Final report

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1 Acknowledgments

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2 Executive summary

The Harnessing Appropriate-scale Farm mechanisation In Zimbabwe (HAFIZ) project was implemented between 21 January 2021 to 31 October 2023 in Zimbabwe and in South Africa. The aim of the project was to support investments by the Government and by the private sector in appropriate-scale farm mechanisation in Zimbabwe, particularly around mechanised *Pfumvudza*, and transfer learnings to South Africa. The overall goal of the project was to improve access to mechanisation and reduce labour drudgery whilst stimulating the adoption of climate-smart/sustainable intensification technologies (contrary to high labour demand in a context of current low level of mechanisation).

Under objective 1 (targeting mechanisation investment), the project effectively deployed multilayer data analysis to develop guidelines, presented in this report. We recommend prioritizing investments in mechanisation in Northeastern Zimbabwe (Mashonaland West, Mashonaland Central, Mashonaland East, and Manicaland provinces) where the Ruthenberg coefficient, land:labour ratio, and value of crop production are greatest and where market access and interannual rainfall variability is the smallest. For South Africa, and due to similar reasons, we recommend prioritizing investments in mechanisation in Mpumalanga province. In Zimbabwe, the spatially explicit recommendation domains were validated with household and machinery sales data from the Ministry of Lands, Agriculture, Fisheries, Water and Rural Development (MLAFWRD), and the private sector, respectively. Further research with ground data is required to validate the delineated niches in South Africa and to simulate aggregate benefits for food security and employment from targeted vs. blanket investments in mechanisation in both countries. The workflows developed to generate the recommendation domains are fully open-source and reproducible, making it possible to re-apply in other countries at minimal cost.

Four sub-activities were carried out under Objective 2 meant to understand customer profiles for different types of equipment in different locations; assess adoption and impacts of different pieces of equipment in two contrasted sites where sales are aggregated; qualitative understanding of drivers of adoption and impacts of appropriate-scale farm mechanisation, and impact assessment of appropriate-scale farm mechanisation among service providers, women and youth. These activities were accomplished using qualitative and quantitative surveys with three main findings. First, there is a wide variety of farm machinery bought by farmers in Zimbabwe including two- and four-wheel tractors, fertiliser application, land preparation, planting, dairy, irrigation, harvesting, post-harvest processing, feed processing, and transportation. This shows that there is a wide diversity of appropriate-scale mechanisation options used by the farmers in Zimbabwe. Most of the customers who bought farm equipment relied on salaried employment and on off-farm businesses as primary occupations, and the majority purchased the farm machinery and equipment as a once off payment. Second, farmers invest in both ‘power-intensive operations’ (e.g., land preparation) and ‘control-intensive’ operations (e.g., planting and weeding). While the control intensive operations are limited for most farmers, there is a wide range of equipment for power intensive activities. This leaves weeding less attended to and yet it is one of the most labour-intensive operations. This finding implies a need to make available mechanical weed control methods. Important drivers of adoption of farm machinery include wealth (proxied by farm size, number of livestock), being a male-headship of a household, use of hybrid seeds and engaging in some form of forward marketing arrangements or contract farming. Third, service providers for tillage and threshing are more dominant, pointing to high demand and the existence of a market for these services. Most service providers are based on their farms, big towns and growth points, hence are not easily accessible to farmers who want to hire mechanisation services. In terms of the machinery owned and used, four-wheel tractor (4WTs) and shellers dominate, followed by 4WT drawn rippers and planters. Other equipment owned by Service Providers include peanut butter making machines and water pumps and less owned are 4WT-drawn boom sprayers, silage cutters and mixers, threshers, oil pressers and incubators. Prioritised services most demanded by women include ploughing, threshing, transportation harvesting, planting and water pumps.

Objective 3 of the project aimed to develop and test prototypes of two-wheel tractor operated implements for mechanised *Pfumvudza* (basin digger and bed planter). Need assessment, involving different levels of stakeholders, suggested that both the basin digger and the bed planter should be powered by a two-wheeled tractor, operated by single person, and must have a seat for the operator. The desired capacity of the basin digger should be 3–4 *Pfumvudza* plots per day (i.e., 1465 planting basins or a single plot in 2–3 hours), and its price should not exceed AU$ 1550. The capacity of the bed planter should be about 0.3 ha/h and its price should not exceed US$ 2326. Based on the above criteria, a double row prototype basin digger and a single row bed planter was designed and fabricated at the Zimplow/Mealie Brand's workshop in Bulawayo, Zimbabwe. Pre-test results suggested that the rotary blades (forward rotation, vertical) were vibrating too much due to soil resistance during digging basin. To solve the vibration problem, a vertical auger type double row basin digger was designed and fabricated. The second prototype has been undergoing field test and refinement. The early results show that the augers could dig two basins at the same time but digging basins on the go still not fully achieved. On the other hand, the bed planter prototype fabricated with the seed and fertilizer placement capability is going through pre-tests.

Under Objective 4, three twice-yearly multi-stakeholder round tables meetings were organised where participants from MLAFWRD and other Ministries, CIMMYT, private sector representatives, NGOs, mechanisation service providers and media attended. The meetings identified and agreed on action points based on SWOT analysis covering the following key areas aimed at accelerating smallholder farm mechanisation initiatives:

- promotion or demand creation
- capacity development
- coordination amongst stakeholders
- information and communication
- research and development and
- finance

The MLAFWRD project members participated in advocacy meetings and events (e.g., field days). A mechanisation exposure visit was organised during 8–16 August in India and consisted of the five participants from Zimbabwe and South Africa. The exposure visit to India covered visiting mechanisation hiring centre/co-operative, mechanisation projects/trials of BISA (Borlaug Institute for South Asia), and visiting three manufacturers in Punjab followed by visiting the mechanisation research, development and testing activities and facilities at the Chaudhary Charan Singh Haryana Agricultural University, Hisar in the Haryana province. The communication products (dashboards, reports, drawings, etc.) are reposited in the Hello Tractor knowledge platform (https://hellotractor.com/).

It is recommended and expected that the project finding should be disseminated among the partners (e.g. spatial targeting by MLAFWRD and Kurima Machinery) and CIMMYT would provide technical backstopping needed. The prototype machinery developed need further field testing and fine tuning that should be completed with the remaining period of the project and handed over to the ministry and industry for demonstration and scaling in any follow up projects of any if the partners.

3 Background

Southern Africa is one of the regions most affected by climate change, resulting in a reduction of the length of the growing season and more erratic and unpredictable rainfalls (Lobell et al., 2008). The Government of Zimbabwe responded to this pressing challenge for its national agriculture by embarking on an ambitious program of promotion of a system of manual conservation agriculture (defined as the combination of minimum soil disturbance, a permanent soil cover and crop diversification; https://www.fao.org/conservation-agriculture/en/) – known as *Pfumvudza* – which has reached 2.2 million smallholder farmers during the past 2020–21 season. However, this practice can only be adopted on small areas because of the labour intensity it involves in digging basins (22,222 planting basins per ha) with hand hoes (Rusinamhodzi, 2015).

As a result, the Government (through a partnership with CIMMYT and the private company Kurima Machinery and Technology) has developed a five-year implementation strategy and alliance to support appropriate-scale farm mechanisation in the country. Appropriate-scale farm mechanisation refers to mechanized solutions that are technically, environmentally, and economically appropriate for use in smallholder settings. In the context of Zimbabwe, it encompasses a range of technologies powered by small engine (less than 25 HP) – including two-wheel tractors, small four-wheel tractors ('mini tractors') and their ancillary equipment, self-powered technologies such as shellers, threshers, milling machines, etc, and small pumps – as well as delivery models (rural service providers, etc). This strategy is largely informed by the findings of a previous ACIAR investment in Zimbabwe (and other countries in East and Southern Africa): the 'Farm mechanisation and Conservation Agriculture for Sustainable Intensification' (FACASI) project (https://www.aciar.gov.au/publication/technical-publications/farm-mechanisation-and-conservation-agriculture-sustainable-intensification-final). The strategy was implemented by an alliance of the Government of Zimbabwe, Kurima Machinery and Technology (and other private sector companies involved in appropriate-scale farm machinery) and CIMMYT. The demands from this alliance are (1) to support the Government by modelling the outcome of alternative investments (volume, targeting, etc) in the country, (2) to support private sector through better targeting (e.g., profile of likely adopters), 'business intelligence' (i.e., market information) and through Research and Development (e.g., exchange of designs from the region and beyond, second generation engineering, capacity development on state-of-the-art engineering), (3) to support coordination through e.g., round tables, and (4) to support information exchange, regionally and globally.

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

- Can data driven and spatially-explicit recommendations increase returns on investment in appropriate-scale farm mechanisation for the Government and for private sector?
- Can affordable and appropriate equipment powered by two-wheel tractors be developed to mechanise *Pfumvudza* and scale-out the technology?
- What technology, approach, knowledge and skills could be shared nationally, regionally and globally to increase adoption of appropriate-scale farm mechanisation?

4 Objectives

4.1 Objective 1: To guide public and private investments in appropriate-scale farm mechanisation through spatial targeting and projection of aggregate benefits

This objective aimed at delineating the spatial niche for mechanisation in Zimbabwe and South Africa, and within that niche, the niche for appropriate-scale farm mechanisation, based on expert knowledge, publicly-available spatial products, and sales data. The ex ante analysis recognized five main drivers of mechanisation: (1) the level of intensification of current farming systems, (2) the scarcity of labour for agricultural activities, (3) the market demand for agricultural commodities, (4) the share of plough positive crops and, (5) the availability and use of complementary inputs. Conversely, it was hypothesized from the findings from the FACASI project that appropriate-scale farm mechanisation is driven by small and fragmented plots, low density of draught animals, relatively deep and rock-free soils (shallow and rocky soils are not easily handled by low horse-power tractors) and relatively hilly terrains (for which large tractors are poorly suited).

The outputs of this objective include:

- Delineation of product niches for different pieces of equipment, based on expert knowledge
- Collation (and development) of spatial layers relevant to the analysis in Zimbabwe and in South Africa
- Ex-ante spatial targeting for appropriate-scale farm mechanisation in Zimbabwe and in South Africa
- Collation of spatially-explicit sales data of different pieces of equipment
- Evaluation of spatial targeting based on spatially-explicit sales data
- Simulation of aggregate benefits (e.g., food security, employment, change in GHG, livestock productivity, disaggregated by gender) from different investment scenarios (different level of investment, different spatial targeting) in Zimbabwe and South Africa

4.2 Objective 2: To support machinery dealers and manufacturers with better understanding and targeting of their customers

This objective aimed at better understanding how economic, environmental, technical (ease of use and efficiency), socio-cultural dynamics (gender, women, and youth), institutional/organizational and policy variables influence adoption of appropriate-scale farm mechanisation, disaggregated by equipment type, for both service providers and users.

The outputs of this objective include:

- Understanding of customer profiles, for different types of equipment in different locations
- Adoption and impact study for different pieces of equipment in two contrasted sites where sales are aggregated
- Qualitative understanding of drivers of adoption and impacts of appropriate-scale farm mechanisation
- Impact assessment of appropriate-scale farm mechanisation adoption among service providers and users, and among women and youth (inter- and intra-household dynamics)

4.3 Objective 3: To develop and test prototypes of two-wheel tractor operated implements for mechanised *Pfumvudza*

This objective aimed at designing and developing affordable two-wheel tractor driven prototype machines to mechanise *Pfumvudza*, with the goal of reducing drudgery, time and cost of basin digging and thus stimulate the scaling of *Pfumvudza*, focusing on two products: (1) a basin digger, and (2) a bed planter.

The outputs of this objective include:

- Need assessment and conception of basin digger and bed planter prototypes
- Design of basin digger and bed planter prototypes
- Development of basin digger and bed planter prototypes
- Development of lab and field-testing procedures
- Prototype testing and evaluation
- Re-engineering and product refinement
- Participatory testing and evaluation of prototypes and fine tuning.
- Development of manufacturing process

4.4 Objective 4: To enhance information exchange among value chain actors in Zimbabwe, as well as regionally and with South Asia

This objective aimed at enhancing information exchange – and dissemination of project findings – among value chain actors of appropriate-scale farm mechanisation in Zimbabwe and globally (ensuring Global Access), and at stimulating exchange of expertise, knowledge and designs between Southern Africa (Zimbabwe and South Africa) and South Asia (Bangladesh specifically).

The outputs of this objective include:

- Twice-yearly multi-stakeholder round tables
- Participation of MLAFWRD project member(s) in advocacy meetings and events (e.g., field days)
- Repositing of communication products (dashboards, reports, etc) in the Hello Tractor knowledge platform
- Exposure visit to Bangladesh (changed to India) for key representatives of the public and private sectors (Zimbabwe and South Africa)

5 Methodology

5.1 Objective 1

To guide public and private investments in appropriate-scale farm mechanisation through spatial targeting and projection of aggregate benefits

Key informant interviews were conducted in Zimbabwe and South Africa with the objective of gathering past experiences and ongoing activities with appropriate-scale farm mechanisation in the country. Spatial layers relevant to the spatially explicit ex-ante analysis of farm mechanisation in Zimbabwe and South Africa were collated. The collated spatial layers included the Ruthenberg coefficient, land:labour ratio, rainfall variability around planting time of annual crops (November-January), value of crop production, market access, area of annual crops, level of crop intensification, cattle, density, rooting depth, and terrain slope. All spatial layers for Zimbabwe and South Africa were standardized to a common spatial extent and resolution. We decided to use data from spatial products available for all sub-Saharan Africa to ensure the scalability of the workflow to other countries, and to avoid limitations accessing household survey data at national level (which is often sensitive to obtain).

The framework in Figure 1 was used to delineate the farm mechanisation niche, and the appropriate-scale farm mechanisation niche. The framework recognizes five main drivers of mechanisation: (1) the level of intensification of current farming systems, (2) the scarcity of labour for agricultural activities, (3) the market demand for agricultural commodities, (4) the share of plough positive crops and, (5) the availability and use of complementary inputs. Ruthenberg (1980) postulated that the level of intensification of farming systems – proxied by the Ruthenberg coefficient, the ratio of cultivated land over total land (cultivated and fallowed) – is an endogenous factor driving technological change in agriculture, including mechanisation. Labour scarcity is an outcome of changes in the economic system, particularly increasing land:labour ratio (Binswanger and Ruttan, 1978) and time constraints for performing critical operations (e.g., short planting window). The market demand for agricultural commodities can be proxied by the share of cash crops in current farming systems and the distance to urban centres, and the share of plough positive crops can be proxied by the share of annual crops. Finally, complementary inputs such as irrigation and fertilisers have also been found to be drivers of mechanisation (Diao et al., 2016). The 'appropriate-scale farm mechanisation niche' can be delineated from the mechanisation niche considering plot size, cattle density, soil properties and terrain roughness. Indeed, findings from the FACASI project suggest that the 'appropriate-scale farm mechanisation niche' is characterized by small and fragmented plots, low density of draught animals, relatively deep and rock-free soils (shallow and rocky soils are not easily handled by low horse-power tractors) and relatively hilly terrains (for which large tractors are poorly suited; Baudron et al., 2015). The framework was implemented through a combination of principal component analysis and hierarchical clustering (see Annexes 1 and 2 for Zimbabwe and South Africa, respectively).

The collated spatial layers were developed to capture the different drivers and dimensions associated with the framework presented in Figure 1. This was possible for all drivers of the mechanisation niche (i.e., Ruthenberg coefficient, land:labour ratio, time constraints proxied by rainfall variability at planting time, share of cash crops proxied by the value of crop production, market access defined as the distance to urban centres, and the share of annual crops), except those related to complementary inputs of irrigation and fertilisers. The latter was overcome by using a spatial layer with the level of crop intensification (in t ha^{-1}) as proxy for complementary inputs assuming that grid cells with higher levels of crop productivity might also benefit from more intensive use of complementary inputs. Regarding the appropriate-scale farm mechanisation niche, we were able to compile spatial data for three out of the four drivers required to carve it from the larger mechanisation niche. Those included cattle density, soil depth, and terrain slope. Spatially explicit data on plot size was not available so the land:labour ratio was used as a proxy of plot size to delineate the niche for appropriate-scale farm mechanisation. We note the appropriate-scale farm mechanisation niche was only delineated for Zimbabwe, due to lack of primary (sales/survey) data for South Africa and due to a small and highly clustered mechanisation niche identified for this country (see Section 7.1 and Annex 2 for further information).

The mechanisation and appropriate-scale farm mechanisation niches were further evaluated for Zimbabwe using two sets of primary data. For the mechanisation niche, a national-wide survey conducted by AGRITEX was used to predict the likelihood of presence/absence of different pieces of equipment across the country. Such spatial predictions were contrasted to the mechanisation niche delineated with the secondary spatial data sources and the framework presented in Figure 1. It was more difficult to evaluate the appropriate-scale farm mechanisation niche due to lack of spatial variability and rather small sample size in the spatially explicit sales data of different pieces of equipment compiled by Kurima Machinery and Technology in Zimbabwe (see Annex 3). In this case, only descriptive comparisons were possible to infer whether the largest sales of appropriate-scale farm mechanisation equipment were registered in areas delineated with the spatial targeting exercise.

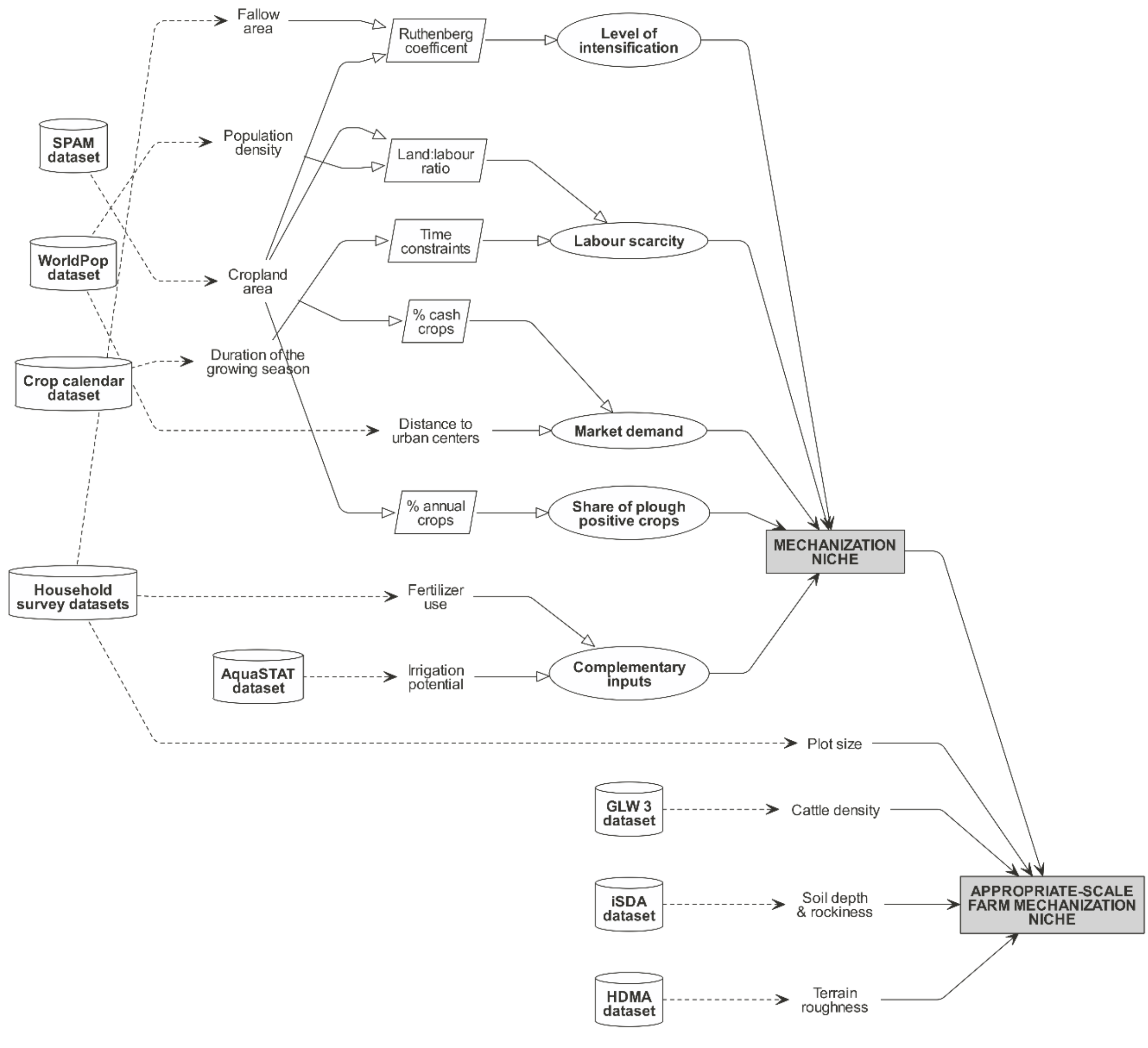

Figure 1 Framework for the ex-ante spatial targeting of mechanisation, and appropriate-scale farm mechanisation developed and used in the HAFIZ project. The data sources used to operationalize this framework are described in Annexes 2 and 4 for Zimbabwe and South Africa, respectively.

5.2 Objective 2

To support machinery dealers and manufacturers with better understanding and targeting of their customers

A telephone survey was administered by Kurima Machinery and Technology, using the Kurima customer database, to better understand customer profiles of appropriate-scale farm mechanisation (disaggregated by equipment type). Two geographic areas where Kurima has had the highest sales of appropriate-scale farm mechanisation equipment over the past three years were selected, and a survey was administered to a randomly selected sample, targeting adopters and non-adopters of small-scale farm mechanisation. The survey was complemented by key informant interviews, individual-detailed interviews, focus group discussions, and life history, to better appreciate the qualitative dimensions of adoption and impacts of appropriate-scale farm mechanisation.

A combination of qualitative and quantitative (including economic analysis) surveys were used to explore inter- household gender dynamics, and intra-household gender dynamics (e.g., possible negative effects of the adoption of appropriate-scale farm mechanisation on the decision-making power and control over resources by women, possible transfer of labour burden from one task to another e.g., from land preparation, traditionally a men-task, to weeding traditionally a women-task).

5.3 Objective 3

To develop and test prototypes of two-wheel tractor operated implements for mechanised Pfumvudza

The design process commenced with a needs assessment, to ascertain the need, affordability, manufacturability and functional requirements of the basin digger and the bed planter. Expert knowledge was upraised through focus group discussions and key informant interviews of Government staff, private sector, practitioners from the R&D community, existing service providers, farmers (clients of service providers, and in particular *Pfumvudza* farmers), etc.

Based on the needs assessment (Annexes 5 and 6), models were developed and analysed (for their structural stabilities, etc) using computer aided design (CAD) software. Three-dimension modelling, stress analysis and dynamic simulation were conducted. Design for manufacturability, quality, functional deployment and standardization were key in the design process. The basin digger prototypes are intended to produce planting basins (each basin 15 cm wide, 15 cm long and 15 cm deep), at a density of 22,222 basins per ha, under no-tillage whilst maintaining ground cover (crop residues). The bed planter is expected to make new beds or reshape permanent beds (90 cm apart) while sowing seeds and placing fertilisers. The process of bed planting/(re)shaping being a continuous one, is likely to be less time consuming compared to that in mechanical basin digging. As bed planting is combined with other operations such as seeding and fertiliser applications, it would potentially be more attractive than mechanical basin digging.

Based on the need assessment and the CAD models, two basin digger prototypes and a bed planter prototype were fabricated in Zimplow workshop in Bulawayo. A first series of tests were conducted by the project team (Zimplow and CIMMYT), leading to re-engineering and product refinement. The prototype machinery developed need further field testing and fine tuning that should be completed with the remaining period of the project and handed over to the ministry and industry for demonstration and scaling in any follow up projects of any if the partners. Finally, manufacturing processes (including complete drawings, step-by-step manufacturing guidelines, lists of machinery required, list of personnel required, and Standard Operating Procedures for the commercial production of the machines) would be developed for the final prototypes.

It was planned that objective 3 will be carried out with the involvement of at least one masters student (for capacity development). However, the student enrolled dropped the project due to poor progress and complexity of the allocated research project.

5.4 Objective 4

To enhance information exchange among value chain actors in Zimbabwe, as well as regionally and with South Asia

Project progresses were evaluated during twice-yearly roundtable meetings, and progress of other interventions taking place in the country (led by the Government, the private sector or development NGOs) were also be presented. Critical success factors that could address weaknesses in the appropriate-scale farm mechanisation value chains were also identified during these roundtables (through SWOT analysis), and potential linkages established (linkages between manufacturers, dealers, financial institutions and farmer's groups have been established during past roundtables organized by FACASI).

The project's experience and findings were represented in the national advocacy meetings and other events (e.g., field days) focusing on appropriate-scale farm mechanisation in Zimbabwe, through its country coordinator/MLAFWRD representative (Tirivangani Koza). This also ensured that project findings were incorporated in the five-year appropriate-scale farm mechanisation strategy developed by the Ministry.

Knowledge products generated by HAFIZ would be reposited – and made publicly available – in the knowledge platform hosted by the globally acclaimed company Hello Tractor, and initiated during the implementation of FACASI (https://knowledgeplatform.hellotractor.com/). This would include interactive dashboards, manufacturing system designs of the basin diggers and the bed planter, and key reports. Finally, HAFIZ organized an exposure visit to India for two representatives of MLAFWRD (Tirivangani Koza and his Chief Director Mr Edwin Zimunga), a postdoctoral fellow from the UKZN, a senior member of the South African Department of Agriculture, Land Reform and Rural Development, and a CIMMYT scientist with excellent knowledge of the appropriate-scale farm mechanisation landscape in Bangladesh (Dr Md Abdul Matin).

6 Achievements against activities and outputs/milestones

Objective 1: To guide public and private investments in appropriate-scale farm mechanisation through spatial targeting and projection of aggregate benefits

No.	Activity	Outputs/ milestones	Completion date	Comments
1.1	Delineation of product niches for different pieces of equipment, based on expert knowledge	Short report with product niches for different pieces of equipment	3/1/2022	Completed. Dimensions and indicators, as well as prioritizations of these, conducted through expert knowledge (Annexes 7 and 8)
1.2.a	Collation (and development) of spatial layers relevant to the analysis in Zimbabwe	Stack of spatial layers relevant for the ex-ante analysis	6/1/2022	Completed (see Figure 1 and Annex 4 for further details)
1.2.b	Collation (and development) of spatial layers relevant to the analysis in South Africa	Stack of spatial layers relevant for the ex-ante analysis	12/1/2022	Completed (see Annex 2 with activities of South Africa)
1.3.a	Ex-ante spatial targeting for appropriate-scale farm mechanisation in Zimbabwe	Spatial layer of recommendation domains for appropriate-scale farm mechanisation in Zimbabwe	9/1/2022	Completed: documented workflow and results provided in Annex 1
1.3.b	Ex-ante spatial targeting for appropriate-scale farm mechanisation in South Africa	Spatial layer of recommendation domains for appropriate-scale farm mechanisation in South Africa	3/1/2023	Completed (see Annex 2 with activities of South Africa)
1.4	Collation of spatially-explicit sales data of different pieces of equipment	Spatial-explicit database of sales data.	9/1/2022	Completed (see Annex 3)
1.5	Evaluation of spatial targeting based on spatially-explicit sales data	Recommendation domains overlayed with sales data	12/1/2022	Completed for Zimbabwe only due to lack of data for South Africa (see Annex 9)
1.6.a	Simulation of aggregate benefits (e.g., food security, employment, change in GHG, livestock productivity, disaggregated by gender) from different investment scenarios (different level of investment, different spatial targeting) in Zimbabwe	Simple investment plan for Zimbabwe, and possibly dashboard	3/1/2023	It will be developed after the project as part of a peer-reviewed publication for Zimbabwe
1.6.b	Simulation of aggregate benefits (e.g., food security, employment, change in GHGs, livestock productivity, disaggregated by gender) from different investment scenarios (different level of investment, different spatial targeting) in South Africa	Simple investment plan for South Africa and possibly dashboard	6/1/2023	Not completed due to lack of data

Objective 2: To support machinery dealers and manufacturers with better understanding and targeting of their customers

No	Activity	Outputs/ milestones	Completion date	Comments
2.1	Understanding of customer profiles, for different types of equipment in different locations	Short report on customer profiles	6/22/2022	Completed (see Annex 10)
2.2	Adoption and impact study for different pieces of equipment in two contrasted sites where sales are aggregated	Report on adoption and impacts of mechanisation	12/22/2022	Completed (see Annex 11)

2.3	Qualitative understanding of drivers of adoption and impacts of appropriate-scale farm mechanisation	Report on qualitative drivers of adoption and impacts of mechanisation	4/30/2023	Completed (see Annex 12)
2.4	Impact assessment of appropriate-scale farm mechanisation adoption among service providers and users, and among women and youth (inter- and intra-household dynamics)	Impact assessment report, focusing on service providers and users, and on women and youth	06/30/2023	Completed (see Annex 13)

Objective 3: To develop and test prototypes of two-wheel tractor operated implements for mechanised Pfumvudza

No.	Activity	Outputs/ milestones	Completion date	Comments
3.1	Need assessment and conception of basin digger and bed planter prototypes	Report on need assessment and design considerations (Annexes 5 and 6)	3/1/2 022	Completed
3.2	Design of basin digger and bed planter prototypes	Computer models of product designs (Figures 8, 10 and 12)	Basin digger 2/1/2023 Bed planter 6/1/2023	Completed
3.3	Development of basin digger and bed planter prototypes	Equipment for field evaluation/validation (Figures 9 and 11)	7/1/2022	Completed
3.4	Development of lab and field-testing procedures	Test protocols (Appendix 12)	8/1/2023	Completed
3.5	Prototype testing and evaluation	Field testing report and recommendations for improvement	9/10/2023	Delayed as the prototypes need further refinement. Zimplow has plan to fine tune the prototypes and release them commercially.
3.6	Re-engineering and product refinement	Final product design	9/15/2023	Delayed as the prototypes need further refinement
3.7	Participatory testing and evaluation of prototypes and fine tuning	Field testing report and prototype selected for commercial manufacturing	9/15/2023	Delayed as the prototypes need further refinement
3.8	Development of manufacturing process	Manufacturing Systems Design	9/20/2023	Delayed as the prototypes need further refinement

Objective 4: To enhance information exchange among value chain actors in Zimbabwe, as well as regionally and with South Asia.

No.	Activity	Outputs/ milestones	Completion date	Comments
4.1	Twice-yearly multi-stakeholder round tables	Twice-yearly multi-stakeholder round tables	Jun-23	Milestone achieved. Three roundtable meetings were held with relevant stakeholders.

No.	Activity	Outputs/ milestones	Completion date	Comments
4.2	Participation of MLAFWRD project member(s) in advocacy meetings and events (e.g., field days)	Short reports	6/30/2023	Milestone achieved. MLAFWRD project team members participated in a number of advocacy meetings and events to promote awareness on appropriate farm mechanisation. Highlights of the Training of Trainers and Awareness creation events presented in Annex 19.
4.3	Repositing of communication products in the Hello Tractor knowledge platform	Drawings, dashboards, reports, etc.	9/20/2023	Would be completed over the next month
4.4	Exposure visit to India for key representatives of the public and private sectors (Zimbabwe and South Africa) *NB This visit was planned for Bangladesh, but due to visa issues, was shifted to Indian upon approval from ACIAR*	Visit report (Annex 15)	16/8/2023	Milestone achieved

7 Key results and discussion

7.1 Objective 1

To delineate product niches, experts met on March 2022 to identify key drivers of mechanisation, and indicators/proxies of these drivers. This was complemented by key-informant interviews with representatives of the private sector, academia, and the government and a SurveyMonkey administered participants of the project twice yearly roundtables. Key outcomes of these activities are presented in detail in Annexes 7 and 8.

The following spatial layers were used to delineate the mechanisation niche: Ruthenberg coefficient (ratio of total cropland in a grid cell relative to the total area of a grid cell), land:labour ratio (ratio between total cropland and rural population in each grid cell), intra-annual rainfall variability (intra-annual rainfall variability between the months of November and April), value of crop production (total economic value of crop production in a given grid cell), distance to market (travel time to human settlements with more than 50,000 people), share of annual crops (area of all annual crops in each grid cell), and cropping intensity (ratio of total crop production and total cropland in a grid cell, used as a proxy for complementary inputs). Within the mechanisation niche, the following layers have been identified to delineate the appropriate-scale mechanisation niche: cattle density (number of cattle in each grid cell), plot size (proxied by land:labour ratio), soil depth (proxied by rooting depth), and slope of the terrain. The spatial distribution of these layers across South Africa and Zimbabwe and is provided in Annexes 2 and 4, respectively. (Note that land:labour ratio can be affected by national parks, which were not masked in these layers).

Four recommendation domains for mechanisation were identified in Zimbabwe and South Africa (Figure 2). Recommendation domains 3 and 4 depict areas where investments in mechanisation should be prioritized across Zimbabwe, referring mostly to the Northeastern and Eastern parts of the country (Figure XX). These recommendation domains are suitable for mechanisation as they exhibit (1) a high Ruthenberg coefficient, access to markets, and value of crop production, (2) a high land:labour ratio, particularly for recommendation domain 3, whereas the land:labour of recommendation 4 was comparable to that of recommendation domain 2, and (3) a low rainfall variability in the months of November-January, particularly for recommendation domain 4 (Figure 3). Recommendation domains 3 and 4 are also the areas where the largest number of tractors and implements for land preparation and transport (planting, spraying and fertilization to a lower extent) were recorded in a national wide survey recently conducted in Zimbabwe (see Annex 9). Spatial predictions of the likelihood of presence/absence of specific mechanisation implements from this national-wide survey further confirm these results (see Annex 9). We conclude that efforts to target mechanisation in Zimbabwe should prioritize recommendation domains 3 and 4, in Northeastern and Eastern Zimbabwe, rather than areas in Southern and Western parts of the country.

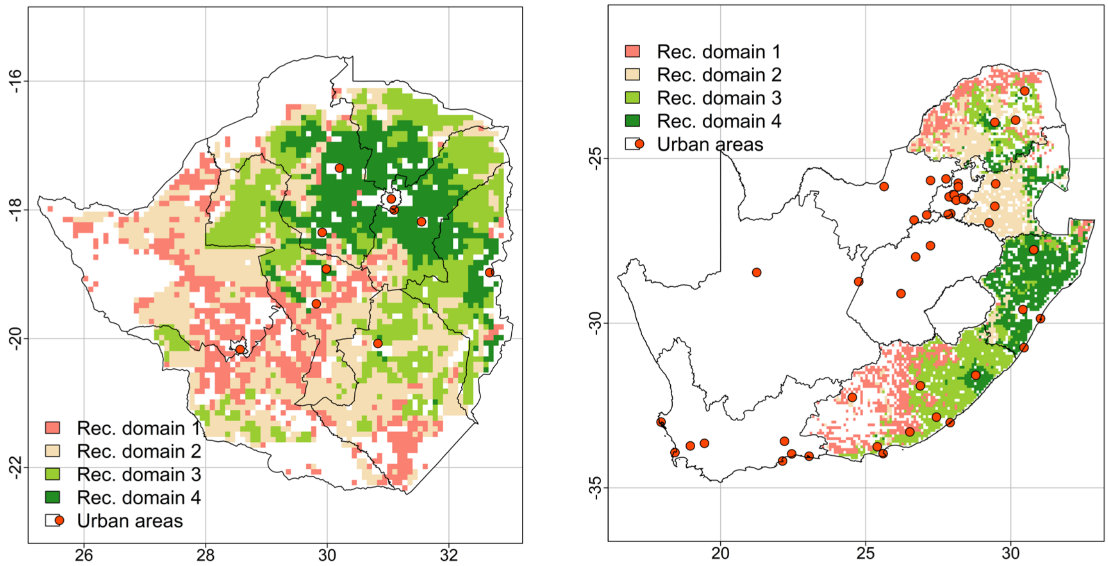

Figure 2 Recommendation domains for spatial targeting of mechanisation activities in Zimbabwe (left) and South Africa (right) identified with principal component analysis and hierarchical clustering. See text for further explanation and Annex 1 for the annotated R workflow used to derive these results

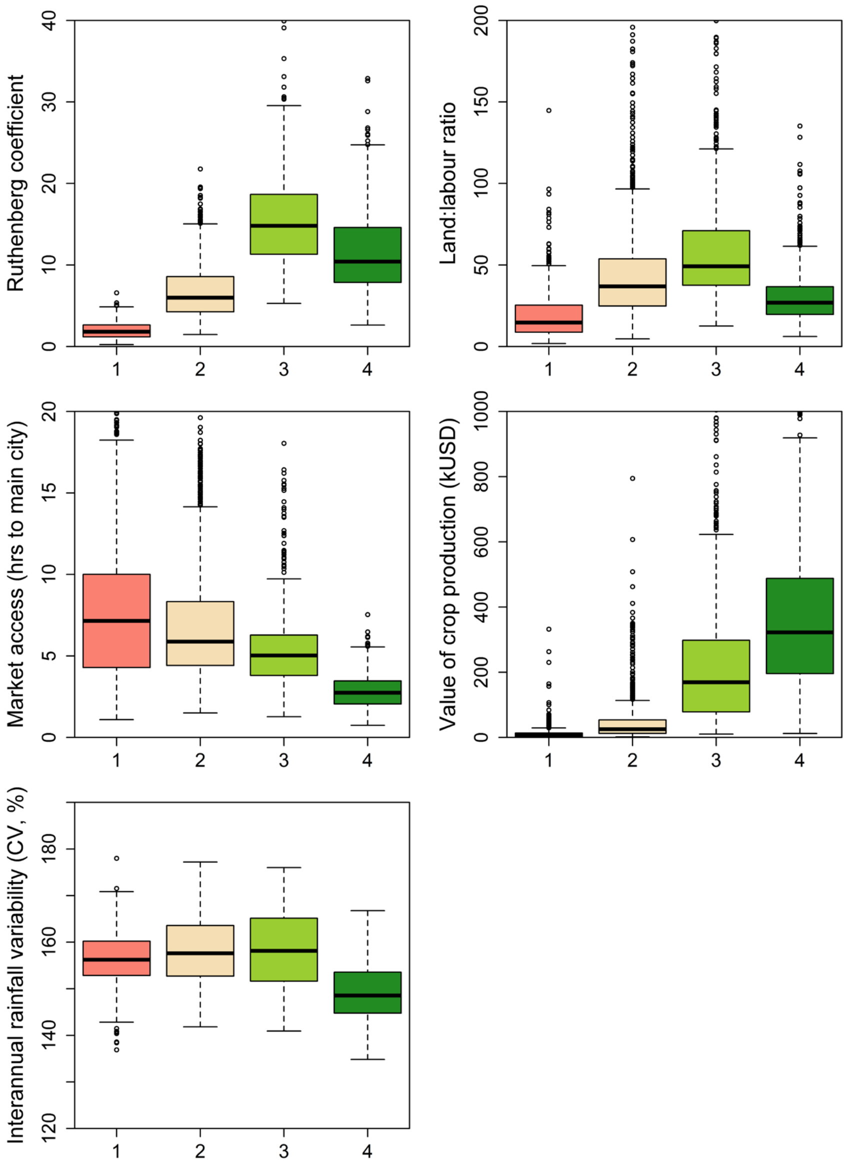

Figure 3 Variability in the input spatial layers across the four recommendation domains identified to target mechanisation in Zimbabwe. Please refer to Figure 2 for the spatial distribution of the four recommendation domains.

In South Africa, it is advisable to target investments in mechanisation in recommendation domain 2, covering Mpumalanga and parts of Limpopo provinces (Figure 2). Indeed, recommendation domain 2 encompasses areas with the greatest Ruthenberg coefficient, land:labour ratio, and value of production together with good market access and low interannual rainfall variability for the months of November-January (see Figure 24 in Annex 2). Recommendation domain 4, covering large tracts of KwaZulu Natal province, could potentially be suitable for mechanisation, as its only difference with recommendation domain 2 is the much low land:labour ratio (see Figure 24 in Annex 2). Yet, such low land:labour ratio indicates that a balance between cropland and rural population and probably low labour constraints in the farming systems of the region. For this reason, we recommend targeting mechanisation in South Africa to recommendation domain 2 (Mpumalanga and parts of Limpopo province). Finally, we were not able to validate the recommendation domains for South Africa with farm survey or company sales data due to lack of suitable datasets in the country to do so. Future research should pay attention to this aspect.

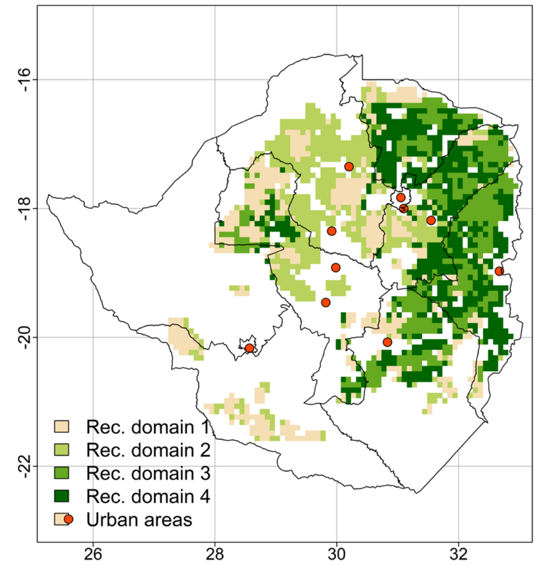

Figure 4 Recommendation domains for spatial targeting of appropriate scale farm mechanisation in Zimbabwe identified with principal component analysis and hierarchical clustering. Note that the appropriate scale mechanisation refers to recommendation domains 3 and 4 identified in mechanisation niche (Figure 2). See text for further explanation and Annex 1 for the annotated R workflow used to derive these results.

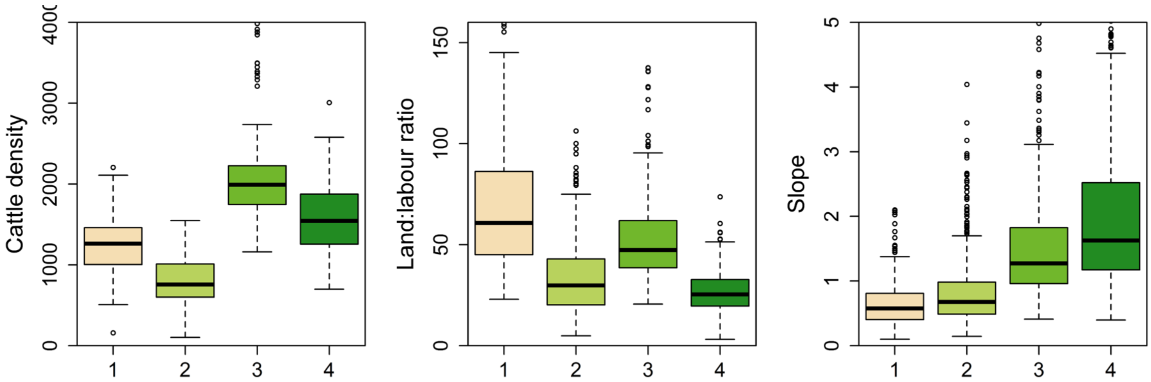

Figure 5 Variability in the input spatial layers across the four recommendation domains identified to target appropriate scale farm mechanisation in Zimbabwe. Please refer to Figure 4 for the spatial distribution of the four recommendation domains.

The appropriate scale mechanisation niche was further delineated from the mechanisation for Zimbabwe. Again, four recommendation domains were obtained to target appropriate scale farm mechanisation (Figure 4). Recommendation domain 2, located across the Central and Northern parts of the country, is the most suitable to target appropriate scale farm mechanisation that is motorized due to low density of cattle and low land:labour ratio (a proxy for small plot sizes; Figure 5). Conversely, recommendation domain 3, located in the Eastern highlands, could also benefit from appropriate scale farm mechanisation powered by draught animals due to high cattle density, relatively high land:labour ratio, and fairly large slopes (Figure 5). Recommendation domains 2 and 3 do not fully coincide with the largest sales of appropriate scale farm mechanisation, by Kurima Machinery, in Zimbabwe (see Figure 1 in Annex 3). This could be explained by several factors including the fact that the sales of Kurima Machinery are project driven, and hence biased by site selection of projects, and in areas adjacent to Harare, where rural-urban linkages are greatest. An analysis of the appropriate scale mechanisation niche was not conducted for South Africa mainly because the appropriate scale mechanisation niche is conditional to the mechanisation niche. Considering that only four provinces were assessed, given the smaller area covered by the mechanisation niche, the appropriate scale mechanisation niche would be much smaller. Moreover, the absence of household level data limited the information required to map the niche.

7.2 Objective 2

7.2.1 Survey of machinery purchasers and users

A telephone survey of 263 customers of the private company Kurima Machinery, from a database of 403 who bought different types of farm machinery between 2019 and 2021, was completed. Ninety-six customers refused to participate in the survey and the remaining 44 customers were unreachable on available contact numbers. The survey results highlight three key messages. First, there is a wide variety of farm machinery and equipment bought by farmers in Zimbabwe including two-and four-wheel tractors, engines and equipment for fertilizing, land preparation, planting, post-harvesting, feed processing, dairy, irrigation, processing, harvesting and transportation. This echoes the current drive for appropriate farm-scale mechanisation beyond land preparation equipment only. Second, 36% of the customers who bought farm equipment relied on salaried employment as the primary occupation and 68% on off farm business as a source of income, highlighting the important role played by emergent farmers as drivers of mechanisation. And lastly, there is a strong business case for mechanisation given that 78% of the customers purchased the farm machinery and equipment as a once off payment and 14% bought on lay-buy or as a loan using their own resources.

A second assessment focused on actors in the mechanization value chain. Different actors in the mechanization value chain are concentrated in different places. Mechanics and service providers have a significant presence in villages and farms, while growth points serve as the business base manufacturers/fabricators. A notable percentage of mechanics and service providers operate from growth points. Local towns within districts are preferred by retailers, while a smaller percentage of manufacturers/fabricators and mechanics choose this option, but most manufacturers/fabricators and retailers opt for towns within provinces as their business base. Most manufacturers/fabricators and service providers interviewed were new in the business at 1-5 years, suggesting a newer establishment for these professionals. Manufacturers/fabricators and retailers show a substantial presence in business for more than 10 years, showing a higher level of experience and longevity in their respective fields. Service providers are very new in the mechanization value chain in most places visited. In terms of capacity, manufacturers/fabricators showed an elevated level of technical skills and did a large proportion of mechanics and retailers. On-the job training opportunities were prevalent among service providers and mechanics, indicating the importance of practical knowledge in these fields. As would be expected, financial skills and business skills were lacking among manufacturers/fabricators and mechanics. These finding are suggestive of a need for capacity development of different actors in the mechanization value chain.

7.2.2 Survey of machinery users

A household survey was conducted in the districts of Chegutu and Zvimba, the two district where Kurima Machinery recorded the highest sales of different machinery between 2019 and 2021 according to the telephone interview data. We selected 10 to 13 villages in each of Chegutu and Zvimba districts based on prevalence and absence of mechanisation for treatment and control groups, respectively. We used ward/village lists obtained from AGRITEX and village heads to randomly sample 488 households from each of the treatment and control villages within wards for a total sample of 976 households.

Results suggest that four-wheel tractors were the most prevalent, used by 56% of the surveyed households. Other land preparation equipment and machines such as 2WTs and

4WTs, ploughs, disk ridgers, disk harrows, rippers, rotavators were used by 46% of the sample. Stationary engines used for irrigation such as diesel and petrol engines and electric motors were used by 23% of the sample while post-harvesting equipment such as maize and peanut shellers and threshers are only used by 15% of the sample (Figure 6). Processing and planting equipment are used by about 4% of the sample each, while diary equipment was used by less than 1% of the sample. The distribution of equipment was found to be similar between districts (Figure 6, right panel).

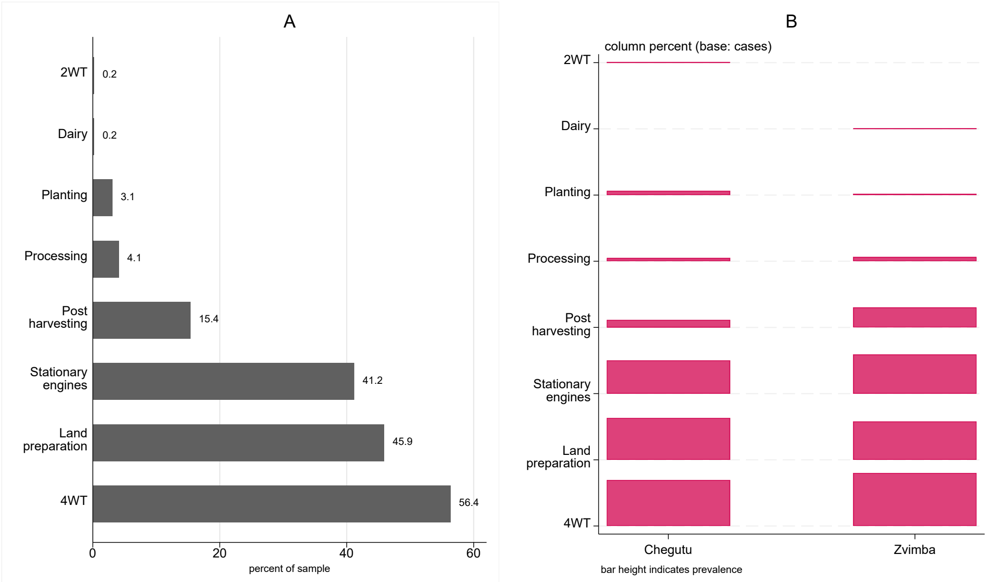

Figure 6 Types of machinery used overall (left panel) and by district (right panel)

The distribution of the equipment types used shows that farmers invest in both ‘power-intensive operations’, such as land preparation, and ‘control-intensive’ operations’, such as planting and weeding. While the control intensive operations are limited to the use of knapsack sprayers for most farmers, there is a wide range of equipment for power control activities. Given that weeding remains among the main challenges for smallholder farming in Zimbabwe (Ngoma et al., 2023), this finding implies a need to make available mechanical and weed control methods.

In terms of machinery ownership modes, individual machinery ownership was the most prevalent. About 55 and 59% of respondents in Chegutu and Zvimba districts owned the machines used (Figure 7). These pieces of equipment were purchased by individuals for cash. This underscores the role played by emergent farmers who tend to have the financial ability to purchase machinery and to provide employment opportunities for operators. The second most popular mode to access machines is through renting/hiring, mentioned by at least 36% of the sample. Renting machines in this case refers to a scenario where a farmer can hire machinery for farm operations from other farmers and/or service providers. Other access modes such as group ownership, loan purchases, gifts, and NGO supported are less prevalent and mentioned by less than 4% of the sample.

In terms of drivers of adoption and access to machinery, there are several key points. The districts are endowed with large populations of farmers who are in need of farm mechanization and providing a business case for the investors. Government and NGO activities in support of farm mechanization are limited in both presence and capacity. In terms of access, individual ownership and use of agricultural machinery and equipment are dominant. However, access to credit is a major constraint to farm mechanization. Small-scale farmers and women and youth are marginalised in terms of both access and use of farm machinery equipment by farmers in the medium-scale areas (A1) who have both financial and land resources (>3ha). Most of the benefits of farm mechanisation are skewed in favour of male-headed households in both small-scale and medium-scale farms, with the former only being able to access very limited ranges of equipment and capacity utilisation. Like many other farmers in the study sites, they lack collateral demanded by banks and private financial agencies to fund farm mechanization and other operations. In addition, access to machinery is hindered by the cost of hiring. While Internal Savings and Lending (ISAL) groups hold promise, they are under-capitalised. Other challenges associated with poor farm mechanization are beyond farmers' control. These include hyperinflation, dual and misaligned pricing of inputs and commodities, bureaucracy, and high cost of inputs, as well as unavailability of technologies for both production and post-harvest loss control. Finally, culture is a major factor limiting access to farm mechanisation for women and youth.

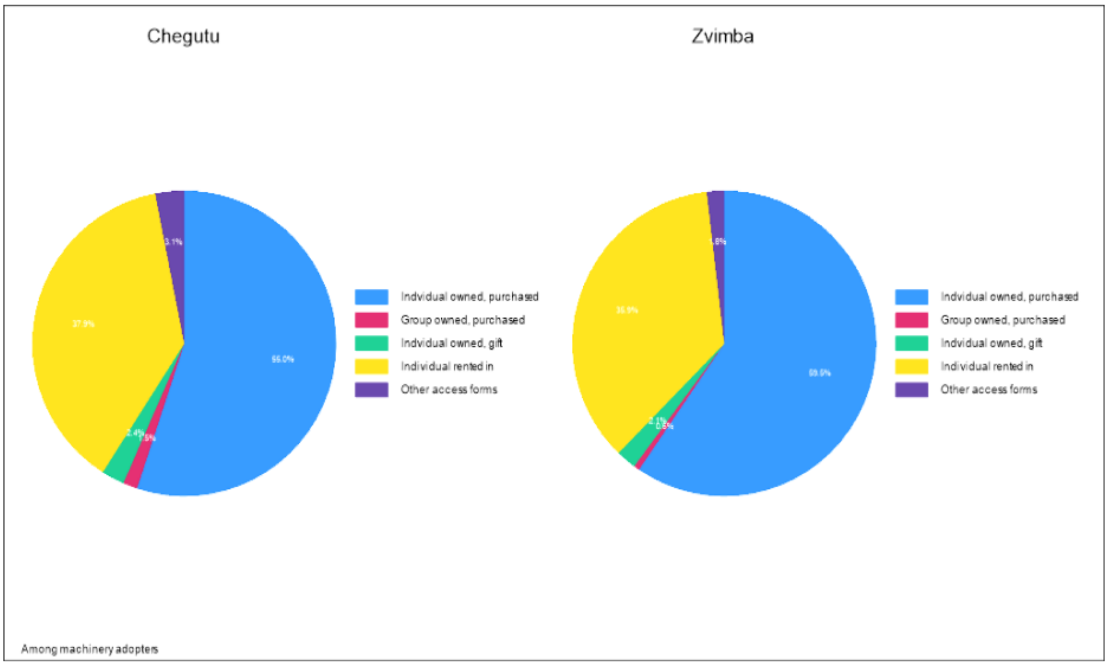

Figure 7 Machinery access and ownership modes by district

After controlling for several variables in a multi regression framework, results suggest that adopting different pieces of machinery is associated with an increase in farm and household incomes by some 78 to 104%, and in crop income and crop production by 67 to 113%. Except for crop income, the distributional effects are larger in the 50^{th} and 75^{th} percentiles for farm and household income. These findings imply a need to better target mechanisation options. There are several other important drivers of livelihoods (farm and household incomes). Positive drivers include wealth (proxied by farm size, number of livestock), being a male-headed household, using hybrid seeds and engaging in some form of forward marketing arrangements such as contract farming. Social capital as measured by membership to a farmer organization is associated with higher household income in the 75^{th} percentile of the income distribution.

When narrowed down to service providers, tillage and threshing are more dominant, pointing to high demand and the existence of a market for these services. Most service providers are large farmers based on their own farms, in big towns and at growth points. This makes service provision not easily accessible to farmers at the last mile. This also leads to increasing cost in terms of travel to their service points for farmers. This is termed dead mileage. This points to the need to decentralise service provision to save cost and time. The majority of service providers are self-funded (95%), with very few reporting funding from the government (5%). Majority of service providers are not registered which makes access to formal loans very difficult. Ownership of 4WTs and shellers is dominant, 52.4 % and 42.9%, respectively. This is followed by ownership of 4WTs drawn rippers and planters (23.8%). Other equipment owned by Service Providers include peanut butter making machines and water pumps and less owned at 4.8% are 4WT drawn boom sprayers, silage cutters and mixers, threshers (only in Chegutu District), oil pressers and incubators. This again points to service providers being concentrated in power machinery. Land preparation, planting and transportation are the major services, followed by weed and pest control and agro processing. Their services are also less accessible to majority of youth and women, with 9.1% of women and 18.2% youths, reporting using for 4WTs for 50 to 75% of their farm operations, respectively. Prioritised services most demanded by women include ploughing (78%), threshing, transportation, harvesting, planting, and water pumps. This points to the need to invest and support for 2WTs that are cheaper and affordable to low resources farmers. Analysed data also shows that most of the service providers currently provide most of their services to emergent farmers who are relatively more resourced. This result indicates the challenge of providing access to power for the least endowed farmers. Smaller service providers, operating less expensive 2WT, located closer to their customers could be a response but their sustainability (based on profitability) would deserve further investigations.

7.3 Objective 3

7.3.1 Need assessment and conception of basin digger and bed planter prototypes

The questionnaire-based need assessment of the basin digger and bed planter (ridge planter) revealed the following requirements.

Basin digger

- The digger should be powered by a two-wheeled tractor, operated by single person, and have a seat for the operator for riding
- It should be able to work in dry to ideal soil conditions during the months of June to November
- It should complete digging a *Pfumvudza* plot (624 sq m) in 3 hours
- Majority of the respondents liked U-shaped basins followed by -shaped (trapezoidal-shaped) which is the result of using hand hoes.
- The digger should be equally suitable for operation by women and men
- Age of the operator was suggested to be min 7 years (!) and maximum 77 years (average 30 years)
- A small number of people expected that the digger should be light weight for hand carrying, while majority would accept it if carried on a trailer
- The design of the digger should be simple enough for the local artisans to repair locally
- The digger should have the ability to dig basins in the same place each year
- Respondents differed greatly (US$ 15–US$ 1000) over the expected price of the digger (average US$ 306)
- From the local manufacturing perspective, a market of 40,000 diggers/year would make business sense

Bed Planter

- The bed planter should be powered by a two-wheeled tractor, operated by single person, and have a seat for the operator for riding
- Rotary tilling mode of bed making was suggested by majority of the participants
- The beds should be permanent (beds made once and then maintained over years)
- The bed planter should be able to work in dry to ideal soil conditions during the months of October to December (when rain starts)
- The desired capacity of the bed planter should be about 3.6 h/ha (vs. manual bed planting takes 38.5 person-h ha^{-1})
- Farmers are willing to pay US$ 89±76/ha for hiring bed planting services
- Majority of the respondents liked Trapezoidal-shaped beds
- The bed planter should be simple enough for the local artisans to repair locally
- Respondents differed greatly (US$ 20–US$1500) over the expected price of the bed planter (average US$ 521)
- From the local manufacturing perspective, a market of 500 bed planters/year would make business sense

Both the basin digger and the bed planter should be powered by a two-wheeled tractor, operated by single person, and must have a seat. The desired capacity of the basin digger should be 3–4 *Pfumvudza* plots per day (1465 planting basins in 2–3 hours), and its price should not exceed US$ 1000. The capacity of the bed planter should be about 0.3 ha h^{-1} and its price should not exceed US$ 1500.

Basin digger – soil constraints: It is a recommended and common practice in Zimbabwe to dig the basins before the rainy season (ie. in **dry soil condition,** June-November) so that they are ready to accumulate rainwater once the rain starts (one major benefit of basins). Also, the farmers need to show the basin dug plots ahead of the season to extension officers to qualify for free govt input.

Bed planter – soil constraints: Bed planter needs intensive tillage - at least for the first season - which needs **wet soil condition** (October – December); it cannot be done in dry soil condition due to: 1) high power requirement, and 2) there needs some soil moisture (improves soil cohesion/binding) for formation of the beds.

7.3.2 Basin Digger Prototype 1

Based on the above criteria, a double row prototype basin digger was designed and fabricated at the Zimplow/Mealie Brand's workshop in Bulawayo, Zimbabwe. Pre-test results suggested that the rotary blades (forward rotation, vertical) used on the digger to dig the planting basins were vibrating too much due to soil resistance. To solve the vibration problem, a vertical auger type double row basin digger was designed and developed. This second prototype is awaiting pre-test. The bed planter prototype is still in the testing phase. Appendix 12 presents the test protocols adopted for both the basin digger and bed planter.

Table 1 Functional component of the Basin Digger Prototype 1

Part No.	Function
1	Hold system components and parts. Offers rigidity and imparts system weight vertically onto blade for penetration
2	Transmits rotational motion of PTO spur gears to tool shaft through belts
3	Power transmission-engine rpm
4	Power transmission-engine rpm
5	Power transmission- engine rpm
6	Power transmission-engine rpm
7	Impart reciprocating motion, regulates inter-row spacing
8	Digs soil out of basin station
9	Power transmission
10	Stabilises reciprocating assembly within frame
11	Power transmission-reciprocating motion
12	Reduces vertical impulse of blades at the downward phase of reciprocating amplitude at soil-tool interface to protect tool.
13	Shock absorber, reduce impulse, tool protection
14	Arm-cam connection
15	Component Of the Shelf –power transmission
16	System stability

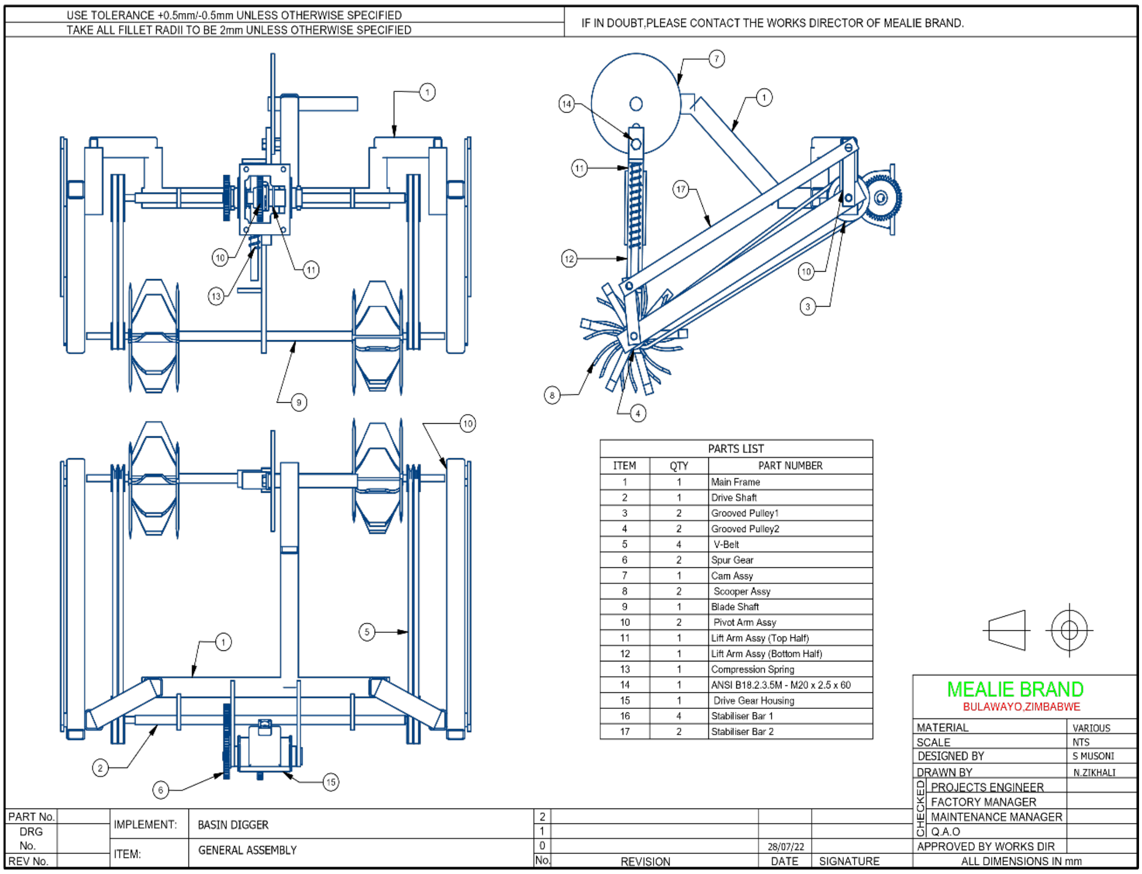

Figure 8 CAD model of Basin Digger Prototype 1 (two-wheel tractor operated)

Figure 9 Fabrication of the Basin Digger Prototype 1 (two-wheel tractor operated) at the Zimplow factory in Bulawayo

<u>Functionality Tests</u>

The functional components of the digger were all performing but its rotary blades got stuck in the ground upon engaging soil and continued motion when pulled out of the ground leading shallow scratching of soil rather than digging the desired basin. The configuration of the blades used required high power shearing of soil and residues with root structure which was not achieved with Basin Digger Prototype 1. No further tests were carried out as the system performed poorly. Hence the second model with an augering system was developed adopting from the hand auger.

7.3.3 Basin Digger Prototype 2

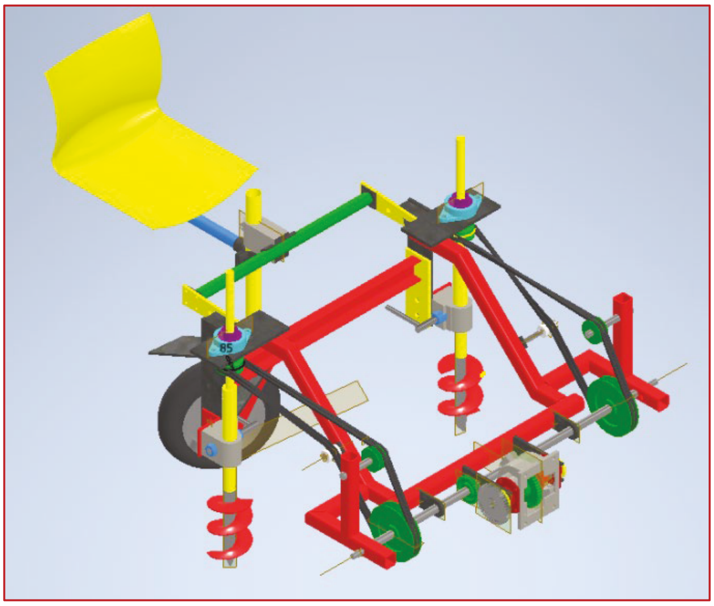

Figure 10 CAD Model of the Basin Digger Prototype 2

Figure 11 Field testing of the Basin Digger Prototype 2

The prototype has been undergoing field test and refinement. The early results show that the augers of the could dig two basins at the same time but digging basins on the go still not fully achieved.

7.3.4 Bed planter Prototype

Figures 12 and 13 show the CAD model of the bed planter and the fabricated prototype, respectively. It is as per design of the BARI Bed planter https://camachinery.org/archives/projects/bari-bed-planter. The bed planter was tested at the Institute of Agricultural Engineering (IAE), Harare (Fig. 13b)

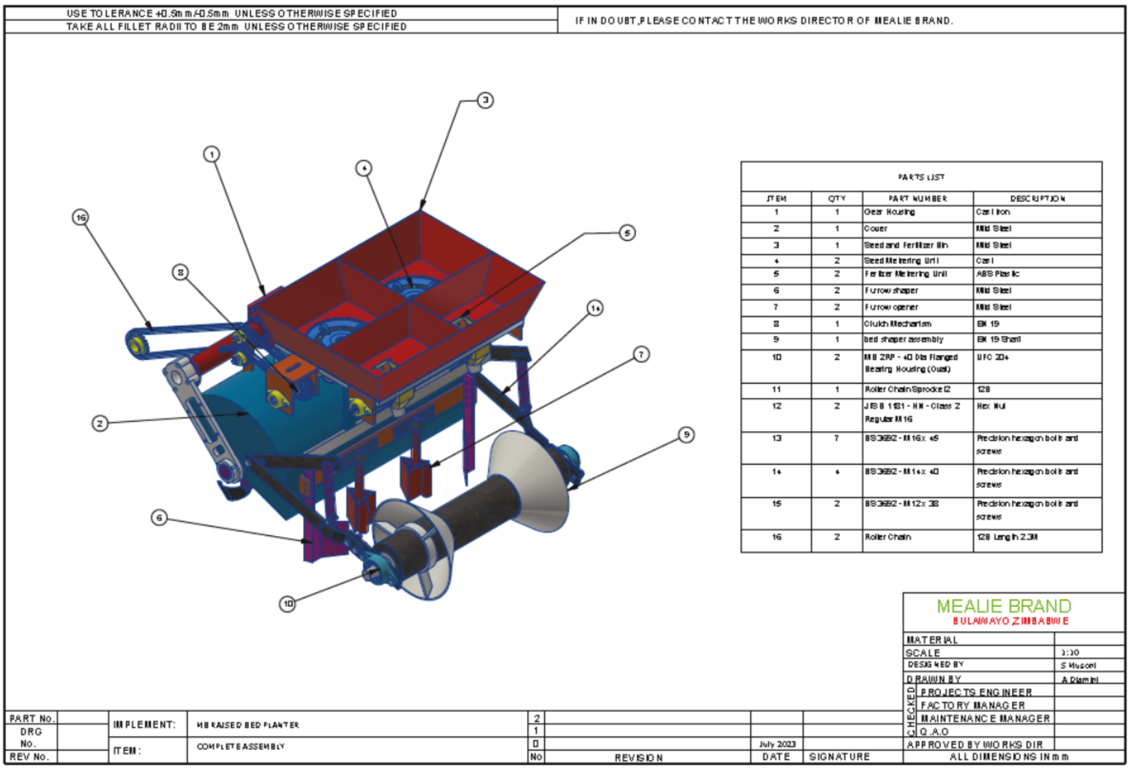

Figure 12 CAD model of the Bed Planter

Figure 13 Prototype Bed planter fabricated at the Zimplow workshop in Bulawayo and tested at the Institute of Agricultural Engineering (IAE), Harare

7.4 Objective 4

7.4.1 Twice-yearly multi-stakeholder round tables

All three stakeholder roundtable meetings were held in Harare (16 March 2022, 29 September 2022, and 31 March 2023) as most of the stakeholders are based in Harare.

Meetings were attended by participants from relevant departments in the Ministry of Lands, Agriculture, Fisheries, Water and Rural Development (MLAFWRD) and other Ministries, CIMMYT, private sector representatives, NGOs, mechanisation service providers and media. The meetings identified and agreed on action points based on SWOT analysis covering the following key areas aimed at accelerating smallholder farm mechanisation initiatives:

- promotion or demand creation
- capacity development
- coordination amongst stakeholders
- information and communication
- research and development and
- finance

7.4.2 Participation of MLAFWRD project member(s) in advocacy meetings and events (e.g., field days)

The MLAFWRD through the Institute of Agricultural Engineering (IAE) collaborated with extension services, smallholder farm mechanisation equipment dealers and other district stakeholders to represent HAFIZ during field days, equipment demonstrations, farmer trainings, as well as at equipment commissioning/handover ceremonies in rural districts around the country. At least 2,300 people attended these outreach events where farmers obtained awareness and information on various smallholder farm mechanisation technologies.

In addition, the MLAFWRD represented HAFIZ during advocacy meetings (FAO Hand-in-Hand Initiative meetings, meetings with local farm machinery dealers, and workshops where paper presentations were made on appropriate farm mechanisation) attended by at least 525 participants. The MLAFWRD also participated in Webinar meetings on Framework for Sustainable Agricultural Mechanisation in Africa (F-SAMA) reflecting on the on-going efforts to increase availability and access to farm power. The MLAFWRD is working closely with private sector and developed the Agricultural Mechanisation Development Alliance that aims to promote national farm mechanisation.

Farm mechanisation learning visits to IAE by farmer groups, technology displays at the Zimbabwe International Trade Fair, Zimbabwe Agricultural Shows, provincial agricultural shows, engagement of Standards Association of Zimbabwe in developing standards for 2-wheel tractors, shellers and other smallholder farm mechanisation equipment, information and communication (through press, TV and radio programmes, posters and brochures) were other advocacy activities undertaken by the MLAFWRD to create awareness and demand for smallholder farm mechanisation technologies.

7.4.3 Repositing of communication products (dashboards, reports, etc) in the Hello Tractor knowledge platform

This will be done before closure of the project.

7.4.4 Exposure visit to Bangladesh for key representatives of the public and private sectors (Zimbabwe and South Africa)

This mechanisation exposure visit was done during 8–16 August in India and consisted of the following five participants from Zimbabwe and South Africa. Although, it was planned for Bangladesh where two-wheeled tractors and small engine/motor driven machinery have revolutionised the agriculture, it was not possible at the end as most of the participants did not get any feedback on their Bangladesh visa applications even after 11 months. The exposure visit to India covered visiting mechanisation hiring centre/co-operative, mechanisation projects/trials of BISA (Borlaug Institute for South Asia), and visiting three manufacturers in Punjab followed by visiting the mechanisation research, development and testing activities and facilities at the Chaudhary Charan Singh Haryana Agricultural University, Hisar in the Haryana province. A detailed visit report (draft) is and attached with this report (Annex 15).

- Chief Director, Department of Agricultural Engineering, Mechanisation, and Soil Conservation; Ministry of Lands, Agriculture, Fisheries, Water, and Rural Development; Government of Zimbabwe; 1 Borrowdale Road, Harare, Zimbabwe.
- Head, Institute of Agricultural Engineering, Ministry of Lands, Agriculture, Fisheries, Water, and Rural Development; Government of Zimbabwe; 1 Borrowdale Road, Harare, Zimbabwe
- Mechanisation Specialist, Institute of Agricultural Engineering, 141 Cresswell Road, Weavind Park, Pretoria, South Africa.
- HAFIZ Postdoctoral Fellow, University of KwaZulu-Natal, Centre for Transformative Agriculture and Food Systems, Private Bag X01, Scottsville, 3209, South Africa
- Mechanisation Specialist, South Africa Regional Office, International Maize and Wheat Improvement Center (CIMMYT), Mt. Pleasant, Harare, Zimbabwe

8 Impacts

8.1 Scientific impacts – now and in 5 years

HAFIZ advanced knowledge on the drivers (biophysical and socio-economic) for widespread adoption of farm mechanisation and appropriate-scale farm mechanisation in Zimbabwe and South Africa. The project pioneered the application of an 'agronomy-to-scale' (through spatially explicit analyses which integrate biophysical and socio-economic information and analysis of survey and sales data) approach to mechanisation. The workflows developed and validated during the project are generic fully reproducible and can be applied to other countries at minimal cost in the future. The project also contributed to a better understanding of the interactions among implements, cropping systems, biophysical and socio-economic conditions. Finally, the project provided insight regarding the factors necessary to the creation of a business-friendly environment for the delivery of appropriate-scale farm mechanisation to smallholders in Zimbabwe (and South Africa).

Several peer-reviewed publications have been planned from the analyses conducted in this project. Manufacturing guidelines for the three types of equipment developed by HAFIZ were also published. All documents are openly accessible on the knowledge platform of the project.

Under objective 2, the project contributed to a better understanding of the types of machinery demanded by farmers, the types of farmers who buy machinery and the impacts of adopting machinery on livelihoods. The application of Quintile Treatment Effects Approach (QTE) to understand the distributional impacts of farm equipment adoption advances our understanding of the distribution effects beyond the mean. In addition, the project contributed to the understanding of the types of machinery demanded by different types of customers. By identifying the types of machinery and equipment bought by which types of farmers, the studies can help to better target future investments in mechanisation.

Once fine-tuned further, the developed prototype basin diggers and the bed planter would help in testing and adoption of climate smart crop production practices of *Pfumvudza* and permanent bed planting. They will reduce human drudgery, save time and labour and thus the cost of operations. Further fine tuning and participatory field evaluation should include:

Basin digger:

i) The current design aiming basin digging on the go (bionic knees) is not functioning properly, which needs to be addressed.
ii) A simpler design of the basin digger (stopping, digging 4–8 basins/stop using 4–8 augers, lifting, and then moving forward to the next stop) can also be considered that may potentially reduce complexity and cost;
iii) The current power transmission system (2WT to augers of the basin digger) is too complex; needs simplification to improve transmission efficiency
iv) The current augers of the 2WT basin digger could be replaced with the commercially available spiral augers of handheld basin diggers.
v) A step-by-step approach of testing the commercially available low-cost handheld basin digger followed by attaching a couple or more of those handheld basin diggers to the 2WT could also be considered.

Bed planter:

i) To improve the bed shape and its rigidity, the support wheels should d be replaced with a bed shaper following the original BARI BP design
ii) The seeding mechanism should be modified/adjusted so that it can plant a single row of maize or sorghum (instead of two), but two rows of soybean, cow pea and other beans on top of the bed.

8.2 Capacity impacts – now and in 5 years

A postdoc from UKZN (Dr Wadzanai Mafunga) was trained on spatial analysis using R. A staff member from Kurima Machinery and Technology (Kudzaishe Makahamadze) was trained on survey methodology and data analysis. Two MSc students from the Department of Community and Social Development of the University of Zimbabwe (Kudzai Mhishi and Felistas Kavayi) conducted their attachment under Objective 2 of the project and produced their MSc theses with support from the project.

Knowledge and information have been passed on to AGRITEX and Mechanisation technical staff at national and provincial levels through meetings described in Annex 2.

The project supported the development and documentation of R workflows that will be used for future trainings on spatial targeting of technologies in sub-Saharan Africa. This is envisioned through partnership with the OneCGIAR initiative on Excellence in Agronomy.

The Department of Agricultural Engineering and Soil Conservation through the IAE, has initiated collaboration with local industry to conduct reverse engineering on local production of component parts of two-wheel tractors, direct seeders, and multi-crop thresher. Reverse engineering work is being carried out by three local private companies (e.g. Zimplow, ProChoice) and two tertiary institutions. The IAE would support and provide necessary training for local manufacturing of the basin digger and bed planter prototypes being developed. All these efforts would help expand local farm machinery manufacturing industry and wider adoption of mechanisation in near future. The prototypes developed could also be tested, fine-tuned and fabricated in South Africa so that the smallholder farmers there would also get befitted.

8.3 Community impacts – now and in 5 years

Such a short and small project is not expected to have discernible impact now. The project has shown that the theory of change remains valid: targeting better future mechanisation effort will maximise the return on this investment and provide the impacts.

8.3.1 Economic impacts

The involvement of MLAFWRD will influence and improve enabling environment for private sector companies involved in appropriate scale farm mechanisation. In line with developing agricultural mechanisation to reach rural households coupled with the need to increase agricultural productivity Government is expected to increased budget spending in appropriate-scale farm mechanisation.

Anticipated increased demand for appropriate farm mechanisation equipment will stimulate commercial production of equipment to mechanise *Pfumvudza* and make farming more profitable.

Through customer profiling, there will be better targeting by private sector when marketing appropriate-scale farm machinery. Thus, their returns on investment would be higher and encourage them to expand their businesses.

8.3.2 Social impacts

Availability through manufacture of appropriate farm mechanisation technologies by private sector will facilitate women and youths to access, own and use technologies. With more information on appropriate farm mechanisation technologies through extension and training services offered, it is expected that there will be demand for technologies. Adoption of these technologies will reduce labour demand, help reduce child labour in farming, and improve farm productivity and livelihoods of targeted farmers.

8.3.3 Environmental impacts

Mechanised *Pfumvudza* is a climate smart practice and has positive impact on the environment due to low soil disturbance, precise use of seed, fertilizer and water, and residue retentions. As more farmers become aware of Mechanised *Pfumvudza* traditional practices will gradually be phased out, paving way for more sustainable practices.

8.4 Communication and dissemination activities

The Table 2 below shows communication and dissemination activities and the respective value chain actors (Please refer to Annexes 16–19). The activities will enhance information exchange among value chain actors in Zimbabwe as well as regionally and globally.

Table 2 Communication and dissemination activities and the respective value chain actors

Communication and dissemination area	Activities	Responsible person
Promotion or demand creation	Organise and attend equipment demonstrations, expos, field days and Agri-shows	IAE Training Branch Agritex Training Branch Dealers and Manufactures of farm equipment Development agencies (CIMMYT, FAO, CTDO)
Capacity development	TOT courses on Farm Mechanisation (operation, repair and maintenance) for Mechanisation, Agritex extension staff and development agencies	MLAFWRD-Department of Agricultural Engineering, Mechanisation and Soil Conservation Training Branch Agritex Provincial officers Development agencies
Coordination amongst stakeholders	Organise meetings and technology demonstrations for stakeholders	MLAFWRD- Department of Agricultural Engineering, Mechanisation and Soil Conservation Private sector equipment dealers and manufacturers
Information and communication	Press articles	MLAFWRD- Department of Agricultural Engineering, Mechanisation and Soil Conservation Electronic and Print Media (Radio, Press, and TV)
	TV and radio programmes	
	Information brochures and posters	
	Radio and TV Jingles with relevant technology promotional messages	
	Various news clips, radio and TV presentations	
	Articles to be published regularly in farmer magazines	
Research and development	Publish research results for developed or tested equipment Develop and publish extension messages from research results	Research institutions Manufacturers Artisans

A popular article has been drafted (Annex 20) that will be published online. The most impactful communication products from the project would be reposited on the knowledge platform hosted by Hello Tractor (http://knowledgeplatform.hellotractor.com/) before the end of the project.

9 Conclusions and recommendations

9.1 Conclusions

Objective 1 focused on guiding public and private investments in appropriate-scale farm mechanisation through spatial targeting in Zimbabwe and South Africa. This entailed the delineation of product niches for different pieces of equipment through stakeholder consultations, collation and development of spatial layers from secondary and widely available data sources, ex-ante spatial targeting for appropriate-scale farm mechanisation through a combination of principal component analysis and hierarchical clustering and, finally, the evaluation of the spatial targeting with sales and farm survey data. Seven spatial layers were collated to delineate the mechanisation niche (Ruthenberg coefficient, land:labour ratio, rainfall variability around planting time of annual crops, value of crop production, market access, area of annual crops, and level of crop intensification) and three spatial layers were used to further delineate the appropriate-scale mechanisation niche from the mechanisation niche (cattle density, slope, and land:labour ratio as a proxy for plot size). Our results for Zimbabwe indicate that mechanisation is best targeted in the country to the Northeastern and Eastern regions of the country, not to the Southern and Western regions of the country, as the former regions had the greatest Ruthenberg coefficient, land:labour ratio, and value of crop production as well as the greatest likelihood of presence of motorized implements as captured through a recent nationwide farm survey. Within the areas suitable for targeting mechanisation in Zimbabwe, and in the context of appropriate-scale farm mechanisation, regions in Central and Northern parts of the country are likely most suitable for motorized equipment whereas regions in Eastern highlands are likely most suitable for animal drawn equipment. For South Africa, our results indicate that investments in mechanisation should be prioritized to Mpumalanga and parts of Limpopo provinces, over Eastern Cape and KwaZulu Natal, due to higher Ruthenberg coefficient, land:labour ratio, and value of production in the former. We conclude that spatial targeting at regional to national levels, in tandem with stakeholder consultations, can increase returns on investment to appropriate-scale farm mechanisation and should be undertaken prior to project implementation. Finally, the workflows powering the data-driven approach used in Objective 1 are reproducible and easy to transfer to new geographies in a cost effective way.

From Objective 2, results indicate that machinery customers and farmers need a wide variety of farm machinery and equipment. These include two-and four-wheel tractors, fertilizing, land preparation, planting, post-harvesting, feed processing, dairy, irrigation, engines, processing, harvesting and transportation equipment. Of these, the top three include four-wheel tractors and associated attachments for land preparation and stationery engines. Most customers who bought farm equipment are salaried employees, and a good proportion (68%) earned income from off-farm business. About 78% of the customers purchased the farm machinery and equipment as a once-off payment and 14% bought on lay-buy or as a loan using their own resources. This suggests a good business case for mechanisation. The distribution of the equipment types used shows that farmers invest in both ‘power-intensive operations’, such as land preparation, and ‘control-intensive’ operations’, such as planting and weeding. Major drivers of adoption of farm mechanisation include male headship of households, literacy (at least secondary education), large farm size (>4 ha), livestock (>30 cattle) and wealth. Adoption of different pieces of machinery is associated with an increase in farm and household incomes of 78 to 104%. The impacts are larger in the 50th and 75th percentiles for farm and household income distributions. Results from objective 2 also show that service providers or business operators engage in various activities which further limits specialisation. For example, individual mechanics service diverse equipment ranging from 4WTs and accessories to silage cutters, shellers and peanut butter machines. Targeting farmers who can pay for the services will encourage private sector players to support sustainable smallholder mechanisation while, models such as group hire, and purchases can be pursued for more inclusive mechanisation and led by government and civil society. Because wealth is a strong driver of access to mechanization, there is a need to design socially inclusive mechanisation programs that cater for less resourced farmers, especially women, youth, and other vulnerable groups.

Under Objective 3, the developed basin digger and bed planter prototypes needs further improvement (simplification or replacement of the bionic knee and power transmission system) and fine tuning after field evaluation). Addressing them will require additional work and investment. The prototype basin diggers and the bed planter developed are suitable to be operated using a two-wheel tractor which has been becoming more and more popular in Africa. It is also expected that, **once the suggested improvement is complete**, the machines would encourage adoption of the climate smart crop production practices of *Pfumvudza* and permanent bed crop production. However, the prototypes need wide testing and refinement together with the farmers and industry partners before scaling out through government and other actors.

The project created a platform for bringing together value chain actors through various advocacy events and roundtable meetings to promote appropriate-scale farm mechanisation initiatives in Zimbabwe and in the region.

Different value chain actors were able to exchange information to guide public and private investments in appropriate mechanisation through spatial targeting, projection of aggregate benefits as well as to support machinery dealers and manufacturers with better understanding and targeting of customers.

Information developed will influence value chain actors in ensuring the acceleration of smallholder farm mechanisation initiatives for farmers to access appropriate farm machinery and equipment for mechanised *Pfumvudza*.

9.2 Recommendations

Based on the findings under this project, the projects recommend the following:

The project tends to recommend the follow based on the learnings.

- Spatial targeting of appropriate-scale farm mechanisation is possible in Zimbabwe and South Africa. We recommend stakeholders in Zimbabwe and South Africa to adopt the recommendation domains identified, and validated by stakeholders, in this project when devising future programs scaling farm mechanisation in sub-Saharan Africa. It is logical to assume that targeting would increase return on investment, but this remains an assumption at this stage.
- The data-driven approach and workflows developed in this project are reproducible and can be re-applied to other countries in a cost effective way. It is therefore recommended to expand the methodological approach to other countries to identify recommendation domains for targeting farm mechanisation prior to project implementation.
- Future research is recommended to evaluate and validate the identified recommendation domains with empirical data from farm surveys covering wide geographic areas. Such data are not readily available in most countries hence, data collection campaigns will need to be designed. Such quantitative assessments must be combined with stakeholder engagement in the targeted geographies.
- Aggregated benefits associated with different strategies of targeting investments in farm mechanisation (e.g., blanket vs. targeted approach) need to be revisited with

better quality data on impacts of adopting mechanisation on farm production and income, and rural employment, among others.

- There is a need to design socially inclusive mechanisation programs that cater for less resourced farmers, often intersecting with women, youth, and other vulnerable groups.
- There is need to provide information ex-ante on the most appropriate, cost-effective, and profitable machinery combinations to invest in.
- There is a need to rethink and broaden the scope of appropriate-scale farm mechanisation to include power and control intensive demand driven and market led mechanisation equipment to increase their relevance to farmers' needs and sustainability.
- Stakeholders such as civil society and academic institutions should step up and support more socially inclusive business and finance models for mechanisation such as group ownership.
- Further testing of the developed machinery and documentation is suggested so that the results can be disseminated widely and the protypes can be scaled through government and other channels who has been promoting climate smart agriculture.
- Further work in research, testing and development of equipment to mechanise *Pfumvudza* is necessary to avail more options for appropriate-scale farm mechanisation.
- The MLAEWRD should strengthen the capacity of the Institute of Agricultural Engineering and provide necessary resources for advocacy events, coordination of value chain actors as well as for capacity building of extension staff.

10 References

10.1 References cited in report

Andersson Djurfeldt, A., Djurfeldt, G., & Bergman Lodin, J. (2013). Geography of gender gaps: regional patterns of income and farm–nonfarm interaction among male- and female-headed households in eight African countries. *World Development*, *48*, 32–47. https://doi.org/10.1016/j.world dev.2013.03.011

Araya, T., Gebremedhin, A., Baudron, F., Hailemariam, M., Birhane, E., Nyssen, J., Govaerts, B., & Cornelis, W. (2020). Influence of 9 years of permanent raised beds and contour furrowing on soil health in conservation agriculture based systems in Tigray region, Ethiopia. Land Degradation and Development, October, 1–15. https://onlinelibrary.wiley.com/doi/10.1002/ldr.3816.

Awoke, B. G., Baudron, F., Antille, D. L., Kebede, L., Anawte, D. A., Tikuneh, D. B., & Aikins, K. A. (2020). Evaluation of two-wheel tractor attached seeders used in conservation agriculture systems of Ethiopia. ASABE 2020 Annual International Meeting. https://elibrary.asabe.org/abstract.asp?aid=51391

Baudron, F., Misiko, M., Getnet, B., Nazare, R., Sariah, J., & Kaumbutho, P. (2019). A farm-level assessment of labour and mechanisation in Eastern and Southern Africa. Agronomy for Sustainable Development, 5. https://link.springer.com/article/10.1007/s13593-019-0563-5.

Baudron, F., Nazare, R., & Matangi, D. (2019). The role of mechanisation in transformation of smallholder agriculture in Southern Africa Experience from Zimbabwe. In R. A. Sikora, E. R. Terry, P. L. G. Vlek, & J. Chitja (Eds.), Transforming Agriculture in Southern Africa (1st edition, pp. 152–160). Routledge.

Baudron, F., Sims, B., Justice, S., Kahan, D. G., Rose, R., Mkomwa, S., Kaumbutho, P., Sariah, J., Nazare, R., Moges, G., & Gérard, B. (2015). Re-examining appropriate mechanisation in Eastern and Southern Africa: Two-wheel tractors, conservation agriculture, and private sector involvement. Food Security, 7(4), 889–904. https://doi.org/10.1007/s12571-015-0476-3.

Baudron, F., Thierfelder, C., Nyagumbo, I., & Gérard, B. (2015). Where to target conservation agriculture for African smallholders? How to overcome challenges associated with its implementation? Experience from Eastern and Southern Africa. Environments, 2(3), 338–357. https://doi.org/10.3390/environments2030338

Binswanger, H., & Ruttan, V. W. (1978). Induced Innovation. The Johns Hopkins University Press.

Creswell, J. W. (2013). Qualitative Inquiry & Research Design: Choosing among Five Approaches (3rd ed.). Thousand Oaks, CA: SAGE.

FAO. (2011). *Women in agriculture: Closing the gender gap for development. The state of food and agriculture 2010–11*. Food and Agriculture Organization (FAO). https://www.fao.org/fileadmin/templates/cpesap/C-RESAP_Info_package/Links/Module_6/Women_in_agriculture.pdf

DFID (2005) Sustainable Livelihoods Guidance Sheets. DFID, London, U.K. www.livelihoods.org/info/info_guidancesheets.html#6

Diao, X., Silver, J., & Takeshima, H. (2016). Agricultural mechanisation and agricultural transformation (Issue February).

Jaleta, M., Baudron, F., Krivokapic-Skoko, B., & Erenstein, O. (2019). Agricultural mechanisation and reduced tillage: antagonism or synergy? International Journal of Agricultural Sustainability, 17(3), 1–12. https://doi.org/10.1080/14735903.2019.1613742

Kahan, D., Bymolt, R., & Zaal, F. (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

Lobell, D. B., Burke, M. B., Tebaldi, C., Mastrandrea, M. D., Falcon, W. P., & Naylor, R. L. (2008). Prioritizing climate change adaptation needs for food security in 2030. Science, 607(319), 607–610. https://doi.org/10.1126/science.1152339

Losch, B. (2012). Agriculture: The Key to the Employment Challenge. Perspective No. 19. Montpellier: CIRAD. https://hal.archives-ouvertes.fr/hal-00741091v2/file/Perspective19_Losch_eng.pdf

Ngoma, H., Marenya, P., Tufa, A., Alene, A., Chipindu, L., Matin, M. A., Thierfelder, C., and Chikoye, D. 2023. Smallholder farmers' willingness to pay for two-wheel tractor-based mechanisation services in Zambia and Zimbabwe. Journal of International Development, 2023, 1–22. https://doi.org/10.1002/jid.3767

Rusinamhodzi, L. (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.

Ruthenberg, H. (1980). Farming Systems in the Tropics. Clarendon Press.

Sacks, W.J., D. Deryng, J.A. Foley, and N. Ramankutty (2010). Crop planting dates: an analysis of global patterns. Global Ecology and Biogeography 19, 607-620. DOI: https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1466-8238.2010.00551.x

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(June 2018), 39–51. https://doi.org/10.1016/j.agsy.2019.04.009

Van Loon, J., Woltering, L., Krupnik, T. J., Baudron, F., Boa, M., & Govaerts, B. (2020). Scaling agricultural mechanisation services in smallholder farming systems: Case studies from sub-Saharan Africa, South Asia, and Latin America. Agricultural Systems, 180(December 2018), 102792. https://doi.org/10.1016/j.agsy.2020.102792

Websites

[1] Spatial Allocation Production Model (SPAM): https://www.mapspam.info/

[2] Open Spatial Demographic Data and Research (WorldPop): https://www.worldpop.org/

[3] FAO's Global Information System on Water and Agriculture (AQUASTAT): https://www.fao.org/aquastat/en/geospatial-information/global-maps-irrigated-areas

[4] Gridded Livestock of the World (GLW3): https://www.fao.org/land-water/land/land-governance/land-resources-planning-toolbox/category/details/en/c/1236449/

[5] iSDA-soil: https://www.isda-africa.com/isdasoil/

[6] Digital Elevation Model from the Hydrologic Derivatives for Modelling and Analysis (HDMA): https://www.sciencebase.gov/catalog/item/591f6d02e4b0ac16dbdde1c7

10.2 List of publications produced by project

Journal articles

- Under preparation

Working Paper & Reports

- Not applicable

Theses

- Not applicable

Drawings

1. Bed planter prototype (Annex 21)

Manuals & guidelines

1. Basin digger test protocol (Appendix 14)
2. Bed planter test protocol (Appendix 14)

Briefs, factsheets and bulletins

Media stories

1. Harnessing appropriate scale farm mechanisation for smallholder farmers in South Africa. https://www.cimmyt.org/projects/hafiz/
2. Turning the mechanization wheels on Zimbabwe's small-scale farms. https://www.cimmyt.org/news/turning-the-mechanization-wheels-on-zimbabwes-small-scale-farms/