NEEDS ASSESSMENT STUDY OF SMALL AGRICULTURAL EQUIPMENT FOR MECHANIZATION IN UGANDA









Report by

Dr. Ahamada Zziwa

Makerere University, Kampala Uganda

3rd October 2022

Table of Contents

1 BACKGROUND, OBJECTIVES AND METHODS 1

1.1 Background 1

1.2 Overall Objective 1

1.2.1 Specific Objectives 1

1.3 Scope and Assumptions 2

1.4 Methodology 2

2 FINDINGS AND IMPLICATIONS FOR SMALL-SCALE AGRICULTURAL MECHANIZATION 3

2.1 Mechanization needs and gaps for selected priority enterprises 3

2.1.1 Maize Value Chain 3

2.1.2 Coffee Value Chain 6

2.1.3 Banana Value Chain 7

2.1.4 Beans Value Chain 9

2.1.5 Cassava Value Chain 9

2.1.6 Irish Potato Value Chain 10

2.1.7 Millet and Sorghum Value Chains 11

2.1.8 Sweet Potato Value Chain 11

2.1.9 Poultry Value Chain 12

2.1.10 Mechanization needs for Karamoja Sub region 13

2.2 Factors influencing demand for, supply of and utilization of small agricultural equipment 13

2.2.1 Factors influencing demand of small agricultural equipment 13

2.2.2 Factors influencing supply of small agricultural equipment 15

2.2.3 Factors influencing utilization of small agricultural equipment 17

2.3 Drivers and barriers to adoption of small agricultural equipment 19

2.3.1 Drivers 19

2.3.2 Barriers to adoption 20

2.4 Strategies for commercialization and sustainable adoption of small agricultural equipment 21

2.5 Supply chains for small agricultural equipment and supplementary services in Uganda 23

2.5.1 Main Sources and suppliers of small agricultural equipment 24

2.5.2 Locally Manufactured Machinery 26

2.5.3 Locally developed technologies by DABE Makerere University and AETREC 29

2.5.4 Imported agro Machinery – key drivers, main importers and sources 29

2.5.5 Mechanics and Machinery Hire Service Providers 31

2.6 Gender analysis of participation in the small agricultural equipment ecosystem 31
2.7 Demand for Agricultural Mechanization and opportunity for investment in mechanization 32
2.7.1 Identified small mechanization needs for priority crops and livestock 33
2.7.2 Anticipated costs of some identified mechanization needs 39
2.8 Potential small agricultural equipment 40
2.8.1 Crop value chain 40
2.9 Mechanization needs and gaps for the priority crops and livestock value chain 53
2.9.1 Strategies to ease adoption and commercialization of mechanization technologies 56
2.10 Demand and supply analysis of agricultural equipment 57
2.10.1 Factors influencing demand for, supply of and utilization of the equipment 57
3 CONCLUSIONS AND RECOMMENDATIONS 58
3.1 Conclusions 58
3.2 Recommendations 59
4 REFERENCES 62

Acronyms

AEATREC	Agricultural Engineering and Appropriate Technology Research Centre
ASSP	Agriculture Sector Strategic Plan
BMAU	Budget Monitoring and Accountability Unit
CGIAR	Consortium of International Agricultural Research
DABE	Department of Agricultural and Biosystems Engineering
DAP	Draught Animal Power
MAAIF	Ministry of Agriculture Animal Industry and Fisheries
MFPED	Ministry of Finance, Planning and Economic Development
MUZARDI	Mukono Zonal Agricultural Research and Development Institute
NaCORI	National Coffee Research Institute Uganda
NARIs	National Agricultural Research Institutes
NARO	National Agricultural Research Organization
NaSARRI	National Semi Arid Resources Research Institute
NDP	National Development Plan
PPPs	Development of public-private partnerships
RECs	Research Extension Centers
SAIMMCO	Soroti Agricultural Implements and Machinery Manufacturing Co. Ltd.
SOCADIDO	Soroti Catholic Diocese Integrated Development Organization
UMA	Uganda Manufacturers Association
UNBS	Uganda National Bureau of Standards
USSIA	Uganda Small Scale Industries Association
VECO EA	Vredes Eilanden Country Office East Africa

EXECUTIVE SUMMARY

Background and objective - In Uganda there is low productivity and production for both crop and livestock mainly by smallholder farmers due to limited deployment of farm mechanization. This study was conducted to document the smallholder mechanization needs, current levels of mechanization, types of machinery and the drivers and barriers to adoption of the existing machinery applicable to maize, coffee, banana, beans, cassava, potato, millet, sorghum, sweet potato and poultry value chains in Uganda.

Study Approach and Scope - The study targeted the agro-ecological zones of the priority crops and livestock, and was conducted over a period of two months from September to October 2022. Blended methods including:- desk literature review, key informant interviews, field visits, virtual and phone interviews were used to collect and synthesize data to address the objectives of the study. A value chain approach was used to explore mechanization needs at land preparation (e.g. ploughing), production (sowing, planting, weeding)] harvesting, postharvest, storage and value addition for the priority crops and livestock. The study was conducted country wide and targeted small-scale agricultural machinery users, researchers and promoters in the priority crops and poultry value chains. The study focused on the small agricultural equipment applicable to priority crops namely maize, coffee, banana, beans, cassava, potato, millet, sorghum, sweet potato and poultry value chains. The targeted small agricultural equipment in the context of this study included equipment whose acquisition cost does not exceed seven million Uganda shillings (USD 2,000).

Key Findings and Conclusions

Levels of mechanization and small scale mechanization needs - The study has revealed that there are low levels of mechanization (estimated at less than 10%) and that there are specific mechanization needs for the priority crops and livestock which need to be addressed to boost productivity and profitability of smallholder farmers. There are a number of missing relatively affordable technologies with high potential to transform smallholder farming; and almost 50% of these can reverse engineered and locally produced to suit the Ugandan context.

Feasible small agricultural equipment required at the different nodes of the value chain – There are several promising small scale technologies for the priority crops and livestock which can be made locally but with a number for importation and probably reverse engineering to fit local context. The study revealed a high demand for locally fabricated machinery in Uganda, due to: - suitability of technology to local needs; durability in comparison with imports from China; convenience and proximity to farmers. It was also found out that capability of the local fabrication industry is limited to the manufacture of "simple" machines.

Priority Smallholder mechanization needs for the crops and livestock

Enterprise	Mechanisation Need		
	Production	**Harvesting**	**Value addition**
Maize	• Seed planters • Weeders for walking tractors		• Low cost mills • Hand cranked maize sheller • Motorized shelling technology • Pedal operated multi-seed cleaner (destoners)
Cassava		• Cassava harvester	• cassava chipper • Cassava graters

			• Small engine-powered mills
Irish Potato	• Light-weight ridgers • Potato planter	• Potato harvester	• Slicers or chips making machine
Sweet Potato	• Light-weight ridgers • Sweet potato planters • Small-scale mechanical sprayers	• Sweet potato harvester	
Beans	• Jab/small-scale planters • Fertilizer dispenser • Power weeders		• Multi-crop threshers • Hermetic storage technologies
Groundnuts	• Ground nut planters	• Ground nut stripper • Gender-responsive shellers	• Peanut butter making machine • Grinding/milling machine • Roaster machine
Arabica Coffee	• Motorized sprayer	• Selective red cherry harvester • Motorized coffee picker	• Motorized coffee pulpers • Innovative all weather/hybrid dryers
Millet & Sorghum	• Millet/Sorghum seeders • Oxen drawn weeders - needs optimization • Planting rake which creates rows during planting	• Small-scale harvesting machinery	• Multi-crop thresher • Multi-purpose mills
Cattle		• Motorized forage chopper (NARO FORA-CHOP)	• Mechanical hay making machine • Pasteurizers • Innovative coolers e.g. evaporative coolers
Bananas			• Cooling/refrigeration Technology • Fiber extraction machine • Flour/starch making technology • Peeling machine
Poultry	• Low cost cages • Chicken debeaker machine • Small scale silos for feed storage • Automated/metered feeders and drinkers • Digital supported weighing technology		• Small hatcheries/Incubators

NB: The priority equipment for each agro-ecological region will be based on priority crops.

Mechanization needs for Karamoja sub-region: The priority crops for the Karamoja sub-region include beans, green gram, cowpeas, millet, maize, sorghum, groundnuts, cassava, sunflower and soybean. Therefore, it is important to support the region with mechanization equipment for land opening, planting, weeding and postharvest handling and value addition for the priority crops. The priority equipment will include: - walking tractor, planters for cereals and small legumes, weeders, threshers, seed cleaners and oil extractors for sunflowers.

Prototypes by AETREC that are ready for promotion. These include the motorized forage chopper, hand planters, ridgers, ground nut strippers, weeders for walking tractors, ox-driven planters and weeders, ox ploughs, hand planters and the hand cranked maize shellers.

Factors influencing the demand for, supply of, and utilization of small agricultural equipment - The study has shown that the key factors influencing the demand for, supply of, and utilization of small agricultural equipment are: the increasing transformation of smallholder farmers from subsistence into commercially oriented, profit focused farmers:- the increased demand for high quality and productivity enhancing technology; increasing penetration of tractor hire services; increasing difficulty to access cheap labor; and increasing financing targeted at Agriculture, driven by increased capacity and confidence by financial institutions in managing the risks posed by agricultural financing. Despite, the gaps there are a number of socio-economically feasible and suitable small scale technologies for the priority crops and livestock in Uganda, which are either locally fabricated or imported or with potential to be reverse engineered to fit priority crop and livestock enterprises.

Key barriers and drivers to technology adoption - The study revealed that the key barriers to technology adoption are mainly the weaknesses in technology transfer, high capital investment costs, and lack of awareness of existence, availability and gainful operation of specific technologies. The study has shown that the main drivers of small scale agricultural mechanization include: the growing importance of commercial farming coupled with reduced labor availability, reduced production cycles attributed to climate change and variability, and the shift towards value added agricultural products for higher profitability.

Main suppliers and sources of small agricultural equipment - The study has revealed that public sector efforts to supply mechanization equipment and services have largely failed. The main supplier of small agricultural equipment in various parts of Uganda is mainly the private sector in form of equipment importers, dealers and local fabricators. The key fabricators include: Tonnet Agro Engineering Co. Ltd, Central Engineering Ltd, Musa Body Machinery Ltd, Ramanand Ltd and Technology Research Network Ltd. The major importers of machinery are Chinese and Asian based importing firms, the leaders among these being Asia Agro Industries, Auto Sokoni Limited, and China Huangpai Food Machines. The major agri-machinery imports into Uganda originate from China and India respectively while countries of origin include United Arab Emirates, Denmark, USA, and the Netherlands.

Levels of Adoption - There are very low levels of adoption of small scale agricultural mechanization (estimated at less than 10%) in the value chains of the priority crops and livestock. A big proportion of smallholder farmers involved in the priority crops and livestock still rely on rudimental technologies, which cripples production and profitability. There is need for innovative business models such as hire services and technology sharing amongst farmers in order to ease acquisition and to maximize returns on investment.

Gender Analysis - Gender analysis revealed that most small scale equipment introduced locally or imported is generally suited for men's tasks as opposed women's labour burden such as sowing, weeding, and post-harvest management. Participation of youth and people with disabilities in the small-scale agricultural machines setting is still limited because of lack of feasible technology options and incentives to attract them into the sector.

The key recommendations from the study include:-

- ✓ ***Addressing challenges of technology affordability and adoption -*** Adopting a "centralized equipment acquisition and hire model" can help to address challenges of technology affordability and adoption as relatively expensive equipment can be jointly acquired or even accessed through hire schemes by farmers with a common interest in a community. This model should be supported by "a complementary technology package approach", which ensures that farmers have a complete set of prerequisite technologies across the crop value chain rather than selective targeting of some value chain nodes. There is need for a joint efforts between public and private sector with the public sector developing a mechanization strategy and cultivating an enabling environment that allows the private sector to operate effectively in a bid to enhance technology adoption. Innovative but sustainable financing mechanisms targeted to easing acquisition of relatively expensive equipment by small holder farmers will also ease technology adoption.
- ✓ ***Capacity building and strengthening of local artisans*** – There is need for hands-on training of rural artisans on operation and maintenance of farm tools and implements and AEATREC can play a critical role giver her experience and expertise. Equipment targeted capacity building and strengthening of local artisans to be able to service, maintain, reverse engineer and multiply the identified technologies will help to address technology gaps. Local artisans should be sensitised on the gender based gaps and considerations to enable them to design and fabricate gender-sensitive equipment to ease adoption. Practical training (in form of demonstrations) of farmers on installation, operation and management of equipment will also be critical key to mechanization success. There is also need for sensitization campaign to effect attitudinal and perception change amongst smallholder farmers to make them aware of the direct benefits of embracing technology in various nodes of the value chains they are involved in.
- ✓ ***Spare support services -*** In order to foster sustainable mechanization support services, there is a need to have genuine spare support services in close proximity to farmers adopting specific technologies. It is also deemed wise to support the establishment of common use repair centers at regional level to ease access to services.
- ✓ ***Promotion of compatible farming*** - There is need to promote adoption of farming systems that are compatible with relevant mechanization technologies to ease adoption and maximize benefits from application of smallholder mechanization.
- ✓ ***Increasing the participation of youth and people with disabilities*** - There is need for deliberate efforts aimed at increasing the participation of youth and people with disabilities in the small-scale agricultural machines setting as either fabricators or operators on farms.
- ✓ ***Locally developed technologies by agricultural engineering departments at Universities -*** There is need to fully develop the prototypes at Universities because test results indicate that they require slight improvement. These technologies include: animal drawn maize planter, animal drawn small grain planter, cassava chipper, forage chopper, groundnut sheller, innovative coolers, motorized maize sheller, oxen drawn weeders, pasteurizers, pedal operated coffee

pulper, pedal operated multi-seed cleaner (destoners), sorghum thresher, solar dryers and the coffee pulper.

- ✓ ***The priority technologies for reverse engineering include:*** - hatcheries/incubators, low cost cages, chicken debeaker machine, coffee harvester, peanut butter making machine, ground nut grinding/milling machine, ground nut roaster machine, banana peeling machine, banana Fiber extraction machine and Hermetic grain storage technologies.

1 BACKGROUND, OBJECTIVES AND METHODS

1.1 Background

In Uganda there is low productivity and production for both crop and livestock due to limited deployment of farm mechanization. Low levels of mechanization adversely affect productivity and production and constrain commercialization and value addition. Farm mechanization could potentially improve timeliness and efficiency of farm operations leading to cost savings and increasing yields. NARO is currently implementing a new strategic plan 2018/19 – 2027/28 which is in line with the National Development Plan (NDP III) that focusses on Agro-industrialization. Correspondingly, NARO in collaboration with CGIAR have adopted a demand-led breeding approach to target several market segments along the commodity value-chain. This market-led approach is expected to enhance adoption and impact attained from use of new and improved technologies such as small agricultural equipment.

It should be noted that whereas smallholder farmers form majority of the farmers in Uganda, most technological interventions mainly by government focus on larger scale farmers and this usually puts smallholder farmers at a disadvantage. The migration of youth to urban areas for quick earning jobs has contributed to seasonal labor shortages and this has driven up the demand for agricultural mechanization among smallholders. There is need to address the mechanization needs of small holder farmers to address the labor shortage challenge as increasing the power supply to agriculture means that more tasks can be accomplished at the right time and larger areas can be cultivated to improve production output and productivity. In addition, farm mechanization releases time to attend to other important activities such as participation in other income generating activities and performance of reproductive roles especially for women. There is need to investigate examine the technologies small holder farmers can and should own and this should consider appropriateness in terms of social, economic and environmental sustainability. Applying environmentally friendly technologies enables farmers to produce crops more efficiently and sustainably. Sustainable agricultural mechanization can also contribute significantly to the development of value chains and food systems as it has the potential to render post-harvest processing and marketing activities and functions more efficient, effective and environmentally friendly. Mechanization is possible at different nodes of the value chain with different returns to investment. Nonetheless, it is important that smallholder farmer mechanization interventions are targeted to the points along the value chain with the highest returns to investment in order to maximize return on investment using the limited resources.

1.2 Overall Objective

The overall objective was to document the smallholder mechanization needs, current levels of mechanization, types of machinery and the drivers and barriers to adoption of the existing machinery applicable to maize, coffee, banana, beans, cassava, potato, millet, sorghum, sweet potato and poultry value chains in Uganda.

1.2.1 Specific Objectives

The specific objectives of the study were to:-

1. Examine factors influencing the demand for, supply of, and utilization of small agricultural equipment.
2. Map out existing actively used types of small agricultural equipment among small-scale agricultural value chain actors in Uganda.
3. Identify socio-economically feasible small agricultural equipment that may be required at the different nodes of the value chain.
4. Identify drivers and barriers to adoption of small agricultural equipment.

5. Establish potential adoption of small agricultural equipment in Uganda.
6. Map out the suppliers of the small agricultural equipment and supplementary service providers e.g., secondary fabricators (artisans), sellers of spare parts, mechanics, machinery hire service providers, etc.
7. Establish the participation of youth, women, men and people with disabilities in the small-scale agricultural machines setting.
8. Evaluate potential of current and other plausible strategies to enable commercialization and sustainable adoption of small agricultural equipment in Uganda.

1.3 Scope and Assumptions

The study was conducted country wide and targeted small-scale agricultural machinery users, researchers and promoters in the priority crops and poultry value chains. The study focused on the small agricultural equipment applicable to priority crops namely maize, coffee, banana, beans, cassava, potato, millet, sorghum, sweet potato and poultry value chains. The targeted small agricultural equipment in the context of this study included equipment whose acquisition cost does not exceed seven million Uganda shillings (USD 2,000). It was assumed that the selected key informants have a broader view of the mechanization needs of the priority crop and livestock and hence would give representative picture of the promising technologies.

1.4 Methodology

The study targeted the agro-ecological zones of the priority crops and livestock, and was conducted over a period of two months from September to October 2022. Blended methods including:- desk literature review, key informant interviews, field visits, virtual and phone interviews were used to collect and synthesize data to address the objectives of the study. A value chain approach was used to explore mechanization needs at land preparation (e.g. ploughing), production (sowing, planting, weeding)] harvesting, postharvest, storage and value addition for the priority crops and livestock.

Literature review was conducted in order to ascertain the factors influencing the demand for, supply of, and utilization of small agricultural equipment for both crop and livestock sectors from production, processing to value addition. An effort was made to explore institutional, environmental, and technical and capacity gaps contributing to a match or mismatch of small agricultural equipment in Uganda. Literature review and key informant interviews were undertaken to identify drivers and barriers to adoption of small agricultural equipment. The acceptability, scalability, sustainability, replicability of specific small agricultural equipment using the Technology Applicability Framework was conducted. An effort was made to identify the gaps in existing technologies that may hinder adoption.

A rapid assessment of the status of smallholder mechanization and extent of small agricultural equipment use in Uganda was conducted using key informant interviews with purposively selected Principal Investigators (PIs) in the ZARDIs, NARIs, RECs, higher research and education institutions, equipment dealers and suppliers as key informants. Prototypes with potential to transform the agricultural sector were also identified using a value chain approach and specifically interviewing Principal investigators in research institutions namely Makerere, Kyambogo, Busitema and Gulu Universities, etc. and those at the Zonal agricultural research institutes. Private artisans and local fabricators who are involved in fabrication and maintenance of small agricultural machinery were also interviewed. An attempt was made to document success case stories on adoption of small agricultural equipment.

An effort was made to identify and map out the suppliers of small agricultural equipment for value chains of selected crop and livestock from pre-production, production, processing to value addition and the supplementary service providers e.g., secondary fabricators (artisans), sellers of spare parts, mechanics and machinery hire service providers etc. The involvement of youth, women, men and people with disabilities in the small-scale agricultural machines setting was also investigated. A gender analysis was used to examine the gender-responsive small agricultural equipment for diverse social groups. A market survey was also undertaken to identify available small agricultural technologies for the priority crop and livestock sectors including their sources, costs involved in production and maintenance, and distribution channels.

2 FINDINGS AND IMPLICATIONS FOR SMALL-SCALE AGRICULTURAL MECHANIZATION

2.1 Mechanization needs and gaps for selected priority enterprises

2.1.1 Maize Value Chain

Current methods and technologies used by smallholder farmers

The production chain for maize comprises of six major stages, each requiring several operations. At each stage smallholder farmers use different techniques and technologies to accomplish the tasks presented as follows: Land preparation, planting and fertilizer application, Weeding, Disease and pest management Harvesting, Transportation, Post-harvest handling (drying, shelling, cleaning, storage) and Value addition (milling and packaging). There are generally low levels of mechanization by small scale farmers involved in maize production (Table 1.1).

Table 1.1: Levels of mechanization at each stage

Farm operations	Mechanization levels		
	Low	Medium	High
Land preparation	*		
Planting and fertilizer application	*		
Weeding	*		
Disease and pest management		*	
Harvesting	*		
Transporting		*	
Drying	*		
Shelling		*	
Cleaning	*		
Storage	*		
Milling			*
Packaging		*	

Key: Low: purely manual, medium: Manual plus machine, and High: Purely machine

Table 1.2 shows the potential technologies which are available but not in full use by smallholder farmers.

Table 1.2 Potential technologies for drudgery reduction in smallholder maize value chains

Stage/Node	Required Operations	Potential technologies*
Land preparation	Bush/weed clearance, stumping, tillage	Light-weight ploughs/harrows, small-scale mechanical sprayers
Planting	Sowing and fertilizer application	Jab planters, small-scale planters cum fertiliser drills
Interculture	Weeding, fertilizing, thinning, spraying, irrigation	Power weeders/cultivators, small-scale mechanical sprayers and fertilizer dispensers
Harvesting	Cob detachment, de-husking and collection	Small-scale maize harvesters
Postharvest handling	Transport, drying, shelling, cleaning, storage	Multi-purpose carts, mobile shellers, multi-purpose seed cleaners, drying platforms, solar dryers, and hermetic storage technologies
Value addition	Milling, packaging	-

These technologies can be powered by humans (but with reduced drudgery and improved productivity), draft animals, small engines (≤ 5 Hp), and walking[1] tractors (power tillers).

Some of the potential technologies are illustrated in Figures 1.1.1 to 1.1.5 below.



Figure 1.1.1: Garden tiller/cultivator

[1] Medium size Tractors (40-80 HP) are mainly used for land preparation, as on farm incomes and profitability increases, walking tractors are a natural progression from animal traction systems.



Figure 1.1.2: Hand-operated seed planter (motorised version available)



Figure 1.1.3: Power weeder



Figure 1.1.4: Push/pull sprayer (motorised version available)



Figure 1.1.5: Single-row maize harvester

2.1.2 Coffee Value Chain

The production chain for coffee comprises of six major stages, each with several operations (Table 1.3). Conventional equipment for mechanization of these operations for large-scale coffee production include ploughs and harrows for land preparation; pit diggers for pitting; cultivators, mowers, manure spreaders, pruners and boom sprayers for interculture operations; coffee pickers/ harvesters for harvesting; trucks and trailers, dryers, silos and mills for post-harvest handling and value addition. Similar to other crops, technologies for large-scale coffee farming are not scale-appropriate for smallholder farmers. However, technologies exist that can be adopted and or adapted for use in smallholder production (Table 1.3). These technologies require human power (but with reduced drudgery and improved productivity), draft animals, small engines (≤ 5 Hp), and walking tractors (power tillers).

Table 1.3 Potential technologies for drudgery reduction in smallholder coffee value chains

Stage/Node	Required Operations	Potential technologies*
Land preparation	Bush/weed clearance, stumping, tillage	Light-weight ploughs/harrows, small-scale mechanical sprayers
Planting	Pitting, transplanting	Pitting machine
Interculture*	Weeding, pruning, manure application, spraying, irrigation	Mowers, small-scale: pruners, cultivators and manure spreaders
Harvesting	Picking, collection	-
Postharvest handling	Transportation, drying, storage	Multi-purpose carts, solar driers, drying platforms
Value addition	-	-

Some of the potential technologies that are not already documented above are illustrated in Figures 1.2.1 to 1.2.3 below.



Figure 1.2.1: Motorized hand-pushed boom sprayer



Figure 1.2.2: Motorized pitting machine



Figure 1.2.3: Motorised coffee picker

2.1.3 Banana Value Chain

The production chain for bananas comprises of six major stages, each with several operations (Table 1.4). Conventional equipment for mechanization of these operations for large-scale banana production include ploughs and harrows for land preparation; pit diggers for pitting; cultivators, mowers, manure spreaders, and boom sprayers for interculture operations; trucks and trailers for transportation. Similar to other crops, technologies for large-scale banana farming are not scale-appropriate for smallholder farmers. However, technologies exist that can be adopted and or adapted for use in smallholder banana production (Table 1.4). These technologies require human power (but with reduced drudgery and improved productivity), draft animals, small engines (≤ 5 Hp), and walking tractors (power tillers).

Table 1.4 Potential technologies for drudgery reduction in smallholder banana value chains

Stage/Node	Required Operations	Potential technologies*
Land preparation	Bush/weed clearance, stumping, tillage	Light-weight ploughs/harrows, small-scale mechanical sprayers
Planting	Pitting, manure application, sucker placement	Pitting machine
Interculture	Weeding, pruning, thinning, mulch/manure application, spraying, irrigation	Mowers, multi-purpose carts, small-scale: mechanical sprayers, cultivators, and manure spreaders
Harvesting	Cutting, collect	-
Postharvest handling	Transport	Multi-purpose carts
Value addition	-	-

In addition to technologies shown above, potential technologies for use in the banana value chain are illustrated in Figures 1.3.1 to 1.3.2 below.



Figure 1.3.1: Push motorised mowing machine



Figure 1.3.2: Hand push/pull manure spreader

2.1.4 Beans Value Chain

The production chain for beans comprises of six major stages, each with several operations (Table 1.5). Conventional equipment for mechanization of these operations for large-scale production of beans include ploughs and harrows for land preparation; planters for sowing; cultivators and boom sprayers for interculture operations; harvesters for harvesting; trucks and trailers, dryers, and silos for post-harvest handling. Similar to other crops, technologies for large-scale production of beans are not scale-appropriate for smallholder farmers. However, technologies exist that can be adopted and or adapted for use in smallholder bean production (Table 1.5). These technologies require human power (but with reduced drudgery and improved productivity), draft animals, small engines (≤ 5 Hp), and walking tractors (power tillers).

Table 1.5 Potential technologies for drudgery reduction in smallholder beans value chains

Stage/Node	Required Operations	Potential technologies*
Land preparation	Bush/weed clearance, stumping, tillage	Light-weight ploughs/ harrows, small-scale mechanical sprayers
Planting	Sowing and fertilizer application	Jab planters, small-scale planters cum fertiliser drills
Interculture	Weeding, fertilizing, thinning, spraying, irrigation	Power weeder, small-scale mechanical sprayers, cultivators and fertilizer dispensers
Harvesting	Cut, collect, thresh	Small-scale bean harvesters
Postharvest handling	Transportation, threshing, storage	Multi-purpose carts, multi-crop threshers, hermetic storage technologies
Value addition	-	-

2.1.5 Cassava Value Chain

The production chain for cassava comprises of six major nodes, each with several operations (Table 1.6). Conventional equipment for mechanization of these operations for large-scale cassava production include ploughs and harrows for land preparation; cassava planter for sowing; cultivators and boom sprayers for interculture operations; cassava harvesters for harvesting; trucks and trailers, cassava graters, dryers, and silos for post-harvest handling; and mills for value addition. Similar to other crops, technologies for large-scale production of cassava are not scale-appropriate for smallholder farmers. However, technologies exist that can be adopted and or adapted for use in smallholder bean production (Table 1.6). For instance the small scale cassava mill is being pilot-tested in Palisa and hence may need performance evaluation and optimization. Some of these technologies require human power (but with reduced drudgery and improved productivity), draft animals, small engines (≤ 5 Hp), and walking tractors (power tillers).

Table 1.6: Potential technologies for drudgery reduction in smallholder cassava value chains

Stage/Node	Required Operations	Potential technologies*
Land preparation	Bush/weed clearance, stumping, tillage	Light-weight ploughs/harrows, small-scale mechanical sprayers
Planting	Pitting, placement, covering	Small-scale cassava planter
Interculture	Weeding, thinning, manure application, spraying	'Mechanical hoe', small-scale mechanical sprayers, cultivators and manure spreaders
Harvesting	Uproot, detach, collect	Small-scale cassava harvester
Postharvest handling	Transport, peeling, washing, grating, drying, storage	Multi-purpose carts, cassava graters, drying platforms, solar dryers, hermetic storage technologies
Value addition	Milling, packing	Small engine-powered mills

2.1.6 Irish Potato Value Chain

The production chain for Irish potatoes encompasses six major nodes, each with several operations (Table 1.7). Conventional equipment for mechanization of these operations for large-scale production of Irish potatoes include ploughs and harrows for land preparation; Irish potato planter for sowing; cultivators and boom sprayers for interculture operations; Irish potato harvester for harvesting; trucks and trailers for post-harvest handling. Similar to other crops, technologies for large-scale production of Irish potatoes are not scale-appropriate for smallholder farmers. However, technologies exist that can be adopted and or adapted for use in smallholder Irish potato production (Table 1.7). These technologies require human power (but with reduced drudgery and improved productivity), draft animals, small engines (≤ 5 Hp), and walking tractors (power tillers).

Table 1.7: Potential technologies for drudgery reduction in smallholder Irish potato value chains

Stage/Node	Required Operations	Potential technologies*
Land preparation	Bush/weed clearance, stumping, tillage	Light-weight ploughs/harrows, small-scale mechanical sprayers
Planting	Manure application, ridging, transplanting	Light-weight ridgers, potato planter
Interculture	Weeding, spraying	'Mechanical hoe', cultivators, small-scale mechanical sprayers
Harvesting	Uproot, detach, collect	Potato harvester
Postharvest handling	Transporting, storage	Multi-purpose carts,
Value addition	-	-

2.1.7 Millet and Sorghum Value Chains

The production chain for millet and sorghum comprises of six major stages, each with a number of operations (Table 1.8). Conventional equipment for mechanization of these operations for large-scale cultivation is available for the whole production chain including ploughs and harrows for land preparation, seed cum fertilizer drills for sowing and fertilizer application, cultivators and boom sprayers for interculture operations, combine harvesters and trucks/trailers for harvesting/shelling and transportation, dryers, silos and mills for post-harvest handling, storage and value addition. While these technologies are not scale-appropriate for smallholder farmers, there are technologies that can be adopted and or adapted for use in smallholder millet and sorghum production (Table 1.8). These technologies can be powered through human power (but with reduced drudgery and improved productivity), draft animals, small engines (≤ 5 Hp), and walking tractors (power tillers).

Table 1.8: Potential technologies for drudgery reduction in millet and sorghum value chains

Stage/Node	Required Operations	Potential technologies*
Land preparation	Bush/weed clearance, stumping, tillage	Light-weight ploughs/harrows, small-scale mechanical sprayers
Planting	Sowing and fertilizer application	Jab planters, small-scale seed cum fertiliser drills, and manure spreaders
Interculture	Weeding, spraying, fertilizing, thinning,	'Mechanical hoe', small-scale mechanical sprayers, cultivators
Harvesting	Cutting, threshing	Small-scale harvesting and threshing machinery
Postharvest handling	Transporting, threshing, storage	Multi-purpose carts, multi-crop threshers, hermetic storage technologies
Value addition	Milling, packing	Multi-purpose mills

2.1.8 Sweet Potato Value Chain

The production chain for sweet potatoes encompasses six major nodes, each with several operations (Table 1.9). Conventional equipment for mechanization of these operations for large-scale sweet potato production include ploughs and harrows for land preparation; sweet potato planting machine sowing; cultivators and boom sprayers for interculture operations; sweet potato harvester for harvesting; trucks and trailers for post-harvest handling. Similar to other crops, technologies for large-scale production of sweet potatoes are not scale-appropriate for smallholder farmers. However, technologies exist that can be adopted and or adapted for use in smallholder Irish potato production (Table 1.9). These technologies require human power (but with reduced drudgery and improved productivity), draft animals, small engines (≤ 5 Hp), and walking tractors (power tillers).

Table 1.9: Potential technologies for drudgery reduction in smallholder sweet potato value chains

Stage/Node	Required Operations	Potential technologies*
Land preparation	Bush/weed clearance, stumping, tillage	Light-weight ploughs/harrows, small-scale mechanical sprayers
Planting	Ridging, planting	Light-weight ridgers, sweet potato planters
Interculture	Weeding, spraying	'Mechanical hoe', cultivators, small-scale mechanical sprayers
Harvesting	Uproot, detach, collect	Sweet potato harvester
Postharvest handling	Transporting, storage	Multi-purpose carts,
Value addition	-	-

2.1.9 Poultry Value Chain

There are a number of existing and potential small scale technologies that can help reduce drudgery, boost productivity and contribute to value addition for higher profitability in the poultry value chain as summarised in Table 1.10.

Table 1.10: Potential technologies for drudgery reduction in smallholder poultry value chains

Stage/Node	Potential technologies*
Feed preparation	• Pelleting machine • Destoners for removing stones
Brooding	• Innovatively designed and constructed heater with less carbon dioxide and carbon monoxide generation
Feed provision	• Automated feeders – with a conveying system to minimise feed contamination and is less cumbersome
Water provision	• Cost effective drinkers [nipple-based automated drinkers] with reduced chances of contamination
Litter management	• House designs with improved air circulation systems to ensure proper drying of litter. • Alternative flow designs [with provisions for litter separation] using locally available materials e.g. bamboo • Ammonium detection machine to help check the concentration in litter to monitor ammonium levels to avoid suppressing feeding rates of birds.
Egg collection & storage	• Conveyor system for egg collection in cages • Laying boxes
Value addition	• Packaging eggs in shock absorber boxes • Different sized crates for enabling sorting of eggs into different sizes to enable size-based sorting, grading and pricing. • Small poultry slaughtering equipment – cones • Digital supported weighing technology for enabling ascertaining growth rates of chicken in a group – e.g. special basket • Labelling machine

2.1.10 Mechanization needs for Karamoja Sub region

The priority mechbisation needs for the Karamoja sub-region along the production, harvesting and value addition include:-

Priority Smallholder mechanization needs for Karamoja Sub region

Enterprise	Mechanisation Need		
	Production	**Harvesting**	**Value addition**
Maize	• Seed planters • Weeders for walking tractors		• Low cost mills • Hand cranked maize sheller • Motorized shelling technology • Pedal operated multi-seed cleaner (destoners)
Cassava		• Cassava harvester	• cassava chipper • Cassava graters • Small engine-powered mills
Soybean/Beans	• Jab/small-scale planters • Fertilizer dispenser • Power weeders		• Multi-crop threshers • Hermetic storage technologies
Groundnuts	• Ground nut planters	• Ground nut stripper • Gender-responsive shellers	• Peanut butter making machine • Grinding/milling machine • Roaster machine
Millet & Sorghum	• Millet/Sorghum seeders • Oxen drawn weeders - needs optimization • Planting rake which creates rows during planting	• Small-scale harvesting machinery	• Multi-crop thresher • Multi-purpose mills

2.2 Factors influencing demand for, supply of and utilization of small agricultural equipment

2.2.1 Factors influencing demand of small agricultural equipment

Labour supply

Technically, mechanization as an input to agricultural production is adopted as a labour-saving technology (Pingali, 2007). Consequently, the demand for and use of mechanization technologies is primarily driven by labour supply dynamics (Daum and Birner, 2020). Thus, when labour is abundant and relatively cheap, adoption of agricultural equipment will be unattractive. Conversely, trends that create labour shortages leading to increased labour costs tend to incentivise farmers to adopt mechanization (Daum, 2015; Sims et al., 2016; Sims and Kienzle, 2017). In Uganda, the agriculture sector is reported to employ at least 72% of the workforce and this labour force is only envisaged to shift away from agriculture to industry through sustainable industrialisation (NPA, 2020).

State of farming systems

The nature of inputs, including mechanization, used by farmers is influenced by the level of intensification in the agricultural production systems employed. When farming communities remain in low-intensity and low-productivity farming practices, their power requirement can be fulfilled with human labour (Pingali, 2007). According to MAAIF (2016), majority of farmers in Uganda are subsistence-orientated smallholders who use few intermediary inputs and rudimentary technology to produce low-value crops. Similarly, fragmentation of farmland through subdivision renders conventional mechanization uneconomical (MFPED, 2017). Consequently, demand for mechanization in such farming systems will be relatively low.

Cost of Mechanisation technology (Affordability)

Mechanization technologies are relatively expensive and require significant upfront cost far beyond what most smallholder farmers can afford from their own resources (Sims and Kienzle, 2017; Kirui, 2019; Van Loon et al., 2020). The high capital costs associated with mechanization mean that smallholder farms are not in a position to utilize them efficiently, making them unattractive (FAO & AUC, 2018). According to MAAIF (2016), mechanized agriculture is still low due to limited awareness, costs of mechanisation in rural areas and limited awareness about the scope of mechanized agriculture among the rural populations.

Farmer awareness about smallholder technologies

The study revealed that majority of small holder farmers are not aware about the smallholder technologies that could transform their crop and livestock value chains (Wanyama et al (2016). This is particularly the case for less commercially oriented enterprises such as banana, beans, millet, sorghum, and sweet potato. However, it was noted that for the commercially oriented enterprises such as maize, poultry, ground nuts and coffee the levels of awareness of particularly value addition technologies is relatively high (Nsubuga et al, 2021). This calls for deliberate awareness campaigns about the existence of low cost technologies by various stakeholders to help farmers know the technologies for the various nodes of their production chain.

Farmer's income levels

The low income levels of smallholder farmers negatively affect demand for, supply of and utilization of small agricultural equipment in Uganda (Anderson, Learch, and Gardner 2016) because majority of smallholder farmers cannot even afford cheaper equipment, much as they would be interested in adopting the technology. The low income levels coupled with the high cost of the critically needed equipment hinders adoption.

Farmers' skills and knowledge to operate the machine

The study has revealed that a big proportion of smallholder farmers lack the prerequisite skills and knowledge to operate even the basic agricultural machinery and the situation gets worse when it comes to their maintenance (Obura *et. al*., 2020). This is because there are few capacity building initiatives focusing on small agricultural mechanisation for smallholder farmers as most studies in extension have in the past been focusing on agronomic practices. The lack of skills and knowledge to operate small scale agricultural machinery skills and knowledge leads to sub-optimal utilisation of agricultural equipment.

Availability of spares

There has also been a challenge of lack of spares for mainly the imported small scale agricultural machinery in Uganda. -For instance some agricultural equipment, mainly procured on behalf of farmers under NAADS had no spare parts in some parts of the country (). As a result, most of the imported small scale agricultural machinery mainly from India is abandoned due to simple breakdowns which could easily be fixed if there existed appropriate spares in the accessible places.

Availability of support services (repair and trainings)

The lack of support services in form of repair and trainings closer to the rural areas where smallholder farmers operate affects demand for smallholder agricultural mechanisation equipment.

Poor access to information about the availability of the equipment

Most small scale farmers in remote areas have minimal or no access to information about suppliers of agricultural equipment.

2.2.2 Factors influencing supply of small agricultural equipment

Public sector mechanization interventions

Public sector efforts to promote mechanization are centrally planned with a strong focus on importing machinery while knowledge and skills development are often neglected (Mrema et al., 2008; Daum and Birner, 2020). Consequently, technologies have been introduced without proper consideration of their suitability, the capacity of farmers to utilize them or the availability of skilled personnel with ability to operate and maintain these technologies (Sims and Kienzle, 2017; Van Loon et al., 2020). These interventions have limited integration of complementary actors in the mechanization value chain including manufacturing, supply, distribution, sales, and after-sales services yet they tend to cloud-out the private sector, rendering the interventions ineffective (Van Loon et al., 2020). In Uganda, government has over the last 15 years procured and distributed various equipment to farmers either free of charge or at subsidized prices to meet the sector objectives. However, despite the deliberate efforts for agricultural mechanization, a number of factors hinder access and use of the equipment by farmers in Uganda (MFPED, 2017).

Availability of hire services markets

According to FAO & AUC (2018) farm size has had less influence on the pattern of mechanization in places where rental markets exist or can be established, indicating that hire services are a potential remedy for inability of smallholder farmers to invest in their own agricultural machinery. However, private supply chains are not always fully developed or well-organized, due to crowding out/distortion caused by government policies and programs, the high fixed investments required, and other market failures (Diao et al., 2014; Diao, 2016; Sims et al., 2016). Moreover, agricultural machinery suppliers and service providers are mostly found in urban centres owing to the perceived low demand in rural areas. Thus smallholder farmers are often isolated by distance and poor road and communication infrastructure (Sims et al., 2016). This means that demand for mechanization from small-scale farmers does not always lead to an adequate supply response as service providers are often reluctant to serve small farms, because their fields are small, fragmented, and spatially dispersed (Daum, 2015). This is aggravated by lack of understanding, unity and initiative among smallholder farmers for self-organisation to address their needs and challenges.

Availability of supporting infrastructure

Accessibility of farm machinery to the end-user is a major determinant of the ease with which mechanization is adopted by farmers. Besides farmers' access to mechanization being constrained by limited access to finance and an unconducive business environment, level of road infrastructure also emerges as a marked influence on the demand for mechanization. Better road infrastructure results in better access to fields and local markets and increases the use of agricultural machinery for off-farm activities which increases the incentive for their adoption (World Bank, 2010; FAO & AUC, 2018; Van Loon, 2020). This would be enhanced by the presence of local entrepreneurs engaged in the mechanization supply chains to ensure availability of repair and maintenance services and spare parts (FAO & AUC, 2018). MFPED (2017) reported that inadequate complementary infrastructure, such as power lines and road networks, was a major constraint preventing farmers from using agricultural equipment in Uganda.

Policy and institutional environment

The adoption of mechanization technologies requires a conducive environment characterized by policies, laws and regulations, as well as physical and institutional infrastructure that supports commercial-oriented farming activities and entrepreneurship and input supply, as well as produce handling, processing and marketing (FAO & AUC, 2018). Similarly, policies encouraging industrialization as well as enabling policies contributing to the profitability of farming would increase demand for mechanization. This can lead to the development of suitable low-cost equipment as an alternative to purchasing high-cost and often unsuitable machinery from developed countries (FAO & AUC, 2018).

Demand and ability of farmers to pay

The low demand and inability of smallholder farmers to pay for the small scale mechanisation affects supply of the technologies. As a result suppliers of small-scale agricultural equipment are discouraged from supplying small-scale agricultural equipment for fear of them lying idle in their shops (Diro and Sam, 2015). Therefore, any efforts geared towards enhancing smallholder farmers' ability to pay for the small-scale technologies can contribute to improving supply of the technologies.

Type and profitability of farming enterprises

Most smallholder farmers are engaged in farming enterprises which are not easy to mechanise unless farmers adopt appropriate agronomic practices. Besides, the small parcels of land cultivated by majority

of farmers make it unprofitable to adopt small-scale agricultural mechanisation Uganda (Anderson, Learch, and Gardner 2016). Thus certain farming enterprises do not attract supply of small agricultural equipment.

Availability of well-developed supply network

Availability of well-developed supply network is one of the factors that influence supply of small agricultural equipment as weak or non-existent supply networks usually result into failure of farmers to get access to the required technologies. This study found that the lack of technological inputs, limited flow of inputs and transportation services, and lack of training are some of the main supply chain challenges faced by small scale farmers.

Favourable mechanization policy

Enabling mechanisation policies contribute significantly to improved supply of small scale agricultural equipment. An appropriate and supportive policy framework should ensures that public sector interventions do not stifle growth of the private sector (Pingali, 2007; Diao *et al.*, 2016).

Availability of machinery support services (spares dealers, repair services and training services)

The supply of agricultural machinery is made pretty easier by the availability of spares dealers, repair services and training services. There should be a deliberate effort to avail and ease technology acquisition. This requires concerted efforts of extensionists, researchers and AEATREC to provide mechanization support services for sustainability.

2.2.3 Factors influencing utilization of small agricultural equipment

Profitability of farming

Farmers adopt mechanical technologies when profits generated from their enterprises are sufficient to justify the investment (Diao *et al.*, 2016; FAO & AUC, 2018). Thus access to agricultural markets coupled with equitable farm-gate prices would not only enable farmers to accumulate capital but will also incentivise them to invest in farm machinery as they can recoup their investment (Houmay *et al.*, 2013). On the other hand, low profitability driven by unfavourable market conditions, low farm productivity and limited surplus income constrains farmers' ability to invest in appropriate mechanization inputs locking them a vicious cycle of low productivity and low income (Pingali, 2007; Houmay *et al.*, 2013; Kienzle, 2017).

State of the Agricultural Mechanization Sub-Sector

A well-developed mechanization ecosystem, characterized by availability of appropriate mechanization infrastructure and reliable support services enhances the possibility of farmers' access to mechanization. On the other hand, when supply chains for agricultural mechanization are underdeveloped or inaccessible to farmers especially in remote rural areas, few farmers will be able to access the machinery or services and those who manage to gain access do so at a comparatively high cost (Sims et al., 2016). MFPED (2017) reported that when some of the agricultural equipment break down, they are not repaired due to lack of spare parts and are subsequently abandoned. This is largely because most farm equipment, machinery and spare parts are imported with limited local manufacturing and fabrication capacity.

Suitability of available technologies

Owing to inadequate local capacity to make appropriate technologies suited to the local farming systems and conditions, most mechanization technologies are imported. Most imported farm machinery is unsuitable for small-scale, low-income farmers owing to the limited interest in designing and building simple, low-cost, small-scale machinery suited for these categories of farmers (World Bank, 2010). Consequently, the scale of machinery that is conventionally available is not often suited to the size of smallholder farms that mostly consist of small dispersed fields (Kirui, 2019; Van Loon et al., 2020). The use of such technologies may not be feasible for many smallholders in Uganda because of the associated low utilization rates leading to high cost per unit of output. There has been reports of entire enterprises being abandoned and of equipment supplied having not been used by the farmers as they were considered inadequate and inappropriate (MFPED, 2017). Availability of backup machinery services can also positively increase adoption and utilization of small agricultural equipment as the various production and value addition challenges of farmers would be addressed.

Access to finance

The acquisition and/or adoption of mechanization technologies necessitates finances which smallholder farmers obtain through their own savings; this tends to limit uptake of agricultural mechanization (Sims et al., 2016; Van Loon et al., 2020). On the other hand, financing opportunities either through subsidies or the financial services sector are quite limited as financial institutions hardly lend to smallholder agricultural enterprises (Sims et al., 2016; Kirui, 2019; Van Loon et al., 2020). Where financing is available, the application process for credit is tedious, interest rates are quite high, repayment schedules are stringent and out of sync with production cycles, while the repayment period is too short (Daum, 2015; Sims *et al.*, 2016). In Uganda, growth in access to agricultural finance is generally low due to demand-side factors associated with socio-economic characteristics of farmers, including informal nature of agricultural activities, isolation of rural smallholder farmers, lack of collateral, and lack of commercial viability of smallholder agriculture (Orwothwun and Qutieshat, 2022).

Access to relevant information on machinery availability

The evidence base surrounding mechanization in many developing countries such as Uganda is still quite scarce as national-level statistics do not adequately cover mechanization. Consequently, little is known about mechanization demand, current extent of mechanization, and effects of mechanization so as to make informed decisions (Diao et al., 2016). In addition, extension service providers lack access to relevant information on appropriate agricultural mechanization technologies that can be passed to farmers to stimulate adoption of mechanization (Sims et al., 2016; Krui, 2019). Assessment by the Budget Monitoring and Accountability Unit (BMAU) of the Ministry of Finance, Planning and Economic Development (MFPED) indicated that poor access to information by farmers on the availability of equipment was among the key factors hindering access to and use of agricultural equipment in Uganda (MFPED, 2017). Similarly, MAAIF (2016) reiterated that the use of appropriate agricultural mechanisation technologies is greatly hindered by poor extension services, lack of financial capacity, inadequate skills development and poor marketing system.

Land size

Much as agricultural mechanization is often driven by large farm sizes and enables farmers to further expand their landholdings, it is not a prerequisite for mechanization to be profitable. Reports have

indicated that mechanisation has been profitably adopted by smallholder in Asia. Nonetheless, land expansion appears to be a major factor for the adoption of mechanization (Diao et al, 2016). Mechanisation has also been reported to be a good substitute for household labour on small, intensively-cropped farms and allows for the pursuit of off-farm income generation (Takeshima et al, 2013). There are success stories of emerging mechanization demand among smallholders in Bangladesh with smallholders owning less than 0.2ha reported to be using power tillers mainly imported from China. There is evidence of optimal utilisation of power tiller hiring services which operate beyond land preparation to include threshing, water pumping and transport (Diao et al 2014).

Availability of machinery hire service providers

Availability of machine hire services targeted to smallholder farmers can positively influence utilization of small agricultural equipment. Apart from tractor hire services in Uganda, it is not common practice to find other smaller mechanisation hire services. There are only a few cases of oxen ploughs, threshers, and hullers that are jointly owned and communally utilised. It should be noted that demand for specific mechanization services by groups of smallholder farmers undertaking similar crop and livestock enterprises attracts mechanisation hire services.

Availability of skilled operators

Availability of skilled operators is one of the key factors positively influencing utilization of small agricultural equipment especially for the highly specialised equipment. It is for this reason that capacity building seminars, skilling of artisans and on-farm demonstrations on operation and maintenance of specific agricultural equipment is one of the key components of strategic mechanisation programs. Lack of skilled operators of even the cheapest agricultural equipment leads to underutilisation and breakdown of machinery due to inappropriate use.

2.3 Drivers and barriers to adoption of small agricultural equipment

2.3.1 Drivers

The main drivers of small scale agricultural mechanization have been:

- ***Growing need for commercial farming*** and the growing need for higher and faster production necessitates adoption of mechanization to cope with increased labor requirement. It is common practice to find a number of commercially leaning farmers gradually adopting low cost technologies to enable them meet the demand for their products.
- ***Reducing labor availability*** for farming exacerbated by rural urban migration – with the reducing availability of manual labour due to rural urban migration for quick paying jobs, smallholder farmers are being attracted to small agricultural equipment to cope with the gap.
- ***Reducing production cycles attributed to climate change and variability*** – means that farmers have to adjust and use land preparation approaches that can ensure quicker and larger land preparation to fit within reduced planting times and shorter durations of rain.
- ***The increasing shift towards value added agricultural products*** for increased profitability has pushed smallholder farmers to adopt specific value addition technologies for mainly commercially oriented enterprises such as ground nuts, coffee and maize. This

- ***Increasing number of machinery hire service providers*** (e.g ox traction, walking tractor, big tractor, shellers, threshers, chippers, etc). The high acquisition and maintenance costs of some of these technologies means that smallholder farmers can only access them through a pay and use/hire scheme. A tractor is recognized as both more efficient and cheaper than other forms of farm power. In addition, the growing importance of commercial farming and the formation of farmer group structures support the collective acquisition and ownership of high value assets such as tractors. Tractor hire services are extremely important as a model that unlocks access for tractor machinery. These business models present interesting avenues toward affordably, profitably and sustainably increasing access of tractor services to small scale farmers because they provide readily available access without the necessity of ownership. Further, tractor hire services not only provide an efficient land cultivation service than animal or hand powered systems, they are in fact cheaper than both. For instance, tractors require only 3.75 tractor hours for the primary cultivation (ploughing and harrowing) of a single hectare of land versus 40 hours required when using a team of oxen or 750 hours when done manually with the hoe. Based on the practical experiences of Ladwong Farming Limited, a tillage service provider in Northern Uganda, it costs about the same UGX 80,000 ($27) to hire either a tractor or alternatively ox plough services to clear an acre of land in Northern Uganda. However, in the case of ox- plough services, it usually takes 3 days, and ultimately requires some additional costs relating to free meals and some light alcohol that would usually be provided for the crew of usually 3 persons manning the ox-ploughs. Use of hired labour will on the other hand usually not cost less than UGX 100,000. Tractor hire services have evolved from simple one-man with a tractor for hire operations to well-structured services provided by formalized enterprises. The implications of this are important, because formal entities contract with tractor selling or leasing firms, and access external financial support, which can attract public (Donor/INGO) investments as credible institutions with good governance practices. Such companies therefore present a viable market for affordable good quality 2nd hand tractor imports.

2.3.2 Barriers to adoption

The key barriers to small scale technology adoption are:

- lack of awareness of existence,
- Weaknesses in technology transfer,
- high acquisition costs,
- Limited skills on operation of specific technologies.
- Limited availability of spares and repair services
- Low local capacity to manufacture
- Wrong attitude by Ugandans towards usage of small-scale machinery

Despite several effective machinery innovations that could improve on-farm performance, adoption of technology remains very low, largely because of technology transfer weaknesses. The local fabrication industry - the conduit between innovators and end users, responds to and manufactures in direct response to actual prevailing consumer demand, and while technologies are designed to meet existing needs, these needs by farmers are not translating into effective demand. Other barriers to technology adoption include:

- Limited awareness of existence, availability and application of specific equipment.
- High acquisition costs – some technologies are not affordable at least by majority farmers.
- Lack of technical expertise to use specific equipment necessitating capacity building.

Tractors are not suited to some local situations - tractors will be optimized in farming systems where land is generally flat, and where meaningful land holdings rather than tiny plots are worked. These conditions are found more in the Northern and Eastern regions of the country, and less so in the South-Western region, which tend to be hilly, and more congested- taking Kabale - one of the major districts as an example. While it will always make commercial sense for a commercial farmer to invest in such a technology regardless of one's location, and land characteristics, this applies less to tractor hire services, which could be more effective in more tractor friendly terrain.

2.4 Strategies for commercialization and sustainable adoption of small agricultural equipment

Develop an enabling environment

An enabling environment comprising of suitable policies, institutions and regulations is necessary to facilitate the scaling of mechanization initiatives thereby increasing the use of mechanization infrastructure (Sims *et al.*, 2016; Van Loon *et al.*, 2020). The primary focus of government should be the creation of this enabling environment with the aim of developing sustainable private-led mechanization sector that is functioning effectively (Sims and Kienzle, 2006). Areas that need immediate attention include, but are not limited to, appropriate technologies, farmer awareness and capacity building, financing mechanisms, creating effective linkages between actors in the value chain, availability of relevant information to various actors, and effective coordination of mechanization initiatives. Government of Uganda has made concerted efforts to promote mechanization including investment in infrastructure for development and responding to the increasing demand for agricultural machinery operators and mechanics (MAAIF, 2016).

Development of public-private partnerships (PPPs)

Increasing access to mechanization by smallholder farmers requires an environment conducive to private sector participation in the mechanization value chain, especially in the supply of mechanization inputs. It is necessary for the private sector to be supported through public-private partnerships aimed at building this capacity (Sims and Kienzle, 2017). This would be instrumental in increasing access of smallholder farmers to machinery through innovative business models including renting or hiring from service providers and thereby reducing farmers' individual cost burdens of purchasing, owning, and maintaining the machines (Van Loon *et al.*, 2020). Over the recent past, Government of Uganda implemented interventions aimed at promoting the acquisition and utilisation of agricultural mechanisation technologies with focus on development of PPP arrangements. These interventions were envisaged to stimulate ownership and use of agricultural machinery so as to motivate farmers to venture into mechanised agriculture (MAAIF, 2016).

Improved information availability and flow

The adoption of mechanization by smallholder farmers can be enhanced through provision of relevant information through platforms that are suitable for smallholder farmers. Relevant information can include performance of different machines, cost-benefit analyses of mechanized farm operations, services available and profile of farm machinery adopters necessary for making informed decisions (Sims et al., 2016; Sims and Kienzle, 2017; Van Loon et al., 2020). In Uganda, government has prioritised strengthening capacity for technical information acquisition, equipment evaluation and sustainable operation of agricultural machinery through developing, packaging and disseminating easy to use manuals for agricultural machinery and tools; conducting skills acquisition training and demonstration events on use and maintenance of agricultural machinery and tools for farmer groups and service providers (MAAIF, 2016).

Development and promotion appropriate technologies

Strengthen research institutions to continue developing technologies suitable to our local conditions.

Promotion of local manufacture

The local manufacture of user-friendly and scale-appropriate machinery adapted to the farm size, production conditions, and limited resource endowments of smallholder farmers should be encouraged and facilitated (Van Loon *et al.*, 2020). This should however be done through participatory technology development involving partnerships between the private sector, research institutions and farmers so as to build local capacity and reduce dependence on importation (Sims and Kienzle, 2017). In Uganda, government set out to promote sustainable local manufacture and maintenance of suitable agricultural machinery by targeting various strategic commodities through priority actions including establishing a comprehensive agricultural mechanisation policy and strategy, supporting skills development, and identifying priority technologies to be locally manufactured (MAAIF, 2016).

Demand creation and stimulation

Creation of demand (where it is non-existent or insignificant) and its stimulation (where it exists) among smallholder farmers can be facilitated through a variety of strategies including machinery demonstrations and field days during which farmers can learn from other farmers who are already utilizing appropriate machinery (Van Loon *et al.*, 2020). The resulting learning and technology spill-over effects from these initiatives can be an important avenue through which mechanization technology can diffuse to more farmers (Diao *et al.*, 2016). Another avenue for demand creation and stimulation is the development of access to mechanization as a service as opposed to ownership of mechanization infrastructure. Mechanization as a service stream necessitates availability of entrepreneurs, who may be farmers, who are willing to provide the services coupled with an enabling environment that incentivises them to do so (Sims and Kienzle, 2017). Eventually, when sufficient demand forms, private supply chains providing machines and equipment, hiring services, and repair services will form (Diao *et al.*, 2016).

Agricultural machinery is recognized in Uganda as one of the critical farm inputs whose access by farmers is targeted to be increased through government investment. Consequently, government set out to formulate and implement incentive frameworks for acquisition and financing of labour saving technologies including developing incentive packages for farmers to take up mechanisation technologies, sensitising and training stakeholders on strategies to access mechanisation finance, and linking relevant stakeholders to ensure implementation of the selected incentive packages (MAAIF, 2016).

Gender-focussed mechanization

Efforts should be made to ensure that as supply chains for sustainable mechanization options evolve, they are strengthened with focus on improving women's access to farm power through the development of user-friendly, convenient, smaller-sized machinery with woman workers in mind (Sims and Kienzle, 2017). Similarly, incentives are required for the private sector to scale agricultural mechanization initiatives targeting and engaging women farmers and the youth by investing in supportive infrastructure and training (Kirui, 2019). In Uganda, gender was identified as one of the five cross-cutting issues impacting on the performance of the agricultural sector that were to be adequately

mainstreamed in all activities implemented in the sector, including promotion of mechanisation (MAAIF, 2016).

Innovative business models

It is important to identify business models for providing mechanization infrastructure and services appropriate to local conditions (Sims et al., 2016). For example, farmers can be mobilized and trained on bundling their demands for mechanisation services while service providers should as well bundle their supply of mechanisation services. This cluster-based cooperative system for service procurement has potential for reducing transaction costs, improving access to services and increases the bargaining power of farmers.

Research and training

Significant research is required to better understand the mechanization landscape and dynamics including the changing nature of mechanization requirements for different farmer categories, extent and effectiveness of different supply models, and the likely impacts of mechanization (Diao *et al.*, 2016; FAO & AUC, 2018). As part of the strategy for improving mechanisation GoU set out to establish an agricultural mechanisation resource centre for training machinery operators, generating technical information and provision of referral workshop services for testing and evaluating agricultural machinery. In addition, the capacity of technical and vocational institutions to train agricultural mechanics and technicians was to be strengthened (MAAIF, 2016).

2.5 Supply chains for small agricultural equipment and supplementary services in Uganda

Supply chain refers to the processes of production and distribution of a good or service across different actors; the supply chains for mechanization cover the manufacturing and importation of machines, mechanized service provision, and spare parts and repairs services for machinery maintenance (Diao *et al.*, 2016). Thus the farm power and machinery supply chain includes the range of stakeholders including manufacturers, importers and distributors, hire service providers, repair and maintenance providers, and farmers; all stakeholders need to make a profit enabling the supply chain to be sustainable over time (Sims and Kienzle, 2009).

A properly-functioning mechanization supply chain should be able to provide efficient mechanization services to farmers along the whole chain of production. Where private demand naturally occurs, the supply chain that emerges generally is shaped by the nature of the demand, and the technologies favoured by owners and users are typically either developed or imported. On the other hand, lack of a well-functioning mechanization supply chain results in an acute farm power shortage, with detrimental impact on agricultural production and rural livelihoods (Sims and Kienzle, 2009).

When mechanization is introduced without involving the private sector, mainly through governments or international non-governmental organizations, the type of technologies brought in depends on preferences of funders irrespective of existence of established support services for spares and maintenance. On the other hand, private traders tend to import technologies or brands that are

preferred or known by farmers and for which spares and repairs are available (Diao et al., 2016). However, private supply chains do not always have the capacity, at least in the short term, to deliver the full range of machines and services demanded by farmers and thus may require technical, policy, or coordination support to perform efficiently. Whereas public sector efforts to supply mechanization equipment and services have largely failed, the public sector has a role to play in complementing the activities of the private sector, particularly in developing a national mechanization strategy and to cultivate an enabling environment that allows the private sector to operate effectively (Sims and Kienzle, 2009).

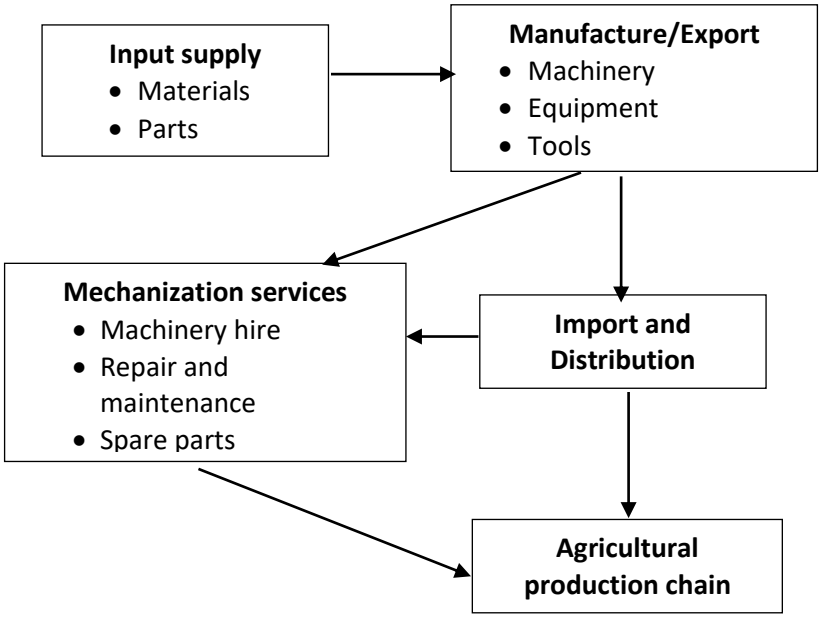


Figure 2.1: Generic mechanization supply chain

2.5.1 Main Sources and suppliers of small agricultural equipment

There is a robust demand for locally fabricated machinery in Uganda, due to a number of key factors including (i) appropriateness of technology - designed to suit local needs (ii) Durability especially as compared to imports from China, (iii) Convenience - easy to tailor to fit into client's specific circumstances and (iv) proximity - given that local fabricators could be more easily accessible compared to importers normally based in a few Urban centers.

The main sources/suppliers of small agricultural equipment in various parts of Uganda are mainly the private sector in form of equipment importers, dealers and local fabricators (Table 1.11).

Table 1.11: Private sector in mechanization development, use and dissemination

Category	Name
Local /domestic manufacturers of agricultural mechanization and processing equipment & spares	• Soroti Agricultural Implements and Machinery Manufacturing Co. Ltd. (SAIMMCO) focusing on Draught Animal Power (DAP) implements and postharvest technologies such as oil presses, rice hullers and nut shellers, • Tonnet Agro Engineering Co. Ltd. currently manufacturing an assortment of postharvest equipment such as maize mills and hullers, groundnut shellers and paste grinders, seed cleaners for all cereals, cassava a chippers and graters, feed mixers and feed mills and forage choppers. • Bora Agro-Technologies Ltd. specialized in the design and manufacture of post-harvest handling equipment.
Importers, distributors and dealers in farm machinery, equipment and their-spares	• Engineering Solutions: Massey Ferguson and other agricultural equipment • Akamba Enterprises: Itimco tractors • Cooper Motors Corporation - New Holland • Farm Engineering: Sunalika • Agrotec - Mahindra • Wavaholdings - Deutz, tried tractor hire & failed • Heavy Duty (Uganda) - Massey Ferguson • Car and General - Tafe tractors • Chinese Machinery (U) Ltd. - walking tractors and post-harvest technologies such as wheat & maize milling equipment, rice hullers and juice extractors • Farm Rite Machineries & Equipment Ltd. - New Holland tractors and other agricultural equipment. • JBT Engineering Works - manufacturing and marketing the motorized Maize sheller and the rice thresher; • Agro-machinery and Equipment Manufacturing Company - manufacturing and marketing the hand cranked maize sheller among others
Non-Government Organizations (NGOs) engaged in agricultural mechanization	• Sasakawa Global 2000 • Soroti Catholic Diocese Integrated Development Organization (SOCADIDO) • Appropriate Technology AT (U) • Vredes Eilanden Country Office East Africa (VECO EA) • Heifer International, • SNV (Dutch Development Organization)
Lead buyers of advanced AE technology	• Large sugar cane, rice, and tea estates • Sugar Estates: Kakira, Lugazi, Kinyara • Tea Estates: Mcleod Russel, Igara, Mukwano • Coffee processors
Informal sector	• Informal-sector small-scale enterprises and artisans *'jua kali'* with no formal education or training plays a key role in the development of AETs such as rice hullers, fire fuelled ovens, rice hullers, maize mills, coffee de-hullers, maize graders, feed mixers, nut crashers, chuff cutters etc.

Source: Wanyama *et al* (2016)

Strengths and weaknesses

Strengths

The keys strengths in the supply chain for small agricultural mechanization include:

- Increasing access to local fabricators - the existence of firms that have made initiatives to import and fabricate technologies for small holder farmers. It should be noted that local innovations tend to align more directly with end users specific needs, in terms of affordability and convenience given. This is making local technology innovations increasingly important in meeting small scale technology requirements of Ugandan farmers.
- Some equipment suppliers have good experience in small manufacturing like TONNET and Musa body. The same companies have been providing repair and service support to small holder farmers and the fact that they are familiar with local needs and working conditions enables them produce relevant technologies for smallholder farmers.
- Most of the equipment fabricators accept installment payments which helps small scale farmers who can't make full payment at once.

Weaknesses

- Limited capacity interns of machinery and human resource for mass production to enjoy economies of scale.
- Limited access to cheap materials e.g. Steel from China
- Limited market coverage with most supply companies concentrated in urban centers, mainly Kampala leaving the rural community almost not served.
- Sometimes their products are not genuine and hence have shorter service lives.
- Most equipment suppliers in Uganda do not offer after-sale services to clients.
- Some of them sell their equipment expensively with the intention of making huge profit margins.
- Most fabricators and equipment suppliers do not have repair centers in rural areas. So in case of breakdown, the equipment has to be taken back to town or sometimes abandoned.

2.5.2 Locally Manufactured Machinery

The two (2) categories of machinery locally manufactured are: (i) farm power equipment - tools and equipment used in primary production and post-harvest handling and (ii) processing equipment- used by SME's adding value to agricultural produce. The most in-demand locally fabricated machinery is that produced for the grain milling and animal feeds sectors. In addition, local fabricators also satisfy the demand for bakery machinery (ovens, dough mixers) and coffee processing machinery (hullers). Surprisingly, the prices of locally manufactured machines are not necessarily cheaper than imports, even against those from China and India.

Local Manufacturers

The local fabrication industry comprises hundreds of actors, widely dispersed across the country, closer to potential customers. This section highlights the most important actors, with potential for synergy and partnership with Dutch traders.

Tonnet Agro Engineering Co. Ltd (Tonnet)

Perhaps the most competitive of the local fabricators, is a company offering agro and food processing machinery and equipment, agro- implements, and spare parts. Started in 1995, it is a formally registered company with membership under USSIA, and UMA. Products of well-respected quality are produced, and the company in addition to marketing products to local agro-processors and farmers is regularly engaged by Institutional buyers such as GoU, WFP, and it also exports products to neighbouring countries including Rwanda, Kenya and Southern Sudan. Tonnet is one of local fabricators with a well-structured workshop layout and management systems and controls. Tonnet has expressed interest in and is actively seeking partnerships with foreign companies, under which local assembly of quality agri-machinery can be made.

Central Engineering Ltd

They are located at the outskirts of the Central Business District, Kampala. The company has not set up a planned workshop layout to allow systematic production. Like most workshops or fabricators, they produce on order and therefore have no finished products on the shelf but have prefabricated parts for the fast moving machines like the maize mills and hullers. They employ about 6 fabricators each with different specialties, though, they all weld but the level of skill varies with the complexity of machines. The most produced machines are maize mills, hullers, feed mixers, dough mixers and ovens respectively. They use basic machines like arc welders, angle grinders, pillar drills, hand drills and sheet rollers. They deal with largely mild steel and there is limited knowledge of the importance of stainless steel by their clients. There is no deliberate effort to educate and give options about the use of food safe materials.

Musa Body Machinery Ltd

It is located in Katwe a busy fabrication hub of Uganda and is one of the oldest fabricators in the business. Musa Body Machinery is famous for being among the first to innovate locally appropriate technology, contributing to the development of local industry. Due however to competition from cheaper, better finished and increasingly accessible imported machinery from China and India, Musa Body has opted to participate in the import and trade of agri-machinery imports. Key imports sold include; sachet packaging machines, dough mixers, bottlers and catering equipment. They still fabricate the maize mills, hullers, ground nut shellers, feed mixers, juice extractors and coffee hullers. The agro processing machines are also made on order because different clients have different and often specialized needs. They also depend on the basic typical machine tools like arc welders, drills, benders and roller

Ramanand Ltd

This is an Indian owned company on 6th Street Industrial Area Kampala, which fabricates agro processing machinery and imports the same. They have a great foothold of the market and make products for commercial farmers. Ramanand produces maize mills, huller, rice mills and polishers, ground nut shellers and feed mixers. The specialized machinery made are the commercial dryers and silos. These are imported and assembled by the company at the client's site since there is limited demand and the number of customers is not sufficient to sustain the daily production of these machines. Ramanand also engages in aluminum profile fabrication.

Technology Research Network Ltd

This company is situated in at the outskirts of Central Business District, Kampala and employees about 6 fabrication experts and calls in specialists depending on the work. This is one of very few companies which can be described as specialized because it does actual engineering design, 3D modeling and then fabricates machinery on behalf of the client. They are specialists in stainless steel, factory maintenance and automation. They produce literally all machines but the main machines are maize mills, ovens, hatcheries and food dryers. The kinds of machine tools in use are the arc welding, drills, grinders, rollers and benders. In the event of specialized work, they sub contract the work to skilled people in other institutions.

Limitations

The capability of the local fabrication industry is limited to the manufacture of "simple" machines which are easy to reverse engineer. More complex machinery such as dairy processing equipment is often beyond the capacity of local manufacturers. In addition, there is limited ability by local fabricators to manufacture stainless steel based products. This gap is created by a combination of factors including (i) a lack of skill, (ii) a lack of equipment and (iii) the high cost of stainless steel. This is a gap that is currently filled by imports. Low efficiency and performance is a major weakness cited by users. Despite the fact that locally fabricated machinery could be more robust, easier and cheaper to build, and therefore most of the time more affordable, quite often, poor design, due to lack of in-depth expertise and capability by local manufacturers, makes machines very inefficient, resulting in high operational costs and downtime.

2.5.3 Locally developed technologies by DABE Makerere University and AETREC

The study has revealed that there are a number of promising technologies for the priority crops and livestock have been developed and piloted by AETREC and Makerere University with good field performance as summarized in Table 1.12.

Table 1.12: Smallholder technology prototypes at Makerere University and AETREC

AETREC	MAK
• NARO Hand Cranked Maize Sheller • Weeders for walking tractors • Cassava chipper (NARO CAS-CHIP-1) • Ridgers (for Irish potato mounds) • Ground nut stripper • Planting rake for millet/sorghum • Motorized forage chopper (NARO FORA-CHOP) • Low cost cages • Ox driven weeders • Ox driven planters • Ox ploughs • Planters	• Animal drawn small grain planter • Cassava chipper • Forage chopper • Groundnut sheller • Motorized maize sheller • Oxen drawn weeders • Ox drawn maize planter • Pasteurizers • Pedal operated coffee pulper • Pedal operated multi-seed cleaner (destoners) • Sorghum thresher • Coffee pulper • Solar dryers

Test results for prototypes developed by the Department of Agricultural and Biosystems Engineering at Makerere University indicate that the cassava chipper, maize sheller, coffee pulper and groundnut sheller require minor improvements for better functionality and also require use of standard food grade material for their construction in order for them to be up-scaled. Therefore, these technologies need to be improved prior to piloting and promoting amongst small holder farmers with follow-up adoption studies to inform technology refinement.

2.5.4 Imported agro Machinery – key drivers, main importers and sources

Drivers

The key drivers of imported machinery are quality and complete lack of feasible technology options. Imported equipment is thought to be of superior quality than the local machines and is preferred where quality and efficiency are key parameters. Similarly, the limited ability for local fabrication where there are shortcomings in the capacity to locally produced specific agri-machinery is also a major factor in the importation of agri-machinery.

Major importers and main sources

The major importers of machinery are Chinese and Asian based importing firms, the leaders among these including (i) Asia Agro Industries, (ii) Auto Sokoni Limited, and (iii) China Huangpai Food Machines- all of whom import a wide range of agri-machinery items. Consequently, the major agri-machinery imports into Uganda originate from China and India respectively. Other important countries of origin for include Arab Emirates, Denmark, USA, and the Netherlands.

Auto Sokoni & Agro Sokoni

Sister companies, these firms import a whole range of machinery spare parts ranging from auto motive parts, maize mills, rice hullers, maize hullers, feed mixers, engines and mortars. Most of their engines are imported from China and so applies to the machines. Interesting to note is that though owned by Indian proprietors, most of the machines sold are sourced from China. This highlights the competitiveness of Chinese imports in the Ugandan market. These companies are affiliated with sister operations in Kenya, from where fabrications of some machinery is done. This is the biggest importer of food processing agri-machinery in Uganda.

China North Machines

China North Ltd is a Chinese company that imports an assortment of machines at a very competitive price and usually the lowest price. It achieves massive sales since Ugandans are price sensitive. They also deal in machine parts and receive orders for any machines required and deliver them to clients in Kampala. They have two showrooms on within the Central Business District of Kampala.

Dairy Machinery Importers

There is presently one leading supplier of dairy equipment in Uganda, Snowman Ltd. This company sells both new and used equipment. They have a dealership with Du Pont and a range of European suppliers. Apart from coolers, homogenizers, tanks, packaging materials among others they too offer maintenance services. They are located on 7th street industrial within the Central Business District.

Tractor selling Companies

The 3 leading tractor companies include (i) Engineering Solutions- sellers of Massey Fergusson tractors; (ii) Tata Uganda (iii) and Cooper Motors Corporation- the sellers of New Holland Tractors. Engineering Solutions is the market leader tractor supply in Uganda.

Categories of imported machinery

The leading import categories relating to agri-machinery include (i) tractors, (ii) grain processing machinery, (iii) packaging machinery, (iv) Dairy processing machinery (v) Machinery for primary production of crops and (vi) Poultry farming equipment.

All **milk coolers** are imported. There is presently no local capacity to build this machinery. The leading supplier of this equipment, Snowman's, deals mostly in 2nd hand equipment. There are also a few other small importers.

Hatchery machinery is predominantly imported. Supply appears dominated by Chinese and Indian imports, with a cross section of hatchery owners interviewed indicating a satisfactory level with the performance of this equipment. There is only one notable local manufacturer of hatcheries - Butenga Chick Star Ltd - whose key competitive advantage is his ability to supply smaller sized hatcheries. Growth in demand for hatchery capacity to meet the fast growing demand for poultry products will continue to present opportunities for imports.

2.5.5 Mechanics and Machinery Hire Service Providers

The main machinery hire service providers in Uganda include:-

I. ***Private owners with tractors which are hired out*** - Main hire service providers are informal and migratory by people privately owning tractors who keep moving from one area to another with linkages to farmers made by brokers who link farmers to tractors in various parts of the country. For instance a tractors can move as far as Kabale from Kiryandongo with variation in seasonal demand.

II. ***NAADS/OWC*** gave tractors to SACCOs, cooperatives, clusters - other farmers can access through lead farmers - pay a dry rate for fuel, operator and service fee at an agreed rate. NAADS/OWC acquired tractors with additional implements including plough, 7-tonne trailers and forage choppers for silage making in selected districts mainly Western Uganda. They target farmers who are organised in clusters. Groups of up to 20 farmers each contributed 1m to raise 20m with a tractor management committee (Case of Lyantonde). Every 3 sub-counties have access to a tractor. Lost some tractors to accidents and cluster committee supposed to repair.

III. ***ENGSOL*** has been trying to station tractors in various stations but haven't yet made a breakthrough is the main supplier of tractors.

As for mechanics and servicing, this is mainly done by other existing automobile garages that are spread in various parts of the country but with most spares procured from well-established tractor supply companies such as ENGSOL.

2.6 Gender analysis of participation in the small agricultural equipment ecosystem

Women make up more than half of Uganda's agricultural workforce, mainly engaged in small scale crop and livestock production. For Uganda, in particular, women have limited access to labour saving technologies (MFPED, 2016) and this limits their full participation in agriculture. IMen and women are often involved in different types of value chains, which result in different sets of needs and priorities in terms of mechanization interventions. However, mechanisation interventions tend to focus on efficiency and quality in mechanisation processes without looking at the socio-economic and gendered contexts in which they are embedded (Kawarazuka, 2018). Gender gaps exist in the hands-on use of technologies as well as in farmers' ability to rent and hire machinery with women's full participation constrained by a number of technical, economic, and cultural barriers (Theis et al., 2018). A major challenge is the misconception that mechanization technologies are operated by men and as such design considerations are based on ergonomic measurements of men and testing mostly involves men. In addition women have fewer avenues to let their needs be known by researchers and technology developers as they are much less consulted by extension and researchers (Shaw, 2020).

Consequently, most equipment introduced is generally suited for work that is traditionally considered to men's tasks such as land preparation while tasks that contribute to women's labour burden such as sowing, weeding, and post-harvest management are not addressed (Shaw, 2020; Eerdewijk and Danielson, 2015). The small-scale agricultural machinery enterprises are dominated by men who are

mainly involved in fabrication, mechanics and supply of spare parts. The involvement of women and PWDs is still low (Table 1.13).

Table 1.13: Participation of women, men and PWDs in small-scale machinery setting

Segment	Women	Men	PWDs
Fabricators		*	
Spare parts dealers		*	
Mechanics		*	*
Hire service providers	*	*	
- Ox traction		*	
- Walking tractors		*	
- Tractors		*	
- Shellers/Threshers	*		
- Mills		*	

2.7 Demand for Agricultural Mechanization and opportunity for investment in mechanization

Agricultural mechanization is the continued application of farm equipment to make activities such as land preparation, crop production, harvesting, processing and transportation of goods more efficient and less cumbersome (Van Loon et al, 2018). It is estimated that the demand from agricultural production will double by 2050, with 70% of the increase coming from developing countries (Brown, 2022). Given the fact that 80% of the 41 million farmers in Africa are smallholders, it is imperative that ways of increasing their productivity is prioritized. In Sub-Saharan Africa, nearly 70% of farm operations are performed manually (mainly by women and children), 20% by draft animal technology and only 10% by mechanical power (Brown, 2022), thus creating a huge opportunity for investment in mechanization of small-holder farmers in this region. For example, 90% of the maize produced in Uganda is cultivated manually on small-scale farms with limited access to appropriate technology and these farms constitute close to 86% of the country's farming community (Obura et al, 2020). It is projected that demand for maize will increase by 4%-8% per annum over the next two decades as a result of increased population (Obura et al, 2020). Meeting this demand will require increased use of small-scale agricultural equipment such as the integrated ox-drawn tool driven by animal draught power for ploughing small-scale maize gardens. It should also be noted that animal draught power can optimally be applied to many alternative uses in addition to providing traction of ox-ploughs during land cultivation. For instance the animals can be used to for drawing planters, weeders, Ox-carts and for pulling other forms of transportation. In Kapchorwa particularly, where the landscape is mountainous with steep roads, a number of clients have already requested for loans from banks to purchase animals and the attached equipment to help them in the different farm operations (Segirinya, 2008).

2.7.1 Identified small mechanization needs for priority crops and livestock

Small Scale Irrigation Equipment

Over dependence on rain-fed crop production makes communities involved more prone to droughts and periods of water scarcity which significantly affect crop and livestock production (Nakawuka, et al 2018). As a result of the ever changing rainfall patterns due to climate change, sustained production of various crops requires affordable and reliable small scale irrigation equipment (Segirinya, 2008). Equipment like treadle pumps, solar powered water pumps, diesel and petrol-powered water pumps can be used to provide water for both irrigation and for livestock. Several small-scale farmers from different parts of the country for example Masindi, Kuumi, Otuke and Mukono have attributed their increase in profits from the farm to using such irrigation equipment to boost their agricultural production.

Maize

Besides ploughing, maize shelling is still a big challenge for small scale farmers in Uganda with many of them still using traditional maize shelling methods like pressing the maize grains from the cob using a thumb, rubbing two maize cobs with each other and beating the maize cobs in a sack using sticks (Nsubuga et al, 2021). There is therefore a need to use manual and motorized mobile and immobile maize shellers for improved maize shelling technologies. Technologies like a solar-charged, two-wheel traction platform developed by Kansas State University suitable for performing field operations such as tillage, planting and weed control with provision for providing power to conduct operations like shelling, threshing and milling can play a significant role in bridging the mechanization gaps in the different value chain nodes (Brown, 2022).

Groundnut

Groundnut is a stable legume and fast becoming cash crop in Uganda (Gardebroek, and Hernandez, 2014). Ground seeds contain 40-50% oil, 20-50% protein and 10-20% carbohydrates depending on the variety (Okello, 2015). With cost of animal proteins becoming increasingly prohibitive, groundnuts are becoming an even more important source of proteins. Groundnuts are consumed raw, roasted, blanched, as peanut better, crushed and mixed with traditional dishes as a sauce. Within the groundnuts value chain, shelling of groundnuts is still a challenge. The traditional way of shelling is to crack the kernels with hands but with the increasing demand for groundnuts, this method is time consuming and cannot match with the increasing acreages. In some areas, shelling is done by artisan fabricated shellers – these have limitations in that they are not fit for the various groundnut varieties grown by farmers. The current practice by local fabricators is to produce one type of sheller going by the 'one-size fits all approach' which results in postharvest in postharvest losses. Hence the need to mechanize the ground nut shelling operation by using either the manual or motorized groundnut shelling equipment.

Key informant interviews revealed that groundnut planting is mainly done manually but there is need for gender sensitive planters to reduce the burden of manual planting. Ox-drawn and tractor drawn planters need slight modification for improved precision. There can also be a deliberate effort to focus on their appropriate calibration to enable timely planting of relatively larger areas in a shorter time. In some areas harvesting and pulling out of groundnut pods is done using ropes. Weeding is mainly manual with some few communities using ox-drawn ploughs for land preparation. Less than 20% of large-scale groundnut farmers use harvesters. Stripping of pods is very cumbersome as it's largely done by hand. Out of desperation, a few farmers are improvising by using motorcycle spokes to do the pod stripping.

Promising Technologies with potential for reverse engineering include Gravelin 25000 USD sheller – which shells 1 bag of g/nuts in 30 minutes. This is too costly and its efficiency could be improved through

reverse engineering. Some of the design improvements could be the hopper resizing to hold more g/nuts.

Cereals and legumes

Currently planting, weeding, spraying and postharvest handling are carried out using manual technologies which defeats quality and quantity efforts by small scale farmers. In the east and bother parts of Uganda, animal traction is commonly used for land opening and the same could be scale up for planting and weeding with technology modification. Failure to produce required quantities has been reported and this has been attributed to predominant use of cumbersome rudimental technologies mainly the hand hoe. The main hindrances to mechanization in some nodes of the sorghum and millet value chains have been limited research emphasis due to the fact that the two crops are predominantly crops of smallholder farmers. Most farmers in Uganda grow different legumes at different times and all these crops undergo the primary processing of threshing which is so demanding in terms of labour, tiresome and time consuming (Geofrey, 2016). Some of the available crop threshers on the market are limited to one crop which prompts the farmers to look for other alternatives for the rest of the crops which is costly. This necessitates the use of a multi-crop thresher that can thresh for example rice, millet, soybean and sorghum without requirement of another thresher.

Other interventions to ease mechanization of value chain activities for cereals and legumes include:-

- NaSARRI is moving towards developing an incubation center aimed at supporting value addition/product development from millet and sorghum e.g. millet-based baby foods
- Promoting and adopting planting in lines/rows for compatibility with selected agricultural mechanical implements.
- Promoting group technology ownership and shared utilization models such as moving from home to home which could create employment for youth.
- Making prototypes affordable, available and accessible with deliberate efforts to attract private sector to support multiplication, maintenance and service provision.
- Capacity building of farmers to utilize the technologies.

Coffee

Coffee is another crop that fetches millions of dollars for Uganda with a production for financial year 2021/2022 totaling to 6.26 million bags worth US$ 862.28 million compare to 6.26 million bags worth US$ 559.16 million for financial 2020/2021 (UCDA, 2022). Despite the high export earnings from coffee, individual small scale Arabica coffee farmers earn less than they should have earned because they cannot afford the expensive wet processing coffee pulpers to add value to their coffee. Hence, they are forces to see their coffee with no value added. Hence the demand for small scale coffee pulpers for Arabica coffee farmers in regions like areas around Mt. Elgon and Mt. Rwenzori is high. The study also focused on harvesting and value addition needs for coffee aware of the fact that coffee ripens unevenly and moreover in the wet season and the fact that manual coffee picking is slow and there are notorious insects that injure pickers. It was also noted that the wet cloudy environment means that the cherries dry at a slower rate. Besides, the excess and usually acidic water is a big challenge for disposal which requires technological innovations to address.

Other challenges and promising interventions include:-

- Coffee weeding is laborious, there is need for simple lost cost semi or fully mechanized equipment to reduce the labor intensiveness.
- Coffee irrigation needs to be addressed especially in water stressed areas.

- Value addition to wastes (husks and fresh red cherries skins), this area need innovation to recover energy, fertilizer and other vital products, its currently totally missing.
- There is need for adaptive design of innovative harvesters aware of the fact that Ugandan coffee doesn't ripen at the same time. Innovative harvesting technology (***selective red cherry harvester)*** to maintain quality during picking. This technology can be based on Artificial intelligence – for only picking red and leaving green cherries behind. It would be good to think about a non-destructive harvesting technology.
- Drying is a challenge for quality control in the coffee value chain. Due to the fact that quality coffee comes with careful and consistent drying, there is need to develop/adopt ***innovate efficient driers*** that dry coffee faster without compromising quality.
- The pulping process for farmers that use the wet process is so wasteful in terms of water usage. There is need for innovations into ***water efficient (semi-dry) pulpers***.
- There is also need to consider low cost coffee washing water recycling and purification technologies and also purification of acidic water and also considering beneficiation options such as its conversion into fertilizers.
- ***Hullers*** to be used by small-scale farmer groups.
- There is need for ***an appropriate irrigation technology*** suitable for coffee and compatible with current agronomic practices to address climate change and related water stress challenges.
- Need for ***non-destructive coffee quality assessment*** technique for quickly checking bean size, moisture content and MC water activity to ease coffee grading.

Potatoes

Potato growing is mainly done in the hilly areas of Fort portal where there are few areas where ploughing using a tractor is possible, majority of people still use the hand hoe which leads to losses as many are cut during harvesting. This necessitates the use of hand operated machines to do the ploughing, land opening, planting, weeding and harvesting. In addition most of the work is done by women – for instance during commercial potato production, women are more reliable sources of labor for field operations. Therefore, gender sensitive potato production technologies such as planters and harvesters are needed. Youth come in at spraying and transportation, which is cumbersome since it is mainly done manually and it is costly to transport potatoes from gardens to the main roads. Appropriate transportation technology is needed to address the transportation challenge. There is a hand operated tractor whose adoption is still low due to lack of capacity to operate it. Some of the identified **technologies include:- p**otato planter (UNASPA), forked hoes which requires power to support and pull and Value addition – small-scale techs to support cottage industries – technologies for slicing (slicers for chips making), washing, sorting and packaging.

Bananas

The study has revealed that the most labor intensive activities for banana are ploughing and digging holes. It was also noted that use of mechanical weeders may not be an appropriate mechanization strategy in well-established banana plantations to reduce drudgery since it would disturb the root system as the plantation establishes itself. Therefore appropriate weeding technologies need to be innovated for bananas. There are also challenges with the chopping of the corms from the underground banana stems for ethanol extraction and this necessitates an appropriate chopper. Some of the identified post-harvest technologies for improvement and optimization include: - peeling machine which takes into consideration/harmonizes the variation in variety and shape of the banana fingers; flour/starch making value addition technology; fiber extraction/processing technology. It was noted that

– a locally developed fiber extraction machine has been developed but its efficiency is still very low and hence requires modification and improvement. For the banana value chain, there is need for reverse engineering of technologies mainly from Philippines, India and Thailand.

Poultry

Besides the crop sector, the livestock sector which includes cattle, poultry, goats, etc. is another sector in Uganda under agriculture where a number of small-scale farmers are involved. Livestock is raised by 74% of the agricultural households in which case the main purpose is for sale with 26% of the agricultural households raising livestock exclusively for sale and an addition 52% raising livestock mainly for sale with some for their own consumption (UBOS, 2022). Only 3% raise livestock solely for their own consumption. Poultry has the potential of transforming lives of key smallholders (majority of whom are women) by increasing household incomes (MAAIF, 2019). Poultry provides its value chain actors an opportunity to leverage the big market for its products and by-products, created by the growing population. Within the poultry value chain, debeaking is one of the activities that is still manually done and time wasting yet very crucial in the proper management of poultry. The first one is normally done at 15 days and the second one at 8-10 weeks of age (MAAIF, 2019). The use of debeaking equipment can fasten the debeaking process for poultry farmers that have 100s of chicken. Also, given the fact that poultry rearing is very common in urban centers where space is limited, the use of poultry cages is a perfect solution to the limited space in such areas. Small hatcheries to service clients "out of the way" of the major hatcheries is another emerging need. According to sector experts, close to 90% 61 of orders for Day Old Chicks (DoC's) are for sizes between 100 and 500 birds. These smaller sized customers are less sensitive to biosecurity considerations, and are not only more flexible in terms of where they source DoC's, but are equally more price conscious.

The identified small equipment challenges in the Poultry sector include:-

Overall the technology-related challenges constraining small scale farmers' desire to intensify production in the poultry sector are to do with infrastructure and equipment set up as outlined below:-

- **Cages** - lack of appropriate **low-cost caging** systems suitable for rearing local chicken, which majority of smallholder farmers are involved in. Cage systems and automated feed delivery systems are mainly imported and as such are very costly and unaffordable. The lack of appropriate poultry production technology leads to inadequate space for poultry production and this contributes to suboptimal production capacities. The lack of appropriate cage systems complicate manure management for beneficiation options.
- **Storage** - The lack of small scale silos to ease feed and ingredient management. Exiting silos are large-scale and are not locally fabricated – e.g. a 30Tonne Silo cost about USD 30,000. The lack of affordable reliable storage systems contributes to poor storage which is evidenced presence of aflatoxins and molds.
- **Feed processing** – lack of low cost (millers, mixers, pelleting machines, bagging and weighing machines). Some efforts have been made locally but the existing prototypes need refinement and fitting to appropriate production.
- **Abattoir – small processing** lines and value addition innovative technologies which exist in developed nations need to be considered – these include:
    i. **De-feathering machine** – to minimize dependence on hot water soaking methods which affect shelf life and quality of the meat.
    ii. **Slicing machine** – to generate uniform meat cuts as demanded by high end buyers.
- Current ***incubators*** are still expensive, and some are relatively large scale – meaning they are not appropriate for smallholders.

- Small scale feed mixer technologies that are affordable are missing for the small farmers.
- Water ***metering systems*** at a small scale are still a big challenge. Farmers use a bucket inverted in a basin and this is not very effective it wastes water by contamination and it also wets the litter.
- There is need to develop innovations in the area of locally made cages from locally available materials to reduce on the caging costs. There is a prototype of a locally developed cage by Dr. Henry Mulindwa which is being piloted at MUZARDI.

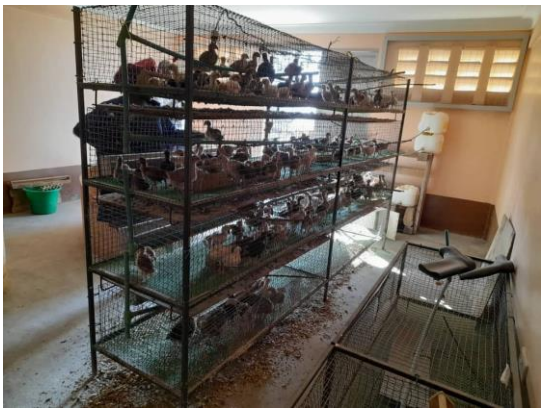


Figure 2.2: Locally developed cage at MUZARDI

- There is need to innovate small scale and mobile feed mixers that can integrate a variety of new feed materials including vegetables and herbs.

Hatcheries

There are a few hatcheries concentrated in Kampala. It is a common thought among most industry actors that the present supply of Day old Chicks (DoC's), is falling far short of existing demand, and the major reasons supporting this thinking is the extensive waiting times experienced by most farmers from order placement to supply which ranges anywhere between 30 to 90 days. According to a fairly recent study, there are at least 13 commercial hatcheries with a combined minimum capacity of only 510,000 eggs a week. In addition to these are several small-scale hatcheries. Taken collectively, it is suggested that there is sufficient local capacity for the production of DoC's. The Industry however is inadequately serving existing markets. The local demand for DoC's by 2012, was estimated at 15 million, of which 11-12 million were locally supplied, with the remaining 3-4 million chicks imported. While major hatcheries have expanded existing capacity, the significant demand and supply gaps signal prospects for viable entry of new hatcheries. There is need for innovate incubators that are based on renewable energy such as solar or hybrid ones that use both solar and electricity as this could reduce on the cost of hatching chickens.



Figure 1.3: Locally developed Incubator at MUZARDI

Cattle

In economic value, cattle are considered the most important livestock although other animals such as goats, sheep, pigs and poultry are equally important (UIA, 2016). Cattle are the main source of meat and milk with the greatest concentration being the "cattle corridor" extending from South-Western to North Eastern Uganda. This corridor covers the districts of Ntungamo, Mbarara, Mpigi, Kiboga, Luwero, Apac, Lira, Soroti, Kumi, Mbale, Moroto and Kotido. Uganda's beef is ranked 5th best in the World because of its yellow fat that does not contain cholesterol mainly because the cattle are naturally grazed (UIA, 2016). An estimated 90% of the national cattle herd is kept under pastoral and mixed small holder farming systems. Commercial beef ranking is limited accounting for less than 10% of the national herd. For milk production, the country has registered an increase in milk production from 400 million litres in 1986 to 2.51 billion litres in 2018 (DDA, 2019). Rural milk collection centers increased from 461 with total installed capacity of 1.7 million litres in 2017/18 to 471, with total capacity of 1.8 million litres in 2018/2019 (DDA, 2019). The value of marketed milk increased from USD 784 million (UGX 2.87 trillion) in 2017 to USD 850 million (UGX 3.1 trillion) in 2018 [14]. Diary processing plants have increased from 100 with processing capacity of 2.7 million litres in 2017/28 to 120 with a total processing capacity of 2.72 million litres (DDA, 2019). Despite the growing of meat and milk agribusinesses, mechanization of farm operations by the small-scale cattle farmers is still low. For example, silage making and milking operations are done manually. Spraying of cattle is still being done using knapsack sprayer which waste a lot time especially when the animals are many. The adoption of hay making equipment, petrol engine driven silage cutter, milking machines, and portable motorized power sprayer can help improve the situation.

2.7.2 Anticipated costs of some identified mechanization needs

The list of agricultural equipment suitable for adoption by smallholder farmers for both crop and livestock subsectors along with their corresponding prices (up to 7,000,000 UGX) is shown in the Tables 1.14 &1.15.

Table 1.14 List of small-scale agricultural equipment and their prices for Crop subsector

EQUIPMENT	ESTIMATED COST	
	UGX	US$
Farm operation		
Hand push seeder (manual planter)	550,000	145
Irrigation Equipment	6,500,000	1,717
Ox-plough	500,000	132
Waking tractor	6,500,000	1,717
Garden Weeder	1,000,000	264
Treadle pump	650,000	172
Motorized garden sprayer	650,000	172
4stroke garden weeding machine	2,000,000	528
Post-harvest Operations		
Immobile maize sheller	4,500,000	1,189
Manual coffee pulper	1,200,000	317
Ground nut paste making machine	5,500,000	1,453
Tarpaulins (UNICEF quality)	300,000	79
Rice Thresher machine	2,500,000	661
Manual groundnut shelling machine	700,000	185
Single crop thresher	3,000,000	793
Multi-crop thresher	4,500,000	1,189
Grain moisture meters	2,800,000	740
Motorized coffee pulpers	5,500,000	1,453

Source: https://jiji.ug/farm-machinery-equipment

Table 1.15: List of small-scale agricultural equipment and their prices for Livestock subsector

EQUIPMENT	ESTIMATED COST	
	UGX	US$
Silage, Hay making machine	2,800,000	740
Milk Cans	150,000	40
Petrol engine driven silage cutter	3,000,000	793
Portable Motorized Power sprayer	850,000	225
Poultry cage	1,600,000	423
Milk Cooler	6,000,000	1,585
Feed mill machine	4,500,000	1,189
Silage bags 90-140kgs	10,000	3
Manual Animal Feed Mixer	2,200,000	581
Feed mixer	8,000,000	2,114
Chicken Automatic Debeaker	900,000	238
Milking machine	4,500,000	1,189
Egg incubator	1,500,000	396

Source: https://jiji.ug/farm-machinery-equipment

2.8 Potential small agricultural equipment

This section of the report focuses on the potential for adoption of small agricultural equipment in Uganda. Value chain nodes whose operation are energy-intensive and/or time constrained will show high potential for adoption. Hence equipment for carrying out operations like land preparation, planting, weeding, irrigation, harvesting, coffee pulping, milk cooling, chicken debeaking and milking will show high potential for adoption. Depending on the enterprise involved, the small-scale farmer can be able to pay for the equipment using the annual profits in the respective pay-back-period. Some of the adopted equipment for the priority crops and livestock value chains are highlighted in section 2.8.1 (Tables 1.16 to 1.24).

2.8.1 Crop value chain

Primary production level is dominated by small holder and subsistence farmers, who produce most of the country's food but rely 90% on hand powered tools to do so, with animal traction supporting only 8% of farm activity, and mechanized equipment accounting for a marginal 2% of farm power. The processing sector on the other hand is dominated by the micro SME's which accounts for up to 80% of food manufacturing companies.

Table 1.16 Land Preparation

No.	Equipment	Description	Photo
1	Animal drawn light weight plough	• Mainly used in Eastern and Northern Uganda. • The plough has a weight of only 28 kg as compared to ploughs in the market which have a weight of 45 - 50 kg. • Has a mean field capacity of 0.065 ha/h and works at an average depth of 75 mm and a width of 230 mm • Ideal for the common small East African Zebu oxen and for donkeys.	
2.	Ox drawn ripper	• Designed to rip a narrow furrow for minimum soil disturbance. • Rippers come in various types and sizes to suit different soil conditions. • Used to support the conservation farming methods being implemented through Climate Smart Agriculture for conservation tillage.	

3.	Ox driven Harrowers	Mainly used in Eastern and Northern Uganda	
4.	Ox-drawn ridgers	Single row ridger for Irish potato mounds	
5.	Walking tractor drawn ploughs	Single axle Moldboard ploughs for walking tractors • Works effectively under local soil conditions • Modifications were made so that the shear and moldboard are easily replaceable	
6	Walking tractor drawn harrowers	As described above	

7	Power tiller drawn moldboard ridge	Two-row moldboard ridger that works effectively under local soil conditions	

Table 1.17 Planting

No.	Equipment	Description	Photo
1.	Hand planters (Jab planters)		
2.	Ox driven planter	Single row planter	
3	Animal drawn ripper planter	Developed as an attachment to the normal plough beam. By changing the seed plate, it plants many large seeded crops, namely, maize, groundnuts and beans. Capacity: 4 acres/day	

Table 1.18 Weeding

No.	Equipment	Description	Photo
1	Animal drawn inter-row weeder	The weeder has a weight of 32 kg with a mean working output of 0.25 ha/h Adjustable in row spacing of 30 - 90 cm SAARI and AEATREC Weeder	
2.	Weeders for walking tractors	Equipment used for soil cultivation by small scale farmers in Uganda include walking tractors, hand hoes, and ox-ploughs	 
3.	Animal drawn knife roller	The Knife Roller consists of a hollow steel cylinder, 6mm thick, approx. 115 - 200 cm wide and 60 - 70 cm in diameter. Ends are welded to be filled with water if needed. Approx. 8 - 12 blunt knives are placed every 19 cm. It is used for mechanical management of weeds in conservation agriculture	

Table 1.19 Crop Protection

No.	Equipment	Description	Photo
1	Knapsack sprayer	Knapsack sprayers typical backpacks with spray guns) are the commonly used sprayers	
2.	Adapted knapsack for manual traction	Multi-row sprayer	

Table 1.20 Harvesting and transport

No.	Equipment	Description	Photo
1	Groundnut strippers	The groundnut stripper consists of a square frame of vertical legs and a horizontal strip of expanded metal fixed on each side of the frame in the form of comb. The stripping of the pods is accomplished by drawing a handful of vines across the comb with a slight force.	

		• These are simple manual equipment designed for plucking groundnut pods from their stems during harvesting. There two models: Single head and Double head. • Output: – Single head is 10 – 11.8kg/hr as opposed to 4.0kg/hr for hand stripping – Double head is 35.8kg/hr. against 15.8kg/hr or the same people stripping by hand – Stripping efficiency: 98.8 – 99% – Maximum pond damage: 0.5%	 
2.	Animal drawn trailer	Some are locally made and used mainly for transportation of agricultural produce	
3.	Tractor drawn trailer	Mainly used for flat terrain transportation	

Table 1.21 Postharvest handling and value addition

No.	Equipment	Description	Photo
1.	Hand cranked maize shellers	Removes maize from the cob and uses humans as source of power with an output capacity of 50-60 kg/h. With zero level of broken grain, the hand cranked maize sheller is ideal for shelling home saved seed	
2.	Pedal operated multi-seed cleaner (destoners)	• Locally designed and fabricated with Support from the Makerere Research and Innovation (MakRIF) Government of Uganda Fund. • It is mainly used for cleaning various types of seed.	
2.	Motorized maize sheller	Used to remove maize from the cobs Driven by a 7 hp diesel engine with an output capacity of 1.2-1.4 t/h of clean grain for 1 L of diesel fuel Has shelling efficiency of 99.5%, with 1.2% – 1.8% broken grain.	

4.	Motorised Sorghum Thresher	For threshing sorghum	
5.	Coffee pulper	Manual coffee pulper for wet coffee processing	
6.	Motorized cassava chipper and grater	Used for slicing cassava to small pieces to increase rate of drying Driven by a 3.5 hp engine, with an output capacity ranging from 450 – 600 kg/h of grated/chipped tubers for 1 L of fuel	
7.	Manual cassava/potato chipper	There are locally made chippers but can also be imported. Cost ranges from US$ 300 - 400	

8.	Cassava millers	Some value addition relating to milling of cassava flour is currently done	
9.	Engine-powered Maize Hammer mill	Hulled grain is fed into the mill Hammer mill grinds maize by impact. Grain hit hammer, each other & also sheared between screen holes shattering into fine particles The broken grains are retained until its size is reduced enough to allow it pass thru the screen. Output of hammer mill depends on size of engine, size of screen holes, variety of maize & moisture content of maize	
10.	Ground nut paste making machine	Various models exist on the Ugandan market. Price range from as low as 800,000/= up to 10millio depending on scale and capacity	
11.	Solar dryer	Various models and sizes have been designed and constructed. Price range from	

Table 1.22 Water harnessing and utilization

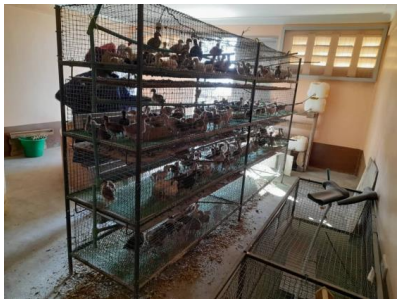
No.	Agricultural Equipment	Description	Photo
1.	Treadle pump	Can pump to total head of 6 m and discharge of 80-100 L/min Can be operated by all gender Contributes to reducing the rate of silting in the water reservoir dams which is due to bad traditional livestock watering practices Adaptable for small-scale irrigation	
2.	Low head hydraulic ram pump	Pump is powered by water Water can be raised to a delivery head of 45-50 m at a fall of 2-5 m Pumps 0.5-1 L/s and can thus irrigate 0.2-0.4 ha per day Easy to maintain and service. All serviceable parts can be fabricated locally using simple tools	
3.	Rain gun sprinkler	• These rain gun sprinkler have from 90°, 180° to 360° spray nozzle rotation • They cover large target areas and spray water droplets evenly. • Very applicable to small scale farming	
4.	Drag hose		

			
	Motorized pump adapted to walking tractor	It can be imported and the cost ranges from US$ 150 – 500	
	Motorized irrigation pump	A variety of irrigation implements are used depending on the financing capabilities of the farm operator and suitability of the implement according to sources of water. In general, centrifugal pumps, submersible pump, sprinkler, drip irrigation etc. are used for irrigation purposes.	

Table 1.23 Farm power

No.	Agricultural Equipment	Description	Photo
1	Low cost multi-purpose tractor dubbed *'MV-Mulimi'*	Capable of performing five functions namely, hauling, threshing, water pumping, phone charging and ploughing, the three-wheel tractor was designed to use a low cost single cylinder 8.5-9 kW diesel engine and a carriage capacity of 1500 kg The tractor can achieve a maximum speed of 35 km/h at no load conditions with an average fuel consumption of 0.04 L/km.	
2.	Walking tractors	• Walking tractors are available in Uganda, and are supplied by several of the leading agri-machinery importers. Depending on capacity, walking tractors cost between 4 and 6 million shillings ($1,300-$2,000); these are primarily imported from China. • From the experience of smallholder farmers, walking tractors provide more productivity than animal traction systems. Walking tractors can also be retrofitted with several implements to support a wide range of on farm services. The waking tractor is an initiative supported by the government through NAADS, and other arms	

Table 1.24 Poultry Value Chain

No.	Agricultural Equipment	Description	Photo
1	Locally made cage	This is a new innovation by Dr. Henry Mulindwa of Namulonge to make cages affordable. It is constructed out of	
2	Double ribbon feed mixer	Feed mixer capacity is 120 kg/h. It is powered by a single phase 1.5 hp geared motor 98 r/min output speed A mixer that blends animal feed ration uniformly unlike the traditional mixers A reasonably bigger capacity, appropriate for large-sized farms Ergonomically variable machine Reproducible and affordable	

2.9 Mechanization needs and gaps for the priority crops and livestock value chain

The study investigated socio-economically feasible small agricultural equipment for the priority crops and livestock. The study revealed that there are a number of missing small scale technologies at the critical value chain nodes of the targeted crops and livestock despite the fact that these would go a long away in increasing their productivity and profitability. Table 1.25 shows the technologies which are currently missing and can be adaptively introduced to ease production and reduce drudgery in specific crop or livestock value chains.

Table 1.25: Identified smallholder mechanization Needs for the priority crops and livestock

Identified smallholder mechanization Needs for the priority crops and livestock

Enterprise	Mechanisation Need
Maize	• Garden tiller/cultivator • Motorized maize shelling technology • Hand-operated seed planter (motorized version available) • Push/pull sprayer (motorized version available) • Single-row maize harvester • Low cost mills • Row weeders, (there are small weeders costing approximately US$ 500 • Fertilizer spreaders for dispensing fertilizer • Equipment for testing grain quality [grain density, MC, etc.] • Small dryers for research purposes – these are usually digitalized • Seed treating technology – can be reverse engineered Movable seed handling trolleys/shelves for seed storage in lab setting – can be reverse engineered • Sub-soilers for deeper land preparation • Cold storage technologies for safe storage of germplasm and breeding materials • Disc ploughs • Hand cranked maize sheller • Sprayers for pest management • Pulping machine for converting maize straw/stover into animal feed • Pedal operated multi-seed cleaner (destoners)
Cassava	• Light-weight ploughs/harrows • Small-scale mechanical sprayers • Cassava planter • Mechanical hoe • Cultivators • Manure spreaders • Small-scale cassava harvester • Multi-purpose carts • Cassava graters • Solar dryers • Hermetic storage technologies • Small engine-powered mills
Irish Potato	• Potato planter • Forked hoes • Light-weight ploughs/harrows

	• Small-scale mechanical sprayers • Light-weight ridgers • Potato planter • Mechanical hoe • Cultivators • Mechanical sprayers • Potato harvester • Multi-purpose carts • Slicers or chips making machine
Sweet Potato	• Light-weight ploughs/harrows • Small-scale mechanical sprayers • Light-weight ridgers • Sweet potato planters • Mechanical hoe • Cultivators • Sweet potato harvester • Multi-purpose carts
Beans	• Small-scale bean harvesters • Jab planters • Small-scale planters cum fertilizer drills • Power weeder • Small-scale mechanical sprayers • Cultivators and fertilizer dispensers • Multi-purpose carts • Multi-crop threshers • Hermetic storage technologies • Light mortised planter • Thresher • Low cost irrigation technologies • Motorized seed dressers to reduce the drudgery at bean pre-production stage • Hybrid dryers • Value addition techs – Auto-fillers – Auto sealers – Auto packing techs – Low cost technologies for making soup thickeners – Low cost boiler for precooking beans – Pedal operated multi-seed cleaner (destoners)
Groundnuts	• Gender-responsive shellers • Ground nut stripper • Semi-automated seed counters • Value addition technologies:- – Testa removing technology – Roaster machine – Peanut butter making machine – Grinding/milling machine

	– Briquetting machine for adding value to g/nut shells – Egg tray making machine for adding value to the shells
Arabica Coffee	• Motorized pitting machine • Motorized coffee picker • Water efficient coffee pulper • selective red cherry harvester • Innovate efficient driers • Non-destructive coffee quality assessment technology • Motorized coffee pulpers • All weather/hybrid Solar dryers • Coffee hullers
Millet & Sorghum	• Multi-crop thresher • Planting rake which creates rows during planting • Oxen drawn weeders – needs optimization • Oxen drawn harrow – developed by NaSARRI for land preparation • Dryers • Light-weight ploughs/harrows • Small-scale mechanical sprayers • Jab planters • Small-scale seed cum fertilizer drills • Manure spreaders • Mechanical hoe • Cultivators • Small-scale harvesting and threshing machinery • Multi-purpose carts • Hermetic storage technologies • Multi-purpose mills
Cattle	• Mechanical hay making machine • Motorized forage chopper (NARO FORA-CHOP) • Milk cooler • Milk mechanical milk cooling technology • Pasteurizers • Evaporative coolers
Bananas	• Push motorized mowing machine • Hand push/pull manure spreader • Fibre extraction machine • Flour/starch making value addition technology • Peeling machine • Cooling/refrigeration Technology
Poultry	• Small hatcheries/Incubators • Low cost cages to address critical constraints faced by today's farmer including limited space, feed optimization and theft of stocks • Chicken debeaker machine • Small scale silos for feed storage • De-feathering machine • Water metering systems

	• Slicing machine • Pelleting machine • Destoners for removing stones • Automated feeders • Conveyor system for egg collection in cages • Small poultry slaughtering equipment – cones • Digital supported weighing technology for enabling ascertaining growth rates of chicken in a group – e.g. special basket

2.9.1 Strategies to ease adoption and commercialization of mechanization technologies

It should be noted that a lot of research and development work has been done by various research and education institutions including Makerere, Busitema, Kyambogo University, and Agricultural Engineering and the Appropriate Technology Research Centre (AEATREC), Namalerere among others. These efforts have generated prototypes of several promising smallholder targeted equipment which are included in Table 1.25. This is a good starting point in the direction towards multiplication of locally proven technologies and gives hope to availability of technical capacity to build on to reproduce and maintain the equipment. Some of the plausible strategies to ease adoption of small holder targeted mechanization technologies include:-

- Ensuring that planting and agronomic practices are compatible with the mechanization strategy.
- Ensuring that small scale mechanization strategies are targeted to agro-ecological zones as increased demand and adoption of technologies in specific agro-ecological zones can help to increase demand for mechanization support services and private sector can only get attracted into the sector if their involvement makes business sense.
- Mounting deliberate smallholder technology sensitization campaigns to effect attitudinal and perception change amongst smallholder farmers and making them aware of the direct benefits to productivity and profitability of reducing drudgery during the specific crop and livestock value chains and selling value added products as opposed to raw products. This can be buttressed with technology awareness campaigns (practical demos, field days, technology tours, etc.) to various farmer groups.
- Mechanization interventions should be linked to affordable power sources with a deliberate effort to improve power sources for specific technologies.
- In order to ease acquisition and utilization of the technologies there is need for deliberate efforts to ease individual ownership and supporting technology hire services. Adopting “a complementary package approach” to ensuring that farmers have a complete set of prerequisite technologies across the priority crop and livestock value chain.
- Joint engagement of AEATREC and Universities in prototyping innovations and conducting adoption studies and promoting proven concepts and innovations

2.10 Demand and supply analysis of agricultural equipment

2.10.1 Factors influencing demand for, supply of and utilization of the equipment

The study revealed the following as the factors influencing demand for, supply of and utilization of small agricultural equipment:-

- Increasing transformation of small holder farmers from subsistence into commercially oriented, profit focused farmers – appreciative of and enabled to access productivity enhancing inputs, and machinery;
- More prominent role of organized farmer groups and cooperatives in linking small farmers to productive and high value assets such as through the collective ownership for instance of tractors, and milk cooling and processing equipment.
- increasing participation of the mid-income population into agribusiness activities, and consequently the increased demand for high quality and productivity enhancing technology, such as greenhouses
- Large scale commercial farming is on the rise, driven by foreign, local and joint venture businesses.
- Increasing penetration of tractor hire services, which are being recognized as not only more efficient, but cheaper than the alternatives of manual or animal powered systems.
- Becoming more difficult to access cheap labour, particularly as free “Universal education” has absorbed the youth into schools
- The level of financing targeted at Agriculture is on the increase, driven by increased capacity and confidence by financial institutions in managing the risks posed by agricultural financing.

3 CONCLUSIONS AND RECOMMENDATIONS

3.1 Conclusions

The following conclusions can be drawn;

- The key factors influencing the demand for, supply of, and utilization of small agricultural equipment are: the increasing transformation of small holder farmers from subsistence into commercially oriented, profit focused farmers – appreciative of and enabled to access productivity enhancing inputs, and machinery; more prominent role of organized farmer groups and cooperatives in linking small farmers to productive and high value assets through collective ownership for instance of tractors; increasing participation of the mid-income population into agribusiness activities, and consequently the increased demand for high quality and productivity enhancing technology; increasing penetration of tractor hire services, which are being recognized as not only more efficient, but cheaper than the alternatives of manual or animal powered systems; becoming more difficult to access cheap labor, particularly as free "Universal Education" has absorbed the youth into schools; the level of financing targeted at Agriculture is on the increase, driven by increased capacity and confidence by financial institutions in managing the risks posed by agricultural financing.
- A number of socio-economically feasible small scale technologies which are suitable for the priority crops and livestock are available in Uganda. These are either locally fabricated or imported, and majority can be reverse engineered to fit priority crop and livestock enterprises.
- The key barriers to small scale technology adoption are mainly the weaknesses in technology transfer, high acquisition costs, and lack of awareness of existence, availability and gainful operation of specific technologies.
- The main drivers of small scale agricultural mechanization have been: the growing importance of commercial farming coupled with reduced labor availability exacerbated by rural urban migration, reduced production cycles attributed to climate change and variability, and increasing shift towards value added agricultural products for increased profitability.
- The main suppliers of small agricultural equipment in various parts of Uganda are mainly the private sector in form of equipment importers, dealers and local fabricators. The key fabricators include: Tonnet Agro Engineering Co. Ltd, Central Engineering Ltd, Musa Body Machinery Ltd, Ramanand Ltd and Technology Research Network Ltd. The major importers of machinery are Chinese and Asian based importing firms, the leaders among these being Asia Agro Industries, Auto Sokoni Limited, and China Huangpai Food Machines - all of whom import a wide range of agri-machinery items. The major agri-machinery imports into Uganda originate from China and India respectively. Other important countries of origin for include Arab Emirates, Denmark, USA, and the Netherlands. However, there are challenges with quality and service life of most of the imported equipment such as mills.
- There is a high demand for locally fabricated machinery in Uganda, due to a number of key factors including: - appropriateness of technology - designed to suit local needs; durability especially as compared to imports from China; convenience - easy to tailor to fit into client's specific circumstances and proximity as local fabricators could be more easily accessible compared to importers normally based in a few Urban centers. Nonetheless, the capability of the local fabrication industry is limited to the manufacture of "simple" machines which are easy to reverse engineer. Most of the locally produced equipment are characterized by low performance and inefficiency due to lack of in-depth expertise and capability by local

manufacturers, resulting in high operational costs and downtime. There is also limited ability by local fabricators to manufacture stainless steel based products due to a combination of factors including: a lack of skill, lack of equipment and the high cost of stainless steel

- There are very low levels of adoption of small scale agricultural mechanization in the value chains of the priority crops and livestock, consequently small scale agricultural mechanization levels amongst smallholder farmers are still too low at less than 10%. There are a number of missing relatively affordable technologies with high potential to transform smallholder agricultural productivity and profitability for the important nodes of each of the priority crops and livestock. Fortunately, more than 50% of the technologies are already existing in the country, some have already been pilot-tested, some are proven and require scaling while others are promising and require minor modifications and retesting prior to roll out in the appropriate agro-ecological zones. However, there are also promising imported technologies which can be reverse engineered and produced to suit the Ugandan context.
- The gender analysis part of this study revealed that most small scale equipment introduced locally or imported is generally suited for work that is traditionally considered to be men's tasks such as land preparation while tasks that contribute to women's labour burden such as sowing, weeding, and post-harvest management are not addressed. Participation of youth and people with disabilities in the small-scale agricultural machines setting is still limited because of lack of feasible incentives to attract them into the sector.
- There are some relatively improved but rather costly technologies which are suitable for the sensitive nodes of the value chains (land preparation, post-harvest handling and value addition which require innovative business models such as sharing amongst farmers so as to maximize returns on investment.
- There is a robust demand locally fabricated machinery in Uganda, due to a number of key factors including: appropriateness of technology, durability compared to imports from China, convenience and proximity compared to importers who are normally based in a few urban centers.

3.2 Recommendations

- Adopting a centralized equipment acquisition and hire model" can help to address challenges of affordability. With the centralized system, equipment could be jointly acquired or even accessed through hire schemes by farmers within a common interest in a group investment club such as Savings and Credit Cooperative Organization (SACCOs) in a community. For instance Agro-machinery hire services can be an approach - where a group can hire and use a relatively costly equipment, while planters and shellers may require a good management system based on the socio-economic setting. However, there are bottlenecks associated with collective ownership of technologies such as unwillingness to contribute to maintenance and repairs which need to be addressed to make it a plausible strategy.
- There is need to emphasize supply of quality equipment while prioritizing imported agricultural technologies for promotion, adaptive development and reverse engineering. This will require involvement of UNBS to enforce quality standards for imported and fabricated small scale agricultural equipment in a bid to enhance service life and competitiveness of small scale technologies.

- There should be equipment targeted capacity building and strengthening of local mechanics for repair, artisans and technicians in fabrication, operators on proper use and operation and basic maintenance to be able to maintain and multiply the identified technologies to ensure sustainability. Capacity strengthening of fabrication workshops involved in fabrication of smallholder should be considered so that they are well equipped to churn out various types of equipment acquisition. This could also involve improving technology access through demonstrations and availing proven technologies to help target farmers operate the technologies and appreciate the benefits. There is also a need for a deliberate sensitization campaign to effect attitudinal and perception change amongst smallholder farmers, making a deliberate effort to make them aware of the direct benefits of embracing technology to boost production and the benefits of selling value added products as opposed to raw products among others.
- Local artisans, private sector and universities could jointly work together to address the capacity challenges. Adaptive technology development should be supported by building local capacity in Research and development. There is need for capacity building on gender based gaps to ensure that local artisans are able to design and fabricate gender-sensitive equipment and to spearhead reverse engineering of highly demanded but mainly imported technologies targeted to smallholder farmers.
- There is need to adopt "a complementary technology package approach", which ensures that farmers have a complete set of prerequisite technologies across the crop value chain (e.g. hullers, chipper, branding and packaging equipment, etc.) rather than selective targeting of some value chain nodes as a precursor to aggregating produce, collecting marketing and selling.
- The study has revealed that public sector efforts to supply mechanization equipment and services have largely failed, thus the need for a joint effort between public and private sector with the public sector developing a mechanization strategy and cultivating an enabling environment that allows the private sector to operate effectively.
- In order to foster sustainable mechanization support services, there is a need to have genuine spare support services in close proximity with farmers adopting specific technologies. The spares can be pooled together through capital based common interest and machinery use coupled with capacity building support for the artisans to enable them to produce and rightly fix first worn-out parts e.g. yokes appropriate for equipment targeted to different crops. It is also deemed wise to support the establishment of common use repair centers at regional level to ease access.
- There is a need to explore use of ICT to help farmers get easy access to information on varieties, inputs, and weather forecast data including signals of when to plant using affordable digital platforms.
- There is need to promote farming systems that are compatible with relevant mechanization to ease adoption and maximize benefits from application of smallholder mechanization.
- There is need for innovative but sustainable financing mechanisms to ease acquisition of relatively expensive equipment.
- There is need for deliberate efforts aimed at increasing the participation of youth and people with disabilities in the small-scale agricultural machines setting as either fabricators or operators on farms.

- There is need to identify and partner with private sector off takers targeting the priority crops and livestock (e.g. The Grain Council of Uganda, breweries, and UGACHICK), research and technology development institutions to prototype and reverse engineer the needed technologies.
- There is need to promote and pilot the technologies already developed by AETREC and other agricultural engineering departments at the various universities amongst smallholder farmers and support their improvement through adoption studies after a specific period of deployment. The technologies for AETREC include: motorized forage chopper, hand planters, ridgers, ground nut strippers, weeders for walking tractors, ox-driven planters and weeders, ox ploughs, hand planters and the hand cranked maize shellers. For Makerere University the technologies which require slight improvement prior to pilot include: animal drawn maize planter, animal drawn small grain planter, cassava chipper, forage chopper, groundnut sheller, innovative coolers, motorized maize sheller, oxen drawn weeders, pasteurizers, pedal operated coffee pulper, pedal operated multi-seed cleaner (destoners), sorghum thresher, and the coffee pulper.
- The priority technologies for reverse engineering include: - hatcheries, low cost cages, chicken debeaker machine, coffee harvester, peanut butter making machine, ground nut grinding/milling machine, ground nut roaster machine, banana peeling machine, banana Fiber extraction machine and Hermetic grain storage technologies.

4 REFERENCES

Anderson J., Learch E C. ., and Gardner S. T. (2016). National Survey and Segmentation of Smallholder Households in Uganda. Understanding Their Demand for Financial, Agricultural, and Digital Solutions.

Brown L. (2022), “Power for Mechanizing Small Farms in Sub-Saharan Africa Share this content :,” 2022.

Daum T. and Birner R. (2020). Agricultural mechanization in Africa: Myths, realities and an emerging research agenda. Global Food Security 26, https://doi.org/10.1016/j.gfs.2020.100393

Daum, T. 2015. “Sustainable Mechanisation: A Hard Row to Hoe.” Rural21 49 (2): 20-22. DOI: 10.13140/RG.2.1.4392.4249

DDA, “Annual Performance Report FY 2018 / 2019,” 2019.

Diao X, Silver J. and Takeshima H. (2016). Agricultural Mechanization and Agricultural Transformation. International Food Policy Research Institute.

Diao X., Cossar F., Houssou N., Kolavalli S. (2014). Mechanization in Ghana: Emerging demand, and the search for alternative supply models. Food Policy, 48(C): 168-181.

Diao X., Silver J., and Takeshima H. (2016). Agricultural Mechanization and Agricultural Transformation. International Food Policy Research Institute (IFPRI), Discussion Paper 01527

Diao, X., Cossar, F., Houssou, N., & Kolavalli, S. (2014). Mechanization in Ghana: Emerging demand and the search for alternative supply models. Food Policy, 168-181

Eerdewijk and Danielson K. (2015). Gender matters in farm power. Royal Tropical Institute

FAO & AUC (2018). Sustainable Agricultural Mechanization: A Framework for Africa. Addis Ababa. 127pp.

Food and Agricultural Organization (2006): Farm power and mechanization for small farms in sub Saharan Africa

Food and Agricultural Organization (FAO) (2008): Agricultural Mechanization in sub-Saharan Africa: time for a new look.

Food and Agricultural Organization (FAO) (2013): Mechanization for Rural Development: A review of patterns and progress from around the world

G. M. Diiro and Sam A. G. (2015). Agricultural technology adoption and nonfarm earnings in Uganda: a semi parametric analysis. The Journal of Developing Areas, Vol. 49, No. 2 (Spring 2015), pp. 145-162

Gardebroek U., and Hernandez (2014). “Gender impacts on adoption of new technologies: the case of improved groundnut varieties in Uganda,” African J. Agric. Resiurce Econ., vol. 9, no. 4, pp. 300–308, 2014.

Geofrey O. (2016), “Design and construction of an improved multi-crop engine powered threshing and seperation machine for legumes,” no. May, 2016.

Houmy K., Clarke L. J., Ashburner J. E., and Kienzle J. (2013). Agricultural Mechanization in Sub-Saharan Africa Guidelines for preparing a strategy. Integrated Crop Management Vol. 22, FAO, Rome.

J. Van Loon, (2008). L. Woltering, T. J. Krupnik, F. Baudron, M. Boa, and B. Govaerts, “Scaling agricultural mechanization services in smallholder farming systems: Case studies from sub-Saharan Africa, South Asia, and Latin America,” Agric. Syst., vol. 180, no. December 2018, p. 102792, 2020, doi: 10.1016/j.agsy.2020.102792.

Kawarazuka, N., Prain, G., Forsythe, L., Mayanja, S., Mudege, N.N., Babini, C., Polar, V. (2018). Gender in Agricultural Mechanization: Key guiding questions. Lima, Peru: CIP.

Kirui K. O. (2019). The Agricultural mechanization in Africa: micro-level analysis of state drivers and effects. ZEF – Discussion Papers on Development Policy No. 272, Center for Development Research, Bonn, pp. 56.

MAAIF, "POULTRY TRAINING MANUAL For Extension Workers In Uganda," 2019. [Online]. Available: https://www.agriculture.go.ug/wp-content/uploads/2020/07/MAAIF-Poultry-Manual.pdf

Ministry of Finance, Planning, and Economic Development [MFPED] (2017). Access and Use of Agricultural Equipment in Uganda: What are the Hindering Factors? BMAU Briefing Paper, 19/17, Government of Uganda.

Ministry of Finance, Planning, and Economic Development [MFPED] (2016). Are agriculture sector policies and interventions in Uganda gender sensitive and responsive? BMAU Briefing Paper, 2/16, Government of Uganda.

Mottaleb K., Krupnik T., and Erenstein O. (2016). Factors associated with small scale agricultural machinery adoption in Bangladesh: Census findings. Journal of Rural Studies, 46, pp. 155 – 168.

Mrema G. C., Baker D., & Kahan D. (2008). Agricultural mechanisation in sub-Saharan Africa: Time for a new look. FAO Occasional Paper 22.

Nakawuka P., Langan S., Schmitter, P. and Barron J., "A review of trends, constraints and opportunities of smallholder irrigation in East Africa," Glob. Food Sec., vol. 17, no. October 2017, pp. 196–212, 2018, doi: 10.1016/j.gfs.2017.10.003.

National Planning Authority [NPA] (2020). Third National Development Plan (NDPIII), 2020/21 – 2024/25

Nsubuga, D., Kabenge I, Zziwa A., Kiggundu N. , Wanyama J. and Banadda N. (2021). Improving Maize Shelling Operation Using Motorized Mobile Shellers: A Step towards Reducing Postharvest Losses in Low Developing Countries. Intech Open, 2021, [Online]. Available: http://dx.doi.org/10.5772/intechopen.101039

Obura L. J. M., Kambugu R. K., Kiggundu N., Balimunsi H. K., and Kyamanywa S.,(2020). "Development of an Integrated Tool for Small-Scale Maize Farming in Uganda," Agric. Sci., vol. 11, no. 07, pp. 653–666, 2020, doi: 10.4236/as.2020.117042.

Okello D. K. (2015). Groundnut seed production manual for Uganda. 2015. [Online]. Available: https://www.researchgate.net/publication/277558622_Groundnut_Seed_Production_Manual_for_Uganda_2015

Orwothwun C. and Qutieshat A. (2022). Agriculture Value Chain Finance in Uganda: A Brief Review of Literature. Open Access Library Journal, 9, 1-18. doi: 10.4236/oalib.1108645.

Pingali P. (2007). Agricultural mechanisation: adoption patterns and economic impact. In: Evenson R. and Pingali P. (Editors). Handbook of Agricultural Economics, Volume 3, Pages 2780 – 2804, Elsevier B.V., DOI: 10.1016/S1574-0072(06)03054-4.

Segirinya J., "Production Investments," pp. 39–66, 2008.

Shaw G. (2020). Gender and Agricultural Mechanization in Ethiopia: Rapid assessment.

Sims B. and Kienzle J. (2017). Sustainable agricultural mechanization for smallholders: what is it and how can we implement it? Agriculture, 7(50); https://doi.org/10.3390/agriculture7060050

Sims B. G. and Kienzle J. (2006). Farm power and mechanization for small farms in sub-Saharan Africa. FAO, Rome

Sims B. G. and Kienzle J. (2009). Farm equipment supply chains. Guidelines for policy-makers and service providers: experiences from Kenya, Pakistan and Brazil. FAO, Rome

Sims B., Hilmi M. and Kienzle J. (2016). Agricultural mechanization: A key input for sub-Saharan African smallholders. Integrated Crop Management Vol. 23, Food and Agriculture Organization of the United Nations.

Takeshima H. and Lawal A. (2018). Overview of the Evolution of Agricultural Mechanization in Nigeria. International Food Policy Research Institute, Discussion Paper 01750

Takeshima, H., Nin-Pratt, A., & Diao, X. (2013). Mechanization and agricultural technology evolution, agricultural intensification in Sub-Saharan Africa: Typology of agricultural mechanization in Nigeria. American Journal of Agricultural Economics, 1-7

Theis, S., Sultana, N., Krupnik, T.J. (2018). Overcoming gender gaps in rural mechanization: Lessons from reaper-harvester service provision in Bangladesh. Gender, Climate Change and Nutrition Integration Initiative (GCAN) Policy Note 8; the Cereal Systems Initiative for South Asia (CSISA) Research note 9. Dhaka, Bangladesh.

UBOS, (2022). "Annual Agricultural Survey (AAS) 2019 – Statistical Release, 2022.

UCDA, "Uganda's coffee exports for FY2021/22 hit 6.26 million bags despite the drough," 2022. [Online]. Available: https://www.ugandacoffee.go.ug/node/238

UIA, "Agriculture (Beef)," 2016.

Van Loon J., Woltering L., Krupnik T. J., Baudron F., Boa M., and 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://doi.org/10.1016/j.agsy.2020.102792

Wanyama J. *, Banadda N., Kiyimba F., Okurut S., Ahamada Zziwa, A., Isa Kabenge, I., Mutumba, C., Tumutegyereize, P., Allan John Komakech, J. K., Kiggundu, N. (2016). Profiling Agricultural Engineering Technologies for smallholder Agriculture Mechanization in Uganda. Agric Eng Int: CIGR Journal, 18(4):40-51.

World Bank (2010). Farm Mechanization: A New Challenge for Agriculture in Low and Middle Income Countries of Europe and Central Asia. Regional Review. World Bank Working Paper No. 53318-SAS