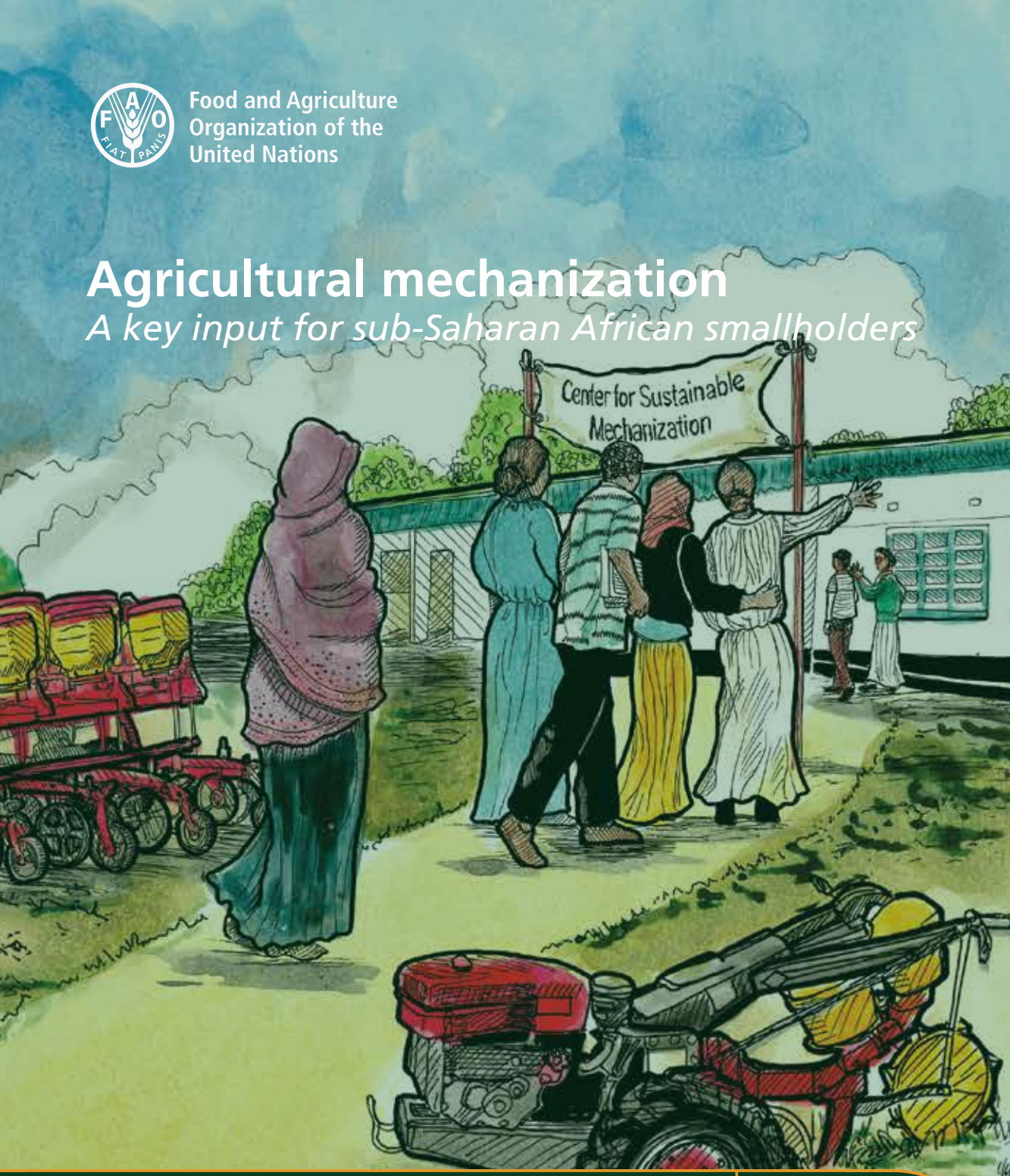
Food and Agriculture Organization of the United Nations

Agricultural mechanization

A key input for sub-Saharan African smallholders



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Agricultural mechanization
A key input for sub-Saharan African smallholders

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FOREWORD

The United Nations General Assembly (UNGA) formally adopted the sustainable development goals (SDGs) on 25 September 2015. The SDGs build on the Millennium Development Goals (MDGs) and focus on building a sustainable world where environmental sustainability, social inclusion and economic development are equally valued. The SDGs offer a vision of a fairer, more prosperous, peaceful and sustainable world for both the developing and the developed world. The SDGs are interconnected with FAO's work. The first and second goals – "No Poverty" and "Zero Hunger" are associated with three of FAO's strategic objectives, "Help eliminate hunger, food insecurity and malnutrition", "Make agriculture, forestry and fisheries more productive and sustainable" and "Reduce rural poverty". The FAO Director-General, when addressing the UN plenary in September 2015, noted that: *the second goal – which is to "end hunger, achieve food security and improved nutrition and promote sustainable agriculture" – must be urgently pursued as rapid progress on that front is the key to the other goals.*

FAO is well positioned to support countries, especially in Africa, in achieving the SDGs. We cannot afford to miss the opportunity to become Generation Zero Hunger. FAO's work on sustainable production intensification and agrifood systems development is an integral part, and agricultural mechanization plays a pivotal role in this process.

In order to feed the burgeoning world population, it is necessary to intensify agricultural production systems. However, this intensification must not come, as has often happened in the past, at the expense of our natural resource base. FAO's ecosystem-based "Save and Grow" paradigm recognizes this and proposes a new vision for sustainable crop production intensification – one that is both highly productive and environmentally protective. Save and Grow incorporates conservation agriculture (CA), healthy soils, improved crops and varieties, efficient use of water and integrated pest management. This volume of the *Integrated Crop Management* series shows how smallholder-focused farm mechanization can be developed to be entirely compatible with Save and Grow.

Under the Comprehensive Africa Agriculture Development Programme (CAADP) of the African Union in the New Partnership for Africa's Development (NEPAD), Africa is in the middle of agricultural transformation. Sustainable agriculture mechanization will play a significant role in fuelling this transformative change.

There is no doubt that the application of farm power to appropriate tools, implements and machines – "farm mechanization" – is an essential agricultural input in sub-Saharan Africa (SSA) with the potential to transform the lives and economies of millions of rural families. For example, farm mechanization can facilitate increased output of higher value products while eliminating the drudgery associated with human muscle-powered agricultural production. Improved livelihoods for smallholder farmers means increased access to input supply chains and integration in modern food systems, resulting in improved incomes, numerous and renewed business opportunities, further value addition and overall improved livelihoods for smallholder families. Moreover, agricultural mechanization in its broadest sense can contribute significantly to the sustainable development of food systems globally, as it has the potential to render post-harvest, processing and marketing activities and functions more efficient, effective and environmentally friendly.

This volume of the *Integrated Crop Management* series focuses specifically on agricultural mechanization, the opportunities provided by mechanization for intensifying production in a sustainable manner, value addition and food systems development, and the inherent opportunities implied for improved local economies and livelihoods. The establishment of viable business enterprises, agriprocessors, transport services and similar activities along the food production chain as a result of increased agricultural mechanization in rural areas is crucial for generating employment and income opportunities and, thereby, enhancing the demand for farm produce. Mechanization plays a key role in enabling the growth of commercial agrifood systems and improving the efficiency of post-harvest handling, processing and marketing operations. As such, it can have a major influence on the availability and accessibility of more nutritious food, contributing to increased household food security.

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ACRONYMS

AfDB	African Development Bank
AGCO	Agriculture Company Corporation
AGP	Plant Production and Protection Division
ANTAM	Asian and Pacific Network for Testing of Agricultural Machinery
CA	conservation agriculture
CAADP	Comprehensive Africa Agriculture Development Programme
CEMA	European Committee of Associations of Manufacturers of Agricultural Machinery
CNH	Case New Holland
EDRI	Ethiopian Development Research Institute
FAO	Food and Agriculture Organization of the United Nations
FBS	farmer business schools
FFS	farmer field schools
GFP	German Food Partnership
GHG	greenhouse gas
GR	Green Revolution
IFPRI	International Food Policy Research Institute
ITC	information and communication technologies
MDGs	Millennium Development Goals
NCAMs	National committees on agricultural mechanization
NEPAD	New Partnership for Africa's Development
OECD	Organization for Economic Cooperation and Development
PIA	Potato Initiative Africa
RNAM	Regional Network for Agricultural Machinery
R&D	research and development
SAMS	Sustainable Agricultural Mechanization Strategies
SDGs	sustainable development goals
SSA	sub-Saharan Africa
UN-CSAM	United Nations Center for Sustainable Agricultural Mechanization
UNESCAP	United Nations Economic and Social Commission for Asia and the Pacific
UNGA	United Nations General Assembly
UNIDO	United Nations Industrial Development Organization

CHAPTER 1

The context of agricultural mechanization

The 17 sustainable development goals (SDGs) successfully came into being when the United Nations General Assembly (UNGA) formally adopted them on 25 September 2015.

The Food and Agriculture Organization of the United Nations (FAO), with its expertise and resources, is well positioned to support countries, especially in Africa, in achieving the SDGs; the opportunity to become Generation Zero Hunger cannot be missed. FAO's work on sustainable production intensification and developing green food value chains (FAO, 2014a) will be part of this effort, and agricultural mechanization has a key role in this development process (Figure 1).

FIGURE 1

The potential contribution of mechanization to green food value chain development

Production	Post-harvest / storage	Processing	Marketing
Crop establishment	Drying	Chopping	Packaging
Weeding	Grading	Milling	Transport
Fertilization	Winnowing	Grinding	
Irrigation	Cleaning	Pressing	
Crop protection	Storage		
Harvesting			

Source: Breuer *et al.*, 2015 (adapted).

There is no doubt that agricultural mechanization for the multitude of smallholder farmers in sub-Saharan Africa (SSA) has been a neglected issue for too long. The application of farm power to appropriate tools, implements and machines – "farm mechanization" – is an essential agricultural input with the potential to transform rural families' livelihoods by facilitating increased output of higher value products while eliminating the drudgery associated with human muscle-powered agricultural production. Such an improved situation for smallholder farmers can enable access to input supply chains and integration in modern food systems and thus provide for more

income, renewed business opportunities and further value addition. Moreover agricultural mechanization in its broadest sense can contribute significantly to the development of food systems, as it has the potential to render post-harvest, processing and marketing activities and functions more efficient, effective and environmentally friendly.

FAO (2014b) summarizes the main reasons for changing the power source for crop production from muscles (human or animal) to tractors:

i. Potential to expand the area under cultivation.
ii. Ability to perform operations at the right time to maximize production potential.
iii. Multifunctionality – tractors can be used, not only for crop production, but also for transportation, stationary power applications and infrastructure improvement (drainage and irrigation canals and road works).
iv. Compensation for seasonal labour shortages (or, indeed, release of labour for more productive work.
v. Reduction of the drudgery associated with the use of human muscle power for tasks, such as hand hoeing for primary tillage – especially important in tropical areas where high temperatures and humidity (sometimes associated with inadequate nutrition) make manual work extremely arduous.

In spite of these perceived benefits and the fact that animals had been largely replaced by tractors in both the United States and Western Europe by the 1950s, arguments were still put forward urging caution in the developing world (as highlighted by FAO, 2008). The main preoccupation was the effect of mechanization on rural employment opportunities. At the time, it was not understood that mechanization affected mainly on-farm family employment, not hired labour. Mechanization, in fact, enables farm family members not only to increase farm productivity via production intensification and/or expansion, but also to seek off-farm employment opportunities as a result of the increased time made available to look for and be engaged in such employment. Moreover, it was not appreciated that mechanization applied only to specific farm production tasks (in particular land preparation), and consequently had little effect on hired labour unemployment as previously presumed. The International Food Policy Research Institute (IFPRI, 2016a) enriches the debate on the social factors associated with mechanization by pointing out that in the past, forced mechanization was associated with the displacement of tenant farmers and rural labour. However, in Africa, mechanization is more likely to increase labour demand when it enables more land to be cultivated (and when it is profitably applied along the value chain). IFPRI points out that mechanization is just one component in the agricultural intensification process; mechanization should not actually initiate intensification where it is not already driven by population pressure and

market demand. IFPRI quotes Boserup (1965) in this respect and concludes that there are many areas where demand for mechanization has emerged from the smallholder sector. Moreover, mechanization increases value addition (post-harvest operations and primary and secondary processing), as well as services to support agricultural mechanization development. Given the widening array of mechanization options available, employment in primary agricultural production is expected to decline, and this is a credit to the increasing productivity of farming. However, jobs are not actually "lost", because increasing agricultural productivity means that more jobs are created in secondary employment related to agriculture, for example, in the agrifood value chain and machinery-related services.

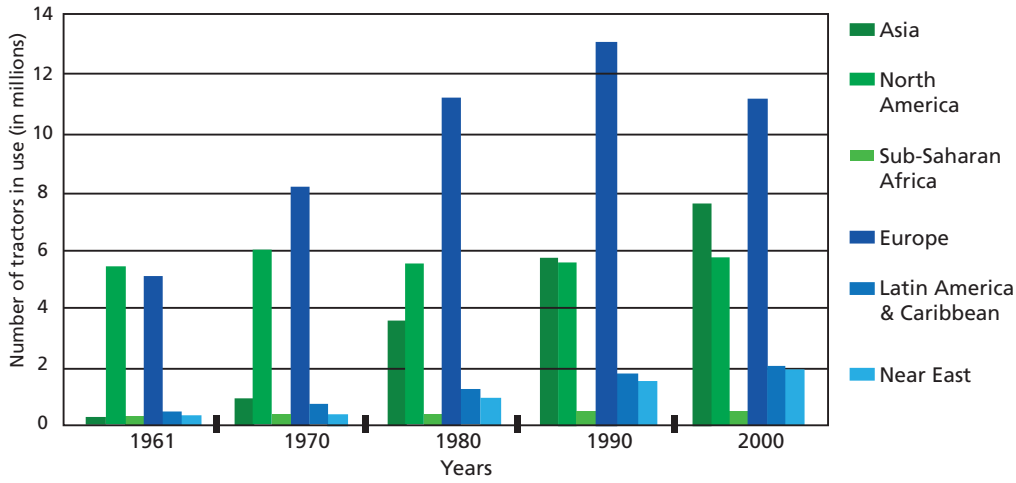
Other concerns were expressed with regard to agricultural mechanization. Fuel costs were high and continually rising, and fields were small and fragmented and therefore perceived as an obstacle to tractorization – without land consolidation mechanization would not be viable. All these considerations led to a reduced focus on mechanization as an essential input throughout the 1980s. In contrast, the momentum in Asia and Latin America continued unabated.

In fact, the routes to agricultural mechanization in Asia, for example, provide interesting insights – in terms of experience, lessons learned and knowledge exchange – on how SSA can mechanize its agricultural and food sectors. In West Africa, Ghana and Nigeria are learning from Bangladesh's experience in agricultural mechanization (IFPRI, 2016b). Lessons learned include development and use of mechanized technologies (mainly 2-wheel tractors), fostering and development of the private sector (an enabling business environment with public support, research systems connected to stakeholders, and good equipment distribution networks especially in rural areas), infrastructure development (development of feeder roads into main road networks), elaboration of the financial system (appropriate financial products developed to enable investment in agricultural equipment), organization of the fiscal system (reduction of import tariffs on machinery), enhancement of extension service networks (mainly rural and connected to research and development centres) and, importantly, policy implementation (several government agencies collaborating together). Further, in East Africa, specifically Ethiopia and Kenya, IFPRI and the Ethiopian Development Research Institute (EDRI) (IFPRI–EDRI, 2016c) report that lessons learned from Bangladesh are being used to foster and support both countries' mechanization efforts. Moreover, in terms of small-scale engine technologies (single cylinder diesel engines) and their diffusion throughout South Asia in the past 50 years, there may be important lessons to learn for SSA. Indeed, such engines are used for multipurpose functions: 2-wheel tractors, shallow tube well pumps, river boats, road and track transport vehicles, harvesters, threshers, grain mills, timber mills and processing equipment (IFPRI, 2015c).

Taking the number of 4-wheel tractors as an indicator of advancement in mechanization, FAO (2008) reports the following trends over the past 40 years (Figure 2):

- In Asia, tractor numbers increased fivefold between 1961 and 1970, from 120 000 to 600 000 units. Thereafter, the number increased tenfold, reaching 6 million units in 2000. Numbers have since continued to increase, especially in India, where tractors numbered 2.6 million in 2010 (FAO, 2013a), and China, where they numbered over 2 million in 2008 (FAO, 2013b).
- In Latin America and the Caribbean, tractor numbers increased 1.7 times between 1961 and 1970, from 383 000 to 637 000 units, and thereafter tripled to reach 1.8 million in 2000.
- In the Near East, the picture is similar to Latin America, as tractor numbers doubled from 126 000 to 260 000 between 1961 and 1970 and then increased 6.5 times to reach 1.7 million in 2000.
- In sub-Saharan Africa, the trend has been rather different. In 1961, the number of tractors in use (172 000) exceeded the number both in Asia and in the Near East. They then increased slowly, peaking at 275 000 in 1990 before declining to 221 000 in 2000.

FIGURE 2
Tractor use by region, 1961–2000



1. Asia includes the People's Republic of China, Japan and India as well as Oceania and Pacific countries.
2. North America includes United States, Canada, Bermuda and Greenland.
3. Sub-Saharan Africa includes all countries on the continent except North African Arab countries (Algeria, Morocco, Tunisia, Libya, Egypt and Sudan).
4. Europe includes ex-USSR up to 1990, thereafter including the Russian Federation and Ukraine and the Baltic States, ex-Asian Soviet Republics are excluded.
5. LAC includes Latin America and the Caribbean.
6. Near East includes all mid-Eastern countries and North African Arab countries.

Source: FAO, 2008.

The world population (currently 7.31 billion) is forecast to reach 9 billion by 2050 and exceed 11 billion by the end of the century. The world's 500 million smallholder farms currently account for around 80 percent of global food production and it is primarily they who will have to respond to the need to increase food production by over 60 percent (compared with 2007) by 2050 (FAO, 2011a). At present, many smallholder farms have limited access to production inputs, especially mechanization; they therefore reach low levels of productivity, and often contribute to the increase in negative environmental impacts on already dwindling natural resources. They also have fewer opportunities to access markets and take advantage of the numerous value-adding activities that more developed food systems can provide. At the same time, the rural population is expected to decline as people, especially the young and fit, migrate to urban centres in search of a life characterized by less drudgery than that offered by agriculture. There is also a growing feminization of smallholder agriculture, especially in SSA, as women are increasingly left in charge of the family farm while the men migrate in search of higher incomes. Agricultural mechanization can offer women in rural areas opportunities appropriately adapted to cultural, social and traditional work norms, and to the overall development of local economies; however, these opportunities are often underestimated. Currently 50 percent of the population in developing countries lives in the rural sector and this is projected to fall to 30 percent by 2050 (FAO, 2009a). However while Africa urbanizes, its rural population will continue to grow at a rate of more than 1 percent per annum beyond 2045. Sub-Saharan Africa is expected to grow by more than 353 million additional rural dwellers between 2015 and 2050 (AfDB *et al.*, 2016). This population growth, though, will still see the migration of youth and others to urban centres in search of higher paying jobs that are less labour intensive than farming. Given the current important role of human muscles in smallholder agriculture, there are serious power limitation implications (Sims and Kienzle, 2015).

The power sources for developing country agriculture are human muscles, draught animals and tractor engines. The use of the different sources varies across regions (Table 1). In sub-Saharan Africa, large farms and the emerging agricultural sector (farms of 20–50 ha) do not generally have a problem with access to farm power, but smallholder farms (typically < 2 ha) experience extreme difficulty.

TABLE 1
Sources of power for land preparation (% of total)

	Human muscle power	Draught animal power	Engine power
Sub-Saharan Africa	65	25	10
East Asia	40	40	20
South Asia	30	30	40
Latin America and the Caribbean	25	25	50

Source: FAO, 2006.

In general, there is an increase in engine power while the number of draught animals is falling, although at local level animals can still be very important. The move away from muscle power towards tractors and engines for pumping and post-harvest operations has been much more rapid in Asia and Latin America. Draught animal numbers in India and China are falling dramatically (from a peak of > 100 million in both countries) and are being replaced with 4-wheel tractor power; whereas in Bangladesh, draught animals have been replaced by 2-wheel tractors, which now perform 80 percent of land preparation.

The green revolution is credited, especially in Asia, with having kick-started the shift to profitable commercial farming, alleviating rural poverty, saving large areas of fragile land from conversion to extensive farming, and helping to avoid potential hunger threats in the face of a growing world population. Overall, the proportion of undernourished in the world population declined from 26 to 14 percent between 1969 and 2002 (FAO, 2009b).

However, there have been serious negative consequences. The enormous gains in agricultural production and productivity were often accompanied by deleterious impacts on the rural natural resource base and ecosystem functions, jeopardizing the productive potential of agriculture and impacting agrifood value chains. At production level, many of the effects are easily observable: land degradation (through erosion and compaction), salinization of irrigated areas, over-extraction of groundwater, build-up of pest resistance and decline of biodiversity. The uncertainty and variability of yields and reduction in product quality, combined with degraded lands and depleted water resources, have made smallholder-level processing and value addition a far more risky business.

In Africa, the green revolution has not had the same impact as in Asia. Mechanization and intensification, fertilizer use and adoption of other modern technologies have all remained at low levels across most of the continent. Nevertheless, degraded lands are widespread throughout the continent for a wide range of reasons, including the continuous use of the plough (or hand hoe) resulting in soil degradation, plough- or hoe-pans in the soil profile and loss of fertile top soil (Kienzle and Sims, 2015). Soil erosion is extensive in many regions of Africa, especially considering the current low level of mechanization. In the long term, if Africa intensifies and mechanizes its agriculture on a large scale, it must do so with care and in line with the principles of sustainable production intensification summarized by FAO in its "Save and Grow" guidelines. Save and Grow is based on environmentally friendly conservation agriculture (CA) mechanization with the aim of achieving resilience in the face of a changing climate (FAO, 2011a, 2016a). Farming systems for sustainable production intensification offer a range of productivity, socio-economic and environmental benefits to producers, to

other food value chain actors and to society in general. Implementation of Save and Grow enables:

- improved and stable environmentally friendly production, food distribution and profitability;
- efficient use and conservation of natural resources;
- adaptation and reduced vulnerability to climate change;
- enhanced ecosystem functioning and services; and
- reductions in agricultural greenhouse gas (GHG) emissions and agriculture's "carbon footprint".

In summary, agricultural mechanization in the twenty-first century should be simultaneously: environmentally compatible, economically viable, affordable, adapted to local conditions and, in view of current developments in weather patterns, climate-smart.

These proposed farming and food systems are based on four technical principles:

- Achievement of increased agricultural productivity while enhancing natural capital and ecosystem services.
- Higher rates of efficiency in the use of key inputs, including water, nutrients, pesticides, energy (including farm power), land and labour.
- Use of managed and natural biodiversity to build system resilience to abiotic, biotic and economic stresses.
- A more effective, efficient and environmentally friendly food system resulting from increased agricultural mechanization.

The farming practices required to implement the first three principles differ according to local conditions and needs, but in all cases are based on the following concepts:

- Limited soil disturbance by minimizing mechanical tillage to maintain soil organic matter, soil structure and overall soil health.
- Enhancement and maintenance of a protective organic cover on the soil surface, using crops, cover crops or crop residues, to protect the soil surface, conserve water and nutrients, promote soil biological activity and contribute to integrated weed and pest management.
- Cultivation of a wider range of species – annuals and perennials – in associations, sequences and rotations including trees, shrubs, pastures and crops, to enhance crop nutrition and improve system resilience.

In practice, this involves the wide-scale application of conservation agriculture practices (FAO, 2015a).

This paper is specifically about agricultural mechanization and the opportunities it provides for sustainable intensified production, value addition and agrifood value chain development, in addition to the inherent opportunities

for improved local economies and livelihoods (FAO, 2007). The establishment of viable business enterprises, such as agriprocessors and transport services, as a result of increased agricultural mechanization in rural areas, is crucial for creating employment and income opportunities and enhancing the demand for farm produce. Mechanization plays a key role in enabling the growth of commercial agrifood systems and increasing the efficiency of post-harvest handling, processing and marketing operations. Consequently, it determines food availability and accessibility, as well as food prices paid by urban and rural poor, thus contributing to increased household food security. IFPRI (2016a) concurs by concluding that increased accessibility of agricultural mechanization can contribute to Africa's agricultural and economic transformation.

CHAPTER 2

Challenges faced by agricultural mechanization in sub-Saharan Africa

Agricultural mechanization – in fact mechanization throughout the food system – is affected by a series of constraints in sub-Saharan Africa. In a given location (or country) these constraints must be identified and strategies conceived to alleviate them and allow for the development of mechanization services to benefit all farmers, especially smallholder producers and other actors in agrifood value chains. The World Bank's project on "Enabling the Business of Agriculture" focuses on identifying and monitoring regulations that negatively affect agriculture and agribusiness markets. Machinery is identified as a key input and market enabler (World Bank, 2016). Some of the potential challenges are discussed below.

2.1 AFFORDABILITY

Smallholder farmers are, almost by definition, resource poor and often have difficulty investing in physical assets in general and in agricultural machinery in particular. In many countries, agricultural machinery suppliers are only found in the larger towns and cities, as the perceived low demand in rural areas for equipment does not always justify the establishment of distribution networks. Smallholders are often isolated by distance and poor infrastructure (especially feeder roads). There is limited access to sources of financial credit due to the:

- lack of availability of financial products specifically focused on farm equipment investment;
- misconception of many financial institutions regarding the need for targeted financial products for investment in equipment;
- basic nature of agricultural production – i.e. a high-risk business;
- reluctance of commercial financial institutions (mainly banks) to extend credit to poor farmers with little collateral; and
- The lack of financial products to serve the purposes of small-scale farm mechanization.

Experience from other parts of the world shows that extending credit products to farmers to invest in agricultural machinery not only allows them

to raise their productivity and participate more fully in the market economy, but can also incentivize the local machinery manufacturing industry to supply their needs (Casão-Junior *et al*., 2012).

The restricted purchasing power of smallholder farmers depends on a series of factors impinging on the farm family's economy:

- Low yields (basic grain crops of < 1 tonne/ha) – caused by many factors, including lack of adequate inputs (especially seed and fertilizer) at the right price and the right time, climate change (with longer drought periods and more frequent storms) and the degraded condition of many agricultural soils.
- Poor marketing facilities and inadequate rural, farm-to-market, infrastructure – resulting in poor returns to smallholder crop production.
- Low market prices.
- High transport costs.

Farmgate price issues are a potentially major disincentive for smallholder farmers. Private sector-led input and output markets have not developed as quickly as expected and farmers are constrained by a lack of free competition in these markets, resulting in high prices for agricultural inputs as well as lower farmgate prices for produce compared with other regions of the world. The consequent reduction in farm incomes and the lack of incentives to market produce have led to an overall decline in the level of investment in agriculture. This is reflected in low investments in fixed assets, such as agricultural machinery, that commonly have high start-up investment costs and returns spanning a long period, and which may be economically unsustainable for smallholders (even if profitable). This trend was documented in Ghana and Nigeria (IFPRI, 2012, 2014a, 2014b).

At the same time, farmer organizations have had limited success in improving smallholders' access to markets and public services with mixed results in terms of providing machinery services to members. Although farmer organizations do recognize the economic and social benefits to farmers of mechanized services, they are not always able to coordinate such services at managerial level. However, some grassroots farmer organizations (e.g. cooperatives) successfully deliver mechanization services to their members. For example, in Benin, Herbel *et al*. (2015) report that cooperatives furnishing successful mechanization services to members are organized at field level (a bottom-up approach) and provide good economic returns to their members, with a subsequent positive impact on members' social standing. The cooperatives also have useful contacts with banks and other key stakeholders at local level. In Nigeria cooperatives providing mechanization services can deliver both economic and social benefits to their members with a system organized at local level, based on the active participation of small-scale farmers and the concept of self-help (Abdulquadri and Mohammed, 2012).

Land tenure is one of the most important issues in agriculture; in many countries, a lack of security of tenure severely hinders investment in the agricultural sector. For a successful transition from semi-subsistence farming to profitable, productive agriculture, land tenure must be secure and guaranteed by the state as well as by local laws and traditions. This gives farmers the security and confidence to invest in mechanization and other production-enhancing inputs. In some countries, there are laws to regulate land tenure but they are not always effective. For example, where there is a tradition of common land ownership by clans and extended families, it is difficult to commercialize farming and very challenging to change such patterns of land ownership. In many countries, despite the introduction of national legislation, no "secure" land transaction can take place without the participation of the traditional chiefs; an investor must provide "gifts", not only when farming commences, but when a change of title takes place. Other issues – such as "land-grabbing" – are becoming more widespread and serious as the world population grows and climate change adds uncertainty to agricultural production (Pearce, 2012). Furthermore, increasingly unpredictable rainfall, dwindling ground and river water resources, and water tenure disputes (FAO, 2016b) – in addition to those related to land tenure – create an adverse environment for increased farm commercialization.

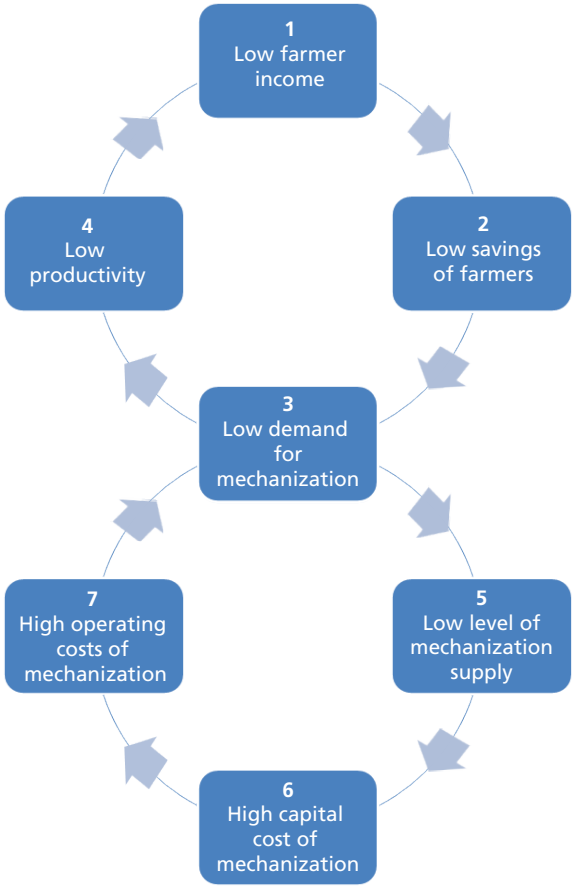
Smallholders operating just above subsistence level tend to be extremely risk-averse. For the rural family, a reliable source of food throughout the year – even if well below the level of potential yields for the region – is preferable to a situation where yields may be very high in favourable seasons, but very bad in adverse years. A steady yield (albeit low), resistant to the vagaries of the weather is preferable, but does not necessarily result in a marketable surplus. For these reasons, without financial assistance, it is unlikely that smallholders can invest in the kind of mechanization technologies that could lift them out of their precarious condition.

2.2 AVAILABILITY

Tractors and agricultural machinery can be either imported or locally made, with potential associated problems in both cases. Locally produced machinery is usually low in quality and high in price. This is due to the underdeveloped nature of the machinery manufacturing industry, which in turn is largely the result of poor demand. Moreover, supply chains providing support to owners of tractors and agricultural machinery with spare parts, advice and other services (especially clean fuel) are often underdeveloped and do not easily reach remote rural areas (FAO, 2009d).

Analysis of the limited adoption of mechanization and of the relationships between the different determinants clearly indicates that SSA conditions have led to the creation of a restrictive environment, which has held back the development of mechanization (Figure 3).

FIGURE 3
Factors weakening the demand and supply of agricultural mechanization



Source: FAO, 2013d.

Figure 3 shows that low farmer income (1) – discussed above in 2.1 – results in very low potential for investment in inputs (2). Inputs refer not only to seed and fertilizer, but to agricultural machinery, and therefore there is low demand for tools and machines (3). This lack of investment in production-enhancing technologies results in very low levels of productivity (4), which further consolidates the continuing situation of low farmer income (1).

The lack of demand for mechanization drives another debilitating element: supply (bottom half of Figure 3). The poor supply of tools, equipment and power sources (limited choice and low volume of sales) (5) tends to lead to higher costs of agricultural mechanization (6), which in turn leads to higher ownership and running costs (7). The high cost of using farm machinery completes the vicious circle, leading back to low demand.

These interrelated factors illustrate the structural constraints faced by most African countries with regard to the increased adoption of mechanized farming methods. They highlight how demand and supply of agricultural mechanization inputs are interdependent. On the other hand, they also indicate how debilitating factors can be converted to enabling ones.

2.3 LACK OF FARMER SKILLS

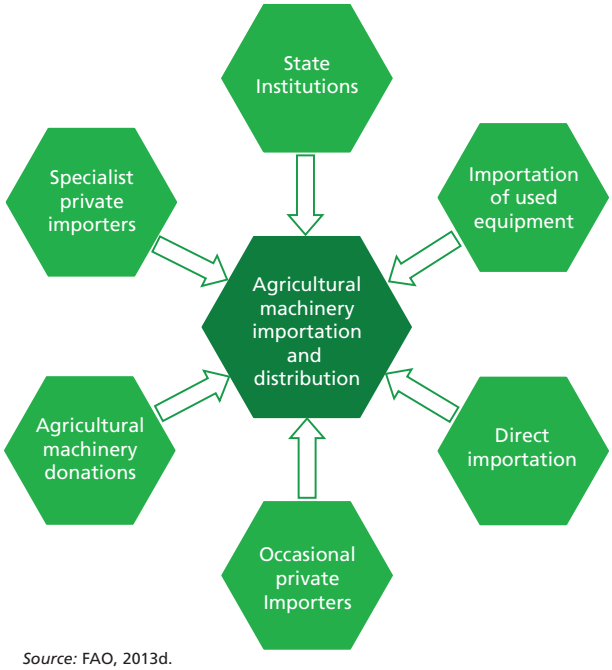
Although African farmers have a great deal of traditional knowledge and experience accumulated over generations, they have relatively limited access to new knowledge. The level of farmer training is relatively low and opportunities for further training are limited. Public and private extension and training services do not easily reach rural and remote areas, as distances are great and transport can be scarce. If demand for extension and training is low, it may be difficult to justify such activities in economic terms. There is a high rate of illiteracy among rural farming populations; this hinders the improvement of agricultural production and productivity and of the general level of farm management. For example, in many SSA countries, only land preparation and transportation are done using tractors (FAO, 2009c), while other operations, such as seeding and harvesting, are mostly carried out manually. Farmers lack the knowledge and skills to operate mechanized equipment (FAO, 2011c), and when machines *are* used, this lack of proficiency leads to misuse and mismanagement of machinery – especially of more sophisticated machines.

2.4 CONSTRAINTS WITHIN THE PRIVATE SECTOR

The whole of the farm machinery subsector, encompassing manufacturers, importers, distributors, retailers and hire services business enterprises, faces constraints that hinder its development. Numerous constraints are common to other developing subsectors in the private sector, for example: lack of enabling laws to facilitate business start-ups and enterprise operations, complex fiscal systems, punitive import regulations and rigid labour laws. Private sector agricultural machinery manufacturing is at an early stage in many countries across SSA; it is hampered by international competition and imports, and held back by less developed distribution networks. Markets for mechanization hire services are also in their infancy; there is usually very little demand due to the lack of awareness among smallholders of the need for mechanized services. Low demand is mainly a consequence of lack of development, but there are also other constraints.

2.4.1 Agricultural machinery importation and distribution

FIGURE 4
Agricultural machinery importation and distribution



Source: FAO, 2013d.

Farm machinery is imported and distributed through a range of channels (Figure 4). Some are more successful and sustainable than others:

Specialist private importers of agricultural machinery are usually franchises that import and sell a limited number of select brands. The import company obtains the franchise from the manufacturer. These companies are typically located in the country's capital city, but they may also have branches in other major cities and towns. They are traditionally franchises of major Western agricultural machinery manufacturers, but in recent years, Asian and Latin American manufacturers have moved into the market. Nevertheless, sales of major items of equipment (tractors and combine harvesters) remain very low in almost all SSA markets. For this reason, franchise companies tend to diversify their activities, selling other kinds and brands of equipment.

Occasional private importers are usually general traders with no specialist knowledge or experience of farm machinery. Such companies tend to import a batch of machines and once they are sold there is no further obligation to provide spare parts or services. A subsequent batch of machines might well come from a different manufacturer. Farmers who purchase from these companies generally lack experience; they are unaware that there may be future problems with spare parts and repair services.

State institutions and aid agencies in some countries become involved in the importation of farm machinery. Moreover, several African countries have created local tractor assembly plants in a misguided effort to promote agricultural mechanization or with the objective of providing lower cost machinery. Batch importation of farm machinery also takes place when governments and aid agencies issue tenders for the purchase of large quantities of farm machinery. As with private imports, the machinery generally bypasses the local distributor who thus has no obligation to provide spare parts or services. Tenders are usually evaluated based on price with no regard for whether the bidder has a local agent or is able to provide post-sales services. Machines therefore tend to end up as "orphans" with no spare parts or back-up services. As a result, they often have a very short operating life – they may be cheap initially, but they end up being very expensive.

Donations of agricultural machinery and other implements are often made to African countries. Unfortunately, however, almost all these well-intentioned programmes fail to produce the desired results. There is a lack of compatibility between products manufactured in donor countries and other machines already on the market and, therefore, spare parts are unavailable. Donated machines quickly become "orphans": no services are available and once the first breakdowns occur, the machines cannot be repaired. In many countries, machinery "graveyards" exist.

Direct importation is only an option for large-scale farmers and agri-industrial companies. They may choose to import machinery directly from abroad, attracted by major discounts on large orders. The company or farm needs sufficient resources to stock spare parts and carry out maintenance and repairs. Direct importation is also a solution when particular specialized machinery is required, for example sugar-cane harvesters.

Importation of used equipment, particularly tractors, combine harvesters and other specialized machinery, is an additional means to meet demand in some countries, and may provide farmers with an alternative source of cheaper machinery. However, in practice, this system is not necessarily beneficial to farmers, as the importer does not always provide additional services, such as repairs and provision of spare parts. Importation and sale of used machinery tends to occur in countries where technicians are available with a relatively high level of skills and knowledge, but where labour costs are low. The public sector may be tempted to become involved in the importation of machinery – new or used. However, without specialized knowledge of agricultural machinery, failure is almost inevitable.

2.4.2 Manufacturing of farm tools and machinery

The manufacturing industries in SSA countries produce a wide range of hand tools, farm implements and processing equipment. Facilities vary among countries: in some, only the simplest of hand tools are made, and mostly

in the artisan (blacksmith) sector; in others, sophisticated manufacturing facilities exist. Bilateral and multilateral cooperation have also had a role over the years in farm tool and machinery manufacturing, but the industry is not always sustainable due to erratic supplies of raw material, fluctuating demand and quality issues, in addition to difficulties arising when projects make bulk orders – all problems commonly encountered in private sector development. Currently, there are three different kinds of manufacturer: state-owned and operated companies; private industrial enterprises; and informal artisan activities.

2.4.3 Maintenance and repair services

Maintenance and repair of hand tools and animal traction implements is generally straightforward, carried out at local level by small workshops in the informal sector. On the other hand, training and refresher courses are not always available – a phenomenon common to other micro-enterprises in the private sector. The availability of spare parts has improved in some countries following standardization, which facilitates interchangeability between tools sourced from different manufacturers. However, this is not the case for motorized farm machinery and equipment, particularly tractors. Maintenance facilities are poor and there is often a critical lack of spare parts, leading to long periods of down time, underutilization of equipment and, eventually, premature write off. A few decades ago, there was much emphasis on public sector programmes and projects to develop agricultural mechanization maintenance and repair centres. However, these were not very successful and most have since fallen into disuse.

2.4.4 Hire services

While mechanization hire services exist in many countries, there are various constraints: lack of market access; low demand; absence of financing; and limited know-how with regard to running an enterprise and maximizing profits (Hilmi, 2013). For example, in Nigeria (IFPRI, 2015b), numerous market and social imperfections hinder the effective commercialization of hire services – tractors are expensive, loans are not available due to high transaction costs and equipment sharing is almost non-existent.

Machinery hire services can cover a wide range of operations:

- crop operations (e.g. soil tillage, planting and spraying);
- post-harvest services (e.g. threshing, shelling and processing);
- transport services; and
- collection of biowaste and other refuse in rural, peri-urban and urban areas.

It is important to note that hire services are not limited to motorized operations – they are also available when the source of power is animal draught.

During the 1960s, several countries established public-sector-operated farm machinery hire services in an attempt to include small farmers in growing markets for high-value commodities. Most of these schemes – principally for the provision of tractor hire services – did not achieve the envisaged outcomes or produce the anticipated benefits. While some government subsidies may still be available, for the main part SSA has witnessed the demise of such schemes for many reasons, in particular:

- small fields with long travel distances;
- unaffordable hire charges;
- missed payments;
- inflexible and inefficient public sector administration;
- lack of operator and mechanic incentives;
- breakdowns; and
- non-sustainability of subsidies required to keep the service running.

Public sector tractor hire services are, therefore, unsustainable, unless combined with an entrepreneurial spirit and private sector partnerships. For example, in Ghana (IFPRI, 2013), the agricultural mechanization service centres promoted by the Government were not optimized for farmers; at the same time, the direct importation of agricultural machinery by the Government inhibited private imports of appropriate and affordable machinery. In contrast, a promising model for sustainable mechanization is the development of a mechanized service hiring market, where medium- and large-scale tractor-owning farmers provide hire services to small-scale farmers (IFPRI, 2015d).

In many countries, the private sector does provide hire services, albeit on a very small scale; indeed, the typical situation is that tractor owners have spare capacity and hire out their machines to generate income to help cover their costs. Clientele are usually neighbouring farmers, known to the owner, who can thus be confident that he/she will receive payment – sometimes in kind – for the work carried out. There is an increasing phenomenon of local entrepreneurs investing in two or three machines and running small-scale contractor (hire) businesses, typically in communities where the contractor knows his/her clientele. To improve profitability, private sector tractor hire services should diversify the operations offered to enable them to market their services all year round.

2.5 GENDER ISSUES IN SMALLHOLDER MECHANIZATION

In sub-Saharan Africa, women usually contribute 60–80 percent of the labour for food production and have extensive traditional knowledge of dealing with natural resources and the natural environment. In a study conducted in

Kenya and Ethiopia (van Eeredewijk and Danielsen, 2015), the labour burden for women was concentrated in weeding, tillage and land preparation; post-harvest management and transport of agricultural produce; and chopping and collecting fodder, fetching water and child care. The authors found few signs of mechanization to lessen the burden, because the assumption is that women are expected to work hard. Advocating for a reduced work burden for women does not fall within social norms, and women themselves do not have time available to access resources and information that might lead to the reduction of the work burden via investment in mechanization. In fact, it is often men who conduct commercial transactions at farm level and consequently men who make decisions and control the resources required to invest in mechanization (especially capital). Moreover, with the ongoing trend of male migration to urban areas, coupled with the advancement of climate change, women have an increasingly central role in agricultural production and commercialization; nevertheless, they still have little access to mechanization.

CHAPTER 3

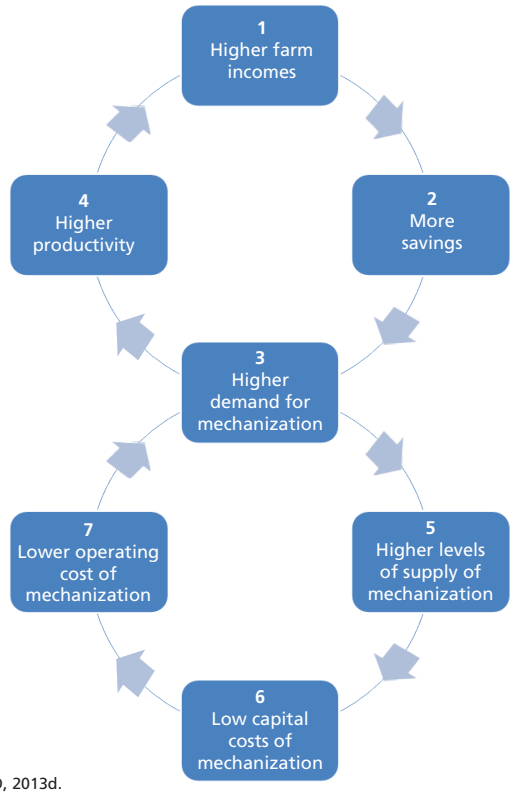
Opportunities provided by agricultural mechanization in sub-Saharan Africa

3.1 RAISING FARMERS' INCOMES THROUGH SUSTAINABLE CROP PRODUCTION INTENSIFICATION AND SUSTAINABLE COMMERCIALIZATION

Given the current state of agricultural mechanization in sub-Saharan Africa, the most promising prospect is to convert the vicious cycles (Figure 3) into *virtuous* cycles (Figure 5).

FIGURE 5

Virtuous cycles resulting from sustainable crop production intensification



Source: FAO, 2013d.

Figure 5 shows that a sustainable increase in farm family income (1) can have a positive knock-on effect on the supply of essential farm power and mechanization. First, raised incomes allow greater savings (2), and the demand for agricultural mechanization services or the acquisition of farm machinery (and other inputs) become feasible prospects for the farmer (3). This in turn raises productivity (4), leading to further improvements in farm incomes. At the same time, in the lower circle, it can be seen how increased demand for agricultural mechanization (3) leads to a concomitant improvement in supply as a market response (5). An expanding market means that operating costs per unit are reduced (6) and prices can fall without jeopardizing profitability (7). Lower costs are a catalyst for increased demand (3) and, hence, the virtuous cycle is complete.

Ending poverty is the UN sustainable development goal (SDG) 1 and a global priority. FAO (2015d) points out that 80 percent of the world's extreme poor live in rural areas and are mostly dependent on agriculture. In addition, agricultural growth in low-income and agrarian economies is at least twice as effective as growth in other sectors in terms of reducing hunger and poverty. Farm family incomes can be improved through investment in rural development, establishing social protection systems, building on rural–urban linkages and focusing on boosting the incomes of the critical agents of change, including smallholder farmers.

Raising the productivity of smallholder farmers must be a sustainable process, taking into account the lessons learned from the green revolution (GR). Beginning in the 1950s and continuing through the 1960s, the GR produced changes in crop varieties and agricultural practices worldwide (Royal Society, 2009). The production model, which focused initially on the introduction of genetically improved, higher-yielding varieties of wheat, rice and maize in high potential areas (Hazell, 2008; Gollin *et al*., 2005), was based on homogeneity, promoting genetically uniform varieties grown with high levels of complementary inputs (e.g. irrigation, fertilizers and pesticides), often replacing more environmentally friendly practices. Fertilizers replaced organic soil quality management, while herbicides and pesticides provided an alternative to crop rotation as a means of controlling weeds, pests and diseases (Tilmann, 1998).

However, as described above in Chapter 1, the GR had serious negative consequences. It is now imperative to introduce sustainability into the future productivity increases required, in particular in SSA. The Save and Grow paradigm (FAO, 2011a, 2016a) advocates stewardship of fragile natural resources, combined with intensification of crop production through greatly enhanced land husbandry methods, including conservation agriculture.

The sustainable increase in productivity is just one important aspect of raising smallholder incomes and developing new opportunities for mechanization; there is also a need for sustainable commercialization of farm products.

Smallholders could increase commercialization opportunities by adopting equipment for on-farm value addition or improved transport to market. Increased access to more sustainable and lucrative forms of commercialization will raise incomes and provide further opportunities for mechanization.

3.2 NEW OPPORTUNITIES FOR AGRICULTURAL MECHANIZATION DEVELOPMENT

In many African countries, despite the challenges discussed above in Chapter 2, there are numerous opportunities for mechanization development in the near future. Following decades of decline in per capita food production, there is now a new climate of optimism combined with a modified international investment landscape. The agriculture sector is projected to become economically sustainable because of the rapid expansion of urban centres and the associated demand for agricultural products, in addition to the increases in international food commodity prices. The new situation will provide opportunities for the adoption and expansion of agricultural mechanization for many reasons:

3.2.1 Increasing agricultural wages

The development and expansion of off-farm employment and the disenchantment of rural youth with arduous agricultural work (hard physical labour and drudgery) have triggered a rural–urban migration of young people. This has led to a shortage of manual labour, particularly at peak times, which has caused rural wages to increase.

Ratolojanahary (2016) suggests that the cost of labour influences the uptake of agricultural mechanization. If the cost of labour remains low, there is little incentive for farmers to invest in machinery; high labour wages act as an incentive for mechanization. The situation is, however, country specific, and generalizations for the whole of SSA should be avoided. Labour shortages are sometimes filled by migrant workers from other regions or countries, with a fall in the corresponding high wages. This new demand for work and consequent reduction in wages removes the incentive to invest in agricultural mechanization. On the other hand, labour shortages in some countries have increased the demand for hire services to complement hired labour, especially at peak times (e.g. crop establishment and harvesting).

3.2.2 New sources of farm machinery more suitable for African conditions

Western technology – once a very important source of farm machinery for Africa – has become increasingly sophisticated, therefore less suitable for African smallholder conditions and less affordable for African farmers.

However, the new emerging industrial economies, such as India, China and Brazil, have stepped in to provide new sources of tractors and farm machinery,

which are increasingly present in local markets. This machinery is often more suitable for African conditions and is considerably cheaper than machinery manufactured in Western Europe or North America. In particular, economical versions of unsophisticated 2- and 4-wheel tractors are adequate for supplying the tractive power for smallholder farms; they may be owned directly or cooperatively, or purchased by enterprises to provide mechanization services.

Nevertheless, although Chinese, Brazilian and Indian equipment tends to be cheaper and more low-tech, evidence from the field points to increased risk (and therefore cost) arising from its inferior quality and consequent tendency to break down earlier. What is more, compared with technologies from established multinational companies, the quality of the after-sales service can vary. Western manufacturers, such as AGCO, John Deere and CNH, typically export machines to Africa that they produce themselves in India (John Deere) and Brazil (AGCO). These products tend to be solid, quality equipment, but cheaper and better adapted to the SSA market; one example is the AGCO starter kit of implements, which is low in price (USD 20 000) and based on an MF35 tractor (IFAJ, 2015).

3.2.3 Need for more innovative and energy-efficient sustainable mechanization concepts in line with the FAO "Save and Grow" paradigm

African countries must adapt to the world energy crisis and to new energy-saving technologies. Energy efficiency concepts must be further developed and alternative energy sources adopted. Given the potential for the exploitation of solar energy, the continent is the focus of attention regarding the development and use of solar power. There are already numerous technologies available for drying vegetables and fruits, pumping water and providing electrical energy. As discussed above in Section 3.1, FAO's Save and Grow concept leads the way for sustainable crop production intensification with leaner and more precise and energy-efficient production technologies, such as reduced and no-tillage or direct-seeding practices. Wider availability of cheap precision farming tools must be integrated in parallel with increased mechanization, making the most of information and communication technologies' (ITC) apps to obtain constant updates on the meteorological conditions and pest and weed situation, as well as on market prices for commodities and inputs. A good example of a precision farming tool is the hand-held GreenSeeker for the precision application of expensive fertilizer inputs (Trimble, 2016).

3.2.4 Climate-smart and conservation agriculture – the need for environmentally sustainable mechanization

The effects of climate change cannot be denied, and further episodes of violent storms, higher temperatures and increased drought can be expected (IPCC,

2014). Given the continuing emissions of greenhouse gases (GHGs), these damaging events will not only continue to occur, but will increase in severity. Agricultural innovation is therefore vital if crop production is to continue; and if production is to be intensified, the innovations will need to be very robust indeed. Major international donors and world leaders have appealed for new agricultural concepts that are more climate-smart (FAO *et al.*, 2014). Agricultural machinery has sometimes been criticised for its potentially negative impact on the environment – especially when used for fuel-hungry and degradation-inducing soil tillage. The development of new machines and precise techniques that are more protective of the environment is the key to climate-smart agriculture. One powerful concept is conservation agriculture (CA). In CA, a permanent cover is maintained on the soil and direct seeding is used through the vegetative cover. At no time is the fragile soil exposed directly to solar radiation, high winds or high intensity precipitation. Direct seeding is only possible thanks to the development of specialized equipment. Other developments or technologies are anticipated to tackle emerging environmental problems. Climate-smart agriculture is a vital tool for building resilience against the extreme weather events that are expected to intensify as a result of climate change.

3.2.5 New need for sustainable business models for mechanization in Africa

In general, the demand for mechanization services in SSA is latent: there is a need, but potential customers – mainly smallholders – are not aware of the existence of such services. In order to expand agricultural mechanization and develop the agricultural and machinery sectors in general, it is necessary to sensitize customers with regard to the services available. In addition, it is important to identify business models appropriate to local conditions in the various SAA countries. Business models may vary between and within countries and over time: one type of business model may be suitable for starting a machinery service business, another for enabling it to grow and prosper. Although SSA regions may seem underdeveloped in terms of economic activities, there is excellent potential for the development and adoption of new ideas for business models adapted to the prevailing conditions. This potential should not be overlooked as it represents a great opportunity for innovative business enterprises (FAO, 2012).

3.2.6 Public–private partnerships

Many mechanization initiatives involve close collaboration between the public and private sectors. For example, the Potato Initiative Africa (PIA) – operating in Nigeria and Kenya – is implemented within the German Food Partnership (GFP) and involves private sector agricultural machinery suppliers. A staple crop, potato – like other root and tuber crops – is labour intensive and many

smallholders are dependent on hand labour. The potential for mechanization is therefore great, but producers face numerous challenges. The PIA was launched in 2012 and the initial results are currently under evaluation (Breuer *et al*., 2015).

FAO and the European Committee of Associations of Manufacturers of Agricultural Machinery (CEMA) recently agreed on a new partnership to promote sustainable agricultural mechanization in developing countries. The focus is on managing and disseminating knowledge on sustainable approaches to agricultural mechanization, leading to technical programmes to support innovation in mechanization and facilitate the implementation of sustainable mechanization initiatives at field level (FAO, 2015b).

Wholly private initiatives include the new Model Farm Project in Zambia, where the international agricultural machinery company, AGCO, launched a model training farm on 150 ha to enable farmers to get hands-on experience by working with modern machinery. The model farm is divided into a wide range of demonstration crop areas that can be planted, cultivated and harvested using a diverse range of equipment. The training facility is designed for all kinds of producers, from smallholders to commercial-scale farmers (AGCO, 2015).

3.3 INVESTING IN AGRICULTURAL MECHANIZATION FOR SUB-SAHARAN AFRICA

In 2009, FAO and UNIDO (United Nations Industrial Development Organization) joined forces to debate the opportunities and needs for investment in agricultural mechanization in SSA (FAO, 2011c). The recommendations that emerged focused on facilitating support for both private and public sector investment flows into the development of 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 then to 20 percent by 2050 – and their replacement with a combination of draught animal power and tractors. The principal recommendations were as follows:

3.3.1 Establish national committees on agricultural mechanization

National committees on agricultural mechanization (NCAMs) comprising representatives of all major stakeholders, such as ministries of agriculture, finance, industry and trade; farmers' organizations; financial institutions; manufacturers and dealers; and research and development (R&D) institutions, can assist governments to:

- review national policy on mechanization;
- review the need for a national mechanization strategy;
- ensure the compatibility of machinery entering via aid packages; and
- prepare action plans for capacity building.

3.3.2 Create an enabling environment

An enabling environment of policies, institutions and regulations can facilitate the increased use of tractors and associated agricultural machinery by:

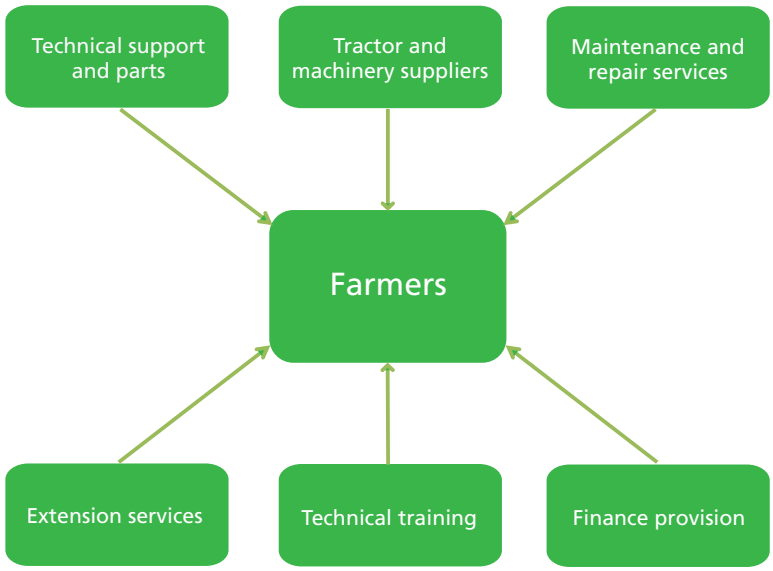
- promoting and supporting local entrepreneurial machinery contracting businesses;
- rationalizing regulations for the use of tractors for off-farm applications (especially rural road infrastructure contracting); and
- increasing the area under irrigation where feasible.

3.3.3 Increase investment in agricultural mechanization

It is crucial to encourage the financial sector, including banks and other lending institutions, to facilitate credit lines to farmers and others wishing to invest in tractors and agricultural machinery.

3.3.4 Capacity building

FIGURE 6
Stakeholders in the farm machinery support network for smallholder farmers



A thorough analysis is required of the existing situation and of the measures needed to ensure that adequate training facilities exist to promote safe and environmentally friendly mechanization. Training programmes should be developed to cover the needs of farmers, operators, mechanics and other relevant stakeholders involved in the provision of agricultural machinery services (Figure 6). Training centres should be attached to existing further

education institutions with the aim of integrating the various knowledge blocks required in mechanization and agrifood value chains and ultimately producing highly qualified mechanization business managers.

3.3.5 Establish a code of practice for agricultural machinery suppliers

The supply of good quality, safe agricultural machinery is a basic requirement for promoting agricultural mechanization. Machinery needs to be high quality, reliable and reasonably priced. Technical back-up and after-sales service are essential for the supply of parts, maintenance and repairs. A code of practice agreed by industry institutions and stakeholders can help to guarantee good service to end users and can be drawn up under the guidance of, for example, FAO and UNIDO.

3.3.6 Create regional networks of agricultural mechanization

Regional networks should encourage membership among R&D institutions, professional organizations, farmers' organizations, manufacturers and distributors. It is vital to forge links with existing networks related to mechanization, CA and draught animal power. FAO and UNIDO have appropriate expertise, which they are willing to share.

While some recommendations will be more relevant than others, depending on the situation in each SSA country, the deliberations of this high-level international group of experts highlight the importance of extending mechanization services to smallholder farms.

CHAPTER 4

The way forward: suggested action

There are numerous examples of in-depth analysis of the agricultural mechanization scenario in developing countries over the years (FAO, 2008, 2011c, 2014b; FAO and UNIDO, 2008). There are five recurring themes:

1. Farm power and mechanization are essential inputs if agricultural productivity and production are to increase and manage to feed the world's burgeoning population.
2. The intensification of crop production must be sustainable: its environmental footprint must be as low as possible, and in any case lower than the rate of natural renewal.
3. Top-down solutions are rarely successful; all stakeholders need to be considered from the outset and the private sector must lead the development process on the ground.
4. The role of the public sector is to provide an enabling environment for the private sector to perform without unnecessary obstacles.
5. A holistic, value-chain approach is necessary for agricultural mechanization, going beyond green production and into post-harvest, processing and marketing activities.

To summarize (FAO and UNIDO, 2008):
If agricultural mechanization efforts are to succeed in Africa, there is an urgent need for all concerned, be they farmers, supporters, planners or policy makers, to understand and contribute to agricultural mechanization efforts across the entire farming system and with a value chain perspective.

The principal recommendations cover the following areas:

4.1 INTEGRATION OF AGRICULTURAL MECHANIZATION IN PAN-AFRICAN POLICY FRAMEWORKS

There is a need to sensitize and raise awareness at pan-African level of the potential of agricultural mechanization for development. It is essential to develop appropriate policies, supranational in nature and refocused at regional

level. The Comprehensive Africa Agricultural Development Programme (CAADP) framework of the New Partnership for Africa's Development (NEPAD) provides a viable platform, involving policy-makers from the African Union. CAADP can play a crucial role in the further integration of agricultural mechanization polices and strategies at national level.

4.2 SUSTAINABLE AGRICULTURAL MECHANIZATION STRATEGIES

Mechanization should not be limited to on-farm practices; economies of use can be enhanced by incorporating off-farm applications. Moreover, agricultural mechanization is successful when there is an effective demand for farming outputs (including on- and off-farm value addition). In order to achieve sustainability, it is essential to consider the entire agrifood chain, including financing of the necessary capital investments (FAO, 2014b). It should be noted that mechanization technologies for agrifood chains contribute to waste avoidance, help maintain rural infrastructure and provide employment opportunities.

Sustainable mechanization involves an increase in production combined with conservation of the natural resources (in particular soil and water). It is vital that future mechanization models conform to FAO's Save and Grow paradigm. According to Save and Grow, agriculture must be productive and profitable for the farmer, while contributing to the conservation of resources and the delivery of ecosystem services. As the negative effects of climate change are increasingly apparent, the large-scale application of conservation agriculture is essential to maintain food production. CA practices involve soil protection, water conservation, and precise and efficient energy use and input application. It is vital to reduce the emission of GHGs during agricultural production, while sequestering carbon in untilled soil and preserved forest areas.

Agricultural mechanization strategy formulation has been a key FAO activity for several decades (FAO, 2013c, 2013d). For a consistent and coherent change in the use of agricultural mechanization, it is necessary to formulate and implement a plan, especially since major changes are required for sustainable agricultural mechanization. During the formulation process, reference should be made to the FAO guidelines (FAO, 1988) and it is important that the approach adopted is both **participatory**, to hear the views of the multiple stakeholders, and **systematic**, given the complexity of agricultural mechanization.

During the process, participatory workshops should be organized to involve the spectrum of interested actors from all along the agri-food value chain, beginning with an inaugural workshop. Formulation comprises four major steps (Figure 7).

FIGURE 7
Progressive steps in the formulation of an agricultural mechanization strategy

Source: FAO, 2013c.

- Step 1 involves a thorough analysis of the situation, with experts focused on their particular specialization.
- Step 2 entails a second participatory workshop to gather views on the existing situation.
- Step 3 is the strategy and action plan formulation, aligned with national development goals and policies refined during a third workshop.
- Step 4 involves further definition of the plan with preparation of a portfolio of project profiles. The results are presented at a final participatory workshop.

Throughout this process, the concept of **sustainability** is the absolute priority. Although the FAO guidelines have been used in several countries in Asia and Africa, and were adopted by the Regional Network for Agricultural Machinery (RNAM) in Asia, it is difficult to know how useful the strategies developed have been as there has been no specific evaluation of the programme (FAO, 2014b). It is necessary to revise the original guidelines and adapt them to the specific requirements of current mechanization needs, especially with regard to sustainability. The objective is to produce Sustainable Agricultural Mechanization Strategies (SAMS) that meet the requirements of individual countries.

4.3 SUSTAINABLE AGRICULTURAL PRACTICES FOR SMALLHOLDERS

Agricultural mechanization can make an important contribution to the improved use of natural resources and the overall "greening" of agriculture, in particular at smallholder level. Mechanization technologies enable smallholders to enhance yields through the adoption of intensification, conservation agriculture, and other climate-resilient, labour- and energy-efficient, and gender-friendly practices. Importantly, mechanization also enables a rational and efficient approach to farming in the long term, increasing the prospect of sustained profitability over time and leading to increased ecosystem resilience and long-term sustainability of smallholder systems. The FAO farmer field school (FFS) approach has been successfully implemented in many African countries in the context of integrated pest management. There is scope for expansion of the FFS concept to include themes such as sustainable intensification and small-scale mechanization support at field

level (FAO, 2015c). For example, tools and mechanization technologies could be introduced to help adapt to climate change threats at local level. The FFS approach can help change the common perception that agricultural mechanization technologies should come in the form of free donations; on the contrary, to achieve sustainability, it is essential that they be part of FFS or farmer-group-based investment decisions To this end, a well-organized FFS could become the focal point for innovative finance schemes such as "matching grants" or "village savings and loan groups".

4.4 SPECIFIC BUSINESS MODELS FOR SMALLHOLDER UPSCALING

Smallholders are commonly relegated to the margins of agrifood value chains and they do not easily find their niche in modern food systems. The identification and specification of appropriate business models for smallholder mechanization can provide numerous opportunities for improved access to and integration in agrifood value chains with more reliable supplies, increased volumes of produce, timely deliveries and value addition.

4.5 ECONOMIC ADVANTAGES OF MECHANIZATION FOR SMALLHOLDERS

It is important to identify models that not only provide economic benefits to famers, but which can be self-generating in the development of the smallholder sector. There is ample evidence that farmers who – thanks to mechanization – achieve quality and good yields, and consequently higher revenues, tend to spend their new wealth rather than re-invest it in the farm business. Small-scale farmers must receive guidance on how investments in equipment repair and maintenance and in other productive revenue-generating assets can reinforce their economic standing. For example, investment in equipment that serves a range of functions is a wise move: not only can services be sold to other farmers, but the different operations offer good potential to provide for positive economic outcomes.

4.6 SOCIAL ADVANTAGES DERIVED FROM MECHANIZATION

Agricultural mechanization has the potential to produce social opportunities (and outcomes) for small-scale farmers. It can reduce the risk of low yields thanks to increased cropping intensity and timely planting, weed control and harvesting, and can facilitate storage, resulting in better food security and improved nutrition for the farm family. Mechanization enables small-scale farmers to diversify their income sources, as they cease to rely on only crops for income and gain access to revenues from services offered to other local farmers. This in turn can reinforce social relations in local communities and provide for greater social harmony and well-being. Poor infrastructures and lack of transport are important constraints in remote rural areas. Agricultural

mechanization can provide transport for rural people and rural produce, improving mobility and creating opportunities for commercialization. There are also potential opportunities for a change in gender relationships, as smallholder farm families become more enabled and have more time to search for off-farm employment opportunities.

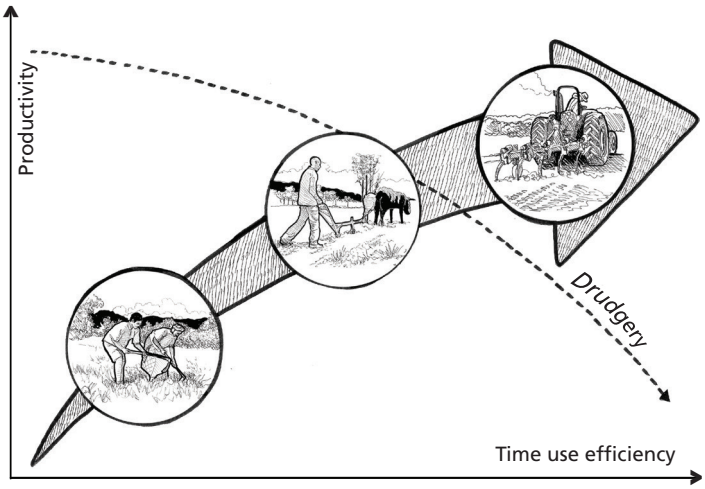
4.7 MECHANIZATION AND GENDER

The feminization of agriculture offers a series of opportunities for increased agricultural mechanization at farm level and in the agrifood value chain that are economically, environmentally and socially sustainable. Women tend to be proficient in natural resource management. Given the prevailing conditions of climate change and natural resource degradation, it is important to combine women's knowledge with the employment of appropriate machines designed for use by women farmers in order to make food production more environmentally sustainable.

Reducing drudgery for women and speeding up farm and household operations are just two of the potential advantages of appropriately adapted and culturally and socially sensitive mechanization. However, there are numerous constraints limiting women's adoption of technologies, not least their lack of access to and control of resources, combined with cultural norms, values and assumptions (van Eerdewijk and Danielsen, 2015). Interventions to support the adoption of mechanization need to address local norms and values; this may in turn facilitate access to resources. Studies show that if women's access to productive resources were on par with that of men, farm yields would rise by 20–30 percent (FAO, 2011b). It thus makes sense to consider how women can access or have control of resources invested in mechanization (Figure 8).

FIGURE 8

Agricultural mechanization and its potential to reduce the drudgery of hand-powered efforts and increase labour and agricultural productivity



Source: FAO, 2013d.

Enabling women's access to mechanization – the "feminization" of mechanization – requires a theory of change that is not only based on technological aspects, but which addresses a wider spectrum of constraints faced by women. Once these constraints have been addressed, the focus should be on technology. First and foremost, young girls must have access to education. Once this is achieved, active engagement in the discussion of local norms and assumptions is vital, encouraging group formation and collective action, and facilitating access to and control over resources. The focus can then turn to women's needs in terms of technologies and their related design parameters, with the objective of providing women-centred labour-saving mechanization technologies at production and other stages in the agrifood value chain.

4.8 INSTITUTIONAL AND ORGANIZATIONAL ARRANGEMENTS FOR INCREASED SMALLHOLDER MECHANIZATION

Smallholders who group together – for example, in producer organizations – have improved access to agricultural mechanization opportunities. Increased access to various sources and types of financing, more sharing of knowledge, improved bargaining power, increased value addition and greater opportunities to optimize agricultural mechanization and realize its full potential will all contribute to improving commercial farming, enabling further integration into modern agrifood systems.

4.9 INCREASED INTEGRATION INTO AGRIFOOD VALUE CHAINS

Agricultural mechanization is a cornerstone for smallholder integration into modern food systems. Mechanization not only applies at farm level, but it has an important role in value addition, for example in improved post-harvest operations, and processing and marketing activities. Furthermore, it saves time between harvesting and consumption, allowing more time for marketing.

4.10 INCREASED AGRICULTURAL MECHANIZATION WITH PRIVATE SECTOR DEVELOPMENT

By fostering private sector development within the context of agricultural mechanization, it is possible not only to increase the manufacturing base for agricultural mechanization in Africa, but also to provide opportunities for more South-South Cooperation among manufacturers, dealers and institutions. Private sector development can support smallholder enterprises at field level, with farmers providing mechanization hire services to other farmers. This leads not only to higher farm yields, but to greater demand for vehicles, equipment and tools at national level, creating a mutually reinforcing virtuous circle.

4.11 FOSTERING FURTHER SOUTH-SOUTH COOPERATION IN AGRICULTURAL MECHANIZATION: KNOWLEDGE-SHARING PLATFORM

Common lessons learned during development and the sharing of experiences within the context of South-South Cooperation can create a knowledge-sharing platform for improved agricultural mechanization in Africa. This could lead to technology and know-how transfer in terms of machinery, tools and equipment, in addition to sharing of experiences about the application of models that do or do not work at national and local level. The sharing of policies and strategies for agricultural mechanization – both successful and not – can further enhance the collaboration, fostering more specific and targeted policies and strategies. China has much to offer in terms of South-South Cooperation for agricultural development in Africa (Sims and Kienzle, 2016). China's smallholders have benefited greatly from government policies to subsidize the acquisition of agricultural machinery, and the country has good extension services. China is also one of the world's largest farm machinery manufacturers and the China-Africa Machinery Corporation founded by the YTO Group focuses on the transfer of technology in the interests of smallholder farm development in Africa. Another potential area of productive South-South Cooperation is the establishment of a centre for sustainable agricultural mechanization in Africa along the lines of Asia's United Nations Center for Sustainable Agricultural Mechanization (UN–CSAM) (see Section 4.13 below).

4.12 FIELD-BASED CAPACITY BUILDING AND CAPACITY DEVELOPMENT FOR AGRICULTURAL MECHANIZATION

Field-based methods of capacity building and capacity development for agricultural mechanization need to be integrated with experienced and well-tested training methodologies. Agricultural mechanization can be integrated at field level into farmer field schools (FFS) and farmer business schools (FBS). This not only provides a sound basis for smallholder competency development in agricultural mechanization, but acts as a source of data and information to feed into development projects, R&D organizations (national and international, public and private) and educational institutions, such as vocational secondary schools and universities across Africa.

4.13 REGIONAL CENTRES OF AGRICULTURAL MECHANIZATION

It is important to continue to encourage and support SSA's existing centres of expertise in agricultural mechanization, be they agricultural engineering institutes, university faculties, or research and testing centres. However, there is also a need for regional centres of excellence that can guide national policy towards sustainable agricultural mechanization. In close collaboration with farmers, other value chain actors, manufacturers, relevant private

sector stakeholders and national government organizations, these centres of excellence can engage in R&D, machinery testing and training, wherever deemed appropriate and useful for the private sector. It is vital that the centres focus on the stakeholders' interests to ensure that they do not research concepts (farming methods and machinery) that then remain at the prototype stage. At the testing stage, it is important to keep in mind the machinery's potential users.

An interesting model to study is the Asian United Nations Centre for Sustainable Agricultural Mechanization (UN–CSAM) (UN–CSAM, 2016). Asia's large agricultural machinery manufacturing sector requires incentives for the manufacture of equipment for sustainable mechanized agricultural practices. National and regional standards and testing centres are directed by the Asian and Pacific Network for Testing of Agricultural Machinery (ANTAM) under the auspices of the Beijing-based UN–CSAM of the United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP). Capacity building for SAMS implementation is an important undertaking as agricultural engineering training and education programmes are in decline worldwide. Capacity building focuses on youth and integrates other factors, including natural resource protection and gender issues.

The UN–CSAM objectives are to enhance technical cooperation among members and associate members of UNESCAP as well as other interested Member States of the UN, through extensive exchange of information, sharing of knowledge and promotion of R&D and agri-enterprise development in the areas of sustainable agricultural mechanization and technology, in order to attain the internationally agreed development goals, including the SDGs, in the region.

UN–CSAM achieves the above objectives by focusing on the following areas:

1. Assistance in the improvement of agricultural engineering and sustainable agricultural mechanization.
2. Enhancement of farm mechanization technologies in addressing issues related to subsistence farming.
3. Increased food security and poverty reduction through the promotion of agri-based small and medium-sized enterprise development and commercial farming to seize opportunities for increased market access and agrifood trade.
4. Promotion of an agri-based enterprise cluster concept and enterprise development activities to enhance the capabilities of members in identifying potential agricultural commodities in their respective countries on a clustering basis.
5. Regional cooperation in green agritechnology transfer, including through networking of focal point national institutes in UN-CSAM member countries and other relevant institutions.

6. Establishment of an interactive Internet website to allow members full access to information and technology databases, including the sharing of expert systems and decision support systems for financial management of small and medium-sized enterprises.
7. Strengthening of outreach services at field level in countries across SSA, in particular extension, training and demonstration services.
8. Promotion of the technology transfer process from research and development institutes to agricultural and farm machinery extension systems in member countries for poverty reduction.
9. Assistance in the dissemination and exchange of sustainable and commercially successful machinery and related drawings of appropriate tools, machines and equipment.
10. Implementation of technical assistance projects, capacity building programmes, training workshops and seminars and advisory services on sustainable agricultural mechanization and related food safety standards.
11. Creation of access to the resources of developed countries to build the capacity of member countries.
12. Capacity building and development in economics, business, finance, marketing and entrepreneurship in relation to agricultural mechanization.

The UN-CSAM model can be adopted to establish similar centres in Africa with a focus on appropriate sustainable mechanization and encompassing the whole agrifood value chain in their remit.

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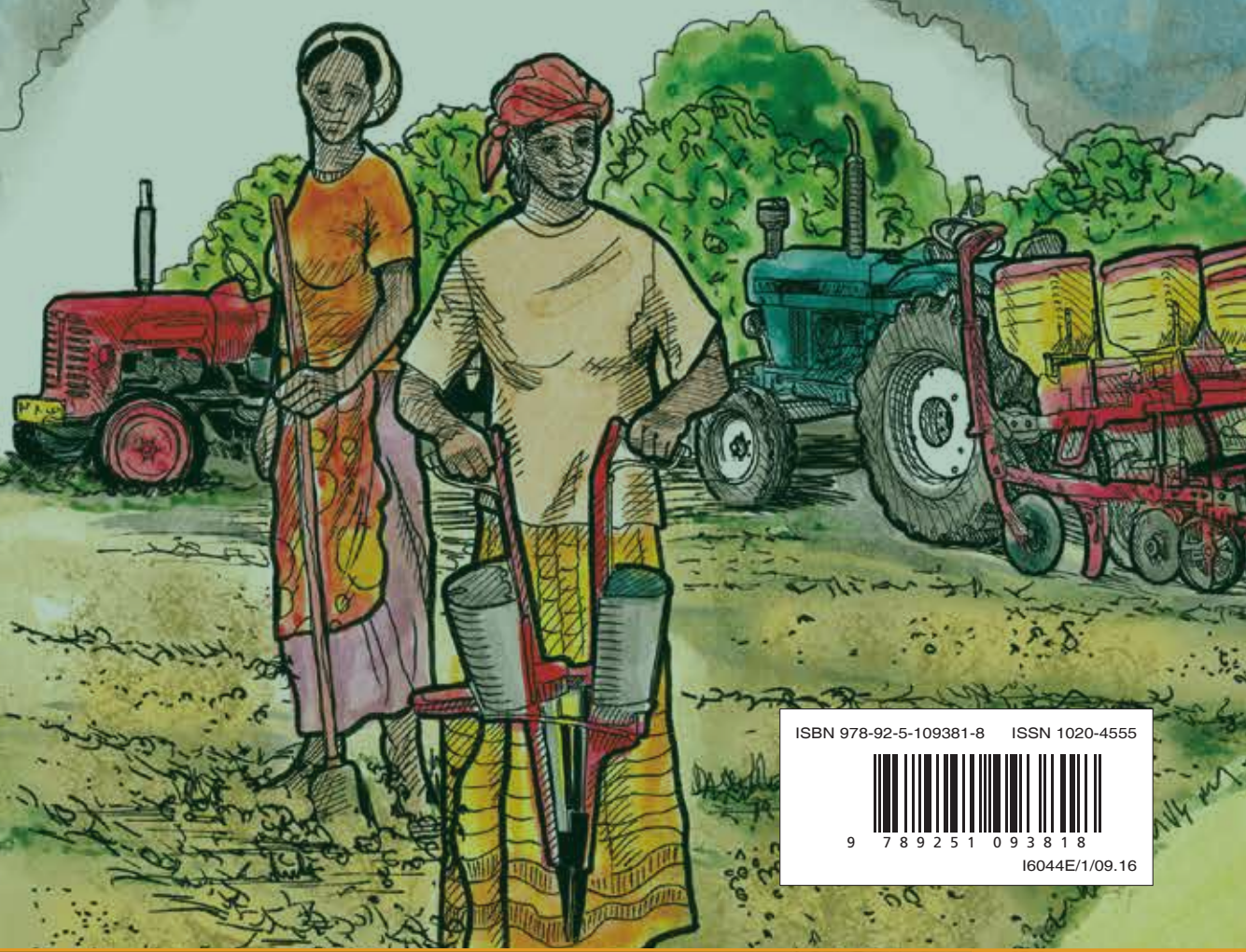
Mechanization provides opportunities for intensifying production in a sustainable manner, value addition and food systems development, and improved local economies and livelihoods. It also plays a key role in enabling the growth of commercial agrifood systems and improving the efficiency of post-harvest handling, processing and marketing operations. It can have a major influence on the availability and accessibility of more nutritious food, contributing to increased household food security.

The application of farm power to appropriate tools, implements and machines – "farm mechanization" – is an essential agricultural input in sub-Saharan Africa with the potential to transform the lives and economies of millions of rural families.



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