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Transforming Africa's Agriculture Value Chains

A Malabo Montpellier Panel Report 2018


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Foreword

Mechanization in the African food and agriculture system needs rethinking and fresh strategies. To raise agricultural land and labor productivity, make rural employment more attractive, and achieve future growth and poverty reduction agendas, governments must embrace the technological, policy, and institutional innovation opportunities afforded by mechanization. Mechanization is not just about tractors. Successful mechanization along the value chain will have to be a priority in future development and growth agendas for African smallholder agriculture. Mechanization is also not just about technology; its success depends on organizational innovations, such as reliable services and cooperation arrangements for and with farmers.

The current report—*Mechanized: Transforming Africa's Agriculture Value Chains*—summarizes the findings of a systematic analysis of what countries at the forefront of progress in mechanization have done right. It analyzes which policy decisions were taken and which interventions were implemented to substantially increase the uptake of mechanization. The report takes a broad perspective on mechanization, including technologies along the entire value chain and how they relate to agricultural development and job creation. The report shows what can be done to sustainably mechanize agriculture to increase production and enhance value addition across value chain segments. The set of policies and practices that are identified, if brought to scale, could have significant impact on agricultural transformation in Africa. The report provides a roadmap for African governments to take concerted action to deliver on the growth and transformation targets set out by the Malabo Declaration and the Sustainable Development Goals.

The Malabo Montpellier Panel, convening 17 leading African and international experts in agriculture, ecology, food security, nutrition, public policy, and global development, seeks to enhance the use of relevant, high-quality evidence to support dialogue and guide policy choices by African governments and their partners. The Panel works with African governments and civil society organizations to provide access to data and analysis that facilitates the design and implementation of policies leading to reduced poverty and improved hunger and nutrition outcomes. The related Malabo Montpellier Forum provides a platform for evidence-based dialogue and exchange among high-level decision makers on African agriculture, nutrition, and food security.

Ousmane Badiane

Co-Chairs, Malabo Montpellier Panel

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THE MALABO MONTPELLIER PANEL

The core mission of the Malabo Montpellier Panel, a group of leading African and international experts from the fields of agriculture, ecology, food security, nutrition, public policy and global development, is to support evidence-based dialogue among policy makers at the highest level. The Panel's reports seek to inform and guide policy choices to accelerate progress toward the ambitious goals of the African Union Commission's Agenda 2063, the Malabo Declaration and the global development agenda. The Panel works with African governments and civil society organizations to provide support and evidence-based research that facilitate the identification and implementation of policies that enhance agriculture, food security and nutrition.

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Introduction

Between 1960 and 1970, African countries witnessed remarkably strong overall economic growth. However, growth performance began to deteriorate rapidly in the following decade, with an average GDP growth of just 1.4 percent per year, while the pace of agricultural growth followed the same declining trends, averaging just 3.2 percent per year throughout the 1990s.[1] By the turn of the century, agricultural growth picked up again, reaching a rate of 4.6 percent per year (between 2002 and 2010). Even during the food and financial crises of 2008–2009, the continent maintained a healthy, positive agricultural growth. Agricultural growth has continued to accelerate into the current decade at an average rate of 5.1 percent—nearly twice the rate of population growth which is 2.7 percent.[2]

But, fifteen years of recovery have merely moved per capita food production back to its level of the early 1960s. The recent progress has been neither long nor strong enough to allow African countries to make up for the ground lost during the preceding decades-long period of economic stagnation and decline. More importantly, with the exception of West Africa, the majority of countries in all the other subregions continue to show agricultural growth rates that fall well below the 6 percent growth target set under the Comprehensive Africa Agriculture Development Programme (CAADP).[3] African countries, therefore, continue to face major challenges that make it necessary not only to sustain the current recovery but to further accelerate its pace.

Africa currently has the highest rates of growth in population, urbanization, and middle-class consumers, which combined are fueling a sharp increase in food demand. This has led to a rapid increase in agricultural import expenditures by African countries. Between 2001 and 2011, the total value of agricultural imports rose tenfold to nearly US$80 billion per year.[4] Failure to further accelerate and sustain growth in the agricultural sector will have major impacts on African countries and global food markets. By missing out on the opportunity to capture a larger share of the growing demand from continental and global agricultural markets, Africa will miss the opportunity to create wealth. At the same time, if food imports by African countries were to continue at their rapid pace of growth, they would put heavy pressure on global food markets. The result would be even higher food import bills and greater food price volatility.

While the recent recovery is encouraging and proof that substantial progress is possible, it is clear from the above trends that more needs to be done to meet future food demands and accelerate agricultural growth and transformation. Fulfilling the poverty reduction agenda through faster, inclusive agricultural growth is still unfinished business. The ultimate contribution of agricultural sector growth to wealth creation and poverty reduction will depend on the extent to which it is linked to increases in sustainable land productivity and labor productivity, especially in the context of rapid population growth.

Africa currently has the highest rates of growth in population, urbanization, and middle-class consumers, which combined are fueling a sharp increase in food demand.

Any future growth and poverty reduction agenda, therefore, must address the technological, policy, and institutional innovations required to raise agricultural land and labor productivity faster than has been the case to date. A key target of such an agenda should be to harness the opportunities for mechanization at each stage of the agriculture value chain.[5] The mechanization of value chains, when done right, can and must be employment-enhancing and need not be labor-replacing.

Currently, Africa is the region with the least mechanized agricultural system in the world. African farmers have 10 times fewer mechanized tools per farm area than farmers in other developing regions, and access has not grown as quickly as in other regions.[6] Furthermore, Africa has the highest share of food loss and waste, which totals 36 percent. The major share of this, about 30 percent, is lost due to poor harvest, post-harvest, processing, and packing processes.[7] The lack of proper storage facilities remains a major cause of post-harvest losses in Africa since cold-storage facilities are non-existent or inaccessible to the majority of smallholder farmers. Technological strategies and innovations along the food value chain could help to decrease these losses.

The use and power of tractors in Africa has barely increased over the past 40 years and remains negligible compared to other regions in the world. In 1980 there were just two tractors per 1,000 hectares; by 2003 this had fallen to 1.3. By comparison, in Asia and the Pacific region there were 7.8 tractors per 1,000 hectares in 1980, with 14.9 by 2003. In 1960, Kenya, Uganda, and Tanzania each had more tractors in use than India. However, by 2005, India had 100 times more tractors in use than all three countries combined.[8] There are strong disparities between North Africa and sub-Saharan Africa: in 2007, only about 37 percent of tractors in Africa were found in sub-Saharan Africa, with West and

Central Africa showing the lowest uptake on the continent, with 9 and 2 percent, respectively.[9]

State-led mechanization efforts across Africa in the 1950s and 1960s failed largely due to widespread governance challenges, such as lack of access to locally adapted tools and machinery and limited or no access to spare parts, qualified operators, and technicians. Programs to address these challenges, including large-scale machinery imports, did not lead to the desired transformation of the agriculture sector. The continent is abundant with stories about brand new tractors being left unused under vegetation at the back of fields or under layers of dust in barns.

However, some countries, such as Morocco and Ethiopia, are now embarking on new efforts towards sustainable agricultural mechanization.

In fact, African governments have stepped up efforts to transform agriculture, often delivering exceptional results. Yet the use of mechanization and new technologies along the agriculture value chain still remains low. This was recognized at the continental level and reflected in the Malabo Declaration, under which countries are committed to make investments in suitable, reliable, and affordable mechanization and energy supplies to achieve a doubling of productivity by 2025. While the increased attention to mechanization is to be saluted, everything ought to be done to avoid the mistakes of the past. This requires learning from past failed experiences in Africa, Latin America, and Asia, but also from more recent programs that have succeeded in achieving real, sustainable progress in terms of agricultural mechanization.

Any future growth and poverty reduction agenda, therefore, must address the technological, policy, and institutional innovations required to raise agricultural land and labor productivity faster than has been the case to date. A key target of such an agenda should be to harness the opportunities for mechanization at each stage of the agriculture value chain.

The Action Agenda

The Malabo Montpellier Panel recommends to African governments, the private sector, research institutions, and development partners to substantially increase their policy attention to and investment in advancing mechanization of agricultural value chains to deliver on the targets set out by the African Union's Agenda 2063 and the Malabo Declaration. In the present report, a set of policies and practices has been identified that, if brought to scale, could have significant impact across Africa. Our analysis from several African countries shows what can be done to sustainably mechanize agriculture to increase production and expand the supply of nutritious crops, while providing the necessary training and skill development to smallholders and young people in rural areas. Such an approach will enhance, not reduce, rural employment.

1 Elevate national agricultural mechanization investment strategies to a priority within countries' national agriculture investment plans

The development of national agricultural mechanization investment strategies that form part of countries' national agriculture investment plans must be encouraged by governments supported by the policy and legal frameworks that incentivize private investments in supply of agricultural equipment.

2 Design socially and politically sustainable mechanization pathways

With new emerging machines and technologies on the horizon, it is ever more important that governments design mechanization strategies that generate new employment opportunities for those working in the rural on- and off-farm economies. This is particularly important given how critical employment is reducing poverty and migration and maintaining political stability.

3 Prioritize mechanization along the entire agriculture value chain

Governments must prioritize mechanization along the entire food value chain, not just at the production level. This calls for investments into the design and development of technologies that improve the quantity and quality of food. More emphasis should be placed on post-harvest and processing technologies that help increase the commercialization of farmers' production by adding value to crops, while at the same time reducing food loss and waste and increasing food safety.

4 Investments in supportive infrastructure and vocational training at scale

Governments must increase their investment to build and improve the necessary infrastructure, such as irrigation and transport infrastructure and electricity grids. This infrastructure is needed for smallholder farmers in remote, rural areas to be able to harness the opportunities of new machines and technologies and facilitate access to markets that are otherwise inaccessible. Furthermore, the provision of training facilities needs to be enhanced to expand access to opportunities for skill development and upgrading along the value chain and cooperative systems and the private sector should engage in this.

5 Create a conducive business and services environment

It is essential to incentivize the private sector to take agricultural mechanization to scale through financial securities, smart subsidies, or tax waivers when they get ready to engage with smallholders. Access to new machinery for farming and processing, in particular by smallholders, women, and youth initially requires a supportive fiscal regime in which sales taxes are low and barriers, such as import duties on agricultural machinery, spare parts, and raw materials for local manufacturing, are minimized. A conducive environment would further help to develop entrepreneurial machine-hiring services through the acquisition of machines and tools for production, processing, and trading. Low income smallholders and women farmers will need to be assisted to be able to pay for such services.

6 Develop an African agricultural machinery industry

Africa needs to further develop its own agricultural machinery industries, based on the region's inventiveness and by taking its specific context into account. The industry may grow as a mix of small, creative start-ups and partly in partnership with established international corporations. The private sector can play a crucial role bringing to scale the design, development, and provision of technologies that have proven impactful. Increased cooperation between the private sector and research institutions is needed to strengthen domestic mechanization efforts by developing locally appropriate and affordable machines and technologies. Substantial investments in public-private partnerships must therefore be made to foster research and development, vocational training, and skills development programs and to stimulate innovation along the value chain. This needs to include the design and manufacturing of equipment and the servicing of machinery and tools, for example through mechanization service centers and technical extension services, including the collective action of farmer organizations.

7 Empowering smallholder farmers' and women's groups

To bring to scale locally developed and proven technologies, the integrated provision of services, such as "one-stop shops" where farmers receive advice to match their demand with the appropriate technologies and inputs, is needed. As women in Africa continue to make up a significant share of farm labor, they need to be actively involved in the innovations and scaling around mechanization and the development of new technologies.

Different levels of agricultural mechanization

Mechanization along the agriculture value chain ranges from the most basic hand tools to the most innovative technologies, from the production to the processing and marketing stages. If done in the right way, mechanization should meet the needs of all actors in the food system by improving efficiency and effectiveness at all stages of the value chain, being financially viable and generating new employment opportunities. Through novel processing techniques, mechanization can also unlock demand for nutritious foods, reduce losses at the post-harvest stage, and improve food safety standards. Mechanization, if adapted to local contexts and needs, can result in increased farm incomes, improved livelihoods for smallholder farmers, and new employment opportunities, particularly for women, who continue to dominate the informal food processing and trading sectors.

Based on the power sources, three levels of mechanization can be differentiated: human power-based mechanization, animal power-based mechanization, and mechanical power-based mechanization.

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Human-power-based mechanization

Across Africa, 50 to 85 percent of the work on farms continues to be done manually, through human power alone, without the support of animals or machinery. Women make up a significant share of this.[10] It is estimated that the average female labor share in crop production is 40 percent; it is slightly above 50 percent in Malawi, Tanzania, and Uganda, and substantially lower in Nigeria, Ethiopia, and Niger at 37, 29, and 24 percent, respectively.[11,12] The most widespread tools and hand machines include machetes, hoes, spades, garden forks, axes, knives, sickles, manually powered winnowers, and seed drills. Hand tools tend to be used at various stages of crop production and processing. They are easy to handle and can be manufactured locally. However, the production and processing levels they make possible remain low.

Animal-power-based mechanization

Currently, 25 percent of power for land preparation in Africa – such as plowing, seeding, and mowing – is derived from animal-powered tools. Primary tillage, transport, pumping, and milling are other areas where animal power is used to improve agricultural productivity and diversity. Compared to manual farm work, animal-power-based mechanization increases the capacity of production by five to 20 times.[13] The potential draught power of animals varies greatly, according to the type and size of animal and the animal's nutritional status and general condition. The use of animals as a source of power provides economic gains not only for farmers but also for local economies, with new opportunities in retailing, manufacturing, and servicing of implements – as well as through the processing, marketing, and sale of surplus agricultural products.

Engine-power-based mechanization

Engine-powered machines currently provide an estimated 10 percent of the total power for land preparation in sub-Saharan Africa, and they are usually powered by fossil fuels. However, new wind and solar-powered technologies are currently being developed.[14] Estimates show that a farmer using a combination of power-based mechanization and animal power can provide enough food to feed up to 50 people, compared to just six when using draught animal power alone.[15] There are smaller, frugal innovations and larger-scale machinery that can be moved across farms or hired out. Frugal innovations are defined as innovations that reduce reduce the complexity and cost of machines and tools and their production. While the introduction of mechanical power into agriculture has led to increases in labor and land productivity and has significantly improved the processing and transport of crops, machines also require continued maintenance and at times complex repairs.

In the food processing sector, machines and frugal technologies have allowed farmers to transform their crops and, through value addition, to diversify and improve their incomes. In particular, this generates new opportunities for women farmers, who still dominate the mainly informal processing and trading sector. For example, post-harvest operations such as peeling, chipping, grating, and drying can greatly enhance the value of the cassava crop, allowing farmers to produce fried cassava chips and starch for cooking or flour.[16] The same applies to fruit, such as mango or bananas, that once processed can be sold as dried fruits or jams. Transformed oilseeds, such as peanut or coconut, are used to produce soaps and oil, while processed rapeseed can be used as high-protein livestock and poultry feed.

Mechanization for a better food system

The costs of non-mechanizing

Low levels of mechanization remain one of the main constraints to increasing domestic food supplies in Africa. Post-harvest losses also remain high as a result of improper handling and poor storage capacities at farm levels. In Kenya, for example, an estimated 95 percent of potato damage and loss takes place at the production level and can be ascribed to inadequate harvesting technology.[17] In The Gambia, when NERICA (New Rice for Africa) rice production was doubled between 2007 and 2010, farmers did not have the capacity and tools to harvest and thresh the additional rice, which resulted in reduced quality and amount of produce. In Senegal, high prices for rice in 2009 prompted many farmers to grow a second crop. However, due to the lack of necessary machines and technologies, the harvesting of the second crop spilled over into the period of land preparation for the main-season crop, which substantially reduced the expected additional harvest and income.[18] Studies have shown that the yield penalty incurred by delayed sowing (and weeding) can be as high as one percent per day of delay for many crops.[19]

The use of appropriate machines and technologies, coupled with the right skills to operate them, is a major factor in helping to meet increased consumer demand in urban areas and growing cities. In many cases, however, adequate machinery to process agricultural commodities – to grind the grain, press the oilseeds, or produce starch from roots and tubers – is simply not available, at least not at scale.[20] Estimates indicate that around one million tons of additional milled rice could be available in Africa by halving on-farm post-harvest losses alone through the use of appropriate – locally available, suitable, and adapted – milling machines. This translates to 17 percent of current rice imports per year, worth US$410 million. In addition, such a use of milling machines could potentially lift almost three million people working in rice farming out of poverty.[21]

Furthermore, estimates indicate that over half of fresh fruits and vegetables produced in sub-Saharan Africa are lost or wasted. Nearly half of these losses occur during post-harvest handling and processing.[22] In Nigeria, poor post-harvest handling practices have led to food losses of as much as 20 percent of fish production, 20–30 percent of total grain production, 50–60 percent of root and tuber production, and up to 50 percent of fruit and vegetable production.[23] In many cases, food losses not only lead to food insecurity but also to higher poverty levels.

Access to efficient transport logistics has been found to increase farmers' income by at least 10 percent and up to 100 percent.[24] Transport costs account for one-third of the price of agriculture inputs in some African countries. Poor road infrastructure and quality, isolation from markets, lack of vehicles, and inefficient trucking logistics further increase transport costs, discouraging farmers from commercializing their production due to a lack of profitability.[25] The so-called "first mile" (the distance from farm to the collection point) often only represents 0.4 to 10 percent of the logistics chain length, but 20 to 37 percent of the transport cost for high-value crops such as French beans, bananas, and potatoes.[26] In Kenya's Nyeri County, the cost of transporting onions over the first two kilometers accounts for 10 to 20 percent of the income that farmers would derive from selling their onions. Using motorcycles and animal carts costs 16 to 30 times more, on a ton-per-kilometer basis, than transport by trucks.[27] Improved and more cost-efficient transport systems are therefore essential to minimize the time lags between harvesting, processing, retail, and to reduce overall costs to farmers. Furthermore, adequate temperature control is required to preserve the quality and shelf life of perishable products as they are transported to markets.

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The benefits of mechanization

In addition to its benefits at the production stage, mechanization can contribute significantly to the development of more efficient and inclusive food systems, allowing post-harvest, processing, and marketing activities to become more effective and sustainable, as displayed below. At the post-harvest level, good storage and drying technologies help reduce food losses, improve food safety, and preserve the nutrient content of crops. This allows farmers to store their produce and to negotiate better prices, while consumers have access to more nutritious and varied foods throughout the year.

The benefits of mechanization

- Increases the power inputs to farming activities, hence increasing productivity levels on the same amount of land
- Reduces drudgery in farming activities, thereby enhancing lifestyles
- Improves the timeliness and efficiency of farm operations
- Reduces post-harvest losses
- Accomplishes tasks that are difficult to perform without mechanical aids, including processing and transformation of crops
- Improves the quality and value of work, produce, and processed products
- Provides employment (entrepreneurship) and sustainable rural livelihoods, and
- Contributes to agriculture-led industrialization and markets for rural economic growth.[28]

The risks and challenges of mechanization

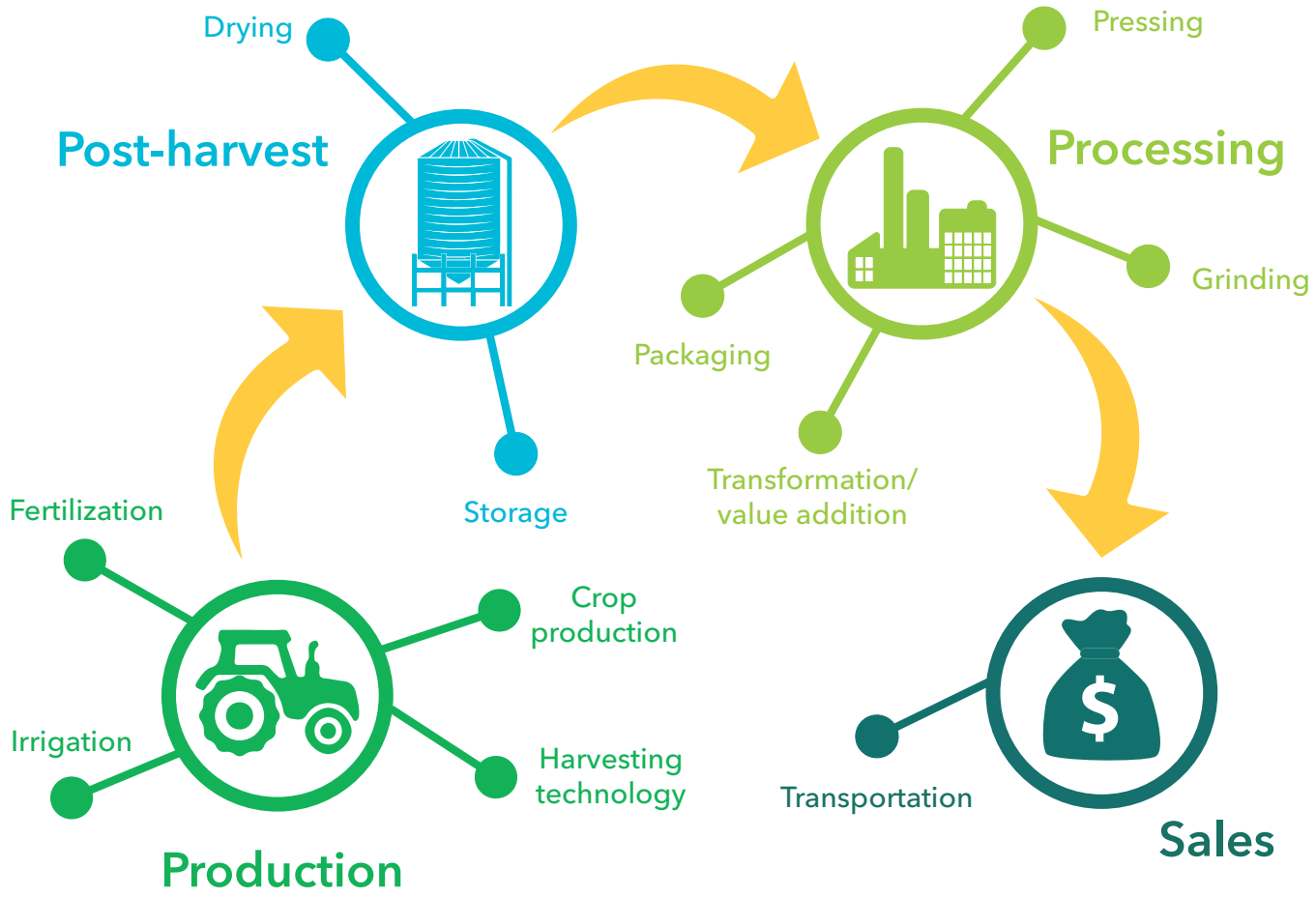
- A possible increase in rural unemployment in areas with no labour shortage
- Risks of soil erosion and compaction due to heavy, fossil-fuel-based machinery
- Misuse and mismanagement of machinery due to a lack of skills and knowledge
- Exclusion of smallholder farmers due to under-developed or too costly provision of machinery, spare parts, and other related agricultural services, and
- Underinvestment in development and testing leading to ill-adapted technologies.

In the processing sector, machinery and new technologies facilitate the transformation of crops, quality enhancement, and value addition. In the sales and distribution stage, reliable and affordable cooling and storage facilities and food transport services are essential to extend shelf-life. This allows smallholders to sell their crops and products more widely, to more consumers and retailers, thereby improving their incomes substantially. The successful integration of smallholder farmers into the agriculture value chain therefore goes hand in hand with the use of mechanized tools and new technologies for food production.

Contribution to food safety, health, and nutrition

Food safety can be improved through mechanized production and processing technologies, including at the very early stages of the production process. For example, the correct application of fertilizer, with the help of modern machines, reduces the chemical contamination of food. Moreover, cooling and drying technologies, as well as storage and transport technologies, play an important role in reducing aflatoxins and other fungus contamination.

FIGURE 1 Mechanization potential in the food value chain



Adapted from: T. Breuer, K. Brenneis and D. Fortenbacher. 2015. Mechanisation – a catalyst for rural development in sub-Saharan Africa. Rural 21, 2: 16-19. http://www.rural21.com/uploads/media/rural2015_02-S16-19.pdf.

Furthermore, modern post-harvest technologies and storing facilities not only help to improve food safety, they also help to preserve the nutrient contents of crops. Taken together, appropriate crating, mechanized drying and packaging, innovations in the cold chain, and temperature-controlled storage, which are especially important for perishable goods, have probably the single largest effect on improving diets and nutrition across the continent. The fresher the products, the higher the nutrient, vitamin, and mineral content consumed. Fresh products are also less prone to contamination, such as microbacterial contamination.

Increased food safety improves the overall nutritional status of both producers and consumers. In children, it can also lead to better growth, mental development, and lifelong achievement. Higher food safety standards reduce the risk of diarrhea and the associated lower nutrient absorption capacity.

A study in Kenya showed that linking farmers to supermarket chains, which requires increased mechanization in both the on-farm and post-harvest segments, increased farmers' incomes and improved their families' diets, reflected in 15–20 percent higher energy, iron, and zinc consumption.[29]

Finally, mechanization can facilitate the commercialization and increase the consumption of neglected yet nutritious crops (such as *Canarium indicum* nuts, *Marama*, and *Bambara*). Although some of these crops are both very nutritious and drought resistant with the ability to produce a reasonable crop even when grown in poor soils, they are not often produced in sufficient amounts. As many of these crops are harvested by hand, post-harvest losses remain substantial. Moreover, manual processing of the crops is very time-intensive. Improved technologies can help to reduce food waste, increase supply and improve quality and food safety.[30,31]

Successful mechanization practices and innovative technologies

Although the level of mechanization remains low, there are many examples across the continent, of innovative technologies and successful mechanization practices improving the capacity of smallholders and other operators to grow, store, process, transform, and transport their crops and products.

Successful small-scale practices at all stages of the agriculture value chain

At the production level

Improved irrigation techniques - The Pedal Pump (PEP)

The Pedal Pump (PEP) is a mechanic irrigation tool for tapping into wells, rivers, lakes or even small ponds, to facilitate water supply to farms and homes. It is used in more than 10 countries across Africa including Kenya, Tanzania, Senegal, Niger, Burkina Faso, Uganda and Mozambique. The main advantages of the pump are its durability and ease of use, both resulting from its simple yet robust cement and wood construction. The pump can be easily assembled and manufactured locally, and in most cases it can be repaired by farmers themselves.

From an ecological perspective, the pump is very valuable, since it does not depend on fossil fuels and only draws relatively small amounts of water. An average of 60 liters of water can be extracted per minute from a depth of three meters using the pedal pump.[32] A study conducted in Magoma, Tanzania, revealed that with the use of the PEP the average farm size was tripled, 58 percent of farmers had diversified their crops and on average, farmers had doubled their yield.[33]

Rice thresher-cleaner

Manual threshing is labor-intensive, arduous and mainly carried out by female rice farmers. In northern Senegal, expensive and often unreliable combined harvesters failed to provide an answer, and the only available type of small-scale thresher was not very efficient, being unable to separate grains from straw after threshing. To improve the efficiency of rice threshing, Africa Rice and the International Rice Research Institute (IRRI) in the Philippines, identified a prototype Asian rice thresher-cleaner, which was adapted to local needs through a partnership with the Senegalese Institute of Agricultural Research (ISRA), the Senegal River Valley National Development Agency (SAED), local manufacturers, and end-users. The aim was to develop a thresher-cleaner that was affordable, locally constructed, and appropriate for smallholders' needs. Whereas manual threshing yields one ton of paddy per day, the thresher-cleaner produces six tons of paddy, and with a grain-straw separation rate of 99 percent no additional labor is required for sifting and winnowing. The price for one thresher-cleaner is approximately US$5,000, with a lifetime of five years. The thresher-cleaner has since become the most widely adopted machine in Senegal's rice sector, with more than 50 percent of the total paddy produced in the country threshed with this thresher-cleaner.[34]

The two-wheel tractor

Based on the experience in Bangladesh, where the agriculture sector is also dominated by smallholder farmers and relies heavily on small machines, smallholders in several African countries have adopted two-wheel tractors for use on their farms. Two-wheel tractors are small and inexpensive, and can be coupled with energy-saving farming techniques such as conservation agriculture, while ensuring profitability for farmers, service providers, and other private-sector actors in the value chain. Moreover, two-wheel tractors can be used for multiple purposes, including transport, post-harvest operations, and water pumping, which leads to high annual rates of return on investment. The two-wheel tractor also lends itself for the hiring-service market. In Bangladesh, for example, although almost all farmers have access to two-wheel tractors, only about one-third of farmers own one. In several countries, including Kenya and Tanzania, two-wheel, toolbar-based seeders or tow-behind seeders are used to seed both larger and small grains, such as maize and cotton or wheat and rice farmed under conservation agriculture. These seeders minimize soil disturbance and maximize the fraction of crop residue retained as surface mulch. Furthermore, two-wheel tractors can also be used in transport, post-harvest operations, and water pumping, and simple equipment, including trailers, threshers, and water pumps can easily be procured or produced locally.[35]

At the post-harvest and storage levels

Solar-powered cold stations

Perishable foods, especially fresh fruits and vegetables, start to deteriorate as soon as they are harvested. They lose weight, texture, flavor, nutritional value, and appeal. Cooling significantly slows down the rate of deterioration, thereby increasing the shelf life of the produce. Solar-powered cold stations for storage and preservation have been introduced in major Nigerian markets, such as the Relief Market in Owerri, Imo state. In this design, energy from solar panels mounted on the roof-top of a cold room is stored in high-capacity batteries, which feed an inverter which, in turn, feeds the refrigerating unit. The walk-in cold room is made of 120mm-thick insulating panels to retain cold. Farmers pay a daily fee of US$0.28 per crate, each crate having a capacity of three tons. The cold stations extend the freshness of perishable foods from two days to 21 days and reduce post-harvest loss in markets and farms by up to 80 percent, increasing farmers' incomes by up to 25 percent.[36,37]

Solar tunnel dryers

Sosai Renewable Energies started working in 2004 in Nigeria to address the issues of poverty and rural development by increasing access to energy and clean water. In Nigeria, peppers represent a valuable cash crop, with an annual harvest that often equals about 40 percent of annual cash earnings for many families. Yet much of the region's peppers are wasted. They are dried outside on the tar roadside, which exposes them to birds, rodents, and rain, as well as contamination from dust and debris. In 2016, the company set up two Innotech 18-meter solar tunnel dryers in Kaduna State, which can be rented by local farmers. The dryers produce clean, high-quality dried peppers; they have the capacity to dry the harvest in half the time required by traditional methods, thereby enabling farmers to dry twice as much of their produce and sell it at premium rates. Since 70 percent of the post-harvest activities are undertaken by women, the company aims to work mainly with female farmers, putting them in charge of renting out the dryers and handling the instalments. Hence, the dryer has also led to economic and social empowerment for women.[38,39]

In the processing sector

Cereal processing

La Vivrière is a local microprocessing company, created in 1992 by a female farmer in Senegal. All products, which are marketed under the brand name WIIW ("Bravo" in Wolof), are based on millet, maize, and cowpea, the most widely grown and consumed crops in Senegal and across West Africa. In 1996, due to the growing demand for its products, La Vivrière started mechanizing the processing segment to increase its daily production capacity. In replacing small-scale artisanal milling, which used domestic cooking utensils and family labor and where all millet processing operations were done manually, 80 percent of the most strenuous tasks were gradually mechanized through the use of dryers and mills. Furthermore, the packaging and labelling of manufactured products has changed significantly, moving from unprinted polyethylene bags to printed, and then multilayered, packaging and product-specific cardboard cases, using barcodes and other commercial information to comply with international trade standards. Initially, products were sold door to door, but now they can be found in supermarkets and at wholesalers and retailers across the country. Some products are also exported to Europe, the United States, and Asia.[40]

Mango processing

Mangoes are grown widely across the eastern province of Kenya. During peak mango season, which lasts from December through March, the supply of mangoes greatly exceeds the demand, leading to high losses for farmers. The Arid Lands Resource Management (ALRMP) project has worked with women mango farmers to maximize profits and reduce losses by facilitating access to fruit processors to process and transform surplus mangoes. Training and an advance of US$4,200 allowed the 40 members of the women's group to invest in a fruit processor, which can produce up to 100 liters of mango juice and pawpaw jam in less than an hour. The juice is then blended with preservatives, hot water, and citric acid to produce a higher quality juice that can compete with other products on the market. The introduction of mechanization in the processing segment has greatly improved the women's income since mango juice sells for US$1 per liter, compared to a mere US$0.01 for four mangoes.[41]

In the transport sector

Donkey carts

In Mauritania, pack donkeys are used to carry water, goods, and people. Recently, the use of carts pulled by donkeys has increased and improved the capacity to transport water, produce, forage, materials, traded goods, people, and urban waste.[42] The cart components are made in Senegal and Mali and assembled in small workshops in Mauritania. Carts cost US$180–US$260 each, implying that some US$5 million has been invested in them over a period of 20 years, and both urban transporters and rural families have found cart investment profitable.[43]

Motorized tricycles

A large proportion of agricultural production in the Pru District of the Brong Ahafo Region of Ghana occurs in rural farming communities remote from the district capital. To facilitate the transportation of crops to markets and retailers, motorized tricycles with a small load-carrying capacity were introduced by the Government of Ghana in 2015. A survey of 137 farming families found that about 97 percent were able to access a means of transport within 24 hours of harvest, compared with 50 percent before the tricycles were introduced. About 33 percent of survey respondents were able to transport more of their agricultural produce than before, and about 94 percent reported considerable savings on transport costs. Access to affordable transport has also reduced losses as farmers do not have to delay harvesting or store produce at home, where spoilage can be high. Some 45 percent of respondents reported no on-farm losses, and 78 percent reported reduced losses from thefts, bushfires, animal destruction, or physical damage. The tricycles are now assembled in Ghana, reducing their cost and making them available even in the remotest areas. The tricycles also enable extension agents to reach hard-to-access areas.[44]

Milk collection and processing

Nearly 90 percent of the milk consumed in Senegal is imported in the form of powder. The productivity of local cow breeds is low, at an average of just 0.7 liters per day, primarily because of lack of fodder. Because of this, and due to limited access to markets, farmers do not view milk as a source of income. In 2005, a local company, the Laiterie du Berger, started processing milk produced by local herders in northern Senegal. The company set up a milk collection system using motorized tricycles to collect milk twice a day from about 800 herders within a radius of 50km around their factory. The company provides herders with fodder for the cattle, veterinary support, and a guaranteed price for their milk. Through an increased and stable income, herders gain opportunities in education, energy provision, and health services. The company now employs more than 100 people across the country and its products, *Dolima yogurt* and *crème fraiche*, are distributed in more than 8,000 points of sale in Dakar and other smaller towns and villages.[45]

Innovative emerging and future technologies

Most farms in Africa have yet to mechanize their production activities, which creates an opportunity to build future strategies on new and emerging technologies that can make the workplace—on and off the farm—safer and more productive while creating employment for the next generation across the value chain. Agricultural mechanization will be augmented by emerging technologies, such as drone technologies, robotics, artificial intelligence (AI), deep learning, machine learning, Internet of Things (IoT), embedded systems and software, intelligent sensors, Big Data, and autonomous agricultural and farming equipment. Just as biological innovations and plant breeding are altering the map of production possibilities and profitability, digital technologies will have considerable implications for the future competitiveness of African farmers in global and regional markets.

For example, by automating tractor steering, farmers of grain, cotton, sugarcane, maize, soya bean, and other crops in Africa stand to gain benefits that include (but are not limited to) the following:

- Reduced operator fatigue and operator experience requirements; sourcing of seasonal skilled labor is increasingly becoming a challenge for many primary producers
- Reduced risk of equipment damage
- Reduced machinery overlap error, resulting in reduced input costs for seed, fertilizer, and pesticides, and
- Allowed adoption of controlled-traffic farming practices, which have delivered reduced soil compaction, nutrient loss, and soil erosion and increased soil health.

GPS guidance has allowed operators with minimal experience to efficiently operate complex equipment. GPS-guided tractors and planters accurately position and automate farm machinery, although cost-effective technologies where the driver monitors systems, are a long way from unmanned operation or being deployed on African farms. These emerging intelligent mechanizations and "smart" agricultural artefacts and equipment (embedded with smart sensors and technologies) will improve, simplify, and accelerate performance. They will also gather, continuously and in real time, complex data that will facilitate improvements in productivity, predictability, and risk-minimization, resulting in new opportunities and efficiencies along the value chains.

Another emerging area is machine telemetry and connectivity for remote farming support. Combining telematics with on-board modems allows remote support, monitoring, and control of farm machinery. Controller software updates can be performed, commands sent, and work orders received remotely, as long as the machines are within a mobile network. As an increasing volume of data is being both uploaded to and downloaded from farm machinery, robust mobile networks and high internet speeds are essential.

While the above technologies may still be out of reach for the large majority of African farmers, now is the time for governments to invest in creating the policy, regulatory, and institutional conditions as well partnerships with the private sector to harness and encourage their use for the benefit of African small farms. Advances in robotics and its application to agriculture are happening fast around the world, and the share of farmers that can already benefit from digital technologies in African agriculture is also growing fast, taking into account that farms ranging from 10 to 20 hectares represent the fastest growing segment in some countries in Africa and already account for more than 5 percent of the farm area in several countries.[46] In addition, IT applications are already being used to facilitate the sharing of agricultural machinery, also referred to as 'uberization'. Such services, which operate for instance in Nigeria, Kenya and Tanzania, are using mobile technologies to link machine owners to farmers and help them keep track of their equipment.

The mechanization of traditional agriculture ecosystems and value chains will continue to experience disruptions, as seen in other industries. How African countries position themselves to harness and deploy digital technologies will determine the future competitiveness of African agriculture and its contribution to African economies. While such technologies may still be out of reach for the large majority of smallholder farmers, now is the time to devise appropriate strategies to equip the next generation of farmers.

Drivers and challenges for agricultural mechanization

Opportunities for agricultural mechanization

The emergence of medium-scale farmers

Although smallholder farmers continue to make up the largest share of farmers in Africa, in some countries there has been a rise in the number of medium-scale farms in recent past years. This has been driving demand for increased mechanization and contributed to a rise in the share of new tractor owners. Medium-scale farms, defined as having a farm size between 5 and 100 hectares, account for a rising share of total farmland and now control roughly 20 percent of total farmland in Kenya, 32 percent in Ghana, 39 percent in Tanzania, and more than 50 percent in Zambia.[47] In Tanzania, the likelihood of purchasing a tractor rises once land size is greater than six hectares. In northern Ghana, half of tractor owners cite land expansion as the primary motivation for investing in tractors.[49] The increased number of medium-scale farmers who are also tractor owners creates new potential for hiring-out services to cater to the needs of smaller farmers, who are otherwise unable to afford investing in larger scale machinery or technologies.

Hello Tractor

Hello Tractor is an agricultural technology company focused on improving food and income security for smallholder farmers reliant on expensive and often unavailable manual labor. Hello Tractor has developed a technology to increase and optimize tractor activity in Africa by connecting tractor owners to farmers through an Internet-of-Things (IoT) digital solution, which bridges the gap between traditional farming and more technologically advanced approaches. The platform simplifies complex data to make tractors profitable as business assets, even in smallholder farming systems. Hello Tractor's technology is an off-the-shelf monitoring device that, when fitted onto a tractor, allows equipment owners to better manage their machines on the farm using an app. Each monitoring device is equipped with an international SIM card, providing GPRS and SMS capabilities for data transmission, and each is built to withstand the demands of agricultural wear and tear. The monitoring device tracks the tractor, relaying critical information to both home base and the operator, providing 24-hour visibility of tractor assets in the field. If the monitoring device is tampered with or removed from the tractor, the owner is notified immediately. The technology fits onto any brand of tractor to help owners manage machine fleets in the field, minimize fraud, and maximize machine value.[48]

Urbanization and the rise of the processing sector

Africa is rapidly urbanizing, with the number of people living in cities projected to increase from 470 million in 2015 to 770 million by 2030. Rapid urbanization, population growth, and increasing incomes all put pressure on Africa's food system to produce more varied and processed foods. While capital cities across the continent are rapidly growing, smaller cities, towns, and villages are also burgeoning. This means an increase in market outlets closer to farmers, which could generate new opportunities in the agriculture value chain. Between 2010 and 2030 the value of urban food markets in sub-Saharan Africa is projected to more than triple, from US$150 billion to US$500 billion.[50]

While urbanization provides new opportunities for agricultural development for large-scale processors and retailers, it is crucial that smallholder farmers be well integrated into the food systems and be equally able to harness these new opportunities. Barriers limiting smallholders' access to inputs—and, crucially, financing—need to be removed to enable locally adapted agricultural mechanization.

Opportunities through the rise of the non-farm economy

In some countries, migration from rural to larger urban areas has led to a rapid decline in farm labor supply. In Ghana, the share of agriculture in total employment has fallen from 60 percent in the 1980s to 40 percent today. The resulting shortage of manual labor, particularly noticeable during peak periods, can lead to a rise in rural wages. Between 1991 and 2013, agricultural real wages across Ghana grew by nearly 7 percent per year. With the rising cost of labor, farmers are more inclined to invest in machinery or to make use of machinery and technology-hiring services where they are available and affordable.[51]

The rise of public private partnerships for mechanization

Mechanization offers opportunities for new and innovative models of public-private partnerships (PPPs) at every stage of the agriculture value chain. There is also scope

for partnerships between the public and the private sectors and research institutions to develop and design new machines and technologies appropriate for local contexts, and to engage in the manufacturing, maintaining, and repairing of related equipments and tools.

Across Africa there are increasing examples of successful partnerships between the public and the private sector. Under its Food and Agriculture Sector Development Policy, the Government of Ghana has sought to mechanize the agricultural sector, working with the private sector to look after the day-to-day provision of farm inputs, including the provision of machinery and support services. As part of the Ministry of Food and Agriculture's Accelerated Agricultural Mechanization policy, about 5,000 30-50kW tractors were imported and made available to farmers and other private-sector operators, giving them the opportunity to acquire tractors within an agreed repayment arrangement.[52] Another intervention in Ghana aims to support the private sector in setting up commercially viable Agricultural Mechanization Services Enterprise Centres (AMSECs) that make tractors, combine harvesters, and planters available at strategic locations. The AMSEC concept was initiated in 2003 to provide timely and affordable mechanized services to farmers who cannot afford agricultural machinery on their own.[53] Each AMSEC was allocated a package of five tractors with basic implements, such as plows and harrows, as well as a trailer. According to the Agricultural Engineering Services Directorate of the Ministry of Food and Agriculture, the decision to allocate five tractors to each center was based on the expectation that each AMSEC could serve about 500 small-scale farmers per season, with average landholdings of two hectares per farmer. Eighty-nine AMSECs had been established by 2011.[54] In Morocco, under the government's Green Plan, the acquisition of agricultural equipment by farmers is subsidized through the Agricultural Development Fund. The objective is to stimulate increased private investment in the agricultural sector and guide it, through targeted subsidies, toward activities that make better use of the country's agricultural potential.

Key challenges in agricultural mechanization

Investment in research and development

Research and development (R&D) into mechanization includes both fundamental scientific research and practical machine development and testing. However, both public and private underinvestment in R&D remains a challenge in Africa, and to date only a few African countries have invested in upgrading their R&D facilities. In Nigeria, the National Centre for Agricultural Mechanization aims at mechanizing Nigeria's agriculture sector by developing simple needs-based technologies that reduce drudgery, increase farm productivity, and improve farmers' efficiency and incomes. Along with other countries such as Ethiopia, Kenya, and Ghana, Nigeria is learning from Bangladesh's experience in agricultural mechanization, in particular its R&D in the use of mechanized technologies such as two-wheel tractors.[55]

In most African countries, the public sector remains the key driver of scientific research, whereas the private sector has traditionally focused on the development of new or improved technologies and machines to increase its business activities. There are cases where the private sector contributes to funding for scientific research that is carried out in universities or in national agriculture research institutions. Nevertheless, there is a lot more that needs to be done by the private sector in working more closely with research institutions, including universities and national research institutions, in the development of machines and technologies that are appropriate to local contexts.

Financing

One of the biggest challenges to successful mechanization across Africa is access to finance. Most farmers across the continent depend on their own savings to buy agricultural inputs, tools, and machinery. The significant upfront cost of agricultural machinery and new technologies is far beyond

the reach of most smallholder farmers, who typically lack collateral for bank loans. This holds them back from investing in machinery. Collective ownership can be a solution; however, it requires time for members to accumulate adequate funding, as well as strong cooperative management and training in machinery use.[56]

Although in some parts of the continent a rise in medium-scale farmers is visible, African agriculture is still dominated by smallholders, who farm an average of one or two hectares. And even among medium-scale farmers loan access is very limited: for example, in Ghana, only 3.4 percent of medium-scale farmers benefited from loans to purchase tractors in 2014.[57] Therefore, smallholders across the continent increasingly rely on hiring services and opportunities for multifunctional tractor use, including using tractor engines to power threshing machines or water pumps. However, the hiring-service market is still in its early stages in most African countries, and both medium-scale farmers and non-farmer entrepreneurs face uncertainty about whether sufficient demand exists. While some farmers occasionally use tractors for carting crops from their fields, motorized tricycles, both imported and locally assembled, remain a more popular option in Africa's rural areas for transporting goods and people. These tricycles are more affordable and consume less energy than most large tractors. As a result, tractors are largely used for plowing, with some owners also using the tractor engine for maize shelling. In Ghana, 90 percent of the revenues generated from tractor service provision are derived from plowing services. The limited opportunities for multifunctional usage further increase the perceived risk of investing in tractors, discouraging would-be owners or hiring-service providers from purchasing tractors and providing services to other farmers.[58]

This is where innovative modalities to lower the cost of access through "Uberization" and other hiring- service models offer real opportunities. They also provide viable alternatives to costly subsidy programs and government-run procurement and distribution schemes.

Meeting local needs

Another challenge is the availability of well-adapted machines for local production systems. Locally produced machinery is usually low in quality and high in price. Provision of spare parts, advice, and other services is often underdeveloped, particularly in remote areas. Adaptation of machinery to current production systems and farmers' needs is urgently needed. The private sector also needs to step up its efforts to provide adequate maintenance and repair services. In many countries, the distribution of both locally manufactured and imported machines and technologies is organized through governments, development partners, or in some cases the private sector. The limited capacity to manufacture mechanization equipment locally increases dependence on imported machinery.

Currently, a majority of the more advanced and powerful machinery is imported from Asia, Europe, and the United States. However, there is often a disconnect between the needs of local smallholder farmers and the design of imported tools and machinery. Smaller land plots mean that certain machinery and technologies are not suitable to meet the needs of smallholder farmers; imported machinery might also not be readily affordable to most smallholders or might simply be unavailable in rural areas.[59] Furthermore, limited access to favorable credit terms for both private importers and potential buyers constrains the import of new machines and keeps private importers and customers concentrated in the second-hand machine market. Moreover,

import procedures are often cumbersome and time consuming, which increases transaction costs and lengthens delivery times. Machinery and spare parts imported by freight shipment can take two to six months to reach rural areas in Africa.[60, 61]

Locally made products are usually manufactured by state-owned and -operated companies, private industrial companies, or informal artisans. The informal sector generally manufactures only simple tools and animal draught tools, whereas larger, structured companies have access to the facilities and technologies to manufacture more powerful and advanced equipment. However, the presence of state- owned manufacturing companies often leads to unfair competition, since these industries are often heavily subsidized and in many cases are given priority in state tenders. The domestic private sector in turn faces challenges related to a poor business environment, cash flow and financing problems, high import duties on raw materials, and high taxation.[62]

In Cameroon, a big factory has recently been forced to cease manufacture of tools and animal traction implements due to high taxation on raw materials and spare parts while imported finished items are subjected to lower taxes and duties.[63] In order to meet the needs of smallholder farmers and other operators along the value chain, the capacity to manufacture and adapt technologies and machines needs to be urgently scaled up. In particular, aligning the complexity of equipment with available skills and the cost of production with financial realities would boost adoption rates, above all among smallholders.

Maintenance and repair

With little extension support, many smallholder farmers still lack the knowledge and skills to operate mechanized equipment and technologies. This can lead to misuse and mismanagement of machinery, especially of more sophisticated equipments.[64] Public and private extension and training services do not easily reach remote areas. In addition, low literacy rates among smallholders may further hamper an efficient use of mechanical equipments.[65] Evidence shows that in many African countries, tractors are primarily used for land preparation and transportation, while other operations, such as seeding and harvesting, continue to be carried out manually.

In addition, farmers are often reluctant to invest additional fees for a second plowing or for levelling and harrowing and instead choose a one-time plowing. In Ghana, for example, only a small fraction of tractors are used for a second plowing or for harrowing, although the harrowing attachments are imported by the government at subsidized prices. Moreover, timely and quality repair services, along with reliable supplies of spare parts, are often unavailable, preventing machines from fully functioning during peak plowing

seasons. In many countries, only a few private dealers provide after-sales services.

Increased investment in institutional and physical infrastructure to expand access to skills development and upgrading is therefore critical. In Morocco, 52 agricultural vocational training centers across the country improve the technical and competitive conditions of agriculture businesses and farms by meeting their skilled human resource needs and by training qualified technicians.[66]

Environment

When combined with poor land management practices, the improper implementation of mechanization can lead to increased pressure on already fragile agro-ecosystems by accelerating soil erosion and compaction, promoting unwanted forest and land use change, and encouraging the over-use of chemical inputs.[67] It is therefore crucial that future mechanization pathways are designed in the most sustainable ways possible. Looking at the long term, countries may consider opportunities to leapfrog stages of technological development through the design and adoption of equipment based on alternative sources of energy and advances in digital technology. These machines will need to increase productivity along the entire value chain while minimizing the cost to environment and the agricultural ecosystem.

Employment

Ideally, mechanization strategies are designed in a way that enables social and economic progress, in particular of those living and working in rural economies, both on and off the farm. Mechanization, as outlined in this report, can not only lead to increased levels of farm productivity, it can also create new opportunities along the agriculture value chain, for example in the processing and marketing stages. However, under some conditions, mechanization may well cause an increase in rural unemployment. It is thus critical to not artificially pursue mechanization when there is no actual demand, for example, in areas where there are no (seasonal) labor shortages and to not subsidize machinery for large scale operations. It is crucial that mechanization strategies be economically and socially sustainable and that they retain or rather generate employment opportunities, particularly for rural populations. In this context, training, skill development, and capacity building and strengthening are all essential.

Skill development and training

Harnessing the demographic dividend

Currently, Africa is home to 1.2 billion people, of whom 60 percent are under the age of 35. The continent's youth population is expected to continue to grow throughout the remainder of the century, more than doubling from its current levels by 2055. In 2015, 226 million youth ages 15–24 were living in Africa, accounting for 19 percent of the global youth population. By 2030, it is projected that the number of youth in Africa will have increased by 42 percent. Every year, an estimated 30 million young people will join the employment market, and Africa's urban labor markets are breaking under the pressure of young people migrating from rural areas into the cities.[68, 69]

Across Africa, youth are struggling with high unemployment and living in poverty. Currently, more than 70 percent of the young population live on less than US$2 per day.[70] According to the International Labour Organization (ILO), youth are twice as likely as adults to be unemployed, and the growing mismatch between the demand and supply for certain skills remains the main driver of high unemployment rates.[71] Although agriculture continues to be the predominant employment sector, among young people agriculture is often viewed as outdated, unprofitable, and hard work. Yet, this is not necessarily the case. Agriculture is a dynamic sector, offering a multitude of opportunities along the entire value chain.

The above numbers suggest a clear imperative: If governments can develop clear strategies on how to attract and support Africa's rural youth to succeed in agriculture, the youth bulge can yield a powerful demographic dividend with tremendous impact on African economies. Increased adoption of agricultural mechanization—especially machines and technologies that are small, affordable, easy to maintain, and adapted to local contexts, such as the two-wheel tractors, solar-powered cold storage facilities, and tunnel dryers—could stimulate jobs and entrepreneurial opportunities for young people in each segment of the agriculture value chain.

Strengthening national capacities – skill development and training

The African Union (AU) has identified agriculture and rural development as key priority areas for which technical and vocational training and skill development are crucial.[72] Without these new skills, indigenous industries, including small-scale crop production, and traditional and informal education and training systems will not adequately spur development. The AU therefore recommends that "member states develop and implement policies and strategies that would provide training opportunities so as to ensure that half of Africa's youth will obtain new or improved skills".[73]

At present, only 2 percent of students in Africa are enrolled in agricultural programs at universities, compared with 26 percent who study humanities.[74] At the secondary school level, agriculture has been introduced as a compulsory or optional subject in some countries; however, in most countries agriculture and agriculture-related training does not feature in the schools' syllabus, and where it does, a strong focus is placed on agricultural production. Other important post-production aspects, such as processing, value addition, and packaging, are not included, and neither are the technical skills needed for animal breeding, machine handling and repair, and dairy technologies. This leads to a roadblock in the growth and expansion of agriculture-related industries in rural areas.

As a result, more than half of rural youth pursue work or training other than farming and often end up underemployed or unemployed. This gap between skills and available jobs also explains why Africa's youth resort to employment in the informal rather than the formal sector.

The question of skills development and upgrading cannot be solved within the traditional general education system. The large majority of current farmers are out of school, yet they need access to training to adapt and expand their skills. So do many of the youth graduating from the traditional schooling system, who might consider entering the agribusiness sector. Moreover, skilled labor is needed in all segments of the agribusiness value chain to deal with specific tasks and handle equipment properly. Such skills can only be acquired in specialized training institutions dedicated to the agribusiness professions.

In sum, without increased attention to and investment in strong vocational training and skill development at scale, African countries will be unable to harness the opportunities of their burgeoning youth populations and those of a dynamic agriculture sector. The mainstreaming of formal vocational training is needed to turn young people and farmers in the food system into skilled entrepreneurs who can run their farms or businesses as economical, productive, sustainable enterprises. It is essential in order to enable farms and companies in the agro-processing sector to sustainably increase their level of productivity, generate

Agricultural education in Benin

In Benin there are four institutions that focus on technical agricultural education: three Colleges of Technical Agricultural Education (CETA) and the agricultural high school Medji of Sékou (LAMS), attached to the Ministry of Technical Education and Vocational Training. The maximum enrolment numbers at CETA and LAMS are fixed at 960 and 1,400 students, respectively. This translates into potential numbers of annual graduates of 240 for CETA and 350 for LAMS. The number of graduates from CETA doubled in 2002 from 120 to 240 per year, while LAMS had 40 graduates in 1998, 80 in 2000, 120 in 2001, 250 in 2002, and 350 in 2006.[75] Teaching at the CETAs is 25 percent theoretical and 75 percent practical. Teaching at LAMS is 40 percent theoretical and 60 percent practical. The main areas of teaching are vegetable production, livestock production, environmental and nature conservation, processing, equipment, economy and management, and general education.[76]

Agricultural education in Ethiopia

In Ethiopia, the mid-level training component of the Agricultural Technical and Vocational Education and Training (ATVET) program was implemented in 2001-2002. Its objective is to produce mid-level skilled, competent, and motivated agricultural practitioners through the provision of pre- and in-service training. This training is carried out in colleges distributed over the regional states. The rapid expansion of ATVET over the last 10 years in Ethiopia has resulted in an increase in the number of ATVET colleges to 25. There are five federal and 20 regional ATVET colleges. These colleges provide a three-year training program to produce a mid-level work force by admitting people who have completed a general education (completing grade 10) in the Ethiopian education system. The training is composed of 30 percent theory and 70 percent practice. The main areas of teaching are animal husbandry, animal health, crop production, natural resources development and conservation, and cooperatives development.[77] More than 22,000 agriculture extension officers (3,000 female) were provided with ATVET skills for knowledge transfer to farmers; 2,400 Farmers Training Centers (FTCs) were provided with relevant infrastructure, and of these 1,840 were fully functional in 2013.[78]

Agricultural education in Morocco

In Morocco, strengthening technical education and vocational training in agriculture is a key element of the Plan Maroc Vert (PMV). A network of 52 institutions with 24 different curricula has been set up across the country to improve the uptake and efficiency of agribusinesses. Furthermore, there are eight secondary schools that prepare young people for the baccalaureate degree in Agricultural Sciences as well as 30 middle schools in rural areas dedicated to training young people in agricultural technology. The trainings seek to improve the overall understanding of the various employment and business opportunities within the agriculture sector in Morocco and to encourage young people to pursue studies or training in this area. All agricultural vocational training institutions provide apprenticeships to improve the employability of rural youth who are not in school but have basic literacy skills. Each year, 10,000 young people receive training in 20 professions.[79]

demand for new crops, raise incomes, and boost their competitiveness on domestic and international markets.[80]

A key priority of government mechanization strategies is to increase investment and create, at scale, the needed institutional infrastructure to mainstream technical and vocational training to close the skills gap. This requires going beyond pilot projects with limited geographic coverage and lifespan or a few institutions targeting young people, and instead provide broad-based access to opportunities for skill development and upgrading for all actors in all segments of agriculture value chains.[81] This should include skill development to operate, maintain, and repair machinery both on the farm and off-farm, and should include all technical skills required to effectively link agriculture and food systems to industry and services. Countries such as Benin, Morocco and Ethiopia have prioritized skill development and vocational training for agriculture, and important lessons can be learned from these programs.

Risks and opportunities

Mechanization can play a crucial role in generating much-needed and profitable opportunities for young people along the value chain. Mechanization will not only help boost production and add value to crops through processing, it also plays key roles in stimulating demand for more nutritious and diversified foods, in decreasing the strenuousness of farming, in opening new markets and opportunities, and in contributing to the quality and quantity of consumers' demands. In all regions of the world, this has historically occurred with a transfer of employment from agriculture to other sectors, including the agri-food industry.

While mechanization can open new opportunities, particularly for rural youth, governments at the same time need to ensure that mechanization does not have a reverse effect on employment, impacting social and political stability.

This is possible through mechanization pathways, that are intensive in employment, both in agriculture and in related rural industries, and which offer the prospect of transitioning smallholder farmers and rural youth into other employment opportunities outside agriculture or off the farm. It is crucial that mechanization solutions be designed to be context-specific, affordable, and appropriate to local needs. This in turn will require substantial new investment into research and the development of new, innovative and locally appropriate pathways that are labor-intensive. This also requires training and skill development for all actors along the value chain.

Continental and global policy frameworks

At the continental level, the African Union Agenda 2063 reflects the common African position to transform Africa's agriculture sector to become more productive and competitive using science and technology. As part of Aspiration #1 – To achieve a prosperous Africa based on inclusive growth and sustainable development – goal #5 commits countries to banish the hand hoe by 2025 and underlines the importance of the contribution of a modern and environmentally sustainable agriculture to overall productivity and food security.[82] These goals are reinforced through the Comprehensive Africa Agriculture Development Programme (CAADP) under the New Partnership for Africa's Development (NEPAD).[83]

Under the Malabo Declaration, countries have committed to making investments in suitable, reliable, and affordable mechanization and energy supplies to double productivity by 2025.[84] In pursuit of the above and other CAADP targets, 42 countries developed their first five-year National Agriculture Investment Plans (NAIP), between 2010 and 2015, while 22 countries are ready to launch their second generation of NAIPs, or are already in the process of its implementation. These efforts underline countries' commitment to transforming agriculture. However, only a few countries have included mechanization in their NAIPs. In 2018, the African Union presented the Inaugural Biennial Report on the Implementation of the June 2014 Malabo Declaration and launched the Africa Agricultural Transformation Scorecard (AATS).[85] The AATS captures 23 performance categories under seven different thematic areas. Under performance area #3 ("Ending Hunger"), indicator (i) is "Access to agriculture inputs and technologies". This reflects countries' commitment to promoting the utilization of cost-effective and high quality agricultural inputs, irrigation, mechanization, and agrochemicals for crops, fisheries, and aquaculture in order to boost agricultural productivity.[86]

At the global level, the need for agricultural transformation is reflected in Sustainable Development Goals (SDGs) #1 and #2.[87] Especially through SDG goal #2—to "End hunger, achieve food security and improved nutrition and promote sustainable agriculture"—the need for enhanced access to technology is highlighted as a key element to sustainably improve the productivity of the agricultural sector.

In 2009, the Food and Agriculture Organization of the United Nations (FAO) and the United Nations Industrial Development Organization (UNIDO) joined forces to debate the opportunities and needs for increased investment in agricultural mechanization in Africa. The main objectives included the reduction of primary land preparation using hand tools – from 80 percent to 40 percent by 2030 and to 20 percent by 2050 – and replacing this method with a combination of draught animal power and tractors.[88] Building on that, the most explicit international paradigm for mechanization is the ecosystem-based Save and Grow approach of FAO, which incorporates methods of conservation agriculture (CA) with the use of improved seed varieties, efficient use of water, and integrated pest management.[89]

In October 2015, the third Africa-India Summit was held, promising cooperation on agricultural growth and improved farming techniques through appropriate and affordable technology, improved crop varieties, and other measures, to achieve a green revolution, initially in eight countries. Both India and African countries also called for raising the investments in agribusiness and the food processing industry, strengthening in-country policies and institutional arrangements for mechanization, improving mechanization supply chains, strengthening capacity, and training and facilitating access to mechanization services through the private sector.[90] Finally, in 2016, the Sustainable Agricultural Mechanization (SAM) strategy and a knowledge platform for technology exchange at the Pan-African level were developed.[91] This was followed by a joint framework, the Framework for Sustainable Agricultural Mechanization in Africa (SAMA), developed by FAO and the AU, designed to contribute to the promotion of investments in and the intensification of agricultural mechanization in Africa, as well as its integration in agricultural development strategies at the country level. SAMA will be launched in 2018.

Delivering on the African Union Agenda 2063 and the SDGs will only be possible through a genuine agricultural transformation that increases agricultural productivity and reduces post-harvest losses, while creating new opportunities for processing and value addition in the agriculture value chain. Agricultural mechanization is now high on the agenda of both public and private stakeholders. This is an opportune moment to invest in and implement sustainable agricultural mechanization strategies across the continent to harness the potential of a thriving African agriculture sector.

Delivering on the African Union Agenda 2063 and the SDGs will only be possible through a genuine agricultural transformation that increases agricultural productivity and reduces post-harvest losses, while creating new opportunities for processing and value addition in the agriculture value chain. Agricultural mechanization is now high on the agenda of both public and private stakeholders. This is an opportune moment to invest in and implement sustainable agricultural mechanization strategies across the continent to harness the potential of a thriving African agriculture sector.

It is a promising case in point that several of the countries studied in this report were able to increase their agricultural growth, at least partly through new mechanized technologies. Many of the interventions and innovations discussed in the report and in the country case studies will help other governments develop country-specific mechanization strategies and policies that favor collaboration between the private sector, research institutions, and the government for the benefit of smallholder farmers, women, and rural youth.

Case studies: experiences and lessons from the country level

Methodology

Several countries across Africa have made remarkable progress in improving the level of agricultural mechanization since the 2000s. Their experiences are reviewed in detail here to draw lessons for other African countries. This report analyzes which policy decisions were taken and which institutional innovations were made to sustainably mechanize the food value chains. The selection of countries was confronted with a lack of proper indicators to measure a country's level of mechanization and incomplete or unavailable data. To identify the best performing countries, the report therefore relied on the average annual machinery growth rates and agricultural output growth rates to measure country efforts in mechanization and their likely impact on the food value chains. The machinery level of a country is represented by the number of agricultural machinery units, expressed in 40-CV (horse-power) tractor-equivalents, and the agricultural output is measured in constant 2005 US dollars.

Table 1 shows rates of machinery growth versus the levels of agricultural growth resulting in four clusters, as shown in Figure 2. In order to establish the clusters, countries' average annual agricultural machinery growth (in percent, between 2005 and 2014) and their average annual agricultural output growth (in percent, between 2005 and 2014) were organized in descending order and divided into three parts.[92] For the purpose of this report, the upper tercile was chosen as the threshold, so the countries showing scores for the average annual machinery growth rate above this threshold, which is 2.6 percent, were grouped within the high machinery growth clusters. Countries ranking below this threshold were grouped within the lower machinery growth clusters. In the second stage, countries that reported an average rate of agricultural output growth above the upper tercile, which is 3.9 percent, were grouped under the high agricultural growth category.[93] Countries below that rate were included under the low agricultural growth category.*

This resulted in a cluster of 11 countries, falling under the combined category of high machinery growth and high agricultural growth rates: Angola, Botswana, Ethiopia, Malawi, Mali, Morocco, Niger, Rwanda, Tanzania, Togo, and Zambia. Although, the analysis cannot explicitly confirm that the high agricultural output growth observed in countries is in fact caused by the high agricultural machinery growth, we consider both measurements as highly relevant in the context of agricultural mechanization. Clustering countries only by their machinery growth would be too one-sided.

Among the above, seven African countries were selected for case studies – Ethiopia, Malawi, Mali, Morocco, Rwanda, Tanzania and Zambia – based on their respective average annual rates of machinery growth and agricultural output growth between 2005 and 2014, and regional representation across the continent.

TABLE 1 Average annual machinery and agricultural output growth rates (in percent), 2005-14[94]

Country	Machinery growth	Agricultural output
Ethiopia	2.75	5.20
Malawi	2.69	6.20
Mali	4.65	4.70
Morocco	3.67	4.00
Rwanda	2.73	5.50
Tanzania	2.88	6.60
Zambia	3.12	8.50

* The primary organization in terciles does not only help to define a relative threshold, considering African countries machinery and agricultural output growth. Both threshold levels are also within a reasonable range of international comparability. An agricultural machinery growth of about three percent is considered as high in the context of mechanization, and an annual agricultural growth rate of about 4 percent is regarded as considerable by many policy makers and researchers.

FIGURE 2 Average annual machinery growth vs average annual agricultural output growth[95]

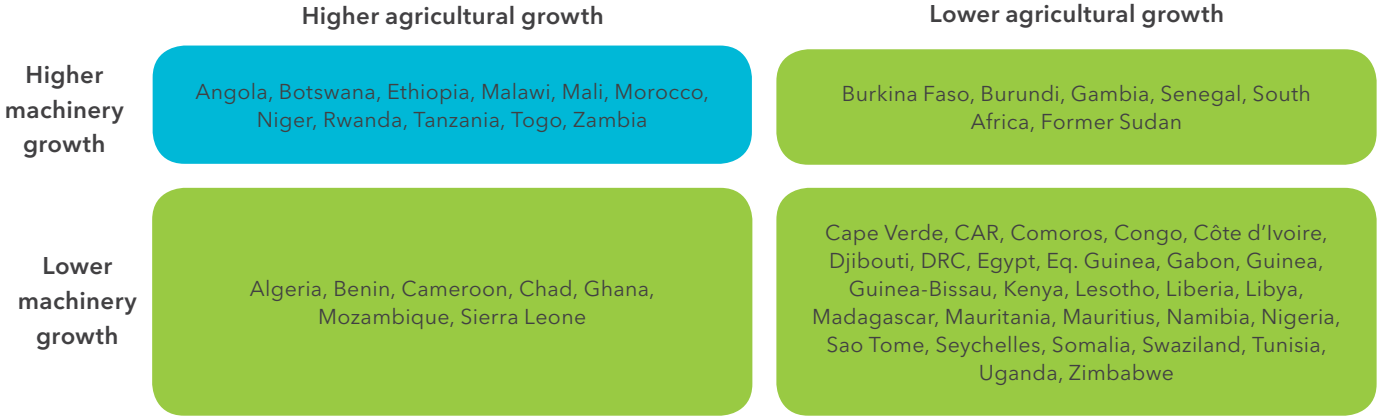


TABLE 2 Institutional innovations, programmatic interventions and implementation modalities of the seven case study countries

Country	Institutional innovations	Programmatic interventions	Implementation modalities
Ethiopia	■ Restructuring of the Agricultural Mechanization Research Directorate within the Ethiopian Institute of Agricultural Research (EIAR) in 2000. ■ Creation of the Agricultural Transformation Agency (ATA) in 2010. ■ Development of Ethiopia's Agricultural Mechanization Strategy, by ATA and the Ministry of Agriculture, institutionalizing agricultural mechanization along the value chain.	■ Importation of machinery by public organization MetEC (since 2005) and private companies. ■ Hiring service for machines, spare parts and servicing by Agricultural Mechanization Service Enterprise (AMSE), established in 2004, and by private companies. ■ Dedicated programs for skill development, machinery import, hiring services, and post-harvest handling by the government and development partners.	■ AMSE led by the ATA and the Ministry of Agriculture with a focus on different segments along the value chain, R&D, and skill development. ■ Active involvement of private sector through public-private partnerships.
Malawi	■ Farm mechanization programs run by the Crops Development Department under the Ministry of Agriculture. ■ Cooperation with the Agricultural Technology Clearing Committee to release new technologies along the value chain. ■ Specification of mechanization targets in the NAIP.	■ Implementation of program of hiring machinery along the value chain by the public and private sectors. ■ Implementation of projects by the government and development partners enabling access to post-harvest machinery and training on new technologies.	■ Key government programs led by the Ministry of Agriculture with a focus on different segments of the value chain, skill development, and research on new technologies. ■ Involvement of the private sector through public -private partnerships.
Mali	■ Creation of the Direction Nationale Du Genie Rural (DNGR) within the Ministry of Agriculture in 2005, dedicated to agricultural mechanization. ■ Creation of the Center for the Study and Experimentation in Agricultural Machinery (CEEMA) within the Institute of Rural Economy (IER) as a major research institution. ■ Introduction of agricultural mechanization curricula at the university level at the Institute for Training and Applied Research (IPR/IFRA). ■ Organization of local manufacturers in cooperatives.	■ Adoption of the Agricultural Mechanization Strategy in 2002, providing direct public investment and financial support to farmers. ■ Local tractor assembly program through the government, with additional direct investments. ■ Program to support young farmers in rural areas for tractor acquisition. ■ Development of agribusiness incubation centers across the country, in 2016. ■ Support to small agricultural processing companies through the Agricultural Competitiveness and Diversification Program.	■ Key programs led by the Ministry of Agriculture with focus on the production and processing segments, as well as skill development. ■ Involvement of private sector operators through public -private partnerships.

Country	Institutional innovations	Programmatic interventions	Implementation modalities
Morocco	■ Department of Agronomy and Agricultural Machinery created within the National Institute of Agronomic Research. ■ Design of fiscal measures to facilitate access to agricultural equipment. ■ Creation of the Association of Importers of Agricultural Equipment (AMIMA) in 1983.	■ Subsidized agricultural equipment acquisition program through the Agricultural Development Fund. ■ Agreements by Plan Maroc Vert partner banks and suppliers of agricultural equipment to provide specific financing opportunities. ■ Program of subsidy under the Plan Maroc Vert to encourage aggregation. ■ Implementation of the National Plan for Irrigation Water Economy to improve traditional irrigation systems.	■ Key government programs led by the Ministry of Agriculture with focus on all the stages of the value chain. ■ Involvement of private sector through public -private partnerships.
Rwanda	■ Expanded role for the private sector in the entire agriculture value chain under the Strategic Plan for the Transformation of Agriculture Phase 3. ■ Agricultural Department established at Development Bank of Rwanda (BRD) for financing the modernization of agriculture. ■ Establishment of the Rwanda Agriculture Board (RAB), to bridge the gaps between research and extension and transform agriculture into a knowledge-based, technology-driven, and market-oriented industry.	■ Implementation of the Agricultural Mechanization Program (2009–2013) for the acquisition of machinery and selling to farmers. ■ Program of Village Mechanisation Service Centres (VMSCs), as government-led hiring services and training centers. ■ Creation of a Department of Agricultural Mechanisation at the University of Rwanda. ■ Support for processing and marketing technologies along the value chain through projects by the government and private businesses.	■ Key government programs including Village Mechanisation Service Centres with focus on the production stage, research and development. ■ Involvement of private sector through public-private partnerships, such as Africa Improved Foods Rwanda Limited, to advance mechanization at all stages of the value chain.
Tanzania	■ Creation of the Centre for Agricultural Mechanization and Rural Technology (CAMARTEC) by the government in 1981, for the adoption and dissemination of locally appropriate technologies. ■ Creation of the Center for the Development and Transfer of Technology (CDTT) of the Tanzania Commission for Science and Technology (COSTECH) in 1986. ■ Establishment of the Agricultural Mechanisation Division by the Ministry of Agriculture. ■ Release of NAIP with priorities on mechanization in 2011.	■ CAMARTEC's undertaking of R&D activities, development of farm machinery, and offer of training and disseminating machinery along the value chain. ■ Equipment loans offered by private companies and hiring services by the Tanzania Farmers Service Centre Limited (TFSC), since 1990.	■ Key government programs led by the Ministry of Agriculture with focus on different segments of the value chain, R&D, and skill development. ■ Involvement of private sector through public-private partnerships.
Zambia	■ Creation of a liberalized system aimed at integrating the private sector in input supply and other value-chain segments through policies and agricultural reforms (since 1990). ■ Provision of technical services on mechanization by the Ministry of Agriculture (since 2015). ■ Formulation of concrete targets for mechanization within the NAIP and the Second National Agricultural Policy (SNAP) in 2016.	■ Creation of the Zambia Agriculture Research Institute (ZARI), to generate and adapt new agriculture technologies, situated within the Ministry of Agriculture. ■ Support of research and technology adaption also through non-profit organizations, like the Indaba Agricultural Policy Research Institute (IAPRI). ■ Supply of machines, offer of training and app based hiring services by private companies.	■ Government key programmes led by the Ministry of Agriculture with focus on different stages of the value chain, research and development, skill development. ■ Involvement of private sec-tor through public-private partnerships.

CASE STUDY

Ethiopia

From 2005 to 2014, the average annual agricultural output in Ethiopia grew by more than five percent. During the same period, the average annual machinery growth rate was almost three percent. The 2018 Biennial Review Report by the African Union showed that Ethiopia is currently on track to meet the Malabo Commitment area #3.1, "Access to agriculture inputs and technologies", with a score of 6.03, above the minimum score of 5.53,** reflecting an ongoing vibrant mechanization process.[96]

The approach taken by Ethiopia, with strong institutional innovations, programmatic interventions, and an emphasis on hiring services, has been shown to be effective in advancing the uptake of mechanization along the value chain. However, as the recent Biennial Review Report has shown, much progress remains to be made to meet national and international targets, including the Malabo commitment of ending hunger by 2025.

Institutional innovations

From the late 1950s, the focus in Ethiopia was on the introduction of mule-pulled plows for tillage practices, publicly led through the two most transformative rural development programs and supported by the Ministry of Agriculture and the Jimma Agricultural Technical School. In 1959, first efforts were made to link education with extension work for various aspects of agricultural engineering at Haramaya University.[97]

In 2000, the Agricultural Mechanization Research Unit was reorganized into the Agricultural Mechanization Research Directorate, situated within the Ethiopian Institute of Agricultural Research (EIAR). Furthermore, Ethiopia has several Regional Agricultural Research Institutes, each with its own structure and mechanization research programs.[98] Since 2002, the government has been promoting mechanization as a fundamental element to achieve agricultural growth and transformation. To enhance the capacity of key stakeholders to achieve this transformation, the Agricultural Transformation Agency (ATA) was initiated by development partners and set up by the government in 2010. The ATA is chaired by the Transformation Council of the prime minister and the Ministry of Agriculture.[99]

Although Ethiopia's NAIP for 2010–2020 failed to explicitly address the need for agricultural mechanization,[100] both the external mid-term review by the Working Group on Rural Development and Food Security and Ethiopia's Growth and Transformation Plan (GTP) acknowledge the need to implement mechanization in order to achieve the objectives set out in the NAIP.[101] In 2014, the Ministry of Agriculture and ATA jointly developed Ethiopia's Agricultural Mechanization Strategy to successfully institutionalize agricultural mechanization along the value chain.[102] The strategy specifically aims to raise the productivity of Ethiopian agriculture by:

- Increasing farm power derived from mechanical/electrical power by 50 percent;
- Reducing the use of animals for agricultural production by 50 percent;
- Promoting agricultural mechanization technologies that can be used by female farmers; and
- Addressing 50 percent of the mechanization needs of pastoralists and agro-pastoralists.

Policy and programmatic interventions

Today, both the public and the private sector are engaged in the agricultural technology supply system, rental services, and tractor imports.[103] Private dealers like Ries Engineering, Motor and Engineering Company of Ethiopia (MOENCO), Gadeb Engineering, CLAAS tractors, and Hagbes have expanded and are now dominating the tractor sales market. Together with the public operation MetEC, the value of imported machinery increased rapidly from US$10 million in 2005/06 to US$70 million in 2013/14. The major contribution (US$60 million) in 2014 was primarily due to the increased import of four-wheel tractors, followed by the import of combine-harvesters.[104] Further, some companies, cooperatives and larger commercial farmers provide rental services to smallholder farmers. Lume Adama Grain Farmers Cooperative Union, a cooperative established in 1997, provides rental access to tractors, seed and grain cleaners, harvesting machinery, and transport trucks for its members and nonmembers.[105]

In fact, rental agreements remain a key element of mechanization in Ethiopia, as almost 70 percent of machinery-using farmers rely on them to plow their fields. In 2004, with initial capital of US$750,000, the Agricultural Mechanization Service Enterprise (AMSE) was established through regulation No. 97/2004, issued by the Council of Ministers, mainly for the provision of agricultural mechanization services on a rental basis. By 2012, AMSE had about 70 tractors, operating four service centers across the country. Another element is a mobile workshop that reaches even the most remote areas in Ethiopia to service the tractors. Most of the tractors owned and operated by AMSE are medium-sized tractors with an engine capacity between 80 and 120 horsepower.[106] The centers not only provide heavy machines, but also provide maintenance services on a rental basis. Further, they provide farm implements and spare parts manufactured domestically or imported, offer transport services of farm produce and farm inputs, introduce the utilization of modern farm implements, and provide training and consultation services for a better and more effective utilization of farm machinery.[107]

In addition to a program focused on mechanization on the production side, the SAA/SG 2000 (Sasakawa Africa Association/Sasakawa Global 2000 Ethiopia) program was established to strengthen capacity for extension service delivery along the value chain. The program seeks to help smallholder farmers acquire knowledge for increased and sustained production and productivity in response

** Malabo Commitment #3.1 "Access to agriculture inputs and technologies" had a minimum score of 5.53 in the 2018 African Union Biennial Review. Over a ten year period (2015-2025), the overall commitment category score is 10.

CASE STUDY

Ethiopia

to market demand.[108] The program covers several themes, including crop productivity enhancement and postharvest and agro-processing. With the introduction of high-yielding rice varieties in Ethiopia in 2007 and the accompanied increase in rice yields, a number of post-harvest handling and processing services were introduced by SAA/SG 2000. Since 2010, the program has trained farmers in the use and operation of mechanical harvesters, threshers, cleaners, improved solar and mechanical dryers, rice mills, and on-farm storage. The introduction of post-harvest technologies has encouraged more farmers to grow rice, allowing them to process the crop quickly and maintain high quality.[109] The demonstration of hermetic storage facilities, particularly PICS bags in Ethiopia, resulted in early adoption because of their protection from insects and their elimination of harmful chemicals in storage.[110]

Mechanization efforts are further supported by development partners and projects using new technologies such as Digital Green. The Heavy Duty Equipment and Commercial Vehicles Academy (HDECoVA) project was launched in 2012 with the objective to set up a model academy. The academy provides vocational training for heavy machinery and trains 25 to 30 students annually. During a four-year course, students access modern machinery and are directly involved in the production and maintenance of machines. In 2013, the center received 665 orders and had revenues of approximately US$800,000 from industrial and agricultural sales. To date, more than 370 students have been trained in the academy.[111] Recent efforts to train farmers on a wide variety of technologies, including tractors, power tillers, rice seeders, and rice mills, are joint projects with the Japanese Association for International Collaboration of Agriculture and Forestry (JAICAF).[112] Recently, the Korean-Africa Forum on Economic Cooperation (KOAFEC) established a trust fund of US$150 million to support Ethiopia on agricultural transformation, especially regarding the development of agro-industrial parks.[113]

CASE STUDY

Malawi

Malawi is currently not on track for meeting Malabo Commitment area #3.1, "Access to agriculture inputs and technologies". Its score of 3.9 out of 5.53, according the 2018 Biennial Review Report by the African Union, reflects the rather low level of mechanization in the country.[114] However, according to our methodology, Malawi is part of a cluster of countries indicating rapid mechanization rates. Malawi has had an average annual machinery growth rate of 2.7 percent and a high agricultural output growth of over 6 percent.

With dedicated mechanization committees and departments as well as a decentralized approach to mechanization and a clear commitment to mechanization along the value chain, the Malawi Growth and Development Strategy has been shown to be effective in advancing the uptake of mechanization along the value chain. However, as the recent Biennial Review Report has shown, progress remains to be made to meet national and international targets, including the Malabo commitment of ending hunger by 2025.

Institutional innovations

The Ministry of Agriculture, Irrigation and Water Development (MoAIWD) seeks to promote agricultural productivity and sustainable management of land resources to achieve food security and increased incomes, thus ensuring sustainable socio-economic growth. The ministry is organized into seven technical departments, including the Crops Development Department, which was created to facilitate producers' access to improved and locally appropriate crop production and agro-processing technologies. The department is responsible for the implementation of farm mechanization programs. It offers training to extension agents and farmer groups in crop production technologies and in post-harvest management of crops, including agro-processing. The department is split into six sections, one of them dedicated to Farm Mechanization. In its function to promote new technologies, the Crops Development Department also works closely with the Agricultural Technology Clearing Committee (ATCC), which releases new production and processing technologies, such as fruit juice extracting machines.[115]

On a subregional level, the four Agriculture Development Divisions (ADDs) play an important role in the mechanization process. Each of the divisions is organized in a different way to reflect local structures and context. For example, the ADD in the Kasungu region mandates the promotion of sustainable crop production through appropriate technologies and the provision of services such as subsidized farm inputs, mechanization, seed production, and crop protection.[116]

In 2010, Malawi developed its National Agriculture Policy (NAP)[117] and its National Agricultural Investment Plan (NAIP).[118] The NAP builds on various policy statements to improve agriculture productivity in the wake of national, regional, and global opportunities and challenges. The NAIP emphasizes specific activities and sets out a clear investment strategy:

- Increase the number of hectares under tractor-hire schemes from 2,090 hectares (2009/2010) to 10,000 hectares in 2013/2014, with total investments of US$10 million;
- Increase the number of hectares under oxenization, from 1,100 hectares to 16,615 hectares in 2013/2015;
- Increase the distribution of hand planks from 1,200 to 60,000 in 2013/2014; and
- Conduct review meetings on farm mechanization and oxenization efficiency in agriculture.

Policy and programmatic interventions

Although not all targets set out in Malawi's NAIP have yet been met, progress is visible. The government has started to work on 530 hectares out of a total 6,293 hectares of the Chikwawa Green Belt Irrigation Scheme in Salima district. Although the project has not yet been completed, it is well on track with 80 percent of the scheme's targets achieved, including the establishment of a lake pump station, booster pump station, reservoir, pipeline, site office, workshop, ablution block, and pivot areas. The government has secured lines of credit for US$10 million and US$40 million, respectively, for irrigation and mechanization from the Indian government, as well for setting up a sugar processing plant in the Salima district.[119]

In addition to the public hiring services, private companies also offer supplies of agricultural equipment. CAMCO Equipment Limited, which has been operating in Malawi since 2000, supplies agricultural machinery and implements along the value chain, including walking tractors, disc plows, harrows, planters, harvesters, trailers, water pumps, sprayers, food processing equipment, harvest machines, and smaller farming tools. CAMCO offers a wide range of products, after-sales services, and spare parts. Since 2000 the company has established 32 distributers and agents in Malawi.[120]

Aligned with the Government of Malawi's National Export Strategy (NES), and managed by Adam Smith International (ASI), the United Kingdom's Department for International Development (DfID) founded the Malawi Oilseed Sector Transformation (MOST) program in 2015. The four-year program aims to expand rural income opportunities by promoting access to the threshing, shelling, and processing of oilseeds. In the groundnut sector, MOST's objectives are to improve access for smallholders to better quality and improved seed and to enable the use of machines along the value chain through mechanical shelling for smallholders and small-scale traders. It is predicted that a total of more than 11,400 beneficiaries with a net average income change of over US$1 million will be reached by March 2018.[121]

A similar project was initiated in 2016 through the Feed the Future Malawi Agricultural Diversification Activity. The five-year project, funded by USAID, aims to benefit 300,000 smallholder households by engaging with private firms providing financing, agricultural processing, and training in new technology and climate-smart agriculture practices for soy, groundnuts, and orange fleshed sweet potatoes. To do so the project forges partnerships with input suppliers, aggregators, finance facilitators, trainers and other specialized companies. Until 2021, the project aims to invest US$30 million in new agricultural loans and US$40 million in new investment, and to establish at least 50 commercial partnerships between buyers and smallholder farmers.[122]

CASE STUDY

Mali

Mali is one of the countries in West Africa that has shown noticeable progress with regard to agricultural mechanization. Between 2005 and 2014, Mali observed an average agricultural machinery growth rate of five percent. During the same period, the level of agricultural output growth rate was also five percent. Strong institutional innovations and programmatic interventions to enhance mechanization have contributed to this progress. However, despite the progress, the 2018 Biennial Review Report by the African Union revealed that Mali is not on track to meet Malabo Commitment area #3.1, "Access to agriculture inputs and technologies", having achieved a score of 4.56 out of 5.53.

Mali has shown ambitions to boost agricultural growth through institutional innovations and programmatic interventions to improve the uptake of mechanization and rural technologies along the value chain. Importantly, the government has placed an emphasis on capacity strengthening and skill development, as well as employment creation for youth and entrepreneurship, so as to increase value addition at post-harvest stages. However, the extent of public-private partnerships in the mechanization of food value chains is still low, and more needs to be done to meet continental and international targets on agricultural transformation.

Institutional innovations

Before 2000, the Malian government was responsible for the provision of agricultural equipment and other agricultural inputs, including seeds and fertilizers. In 2006 the Loi D'orientation Agricole was passed and the Malian government shifted its focus to creating an institutional and economic environment favorable to the development of agricultural mechanization, including strengthening the role of the private sector.[123] Within the Ministry of Agriculture's Direction Nationale Du Genie Rural (DNGR), a division dedicated to agricultural mechanization was created in 2005. The division aims to provide smallholders with appropriate equipment to increase agricultural production. A system for monitoring and evaluating mechanization programs is also carried out by the DNGR. In addition, the Institute of Rural Economy (IER), a major national research institution, aims to contribute to the implementation of the national agricultural research policy, and through the Center for Study and Experimentation in Agricultural Machinery (CEEMA) it tests locally made and foreign manufactured equipment. The CEEMA is also tasked with training farmers in the use of agricultural equipment and village blacksmiths in the production of small animal traction and craft equipment.

Moreover, training programs in agricultural mechanization have been introduced at the university level. The Institute of Training and Applied Research (IPR/IFRA), which is another public institution, has offered education and training in agricultural machinery and agricultural equipment since 2015. The objective is to train students to design, manage, monitor and evaluate projects in agricultural and rural mechanization, including cold circuits, handling systems, transport, drying, storage, and primary processing of agricultural products. Students also learn how to use and maintain agricultural equipment and agricultural industrial units, how to produce, manage, and distribute energy in rural areas, how to design and conduct training programs related to mechanization, and how to develop a business plan.[124]

The private sector also plays an important role in the production of agricultural equipment. In the Office du Niger zone, blacksmiths have organized themselves into a Société coopérative des forgerons de l'office du Niger (Socafon) since the 1990s, and have put in place an efficient structure to ensure the supply of quality tools, at low prices, adapted to local needs, as well as local services for the maintenance and repair of tools. The organization enables blacksmiths to better coordinate their activities, facilitate access to credit, and to stock up collectively on raw materials.[125]

Policy and programmatic interventions

Over the past 15 years, several programs were implemented to increase the level of agricultural mechanization. Following the adoption of the Agricultural Mechanization Strategy in 2002, the government has provided direct public investment and financial support to farmers in the acquisition of 400 tractors and other equipment. To sustain the acquisition of tractors, the imported tractor components were later assembled and sold locally. In addition, the government made direct investments by purchasing 49 percent of the shares of a local tractor assembly plant.[126]

In Mali, smallholders growing main staple crops, such as millet and sorghum, are usually unable to get credit for purchasing agricultural equipment. The government provided interest-free loans of up to US$1,000 for the purchase of a pair of draught animals, a plow, and an animal-drawn cart. Farmers need to provide a down payment of five percent of the loan and are requested to plant trees, which work as a guarantee for the loan. The wood is harvested and sold after five years and the profit is used to repay the balance of the loan if the farmer has not completed the repayment. The rate of repayment has been estimated at about 90 percent.[127]

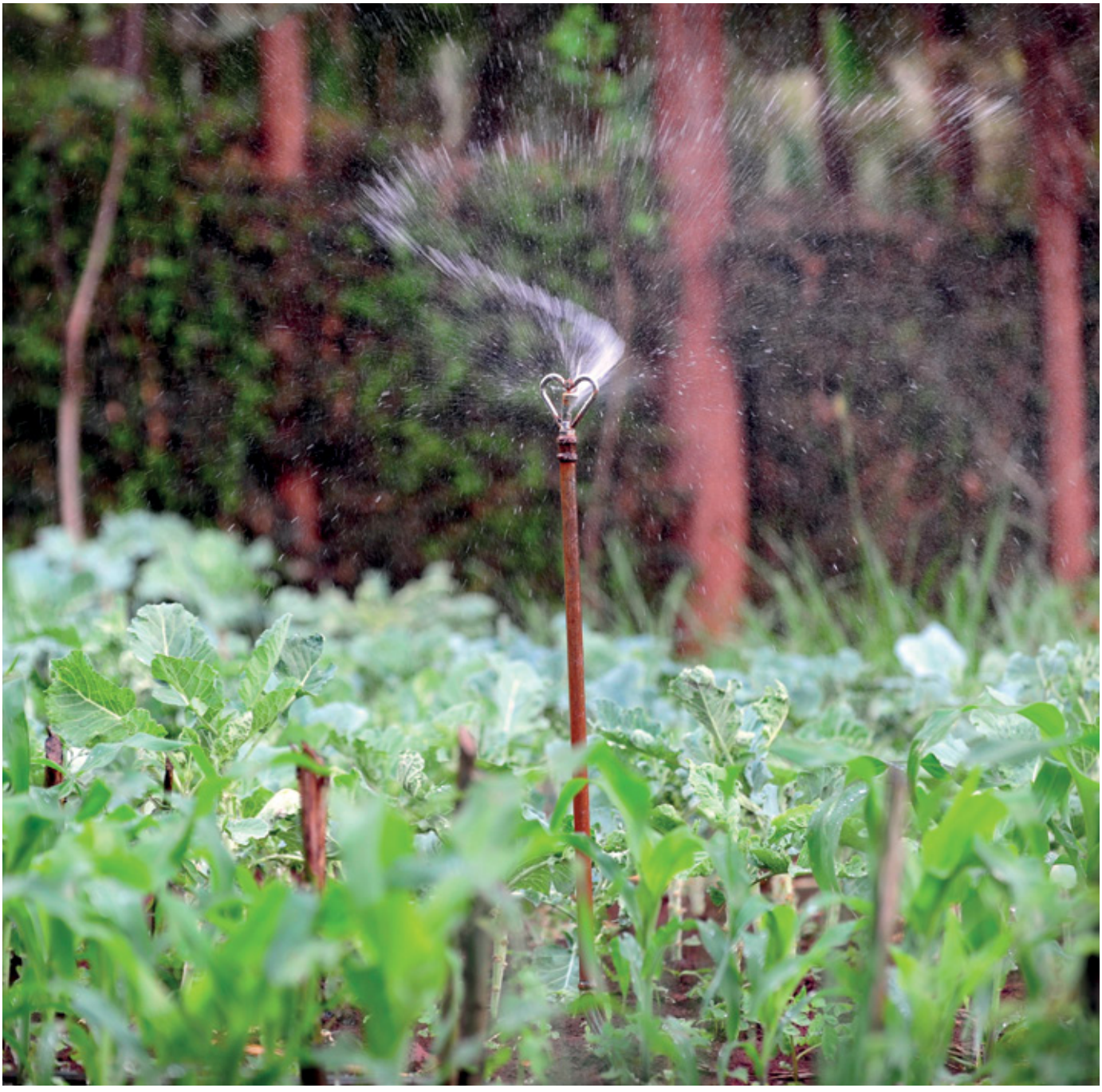
The Government has also developed an assistance program to support young farmers in rural areas. One hundred tractors have been supplied to youths at subsidized prices, interest-free and repayable within 10 years, with a one-year grace period before loan repayments begin. Young farmers also receive training in developing business plans to facilitate access to loans from commercial banks, with the state providing up to 80 percent of the guarantee for the loan.[128]

In 2016, with the aim of creating more employment opportunities and adding value in the agricultural sector, the Government set up an agribusiness incubation center. The incubation center aims to promote entrepreneurship in rural areas based on agribusiness opportunities such as seed marketing and the processing of agricultural products. The goal is to integrate smallholder farmers and young people into the agriculture value chain by facilitating access to resources and new markets and by providing education and skill development.

CASE STUDY

Mali

Through the Agricultural Competitiveness and Diversification Program (PCDA), the Government provides support to small agricultural processing companies. For example, through this support one small company, which had begun with a focus on local grain storage in 1985, was able to expand and diversify its activities. In 2009 it acquired the status of an Economic Interest Group (GIE) under the name Unité de Transformation des Produits Agricoles DADO PRODUCTION, and it is now registered in the trade register of Mali. Through the support of the PCDA, the company can now process and transform agricultural products, particularly cereals. The company received technical support and a grant of US$6,180. With the financial support, the company bought a fonio huller with a capacity of up to 150kg per hour, an electrical fonio destoner with a capacity up to 100kg per hour, a cross-flow mixed dryer with a capacity of 80kg per hour, a gas dryer, and a grain mill. The company increased the number of its employees from four to 16 and now offers eight different products.[129]



CASE STUDY

Morocco

Morocco is making considerable progress on agricultural mechanization. Between 2005 and 2014, the average agricultural machinery growth rate was 3.67 percent, while agricultural output growth reached 4 percent. The 2018 Biennial Review Report by the African Union revealed that Morocco is on track to meet Malabo Commitment area #3.1, "Access to agriculture inputs and technologies", with a score of 7.46, which far exceeds the minimum score of 5.53. This progress is largely due to institutional innovations and programmatic interventions made to enhance mechanization in the country.

Morocco has shown strong ambitions in accelerating agricultural growth and has positioned itself for large-scale adoption of new agricultural technologies through strong subsidy programs. With institutions dedicated to mechanization training and research and strong public-private partnerships, Morocco has shown effective strategies to advance the uptake of mechanization along the value chain.

Institutional innovations

Morocco's Department of Agronomy and Agricultural Machinery is situated within the National Institute of Agronomic Research, which is a public service dating back to 1914 when the first official agricultural research services were created. One of the main activities of the Department is the design, development and testing of new agricultural tools and machinery suitable for the Moroccan context.[130] In addition, an Agricultural Mechanization Training Center (CFMA) was created within the Hassan II Agronomic and Veterinary Institute in 2001 to promote mechanization through training for agricultural advisers.[131] Fiscal measures, such as value added tax exemptions on tractors, combine harvesters and tillers have also been put in place. Furthermore, local private sector importers of agricultural equipment formed the Moroccan Association of Importers of Agricultural Equipment (AMIMA) in 1983 - a lobby group which provides information to its members and represents them externally.[132]

Policy and programmatic interventions

The Moroccan government and private sector have created a joint program to stimulate the purchase of agricultural equipment by farmers. In this program the private sector supplies the agricultural tools and machinery, while the government subsidizes its purchases for farmers through the Agricultural Development Fund, for 30 to 70 percent depending on the type of equipment. Agreements have also been signed by Plan Maroc Vert partner banks and suppliers of agricultural equipment to provide specific financing opportunities.[133,134]

As part of the Plan Maroc Vert, subsidies to encourage the formation of aggregation systems are put in place. The government finances 10 percent of the aggregation cost and pays a premium per production unit (such as hectare, head of cattle, or ton). In the region of Doukkala-Abda, a project involving the aggregation of 10,766 dairy farmers, representing 24 percent of the region's producers, was set up in 2013 around the Nestlé Morocco plan. The breeders own 17,700 cows and are organized into 130 milk collection cooperatives. As part of this project, Nestlé Morocco aggregates the collection of total milk production and provides access to financing for milk production equipment, including irrigation and milking tools. It is estimated that the project will achieve milk production of 74 million liters per year, compared with an initial level of 40 million liters in 2013.[135]

There is evidence that innovations in the mechanization of irrigation systems has allowed the Moroccan agricultural sector to become more resilient to climate change. Due to growing water scarcity, Morocco has implemented a National Plan for Irrigation Water Economy. The plan aims to improve the traditional irrigation system by expanding the use of localized irrigation systems, in particular through drip irrigation. The areas equipped with drip irrigation registered a significant increase between 2008 and 2014, reaching around 450,000 hectares, on the way to reaching the 550,000 hectares planned for 2020 by the Green Morocco Plan.[136]

CASE STUDY

Rwanda

In Rwanda, from 2005 to 2014, average agricultural output grew by more than five percent, while the average annual machinery growth rate was almost three percent. According to the 2018 Biennial Review Report by the African Union it was named as the best-performing country in implementing CAADP's seven commitments. Its score of 6.05 (of a minimum of 5.53) for Malabo Commitment area #3.1, "Access to agriculture inputs and technologies", reflects the government's dedication to transforming the agriculture sector and meeting its target of 25 percent of mechanized farm operations, envisaged under the country's second Economic Development and Poverty Reduction Strategy (EDPRS 2, 2013-2018).[137,138]

Institutional innovations

Increasing the uptake of mechanization in Rwanda is particularly challenging, largely due to the topology and the fragmentation of land holdings (approximately 70 percent of farms have less than one hectare each and are located on hillsides). Traditionally, the government has played a dominant role in the import and distribution of agricultural inputs, including seeds, pesticides, and mechanization equipment. However, under its Strategic Plan for the Transformation of Agriculture Phase 3 (PSTA 3), the government is moving toward an expanded role for the private sector in the entire agriculture value chain. A handful of businesses now sell machinery and provide related support services. In addition, a lease law passed in February 2015 paved the way for small entrepreneurs, including smallholder farmers, to acquire farm machinery. Under the program, more than 33,500 hectares of land have been mechanized so far, and more than 1,500 farmers and agronomists have been trained in modern farming technology.[139]

All mechanization activities in the country are coordinated under the Mechanization Unit within the Land Husbandry, Irrigation, and Mechanization Department of the Rwanda Agriculture Board (RAB). RAB is an autonomous body established to advance Rwandan agriculture into a knowledge-based, technology-driven and market-oriented industry, using modern methods in production and processing.[140] RAB was created through a merger of three agencies: the Rwanda Animal Resources Development Authority (RARDA), the Rwanda Agricultural Development Authority (RADA), and the Institut des Sciences Agronomiques du Rwanda (ISAR), to bridge the gaps between research and extension, strengthen policy processes, and establish efficiency in service delivery through institutional integration. RAB's mandate and institutional arrangement was crafted to align with the CAADP Pillar #4, "Integrated Research, Technology Dissemination and Adoption". The Mechanization Unit promotes appropriate mechanization options for farmers, increases access to farm machinery, and develops local skills and capacity in agricultural mechanization.

The Agricultural Department at the Development Bank of Rwanda (BRD) focuses on financing for the development and modernization of agriculture sector to help the sector reach an annual growth rate of 8.5 percent (from the current 5.5 percent), and increase fertilizer application and irrigation. Since food crop processing remained stubbornly low from 1999 to 2008 (below 6.5 percent),[141] BRD launched an agro-processing development program to strengthen linkages along the entire value chain. The total budget from the BRD of US$170 million from 2017 to 2022 is expected to leverage more than US$24.7 million worth of investments from the private sector. To farmers, BRD provides capital to finance input purchases, supports contract farming, and offers leasing agreements for equipment. In addition, agro-processors will receive up to US$92 million through loans, matching grants, technical assistance, equity investments, and guarantee facilities over the course of five years to support value-addition projects, exports, and job creation. This program will also fund targeted activities in value chain research.

Policy and programmatic interventions

The Agricultural Mechanization Program (2009–2013) within the Ministry of Agriculture and Animal Resources' (MINAGRI) was created to increase agricultural productivity in Rwanda as part of the wider flagship Crop Intensification Program (CIP).[142] With a budget of approximately US$7 million, the program was designed to ensure that subsistence and market-oriented producers had access to the necessary and appropriate equipment. The main activities under the program were:

- Acquisition of machinery and irrigation equipment;
- Establishment of hiring services for various farm equipment;
- Establishment of a testing and inspection workshop for farm machinery; and
- Capacity building for machine operators, individual farmers, and cooperatives.

Under the program, 81 tractors, 250 power tillers, 35 rice planters, five combine harvesters, and several kinds of farm implements – plows, mould boards, harrows/rotavators, water pumps and trailers—were acquired and sold to farmers, individuals, and cooperatives. Five heavy earth moving machines, such as bull dozers, chain loaders, and earth excavators, were also acquired to support government efforts in irrigation development, mainly dams. Besides government imported equipment, an additional 155 tractors were brought into the country by private operators.

To make hiring services more readily available to farmers across the country, under this program the government set up Village Mechanisation Service Centres (VMSCs), where smallholder farmers could hire or buy farm machinery. Sixteen VMSCs were established across Rwanda, as well as six power tiller centers. In addition, 23 technicians completed a six-month training course on mechanization, 20 technicians were trained in tractor operation and repair (in 2011), three technicians were sent to China for a training on agriculture mechanization, four engineers were sent to Japan for training, and one engineer attended an MSc program in agriculture mechanization in India. In total, 136 farmers across

CASE STUDY

Rwanda

the country were trained in power tiller operation, maintenance, and repair, and more than 38 operators are trained and currently employed in different VMSCs.[143] The overall goal was to enable mechanization in 25 percent of farm operations by 2017 and allow one in every four Rwandan farmers to either own and/or hire mechanization machinery by 2020.[144]

Previously, a Department of Agricultural Mechanization was established in 2008 at the University of Rwanda, under the College of Agriculture and Veterinary Medicine (Rubrizi Campus), where several entering classes have now graduated. To date, 95 students are studying for an undergraduate degree program. The department has five permanent academic staff members for teaching, research, and extension services on Farm Power, Farm Machinery, Agricultural, Process Engineering and Renewable Energy Sources. It is actively participating in training farmers on tractor and power tiller operation and the use of irrigation pumps, among other activities. The program also places emphasis on the development of low-cost replicable technologies for sustainable mechanization and fast rural economic transformation to achieve the government's Vision 2020.[145]

Further down the value chain, initiatives such as Muhanga Food Processing Industries (MFPI), a women-only cooperative established by COCOF in 2004, are contributing to mechanization efforts. MFPI buys soya, maize, sorghum, and wheat from five cooperatives (totalling 2,805 farmers, 83.5 percent of whom are women) and six additional local producers to cover gaps in raw material supply. The processed (blended) flour, soya beverage, and tofu are sold locally to supermarkets, nutritional centers, schools, and refugee camps. Longer-term plans for regional exports have also been made. MFPI directly supports 18 full-time jobs; COCOF manages farmer contracts on behalf of MFPI, arranges training for farmers and access to inputs, and will negotiate a fair price for farmers when the enterprise moves to buying pre-sorted soya and maize.[146]

Africa Improved Foods Rwanda Limited is a joint venture between the Government of Rwanda and a consortium of development partners and the private sector. The company manufactures high-quality nutritious complementary foods, produced with locally grown maize and soya beans, which are then milled and blended with micronutrient pre-mix, skim milk powder, and soy oil. AIF has 282 employees, including laboratory analysts, food scientists, mechanics, engineers, marketers, saleswomen and -men, finance experts, and agricultural officers. AIF has a capacity for processing 28,000 metric tons of maize and 12,000 metric tons of soybean annually, and sources about half the produce locally. AIF established rural collection centers, and offers thousands of farmers free transport and free post-harvest services. This has resulted in field rejections for aflatoxin-contaminated maize to drop from 90 percent in season 2017A to 43 percent in season 2017B to 0 percent in season 2017C.[147]

In 2017, the government signed a deal with a Nigerian investor, BlackPace Africa Group, to develop the country's potato industry and help make Rwanda a key producer and exporter of potato products. The five-year, US$120 million project involves construction of two potato processing factories, processing 80,000 to 100,000 ton of potatoes into frozen french fries, potato flakes, and crisps for export markets in Africa and the Middle East. Production capacity is expected to rise to 10 million tons of potato by the fifth year of the project.[148]

CASE STUDY

Tanzania

According to the 2018 Biennial Review Report by the African Union, Tanzania scores 3.67 out of 5.53 on Malabo Commitment area #3.1, "Access to agriculture inputs and technologies". Although Tanzania is currently not on track to meet this commitment, initiatives by the government reflect an increased attention to mechanization in the agriculture value chain.[149] The increased effort is reflected in the country's classification as rapidly mechanizing, with a high annual machinery growth of almost three percent and a high agricultural output growth of 6.6 percent between 2005 and 2014.

The Government of Tanzania has shown a renewed commitment over the last two decades to increase its uptake of mechanization and technologies in the agriculture value chain. With dedicated mechanization and technology transfer centers, applied research and development into agricultural mechanization and rural technologies, and an enabling environment for small business to enter hiring service schemes, Tanzania has made much progress.

Institutional innovations

Between 1960s and the beginning of the 1980s, agricultural production was high on the political agenda. Farmers groups and cooperatives were equipped with machinery, and governance boards were set up to guarantee markets for farmers' produce. In 1981, the Centre for Agricultural Mechanization and Rural Technology (CAMARTEC) was set up by the government to improve the quality of rural life through the development, adaptation, adoption and dissemination of locally appropriate technologies to advance agricultural mechanization, improve housing and rural transport, expand the availability of renewable energies, and improve post-harvest handling processes. The center still operates today and implements several programs in the field of mechanization along the value chain.[150]

In 1986, the Center for the Development and Transfer of Technology (CDTT) of the Tanzania Commission for Science and Technology (COSTECH) was established, and it still operates today. Within CDTT the long-term goal was to create an enabling environment that would stimulate the design and development of sustainable, locally adapted technologies. Over the years the center has worked with different stakeholders, including the Government, NGOs, the private sector, training institutions, entrepreneurs, manufacturers, and international organizations.[151]

By the mid-1980s, when Tanzania became a free-market economy, the government withdrew from many social and economic development services, especially within the agricultural sector. Neither the private sector nor farmers themselves were prepared for this sudden transition. Hence, between the mid-1980s and the early 2000s mechanization dropped off the agenda. During that time, the number of smallholder subsistence farmers increased, municipal services deteriorated, extension services shrank, and the transport infrastructure was in a state of decay.[152] From the early 2000s, increased development partner and government support put agricultural mechanization back on the political agenda, and more efforts were dedicated toward private sector training and capacity building.

Subsequently, the Ministry of Agriculture established the Agricultural Mechanisation Division to build expertise on the mechanization of agricultural production in the country. The division primarily facilitates the upgrading of farm machinery, including the use of renewable energy sources and conservation agriculture equipment.[153] In 2007-2008, a new Crop Mechanization Department was created within the Ministry of Agriculture to foster new investment in agribusiness and crop diversification.

In 2011, the government released the Tanzania Agriculture and Food Security Investment Plan (TAFSIP) aimed at delivering on the CAADP Commitments. The 10-year plan lacks clear indicators and targets. However, the investments in mechanization, rural infrastructure, research development, and improved agricultural input supply through both the public and private sector are set as priority areas to increase agricultural productivity. The plan also acknowledges the need for further extension and investments in mechanization programs and privately-owned mechanization service centers to enable smallholder producers to use ox plows and tractors.

Policy and programmatic interventions

CAMARTEC undertakes research and development in agricultural mechanization and rural technologies for the provision of high-quality technical services to clients in an environmentally friendly manner. The center mainly conducts applied research in agricultural mechanization; develops and manufactures approved prototypes; tests farm machinery; and conducts short course trainings designed to provide practical skills and knowledge, especially for farmers, engineers, governmental organizations, and private enterprises. Moreover, CAMARTEC produces and disseminates agricultural inputs under six different sectors: power and machinery, post-harvest, farm structure and water supply, biogas, cookstoves, and solar and wind. This includes machines like harrow planters, nut shellers, oil press machines, wheel barrows, pulling carts and oxen carts, water harvesting tanks, and brick making tools.[154] Mainly due to financial and regulatory constraints, the company is not working as efficiently as it could.[155] Furthermore, CDTT completed several projects in Tanzania, like the development, manufacture, and testing of a powered plow or the installation of hybrid solar and wind energy systems for the Mary Leakey camp in Olduvai Gorge.

In 2003, Equity for Africa Tanzania (EFTA) was set up by Equity for Africa Limited to enable small businesses and farmers to access finance for farm equipment, such as tractors and other tools and machinery. The company focuses on equipment loans of up to US$60,000. For mobile products, including tractors and harvesters, the loan scheme requires a 20 percent advance payment, with a 36-month repayment schedule, starting 60 days after delivery. In the case that a farmer is unable to make the repayment, the company reclaims ownership. Only five to six percent of the company's loans end in repossession. In 2004, EFTA offered the first lease and in the following five years invested a total of US$465,000.[156,157]

CASE STUDY

Tanzania

The Tanzania Farmers Service Centre Limited (TFSC) was established in 1990 to provide much needed agricultural machinery for plowing, planting and harvesting for small and medium scale farmers. Although it started out with hiring services only, the company has now diversified to selling agricultural machinery and spare parts, and offering workshop facilities for the repair of machinery. For reasonable prices, calculated per acre of land, farmers can hire tractors, plows, moldboards, boom sprayers, harrows, transport, and sowing and offloading facilities. Besides TFSC's hiring scheme, the company sells agricultural machinery and implements, offers workshops for the repair of agricultural machines, and sells spare parts. TFSC is located in Arusha with two branches in Dar es Salaam and Iringa.[158]

In Tanzania's central region, the Rural Livelihood Development Programme (RLDP) (2005-2015) sought to increase income and employment opportunities along the sunflower value chain. In addition to improving seed quality and access to financing their purchases, such as a technology for sunflower oil refining, RLDP facilitated a study tour for eight processors to India and China to learn about the latest processing technologies.[159] RLDP was eventually able to successfully lobby the government to remove import taxes on machines and spare parts as well as reintroduce taxes on imported palm oil. During its 10-year lifespan, RLDP reached more than 91,000 farmers, whose income rose by 43 to 79 percent.[160]

CASE STUDY

Zambia

Zambia performs remarkably well in terms of mechanization, with an average agricultural machinery growth of over three percent within the last 10 years. Agricultural output grew on average by about 8.5 percent over the same period. Zambia also achieved an overall score of 5.74 out of a minimum score of 5.53 in the 2018 Biennial Review Report by the African Union concerning Malabo Commitment area #3.1, "Access to agriculture inputs and technologies". Although most smallholder farmers in Zambia still depend on ox-drawn implements, the country's relatively good score under #3.1 and its ranking as a fast mechanizing country are reflections of an ongoing vibrant mechanization process.[161]

Zambia has shown strong ambitions to leapfrog agriculture as a growth and employment creator, and has positioned itself for large-scale adoption of new agricultural technologies. With dedicated Farm Power and Mechanization Centers, as well as strong national research capacities and a recognition of the role of the private sector, Zambia has shown itself to be effective in advancing the uptake of mechanization along the value chain. However, as the recent Biennial Review Report has shown, progress remains to be made to meet national and international targets, including the Malabo commitment of ending hunger by 2025.

Institutional innovations

Starting in the early 1990s, agricultural policy has undergone major changes in Zambia, with a shift from solely governmental interventions to a liberalized system aiming to integrate the private sector in various aspects of agricultural production, including input supply, processing, marketing and extension service provision. In the beginning of the 2000s, the government also implemented a set of policies aimed at agricultural reforms to promote privatization and trade reforms, leading to higher investment and a strong growth in export crops such as cotton and horticulture.[162] In 2015, the Ministry of Agriculture and Livestock was divided into the Ministry of Agriculture and the Ministry of Fisheries and Livestock. Since then, the Ministry of Agriculture has been mandated to provide technical services on irrigation, farm power, mechanization, and land husbandry.

The Zambia Agriculture Research Institute (ZARI), the largest agricultural research entity in Zambia, is situated within the Ministry of Agriculture. The objective of the department is to provide high-quality, appropriate, and cost-effective services to farmers, generating and adapting crop, soil, and plant- protection technologies and machines. Under the Farming Systems and Social Sciences Division (FSSS), the objective is to adapt technologies to farmers' socio-economic and cultural settings while trying to involve them fully in the technology adaptation process. In order to increase the adaptation of technologies, ZARI tests and improves machines and technologies on-farm and strengthens the linkages between researchers, extension workers, and farmers.[163] ZARI also works with partner organizations, such as the African Agricultural Technology Foundation (AATF), to promote agro-processing initiatives in the cassava value chain. In 2016, the two launched a Cassava Mechanisation and Agro Processing Initiative.[164]

Furthermore, the promotion of agricultural mechanization of crop production systems is one of the key policy objectives of Zambia's NAIP, with the aim of increasing the area under mechanized agriculture from 375,000 hectares to 3,000,000 hectares by 2018.[165] In addition, the Second National Agricultural Policy (SNAP) was developed in 2016 to address challenges including the continued low levels of agricultural mechanization among smallholder farmers. In particular, SNAP seeks to promote farm power and mechanization for smallholder farmers and to establish Farm Power and Mechanization Centres, which will build 20 low-cost communal irrigation schemes and dams, 14 livestock breeding centers, and 109 fish seed production centers by 2018.[166,167]

Policy and programmatic interventions

In addition to the governmentally led research center, the Indaba Agricultural Policy Research Institute (IAPRI), a nonprofit center, was established in 2011, enabling collaboration between public and private stakeholders in the agricultural sector. IAPRI is mainly funded through the Swedish International Development Agency (Sida) and the US Agency for International Development (USAID) and is led by a local board of directors drawn from various public and private sector stakeholders. In line with their vision, "A Zambia free of hunger, malnutrition and poverty through sustainable agricultural transformation", IAPRI conducts research on mechanization and on agricultural productivity to analyze effects on smallholder productivity and poverty reduction.[168]

NWK Agribusiness is a private Zambian company that specializes in supplying a full range of up-to-date general agricultural goods. NWK was founded in 2000, and 12 years later the business started to engage in a business model with a broader agri-services focus. Since then, the company has offered storage solutions and retail outlets. The aim is to provide farmers with easier access to mechanized technologies and to post-harvest storage solutions, to enable them to sell their crops at later stages and at higher prices. In particular, the Yield/COMPACI program assists in the pre-financing of machines like tractors to increase smallholders' net earnings per hectare. In 2013, this program showed encouraging results, with more than 120,291 farmers trained through it since its inception (23,132 of them female farmers).[169] This success led to a re-launch of the project in 2014. Since then, a total of 94 farmers have received their mechanization packages, including a tractor, a trailer, and a planter and a ripper, worth over US$24,000 each.[170] Other elements are the FISP Electronic Voucher program and the provision of support to smallholder farmers to access improved inputs, agricultural services, finance and renewable energy markets.[171,172]

Another tractor mechanization fund was established through the Zambia National Farmers Union (ZNFU), FAO, and the Ministry of Agriculture and Livestock (MAL) in 2011. This fund was created to increase access to agricultural machinery among small and medium-scale farmers through a revolving fund concept. The offered purchases included tractors, rippers, ripper-planters, maize shellers, trailers, boom sprayers, and other equipment. Benefits are

CASE STUDY

Zambia

access to appropriate machinery at reasonable cost; opportunity to mechanize and commercialize farming; increased agricultural production and productivity; and additional income through hiring out of equipment. As a revolving fund, more farmers would benefit in subsequent years.[173]

Furthermore, through the company Rent to Own (RTO), smallholders can acquire and repay both the asset and loans through payment schedules tailored to their income streams, last-mile distribution, and technical assistance. The company, which was founded in 2010, aims to provide access to credit to over one million direct beneficiaries by 2022. Products include gensets, water pumps, fridges/freezers, laptops, electric stove, butcher saws, dehullers/hammermills, maize shellers, oil presses, tractors, flatbed trucks, bicycles, and solar lights. Between 2010 and 2015, over 1,850 smallholders have been reached and the livelihoods of an estimated 12,500 people in Zambia have been improved through an increased asset base and incomes. Roughly 75 percent of the beneficiaries were men and 25 percent women. By 2015, the total value of assets disbursed had reached US$1.8 million. During the first five years, RTO has disbursed nearly 2,000 pieces of equipment, of which over 1,300 have transferred ownership to the clients while over 600 are still being paid for.[174]

A program initiated in 2012 over eight years, the Effective Grain Storage Project (EGSP) Phase 2 targets smallholder farmers with the aim of mitigating food losses by introducing metal silos as an improved storage technology. The activities of the project include training in the manufacturing of metal silos to provide farmers with better alternative storage solutions.[175] The silos allow farmers to store maize without chemicals for more than six months and therefore to store and maintain the quality of maize until the next year's harvest and to sell their maize for higher prices at the end of the harvest season.

Conclusion

Delivering on the African Union Agenda 2063, the Malabo commitments, and the SDGs will only be possible through an agricultural transformation that increases agricultural productivity while reducing post-harvest losses and creating new opportunities for processing and value addition. As the African Union's Biennial Review Report of 2018 has shown, many countries are still lagging behind in meeting targets on mechanization and access to agriculture inputs and technologies. However, as illustrated by the evidence and case studies in this report, seven African countries – Ethiopia, Malawi, Mali, Morocco, Rwanda, Tanzania and Zambia – have shown how to successfully improve the uptake of mechanization along the entire agriculture value chain. As a result, they have achieved high machinery growth coupled with high agricultural growth rates.

Targeted efforts and interventions are needed by governments and the private sector to promote mechanization in each segment of the value chain and at scale. This leverages the potential of agriculture to drive growth and employment, particularly in rural economies. It is a promising sign that several of the countries studied in this report were able to increase the uptake of mechanization along the entire value chain, thereby increasing their agricultural output growth and generating new off-farm employment opportunities. Their success illustrates interventions and plans that other countries with slower progress in the mechanization of agriculture value chains could adopt. In many other African countries, however, progress remains limited in particular with respect to mechanizing downstream value chain segments. Given the emerging dynamics, with a rising processing sector fueled by rapid urbanization and a growing middle class, derived demand for processing technologies is high. Governments must therefore develop creative and innovative interventions to promote technologies for product and process innovation. For now, this remains the weakest link in the mechanization agenda.

Interventions targeted at increased collaboration with the private sector, skill development and training of youth, and support for emerging domestic agricultural machinery industries are just some of the examples that have enabled countries to make considerable progress. The experience of the seven case study countries can help other governments develop country-specific mechanization strategies and policies that favor collaboration between the private sector, research institutions, and the government.

The Malabo Montpellier Panel therefore recommends to:

1. **Elevate national agricultural mechanization investment strategies to a priority within countries' national agriculture investment plans.**

2. **Design mechanization pathways in a way that they are socially sustainable.**

3. **Prioritize mechanization in every segment of the agriculture value chain, from production, through to post-harvest handling and processing.**

4. **Increase investments in the development of supportive infrastructure and vocational training at scale.**

5. **Incentivize the private sector to take mechanization to scale by creating a conducive business and services environment.**

6. **Develop an African agricultural machinery industry that is context-specific through strong public-private partnerships.**

7. **Empower smallholder farmers and women groups by involving them in the development of locally adapted machines and technologies.**

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