity	outputs/ milestones	completion date	Comments
2.5.2	Study functions of, and loops in social networks as regards how they limit referrals and influence adoption of 2WT	Report on functions and loops in mechanization related social networks Networks including at least 100 households per country analysed	Dec 2018 CIMMYT (lead)	Done as a thesis by MSc student, converted into a paper (See Publications 45 and 60).

Objective 3: To identify improvements in national institutions and policies for wide adoption of two-wheel tractor-based mechanization

no.	activity	outputs/ milestones	completion date	Comments
3.1.1	Review of global success stories on mechanized CA	Synthesis document of lessons learned from the experiences of successful countries in mechanized CA.	TAN, KEN ETH, ZIM: May 2015	Final report produced (as reported in the annual report of May 2015) and converted into a peer-reviewed peer (see Publication 3).
3.1.2	Review of national policies affecting mechanisation (import taxes and regulation, local movement of machinery, etc), agricultural profitability (e.g. subsidies), industrialisation, and businesses and enterprises	Country-level reports on the existing policies and their effects on the expansion of mechanized CA.	KEN, TAN, ETH, ZIM: May 2016	Complete (as reported in the annual report of May 2016).
3.2.1	Organising national policy workshops to identify policy gaps constraints and opportunities	Proceeding of the workshop	KEN, TAN, ETH, ZIM: May 2017	National policy workshops were organised in each country between November 2016 and February 2017, as reported in the annual report of May 2017.
3.2.2	Evaluation of alternative policy options for a wider delivery of 2WT-based mechanisation to smallholder farmers - particular to resource poor and women farmers.	Country-level reports prioritising policy options for a wider adoption of mechanised CA	KEN, TAN, ZIM: Dec 2016 ETH: Feb 2016	Country level evaluation report on policy completed (see Publications 46, 47, 48, 49 and 78).

no.	activity	outputs/ milestones	completion date	Comments
3.2.3	National policy workshops to discuss evidence-based recommendations	Proceeding of the workshop	KEN, TAN, ETH, ZIM: May2017	This activity was combined with 3.2.1

Objective 4: To improve capacity and create awareness of two-wheel tractor-based technologies in the sub-region and share knowledge and information with other regions.

no.	activity	outputs/ milestones	completion date	Comments
4.1.1	Training of ACT staff to operationalise the FACASI Communication Strategy	Training conducted; and staff operationalise the communication strategy effectively	Nov 2014	Completed (as reported in the semi-annual report of November 2014)
4.1.2	Publication of project findings in a series of working papers, in printed and electronic format	Working Papers, available electronically on the web portals and as hard copies in the library	Feb 2017	54 journal articles and working papers (see Publications 1 to 54) 7 briefs, factsheets and bulletins (see Publications 78 to 84)
4.1.3	Collation of working papers and independent documents from project partners in the ACT library and of each of the NARS involved	Enhanced access to theme/client targeted information and new knowledge in classified hard copy monographs and other materials	Dec 2016	ACT library is stocked with materials and documents on farm mechanization and conservation agriculture.
4.1.4	Development of a virtual knowledge management hub hosted by ACT (including web portals, intranets, and virtual discussion forums)	Permanent virtual knowledge sharing platform on 2WTbased technologies	Feb 2017	The FACASI website (http://facasi.act-africa.org/) was constantly updated with resources from the project produced during the first phase of the project and material is still available on the site
4.1.5	Development of a knowledge sharing platform on small mechanization in developing countries	Summaries of discussions on topics. At least 6 discussions per year. Communication products from the first phase available on the platform	Dec 2019	The knowledge platform of the project (http://knowledgeplatform.hellotractor.com/) was constantly updated with content produced during the second phase of the project, and also contained key products generated during the first phase. New content includes:

no.	activity	outputs/ milestones	completion date	Comments
4.2.1	Development and/or strengthening of National CA Task Force	Minutes of National CA Task Force meetings	TAN:	This activity didn't take place in Tanzania
			KEN: May 2015	The project team in Kenya attended 5 significant National CA Task Force or associated meetings (as reported in the annual report of May 2015)
			ETH: Dec 2019	National CA task force was established by the Ministry of Agriculture in 2018.
			ZIM: Dec 2019	The project has been represented in the Zimbabwe CA Task Force through Sepo Marongwe, who is a project member and the chairperson of the task force. Unfortunately, meetings have been irregular since 2014.
4.2.2	Development of promotional and learning materials informed by research outputs targeting farmers and extension agents	Fact sheets, technical bulletins, training materials etc.	TAN: May 2017 KEN: May 2017 ETH: Dec 2019 ZIM: Dec 2019	See 4.1.2, 4.1.4, 4.1.5, and 4.2.4. Also see fabrication drawings and manuals produced during the second phase (http://knowledgeplatform.hellotractor.com/drawings-and-manuals/), as well as factsheets (http://knowledgeplatform.hellotractor.com/factsheets/)
4.2.3	Development and implementation of a training program (on joint learning and innovation, CA, 2WT, etc) targeting innovation platforms	Training manual Training reports	July 2014	Business management for small scale mechanization. A training manual of business management for small scale mechanization was co-produced/co-financed between the project and FAO (see Publication 72). An operator training manual for two-wheel tractor and ancillary equipment in the context of Ethiopia was produced (Publication 71)
4.2.4	Development of promotional and learning materials informed by research outputs targeting farmers and extension agents	Photo-stories at project and country level	Sept 2016	Photo stories completed for the overall project, for Ethiopia and for Zimbabwe and for the 4 countries (Publications 85, 86 and 87)
		Storybook	Sept 2016	Cartoon book completed (Publication 73)
		Production of videos.	December 2019	Videos for all countries have been completed (See Publications 97, 98, 99, 100, 101, 102 and 103)
		FACASI Newsletters	Sept 2016	9 issues were developed (See Publications 88, 89, 90, 91, 92, 93, 94, 95, and 96)
4.2.5	Twice yearly farmer field days conducted in each site	Field day reports	KEN, TAN: May 2017 ETH, ZIM: Dec 2019	At least 2 field days per year and per country took place (see various annual and semi-annual reports). In addition, the project in Zimbabwe undertook live "demonstrations" ran by about 30 rural service providers, with huge impact on demand creation.
4.2.6	Annual advisory and scaling meetings	Minutes of the meetings	Dec 2019	A multi-stakeholder national advisory meeting was organized annual in Ethiopia and Zimbabwe between June 2017 and December 2019.

no.	activity	outputs/ milestones	completion date	Comments
4.3.1	Exposure visit to India and Bangladesh for key members of the project research team	Exposure visit report	Dec 2014	Exposure visit to India in April-May 2013 and in Bangladesh in December 2014.
4.3.2	Regular mentoring trips from Australian researchers to Africa, on a need basis	Capacity-building report	TAN, KEN: Nov 2015	Annual visits be Australian experts at the time of review and planning meetings. 3 missions by Jeff Esdailes (October 2013, February 2014, November 2014).
4.3.3	Practical training of key research staff involved in the project in farm mechanization, engineering and precision agriculture, in mechanization centres of Australia	Training reports	TAN, KEN, ETH, ZIM: Nov 2015	8 researchers (2 per country) participated in a 12 days training on Precision Agriculture organised with the University of Southern Queensland in October-November 2015.

7 Key results and discussion

7.1 Objective 1

7.1.1 Farm-level assessment of labour and mechanization needs in Eastern and Southern Africa

When the FACASI project was designed (2012) and initiated (2013), there was low interest and minimum investments in agricultural mechanization in sub-Saharan Africa. Although the topic is back on the agenda of policy, research and development in the region, whether there is enough demand for mechanization in SSA remains debated. Assessments of demand for mechanization, however, are dominated by macroeconomic analyses, which use data that may be too aggregated to capture regional and household-level diversity in terms of mechanization use and demand. FACASI provided the first assessment of mechanization demand in Africa based on farm-level data (survey of 107 female and 675 male heads of farming households and focus group discussions in 9 communities) spanning four countries in the region. The assessment played a pioneer role in debunking a number of myths related to labour in African smallholder agriculture. It also provided guidance as to what tasks should be prioritised for mechanization, and the form of mechanization needed for this.

The following statements related to African smallholder agriculture are often repeated:

1. Labour is abundant and cheap; thus, farm power does not limit agricultural productivity.
2. Most of the labour is provided by women.
3. Agricultural tasks are carried out almost entirely by family labour.
4. Consolidating land, by enabling "efficient" mechanization, would have a positive impact on agricultural productivity.
5. African agriculture is characterised by a wide gender gap.

In opposition, FACASI data provided evidence of the following:

1. A lack of power is holding productivity back, illustrating a much higher demand for mechanization than macroeconomic analyses suggest, and pointing to a problem of access rather than a lack of demand.
2. Women provide just 7 to 35 percent of the labour invested in farming, far less than the often claimed 60 to 80 percent. Women tend to provide less labour for farming than men and hired labour. Even in female-headed households, women often hire labour or use children as the main providers of labour. Therefore, too much focus on women-friendly technologies may be misguided and reduce the potential impact of mechanization interventions.
3. The majority of farming households in the region hire labour, draught animals and, to a much lesser extent, tractor power to complete agricultural tasks. Therefore, households may be far more inclined to hire mechanization services than commonly thought.
4. Land productivity tends to decrease with increasing farm area (i.e., evidence of the so-called 'negative farm size productivity relationship') in most sites. This questions the potential impact of land consolidation on agricultural productivity in the region, and reinforces the need to embrace the concept of 'appropriate mechanization', which argues that machines should adapt to farm size, and not the opposite.

5. Land productivity does not differ significantly between male-headed households and female-headed households. Social capital tends to be high in these communities, and constitutes a safety net for women-headed households. This is not to deny the usefulness of current interventions targeting women-headed households, but rather highlights the importance of strengthening existing social mechanisms.

In addition, in most sites, farm power invested in crop establishment (land preparation and seeding/planting) had the largest impact on productivity compared to farm power invested in other tasks. This suggests that priority for mechanization should be given to crop establishment, at least from a productivity perspective. Crop establishment (land preparation and seeding/planting) was also mentioned by both men and women as the priority task to mechanise, as it doesn't only affect men – who tends to be more involved in these operations – but also women – as crop establishment affect weeding intensity, one of the main task carried out by women and one that is associated with high drudgery. Such interrelations between male and female labour has rarely been acknowledged previously. In addition, labour displacement is unlikely to occur with the mechanization of crop establishment. Indeed, the largest share of hired labour was found to be invested mainly in weeding and in post-harvest, not in crop establishment. Therefore, weeding and post-harvest operations could continue to be performed by hired labour even if crop establishment is mechanised. Too often, mechanization is viewed as a complete shift from one source of power to another, for all operations, as encapsulated in the 'ladder of mechanization'. This conceptualisation is wrong in our view. A source of power is rarely completely displaced by another. Usually, manual labour, draught power and tractor power tend to coexist (as seen in all FACASI sites). Priority should be given to mechanise the tasks that are the most power-intensive and that are critical for productivity gains, while recognising that other operations will continue to be performed by manual labour and draft power. In the wheat systems of Ethiopia, harvesting was also found to be in high demand by farmers (harvesting of wheat being very labour-intensive and hiring of labour – increasingly scarce at the time of harvesting – representing a large share of the production cost of wheat). It should be noted however than mechanized harvesting was not found to impact productivity significantly and that mechanizing this task could potential displace labour significantly (as close to half of the labour hired in this system is hired for harvesting, see Publication 2).

7.1.2 Role of small-scale mechanization in the sustainable intensification of African smallholder agriculture

Results from on-station and on-farm trials conducted by the project demonstrate that crop establishment with a two-wheel tractor and a direct seeder results in quick crop establishment, saving considerable time and labour for this operation. For example, on-station data from Kulumsa (Ethiopia) during the 2015 season shows that 95.56 ± 18.18 hours ha^{-1} are needed to establish wheat conventionally, while 5.88 ± 0.12 hours ha^{-1} are needed to establish wheat with a 2BFG planter pulled by a two-wheel tractor (i.e., reduction by a factor 16). Similarly, on-farm data from Laikipia (Kenya) during the long rains of 2014 shows that 37.00 ± 1.00 hours ha^{-1} are needed to establish maize conventionally, while 4.10 ± 0.87 hours ha^{-1} are needed to establish maize with a Fitarelli two-row planter pulled by a two-wheel tractor (i.e. reduction by a factor 9.0). These large time savings were achieved with modest diesel consumption: 13.86 ± 4.42 L ha^{-1} in the case of wheat planting in Assela, and 5.07 ± 1.01 L ha^{-1} in the case of maize in Laikipia.

We have registered consistent increase in wheat yield when comparing direct seeding with a 2BFG planter and a two-wheel tractor to conventional crop establishment. Data from on-farm trials in Assela during the season 2015 and 2016 for example shows wheat yields to be 480 kg ha^{-1} higher when using a 2BFG planter and a two-wheel tractor than when establishing wheat conventionally (increase of about 15%). This productivity increase is attributed to row planting and increased precision in seed and basal fertiliser placement (right beside seeds where is it the most needed by the emerging crop).

With maize planting, differences in yield are rare and only observed if enough mulch is retained, and if the first weeding and top dressing are done on time. However, during the 2018/19 season – which was marked by a drought – maize plots established through two-wheel tractor-based direct seeding yielded 63% more than plots established conventionally (2.65 t ha^{-1} vs 1.63 t ha^{-1}, i.e. about 1 ton of additional grain per ha). This was attributed in part to better germination (87% vs 68% of planted seeds).

The Chinese 2BFG could be considered a 'best bet' for wheat and the Fitarelli double row and single row for maize. However, both would need modifications to fit better the wheat-based and maize-based farming systems, respectively. The 2BFG needs modifications of its seed metering device to be adapted to crops such as teff. The Fitarelli double row seeder only allows a minimum inter-row spacing of 80 cm, whilst many farmers in the region require inter-row spacing of 75 cm for their maize., The seeder also lacks ground-following ability, which is an issue in in the fields of Eastern and Southern Africa, which tends to be uneven (no levelling and widespread communal grazing). The Fitarelli single row seeder cannot be ridden off-road, limiting its transportability.

As a response, the project in Zimbabwe worked on double row seeders based on a wheeled toolbar, on which planting units can be mounted and spring-loaded, allowing good ground following ability and good transportability when planting units are raised. It also worked on starwheel planting systems, which reduce draft to a minimum, allowing to use 3 or 4 planting units instead of 2, and thus increase field capacity by 50 to 100%. The project in Zimbabwe also worked on small shellers powered by a 5.5 HP engine (Publication 67) and other implement that can be mounted on the same engine, including a cutter/miller unit (Publication 66).

In Ethiopia, the project worked on improved seed metering units locally produced (Publication 61) and worked on converting rotovators – most two-wheel tractors being imported with a rotovator – into a direct seeder with performances equivalent to a 2BFG (Publication 63). The project in Ethiopia also worked on improved wheat threshers powered by two-wheel tractor (Publication 64) and improved trailers (Publication 62).

7.2 Objective 2

7.2.1 Business model development

The ex-ante analysis conducted in Ethiopia, Kenya, Tanzania and Zimbabwe revealed that the use of two-wheel tractors and their accessories was not economically viable for farmers as individual owners, operating solely on their own farms. However, the same analysis revealed that in some cases, small-scale mechanisation could be an attractive investment for individual farmers if they could provide services at commercial rates to neighbouring farmers and be confident of ongoing demand. Considerable variations were found between countries and sites, depending on topography, soil type and feeder road accessibility for transport services. Such a model – based on service hiring – appears viable in Eastern and Southern Africa as the large majority of farmers in the region currently hire labour, and many of them also hire animal traction services, as illustrated by the results of the baseline of the project (Baudron et al. 2019). The results of the ex-ante analysis also demonstrated that when cultivated area per farm exceeded 2 hectares, and when farming became more commercially oriented (e.g., more cash crop), a business model based on full time service provision (by dedicated service providers) was more profitable than one based on part-time service provision (by part-time farmers, part-time service providers). The profitability of the specialised service provider business model also increased with the range of services offered (land preparation/crop establishment, transport, shelling/threshing) (Kahan, Bymolt, and Zaal 2017).

After 4 years of implementation of the FACASI project, an ex-post analysis was also conducted to evaluate the performance of various types of hire service business models and their impact on smallholders. Six types of business models were identified:

- BM1: Individual ownership/operator model, part-time service provider. Cases in Ethiopia, Kenya, Tanzania, and Zimbabwe.
- BM2: Individual ownership/operator model, full-time service provider. Cases in Tanzania, and Zimbabwe.
- BM3: Collective ownership, individual operator model. Cases in Ethiopia, Kenya, Tanzania, and Zimbabwe.
- BM4: Collective ownership, group operator model. Cases in Ethiopia and Tanzania.
- BM5: Dealer-led vertically integrated model. Cases in Ethiopia and Kenya.
- BM6: Corporate model/multi-purpose hub. Case in Kenya.

The six business models also included different combinations of technologies/services including land preparation alone; land preparation and transportation; and land preparation, transportation and shelling. In some cases, land preparation was represented by minimum tillage (e.g., ripping). The results of the ex-post analysis reiterate the findings of the ex-ante cost-benefit appraisal which showed the full-time (entrepreneurial) model to be most profitable. The group ownership models performed worst of all, facing considerable downtime of machinery due to weak group management and conflicts between group members. Machinery utilisation was another issue as downtime was in general very high and in some cases up to 60%. This resulted in low profitability.

The ex-post analysis highlights the issue of multipurpose use for profit maximisation. In Tanzania, for example, the study reveals that the combined package of a two-wheel tractor, a plough, a trailer and a sheller generate a higher annual profit than the other two packages containing fewer pieces of ancillary equipment. The findings support other studies that show multi-purpose use resulting in high annual rates of investment (Diao et al., 2012; Shetto, 2016). A close relationship was also found between the education and experience of the service provider, the range of services offered, and the level of annual profits and income earned from the business. Land preparation/crop establishment as a specialised service was seen in most cases to be unprofitable by itself, but profitable if combined with transportation and/or shelling. In all cases the entry point for mechanization was not land preparation/crop establishment, but shelling and transport. However, including land preparation/crop establishment to a business providing transportation and/or shelling was found to increase the net present value of the business significantly, and thus be worthwhile. This was particularly true in Ethiopia (where for example the inclusion of a seeder to a business providing transport only would double the net present value, from an average of 4,300 USD to an average of 8,800 USD). In the wheat-based systems of Ethiopia, harvesting was also found to be very unprofitable on its own, though in high demand. Combining harvesting and seeding would however lead to a very profitable business, by ensuring complementarity in term of utilisation of the two-wheel tractor – between the two tasks characterized by seasonality, and maximizing machinery use rate (average net present values was 1,600 USD with harvesting alone, 1,200 USD with seeding alone, but 6,000 USD with harvesting combined with seeding).

Increase in production and productivity, reduction in workloads/drudgery, time savings, reduction in cost of production, reduction in frequency of tillage, better ploughing ability of all farms (large farm) and moisture retention were among the benefits that the users of machinery expected from the hire service. The majority of those surveyed expressed that they received what they were expecting, reporting that hiring the services resulted in increased production volumes, reduced production costs, savings in time and higher soil moisture in their fields. Similarly, benefits were found in the crop gross margins and attributed to better timeliness of critical operations and an expansion of the area under cultivation. The farmers interviewed also report to be satisfied with the services offered (hire service charges, quality of the services provided, timeliness and support). Some 60%, 18%, 68% and 40% of the respondents from Ethiopia, Tanzania, Zimbabwe and Kenya, respectively, were very satisfied with the services provided to them.

Whilst 'bundling' machineries is economically advantageous, the extent to which this is a realistic option depends on the capacity of hire service providers to purchase the accessories and the timing and sequencing of acquisition. The findings show that bundling need not be comprehensive and can take a limited form to include combinations of equipment such as ploughing and transportation, or ploughing and shelling, or shelling and transportation and that offer potential use throughout the year. These more limited bundles of technologies may be the only options available if service providers have limited equity and access to finance. The optimum packages, however, are likely to vary depending on the socio-ecological conditions of different sites. Further research is needed to match the different packages with specific site conditions.

7.2.2 Drivers of adoption

The most commonly cited structural driver was cost, including cost of machinery and spare parts. Costs are given prominence given mechanization actual benefits (immediate and long term) and spill overs are not fully known. Reported benefits included reduced drudgery among rural clientele, and enhanced status of entrepreneurs. Women and youth entrepreneurs noted a sense of pride and status. For male youths in Ethiopia, this was demonstrated by their ability to create a career path and income which would enable them to provide for their families. Women, somewhat conversely, found that the tractor business provide an income, networks and entrepreneurship options outside of the family. Superior incomes compared to public sector (e.g. US$135 per month) were reported, but women were less represented. Barriers to mechanization included access to fuel, operational skills, spare parts and access to support services. Current mechanization usage (e.g., for tillage, threshing, transport), had not reached full potential for adaptive use e.g., in irrigation, along with diversification and equipment combinations for different contexts. Project findings show diversification was essential for small-scale mechanization sustainability, by reducing pay back times for equipment and increasing use rate. Risk was especially seen to be high among youth entrepreneurs, which curtailed financing in Ethiopia.

Critical aspects needed to realise full mechanization potential include policy (economic and social) and legal interventions. These relate to ease of establishing and sustaining businesses. Entrepreneurial resources, especially financing (e.g., lines of credit), knowledge, education and skills, and infrastructure are critical. These along with policy and laws are key to improve societal attitudes, which are further shaped by politics, education systems, demographic dynamics, culture, technology – information organisations (e.g., ICT), institutions and institutional arrangements e.g., insurance and leasing, research, and social inclusivity, especially youth and gender.

Social network ties between/among individuals and organisations occurred at two levels. First, at individual/ local level: opportunities, and constraints affecting individual, service and collective two-wheel tractor decisions. Second, at national level, social and economic stratification (e.g., the class structure, regional social differentiation) including poor connection between rural small-scale mechanization entrepreneurs and large manufacturers or suppliers. Large businesses have low awareness of small-scale mechanization opportunities like the rest of the farming community. These are more limiting for women and youths due to norms, perceptions, and reduced opportunities for mechanization entrepreneurship.

Social institutions are critical aspects of rural mechanization. Social institutions include: i) dominant family (structure); ii) dominant religion; iii) law – communal economic governance e.g., current crisis in Zimbabwe; iv) politics i.e., sound system of decision making e.g., selection of group members in Ethiopia; v) economics – relating to distribution of mechanization services, education system, science – FACASI was also about conservation of soil resources; vi) health – mechanisation-related injuries; and vii) mass media – SMS and social media (mobile phones are key in getting/staying in touch with customers, suppliers). Mechanization ownership models - individual or small group (≤ 5) ownership models were highly viable for small-mechanization entrepreneurship in Ethiopia as opposed to Zimbabwe. Social networks are a key entrepreneurial resource i.e., opportunity structures. Opportunity structure is a key limiting factor among women and youth. Networks offer skills, knowledge, use memory, norms and values, attitudes/motivation They are key for apprenticeship.

Cognitive drivers especially relate to perceived usefulness of mechanization. Because of the short experience with mechanization, rural clientele and entrepreneurs did not have strong perceptions about brands. Studied entrepreneurships were mostly young (< 3 years). The entrepreneurships were also mostly led by young persons. Mechanization-based businesses were perceived as pseudo-formal, offering a level of gratification (unlike usual drudgery associated with rural smallholdership in Africa), and involving mobility. Small-scale mechanization was also perceived to be women friendly. However, small-scale mechanization was perceived to entail more risks (accidents) compared to draught animals.

7.3 Objective 3

The review of national policies of Ethiopia, Kenya, Tanzania and Zimbabwe shows that governments in all four project target countries acknowledge the importance of smallholder mechanization for agricultural growth and improvement in the livelihoods of smallholder farmers. However, there are key policy and strategy gaps identified in achieving these goals. These gaps include (1) heavy duty (tariff) on imported spare parts of agricultural machineries, (2) dominance of the public sector in the agricultural mechanization business and services in some of the countries, (3) limited financial and credit services for agricultural machinery business, ownership and service provision, (4) limited regulatory organisations in inspecting (testing) the quality and standards of imported farm implements, (5) limited rural infrastructure (roads and electricity) for mobility and maintenance services, and (6) limited support to domestic manufacturers, assemblers and workshops for a gradual growth and import substitution of some of the machineries, implements and spare parts that could be produced using domestic capacity.

In general, formulating a clear country-specific agricultural mechanization policy, supported by a detailed implementation strategy that encourages the private sector engagement in machinery business and service provision, is essential to enhance the existing level of agricultural mechanization in these target countries. In these policies and strategies, giving special attention to smallholder farmers who are the main contributors in the agricultural sector is so crucial. Finally, policies related to environment, energy, land tenure and land use, trade/import, agricultural investment, etc all impact the expansion of smallholder mechanization and need to be revisited.

7.4 Objective 4

See Section 8.4.

8 Impacts

8.1 Scientific impacts – now and in 5 years

The project led to 7 peer reviewed publications and 47 working papers (several of them being converted currently into peer reviewed papers). The science generated by the project has also been translated into various products targeting specific audiences (e.g., private manufacturers, policy-makers) with the publication of 7 fabrication drawings (Publications 61 to 67), 10 manuals and guidelines (Publications 68 to 77), 7 briefs, factsheets and bulletins (Publications 78 to 84), 3 photo stories (Publications 85 to 87), 9 newsletters (Publications 88 to 96) and 7 videos (Publications 97 to 103).

The project has advanced knowledge on labour, farm power and appropriate mechanization in Eastern and Southern Africa (see Publications 1, 2, 4, and 5). It also advanced our understanding of drudgery, with a particular emphasis on understanding the gender implications of drudgery (see Publications 5, 43, 50, 51, 59).

Datasets generated from on-station and on-farm evaluation are open access (https://simlesa.cimmyt.org/facasi/resources/?wpv_view_count=8998&wpv-publication-type%5B%5D=agronomy-data) and can be used to evaluate planters' performances in different biophysical and socio-economic conditions.

The project also contributed to better understand how technology adoption in general – and small-scale mechanization in particular – can be scaled through commercialisation (Publications 6, 7, and 11 to 42).

Finally, the project provided insight regarding the factors necessary to the creation of a business-friendly environment for the delivery of two-wheel tractor-based technologies to smallholders (Publication 3 and Publications 46 to 49).

8.2 Capacity impacts – now and in 5 years

There is evidence that the project contributed to 'revitalise' agricultural engineering and mechanization research in Eastern and Southern Africa (see e.g., Fig. 1 below). It also contributed to build the capacity of national researchers to conduct multi-disciplinary research including for e.g., integrated evaluation of technologies (e.g. crop productivity, economic performances, energetic performances, environmental impacts). The project also built the capacity of national researchers to test and evaluate business models – a fairly new research area in the region. More generally, linkages with the industrial and commercial sector stimulated a more demand-driven focus in national agricultural research, expected to ultimately lead to higher adoptability of innovations (see e.g., second generation engineering activities).

The project also resulted in an increase in the number of local dealers importing small-scale mechanization equipment and local manufacturers producing implements for two-wheel tractors – including direct seeders – and small self-powered equipment such as shellers (see Fig. 3 for the example of Zimbabwe).

The project developed the capacity of a large number of rural service providers (e.g., 94 in Ethiopia and 92 in Zimbabwe), mechanics (e.g., 16 in Ethiopia and 15 in Zimbabwe), extension agents (e.g., 32 in Ethiopia and 62 in Zimbabwe), diploma level students (e.g., 18 in Zimbabwe) and university undergraduate students (e.g., 14 in Zimbabwe).

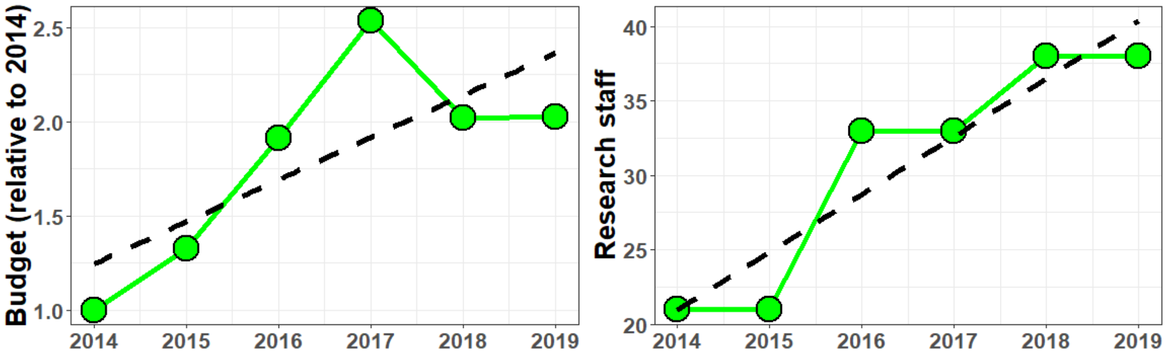

Figure 1 – Growth in the budget and staffing of the Mechanization Directorate of the Ethiopian Institute of Agricultural Research since the inception the project in that country.

The capacity of the small-scale mechanization innovation systems in Ethiopia and Zimbabwe appears to have been increased significantly (see Publication 7; access to finance is now the most limiting 'scaling ingredient'). This resulted in actual adoption – both in terms of number of service providers and number of their clients – higher than projected (in the project document; Fig. 2). We are confident that adoption will continue to increase in the next 5 years.

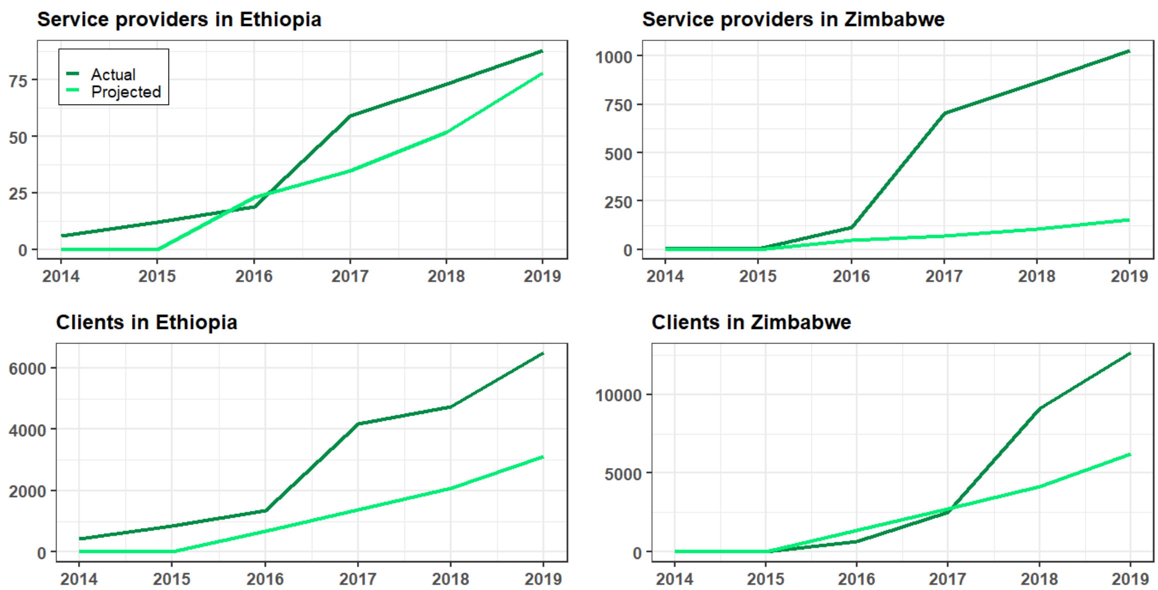

Figure 2 – Growth in the number of service providers and their clients in Ethiopia and Zimbabwe (actual vs. projected) since the start of the project.

8.3 Community impacts – now and in 5 years

8.3.1 Economic impacts

Private sector

Between 2014 and 2019, the project contributed to a remarkable growth in the number of private companies investing in small-scale mechanization in Zimbabwe, despite a deteriorating economic environment (Fig. 3). During the same period in Ethiopia, the number of companies importing two-wheel tractors increased from 2 to 9 and the number of companies importing or manufacturing direct seeders from 0 to 4.

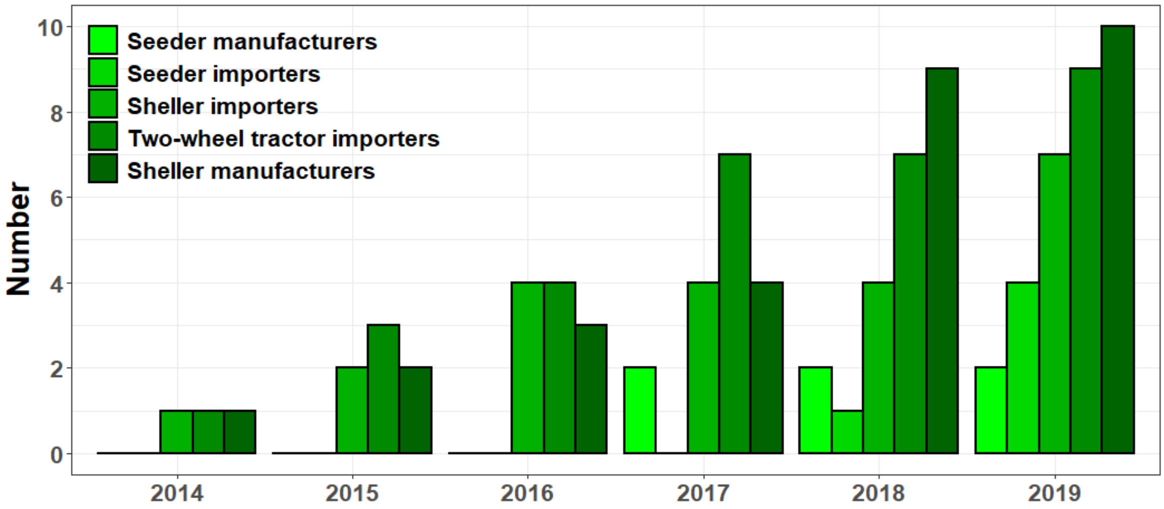

Figure 3 – Increase in the number of dealers and manufacturers providing small-scalel mechanization equipment in Zimbabwe since the start of the project.

Between 2014 and 2019, the number of two-wheel tractors increased from 6 to 88 in project sites of Ethiopia, and from 1 to 99 in project sites of Zimbabwe. In Ethiopia, each service provider has an average of 50 clients. In Zimbabwe planting service providers have an average of 15 clients whilst shelling service providers have an average of 30 clients.

In Ethiopia, service providers using two-wheel tractors – mostly for planting, harvesting, threshing and transportation – were found to generate an average annual profit of US$5,560. This corresponds to a benefit-cost ratio of 2.07 and a payback period of about one year. Looking at individual services, the highest benefit-cost ration was found for threshing (1.6), followed by harvesting (1.3) and planting (1.2). In Zimbabwe, planting service providers were found to generate an average annual profit of US$4,130 (corresponding to a benefit-cost ratio of 1.6 and a payback period of 1.6 year), transport service providers of US$6,400 (corresponding to a benefit-cost ratio of 3.8 and a payback period of 6 months), and shelling service providers of US$1,080 (corresponding to a benefit-cost ratio of 2.7 and a payback period of 3 months).

In Ethiopia, service providers were able to generate a profit in only 2 years and invest in additional machinery. Many aspiring service providers, however, don't have the capital to purchase a two-wheel tractor and implements. Most available financial products require collateral and a legal framework that can facilitate repossession of the asset if necessary.

Through the efforts of the project and other interventions led by CIMMYT, a machinery leasing company (Waliya Capital Goods Finance Business Share Company) recently started providing machinery leasing for small-scale mechanization in Ethiopia. Through this scheme, with only 15-20% cost contribution, aspiring service providers from the Amhara region of Ethiopia can purchase machinery on credit. Similar structures in other regions of Ethiopia (Oromia Capital Goods Lease Finance Business Share Company) are also entering the market, which has the potential to remove one of the major barriers to the scaling of the technology in the country.

In Zimbabwe, the instability of the local currency and high inflation prevents financial organisations from providing medium to long-term loans for machinery acquisition. However, one company (Empower Bank) is now analysing the possibility to provide loans to farmers involved in high value horticultural production because of its interaction with the project. The financial sector also indicated their willingness to work with smallholder farmers who are guaranteed by a reputable organisation so as to reduce risk in their business. However, the financial sector in Zimbabwe has a range of existing products for salaried farmers and those with collateral as they can access a range of loans.

Smallholder households

A recent cost-benefit analysis conducted by the project has demonstrated that adoption of small-scale mechanization services increases the gross margin of wheat producing farmers on average by 76% in Ethiopia, and the gross margin of maize producing farmers in average by 12% in Zimbabwe. In both Ethiopia and Zimbabwe, the gross margin increment for farmers was higher when mechanising planting than when mechanising post-harvest operations. In Ethiopia (wheat-based system), hiring planting services would increase gross margin by 59%, while hiring threshing services would increase gross margin by 6%. In Zimbabwe (maize-based system) hiring planting services would increase gross margin by 8%, while hiring shelling services would increase gross margin by 4%.

8.3.2 Social impacts

The project has focused on low wealth farmers, with small land holdings. Social impacts identified as a result of the interventions are discussed here under the categories gender, youth, household income, entrepreneurship, food security and quality of life.

The inclusion of two-wheel tractors into farm operations such as planting, harvesting and shelling dramatically reduced the time it takes to undertake farming tasks. While many tasks remain manual the reduction in daily drudgery for women in particular was especially noted in shelling operations. For example, women traditionally sat in groups for days shelling maize. One shelling machine could undertake the task in hours, thereby freeing up women for other operations that could increase the household income and food security. Inspired by the efficiency of shelling some women became entrepreneurs and expanded operations, by providing shelling services to neighbours, thereby increasing the household income and importantly increasing their quality of life by reduction of drudgery.

To assess the gender context, the project was organised around four general domains that refer to gender: opportunity structure, access to entrepreneurial resources, cognitive drivers and ease of doing business.

Opportunity structure refers to the notion that opportunities available to people are shaped by social organisation and structure of their society or institution. Women have a disadvantage with regards to opportunity structures, because of traditions or culture that shape entrepreneurial success. The project established networks of rural women entrepreneurs with established business/private sector and government support start-ups, and growth opportunities for their business.

Mechanization is heavily influenced by structural resources. The project catalysed ownership, control and use of mechanization based entrepreneurial resources and positively influenced gender relations and power. In Zimbabwe particularly, the project triggered the generation or re-organisation of entrepreneurial resources including time (and space), knowledge, social networks, institutions, and (finance and equipment) capital.

Beliefs, perceptions and stereotypes built over decades that heavily mediate the entrepreneurial behaviours of both men and women at different levels of mechanization chain have been challenged. Before the project intervention, women were less likely to engage in technical and entrepreneurial aspects of mechanization. They can now employ men as operators of machines, own machines, etc and are not only confined to be clients.

Laws, policies, infrastructures, and institutions matter for men and women. The project has brought to the attention of key stakeholders' evidence that a gender connection beyond the business and client level must also include power relations within households, in the policies and norms of the entire enabling environment beyond local.

The shelling option was also popular with the youth sector, where they found that they could actually develop viable agri-businesses with two-wheel tractors and shelling services. The impact of this for youth was more than food security and reduction in drudgery, it provided a career path in rural areas where the opportunities are limited. Importantly as highlighted by several youths, mechanization entrepreneurship provided them with status in their community. This was partly due to the prosperity but also because they could offer future partners a rural family life. Many of the youth were quite entrepreneurial, once inspired by income from one operation they would establish other operations such as solar panels for phone charging services (70% of Ethiopia has no access to power, World Bank https://www.worldbank.org/en/news/feature/2018/03/08/ethiopias-transformational-approach-to-universal-electrification), complementary food processing services or artisan mechanic workshops to adjust and optimise farming equipment.

The inclusion of mechanization services into farm household income was an important farm systems diversification strategy. Many households in Zimbabwe and Ethiopia are dependent on one crop for their entire annual income. The failure of this crop therefore has devastating consequences on household income and food security. By incorporating farm mechanization into their farm business farmers stated that not only could they diversity crops and deliver mechanization services but they could also value add into processed products such as peanut butter, tomato sauce and jams. Other services were developed once a two-wheel tractor was available: artisans/mechanics refining and designing bespoke implements to operate off the two-wheel tractor motors, transport services for goods delivery from farm to markets, and irrigation pumps services to enable expansion into horticultural crops.

Food security was a key impact of farm mechanization where once these farmers were only producing maize in Zimbabwe or wheat in Ethiopia, mechanization increased the diversity of crops and the creation of shelf stable products which could be stored and used all year round or sold or swapped at markets for other products.

To develop a multi-crop farm business with a range of entrepreneurial services and food products requires new skills, access to information and networks. A major social impact of the project is that farmers are at various levels of expanding their skill base (see Publications 39 to 45), such as farm planning, service provision and value adding.

Farmers have become more knowledgeable about optimising farming systems in response to extreme weather events such as droughts or floods and they are more aware of the cropping options that are enabled by two-wheel tractors, thereby reducing risk to their food security. The use of two-wheel tractors has shortened the time required to plant and harvest thereby enabling farmers to review weather patterns and operate in favourable weather.

A key impact of mechanization that was noted was the development of networks both with other farmers and businesses and government advisors. In particular female farmers formed networks that in some regions have been ongoing. Through networking engagements, farmers developed skills such as negotiating service delivery terms, maintenance of the machinery, marketing and financial management.

In terms of personal wellbeing the increased variety of production systems has also resulted in more nutritious options. Whereas maize was the major options, farmers that have diversified into horticulture are now trading these goods at markets and also producing preserved goods, such as peanut and tomato sauce. This in turn enables additional household income to support the education of their children by the inclusion of such items as electricity into households and reduction of child labour.

The social impact of mechanization is therefore not only contributing to optimisation of farming tasks, but it is increasing household income, capacity, individual wellbeing and food security.

8.3.3 Environmental impacts

A key objective of the project was to accelerate the adoption of conservation agriculture in Eastern and Southern Africa through the promotion of mechanised direct seeding technologies. There are evidences that the project actually led to wider and faster adoption of conservation agriculture, leading to soil and water conservation in the project sites, particularly in sites characterised by steep slopes.

Although this could not be estimated through e.g., a comprehensive life cycle assessment, we expect a shift in power source from oxen to small tractors to lead to reduced emissions of green-house gases. An ox produces ~80 kg CH_4 year^{-1}, which is equivalent to 1840 kg CO_2 year^{-1}. Considering that a pair of oxen can be used to till ~10 ha year^{-1}, this implies that land preparation with oxen produces ~ 368 kg CO_2 ha^{-1}. In comparison, we have estimated emissions of a maximum of 25 kg CO_2 ha^{-1} for two-wheel tractor-based crop establishment, i.e., about 15 times less.

As argued in Publications 2 and 5, small-scale mechanization is a form of mechanization that doesn’t require consolidation. Therefore, by allowing the maintenance of a mosaic of small and fragmented fields, small-scale mechanization may be favourable to biodiversity. In addition, the two-wheel tractor narrower track (1.1 m wheelbase, i.e., far narrower than the track of a ‘conventional four-wheel tractor’) means it can operate in fields where scattered trees, key ecological structures for agricultural biodiversity and a number of ecosystem services, are retained.

8.4 Communication and dissemination activities

In the first phase of the project, ACT was responsible for the communication of the project. Project resources during this phase were collated in an online library (http://facasi.act-africa.org/library.php?com=4). The library has a rich collection of materials on farm mechanization and conservation agriculture and is complemented by a physical library at ACT headquarters in Nairobi, Kenya. The materials can be accessed in various formats: books, manuals, toolkits, reports, proceedings and videos.

The learning resource materials are also available on the virtual knowledge management platform hosted by ACT (http://facasi.act-africa.org/). This online platform will remain a permanent repository for smallholder farm mechanization and resources on conservation agriculture. Awareness on two-wheel tractor-based technologies was created at various levels and using different communication channels. The promotional and learning materials informed by research outputs which were produced and shared included newsletters (Publications 88 to 96), a cartoon book (Publication 73), and videos (Publications 97, 98, 100, 101, and 102). Other products are the photo-stories and photo-books (Publications 85 to 87) portraying the two-wheel tractor for conservation agriculture through pictures and short clips. The FACASI project website (http://facasi.act-africa.org/) was also effectively utilized to share online publications of FACASI events, workshops, analysis reports, partner brochures and fliers. The contents were simultaneously shared through 'SlideShare' (www.slideshare.net/FACASI_FARMPOWER) and social media using the following #tags #Farmpower #2WTs #FACASI as accessible at http://facasi.act-africa.org/#.

In the second phase of the project, the project partnered with Hello Tractor (HT) for the management of the project knowledge platform. The most impactful communication products from the first phase of the project were migrated to this new knowledge platform (http://knowledgeplatform.hellotractor.com/), as well as newly generated content. This included reports of symposia, success stories, two-wheel tractor tutorials, posters, factsheets, drawings and manuals. Analytics of usage shows that the platform is being used extensively with e.g., 16,174 users and 45,522 page views from June 2018 to January 2019 (Fig. 4)

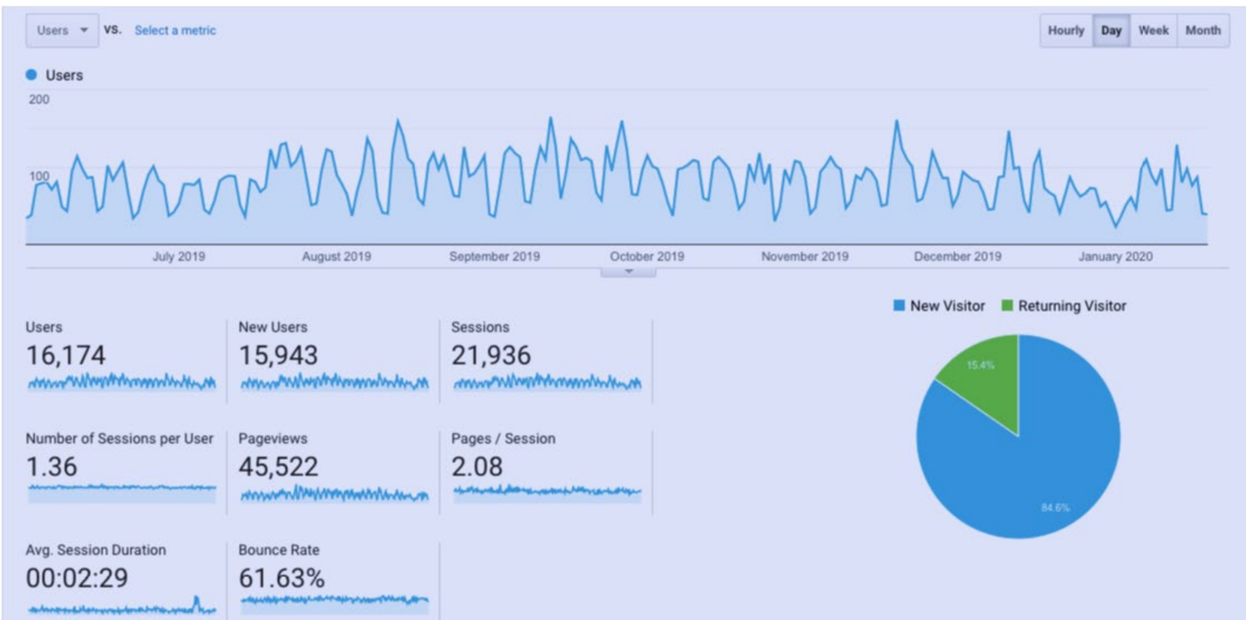

Figure 4 – Analytics of usage of the project knowledge platform hosted by Hello Tractor.

To provide a single point of access to knowledge products and resources generated by ACIAR-funded projects on sustainable intensification in Eastern and Southern Africa, we have migrated project products on the 'Sustainable Intensification of Maize-Legume Cropping Systems for Food Security in Eastern and Southern Africa' (SIMLESA) project website (https://simlesa.cimmyt.org/).

In addition, the project employed a range of communication and dissemination activities to create awareness around small-scale mechanization, including field days, displays at expos, 'live demonstrations' established by service providers, television discussion (Zimbabwe team), workshops and seminars, etc. The videos produced by the project also reached policy makers in the various countries (Zimbabwe in particular). In Ethiopia, the video has also been translated in the two main local languages (Amharic and Oromiffa) and will be used for regional TV channels.

Finally, outputs of the project have been (and continue to be) used by several projects in Africa, multiplying the reach and impact of the project (Fig. 5).

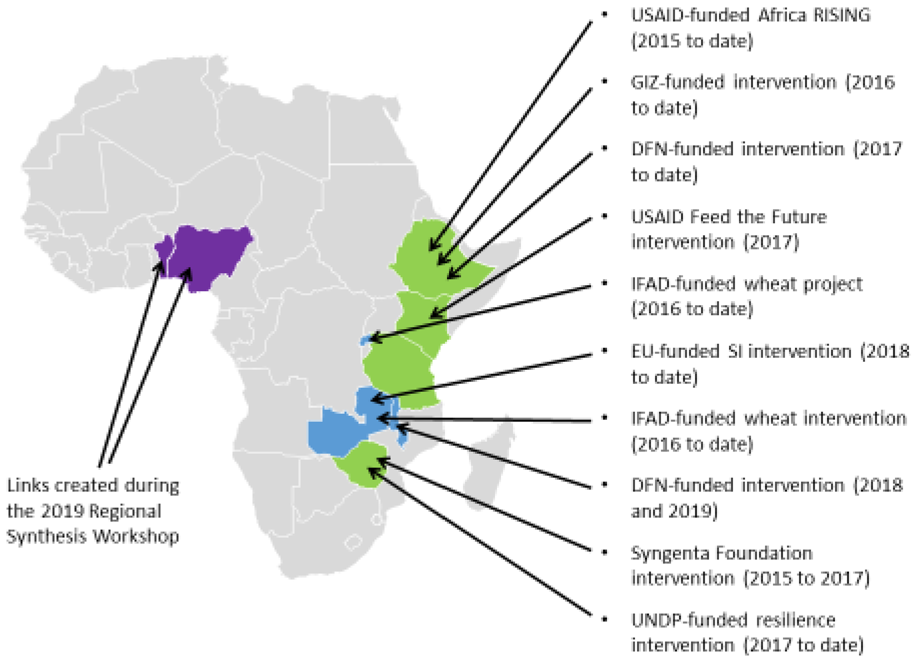

Figure 5 – Interventions other than the project that have made (or are currently making) use of the outputs of the project.

9 Conclusions and recommendations

9.1 Conclusions

The project played a pioneer role in bringing labour and mechanization issues on top of the Research & Development agenda in Africa. It also demonstrated the viability of small-scale mechanization as an alternative pathway to large-scale mechanization (which often requires consolidation), one which probably leads to lower negative social and environmental consequences where small farms and family agriculture dominates.

The project demonstrated that small-scale mechanization could stimulate intensification of African smallholder farming system, in particular through better timeliness of operations and greater precision. However, technologies from other regions often needed adaptation to perform well in the region, because of the specificities of African smallholder farming systems (e.g., uneven field, hard soils due to e.g., limited use of irrigation, long distances between farms, etc), warning against direct South-South transfers.

The project demonstrated that commercialisation – and in particular the provision of mechanization services through specialized rural service providers – can be a viable approach to scale technology adoption, in a way that is inclusive. After an initial investment by the project in the functions of promotion, information, capacity development and coordination, local market actors (including public sector) appear eager to take over these functions. Finance remains the biggest bottleneck, but the development of a machinery leasing scheme in Ethiopia (see Section 8.3.1) is a source of hope.

The next steps involve (1) supporting demand creation by private sector and extension services, (2) supporting Research & Development by manufacturers (in particular through the exchange of designs from the region and beyond, second generation engineering, and capacity development on state of the art engineering), (3) supporting dealers (through 'business intelligence' i.e., market information) financial service providers (targeting i.e., profile of likely adopters, cost-benefit analysis, etc), (5) supporting coordination through round tables, and (6) supporting information exchange, regionally and globally.

9.2 Recommendations

Four phases may be recognised in interventions aiming at improving access to mechanization via an approach of innovation development and scaling through commercialisation: (1) a market assessment phase, (2) a partnership creation and Research & Development phase, (3) a pilot and demonstration phase, and (4) a commercialisation phase.

During the market assessment phase, three issues are critical: (1) the selection of technologies, (2) the selection of sites where piloting will take place, and (3) the selection of early (subsidised) service providers who will test the technologies and be key in creating demand for small-scale mechanization by demonstrating successful technologies in the pilot sites. Regarding technology selection, the experience of the project demonstrates that tasks to be mechanised should not be identified on the basis of drudgery and labour productivity alone. It is important to identify mechanization options that can support business opportunities as well. For example, although land preparation and crop establishment are the most energy-demanding operations and the most critical ones for productivity, the entry point for service providers in term of business was transport and post-harvest activities, not direct seeding and ploughing. The experience of the project also shows that high profitability of service provision can only be achieved through multipurpose use of the two-wheel tractor, to ensure use rate is maximized. The acceptability of direct seeding also appears area-specific, higher for instance in Zimbabwe than in Ethiopia. With regards to site selection in the particular case of the promotion of small-scale mechanisation, the following criteria should be considered: (i) commercially-oriented agriculture (e.g., presence of cash crops), at least partly; (ii) agriculture constrained by labour shortages, at least seasonally; (iii) high cost of maintaining draught animals (e.g., feed shortage); (iv) field accessibility (e.g., feeder roads); (v) existence of hire services (e.g., ox ploughing); (vi) relatively deep and stone-free soils; and (vii) small and fragmented fields. With regards to early service provider selection, the following criteria should be considered: (i) young; (ii) entrepreneurial; (iii) educated; (iv) able to contribute to the cost of the machinery; and (v) preferably having an experience in similar businesses and particularly in mechanics.

During the partnership creation and Research & Development phase, technology adaptation and early commercialisation are expected to take place. Technology adaptation shouldn't be minimised by the belief that there are commercially available options adapted to the circumstance of smallholders in Africa. Although best bets can be identified, they are often sourced from markets outside the region (e.g., China) and there is often a need for adaptation (for best bets to become best fits). In particular, the transportability of seeders often needs to be improved (lower demography in SSA compared to Asia, implying that seeders need to be transported easily or ridden off-road at a decent speed), as well as their soil engagement parts (long dry season in most of the region and limited irrigation compared to Asia, implying that soils tends to be harder at planting). Many seeders available from Asia also lack ground-following ability of planting units, which is needed in most of the region (limited levelling and widespread off-season grazing making fields uneven) whilst their seed metering devices are not adapted to some crops that are widespread in parts of the region (e.g., teff). In addition, the procurement cost (in foreign currency) of some of the best bet planters imported from other regions may be prohibitive to aspiring service providers. Considering cost as well as performance (there is often a trade-off between the two) is important at the early stage of a small-scale mechanization project. This may call for the development of local planters in partnership with manufacturers in the region. For that, understanding the demand (in terms of performance, cost, and other attribute such as transportability) is essential, by involving early service providers and their clients in the evaluation and re-design of planters (this should be an iterative process). A few points need to be considered regarding early commercialisation during this phase. First, it is risky, on the part of projects and the private sector, to commercialise technologies without confidence in their appropriateness for smallholders. Commercialisation should only start after a phase of thorough testing of new equipment and participatory evaluation. Second, it is crucial to involve private sector stakeholders – dealers, manufacturers, etc – in all the steps of the Research & Development stage. The development of first-generation technology may be led by the public sector (particularly when the technologies are new and untested), but second-generation technology development necessitates feedback from users to local manufacturers and dealers. In this regard, it is essential to develop and implement proper policies on machinery standards and quality control (both for imported and locally manufactured machineries) so that machinery owners, service providers and users develop confidence on the quality of the equipment in use. Other relevant policies supporting the expansion of smallholder mechanization also need to be in place. These include: avoiding or reducing import tariffs on farm machineries and spare parts, improving access to finance and credit services to all actors in machinery business (owners, service providers, and users), encouraging private sectors in machinery service provision, facilitating machinery mobility on roads, and favourable policies supporting the growth and expansion of local manufacturers.

During the pilot and demonstration phase, a trigger – marking the exponential investment of private sector actors in commercialisation – is expected to be reached and market inter linkages should develop. However, reaching a trigger requires investment (developing unsubsidised business models is a myth!). Incentive schemes (matching grants, soft loans, guarantee funds, etc.) are necessary to set up supply chain stakeholders in business. It may also take several years (and resources during all these years) before a trigger is reached. It should also be noted that an approach centred on private sector alone may not work when targeting marginal areas (e.g., rain fed systems dominated by staples), or marginal groups (e.g., resource-constrained smallholders), or technologies providing public goods (e.g., conservation agriculture), or complex technologies (not a 'product'). In such circumstances, the public sector has a crucial role to play in commercialisation, in particular through the creation of a conducive business environment to attract private sector actors. For this, demand creation and capacity development (of private sector actors which should be on-going) are crucial. There is no substitute for demonstrations with regard to creating awareness amongst potential service providers, farmers and support institutions.

During the commercialisation phase, strong linkages to support services are vital for the expansion of commercialisation. However, there is a lack of financial products adapted to service providers across the region. In addition, public-sector credits (e.g., in Ethiopia) and subsidies (e.g., in Tanzania) is often associated to poor quality machinery. It should however be noted that very small (and inexpensive) machines (such as single cob shellers) may be adopted without any financial support and be very profitable.

10 References

10.1 References cited in report

Ali, Daniel Ayalew, and Klaus Deininger. 2015. “Is There a Farm Size–Productivity Relationship in African Agriculture? Evidence from Rwanda.” Land Economics 91 (2): 317–43. https://doi.org/10.3368/le.91.2.317.

Asiama, Kwabena Obeng, Rohan Bennett, and Jaap Zevenbergen. 2017. “Land Consolidation for Sub-Saharan Africa’s Customary Lands – The Need for Responsible Approaches.” American Journal of Rural Development, Vol. 5, 2017, Pages 39-45 5 (2): 39–45. https://doi.org/10.12691/AJRD-5-2-2.

Babiker, Monirah, Mohamed Arbab, Yassin Mohmad, and Ibrahim Dagash. 2017. “Microdosing Technology of Fertilizer for Sorghum Production at Shambat, Sudan.” Cell Biology & Development 1 (1): 18–22. https://doi.org/10.13057/cellbioldev/t010104.

Baudron, Frédéric, Jens A Andersson, Marc Corbeels, and Kenneth E Giller. 2012. “Failing to Yield? Ploughs, Conservation Agriculture and the Problem of Agricultural Intensification: An Example from the Zambezi Valley, Zimbabwe.” Journal of Development Studies 48 (3): 393–412. https://doi.org/10.1080/00220388.2011.587509.

Baudron, Frédéric, Moti Jaleta, Oriama Okitoi, and Asheber Tegegn. 2014. “Conservation Agriculture in African Mixed Crop-Livestock Systems: Expanding the Niche.” Agriculture, Ecosystems and Environment 187: 171–82. https://doi.org/10.1016/j.agee.2013.08.020.

Baudron, Frédéric, Michael Misiko, Bisrat Getnet, Raymond Nazare, John Sariah, and Pascal Kaumbutho. 2019. “A Farm-Level Assessment of Labour and Mechanization in Eastern and Southern Africa.” Agronomy for Sustainable Development, 39(2), 17.

Benton, Tim G, Juliet A Vickery, and Jeremy D Wilson. 2003. “Farmland Biodiversity: Is Habitat Heterogeneity the Key?” Trends in Ecology & Evolution 18 (4): 182–88. https://doi.org/10.1016/S0169-5347(03)00011-9.

Biggs, Stephen, Scott E Justice, and David Lewis. 2011. “Patterns of Rural Mechanisation, Energy and Employment in South Asia: Reopening the Debate.” Economic & Political Weekly xlvi (9): 78–82.

Binswanger, H., K. Deininger, and G. Feder. 1995. “Power, Distortion, Revolts, and Reform in Agricultural Land Relations.” Handbook of Development Economics, Vol.3 3: 2659–2772.

Clarke, Lawrence, and Clare Bishop. 2002. “Farm Power - Present and Future Availability in Developing Countries.” In Special Session on Agricultural Engineering and International Development in the Third Millennium. ASAE Annual International Meeting/CIGR World Congress, July 30, 2002. Chicago, USA. https://doi.org/10.1007/s11023-007-9060-8.COPYRIGHT.

Collier, Paul. 2017. “African Urbanization: An Analytic Policy Guide.” Oxford Review of Economic Policy 33 (3): 405–37. https://doi.org/10.1093/oxrep/grx031.

Dahlin, A. Sigrun, and Leonard Rusinamhodzi. 2019. “Yield and Labour Relations of Sustainable Intensification Options for Smallholder Farmers in Sub-Saharan Africa. A Meta-analysis.” Agronomy for Sustainable Development 39 (3): 32. https://doi.org/10.1007/s13593-019-0575-1.

Doss, Cheryl R. 2001. “Designing Agricultural Technology for African Women Farmers: Lessons from 25 Years of Experience.” World Development 29 (12): 2075–92. https://doi.org/10.1016/S0305-750X(01)00088-2.

Harris, F. 2002. “Management of Manure in Farming Systems in Semi-Arid West Africa.” Experimental Agriculture 38 (02): 131–48. https://doi.org/10.1017/S0014479702000212.

Headey, Derek D., and T. S. Jayne. 2014. “Adaptation to Land Constraints: Is Africa Different?” Food Policy 48: 18–33. https://doi.org/10.1016/j.foodpol.2014.05.005.

Hoekstra, Dirk A. 1987. “Economics of Agroforestry.” Agroforestry Systems 5 (3): 293–300. https://doi.org/10.1007/BF00119127.

Holtkamp, R., and J. Lorenz. 1990. Small Four-Wheel Tractors for the Tropics and Subtropics. Their Role in Agriculture and Industrial Development. Technical. Bonn, Federal Republic of Germany.

Kahan, David, Roger Bymolt, and Fred Zaal. 2017. “Thinking Outside the Plot: Insights on Small-Scale Mechanisation from Case Studies in East Africa.” Journal of Development Studies 00 (00): 1–16. https://doi.org/10.1080/00220388.2017.1329525.

Kebede, Laike, and Bisrat Getnet. 2016. “Performance of Single Axle Tractors in the Semi-Arid Central Part of Ethiopia.” Ethiopian Journal of Agricultural Sciences 27 (1).

Lal, Rattan. 2004. “Carbon Emission from Farm Operations.” Environment International. https://doi.org/10.1016/j.envint.2004.03.005.

Magistro, John, Michael Roberts, Steve Haggblade, Fritz Kramer, Paul Polak, Elizabeth Weight, and Robert Yoder. 2007. “A Model for Pro-Poor Wealth Creation through Small-Plot Irrigation and Market Linkages.” Irrigation and Drainage 56: 321–34. https://doi.org/10.1002/ird.

Mapiye, C., M. Chimonyo, and K. Dzama. 2009. “Seasonal Dynamics, Production Potential and Efficiency of Cattle in the Sweet and Sour Communal Rangelands in South Africa.” Journal of Arid Environments 73 (4–5): 529–36. https://doi.org/10.1016/j.jaridenv.2009.01.003.

Masters, William A, Agnes Andersson Djurfeldt, Cornelis De Haan, Peter B R Hazell, Thomas Jayne, Magnus Jirström, and Thomas Reardon. 2013. “Urbanization and Farm Size in Asia and Africa: Implications for Food Security and Agricultural Research.” Global Food Security. Elsevier. https://doi.org/10.1016/j.gfs.2013.07.002.

Moyo, I.A., T.N. Mudimba, D.N. Ndhlovu, S Dhliwayo, S.M. Chikerema, and G Matope. 2017. “Temporal and Spatial Patterns of Theileriosis in Zimbabwe: 2000-2014.” Bulletin of Animal Health and Production in Africa 65 (3): 569–75. https://www.ajol.info/index.php/bahpa/article/view/167662.

Orr, A., B. Mwale, and D. Saiti. 2002. “Modelling Agricultural ‘Performance’: Smallholder Weed Management in Southern Malawi.” International Journal of Pest Management 48 (4): 265–78. https://doi.org/10.1080/09670870210149808.

Pretty, Jules, Camilla Toulmin, and Stella Williams. 2011. “Sustainable Intensification in African Agriculture.” International Journal of Agricultural Sustainability 9 (1): 5–24. https://doi.org/10.3763/ijas.2010.0583.

Roxburgh, Caspar W., and Daniel Rodriguez. 2016. “Ex-Ante Analysis of Opportunities for the Sustainable Intensification of Maize Production in Mozambique.” Agricultural Systems 142: 9–22. https://doi.org/10.1016/j.agsy.2015.10.010.

Rusinamhodzi, Leonard. 2015. “Tinkering on the Periphery: Labour Burden Not Crop Productivity Increased under No-till Planting Basins on Smallholder Farms in Murehwa District, Zimbabwe.” Field Crops Research 170: 66–75.

Singh, Gyanendra. 2006. “Agricultural Machinery Industry in India (Manufacturing, Marketing and Mechanization Promotion).” Status of Farm Mechanization in India, 154–74. http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:Agricultural+Machinery+Industry+in+India+(+Manufacturing+,+marketing+and+mechanization+promotion+)#0.

Tefera, Tadele. 2012. “Post-Harvest Losses in African Maize in the Face of Increasing Food Shortage.” Food Security 4 (2): 267–77. https://doi.org/10.1007/s12571-012-0182-3.

Tittonell, Pablo A, and Kenneth E Giller. 2013. “When Yield Gaps Are Poverty Traps: The Paradigm of Ecological Intensification in African Smallholder Agriculture.” Field Crops Research 143: 76–90. https://doi.org/10.1016/j.fcr.2012.10.007.

Tittonell, Pablo A, Bernard Vanlauwe, Peter A Leffelaar, Edwin C Rowe, Kenneth E Giller, and Keith D Shepherd. 2005. “Exploring Diversity in Soil Fertility Management of Smallholder Farms in Western Kenya II. Within-Farm Variability in Resource Allocation, Nutrient Flows and Soil Fertility Status.” Agriculture, Ecosystems & Environment 110 (3–4): 149–65. https://doi.org/10.1016/j.agee.2005.04.001.

Vanlauwe, B., D. Coyne, J. Gockowski, S. Hauser, J. Huising, C. Masso, G. Nziguheba, M. Schut, and P. Van Asten. 2014. “Sustainable Intensification and the African Smallholder Farmer.” Current Opinion in Environmental Sustainability 8: 15–22. https://doi.org/10.1016/j.cosust.2014.06.001.

Zingore, Shamie, Herbert K Murwira, Robert J Delve, and Kenneth E Giller. 2007. “Influence of Nutrient Management Strategies on Variability of Soil Fertility, Crop Yields and Nutrient Balances on Smallholder Farms in Zimbabwe.” Agriculture, Ecosystems and Environment 119 (1–2): 112–26. https://doi.org/10.1016/j.agee.2006.06.019.

10.2 List of publications produced by project

Journal articles

1. Baudron, F., Nazare, R., Matangi, D. (2019) The role of mechanization in transformation of smallholder agriculture in Southern Africa. Experience from Zimbabwe. In: Sikora, R.A., Terry, E.R., Vlek, P.L.G., Chitja, J. (Eds.) Transformation of Agriculture in Southern Africa. Taylor & Francis. London, U.K. https://www.taylorfrancis.com/books/9780429401701
2. Baudron, F., Misiko, M., Getnet, B., Nazare, R., Sariah, J., Kaumbutho, P. (2019) A farm-level assessment of labor and mechanization in Eastern and Southern Africa. Agronomy for Sustainable Development 39(2),17. https://link.springer.com/article/10.1007/s13593-019-0563-5
3. Jaleta, M., Baudron, F., Krivokapic-Skoko, B., Erenstein, O. (2019) Agricultural mechanization and reduced tillage: antagonism or synergy? International Journal of Agricultural Sustainability doi.org/10.1080/14735903.2019.1613742. https://www.tandfonline.com/doi/abs/10.1080/14735903.2019.1613742
4. Silva, J.V., Baudron, F., Reidsma, P., Giller, K.E. (2019) Is labour a major determinant of yield gaps in sub-Saharan Africa? A study of cereal-based production systems in Southern Ethiopia. Agricultural Systems 174, 39-51. https://www.sciencedirect.com/science/article/pii/S0308521X18306711
5. Baudron, F., Sims, B., Justice, S., Kahan, D., Rose, R., Mkomwa, S., Kaumbutho, P., Sariah, J., Nazare, R., Moges, G., Gérard, B. (2015) Re-examining appropriate mechanization in Africa: Two-wheel tractors, conservation agriculture, and private sector involvement. Food Security, 7, 889-904. https://link.springer.com/article/10.1007/s12571-015-0476-3
6. Kahan, D., Bymolt, R., Zaal, F. (2017) Thinking outside the plot: Insights on small-scale mechanisation from case studies in East Africa. The Journal of Development Studies doi.org/10.1080/00220388.2017.1329525. https://www.tandfonline.com/doi/abs/10.1080/00220388.2017.1329525
7. Van Loon, J.V., Woltering, L., Krupnik, T.J., Baudron, F., Boa, M., Govaerts, B. (2020) Scaling agricultural mechanization services in smallholder farming systems. Case studies from sub-Saharan Africa, South Asia, and Latin America. Agricultural

Systems, 180, 102792. https://www.sciencedirect.com/science/article/pii/S0308521X18314914

Working Paper & Reports

8. Misiko, M., Kaumbutho, P., Mariki, W., Mutua, J., Titi, U., Massawe, P., Baudron, F. (2013) Drudgery and realities of small mechanisation among African smallholders. https://simlesa.cimmyt.org/download/drudgery-and-realities-of-small-mechanisation-among-african-smallholders/
9. Marongwe, L.S., Nazare, R., Baudron, F. (2014) Mapping opportunities for small mechanization and identifying drudgery, bottlenecks and alternative prospects in Zimbabwe. https://simlesa.cimmyt.org/download/report-on-the-focus-group-discussions-fgd-for-mapping-opportunities-for-small-mechanizationidentifying-drudgery-bottlenecks-and-alternative-prospects-in-zimbabwe/
10. Misiko, M., Tsegaye, M., Teshome, B., Getnet, B., Moges, G., Baudron, F., Tirfessa, D., Berta, E. (2014) Assessing drudgery and mapping demand for small mechanisation in Assela and Hawassa of Ethiopia. https://simlesa.cimmyt.org/download/assessing-drudgery-and-mapping-demand-for-small-mechanisation-in-assela-and-hawassa-of-ethiopia/
11. Mulatu, E., Kahan, D. (2015) Economics of two-wheel tractor mechanization – Ethiopia. https://simlesa.cimmyt.org/download/economics-of-2wt-mechanization-ethiopia/
12. Mung'oo, J., Kahan, D. (2015) Economics of two-wheel tractor mechanization – Kenya. https://simlesa.cimmyt.org/download/economics-of-2wt-mechanization-kenya/
13. Titus, B., Kahan, D. (2015) Economics of two-wheel tractor mechanization – Tanzania. https://simlesa.cimmyt.org/download/economics-of-2wt-mechanization-tanzania-2/
14. Edziwa, B., Kahan, D. (2015) Economics of two-wheel tractor mechanization – Zimbabwe. https://simlesa.cimmyt.org/download/economics-of-2wt-mechanization-zimbabwe/
15. Mulatu, E., Kahan, D. (2014) Market analysis for small mechanization – Ethiopia. https://repository.cimmyt.org/handle/10883/20528
16. Mutua, J., Kaumbutho, P., Mung'oo, J. (2014) Market analysis for small mechanization – Kenya. https://simlesa.cimmyt.org/download/market-analysis-for-small-mechanization-kenya/
17. Titus, B., Kahan, D. (2014) Market analysis for small mechanization – Tanzania. https://simlesa.cimmyt.org/download/market-analysis-for-small-mechanization-tanzania/
18. Edziwa, B., Kahan, D. (2014) Market analysis for small mechanization – Zimbabwe. file:///C:/Users/Frederic%20Baudron/Downloads/ZIM%20business%20model%20appraisal.pdf
19. Mulatu, E., Kahan, D. (2015) Business model appraisal report – Ethiopia. https://simlesa.cimmyt.org/download/business-model-appraisal-report-ethiopia/
20. Mung'oo, J., Kahan, D. (2015) Business model appraisal report – Kenya. https://simlesa.cimmyt.org/download/business-model-appraisal-report-kenya/
21. Titus, B., Kahan, D. (2015) Business model appraisal report – Tanzania. https://simlesa.cimmyt.org/download/business-model-appraisal-report-tanzania/
22. Edziwa, B., Kahan, D. (2015) Business model appraisal report – Zimbabwe. https://simlesa.cimmyt.org/download/business-model-appraisal-report-zimbabwe/

23. Mulatu, E., Kahan, D. (2015) Economics of two-wheel tractor mechanization – Ethiopia. https://simlesa.cimmyt.org/download/economics-of-2wt-mechanization-ethiopia/
24. Mung'oo, J., Kahan, D. (2015) Economics of two-wheel tractor mechanization – Kenya. https://simlesa.cimmyt.org/download/economics-of-2wt-mechanization-kenya/
25. Titus, B., Kahan, D. (2015) Economics of two-wheel tractor mechanization – Tanzania. https://simlesa.cimmyt.org/download/economics-of-2wt-mechanization-tanzania-2/
26. Edziwa, B., Kahan, D. (2015) Economics of two-wheel tractor mechanization – Zimbabwe. https://simlesa.cimmyt.org/download/economics-of-2wt-mechanization-zimbabwe/
27. Mulatu, E., Kahan, D. (2015) Financial products for farmers and service providers report – Ethiopia. https://repository.cimmyt.org/handle/10883/20534
28. Titus, B., Kahan, D. (2015) Financial products for farmers and service providers report – Tanzania. https://repository.cimmyt.org/handle/10883/20532
29. Edziwa, B., Kahan, D. (2015) Financial products for farmers and service providers report – Zimbabwe. https://repository.cimmyt.org/handle/10883/20531
30. Kahan, D., Mulatu, E., Titus, B., Edziwa, B. (2015) Financial products to support smallholder mechanization in the FACASI countries of sub-Saharan Africa. https://repository.cimmyt.org/handle/10883/20533
31. Tadesse, E., Kahan, D. (2017) Two-wheel tractor based technology service providers business model performance. A case study of FACASI project's service providers in Meki, Arsi Negele and Hawassa Zuria area of Ethiopia. https://simlesa.cimmyt.org/download/two-wheel-tractor-based-technology-service-providers-business-model-performance/
32. Mwehe, M., Kahan, D. (2017) Synthesis report on the adoption and impact of two-wheel tractor business models on farm households in Kenya. https://repository.cimmyt.org/handle/10883/20530
33. Titus, B., Kahan, D. (2016) The Performance of two-wheel tractor business models (owned by service providers): A case study from Tanzania. https://simlesa.cimmyt.org/download/walking-tractors-business-model-appraisal-in-facasi-project-areas-tanzania/
34. Matangi, D., Kahan, D. (2017) Two-wheel tractors business model appraisal in FACASI project areas – Zimbabwe. https://simlesa.cimmyt.org/download/two-wheel-tractors-business-model-appraisal-in-facasi-project-areas-zimbabwe/
35. Biru, G. (2017) Assessment of two-wheel tractor based agricultural machinery service users in Eastern and Southern Africa. https://simlesa.cimmyt.org/download/assessment-of-two-wheel-tractor-based-agricultural-machinery-service-users-in-eastern-and-southern-africa/
36. Tadesse, E. (2018) Cost-benefit analysis of two-wheel tractor-based mechanization. file:///C:/Users/Frederic%20Baudron/Downloads/Cost%20Benefit%20Analysis%20Ethiopia.pdf
37. Matangi, D. (2018) Cost benefit analysis of small-scale mechanization in Zimbabwe file:///C:/Users/Frederic%20Baudron/Downloads/Cost%20Benefit%20Analysis%20Zimbabwe.pdf
38. Kahan, D. (2018) Study of the performance of two-wheel tractor hire service business models. Case studies from East and Southern Africa. https://simlesa.cimmyt.org/download/study-of-the-performance-of-2wt-hire-service-business-models-case-studies-from-east-and-southern-africa/
39. Tadesse, E., Woodhead, A., Yahaya, R., Assefa, R., Getnet, B., Mupangwa, W., Baudron, F. (2019) Economic impact of two-wheel tractor on smallholder farming

system in Ethiopia. https://simlesa.cimmyt.org/facasi/resources/?wpv_post_search=cost+benefit+analysis&wpv_view_count=8998
40. Matangi, D., Woodhead, A., Misiko, M., Tadesse, E., Baudron, F. (2019) Cost benefit analysis of small scale mechanization: Zimbabwe case study. https://simlesa.cimmyt.org/facasi/resources/?wpv_post_search=cost+benefit+analysis&wpv_view_count=8998
41. Tadesse, E., Woodhead, A., Yahaya, R., Assefa, R., Baudron, F. (2019) Agricultural mechanization market analysis. Case of Ethiopia. https://simlesa.cimmyt.org/download/agricultural-mechanization-market-analysis-the-case-of-ethiopia/
42. Matangi, D., Woodhead, A., Misiko, M., Tadesse, E., Baudron, F. (2019) Agricultural mechanization value-chain analysis in Zimbabwe. file:///C:/Users/Frederic%20Baudron/Downloads/Market%20Analysis%20Zimbabwe%20(1).pdf
43. Misiko, M., Tandayi, B., Matangi, D., Woodhead, A., Tadesse, E., Baudron, F., Mukamuri, B., Nazare, R. (2019) Women and small mechanisation-based entrepreneurship in Zimbabwe. https://simlesa.cimmyt.org/facasi/resources/?wpv_post_search=Women+and+small+mechanisation&wpv_view_count=8998
44. Misiko, M., Tadesse, E., Woodhead, A., Baudron, F. (2019) Structural and cognitive drivers of small mechanisation among youth in Ethiopia. https://simlesa.cimmyt.org/facasi/resources/?wpv_post_search=Structural+and+cognitive+drivers&wpv_view_count=8998
45. Misiko, M., Woodhead, A., Nazare, R., Tadesse, E., Baudron, F. (2019) Networks and small mechanisation entrepreneurship in Ethiopia and Zimbabwe. https://simlesa.cimmyt.org/facasi/resources/?wpv_post_search=Networks+and+small+mechanisation&wpv_view_count=8998
46. Deribe, Y., Jaleta, M. (2017) Review of national policies influencing the expansion of agricultural mechanization in Ethiopia. https://simlesa.cimmyt.org/download/review-of-national-policies-influencing-the-expansion-of-agricultural-mechanization-in-ethiopia/
47. Agwa Agao, T., Jaleta, M. (2017) Review of national policies affecting the spread of small mechanization in rural Kenya. https://simlesa.cimmyt.org/download/review-of-national-policies-affecting-the-spread-of-small-mechanization-in-rural-kenya/
48. Titus, B., Sariah, J., Jaleta, M. (2017) Review of national policies affecting the expansion and development of agricultural mechanization in Tanzania. https://simlesa.cimmyt.org/download/review-of-national-policies-affecting-the-expansion-and-development-of-agricultural-mechanization-in-tanzania/
49. Marongwe, L.S., Koza, T., Nazare, R., Jaleta, M. (2017) Review of national policies affecting the spread of small engines/mechanization in rural areas of Zimbabwe. https://simlesa.cimmyt.org/download/review-of-national-policies-affecting-the-spread-of-small-engines-mechanization-in-rural-areas-of-zimbabwe/
50. Van Eerdewijk, A., Danielsen, K. (2015) Gender matters in farm power. https://simlesa.cimmyt.org/download/gender-matters-in-farm-power/
51. Tsegaye, M. (2014) The Effects of mechanizing harvesting and threshing on the gender dynamics. The case of Arsi-Negelle and Asella. https://simlesa.cimmyt.org/download/the-effects-of-mechanizing-harvesting-and-threshing-on-the-gender-dynamics-the-case-of-arsi-negelle-and-asella/
52. Kahan, D. (2015) Business models for scaling-up two-wheel tractor technologies among smallholder farmers. Theoretical underpinnings and empirical observations. https://knowledgecenter.cimmyt.org/cgi-bin/koha/opac-detail.pl?biblionumber=61120

53. Bymolt, R., Zaal, F. (2015) Moving to mechanization. https://simlesa.cimmyt.org/download/moving-to-mechanization-mechanization-in-maize-farming-systems-in-kenya-tanzania-and-zimbabwe/
54. Kahan, D. (2016) Business models of two-wheel tractors in Southern and Eastern Africa. FACASI Technical Working Paper. https://repository.cimmyt.org/handle/10883/20499

Theses

55. Takure, A.M. (2018) Development of a boom arm and the control systems for combined use with a no-till planter. BSc thesis. Department of soil science and Agricultural Engineering, Faculty of Agriculture, University of Zimbabwe.
56. Mhlanga, R. (2018) Development of a monitoring system for two-wheel tractor based planters. BSc thesis. Department of soil science and Agricultural Engineering, Faculty of Agriculture, University of Zimbabwe.
57. Mbesa, B. (2016) A comparative analysis of business models of two-wheel tractors in Babati District, Manyara region, Tanzania. MSc thesis. Faculty of Science in Agricultural and Applied Economics. Sokoine University.
58. Mvena, T.Z. (2017) Comparative performance of power tillers as an enterprise: individual versus group business model options in Arusha and Manyara regions, Tanzania. MSc thesis. Faculty of Science in Agricultural and Applied Economics. Sokoine University.
59. Tandayi, B.T. (2018) An Assessment of two-wheel tractor-based business models adopted by women entrepreneurs: the case of Farm Mechanization and Conservation Agriculture for Sustainable Intensification (FACASI) implemented in Makonde and Nyanga Districts, Zimbabwe. Faculty of Science in Social Ecology, University of Zimbabwe.
60. Chikutuma, M. (2017) Analysing the social network of technology and information transfer for maize sheller service providers in Zimbabwe. MCs thesis. Farming Systems Ecology Group, Wageningen University.

Drawings

61. EIAR, CIMMYT (2019) two-wheel tractor attached wheat metering unit – Drawings. https://simlesa.cimmyt.org/facasi/resources/?wpv-publication-type%5B%5D=drawings&wpv_view_count=8998&wpv_post_search=metering+unit
62. EIAR, CIMMYT (2019) Trailer drawings. https://simlesa.cimmyt.org/facasi/resources/?wpv-publication-type%5B%5D=drawings&wpv_view_count=8998
63. EIAR, CIMMYT (2019) Fabrication drawings of a two-wheel tractor operated four-row strip tillage wheat seeder from a conventional rotovator. https://simlesa.cimmyt.org/facasi/resources/?wpv-publication-type%5B%5D=drawings&wpv_view_count=8998
64. EIAR, CIMMYT (2019) Fabrication drawings of a two-wheel tractor operated wheat thresher. https://simlesa.cimmyt.org/facasi/resources/?wpv-publication-type%5B%5D=drawings&wpv_view_count=8998
65. UZ, CIMMYT (2019) Boom sprayer drawings. https://simlesa.cimmyt.org/facasi/resources/?wpv-publication-type%5B%5D=drawings&wpv_view_count=8998

66. UZ, CIMMYT (2019) Cutter miller drawings. https://simlesa.cimmyt.org/facasi/resources/?wpv-publication-type%5B%5D=drawings&wpv_view_count=8998
67. UZ, CIMMYT (2019) Double cob sheller drawings. https://simlesa.cimmyt.org/facasi/resources/?wpv-publication-type%5B%5D=drawings&wpv_view_count=8998

Manuals & guidelines

68. Nazare, R., Mushangure, R.O. (2019) Double cob sheller manual. http://knowledgeplatform.hellotractor.com/drawings-and-manuals/
69. Nazare, R., Mushangure, R.O. (2019) Star-wheel planter manual. https://simlesa.cimmyt.org/download/star-wheel-planter-manual/
70. Kahan, D. (2016) Business management for small scale mechanization. A training program for hire service providers. https://simlesa.cimmyt.org/download/business-management-for-small-scale-mechanization/
71. Getnet, B., Alemu, D., Woldesenbet, S., Bullo, T., Baudron, F. (2019) Operator training manual. Two-wheel tractor and ancillary equipment. https://simlesa.cimmyt.org/facasi/resources/?wpv-publication-type%5B%5D=farmer-and-extension-manuals&wpv-publication-type%5B%5D=journal-articles&wpv_view_count=8998&wpv-topic%5B%5D=training-and-capacity-development
72. Sims, B., Kahan, D., Mpagalile, J., Hilmi, M., Santos Valle, S. (2018) Hire services as a business enterprise. A training manual for small-scale mechanization service providers. https://repository.cimmyt.org/handle/10883/19537
73. Mkomwa, S., Achora, J., Mutai, W. (2017) Powering smallholder agriculture un Africa. Two-wheel tractor for farm mechanization and conservation agriculture in Eastern Africa. https://repository.cimmyt.org/handle/10883/20500
74. Kahan, D. (2013) Guidelines for the design and evaluation of business models. https://simlesa.cimmyt.org/download/business-model-design-and-evaluation-guidelines/
75. Rose, R. (2013) FACASI literature review guideline. https://simlesa.cimmyt.org/download/business-model-literature-review-guidelines/
76. Kahan, D. (2015) Guidelines for two-wheel tractor-based farm machinery hiring services. https://simlesa.cimmyt.org/download/guideline-for-2wt-based-farm-machinery-hiring-services/
77. Kahan, D. (2013) Guidelines for a subsector analysis of the 2WT mechanization sub-sector. https://simlesa.cimmyt.org/download/sector-analysis-guidelines/

Briefs, factsheets and bulletins

78. Jaleta, M., Baudron, F. (2017) Commercializing Smallholder Mechanization: The role of public and private sectors. ACIAR Policy Brief. Research findings with policy implications. https://repository.cimmyt.org/handle/10883/19116
79. Gérard, B., Baudron, F., Yahaya, R., Krupnik, T., Justice, S., Van Loon, J. (2017) Mechanization for smallholder farmers. CIMMYT Factsheet. https://repository.cimmyt.org/handle/10883/18164
80. Bossuet, J. (2017) Appropriate mechanization for African smallholder: a pathway to sustainable intensification and rural employment. CIMMYT Info Brief. https://repository.cimmyt.org/handle/10883/19590

81. Gérard, B., Baudron, F., Yahaya, R. (2019) Debunking myths about agricultural labor and mechanization in Africa. CIMMYT Factsheet. https://repository.cimmyt.org/handle/10883/20122
82. Baudron, F., Kahan, D. (2017) Designing and implementing small-scale mechanization R&D projects: Lessons from FACASI. https://simlesa.cimmyt.org/download/designing-and-implementing-small-scale-mechanization-rd-projects-lessons-from-facasi/
83. Van Loon, J., Woltering, L., Krupnik, T., Baudron, F. (2018) Scaling appropriate agricultural mechanization worldwide: two-wheel tractors and smallholders farmers. Poster. http://knowledgeplatform.hellotractor.com/scaling-appropriate-agricultural-mechanization-worldwide/
84. Kahan, D. (2017) Delivering appropriate mechanization to smallholders in sub-Saharan Africa: the FACASI experience. FACASI Technical Bulletin. http://facasi.act-africa.org/library.php?com=4&com2=12&com3=41&com4=

Media stories and videos

85. Bastemeijer, E. (2016) Powering smallholder agriculture in Eastern and Southern Africa. How 2-wheel tractors increase farm power among smallholders. https://repository.cimmyt.org/handle/10883/4468
86. Bastemeijer, E. (2016) Two-wheel tractors & conservation agriculture for sustainable intensification in Ethiopia. http://knowledgeplatform.hellotractor.com/two-wheel-tractors-and-conservation-agriculture-for-sustainable-intensification-in-ethiopia/
87. Bastemeijer, E. (2016) Revitalizing smallholder agriculture in Zimbabwe. Conservation agriculture using 2-wheel tractors.
88. FACASI Newsletter. Issue 1: June 2014. http://facasi.act-africa.org/library.php?com=4&com2=12&com3=13&com4=
89. FACASI Newsletter. Issue 2: September 2014. http://facasi.act-africa.org/library.php?com=4&com2=12&com3=13&com4=
90. FACASI Newsletter. Issue 3: December 2014. http://facasi.act-africa.org/library.php?com=4&com2=12&com3=13&com4=
91. FACASI Newsletter. Issue 4: January-March 2015. http://facasi.act-africa.org/library.php?com=4&com2=12&com3=13&com4=
92. FACASI Newsletter. Issue 5: April-June 2015. http://facasi.act-africa.org/library.php?com=4&com2=12&com3=13&com4=
93. FACASI Newsletter. Issue 6: August-September 2015. http://facasi.act-africa.org/file/20151123_facasi_newsletter_august_september_2015_issue_6.pdf
94. FACASI Newsletter. Issue 7: January-April 2016. http://facasi.act-africa.org/file/20160428_facasi_newsletter_issue_7_january_april_2016.pdf
95. FACASI Newsletter. Issue 8: April-June 2016. http://facasi.act-africa.org/library.php?com=4&com2=12&com3=13&com4=
96. FACASI Newsletter. Issue 9: December 2016. http://facasi.act-africa.org/library.php?com=4&com2=12&com3=13&com4=
97. Regional (2016): https://www.youtube.com/watch?v=oe8J2ee4rAU&t=164s
98. Ethiopia (2016): https://www.youtube.com/watch?v=Q7Ej20NzZ28&t=25s
99. Ethiopia (2018): https://www.youtube.com/watch?v=VjlCuJdKmKs&t=103s
100. Kenya (2016): https://www.youtube.com/watch?v=togiZfnfsnk&t=386s
101. Tanzania (2016): https://www.youtube.com/watch?v=KRfO-chRD3w&t=744s
102. Zimbabwe (2016): https://www.youtube.com/watch?v=MZ1G7yX0kj0&t=529s
103. Zimbabwe (2018): https://www.youtube.com/watch?v=0EYL2jlRV4A&t=96s

11 Appendixes

11.1 List of Acronyms

2WT	Two-wheel tractor
ACIAR	Australian Centre for International Agricultural Research
ACT	African Conservation Tillage
CA	Conservation agriculture
CARMATEC	Centre for Agricultural Mechanization and Rural Technology
CGIAR	Consultative Group on International Agricultural Research
CIMMYT	International Maize and Wheat Improvement Center
CSU	Charles Sturt University
EIAR	Ethiopian Institute of Agricultural Research
FACASI	Farm Mechanization and Conservation Agriculture for Sustainable Intensification
FAO	Food and Agricultural Organization of the United Nations
IFPRI	International Food Policy Research Institute
HT	Hello Tractor
IAE	Institute of Agricultural Engineering +
KENDAT	Kenya Network for Dissemination of Agricultural Technologies
M&E	Monitoring and Evaluation
MFIs	Micro Finance Institutions
M&E	Monitoring and Evaluation
MoA	Ministry of Agriculture and Natural Resources
SIMLESA	Sustainable intensification of maize-legume cropping systems for food security in eastern and southern Africa
SSA	Sub-Saharan Africa
UZ	University of Zimbabwe