Food and Agriculture
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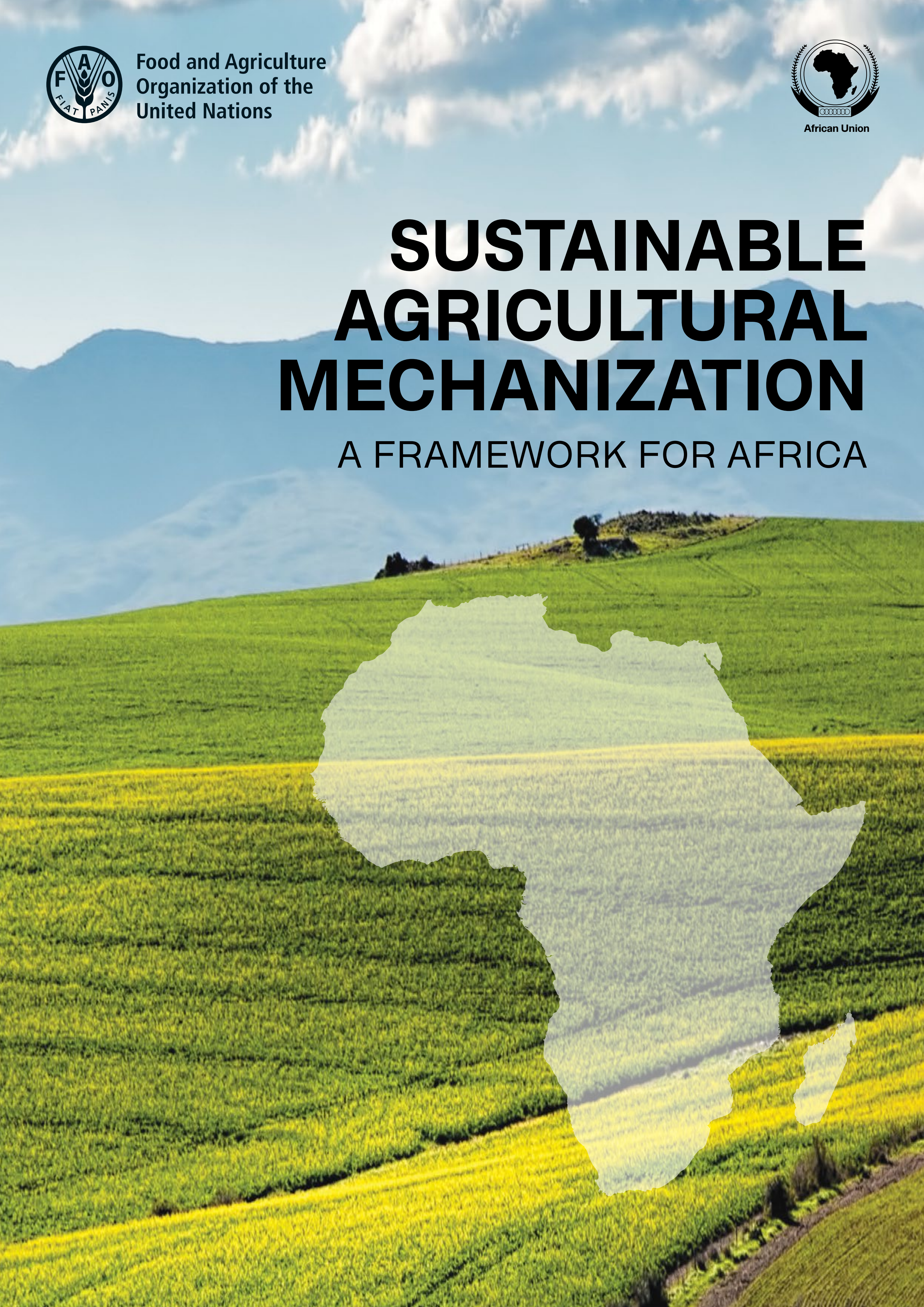
SUSTAINABLE AGRICULTURAL MECHANIZATION

A FRAMEWORK FOR AFRICA



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SUSTAINABLE AGRICULTURAL MECHANIZATION

A Framework for Africa

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Addis Ababa, 2018

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Foreword

Sustainable agricultural mechanization can redeem Africa from perpetual food insecurity.

The African Union Commission (AUC) and the Food and Agriculture Organization of the United Nations (FAO) view agricultural mechanization in Africa as an urgent matter and an indispensable pillar for attaining the Zero Hunger vision by 2025, as stated in the Malabo Declaration of 2014, Goal 2 of the Sustainable Development Goals, and the Prosperous Africa We Want, as indicated in Agenda 2063.

Doubling agricultural productivity and eliminating hunger and malnutrition in Africa by 2025 will be no more than a mirage unless mechanization is accorded utmost importance. The prerequisites for attaining these laudable objectives are enhancing access to mechanization services, improving access to quality and affordable inputs, such as seed and fertilizer, and delivering efficient water resource management systems including irrigation.

This publication, Sustainable Agricultural Mechanization: A Framework for Africa, is a result of continuous and thorough discussions among high-level policymakers and experts of the AU Member States, the AUC, FAO and other partners in the fields of food and agriculture. It aims to inform policymakers and decision makers in the Member States and the Regional Economic Communities (RECs) in Africa, and the wider development community dealing with agricultural development, on the significance of mainstreaming sustainable agricultural mechanization in the overall national and regional agricultural development programmes.

The framework presents a menu of priority elements to be considered by AUC Member States when developing their own national strategies for sustainable agricultural mechanization.

Mechanization in the twenty-first century must follow some core principles. It must be built along the entire agricultural value chain. Must be private-sector driven, environmentally compatible and climate smart, and must also be economically viable and affordable, especially for small-scale farmers who constitute the bulk of African farmers. It is vital that it targets women, who bear the brunt of African agriculture. Finally, mechanization must target youth, specifically to make agriculture more attractive and a choice for employment and entrepreneurship.

To achieve impact, it is important to move quickly towards mobilizing the necessary support for implementation. In this regard, the two agencies have initiated discussions with several countries, the donor community and other key partners, such as the African Development Bank, the World Bank and the Alliance for a Green Revolution in Africa, concerning possible cooperation to support the implementation of this framework. These efforts will be intensified to ensure success. It is our hope that the implementation of this framework document will help catalyze the required investments to support Sustainable Agricultural Mechanization in Africa.

H.E. Josefa Leonel Correia Sacko
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“Our goal is to send the hand hoe to the museum and liberate the African farmer from the backbreaking drudgery of tilling the land by hand.”

–Dr. Nkosazana Dlamini Zuma, Chairperson, from 2012 to 2017, African Union Commission

Preface

The framework for Sustainable Agricultural Mechanization in Africa (SAMA) was developed through a collaboration between the Food and Agriculture Organization of the United Nations (FAO) and the Department of Rural Economy and Agriculture (DREA) of the African Union Commission (AUC).

There are three defining features that distinguish this publication from earlier ones on agricultural mechanization:

1. First, it has been prepared through an Africa-wide consultative process lasting almost two years and covering many steps: AUC's original request for technical support in agricultural mechanization, made to FAO in early 2016; the Inception Workshop held in July 2016; subregional studies and consultations with countries and Regional Economic Communities (RECs) between September 2016 and March 2017; two brainstorming sessions by the drafting team in Addis Ababa in September 2016 and in Nairobi in December 2016; consultations at the ACT/AGRA/FAO/World Bank Workshop in Nairobi in December 2016; the Validation Workshop of stakeholders in May 2017; and finally consideration and approval of the draft framework for SAMA by the AUC Specialized Technical Committee on Agriculture, Rural Development, Water and Environment in October 2017.

2. Second, the document provides a framework for SAMA, outlining (in Chapter 4) the ten priority elements that emerged from the consultative process. Based on these elements, RECs and their member countries can develop their own policies and strategies depending on the prevailing local conditions. Under each element, options are provided for further actions at the country and REC levels, avoiding being prescriptive at the continental level.

3. Third, the framework for SAMA is mainstreamed into the main agricultural development agenda for the continent – the CAADP Framework, the Malabo Declaration and the AU Agenda 2063. Through approval of the SAMA Framework by the relevant policy organs of the AUC, agricultural mechanization moves from the fringes to the mainstream of the agricultural development agenda in sub-Saharan Africa (SSA). The SAMA Framework provides a mechanism for concerted action on agricultural mechanization by all key stakeholders on the continent.

The Editors

Addis Ababa, June 2018

PHOTOGRAPHY: CREATIVE COMMONS CC0

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This publication was prepared under the leadership and technical guidance of Patrick Kormawa, who up to May 2018 was the Subregional Coordinator for Eastern Africa (SFE), FAO Representative to the African Union (AU) and to the UN Economic Commission for Africa (ECA), in collaboration with the Department of Rural Economy and Agriculture (DREA) of the African Union Commission (AUC). The support of AUC throughout the drafting and publication process is greatly appreciated.

The report was prepared by a core team consisting of Geoffrey C. Mrema, who led the drafting of the framework document, and four subregional experts who prepared background papers on the status of agricultural mechanization in the different subregions of Africa: Mathias Fonteh (Central Africa), Pascal Kaumbutho (Eastern Africa), Mataba Tapela (Southern Africa) and Emmanuel Ajav (West Africa). Dr Jerome Afheikena, Consultant (Economics) to FAO-SFE, provided technical and operational support to the team during the early stages. Their commitment to the project and readiness to promptly respond to editorial comments are particularly appreciated.

FAO-SFE provided coordination and technical support to the team. DREA gave valuable support during the process of endorsement by AUC of the SAMA Framework.

The framework benefited greatly from the technical inputs provided by the FAO mechanization task team: Josef Kienzle, Joseph Mpagalile, Santiago Santos Valle and Diana Gutierrez-Mendez. Further inputs were provided from a wide range of experts from governments, research institutions, non-state actors, financial institutions, the private sector and academia. The editors are grateful to various development partners and individuals who actively participated in these processes.

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Abbreviations and acronyms

AASR	Africa Agriculture Status Report
ACET	African Center for Economic Transformation
ACT	African Conservation Tillage Network
ADB	Asian Development Bank
ADC	Agricultural Development Council
AfDB	African Development Bank
AGRA	Alliance for a Green Revolution in Africa
AGRF	Africa Green Revolution Forum
AGS	Rural Infrastructure and Agro-industries Division (formerly Agriculture Support Systems Division, FAO)
AMS	Agricultural mechanization strategy
ANTAM	Asian and Pacific Network for Testing of Agricultural Machinery
APCAEM	Asian and Pacific Centre for Agricultural Engineering and Machinery
APO	Asian Productivity Organization
AQUASTAT	Information System on Water and Agriculture
ARAP	Accelerated Rainfed Arable Programme
ARCEDEM	African Regional Centre for Engineering Design and Manufacturing
ARCT	African Regional Centre for Technology
ASABE	American Society of Agricultural and Biological Engineers
ASAE	American Society of Agricultural Engineers
ASARECA	Association for Strengthening Agricultural Research in Eastern and Central Africa
ATAI	Agricultural Technology Adoption Initiative
ATN	Animal traction network
ATNESA	Animal Traction Network for Eastern and Southern Africa
AU	African Union
AUC	African Union Commission
CA	Conservation agriculture
CAADP	Comprehensive Africa Agriculture Development Programme
CEMA	European Agricultural Machinery Industry
CEMAC	Central African Economic and Monetary Community
CEO	Chief Executive Officer
CGIAR	Consultative Group on International Agricultural Research
CIMMYT	International Maize and Wheat Improvement Center
CKD	Completely Knocked Down
COAG	Committee on Agriculture
ComSec	Commonwealth Secretariat
CORAF	West and Central African Council for Agricultural Research and Development
CSAM	Centre for Sustainable Agricultural Mechanization
CT	Conventional tillage
DAP	Draught animal power
DAT	Draught animal technology
DREA	Department of Rural Economy and Agriculture
EAC	East African Community
EAAFFRO	East African Agricultural and Forestry Research Organisation
EATA	Ethiopian Agricultural Transformation Agency
ECA	Economic Commission for Africa
ECCAS	Economic Community of Central African States
ECOWAS	Economic Community of West African States
FACASI	Farm Mechanization and Conservation Agriculture for Sustainable Intensification
FAO	Food and Agriculture Organization of the United Nations
FARA	Forum for Agricultural Research in Africa
FTE	Full-time equivalent
GAP	Good agricultural practice
GDP	Gross domestic product
GR	Green revolution
HYV	High-yielding variety
IARC	International Agricultural Research Center

IBRD	International Bank for Reconstruction and Development
ICM	Integrated Crop Management
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
ICT	Information and communications technology
IDRC	International Development Research Centre
IFPRI	International Food Policy Research Institute
IGAD	Intergovernmental Authority on Development
ILO	International Labour Organization
ILRI	International Livestock Research Institute
IRRI	International Rice Research Institute
IW	Inception Workshop
KENDAT	Kenya Network for Dissemination of Agricultural Technologies
KNCU	Kilimanjaro Native Co-operative Union
LAC	Latin America and the Caribbean
LSF	Large-scale farm
MSF	Medium-scale farm
NAMA	Network for Agricultural Mechanization in Africa
NEPAD	New Partnership for Africa's Development
NGO	Non-governmental organization
OECD	Organisation for Economic Co-operation and Development
PAPAC	Platform for Agricultural Policy Analysis and Coordination
RESAPAC	Great Lakes Regional Bean Programme
R&D	Research and development
RAF	Regional Office for Africa (FAO)
RAP	Regional Office for Asia and the Pacific (FAO)
REC	Regional Economic Community
RNAM	Regional Network for Agricultural Mechanization
SACCAR	Southern African Centre for Cooperation in Agricultural Research
SACU	Southern African Customs Union
SADC	Southern African Development Community
SAM	Sustainable agricultural mechanization
SAMA	Sustainable Agricultural Mechanization in Africa
SAMS	Sustainable Agricultural Mechanization Strategy
SARCUSS	Southern African Regional Commission for the Conservation and Utilisation of the Soil
SCS	Soil Conservation Service
SEASAE	South and East African Society of Agricultural Engineering
SFE	Subregional Office for Eastern Africa (FAO)
SKD	Semi Knocked Down
SME	Small and medium enterprises
SSA	Sub-Saharan Africa
SSF	Small-scale farm
STC	Specialized Technical Committee
SUA	Sokoine University of Agriculture
TC	Technical committee
THS	Tractor hire services
TSAE	Tanzania Society of Agricultural Engineers
UNECA	United Nations Economic Commission for Africa
UNESCAP	Economic and Social Commission for Asia and the Pacific
UNFPA	United Nations Population Fund
UNIDO	United Nations Industrial Development Organization
USAID	United States Agency for International Development
VFCU	Victoria Federation of Cooperative Unions
VW	Validation Workshop
WAATN	West Africa Animal Traction Network
WB	World Bank
2WD	Two-wheel drive
4WD	Four-wheel drive
2WT	Two-wheel tractor
4WT	Four-wheel tractor

Executive summary

Agriculture is crucial to Africa's development, but the sector is performing well below its potential. Today, about 60 percent of Africa's population depends on agriculture for jobs and livelihoods, yet its contribution to the gross domestic product was a paltry 21 percent in 2016. While Africa has the highest area of uncultivated arable land (202 million ha) in the world, which is about 50 percent of the global total, its productivity lags far behind other developing regions. Yields are only 56 percent of the international average (AfDB, 2016; Jerome, 2017). Crop yields must increase substantially over the coming decades to keep pace with food demand driven by population growth and rapid urbanization in Africa. Mechanization directly and indirectly affects yield gap: it reduces both harvest and post-harvest losses and is the low-hanging fruit that can bridge the gap between actual and potential yield in Africa. Reducing the yield gap is essential if Africa is to reach its goal of Zero Hunger by 2025.

According to the Food and Agriculture Organization of the United Nations (FAO), agricultural mechanization in Africa is still at the first stage: "power substitution". This stage is characterized by the replacement of animate power with mechanical power from internal combustion engines or electric motors to perform energy-intensive tasks, such as primary land tillage and grain milling.

This framework presents the priority elements for national strategies for Sustainable Agricultural Mechanization in Africa (SAMA). The analysis presented in Chapters 2 and 3 calls for a specific approach, involving learning from other parts of the world where significant transformation of the agricultural mechanization sector has already occurred within a three-to-four decade time frame, and developing policies and programmes to realize Africa's aspirations of Zero Hunger by 2025. This approach entails the identification and prioritization of relevant and interrelated elements to help countries develop strategies and practical development plans that create synergies in line with their agricultural transformation plans and realize Sustainable Agricultural Mechanization in Africa. Given the unique characteristics of each country and the diverse needs of Africa due to the ecological heterogeneity and the wide range of farm sizes, the framework avoids being prescriptive. Instead, it provides ten interrelated principles/elements to guide agricultural mechanization efforts.

[1] Throughout this document, "Africa" refers to sub-Saharan Africa.

[2] North Africa is not included in the analysis, as it has advanced in terms of agricultural mechanization compared with the rest of Africa, which must now catch up. Moreover, its agro-ecological zones are different from those in the rest of Africa. Therefore, as mentioned above, the references herein to "Africa" are to sub-Saharan Africa.

Ten priority elements for Sustainable Agricultural Mechanization in Africa (SAMA)

For this report, the conclusions and recommendations of earlier studies were reviewed, including a reflective scope of the progress made (ComSec, 1991; FAO, 2008; FAO and UNIDO, 2010). The report highlights key issues for developing the framework for Sustainable Agricultural Mechanization Strategies (SAMS) for countries in Africa. Further, it presents the technical issues to be considered under SAMA and the options to be analysed at the country and subregional levels. The ten key elements required in a framework for SAMA are as follows:

1. Boosting farm power through appropriate technologies and innovative business models

2. Promoting innovative financing mechanisms for agricultural mechanization

3. Building sustainable systems for manufacture and distribution of agricultural mechanization inputs

4. Sustainable mechanization across agrifood value chains

5. Innovative systems for sustainable technology development and transfer

6. Sustainable transformation of lan preparation and crop/animal husbandry practices

7. Social sustainability and the roles of: i) small scale farmers and their organizations; ii) women; and iii) youth

8. Human resources development and capacity building for SAMA

9. Need for a long-term vision: policy and strategy issues

10. Creating sustainable institutions for regional cooperation and networking

PRIORITY AREAS

First, countries should not attempt to develop mechanization of all commodities at the same time. They need to focus on a small number of priority commodities that can be easily mechanized. Experience around the world has shown that cereals (maize, wheat, rice etc.) can be easily mechanized resulting in large increases in total factor productivity. The focus of sustainable agricultural mechanization (SAM) and the choice of crops to mechanize should be based on the level of total factor productivity to be achieved. Profitability is a conditioning factor and it must be met prior to mechanization: governments should prioritize profitable value chains to mechanize. Mechanization, therefore, needs to be linked to market-oriented enterprises to generate the necessary cash flow to cover capital costs and facilitate loan repayments.

Effective demand for outputs of farming translates into effective demand for equipment and machinery services – but only if farming is profitable. Farm profitability requires attention, because the farm value of crops in many countries in Africa may be too low to support high production costs per unit area (FAO, 2008). Mechanization can make the difference in farm profitability; however, its costs are elevated due to the high costs of procuring machinery and implements (mostly in foreign exchange), the high cost of maintenance and repairs, and the need for thorough land clearance. If farms are not profitable before mechanization, the likelihood of them becoming profitable as a result of mechanization alone is low. In most circumstances, as noted in FAO (2008), it is perhaps more realistic to view farm profitability as a condition that makes mechanization feasible, rather than as an outcome of mechanization.

In addition, when developing national strategies, countries need to prioritize policy environments that support the establishment and operation of viable and sustainable businesses. The environment must feature timely and efficient services that increase the farm power available to farmers. This also encompasses the transformation of conventional tillage (CT) and crop husbandry practices to more environmentally friendly ones, such as locally adapted conservation agriculture (CA) and minimum tillage. Country-level agricultural mechanization strategies should cover the entire agrifood value chain, including harvesting, post-harvest handling and processing operations to reduce food losses, incorporate food safety aspects and strengthen farmer–consumer linkages.

Priority should be given to institutional issues that accommodate the interests of small-scale farmers, women and youth. Other elements of the SAMA Framework include those related to the establishment and operation of viable entities for the manufacture of agricultural machinery and implements, and of franchises and supply chains for their distribution, repair and maintenance at the national and subregional levels. This should, in addition, cover the strengthening of systems for technological innovations and transfer at the national and subregional levels to avoid developing superfluous prototypes.

Human resources development at the artisan, technician and professional levels, and building of the capacity of farmers in commercial agricultural production, particularly the youth and women, are critical to the success of SAMA. Establishment of mechanisms for increasing the flow of financial resources for investments in sustainable mechanization is another critical area. There is also a need to create mechanisms to facilitate the region-wide exchange of information and technologies, as well as to design and implement collaborative regional programmes to achieve economies of scale and scope. A long-term commitment to SAM by key stakeholders involved in policy, strategy formulation, implementation and financing is critical to its success. Those formulating strategies at the national and subregional levels are responsible for tailoring the various elements to the local context.

AREAS FOR IMMEDIATE ACTION

Detailed guidelines are necessary to help member countries design and formulate policies and strategies for SAMA for all three aspects of sustainability of agricultural mechanization interventions: commercial, environmental and socio-economic. Most of the existing guidelines were developed in the 1970s and 1980s, when development paradigms emphasized public-sector dominance and subsistence food security. Another pressing requirement is the development of mechanisms to increase the flow of financial resources for agricultural mechanization investments from financial institutions. This would make loans available to emerging small- and medium-scale commercial farmers and entrepreneurs. The sustainability of agricultural mechanization depends directly on the active involvement of local financial institutions.

It is essential to strengthen the institutional infrastructure that supports the development of agricultural mechanization at the national, subregional and regional levels. This will include, inter alia, the institutions involved in research and innovation, standards and testing, manufacturing and trade in agricultural machinery and implements as well as in technology transfer and extension and capacity building in all its aspects. Centres of excellence and coordinating mechanisms need to be established or strengthened at all levels.

Given the small size of many national markets for agricultural machinery and implements and the lack of critical mass in the human capacity in many national systems, regional cooperation is necessary – not only for the attainment of economies of scale and scope, but also to create sustainable organizations and institutions. In this regard, and as has happened in other regions of the world, the involvement of national, regional and international organizations, including multilateral institutions, governments and farmer associations, is critical to the success of SAMA.

CONCLUDING REMARKS

Leaders in Africa understand the importance of mechanization in the long-term vision of agricultural development and food security. Efforts to accelerate mechanization require substantial political and financial commitment. Without long-term commitment, the prospects for African agriculture and farmers are likely to remain bleak. A new cadre of farmers is emerging in some countries, capable of spearheading and catalyzing the sustainable mechanization effort.

Governments and leaders in the agricultural sector in Africa must make long-term commitments to mechanization while grappling with new problems. The process may at times appear turbulent, but governments and leaders must remain steadfast – just as Asian governments and leaders did in the 1960s and 1970s. The recent momentum observed and the progress attained must be maintained and increased or African agriculture will be doomed to the continued use of antiquated tools and implements, to the detriment not only of food security, but of agricultural development and overall economic growth. Other developing regions have mechanized primary agricultural activities over three to four decades and they are now moving on to higher technological levels. Africa cannot afford to be left behind. Now is the time for transformative action on sustainable agricultural mechanization in this region.


575 MASSEY FERGUSON

1. Mechanization and agricultural development

Farmer drives a tractor loading maize straw in Laikipia County, Kenya.

PHOTOGRAPHY: ©FAO/LUIS TATO

1.1. Introduction

Agricultural mechanization is broadly defined to include the application of tools, implements and powered machinery and equipment to achieve agricultural production, comprising both crop and livestock production as well as aquaculture and apiculture.

Mechanization covers all levels of farming and processing technologies, from simple and basic hand tools to more sophisticated and motorized equipment. It eases and reduces hard labour, relieves labour shortages, improves productivity and timeliness of agricultural operations, increases resource-use efficiency, enhances market access and contributes to mitigating climate-related hazards. Sustainable mechanization considers technological, economic, social, environmental and cultural aspects when contributing to the sustainable development of the food and agricultural sector.

Agriculture makes use of three levels of power sources:

1. manual (with full reliance on human muscles);
2. animal; and
3. motorized (both fossil fuel and electrical).

The term "agricultural mechanization" covers the manufacture, distribution, repair and maintenance, utilization and management of agricultural tools, implements, equipment and machines in agricultural production – for land development, crop and livestock production, harvesting and storage, in addition to on-farm processing and rural transportation (see **Box 1** for mechanization terminology).

Agricultural mechanization in Africa[3] is still at the first stage of the mechanization process, referred to as "power substitution" (see **Box 2** for stages of mechanization). Stage 1 is the earliest developmental stage and involves the substitution of animate power (human muscles or draft animals) with mechanical power (internal combustion engines and/or electric motors) used to perform energy-intensive and often back-breaking tasks, such as primary land tillage and grain milling (FAO, 1981; Rijk, 1983). Such energy-intensive tasks require adequately powered equipment and implements. The mechanization process at this stage is technologically straightforward, involving the introduction of new and higher-level power sources, whether animate or mechanical, typically used for arduous farming or household tasks. More challenging, however, are issues involving the "software" required for effective and efficient utilization and management of the new "hardware" (power source and associated implements) in sustainable and profitable business models. Application of the software depends on the effectiveness and efficiency of the enterprises and franchises that supply the mechanization inputs.

[3] Throughout this document, "Africa" refers to sub-Saharan Africa (FAO terminology) and Africa, south of the Sahara (AU/UNECA terminology).

Box 1. Basic definitions of selected mechanization terminology

The introduction and application of agricultural mechanization in the development process is decided by people with diverse backgrounds, training and interests (FAO, 1981). It is important to have a common understanding of the different terms used to describe agricultural mechanization. The following **terms associated with agricultural mechanization** are used in this report:

1. **Agricultural mechanization**
   embraces the manufacture, distribution and operation of all types of tools, implements, machines and equipment for agricultural land development and farm production as well as for harvesting and primary processing of agricultural produce.
2. **Farm production**
   includes all on-farm activities covering crops, livestock, aquaculture and apiculture.
3. **Tractorization**
   refers to activities associated with the use in agriculture of any type of tractor (single axle, two-wheel tractor [2WT]; two-axle, four-wheel tractor [4WT]; or track-type) and of any power rating.
4. **Power sources**
   in agricultural mechanization are of three types:
   - **Hand-tool technology:**
     tools and implements that use human muscles as the main power source.
   - **Draught animal technology (DAT):**
     machines, implements and equipment powered by animals (e.g. horses, oxen, buffaloes and donkeys).
   - **Mechanical-power technology:**
     mechanization powered by engines and or motors (e.g. tractors and/or motors using petrol/diesel or electricity to power threshers, mills, centrifuges, harvesters, pumps etc.).
5. **Agricultural motorization**
   refers to the application of all types of mechanical motors or engines, regardless of energy source, to activities associated with agriculture.
6. **Agricultural implements**
   are devices that perform agricultural tasks and which are attached to, pulled behind, pushed or otherwise operated by a human, animal or mechanical power source.
7. **Agricultural machinery**
   is a general term that refers to tractors, combines, implements and devices more sophisticated than hand tools and which are animal- or mechanically powered and utilized in agricultural production.
8. **Farm mechanization**
   is technically equivalent to agricultural mechanization but refers only to those activities occurring inside the boundaries of the farm unit covering production of crops, livestock and aquaculture.
9. **Agricultural equipment**
   normally refers to stationary mechanical devices (e.g. irrigation pump sets, hammer mills, centrifuges and milking machines).
10. **Post-harvest operations**
    refer to those activities carried out after harvesting the crop on the farm or on the way to the consumer (e.g. handling, processing and storage).

1.1. Introduction

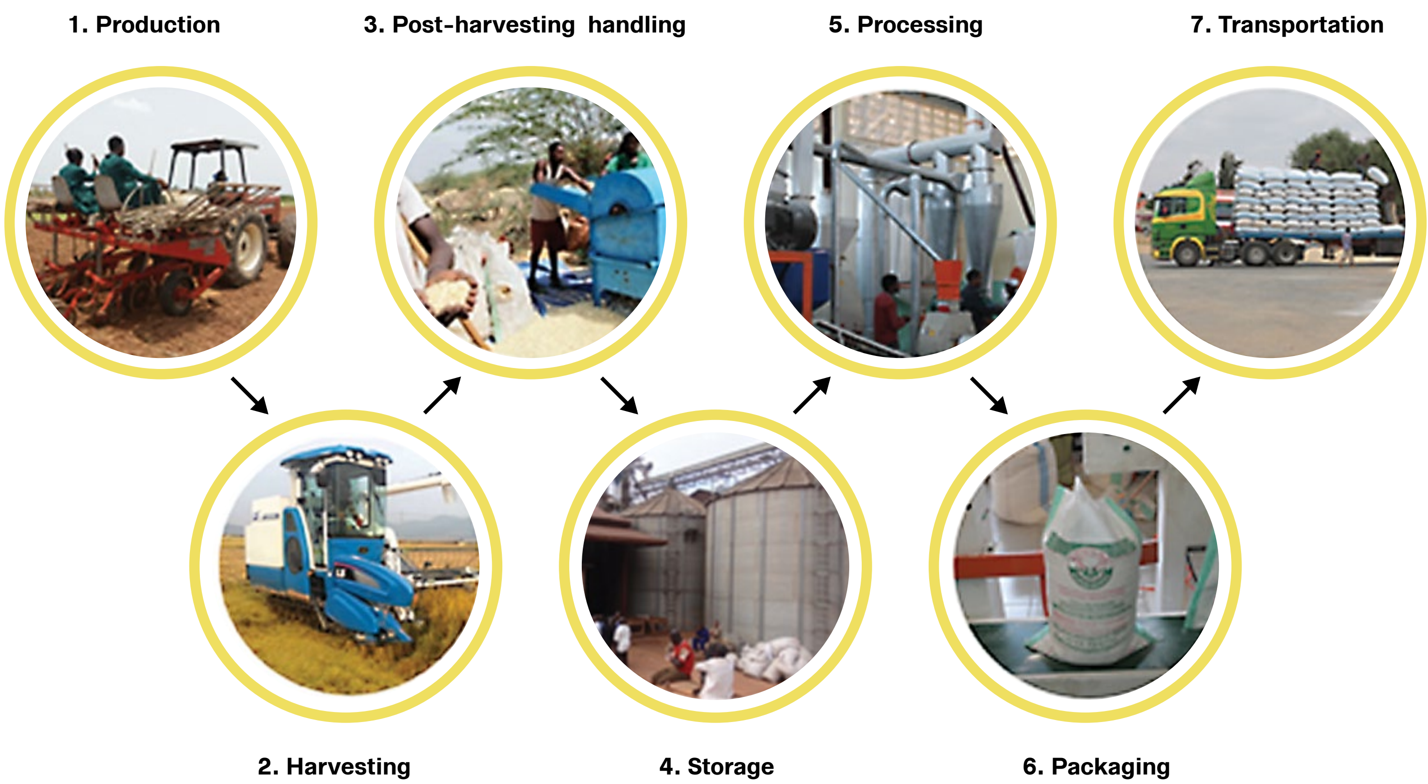
The extent of available farm power conditions the level and process of agricultural mechanization in a given country and is a major indicator of progress attained. Globally, the crucial role of farm power in increasing agricultural productivity was first recognized in 1965: "...farm power with fertilizers, improved seeds, irrigation and pesticides are interdependent for growth in agricultural productivity and overall growth..." (Giles, 1966).

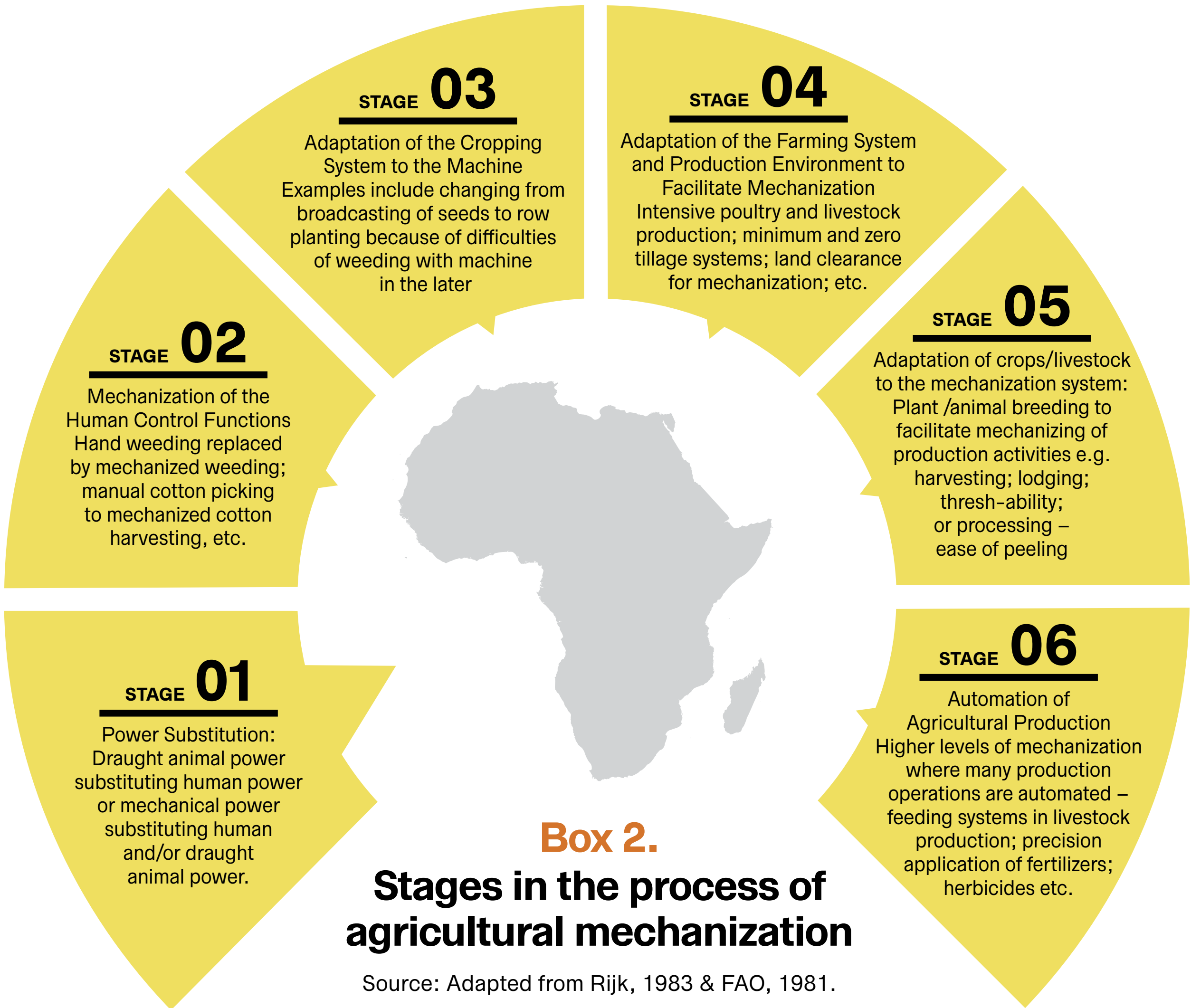
The success of the green revolution (GR) in Asia in the 1970s was attributed mostly to the increased use of high-yielding varieties (HYVs), fertilizers and irrigation; the role of farm power was not examined.

In contrast, the experience of mechanization during 1925–1965 in developed countries, such as the United States of America and Europe, demonstrated the criticality of farm power. According to White (2000 and 2001), the tractor was the "unsung hero" of the economic growth of the United States of America in the twentieth century: it replaced 24 million draft animals from 1925 to 1955 and significantly transformed agricultural productivity and land-use patterns. Similar developments occurred in Europe between 1945 and 1965, facilitated in large part by the US-funded Marshall Plan, when millions of draft animals were replaced by tractors (Carillon and Le Moigne, 1975; Promsberger, 1976; Gibb, 1988).

Figure 1. Agricultural mechanization value chain

Source: FAO, 1981 (adapted)





Box 2.
Stages in the process of agricultural mechanization

Source: Adapted from Rijk, 1983 & FAO, 1981.

When most countries in Africa gained political independence during the early 1960s, the advent of mechanization in developing countries in Asia, Africa, and Latin America and the Caribbean (LAC) was equated to "tractorization". This became the prevailing development paradigm accepted by most development experts and politicians. Indeed, the number of tractors in use in a country is the main indicator of mechanization level in the databases of development agencies, including the Food and Agriculture Organization of the United Nations (FAO), the United Nations Industrial Development Organization (UNIDO) and the World Bank (WB). This is particularly the case in Africa: although agricultural statistics are inadequate, data on the number of tractors in use (crawler, four-wheel two-axle [4WT] or two-wheel single axle [2WT]) is available in FAOSTAT (Corporate Database for Substantive Statistic Data, updated annually since the 1940s) and can be used as an indicator of progress in agricultural mechanization.

1.2. The context: global comparison of the levels of agricultural mechanization

Studies undertaken by FAO at the turn of the century show that the level of mechanization in Africa was still dominated by hand-tool technology. It was especially prevalent in land preparation and crop husbandry activities **(Figure 2)** in all four subregions: Central Africa had 85 percent of its land entirely under this technology, followed by West (70 percent), Southern (54 percent) and Eastern Africa (50 percent). The lower figures for Southern and Eastern Africa are due to the data from two countries: in South Africa, large-scale farms dominate the agricultural sector and tractors are the main technology, while in Ethiopia, draft animal technology has been in use for several millennia. Removal of the data from these two countries would result in similar figures for all four subregions. In most countries, the situation in 2010 remains largely the same as it was in 2000 (FAO, 2013a, 2016).

According to FAO (2008), at the time of independence in the 1960s, Africa was at the same level of mechanization – if not higher – than most Asian countries **(Figure 3)**. If the number of tractors (4WT) in use is an indicator of how far a country or region has progressed in mechanizing its agriculture, the developments in the last four decades of the twentieth century show significant changes in different regions of the world.

In Asia, the number of tractors in use grew by a factor of five between 1961 and 1970 – from 120 000 to 600 000 units, and then increased tenfold to reach 6 million units in 2000. In Latin

Figure 2. Primary land preparation in Africa (2005)

Source: FAO, 2008.

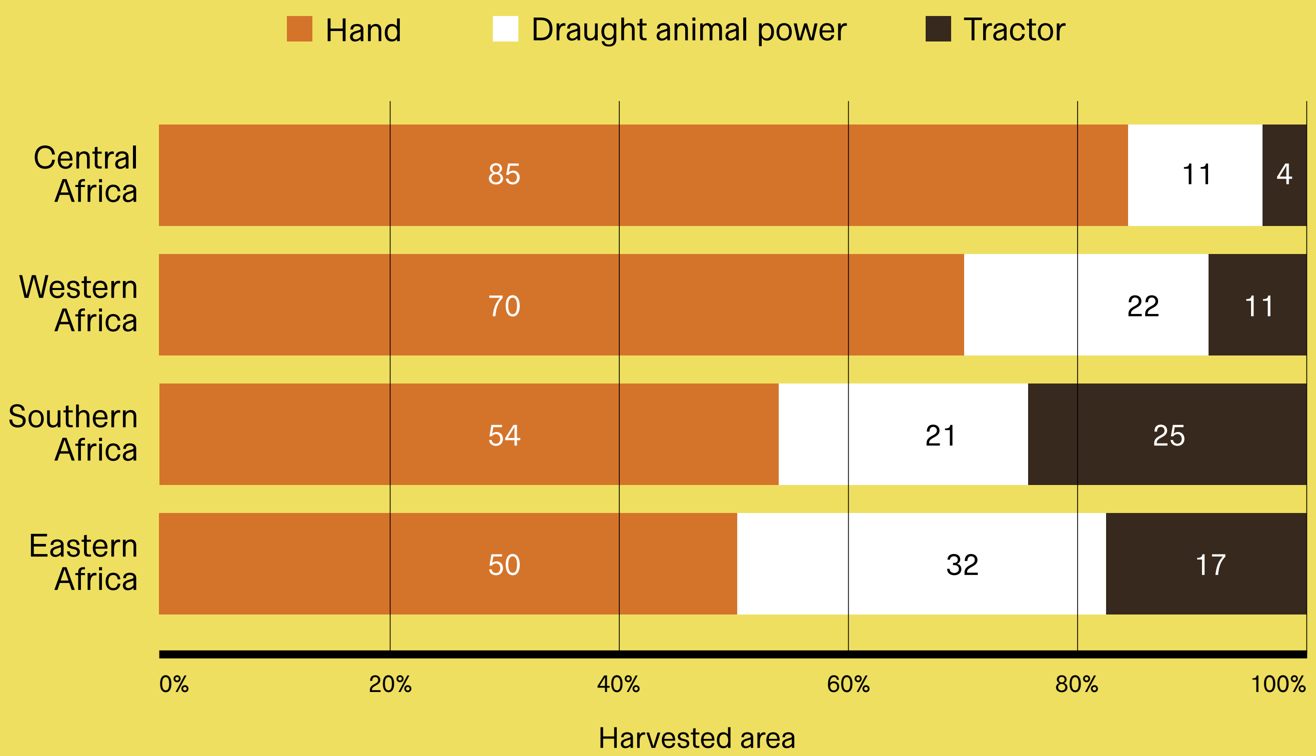
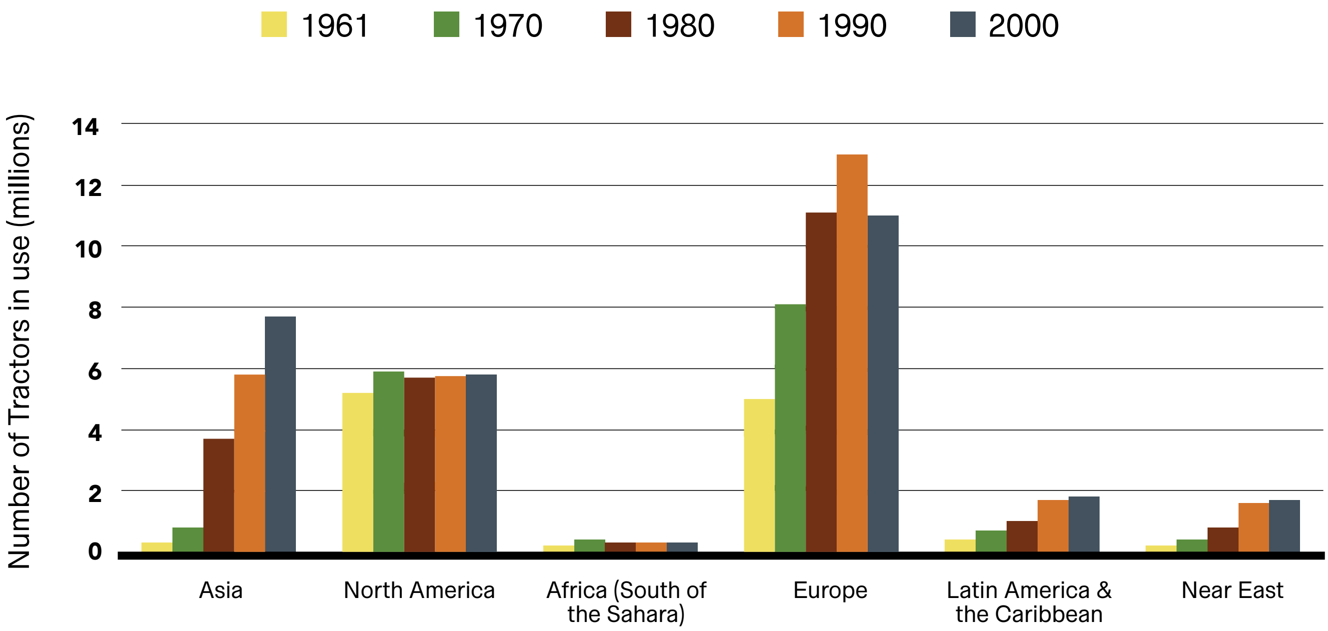


Figure 3. Global tractors in use by region (1961–2000)

Source: FAO, 2008



America and the Caribbean, the number of tractors in use increased 1.7 times between 1961 and 1970, from 383 000 to 637 000 units and almost tripled, reaching 1.8 million units in 2000. In the Near East, the increase was similar to that in LAC, doubling between 1961 and 1970 (from 126 000 to 260 000) and then increasing a further 6.5 times to reach 1.7 million units in 2000.

In Africa, the trend was quite different. While the number of tractors in use in 1961 was higher than in both Asia and the Near East (172 000 vs 120 000 and 126 000 units respectively), it increased very slowly thereafter, peaking at just 275 000 in 1990 before declining to 221 000 units in 2000 (i.e. about 3.3 percent, 11 percent and 12 percent of the number of tractors in use in Asia, LAC and the Near East respectively).

The figures are somewhat poignant. In 1961, Africa had 2.4, 3.3 and 5.6 times more tractors in use than Brazil, India and the People's Republic of China respectively, but by 2000 the reverse was the case: at the turn of the century, there were 6.9, 4.4 and 3.7 more tractors in use in India, the People's Republic of China and Brazil respectively, than in the entire Africa region (including South Africa). Similarly, in 1961, there were approximately 3.4 times more tractors in use in Africa than in Thailand; by 2000, however, Thailand had the same number as Africa.

In 2000, the tractors in use in Africa were concentrated in a small number of countries, with 70 percent in South Africa and Nigeria. If South Africa is excluded, primary land preparation in Africa was estimated to rely entirely on human muscle power on about 80 percent of the cultivated land, with draught animals used on 15 percent and tractors on the remaining 5 percent. In contrast, in Asia, land preparation was performed by tractors on over 60 percent of the cultivated land (FAO, 2008, 2013a).

1.3. Stagnation and decline in the level of agricultural mechanization in Africa

The stagnation – and in several countries, the decline – in the level of agricultural mechanization during the last two decades of the twentieth century became an issue of concern in the development community and among senior policymakers in Africa. While investments in agricultural mechanization in other regions of the developing world were growing rapidly, exemplified by the increase in the number of tractors and other machinery in use, they were stagnating or declining in most African countries. Some donors had shifted their assistance to so-called appropriate technologies (e.g. draft animal technology [DAT] and small 4WTs), but by the 1990s, it was becoming apparent that success was elusive even with these technologies (Starkey, 1988a; Kaul, 1991; Holtkamp, 1991; Mrema, 1991).

Since 2005, the issue has been discussed in the biannual meetings of ministers of agriculture in Africa convened by FAO. Workshops organized by FAO and UNIDO to review the lack of progress in agricultural mechanization in the region resulted in the preparation of a number of papers on the **status of agricultural mechanization** (Bishop-Sambrook, 2003; FAO, 2008; FAO and UNIDO, 2008, 2010). Topics covered include:

1. the declining farm power situation caused by the low numbers of tractors, draft animals and other implements in use;

2. the closure of several factories involved in the manufacture of agricultural machinery and implements; and

3. the declining rural labour force resulting from various factors, including rural urban migration and mortality due to the HIV/AIDS pandemic.

The situation of agricultural mechanization in Africa at the turn of the twenty-first century was without doubt bleak and discouraging (FAO, 2008).

“Beginning in 2005, there was renewed interest in agricultural mechanization in Africa”

1.4. Renewed interest in agricultural mechanization in Africa

Beginning in 2005, there was renewed interest in agricultural mechanization in Africa, sparked by a range of circumstances:

1. **Rise in global food prices in 2008.**
   The increase drew increased attention to investments in agricultural production, including agricultural mechanization inputs. Hand-tool technologies dominated agriculture in most of Africa and the need for transformation was recognized.

2. **Emergence of new suppliers of agricultural machinery and implements from Asia and Latin America.**
   They challenged the commercial hegemony in the agricultural machinery and implements sector – hitherto exercised by suppliers from the Organisation for Economic Co-operation and Development (OECD) industrial countries – both in terms of prices and appropriateness. Many companies from the western world had moved on to manufacturing higher horsepower tractors that were less appropriate to Africa.

3. **Demographic trends in Africa with increased urbanization, in particular of youth and men.**
   They were migrating from rural areas and leaving behind an increasingly ageing and feminized farming population.

4. **Sustainability issues gaining momentum.**
   Concerns included reducing environmental degradation andmitigating the effects of climate change.

5. **Increased investment by many African governments in agricultural production and agro-industries.**
   Investments in irrigationand increased use of inputs (e.g. fertilizers)led to the need for complementary investmentsin agricultural machinery and implements.

All the above influenced the thinking on agricultural mechanization in Africa. As of 2005, new programmes and projects were initiated in many countries and, in most cases, with new players. However, it was also becoming apparent that mistakes from the 1960s and 1970s were being repeated.

1.5. Action by the African Union

Agriculture is crucial to Africa's development, but the sector is performing well below its potential. Today, about 60 percent of the African population depends on agriculture for jobs and livelihoods, yet its contribution to the gross domestic product (GDP) was a mere 21 percent in 2016. Although Africa has the highest area of uncultivated arable land in the world (202 million ha – accounting for about 50 percent of the global total), it lags far behind other developing regions in terms of productivity: yields are only 56 percent of the international average (AfDB, 2016; Jerome, 2017). Crop yields must increase substantially in the coming decades to keep pace with food demand driven by population growth and rapid urbanization in Africa. Mechanization directly and indirectly affects yield gap: it reduces both harvest and post-harvest losses and is the low-hanging fruit that can bridge the gap between actual and potential yield in Africa. **Bridging the yield gap is essential if Africa is to reach its goal of Zero Hunger by 2025**.

Private-sector involvement beyond production remains relatively underdeveloped. There is scope for development in both upstream activities, such as seed and fertilizer distribution, and downstream activities, including dry and cold storage and agroprocessing. Productivity is restrained by fragmented and often insecure landholdings, poor access to finance and slow adoption of new technologies and innovative business models. Only 6 percent of Africa's cultivated land is irrigated, and fertilizer consumption (16 kg/ha of arable land) is considerably lower than in both East Asia and the Pacific (one-twenty-third) and Latin America (one-eighth) (AfDB, 2016; Jerome, 2017).

Furthermore, Africa's agricultural trade has stagnated at just 5 percent of the global total. The continent has steadily lost competitiveness in global export markets over the past 50 years. The value of agricultural exports from Thailand – whose population is less than 10 percent that of Africa – exceeds that from the whole Africa region. Likewise, the value of Brazilian exports is 150 percent higher than the value of African exports (Green, 2013). African countries have made scant progress in value-added exports beyond horticulture.

African governments recognize the important role of agriculture and food and nutrition security in the continent's development and they are determined to remedy the situation. During the past 15 years, the **Summit of the Heads of State and Government of the African Union (AU)** has made decisions and declarations through which governments have committed to a range of initiatives and spending priorities:

2003

Maputo, Mozambique

Maputo Declaration on Agriculture and Food Security –a commitment was made to allocate at least 10 percent of public expenditure to the agricultural sector.

2004

Sirte, Libya

The Comprehensive Africa Agriculture Development Programme (CAADP) was formally endorsed and adopted as the blueprint for agricultural development.

2006

Summit

A commitment was made to allocate 1 percent of agriculture GDP to agricultural research and development.

2006

Abuja, Nigeria

Decisions were taken on fertilizer use in African agriculture.

2010

Abuja, Nigeria

Adoption of the African Agribusiness and Agro-industries Development Initiative (3ADI) calling for increased investments in agricultural mechanization and agro-industries.

2014

Malabo, Equatorial Guinea, 23rd Summit

Malabo Declaration on Accelerated Agricultural Growth and Transformation for Shared Prosperity and Improved Livelihoods.

2015

Addis Ababa, Ethiopia, 24th Summit

Endorsement of the "Agenda 2063 – The Africa We Want" vision.

1.5. Action by the African Union

The Malabo Declaration of the 23rd Summit and the declarations made at the 24th Summit, approving the Agenda 2063 Aspirations, contain significant policy decisions and long-term commitments on agricultural mechanization in Africa with clear targets for the subsequent five decades. The following are notable:

1. **Malabo Declaration:** At their 23rd Summit in July 2014 in Malabo, Equatorial Guinea, the AU Heads of State and Government resolved under Commitment III: Ending Hunger in Africa by 2025, inter alia:

    - To accelerate agricultural growth by at least doubling the current agricultural productivity levels, by the year 2015. In doing so, we will create and enhance the necessary appropriate policy and institutional conditions and support systems to facilitate:

        - sustainable and reliable production and access to quality and affordable inputs (e.g. crops, livestock, fisheries) through the provision of 'smart' protection to smallholder agriculture;

        - supply of appropriate knowledge, information and skills to users;

        - efficient and effective water management systems notably through irrigation;

        - suitable, reliable and affordable mechanization and energy supplies.

    - To halve current levels of post-harvest losses by 2025.

2. **Agenda 2063:** At their 24th Summit, in January 2015 in Addis Ababa, Ethiopia, the AU Heads of State and Government reiterated their full appreciation of and commitment to the African Aspirations for 2063 as outlined in "Agenda 2063 – The Africa We Want". Specifically, under Aspiration 1:

    - We aspire that by 2063, Africa shall be a prosperous continent, with the means and resources to drive its own development, and where:

        - Economies are structurally transformed to create shared growth, decent jobs and economic opportunities for all;

        - Modern agriculture for increased production, productivity and value addition contribute to farmer and national prosperity and Africa's collective food security;

        - The environment and ecosystems are healthy and preserved, and with climate resilient economies and communities.

    - Africa's agriculture will be modern and productive, using science, technology, innovation and indigenous knowledge. The hand-hoe will be banished by 2025 and the sector will be modern, profitable and attractive to the continent's youth and women.

"...agricultural mechanization needs to [...] be private-sector driven, environmentally compatible and climate smart, affordable, friendly to smallholder farmers, and inclusive of the interests of women and youth."

The 25th AU Summit of Heads of State and Government, held in July 2015 in South Africa, had the theme "Year of Women's Empowerment and Development towards Africa's Agenda 2063". At the Summit, several women's groups called for concerted efforts towards agricultural mechanization in Africa. They specifically highlighted the effects on their health and the drudgery associated with the use of the age-old hand hoe, linking this to youth's abandonment of agriculture as they deemed farming to be an unattractive career choice. At the AU Summit, the then African Union Commission (AUC) Chairperson (from 2012 to 2017), Nkosazana Dlamini Zuma, launched a campaign "to confine the hand-hoe to the museum". As a symbolic gesture, she handed over a power tiller (2-wheel tractor) to each of the attending African Heads of State and Government proclaiming "hope that mechanization of agriculture will be achieved within the next ten years".

Several detailed background studies undertaken by the AUC and its organizations informed the decisions of the African Heads of State and Government at their 23rd, 24th and 25th Summits, as well as the Special Summits, which focused on long-term development through a new programme for the transformation of African agriculture under the CAADP Framework of New Partnership for Africa's Development (NEPAD). The studies included the "Science Agenda for Agriculture in Africa", developed by the Forum for Agricultural Research in Africa (FARA) in 2013–14 with the objective of "...connecting science to transform agriculture in Africa". On agricultural mechanization, the Science Agenda recommended the need to "address those factors which have constrained the use of mechanization inputs in African agriculture from technical, policy and environmental perspectives" (FARA, 2014). This reflected the concerns that new initiatives were failing to recall Africa's experience of agricultural mechanization programmes from 1960 to 2010.

Following decisions made at the 25th AU Summit, the AUC approached FAO for technical assistance to develop a programme to accelerate the pace of agricultural mechanization in Africa, including sending the hand hoe to the museum. Consistent with the Malabo Declaration and Agenda 2063, the intent was to mainstream agricultural mechanization and integrate it into the development policies and strategies of African countries, bearing in mind past mistakes and achievements. Consequently, the AUC posited that agricultural mechanization needed to be developed along the value chain, and should be private-sector driven, environmentally compatible and climate smart, affordable, friendly to smallholder farmers, and inclusive of the interests of women and youth.

FAO accepted the request from the AUC and agreed to use resources allocated to a subregional Technical Cooperation Project (TCP) to kick-start the initiative. As a result, an Inception Workshop (IW) was convened in Addis Ababa from 30 June to 1 July 2016. It reviewed the status of agricultural mechanization in Eastern Africa and Africa in general and agreed on a road map for implementation of the project. The IW also recommended that FAO accept the request from the Department of Rural Economy and Agriculture (DREA) of the AUC to widen the scope of the subregional project to cover the entire region. The objective was to produce, through a consultative process, a draft document that would provide a framework for **Sustainable Agricultural Mechanization in Africa (SAMA)**. It was also agreed that SAMA should specifically factor in the needs of smallholder farmers, youths and women, and be anchored on **three pillars**:

1. commercial sustainability;
2. environmental sustainability; and
3. socio-economic sustainability.

A technical committee (TC) of 20 persons was constituted at the IW to provide oversight and guidance and to enhance quality control during the process of developing the framework for a SAMA strategy. The TC reiterated the need for the initiative to take advantage of the request made by the Commissioner of DREA to facilitate the development of a framework for SAMA. The TC also advised that the development of the SAMA Framework should focus on Africa Africa south of the Sahara and be undertaken through a consultative process involving the Regional Economic Communities (RECs) as well as (to the extent possible and depending on available resources) member countries. A framework document would be able to embrace the wide range of diverse and intricate issues involved in agricultural mechanization in a region as large and as complex as Africa, and would be feasible within the envisaged time frame and despite the resource constraints. The framework document could contain a menu of actions and recommendations for use by the RECs and member countries to develop strategies for sustainable agricultural mechanization (SAM).

Experience from other developing regions of the world where significant progress has been made in agricultural mechanization over the past seven decades validates the framework development approach. In the case of SAMA, a **framework offers member countries options and guidance** on the key elements for consideration during the process of formulating their strategies for SAM. Furthermore, while successful **mechanization programmes and projects are location specific**, the formulation of national strategies should be guided by insights and parameters identified within a framework factoring in outlooks with **national, regional and global perspectives**. Africa is so large and diverse that a single agricultural mechanization strategy would be too rigid and narrow. However, several aspects related to policy formulation and strategy development could benefit from a common approach. The framework report, therefore, aims to establish critical issues for consideration and recommend elements for inclusion in the SAMA strategies.

1.6. Methodology of the study

The Subregional Office for Eastern Africa (SFE) of FAO, together with the AUC and the United Nations Economic Commission for Africa (UNECA), was requested to constitute the core team that would superintend the whole process. The process included the mobilization of additional resources for subregional and country studies, and meetings of stakeholders were convened for review and validation of the framework document. Consultants were recruited to undertake a review of key issues for consideration under SAMA at the subregional level under the leadership of the Senior Adviser, Geoffrey C. Mrema, who had been brought on board at the IW. The four consultants who undertook the subregional studies were as follows (including their designations for the 2016–17 study period):

1. **Central Africa:** Mathias Fonteh, Head of the Department of Agricultural Engineering, Tschang University, Cameroon.
2. **Eastern Africa:** Pascal Kaumbutho, CEO, Kenya Network for Dissemination of Agricultural Technologies (KENDAT), Nairobi, Kenya.
3. **Southern Africa:** Mataba Tapela, Ag. Vice Chancellor, Botswana University of Agriculture and Natural Resources, Gaborone, Botswana.
4. **West Africa:** Emmanuel Ajav, Dean of the Faculty of Technology, University of Ibadan, Nigeria.

The consultants carried out a detailed review of the state of agricultural mechanization in their respective subregions, including a review of reports and papers published over the past several decades and interviews with key informants in the member countries. They also visited the headquarters of the main RECs in their respective subregions and held discussions with the officers responsible for agricultural development. SFE provided coordination and technical support to the team through Nomathemba Mhlanga, Agribusiness Officer at SFE, supported by Senior Economist, Jerome Afekhena. The Agricultural Engineers, Josef Kienzle (FAO headquarters) and Joseph Mpagalile (FAO Regional Office for Africa [RAF]) provided the technical backstopping support throughout the process.

The seven experts – Mrema, Fonteh, Kaumbutho, Tapela, Ajav, Mhlanga and Afekhena – worked under the guidance of Patrick Kormawa (SFE) on the assignment. In addition to electronic consultations, they met twice for brainstorming sessions: in Addis Ababa, Ethiopia, from 24 to 27 October 2016 and in Nairobi, Kenya, from 4 to 5 December 2016. The team also participated in a Consultative Meeting on Mechanization Strategy, convened by the WB, FAO, Alliance for a Green Revolution in Africa (AGRA), the African Conservation Tillage Network (ACT) and the European Committee of Associations of Manufacturers of Agricultural Machinery (CEMA), among others, on 1–2 December 2016 in Nairobi. Over 100 experts drawn from public- and private-sector organizations active in agricultural mechanization issues in Africa participated in the meeting, where they discussed new models for sustainable agricultural mechanization in Africa. The team gained useful insights by hearing how these organizations thought the sector should evolve in the coming decades.

In December 2016, the Senior Adviser prepared a zero draft of the framework document and circulated it for comments to the other members of the team, as well as to key officers of FAO (SFE, RAF and headquarters, Rome), UNECA and DREA. A first draft was then produced and distributed to members of the Steering Committee in January 2017 for comment. Based on the feedback received, a second draft was produced, circulated to stakeholders in April 2017; it was discussed in detail at a Validation Workshop (VW) of stakeholders.

1.7. Validation Workshop

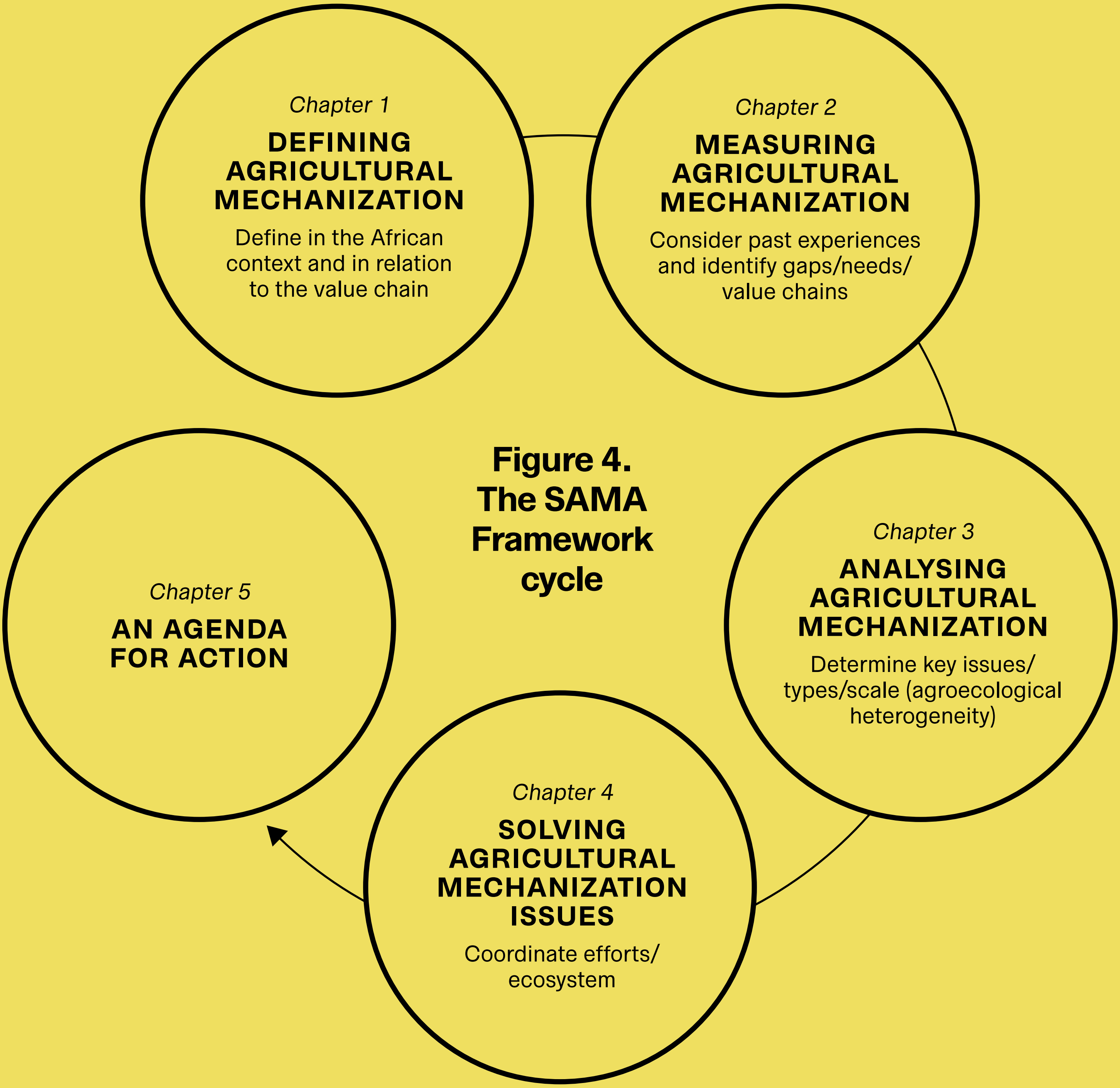


Figure 4. The SAMA Framework cycle

The validation workshop was organized by the AUC and FAO in Addis Ababa, Ethiopia from 11 to 12 May 2017 with the specific objective of discussing and validating the draft report of the framework for SAMA. Fifty-four experts from governments, research and financial institutions, non-state actors, the private sector and universities attended the highly interactive workshop. Some of the participants had attended the IW held in Addis Ababa from 30 June to 1 July 2016 to discuss the modalities for the implementation of the project. The draft report on the framework for SAMA was presented.

The team agreed that a **comprehensive approach** was required in order to look at mechanization holistically, with due consultation of key stakeholders. It was decided to include the entire Africa region with the objective of producing, through a consultative process, a framework for SAMA to help member countries develop their own national strategies.

Experience from other regions in the world where progress has been made in recent years demonstrates the positive impact that such a framework can have, providing guidance to member countries on the process and options available for formulating sustainable agricultural mechanization strategies. While it is recognized that mechanization strategies and policies might be country specific, national strategies are best formulated when guided by insights and parameters identified within a **framework that contains outlooks with regional and global perspectives**. Experience over the past 60 years shows that recommending a single strategy fails to capitalize on the diversity of this large continent. Nevertheless, several aspects related to policy formulation and strategy development could benefit from a common framework. Beyond these common areas, it is more useful to consider policies and strategies in the context of specific situations. The starting point for this study is rooted in the firm long-term commitments on agricultural mechanization made by the African Heads of State and Government at the 23rd and 24th Summits.

1. **Chapter 2** reviews agricultural mechanization developments in Africa, focusing on the period from 1960 when most countries in the region attained their political independence. It concludes with a section on the lessons learned from agricultural mechanization efforts in Africa as well as from other regions in the developing world.

2. **Chapter 3** covers the key issues that must be considered in the development of sustainable agricultural mechanization strategies, based on past experience in the region and future trends, as well as on lessons from other regions of the world where substantial progress has been made in recent years.

3. **Chapter 4** describes the main elements of a framework for sustainable agricultural mechanization strategies in Africa. Emphasis is placed on an approach that cuts across agrifood chains in Africa and the elements are clustered under the three sustainability pillars – commercial, environmental and socio-economic.

4. **Chapter 5** concludes with a call for regional and subregional mechanisms to facilitate advocacy for SAMA and to share knowledge, experiences and technologies.

5. **The References** provide the list of reference documents reviewed.


Using Draft Animal Power in Ethiopia.

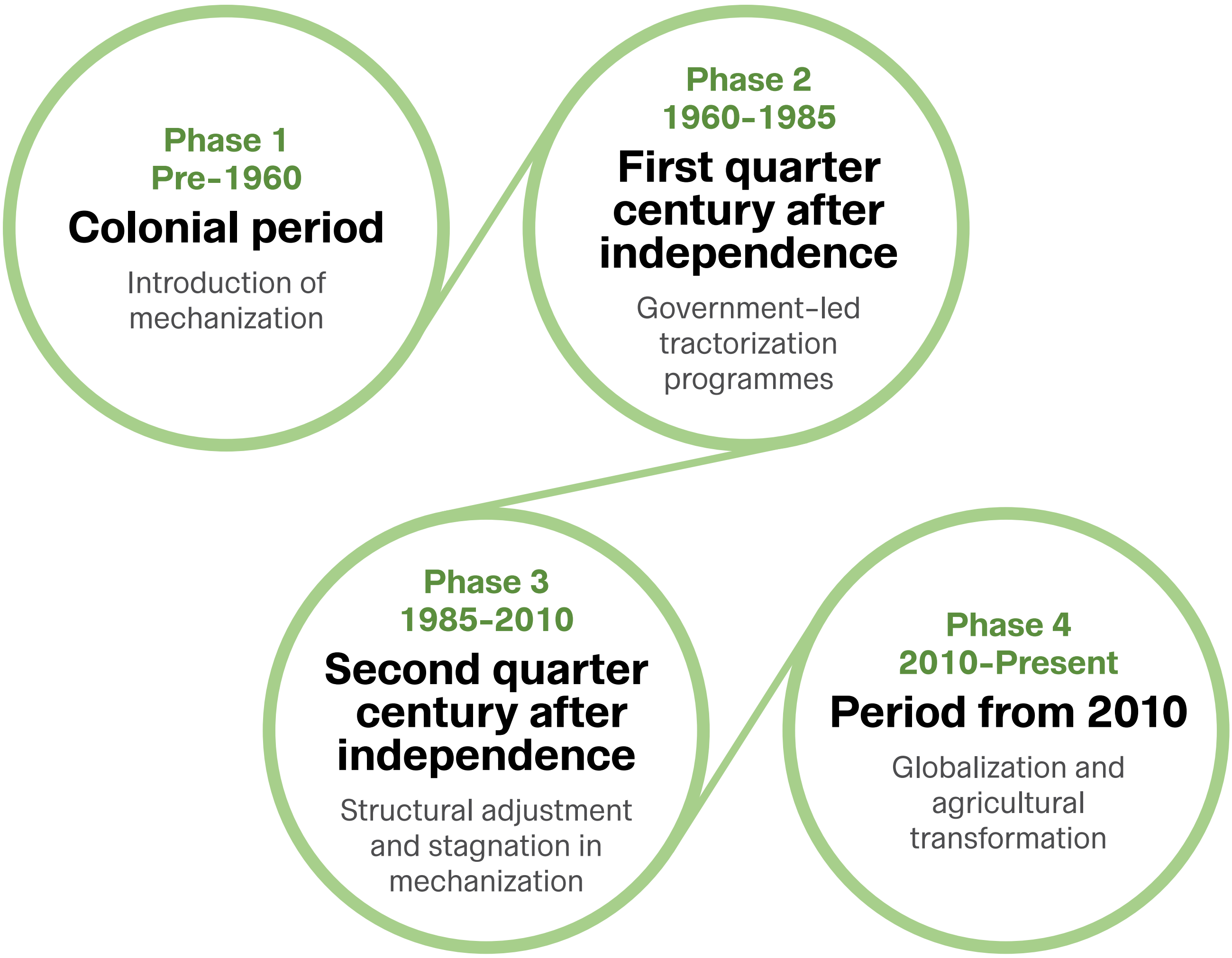
2. Evolution of agricultural mechanization in Africa

PHOTOGRAPHY: PETER WIESER, CC0 CREATIVE COMMONS

Africa has a long history of agricultural mechanization with numerous shifts in policy and strategy, especially during the past 70 or so years. In many cases, failed past projects, which in most cases did not receive adequate ex-post evaluation, have had an inordinate influence on subsequent policy and strategy formulation, as well as on the choice of technology to be adopted.

The **evolution of agricultural mechanization in Africa covers seven periods, broadly aligned with the four phases of the region's evolution of its mechanization programmes:** the colonial period (pre-1960); the first quarter century after independence (1960–1985); the second quarter century after independence (1985–2010); and the period from 2010 to the present **(Figure 5)**.

Figure 5. The four phases of Africa's agricultural mechanization evolution



2.1. Agricultural mechanization during the colonial period

With the exception of South Africa and Ethiopia, agricultural mechanization was introduced in most countries in Africa during the colonial period, starting in the 1890s when much of the region came under colonial rule. The colonial period may be further subdivided into three distinct periods:

The **first period** was prior to 1920 and may be called the **hand-tool technology period**. The predominant type of mechanization technology on settler farms (British, French, German and Portuguese) and on subsistence farms of the native Africans was hand-tool technology (Swynnerton, 1949; Austen, 1968; Allan, 1970; Illife, 1969, 1971). Settler farmers used various methods to get the natives to work as labourers on their farms with hand-tool technology. Draught animals could not be used in crop production in much of the region, largely because livestock was kept in the drier areas by pastoralists, most of whom did not grow crops. The native inhabitants who grew crops lived in the wetter areas where livestock could not be kept because of the tsetse fly.

The **second period** occurred between 1920 and 1945, when **DAT was introduced and disseminated** in parts of Africa where cattle could be kept. Note that in Ethiopia and South Africa, draft animals had been used for several millennia (Ethiopia) and centuries (South Africa). In 1920–1945, advances in the control of livestock diseases – in particular the control of the tsetse fly through bush clearing – made it possible for livestock production to be introduced in new and wetter areas where it had previously not been possible (Ford, 1971). The ox plough was also introduced and contributed to increased crop production, including of cash crops such as cotton (Mayne, 1954, 1955, 1956; Kjoerby, 1983; Starkey, 1986, 1988a; Tiffen et al., 1994). DAT is still used today in drier areas where farmers have a tradition of both livestock and crop farming. However, the bush clearing adopted to get rid of the tsetse fly led to serious environmental degradation (Austen, 1968; Iliffe, 1969; Ruthernberg, 1964; Ford 1971).

The **third period** occurred between 1945 and 1960, when the **colonial authorities established various mechanized commercial farming schemes** in several parts of Africa. During 1920–1965, the tractor was developed and perfected in North America and in Europe, and efforts were made by the colonial authorities to introduce the technology to the colonies in the region (Mayne 1954, 1955, 1956; Hall, 1968; Cleave, 1974; Carrillon and Le Moigne, 1975; Mrema, 1981; Kinsey and Ahmed, 1984; Gibb, 1988). The number of tractors in use in Africa (excluding South Africa) increased from a few hundred before 1945 to more than 23 000 in 1950 and 47 000 in 1960. Several notable programmes with mechanization interventions were implemented during this period and are described below:

SETTLER FARMS

Settler farmers were encouraged to settle in new areas in Eastern and Southern Africa. Medium- and large-scale mechanized farms were established for growing sisal, tea, pyrethrum, cereal grains etc. Settler farmers used a combination of hand-tool technology (hiring native labourers), draught animal technology (on farms where it was possible to keep livestock) and mechanical technologies (especially tractors and other machinery procured through concessional loans provided by the imperial governments of Belgium, Britain, France, Italy, Portugal and Spain). Native farmers continued to grow their food, mostly for subsistence, on small plots, relying entirely on hand-tool technology. In a few places, the cultivation of cash crops, such as coffee, cotton and oilseeds, was encouraged (de Wilde, 1967; Allan, 1970; Bunting, ed., 1970).

GROUNDNUT SCHEME

In 1946–1952, the British colonial authorities established the largest ever mechanized agriculture project in Africa, perhaps in the world: the “Groundnut Scheme”. The Groundnut Scheme was implemented in Tanganyika (today’s mainland of United Republic of Tanzania), Botswana and Nigeria from 1946 to 1950. The plan involved the cultivation of groundnuts on large-scale farms in an area totalling over 1 million ha to address the oilseed shortage faced at the time by the British Empire. A large number of tractors were imported, especially in Tanganyika, the headquarters of the project; some were World War II surplus battle tanks, rudimentarily converted to crawler tractors. The machines were used to clear the land and start groundnut production. After a five-year trial, the scheme failed for a variety of reasons, including lack of proper planning, soil compaction due to the use of heavy equipment, insufficient land planning, inadequate soil analysis and poor managerial skills (Wood, 1950; Lord, 1963; Cleave, 1974; Burch, 1987).

When the Groundnut Scheme was abandoned in 1950, most of the imported tractors were sold to local settler farmers, while a few were bought by African merchants who initiated partially mechanized agriculture in other areas. The Groundnut Scheme is the biggest mechanized agricultural project ever attempted. It involved more effort than any other project implemented by independent African governments in subsequent years and the full narrative is of potential interest to economic historians. The failure of the Groundnut Scheme, despite the massive financial and technical support of the British Government, attests to the complexities of agricultural mechanization in tropical Africa. It is regrettable that research has focused less on this project than on others started after independence (Mrema, 1991).

AFRICAN COMMERCIAL FARMERS

A class of medium-scale farmers (5–100 ha) emerged and started growing commercial/cash crops, including coffee, cocoa, cotton and food crops (e.g. maize, wheat and beans), in several colonies, such as Ghana, Nigeria, Tanganyika, Uganda and Northern Rhodesia (today's Zambia). In addition, smallholder farmers formed strong cooperative unions that concentrated on marketing their produce; they included the Kilimanjaro Native Cooperation Union (KNCU), the Victoria Federation of Cooperative Unions (VFCU) and the Bukoba Cooperative Union (BCU). While some were established well before 1945, they underwent phenomenal growth during 1945–1960 (de Wilde, 1967; Hall; 1968; Clayton, 1973; Cleave, 1974).

SWYNNERTON PLAN

Under this plan, native farmers were settled in the Kenya highlands on newly planned 10–20-acre (4–8-ha) farms that could be viably mechanized (Swynnerton, 1954; IBRD, 1960). Farmers were given title deeds to their newly acquired land, leading to the commercialization of small-scale agriculture in Kenya for cultivation of perennial crops (coffee and tea) and livestock production. The Swynnerton Plan was the response of the colonial authorities in Kenya to the Mau Mau liberation/land war. It set the scene for the establishment of vibrant agro-enterprises and industries anchored on small- and medium-scale farms after independence; it was perhaps one of the most productive agricultural systems dominated by smallholder farmers growing high-value commodities and organized in strong value chains (coffee, tea, dairy and horticulture).

2.2. Agricultural mechanization after independence: 1960–1985

Agricultural mechanization was regarded as high priority by the governments of the new independent states of Africa – especially mechanization of the smallholder sector. The experience during the post-War years of implementation of various mechanization projects on the continent inspired optimism. During the preceding four decades, countries in Europe and North America had changed their farm power situation from one largely dominated by draft animals to one based on mechanical technologies (White, 2000; Gibb; 1988; Giles, 1966). This provided further motivation to those advocating for the transformation of agriculture in Africa. Technical teams fielded by the WB, FAO and other major development agencies also supported the idea of agricultural mechanization (IBRD, 1960; Oluwasami, 1975).

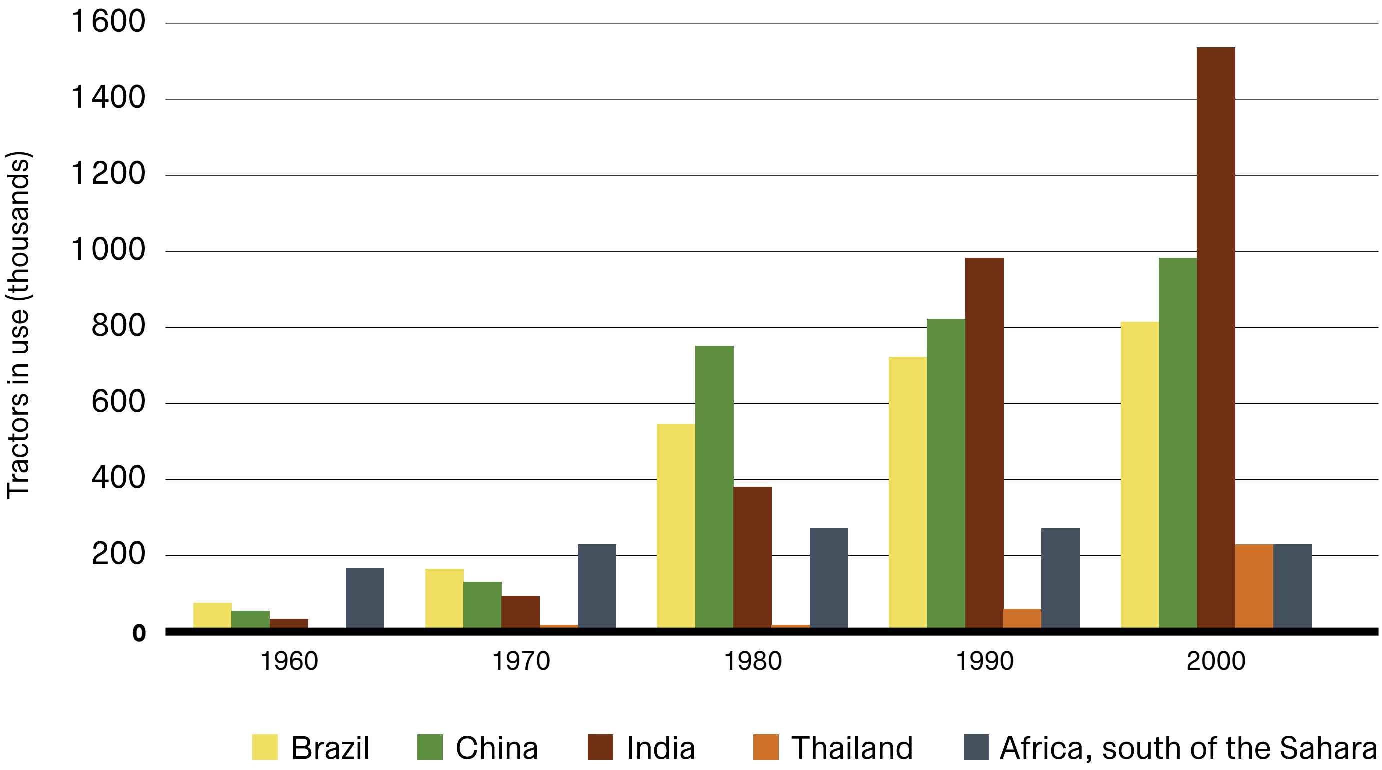
The first quarter century after independence (1960–1985) marks the first stage in the process of agricultural mechanization. At the time, governments in Africa, with technical support from major development agencies, implemented a number of projects to transform rural areas. Their aims included making these areas more amenable to mechanization (IBRD, 1960; Oluwasami, 1975; Makanjuola et al., 1991; Twum and Gyarteng, 1991). This required the establishment of what were regarded as modern settlements – new areas where villagers and urban unemployed were settled and given capital-intensive machinery and implements to transform rural areas and increase productivity and production. Many such settlements, some modelled on the kibbutz schemes of Israel, were established all over the continent at a comparatively high cost to governments (de Wilde, 1967; Kates, McKay and Berry, 1969; Ingle, 1972; Cleave, 1974; Hyden, 1980).

Many of them failed and the machinery ended up abandoned in various locations across the continent. These “graveyards” of broken-down tractors and implements were reported – by mostly western journalists – to be evidence of inappropriate policies and programmes implemented by the newly independent African governments. The book by the French sociologist, Rene Dumont, False Start in Africa, inspired many negative stories in the western media about the wrong developmental path chosen by the governments of independent African countries (Dumont, 1966).

During the same period, other initiatives were born offering tractor hire services through projects operated and managed under the civil service system. One programme was established through a WB loan provided to the VFCU in the United Republic of Tanzania to finance a pilot cultivation scheme known as the Geita Block. The scheme provided over 157 tractors for a public-sector tractor hire service operated under civil service rules (de Wilde, 1967; Lele, 1975, 1976). The scheme failed and the tractors and implements were sold to private operators and progressive farmers who offered ploughing services to small-scale farmers from Mwanza in the northwest of the country to Arusha and Kilimanjaro in the northeast, and sometimes to farmers in eastern and western Kenya (TSAE, 1972, 1973 and 1974; Alcober et al., 1983). Other public-sector tractor hire schemes were

Figure 6. Tractors in use in Africa compared with other developing countries

Source: FAOSTAT-AGS, 2004; FAO, 2008.



established throughout Africa, including several in Nigeria (Kolawole, 1972), Zambia (Dodge, 1977; de Wilde, 1967; Allan, 1970) and Ghana (Gordon, 1970; Twum and Gyarteng, 1991).

Throughout this period, tractor numbers in Africa excluding South Africa increased from about 23 000 in 1950 to 47 000 in 1960 and 84 000 in 1970 **(Figure 6)**. Most of the **leading global companies dealing with agricultural machinery and implements established franchises** and had branches in many parts of the region (Ford, John Deere, Massey Ferguson, Fiat, International Harvester). Ostensibly, the companies were offering efficient and profitable services; moreover, they survived and the sector grew (de Wilde, 1967; Kline et al., 1969; Cleave, 1974; Kurdle, 1975). According to FAOSTAT, the number of tractors in use in countries in Africa peaked in 1985 at 133 888 units, excluding South Africa.

Due to the dominance of large-scale farmers (mostly white), South Africa had a different story. Tractor numbers there increased from 48 000 units in 1950 to 148 000 in 1960, reaching 181 000 in 1980 and peaking at 184 000 in 1990 before starting to decline as farmers switched to higher horsepower tractors. In contrast, in the other countries in Africa, there was simply a reduction in tractor imports and use (ComSec, 1991; Clarke, 1998; Clarke and Bishop-Sambrook, 2002).

2.3. Agricultural mechanization after independence: 1985–2010

The second stage of the mechanization process took place in the second quarter century after independence: 1985–2010. In this period, interest in mechanization based on mechanical technologies waned among the major development agencies. As noted by FAO (2008), by the mid-1970s, policy concerns increased in Africa – as elsewhere – with regard to the welfare effects (employment and income distribution) and economic benefits of tractor mechanization (ILO, 1973). Studies on the economics of private tractor ownership raised concerns regarding financial and economic returns and distorted incentives resulting from the widespread use of subsidies. By the mid-1970s, there was a consensus among development experts that many of the government-managed and operated tractor hire schemes were not achieving their primary objective.

Government-run tractor hire schemes, prevalent in the 1960s and early 1970s, were largely ineffective because of management failures, lack of financial support and inadequate infrastructure (de Wilde, 1967; Seager and Fieldson, 1984; Kolawole, 1972; Lele, 1976; Eicher and Baker, 1982). Other shortcomings included lack of incentives under civil service regulations for tractor operators to work extended hours; poor machinery productivity; low rates of effective machine utilization (ostensibly caused by poor tractor maintenance and the fact that small farms were scattered over a wide area); and the intricacy of civil service bureaucratic systems.

Although government tractor hire projects attracted much attention, the reality in many countries was that the tractors in the schemes were only a fraction of the total number in the national fleet. As noted by Kaul (1991), the aggregate number of tractors in these government-operated hire schemes (estimated at < 3 000 for the period 1945–1980 in the whole of Africa) was too small a sample to provide blanket explanations or prescriptions for the use of tractors in African agriculture. As de Wilde, Chief Economist at the World Bank, noted in 1967:

One is impressed by the diversity of experiences with animal-drawn and tractor-drawn implements in tropical Africa, and by the fact that no comprehensive effort is apparently being made to analyse these experiences and make the conclusions of this analysis to all countries of tropical Africa." In many cases, for instance, it is difficult to determine whether mechanization has failed because it was inherently un-economic or because it suffered from certain technical and managerial problems that could have been avoided or overcome. (de Wilde, 1967)

A solar panel charging up a battery for household use in Catandica, Mozambique.

PHOTOGRAPHY: ©FAO/PABALLO THEKISO

The two studies that attempted a continent-wide review of Africa's progress or lack of progress in tractor mechanization were inconclusive (Kline et al., 1969; Pingali, Bigot and Binswanger, 1987). However, they were undertaken by foreign-based experts who made flying visits to a few projects, offered hasty appraisals and then provided prescriptive recommendations based largely on the performance of government-managed tractor hire schemes operating less than 20 percent of the tractors in use in most countries. Africa-based experts later challenged some of the reasons given for the lack of progress in tractor mechanization (Kaul, 1991; Mrema and Odigboh, 1993; FAO, 2008). They also noted that some of the foreign experts had made similar recommendations on tractor mechanization in Asia in the 1960s and 1970s, and these had been challenged by local experts who were eventually proven right (Binswanger 1978; Singh, 2001, 2013; Lele, 2012).

Due to the poor performance of public-sector-operated tractor mechanization programmes in Africa and shifts in development paradigms, the main donor agencies in the 1970s turned to other technologies in an effort to tackle the mechanization problem (FAO, 2008). In the 1970s and 1980s, considerable amounts of money and resources were invested in research and development aimed at designing "appropriate" machinery and implements for mechanization in Africa (Balis, 1978; Mrema and Odigboh, 1993). Particular attention was devoted to developing intermediate types of tractors suited to agriculture in Africa and other developing countries (Boshoff and Joy, 1966) – for example, the Kabanyolo and Tinkabi mini-tractors used in Uganda and Swaziland respectively. Most intermediate tractors were not successful in the market and were abandoned by 1990 (Holtkamp, 1988, 1989, 1991).

Research was also undertaken on improved animal-drawn implements, such as the two-wheeled multipurpose tool carriers of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), the Mochudi tool carrier (also two-wheeled, multipurpose) and other similar implements (Starkey, 1986, 1988a; Mrema and Patrick, 1991). As noted by Starkey (1988a), although these multipurpose two-wheeled carriers were perfected in workshops and experimental fields at a cost of over USD 50 million in research and development, they were rejected by farmers throughout Africa.

By the late 1980s, it was clear that little progress had been made in mechanizing agriculture in Africa, either with appropriate hand tools or with animal- and mechanically powered implements (Pingali, Bigot and Binswanger, 1987).

Some tractor mechanization programmes implemented in Africa were associated with both technical problems arising from the adoption of unsuitable and unreliable machines and economic problems, such as the inability to achieve the high work rates forecast or to carry out rapid repairs. The weak supporting infrastructure in many rural areas meant that maintenance was a problem, due to a lack of repair shops and spare parts. The use of tractors and heavy mechanization in unsuitable situations was associated with lower agricultural production and environmental degradation. Under these circumstances, **tractor mechanization became a burden** to national economies and to individuals, rather than an essential input with the potential to increase productivity. Several studies carried out in the 1990s supported the view that policies favouring tractors and other forms of capital-labour substitution had negative impacts on production and productivity (Van Zyl, Vink and Fényes, 1987; Belete, Dillon and Anderson, 1991; Taylor, 1992; Panin, 1994; Seleka, 1999).

Despite the poor record of tractorization programmes in the 1960s and 1970s, many African leaders remained convinced that agricultural mechanization was essential for development and economic growth on the continent. They continued to devote resources, albeit at reduced levels, to tractorization programmes through to the late 1980s. However, most governments were subsequently forced by economic structural adjustment programmes to discontinue their support to such projects. By the late 1990s, nearly all government tractor hire schemes had folded, with most tractors either abandoned or sold off to farmers and private tractor operators.

Overall, efforts to promote animal traction fared better, especially in drier areas where small- and medium-scale farmers with a livestock husbandry tradition settled and began to grow cash crops, such as cotton and groundnuts (Starkey, ed., 1998). Donors funded DAT projects implemented by non-governmental organizations (NGOs), and regional animal traction networks (ATNs) were established in the 1990s (Kjoerby, 1983; Starkey, 1988b; Starkey, ed., 1998); however, by the turn of the century, interest in these had waned (FAO, 2008). Nevertheless, field-level studies from the late 1980s through to the 1990s continued to find that animal traction was not substantially profitable or beneficial under small-scale farmer conditions (Jansen, 1993; Jolly and Gadbois, 1996). The studies that did point to the profitability of use of animal traction emphasized that the benefits were strongly dependent on specific situations, for example, where soil and economic conditions permitted intensive land use and profitable farming (Williams, 1996; Adesina, 1991; FAO, 2008).

In addition to limited profitability, **problems affecting the use of animal traction** included the substantial financial burden on farmers during the early years of adoption (Panin, 1988), lack of appropriate recommendations for the pertinent tillage system (Willcocks and Twomlow, 1992), and the opportunity cost of labour and capital for maintaining animals outside of the cropping seasons (Ehui and Polson, 1992). Finally, given the tsetse fly problem, keeping livestock – and hence the use of draught animals – was restricted to the drier zones of Africa (FAO, 1975; Mrema and Mrema, 1993). Further, adoption of DAT by people with no tradition of animal husbandry was extremely low, even after prolonged extension efforts: for example, following over 100 years of promoting this technology in Tanzania, in 2015 its use was confined to a mere six regions of the 25 in the northwest of the country, where over 80 percent of draft animals in use were found (Mrema, 2016). Recurring droughts in many parts of Africa, as well as epidemics of animal diseases, have also contributed to reducing the use of DAT, even in those areas where it had been widely adopted in the 1960s, such as the Southern Province of Zambia.

2.4. Agricultural mechanization after independence: from 2010

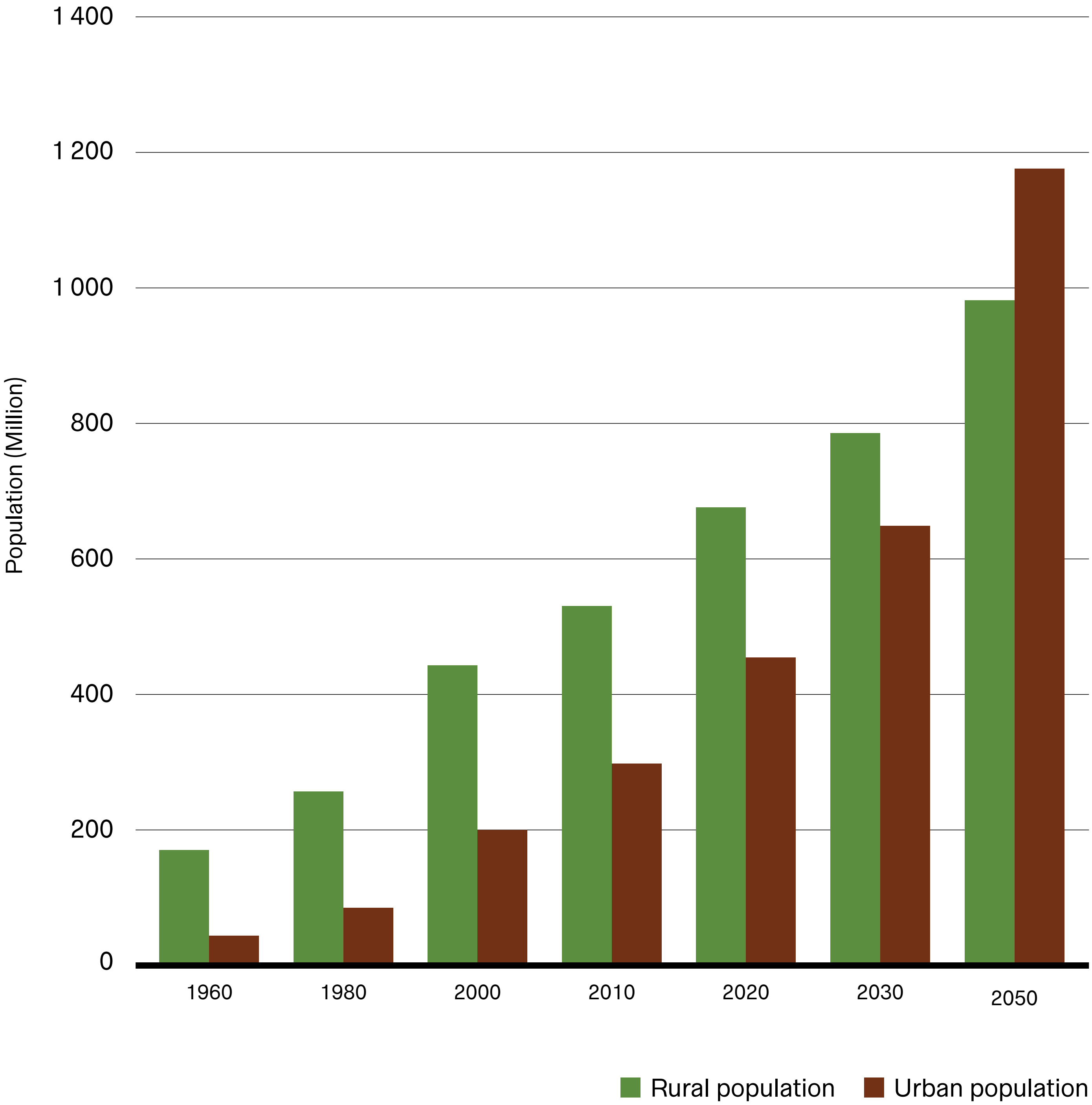
During the first decade of the twenty-first century, there were few new initiatives or new ideas on mechanization in Africa. This was in contrast to the growing number of success stories in Africa that were witness to the vitality and responsiveness of farmers and private-sector firms in introducing new **enterprises and biophysical technologies** when presented with favourable domestic conditions and policy incentives (Gabre-Madhin and Haggblade, 2004; FAO, 2008). FAO was concerned about the declining agricultural mechanization situation in Africa and prepared a paper, presented at the Regional Conference for Africa of Ministers of Agriculture held in Bamako, Mali, in 2005 (Bishop-Sambrook, 2005). This led to a number of countries requesting assistance from FAO to develop agricultural mechanization strategies (AMS) (FAO, 2016).

From 2005, **new suppliers of agricultural machinery** and implements from Asia and Latin America entered the market, offering tractors and implements at lower prices than the traditional suppliers who were largely based in North America and Europe. In addition, new equipment and implements, such as power tillers (or 2WT), were introduced in some countries. These new suppliers are yet to establish fully operational and sustainable local franchises for the supply chains for their machinery and spare parts. It is **essential to establish franchises and develop the trust of local customers** – both of which require time.

Most countries have become more open to investments, and look to local and foreign entrepreneurs to invest also in agricultural development. Early investments were directed at the export sector (e.g. horticulture), but there is growing interest in medium-scale farms that produce food for the local market or for export to neighbouring countries. Agroprocessing and other value-adding enterprises are increasingly attractive to investors, and they require mechanization inputs. Complementary investments in irrigation and other rural infrastructures, including roads and storage facilities, create an enabling environment for investment in agricultural mechanization in some parts of Africa. It may be concluded that there is now a lot of interest in transforming African agriculture: **new opportunities are being created and new players are entering the sector**. The growing population, a significant proportion of which lives in urban areas (**Figure 7**), is having a discernible impact on the pace of agricultural transformation and commercialization. **A new class of commercial farmers is emerging in many countries and is set to influence the pace of agricultural mechanization in Africa.**

Figure 7. Population in Africa

Source: UNFPA.



2.5. Lessons from past experience on agricultural mechanization in Africa

As reviewed in many studies undertaken over the past three decades, the **key factors responsible for the uptake of mechanization** in Asia and other regions in the developing world in the 1970s and 1980s (including some areas in Africa) can be summarized as follows :

1. Presence of a sizeable number of medium-scale farmers and other entrepreneurs – providing mechanization and other services to the more numerous smallholder farmers.

2. Entrepreneurial capacity of farmers and their versatility in adapting to changing markets, technologies and policies (adaptive management).

3. Opportunities to use tractors and other agricultural machinery in off-farm activities, such as transport, construction, repair and maintenance of rural infrastructure.

4. Policies encouraging industrialization resulting in rising real wages and complementary policies contributing to the private profitability of farming.

5. Availability of registered land for purchase or leasing by individual farmers – increasing farm size and subsequent profitability and providing farmers with an opportunity to use their land titledeeds as collateral for credit to buy machinery.

6. High levels of effective demand for mechanized equipment – leading to the development of suitable low-cost equipment (tube wells, power tillers, diesel engines) as an alternative to purchasing high-cost and often unsuitable machinery from developed countries.

7. Presence of local entrepreneurs dealing with repairs and manufacturing, and development of machinery supply chains – ensuring availability of repair and maintenance services and spare parts.

8. Business- and enterprise-friendly policies, laws and regulations, as well as physical and institutional infrastructure – encouraging commercial activities and entrepreneurship in farming and input supply, as well as produce handling, processing and marketing.

Studies from Asia and other developing regions indicate a key role of business and entrepreneurship linked to agricultural mechanization supplies and services.

Other considerations and lessons emerging from the mechanization experience in Asia and Africa in the last five decades of the twentieth century include the following (Binswanger, 1978, 1986; Sargent *et al.*, 1981; Farrington, Abeyratne and Gill, eds, 1982; Burch, 1987; Pingali, Bigot and Binswanger, 1987; Nagy, Sanders and Ohm, 1988; Starkey, ed., 1998; FAO, 2008; FAO-RAP, 2014):

1. Mechanization of processing and pumping tends to precede mechanization of crop husbandry and harvesting operations. Further, mechanization of power-intensive processing and pumping operations can be profitable at low wage rates.

2. Mechanization of difficult and arduous tasks, such as primary land preparation, does not necessarily lead to unemployment.

3. Increases in field productivity stem from combinations of technologies adopted as a package, for example, farm power and mechanization technologies used together with biological technologies.

4. Investments in mechanical technologies depend on farmers being able to generate income and profit from their production. For this reason, sustainable mechanization is often associated with programmes that facilitate or support access to organized markets for whatever farmers produce. On the other hand, farmers who produce for subsistence have to pay for mechanization services from other income sources, suchas remittances and off-farm employment.

5. Tractorization often leads to increases in farm size through land consolidation and procurement of adjacent farms.

6. High capital costs associated with tractors mean that only large farms are in a position to utilize them efficiently. Moreover, farmers who purchase tractors can only maintain profitability by using the tractors also for off-farm activities, such as transport.

7. Where rental markets exist or can be established, farm size has had less influence on the pattern of mechanization (e.g. in India).

8. Substitution of manual labour with tractors has tended to occur as a result of the high supervision costs associated with hired labour, particularly on larger farms.

9. Government subsidies, tax concessions and overvalued exchange rates may have accelerated the pace of tractorization.

10. Efforts to design and promote implements and machinery, especially for particular farming systems or specific groupsof farmers, have not fared well.

11. The perception exists that mechanization programmes operated directly by government agencies have dominated the process of mechanization in Africa more than in Asia. In reality, the tractors in government programmes account for less than 20 percent of the total number of tractors in use, especially in countries with higher numbers of tractors. This myth needs to be debunked.

A review of the data regarding numbers of tractors in use and tractor-use intensity (**Figure 8** and **Figure 9**) for the different African RECs, and a comparison with similar data from other regions of the world, leads to the inevitable conclusion: for the transformation of agriculture and sustainable mechanization to occur in the next two to three decades, serious rethinking is needed at both the national and subregional levels. Such a transformation is possible – it has happened in other parts of the world – but it requires **immediate and concerted action by all key stakeholders at the national, subregional and regional levels.** Both the Malabo Declaration and Agenda 2063 of the AU African Heads of State and Government provide a good foundation in this regard and need to be followed by **concrete plans**. The SAMA Framework is a contribution in that direction.

Figure 8. Number of tractors per 1000 ha of land in different economic regions of Africa

Source: FAOSTAT and World Bank STAT, 2010.

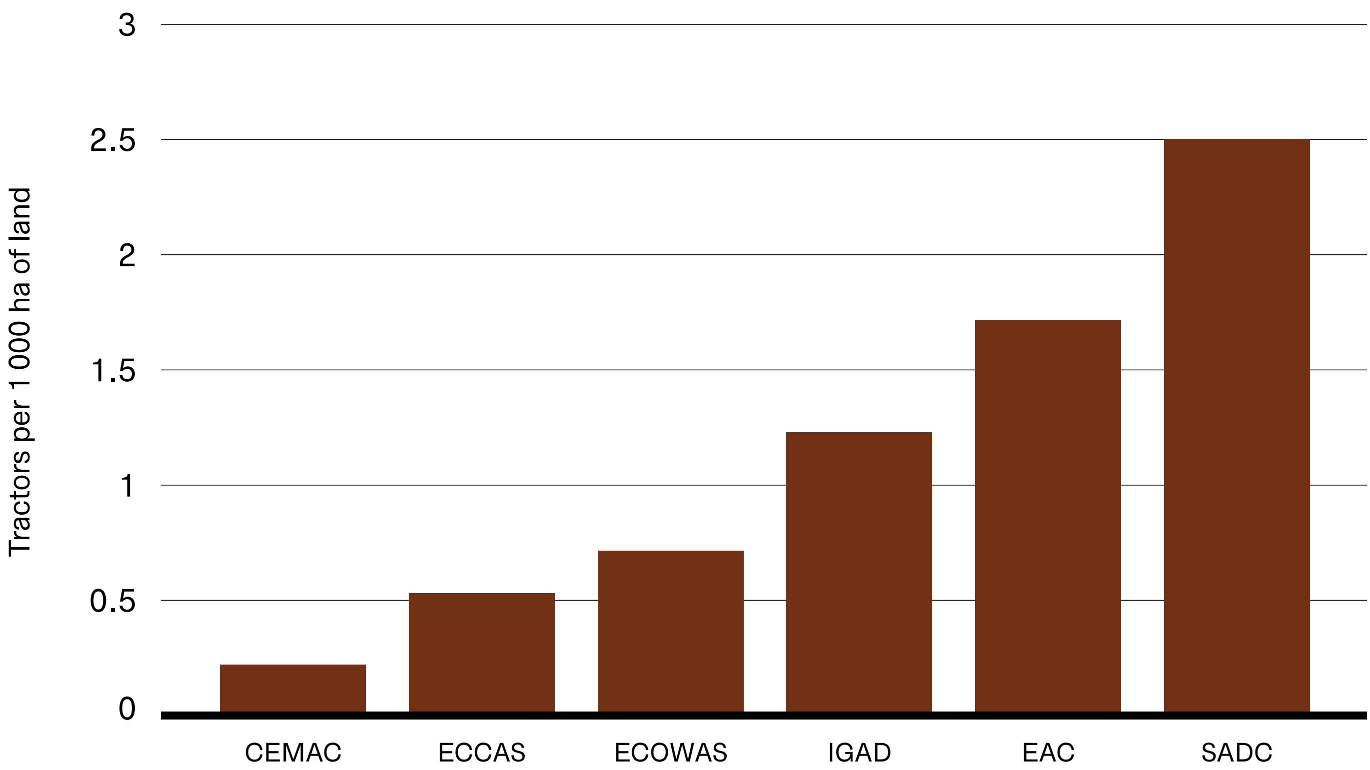
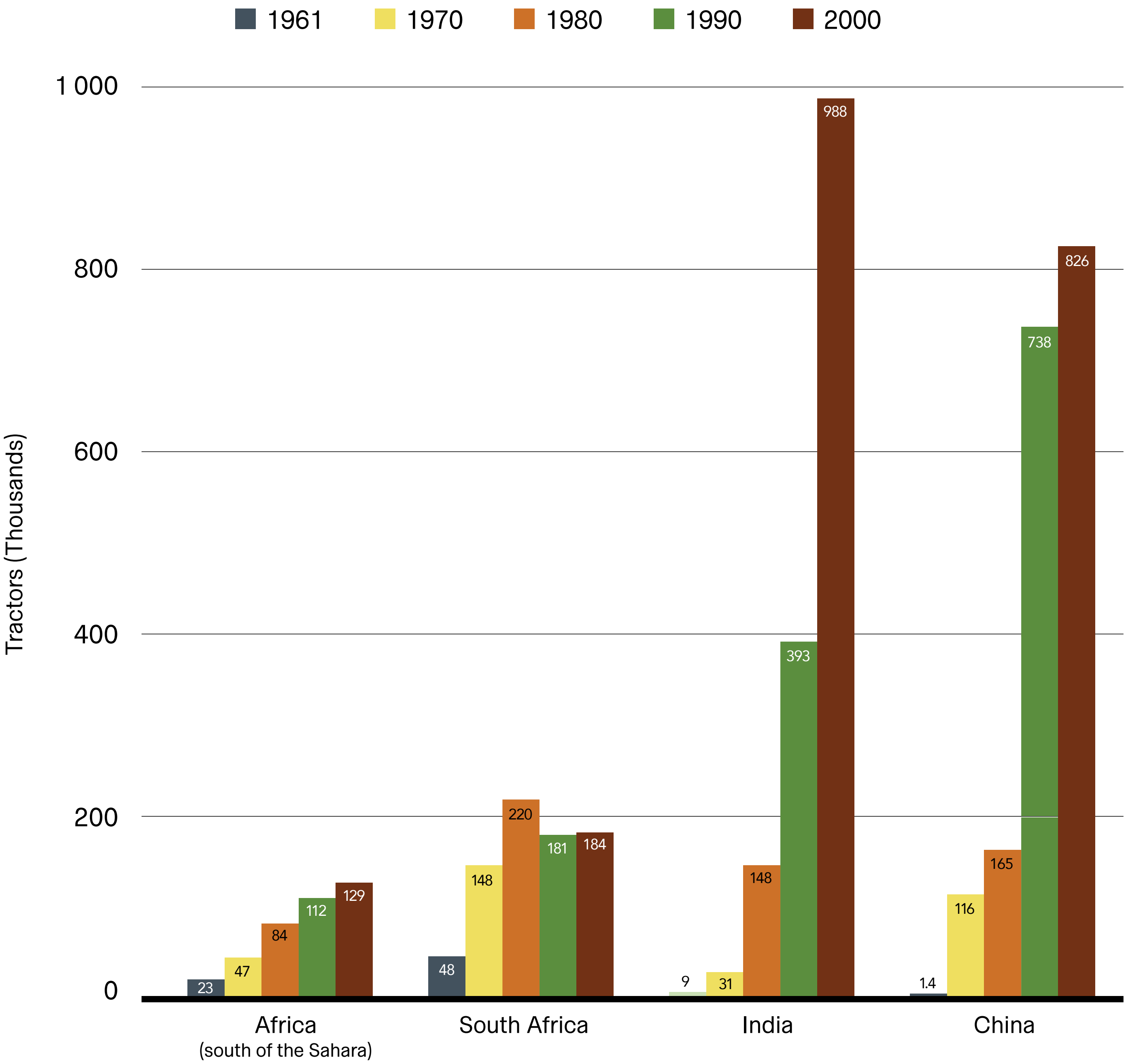


Figure 9. Growth in tractor numbers used in agriculture in different countries (1950–1990)

Source: FAO, 2008.



*Figures for 1970 for South Africa include garden 2-wheel tractors. All other figures are for 4-wheel 2-axle tractors.

Four main policy lessons for mechanization in Africa can be gleaned from the Asian and African experiences of the past five decades (FAO, 2008, 2013a, 2015; Collier and Dercon, 2009; Renpu, 2014; Wang, 2013; FAO-RAP, 2014; Singh, 2013):

1 The overriding issue faced by countries in Asia and Africa during the 1970s was how to develop a highly productive agricultural sector capable of meeting food security needs and competing effectively in national, regional and global markets. The priority is to **increase the profitability for farmers of investments in mechanization by encouraging commercial agriculture and focusing investments and support on both farm and non-farm enterprises**. At the farm level, a critical factor is whether entrepreneurs are ready to invest in machinery for use on their farms and provide mechanization services to other small-scale farmers who are unable to marshal the capital investments required.

2 Mechanization should be viewed strategically within a long-term time frame. Despite the array of studies demonstrating that mechanization is often unprofitable (Binswanger, 1978), medium- and large-scale farmers in South Asia continued their shift to tractor use, and farmers in Southeast Asia introduced diverse types of powered equipment while successful industrialization policies drove up rural and urban wage rates (Balis, 1978; Sarma, 1982). In Asia, policymakers generally regarded the short-term impact of mechanization as less relevant and important. They chose to **take a strategic perspective of mechanization, viewing it as part of a broad-based economic development strategy aimed at economic growth and agro-industrialization**. To this end, governments both stimulated and responded to trends by adopting favourable tax and subsidy policies and supporting nascent input supply industries. At times, policymakers ignored the short-term social costs, and looked instead to the likelihood of increased labour demands following intensification. The result was a dramatic transformation of agriculture over a 50-year period. Despite inefficiencies and undesirable distributional impacts during this process, the transformation of agriculture throughout Asia – in which mechanization was an integral part – is viewed from the African perspective as a success story in terms of productivity gains and export competitiveness.

3 Mechanization is a complex and dynamic process that cannot be appraised only from the standpoint of factor substitution or net contribution to production (Binswanger, 1986). It is important to **recognize that the mechanization process is characterized by fundamental interlinked changes in the structure of the agricultural sector, in the nature and performance of agricultural support services, and in the livelihood strategies of farmers and agriprocessors**. The changes do not necessarily take place simultaneously and do not impact all people in the same way (White, 2000).

4 While political leaders and governments in Africa and Asia have actively promoted agricultural mechanization, its successful development does not depend on the direct involvement of governments in machinery supply, development and financing, or on the provision of mechanization hire services. On the contrary, agricultural mechanization has proved successful where essential supply systems and support services have developed in response to economic demand – in most cases, starting with support services targeting medium- and large-scale farmers. For this reason, decision makers need to **focus on the long-term developmental dimensions of building public- and private-sector institutions and services to support mechanization**, rather than attempt to accelerate short-term technology transfer rates through direct government involvement in machinery supply and services.

2.6. Philosophical vision

Africa still has a long way to go as far as agricultural mechanization is concerned. The region lags behind other developing countries in the use of mechanical power in agriculture (**Figure 8** and **Figure 10**). In the 1960s, statistics on the use of mechanical technologies for Africa and other countries in the developing world (Brazil, China, India and Thailand) were comparable. During the 1980s and 1990s, however, other countries moved so far ahead that by 2000 there were more 4-wheel tractors in use in Thailand alone than in the whole of Africa.

The widespread introduction of agricultural mechanization technologies in the developing world, where there is surplus labour and wages are low, has elicited different reactions from experts in the development community and from agricultural development stakeholders (FAO, 1975, 1981, 2008; Eicher and Baker, 1982; Gemmill and Eicher, 1973). In Africa, the policies and strategies adopted between 1950 and 2015 were subject to massive influences. During the 1970s and 1980s, when prescribing agricultural mechanization policies and strategies – in particular, with regard

Figure 10. Number of 4WTs in use in different RECs

Source: FAO, 2008.

to technology choices for developing countries – policymakers were dealing with different groups of experts holding **four contrasting viewpoints**:

1. **Advanced technologies (mostly internal combustion engines and tractors) should not be widely adopted in agricultural mechanization.**

   i. Mechanically powered agricultural mechanization often leads to displacement of labour and, hence, increased unemployment. Therefore, such technologies are inappropriate in developing countries characterized by an abundance of unemployed labour and low wages.

   ii. Unemployment leads to other socio-economic problems: rural–urban migration; inequitable distribution of wealth and, in many cases, an increase in absolute poverty; and balance-of-payment problems due to the need to import machinery, fuel and sometimes also technical assistance to manage them.

   iii. Adoption of mechanical technologies does not necessarily lead to increased yields or improved land productivity; indeed, biochemical inputs alone may achieve equal or even higher increments.

   iv. A combination of improved hand tools and/or draught animal technologies and biochemical inputs (seeds, fertilizers etc.) is often advocated.

   v. Hand tools and animal-powered technologies are considered substitutes for mechanical technologies in the agriculture of developing countries, especially the smallholder sector.

2. **Use of improved hand tools and animal-powered technologies is a transitional step between the most rudimentary stage in technological development (entire reliance on human muscle power) and advanced technologies (reliance on tractors and other machinery).**

   i. The course of technological development is evolutionary and it is each country's prerogative to aspire to a higher technological plateau.

   ii. Modernity is a legitimate goal, but care is required to ensure that technological, cultural and socio-economic development work together to ensure a well-balanced society.

   iii. Rapid mechanization policies are not advocated, particularly those aimed at the ubiquitous adoption of mechanical technologies by small- and medium-scale farmers.

   iv. Improved hand tools and draught animal power are as "good" and as "economical" as mechanical technologies.

3. **Intermediate technologies – improved hand tools and draught animal technology – are a "delaying" tactic, since alternatives to modern mechanical technologies are not available and accessible.**

   i. Alternatives to mechanical technologies are neither practical nor efficient and are incomparable in terms of economics and productivity.

   ii. The failure of mechanical technologies in developing countries has, in most cases, been due to poor planning, management and supervision.

   iii. Agricultural production is a thermodynamic process (a minimum level of horsepower per hectare is advocated).

   iv. Food and crop production demand require efficiency, maximizing land and labour productivity and resulting in surpluses.

   v. The perception of agriculture in developing countries as a "gigantic programme" to relieve unemployment results in continuous hunger and starvation.

   vi. The energy (from fossil fuels) required to operate tractors and other machinery – even in advanced countries– is less than 5 percent of the total commercial energy used along the value chain and is far less than the energy consumed for other biochemical inputs (Fluck and Baird, 1979; Gohlich, 1984; Stanhill, 1984; Fluck, 1992).

4. **A compromise is required between 2) and 3) above.**

   i. Improved hand tools and draught animal technologies are eighteenth-century technologies, while the modern tractor and combine are twenty-first-century technologies.

   ii. Development of appropriate mechanical technologies is key: multipurpose, affordable for small- and medium-scale farmers, and suited to the farming systems of the developing world.

   iii. The past 50 years have seen the design of "intermediate," "appropriate," "mini-" and "micro-" tractors for use by farmers in developing countries.

   iv. Research and development has been conducted mainly on the Asian subcontinent (e.g. in the Philippines and Thailand) and in more advanced countries in Europe and Africa (e.g. in the case of Tinkabi and Kabanyolo tractors).

2.6. Philosophical vision

Numerous research papers published over the past 50 years agreed with one or with a combination of the above views (FAO, 1975, 1981, 2008, 2013a; FAO-RAP, 2014; Anderson and Grove, eds, 1987). They have often been used as a basis for blanket policy and strategy prescriptions regarding choice of agricultural mechanization technologies. In Asia, policymakers tended to choose option 2) in the short term and option 3) in the medium to long term (FAO, 2008, 2015; FAO-RAP, 2014; Singh, 2013). In Africa, on the other hand, all four options were tested during the six decades from 1950 to 2010. In some countries, policymakers even shifted from one option to another and back again within the same decade (Eicher and Baker, 1982; FAO, 2008).

With the Malabo Declaration in 2014 and the adoption of Agenda 2063 in 2015 by the AU Heads of State and Government, it appears that **Africa has settled on option 3) for the medium to long term**; planned measures include the specific objective of banishing the hand hoe from agriculture by 2025. The overarching goal of the FAO/AUC initiative on developing the SAMA Framework is to provide a menu of options to enable Africa to achieve the agricultural mechanization objectives approved by the AU Heads of State and Government at their 23rd and 24th Summits and as stipulated in the Malabo Declaration and Agenda 2063 Aspirations.

Maintenance of agricultural machinery is important for sustaining its quality.

PHOTOGRAPHY: © FAO/ A. BERRY

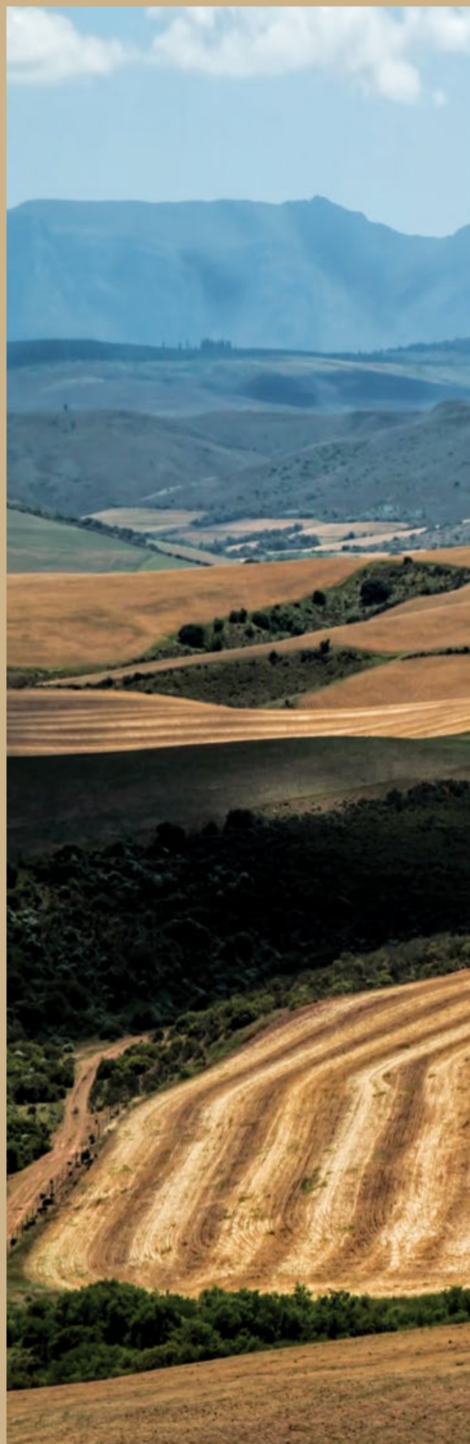
2.7. Conclusion

In a globalized world with free flow of information, many Africans can observe the progress in Asia and other parts of the world where the mechanization of agriculture has occurred over the past six decades. African presidents and ministers have visited India, the People's Republic of China, Thailand and other Asian countries; they have seen how mechanization took place in western countries in the first half of the twentieth century and again in Asia and Latin America in the second half. For this reason, they have difficulty comprehending advice to adopt a **different and untested route in agricultural mechanization**.

For this and other reasons, the Chairperson of the AUC called for the hand hoe to be sent to the museum within the next decade, liberating the African farmer from the drudgery associated with primary land preparation using this hand-tool technology. Both the Malabo Declaration and Agenda 2063 are very clear on the direction the region should follow in the mechanization of agriculture: **banish the hand hoe by 2025**. To achieve this goal, **countries in Africa must transform their agriculture**.

This **framework provides a menu of the options available** to countries in Africa for the development of sustainable agricultural mechanization on the continent. It is the first stage and sets the scene for a more informed and objective discourse along the route towards sustainable agricultural mechanization during the first half of the twenty-first century.

3. Key issues and constraints to sustainable agricultural mechanization in Africa



PHOTOGRAPHY: CREATIVE COMMONS CC0

Lessons learned from the experience of agricultural mechanization in the second half of the twentieth century indicate the need to transform and adjust the farming system in order to sustainably utilize the main indivisible mechanical technologies available. Divisible biochemical technologies (HYVs, fertilizers and plant protection chemicals) can be adjusted to fit the prevailing farming system, while indivisible and lumpy technologies (tractors and combine harvesters) cannot. Moreover, the private sector tends to dominate manufacturing, distribution and on-farm utilization of equipment, and these technologies are, therefore, only available to farmers through commercially viable enterprises. Efforts to develop and manufacture special-purpose tractors and implements designed for small-scale famers in the region (e.g. Tinkabi and Kabanyolo tractors, and ICRISAT's multipurpose animal-drawn tool carrier) or to set up government-operated tractor hire schemes proved unsustainable and were abandoned after a few years of trials (Holtkamp, 1988, 1989; Starkey, 1988a). The **farming system must first be transformed to enable the efficient and effective utilization of available technologies**.

This chapter reviews the **key issues of and likely constraints to Sustainable Agricultural Mechanization in Africa**. The review focuses on sub-Saharan Africa and has been informed by the lessons of the past 50 years in Africa and other parts of the world. It includes key issues relating to the types of farmers (what they produce) and supporting farming enterprises that are able to adopt the new technologies or offer mechanization services to small-scale farmers at competitive and affordable rates. It examines the demographic trends of urbanization, ageing rural population, feminization of farming and the overall likely impact of all these on mechanization and the agrifood value chains; the manufacturing, importation and distribution of agricultural machinery and implements; and the role of public- and private-sector institutions in research and development and in testing and standards. The review also covers the bigger issues of **sustainability – from commercial, socio-economic and environmental perspectives**.

The farming system must first be transformed to enable the efficient and effective utilization of available technologies.

3.1. Farm power as the key input in agricultural mechanization

Based on the experiences of the Asia and Pacific region (Rijk, 1983; Singh, 2013; Wang, 2013; FAO, 2015) and the developed world, including the United States of America (Promsberger, 1976; White, 2000, 2001) and Europe (Esmay and Faidley, 1972; Burch, 1987; Gibb, 1988), farm power (whether animate from human muscles or draft animals, or mechanical from internal combustion engines and/or electrical motors) and implements have been considered as two separate issues. However, in the quest for sustainability, there is a growing tendency to mix the two, further complicating the debate on mechanization in Africa. All other regions of the world tackled first the farm power constraint, using whatever implements were available. This is consistent with what has worked well in Africa in grain milling, and it is important to draw appropriate lessons from that experience. It is also consistent with the decision of the AU Heads of State and Government to prioritize the banishment of the hand hoe from African agriculture by 2025, as stated in the Malabo Declaration and Agenda 2063.

It is also important to note that the **power source is often the most expensive part of any investment or input in agricultural mechanization**. This is the case for the wages of the labourers hired to undertake primary tillage vs the price of the hand hoe, the cost of draft animals vs the price of the plough or cart, or the expense of a tractor vs the price of the disc/mouldboard plough or harrow. In most instances, the implement costs a fraction of the power source (in combine harvesting, the power source and implement/equipment are integrated – an issue considered later). Among its functions, farm power frees farm workers and farmers from the drudgery associated with performing energy-intensive operations that previously relied entirely on human muscle power, such as land preparation, planting, weeding and post-harvest operations (e.g. shelling and milling of grains).

Small-scale farmers appear to be ready to procure services from enterprises that supply farm power for hire, provided it is offered at affordable prices and on a timely basis. The issue then becomes which power source is affordable and readily available on a timely and sustainable basis. **Human muscle power** has typically come from family members, hired labourers from within the locality or migrant labour from nearby districts and regions. However, socio-economic developments – such as availability of social services (e.g. universal primary education), migration of the rural population to urban areas, ageing rural populations and new economic opportunities in regions from where migrant workers originated – have reduced the availability of labour for arduous field tasks even at very basic subsistence levels. The urban population is growing at an increasing rate and is projected to reach 50 percent of the total population before 2035 in most countries of Africa, further compounding the situation.

Over the past 70 years, the provision and use of non-human-muscle sources of farm power (e.g. draught animal power [DAP] and tractors) has dominated the agricultural mechanization debate in Africa and in developing countries in general. The key question for government- and donor-financed programmes and for initiatives financed by the private sector was always how to provide farm power in the most economical and sustainable way rather than which implements are to be drawn or driven by the power source. However, this began to change with the advent of the conservation agriculture (CA) movement and its advocacy of minimum tillage techniques. The primary challenge now is **how to achieve efficient and sustainable utilization of the power source** irrespective of whether it is pulling a disc plough, a minimum tillage implement or more modern seeding technologies. Very few areas have rental markets for the hire of implements, even in regions where there are far fewer implements than tractors available (FAO, 2008; Mrema, 2016).

3.2. Hand-tool technology and human muscle power

Agriculture in Africa is still done using hand-tool technology; it relies almost entirely on human muscle power on about 60–80 percent of cultivated land (**Figure 2**). From an ergonomic point of view, land preparation tasks are the most arduous, demanding massive power input from human muscles. Primary land preparation by hand hoeing is the most difficult task in the tropics, demanding 8–10 kcal/min. (Passmore and Durnin, 1955; Stout, 1979; Fluck and Baird, 1979; Nag and Pradhan, 1992). Planting and weeding demand about 25–40 percent of the power required for hand hoeing. When performing a task, the rate at which energy is demanded is critically important (Boshoff and Minto, 1974; Mrema, 1984; Nwuba and Kaul, 1986). Therefore, engineering design has focused on decreasing the rate of energy demand for operating a piece of equipment, aiming for the ergonomically tolerable level of 3 kcal/min. (**Box 3**).

This provides the rationale for the decision by African leaders to banish the hand hoe from farming (as declared in both Agenda 2063 and the Malabo Declaration). One could also argue that the slash-and-burn system of cultivation has been a response by the African farmer to the drudgery associated with primary tillage, as it reduces the energy required for land preparation from 8–10 kcal/min. with a hand hoe to a more tolerable 3–5 kcal/min. for slashing.

Liberation of the African farmer from the drudgery associated with use of the hand hoe as a basic tool in agriculture is high priority: it is to be achieved by 2025 and has the strong support of African leaders and politicians (AUC, 2016). This is consistent with the individual strategies of several countries to significantly reduce by 2035 the area tilled by the hand hoe.

A woman tends to her family's land in Zimbabwe.

PHOTOGRAPHY: UN PHOTO/MILTON GRANT

Box 3. Drudgery in agricultural tasks: hand-tool technology and human muscle power

The time taken to perform a particular task is linked to the energy needed for that task. From an ergonomic perspective, the rate at which the energy is required is critical (Boshoff and Minto, 1974; Mrema, 1984; Nwuba and Kaul, 1986). Engineering design has focused on reducing the rate of energy demand. Ideally, the **rate of energy required to operate a piece of equipment should not exceed the tolerable level of 3 kcal/min**. For human-powered equipment, this level of energy demand is preferable, even when there is no significant increase in work output per unit time (Boshoff and Minto, 1974; Mrema, 1984).

It is no wonder that many "appropriate" or "intermediate" technologies designed during the 1970s and 1980s and powered entirely by human muscles were not adopted by farmers despite the improved work output. If the equipment does not offer noticeable improvement in the rate of energy demanded from the operator or farmer, it is unlikely to be favourably received (Boshoff and Minto, 1974; Makhijani and Poole, 1975; Mrema, 1984; Stanhill, 1984; Fluck, 1984). It is for this reason that agricultural mechanization aimed at liberating the African farmer from the drudgery associated with the hand hoe has received the strong support of African leaders and politicians (Eicher and Baker 1982; FAO, 2008).

Unlike Asia, where DAP has been used for centuries, Africa is the only region of the world where difficult and arduous tasks, such as primary tillage, are performed entirely with human muscle power on over 60 percent of cultivated land. Indeed, a prison sentence including "hard labour" entails hand hoeing, and is regarded by the judicial system in most of the region as a deserving punishment for the worst crimes. Furthermore, human-powered farming is even one of Adam's punishments for the theft of the fruit of the tree of knowledge: "Accursed is the ground because of you; through suffering shall you eat of it all the days of your life… By sweat of your brow shall you get bread to eat." (Stanhill, 1984)

Other regions of the world moved on long ago, adopting draft animals or machines to free their farmers from the punishment of tilling the land by hand hoeing. **The time has come to free the African farmer from this punishment – at least for basic land preparation.**

3.3. Draft animal power and technologies

While draft animal power (DAP) is a potential intermediate source, its development and dissemination have encountered obstacles in many parts of Africa (Kjoerby, 1983; Winrock and ILCA, 1992; Mrema and Mrema; 1993). Draft animal technology (DAT) has been promoted in the region for over a century, but its adoption has been confined largely to drier areas characterized by a tradition of both livestock and crop husbandry. In these areas, farmers use their animals also for tillage and transport services.

Since the 1950s, cotton cultivation has played a significant role in advancing the adoption of draft animal mechanization. In many countries in Africa, cotton is a cash crop with numerous companies and cooperatives active in marketing and linked to global textile chains. The ubiquitous dissemination and adoption of DAT is hampered not only by the lack of a livestock husbandry tradition among farmers, but also by the presence of the tsetse fly in many parts of the region. DAT is likely to remain concentrated in the drier regions for as long as the prevailing socio-economic conditions remain (**Box 4**).

The heavy soils in many parts of Africa require the use of two to three pairs of oxen, resulting in high investment costs and complicating the training required. In the long term, **DAT faces challenges**, including the growing demand for livestock products and the recurrent costs associated with keeping livestock for draft purposes (e.g. human resources for herding and shortage of grazing land) (Box 4). The demand for livestock products – even donkey meat – is rising throughout Africa; indeed, there are now several abbatoirs in the region for processing donkey meat for export.

Despite its dissemination by NGOs and others, **DAP is regarded by some as outdated**. This perception is heightened by the recent unprecedented pace of technological transformation in other sectors, such as information and communications technology ICT (mobile telephones) and transportation (2- and 3-wheel motorcycles and pickups). The ubiquitous expansion of mechanically powered machinery and equipment, including second-hand vehicles and motorcycles, has created a vast institutional and physical infrastructure for operating and maintaining motorized equipment, which did not exist in 1960s–1980s. **DAT is thus perceived as an obsolete technology and does not appeal to the youth in the twenty-first century.**

Box 4. Leapfrogging the draft animal power stage

In other regions of the world (Europe, Asia, North and South America, and the Near East), **agricultural mechanization evolved through three stages:**

1. hand-tool technology;
2. draft animal technology (DAT); and
3. mechanical technologies.

In most cases, the intermediate stage – DAT – lasted centuries over several generations and farmers traditionally kept livestock both for draft power and for other products (meat, milk etc.). It was expected that Africa too would evolve through the three stages. This has not been the case, due largely to the fact that in much of Africa, those who own livestock suitable for draft purposes are essentially pastoralists and are typically not involved in crop production (e.g. the Maasai in Tanzania and Kenya). In addition, almost two-thirds of the land area of Africa is infested with the tsetse fly, which makes it difficult to keep livestock. Unfortunately, the tsetse-infested areas are located in the humid tropics where there are large tracts of uncultivated land that are potentially suited for crop production. Rendering these areas tsetse free involves massive land clearing, which inevitably leads to severe environmental degradation (Ford, 1971; Tiffen, Mortimore and Gichuki, 1994).

The key question – whether the agricultural mechanization strategy for such areas in Africa should aim to leapfrog the DAT stage – elicits sometimes diametrically opposite views among experts (Kline et al., 1969; FAO, 1975, 2008; Pingali, Bigot and Binswanger, 1987; Den Hertog and van Huis, 1992; Panin, 1994; Mrema and Mrema, 1993; Starkey, ed., 1998).

There are those who advocate the continued promotion of DAT, ostensibly due to the perception that it is a renewable source of power/energy and more environmentally friendly (Dikshit and Birthal, 2010). The veracity of these assertions needs to be scientifically and objectively assessed. As Adams (1988) noted, claims that DAT could be more energy efficient than mechanical technologies defy the basic laws of physics.

After almost two centuries of promoting DAT in Africa, with its adoption limited to the drier areas and to farmers with a tradition of livestock and crop husbandry, **draft power is a decreasing priority for various reasons:**

1. rapid urbanization;
2. rising living standards; and
3. growing demand for livestock products.

Moreover, DAT has an image problem, especially for youth in the twenty-first century: as one African president recently remarked, “DAT is a Before Christ technology (BCT), and we are in the twenty-first century!” **The time may have come to consider leapfrogging this intermediary stage of mechanization.**

3.4. Mechanical power

Four types of mechanical power technology are used in agriculture in Africa with varying degrees of success:

1. Tractors:

    i. traditional two-axle 4WT in either the two-wheel drive (2WD) or four-wheel drive (4WD) versions;
    ii. four-wheel low-horsepower tractors – specially designed for the developing world in the 1960s to 1980s (e.g. Kabanyolo and Tinkabi); and
    iii. power tiller or 2WT – a single-axle tractor developed initially for cultivation in irrigated areas in Asia.

2. Motorized pumps and other water-lifting devices.

3. Motorized harvesting and post-harvest processing equipment (e.g. combine harvesters, threshers and shellers).

4. Grain-milling equipment (e.g. hammer mills, disc attrition and roller mills).

Tractor hire services (THS) have been operated in the region, involving both the traditional tractor (4WT) and – more recently and to a lesser degree – the power tiller (2WT). Some tractors were specially designed for agriculture in the developing world, such as the Swaziland-designed and manufactured Tinkabi tractor, of which thousands were exported to countries in Southern Africa during the 1970s and 1980s. However, the tractors failed and experimentation with this type of farm power stopped in the mid-1990s (Holtkamp, 1989, 1991; Dihenga and Simalenga, 1989).

On the other hand, a case of successful development and dissemination of mechanical technologies in Africa is the hammer mill used for grain milling; lessons on operating machinery hire services can be learned from this.

The **tractor** (4WT and 2WT) and the **grain milling hammer mill** represent the two main types of agricultural machinery technology disseminated (with varying degrees of success) on a relatively large scale over the past seven decades in Africa. However, these technologies are expensive and unaffordable for most farmers, and sustainable rental mechanisms must be established so that farmers – in particular small-scale farmers – can have access to these services. The THS most widely on offer are primary land preparation and transportation; the most important implements are, therefore, the disc plough, harrow and trailer. The **establishment of commercially sustainable agricultural machinery hire services is high priority** in any strategy for sustainable agricultural mechanization.

The establishment of commercially sustainable agricultural machinery hire services is high priority in any strategy for sustainable agricultural mechanization.

There has been much recent interest in **2WT** as a solution to the mechanization problem of Africa. The success of the 2WT in the mechanization of rice-based farming systems in Asia has catalyzed efforts to introduce it to similar systems in the Africa region. New suppliers from Asia have emerged and established supply chains for 2WTs and their accessories and spare parts. The technology has been adopted in a number of districts in different countries, largely in rice-based irrigated farming systems. Other initiatives to introduce the 2WT in non-rice systems are currently being implemented by the Australian-funded regional project, Farm Mechanization and Conservation Agriculture for Sustainable Intensification (FACASI), managed by the International Maize and Wheat Improvement Center (CIMMYT). The FACASI project is being implemented in Ethiopia, Kenya, the United Republic of Tanzania and Zimbabwe, mostly in maize and grain legume farming systems (FACASI, 2014, 2015).

There are many barriers to the adoption of agricultural technologies. As noted by the Agricultural Technology Adoption Initiative (ATAI) in its proposed framework for analysing market inefficiencies which hamper profitability of farms and agricultural mechanization, these barriers include:

1. externalities;
2. input and output market inefficiencies;
3. land market inefficiencies;
4. labour market inefficiencies;
5. credit market inefficiencies;
6. risk market inefficiencies; and
7. informational inefficiencies.

ATAI noted that targeting a single constraint while ignoring the others could prove ineffective; on the other hand, attempts to address all seven simultaneously may be neither cost-effective nor necessary (**Box 5**).

Box 5. Fertile ground for innovation

New technologies such as drones can transform the agricultural landscape.

PHOTOGRAPHY: CREATIVE COMMONS CC0

As seen in other sectors, modern business practices have allowed Africa to leapfrog certain technologies and meet local needs with innovative and often more sustainable solutions. There is great potential for innovation and disruption in African agriculture, particularly as mobile technologies revolutionize access to information and services.

New endeavours take advantage of a situation characterized by:

1. business opportunities arising from agricultural needs;
2. increased access to mobile technologies; and
3. the rise in impact investment in the shifting financial landscape.

New businesses and initiatives are developing across the continent: from solutions that increase smallholders' accessibility to relevant agricultural information, to platforms that make machinery (e.g. tractors) more affordable, accessible and even shareable.

Examples of innovative business propositions emerging in the space of agricultural mechanization:

[2] The inclusion of these business initiatives in Box 5 does not imply that they are recommended or endorsed by FAO or the AUC.

	Brief description	Impact relevant for SAMA
Initiative/ company **AgroSpaces** *Country* **Cameroon**	• Provides a platform for improvement of local agriculture and empowerment of smallholder farmers. • Provides products that ensure sustainable food security and agricultural growth. • Offers services including real-time commodity prices, weather forecast and farming advice. • Provides a platform for farmers to sell their products. The service is provided via mobile phone SMS.	• Increases revenue for farmers as price asymmetries are reduced. • Provides opportunity to use innovative technologies to share information to support agricultural production. • Connects farmers with markets to sell their crops profitably.
Initiative/ company **Farmerline** *Country* **Ghana**	• Aims to transform smallholder farmers into successful entrepreneurs through access to informal inputs and resources to increase productivity. • Works with all partners along the value chain to support farmers to make smart and fair decisions. • Provides real-time agricultural education using mobile phones: weather forecast; good agricultural practice (GAP); and market information, including prices, connecting farmers to markets, farm inputs, solar energy, and financial services.	• Increases knowledge and efficiencies among farmers. • Provides innovative ways of accessing information and inputs services to increase productivity among smallholder farmers.
Initiative/ company **HelloTractor** *Country* **Nigeria**	• Connects farmers to tractors and tractor owners to farmers in need of their services. Offers services using small but versatile tractors suitable for smallholder farmers. • Utilizes tractors fitted with all main implements and GPS tracking system enabling remote smart tractor monitoring, tracking and service booking. • Offers technical support for booking and provides aftersales services for tractor owners.	• Increases access to machinery tailored for smallholder farmers. • Increases smallholders' access to mechanization through an innovative hire service arrangement.
Initiative/ company **SunCulture** *Country* **Kenya**	• Provides support to farmers through an agrosolar irrigation kit that combines a cost-effective solar pump with a high-efficiency drip irrigation system. • Aims to make it cheaper and easier for farmers to grow high-quality crops, such as fruits and vegetables. • Allows farmers to grow more crops with less water.	• Makes irrigation affordable even for smallholder farmers. • Enhances the efficiency and sustainability of the crop production system.

3.5. Agricultural implements and sustainability

During the second half of the twentieth century, the debate on agricultural mechanization in Asia and Africa focused on the source of farm power and its use by small-scale farmers. The impact of the implements hitched to the power sources, in particular those used for land preparation and crop husbandry, was of less concern to most scientists and development practitioners. Land preparation using animals had been practised for centuries in Asia and also in some parts of Africa, particularly in South Africa, Ethiopia and North Africa. The designs of tillage implements pulled by draft animals were the same as those used on tractors – the only difference was that there were more tines/ploughs on those hitched to tractors.

Mechanization studies in Asia and in Africa, in the 1960s and 1970s were not very concerned with the impacts of tillage implements being hitched to draft animals and/or tractors. Research on tillage was more focused on the need to reduce draft power requirements and on the versatility of the implements for multipurpose use, such as ploughing, harrowing, planting and weeding (Lal, ed., 1998; Starkey, 1986). Sustainability was analysed from the perspective of the consequences and impact of biochemical inputs and the power source, rather than on the basis of the types of implements used for land preparation and crop husbandry (Randhawa and Abrol, 1999).

On the other hand, mechanized tillage was considered a major contributor to the dust bowls of the United States of America in the mid-1930s, which led to the establishment of the Soil Conservation Service (SCS) and a major long-term research programme focused on tillage implements and practices. It was in this context that minimum tillage practices and CA gained traction in North and South America (Troeh, Hobbs and Donahue, 1980; Lal, ed., 1998; Friedrich, 2013). The environmental impact of mechanization, especially of tillage implements and practices, became a major concern in Asia and Africa only in the late 1990s and at the beginning of the twenty-first century. It continues to be a feature in the planning of processes for sustainable agricultural mechanization strategies (Jacks, 1942; Anderson, 1992) (**Box 6**).

Box 6. Conservation agriculture (CA)

Source: www.fao.org/conservation-agriculture

Conservation agriculture (CA) is an approach to managing agro-ecosystems for improved and sustained productivity, increased profits and food security, while preserving and enhancing the resource base and the environment (Friedrich, 2013). CA is characterized by **three linked principles**:

1. Continuous zero or minimal mechanical soil disturbance (i.e. no-till and direct sowing or broadcasting of crop seeds, and direct placing of planting material in the soil; minimum soil disturbance from cultivation, harvest operations or farm traffic; in extreme cases, limited strip tillage).
2. Permanent organic matter cover of the soil, especially by crop residues, crops and cover crops.
3. Diversification of crop species grown in sequence or association through rotation, or, in the case of perennial crops, association of plants, including a balanced mix of legume and non-legume crops.

CA principles are universally applicable to all agricultural landscapes and land uses with locally adapted practices. CA enhances biodiversity and natural biological processes above and below the ground surface. Soil interventions, such as mechanical tillage, are reduced to an absolute minimum or avoided, and external inputs, such as agrochemicals and plant nutrients of mineral or organic origin, are applied optimally, in ways and quantities that do not interfere with or disrupt the biological processes (Baker et al., 2007; Tandon, 2007).

In 2010, CA was applied on about 117 million ha around the world and some farms had been practising it for over 30 years (Friedrich, 2013). Over the past 20 years, the global rate of transformation from tillage-based farming to CA has seen an annual increase of 5.3 million ha, rising in the last decade to 6 million ha. CA adoption levels in Argentina, Brazil and Paraguay have reached 70–75 percent of cultivated land, and in Western Australia 90 percent. Adoption in the United States of America – the first country to have significant no-tillage farming – remains low at 25 percent, reportedly due to non-supportive policies (Friedrich, 2013). The same applies in Europe, where only a few countries have adopted CA in extensive areas. In Asia, there has been a significant increase in the adoption of CA in Kazakhstan (> 4 million ha in 2008–2012) and in China (1.3 million ha).

The adoption of CA in **Asia** requires a shift from conventional tillage (CT) practices as well as investment in new implements and equipment; it also entails a steep learning curve in the use of new inputs like herbicides (Tandon, 2007). While the agricultural machinery is not yet manufactured by local companies in Asia, some pieces of equipment are nevertheless beginning to enter the market. CA has to date been developed and perfected in North and South America and Australia by large-scale farmers who invariably use large tractors; this presents an additional challenge for its application in Asia. Furthermore, given the dominance of paddy cultivation in Asia and the Pacific, together with land scarcity in many parts of the region, the third principle of CA – crop rotation and fallowing of land – is difficult to apply.

In **Africa**, CA is implemented by large-scale farmers in Southern Africa (Table 1). While some traditional farming techniques adopted by small-scale farmers in parts of the region (e.g. highlands of Eastern Africa) may be considered CA, the dissemination and adoption of the CA technology is still at a very early stage. The adoption of CA in the region may lead to the introduction and increased use of herbicides, which has its consequences (Rowland, 1974, 1994; Anderson and Grove, 1987; Kayombo and Mrema, 1998; Friedrich, 2013; ACT, 2017).

According to the African Conservation Tillage Network (ACT), CA practices in Africa have been adopted predominantly on large-scale farms in South Africa, Zambia and Zimbabwe, using technologies similar to those developed for North America and Australia (ACT, 2017) (**Table 1**). In recent years, donor-funded projects have promoted the adoption of CA on small-scale farms in these countries. Nevertheless, the percentage of cultivated land under CA is still very small compared with that under CT (ACT, 2017; Friedrich, 2013). Given the dominance of hand-tool technology in land preparation and crop husbandry practices, the promotion of CA has at times been linked to strategies for overall agricultural mechanization and schemes to tackle the farm power problem (FAO, 2008).

The primary challenge of mechanization in Africa is the need to increase the farm power available in order to relieve the African farmer of the drudgery associated with hand hoeing. **CA focuses on the second challenge of mechanization: converting CT implements and crop husbandry practices to CA**. It is important that these problems are handled in the right sequence. Today, CT implements (e.g. disc and mouldboard ploughs and harrows) are used on most of the cultivated land in the region where mechanical technologies have been adopted. Most of the land – especially that cultivated by small-scale farmers – has not been completely de-stumped, hampering the use of other types of implements.


View of South African wheat fields with contour lines.

PHOTOGRAPHY: P. C. ZIETSMAN

Table 1. Cropland area under conservation agriculture (CA) in Africa (December 2017)

Source: ACT, 2017, in collaboration with national ministries of agriculture, NGOs, research institutions and FAO (AQUASTAT).

Country	CA Cropland Area ('000 ha)	Small-scale <5 ha ('000 ha)	Medium-scale 5-100 ha ('000 ha)	Large-scale >100 ha ('000 ha)	As a % of total CA area in Africa	Cropland Area* ('000 ha)	CA area as % of Total Cropland	Year of CA data
Algeria	5.6		5.6		0.41	7 469	0.07	2016
Ghana	30	30			2.2	4 700	0.64	2008
Kenya	33.1	17.7		15.4	2.42	5 800	0.57	2015
Lesotho	2	2			0.15	272	0.73	2016
Madagascar	9	9			0.66	3 500	0.26	2016
Malawi	210.8	210.8			15.43	3 800	5.55	2016
Morocco	6		6		0.44	8 130	0.07	2016
Mozambique	152	152			11.13	5 650	2.69	2011
Namimbia	0.3	0.3			0.02	800	0.04	2011
South Africa	437.5	1.5		436	32.03	12 500	3.5	2015
Sudan	10		10		0.73	19 823	0.05	2009
Swaziland	1.3	1.3			0.1	175	0.74	2015
Tunisia	12		12		0.88	2 900	0.41	2016
Uganda	7.8	5.8		2	0.57	6 900	0.11	2016
United Republic of Tanzania	32.6	11		21.6	2.39	13 500	0.24	2016
Zambia	316	280		36	23.13	3 800	8.32	2016
Zimbabwe	100	90		10	7.32	4 000	2.50	2016
Total	**1 366.1**	**811.4**	**33.6**	**521**	**100**	**103 719**	**1.32**	

* Source: Arable land area from AQUASTAT at http://www.fao.org/nr/water/aquastat/data/query/index.html.lang=en

3.6. Importance of commercial farmers for the sustainability of mechanization

The agricultural sector in many countries in Africa is largely dualistic, with medium- and large-scale farms (MSFs and LSFs) coexisting with small-scale farms (SSFs). The MSF–LSF subsector produces cash and industrial crops, such as coffee, sisal, tobacco, pyrethrum, flowers, horticultural products, tea, maize, rice, wheat, dairy, beef and sugar cane (Mayne, 1955; Eicher and Baker, 1982; Anderson, 1992). At the time of independence in the 1960s, the MSF–LSF subsector was dominated by settler farmers and transnational corporations. After independence, during the 1970s and 1980s, a large number of government-owned state farms were established in many countries; however, the private sector remained the dominant force. Following the economic structural adjustment programmes of the 1990s, most state farms were privatized. The LSFs are highly mechanized and in most countries they own and operate a significant proportion of the 4WT fleet at any one time.

From a mechanization perspective, it is possible to **group farm power typologies according to the following farmer categories:**

1. Subsistence farmers (< 2 ha) rely on family labour and hand-tool technology for all field land preparation and crop husbandry tasks (e.g. primary tillage/hoeing, planting, weeding, harvesting, post-harvest processing, shelling and threshing). They may hire tractors or DAP for land preparation to break the hardpan if they have off-farm income and if the hiring cost is affordable.

2. Small-scale commercial farmers (2–10 ha) normally use DAP (where available – owned/hired) or tractors (2WT owned/hired and/or 4WT hired) for land preparation. Other tasks may be mechanized (e.g. planting for maize, harvesting for paddy, and shelling and threshing for maize and paddy). A few small-scale commercial farmers might own a second-hand 4WT, in which case they offer THS to other commercial and subsistence farmers in order to achieve effective and commercial utilization of their machinery.

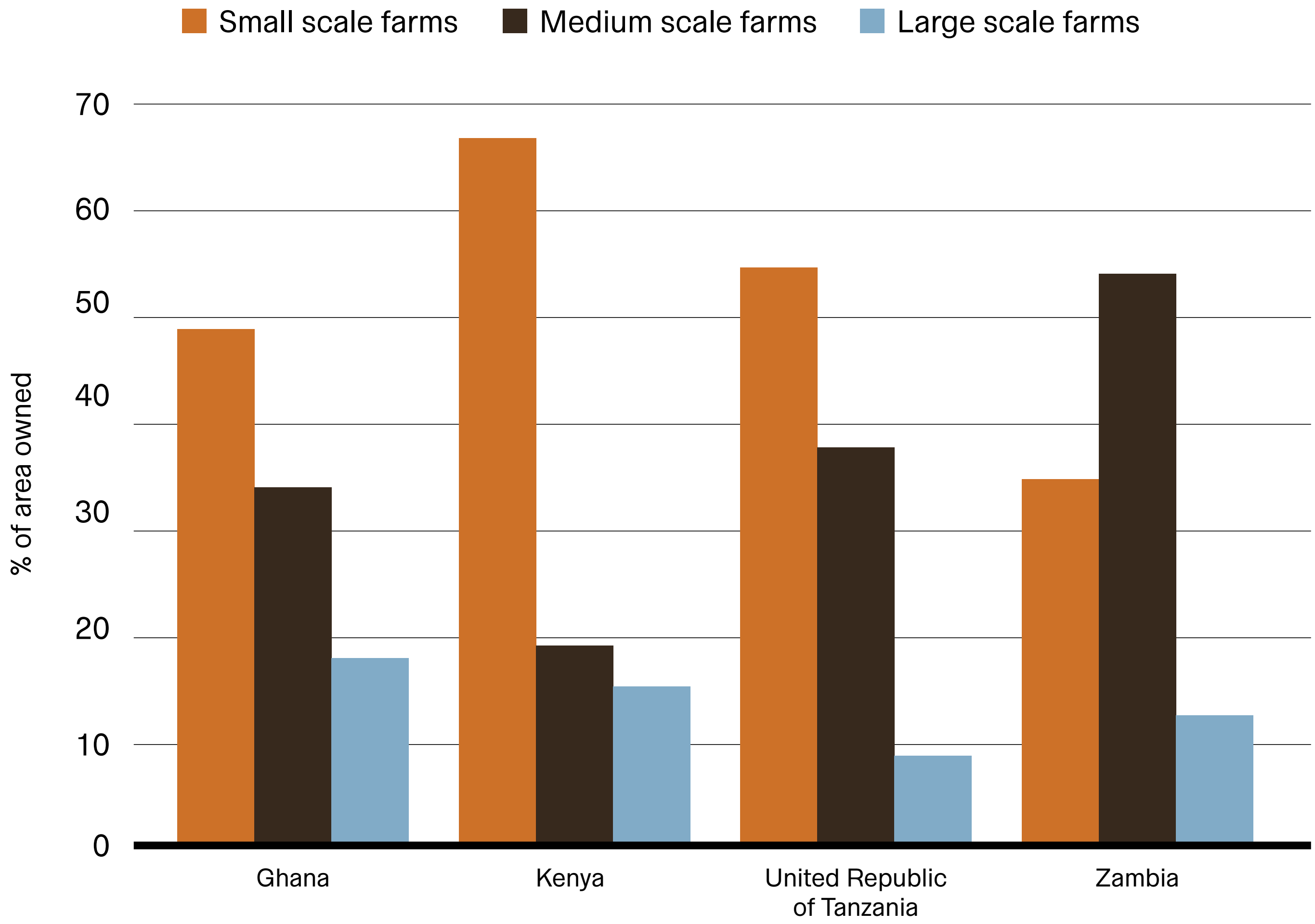
3. Medium-scale farmers (10–100 ha) typically have their own 2WT bought new and/or 4WT bought new or second-hand as well as an assortment of implements. Where efficient THS are available, they may choose not to own their own equipment and prefer instead to rely on hired services. If they do own a 4WT, they are unlikely to attain economical utilization rates on their farms alone and are normally obliged either to offer THS to commercial or subsistence farmers, or to engage in off-farm hire activities (e.g. transportation).

4. Large-scale farmers (100–2 000 ha) usually own a complete range of 4WT with assorted implements. They may have to hire specialized machinery, such as combine harvesters, but may also offer machinery hire services to medium-scale farmers on a contract farming basis for harvesting and so on. Their holdings could be state farms or privately owned commercial farms growing both food and cash crops and are often linked to downstream agroprocessing value chains (e.g. tea and sugar cane processing, and seed production).

At independence in the 1960s, and immediately thereafter, nearly all land under cultivation was owned by subsistence and small-scale farmers in most countries, with the exception of those

Figure 11. Areas of different farm sizes in four countries (2015)

Source: AASR, 2016 – Chapter 2 - Jayne and Amayew.



with large settler populations (e.g. Kenya and Zimbabwe). A recent survey of several countries shows that the ownership pattern of farms began to change at the beginning of the twenty-first century, with an increase in MSFs (**Figure 11**). In 2015, SSFs accounted for 49 percent of cultivated land in Ghana, 53 percent in the United Republic of Tanzania and 34 percent in Zambia. Even more interesting, from a mechanization perspective, was the land owned by medium-scale farmers in the three countries: 33 percent, 38 percent and 54 percent, while LSFs accounted for 18 percent, 9 percent and 12 percent. Only in Kenya is the situation slightly different, with SSFs, MSFs and LSFs accounting for 66 percent, 19 percent and 15 percent of total cultivated land. This situation reflects both the impact of the land settlement programmes in Kenya during the 1950s and 1960s under the Swynnerton Plan and independence era land reform, and the commercialization of the SSF sector with cultivation of high-value cash crops

It is crucial to identify suitable medium-scale farms and encourage the development of viable commercial farming operations that could also provide mechanization services to small-scale farmers

(coffee, tea, dairy and horticulture) (Swynnerton, 1954; Clayton, 1973; Anderson, 1992).

If the transformation occurring in these countries continues and spreads to other countries, it augurs well for agricultural mechanization. Growth of the MSF subsector is vital if sustainable agricultural mechanization is to take place in Africa as it has done in Asia (FAO, 2008, 2015; FAO-RAP, 2014; Collier and Dercon, 2009).

The growth of MSFs depends on the effective demand for agricultural products generated by a growing urban population, high per capita incomes, off-farm employment opportunities and rising wages. An **expanding MSF subsector creates both the need and the opportunity for mechanization** (Clarke and Bishop-Sambrook, 2002; FAO, 2008).

Considering the low profitability of many small farms and the necessary levels of investment, medium- and large-scale (5–200 ha) commercial farmers are in the best position to introduce mechanization, as in Asia (FAO, 2008, 2015; FAO-RAP, 2014; Singh, 2013; Wang, 2013).

Nevertheless, medium-scale commercial farmers still face constraints that limit the profitability of their farming enterprises, and they have found it increasingly difficult to maintain and replace equipment. Meanwhile, the costs of hiring equipment for ploughing are extremely high in Africa (**Figure 18**). Efforts to increase the profitability of medium-scale commercial farming would boost effective demand for mechanical technologies, increasing the supply of machinery hire services to small-scale farmers (Mpanduji, 2000; Agyei-Holmes, 2014). It is crucial to **identify suitable MSFs and encourage the development of viable commercial farming operations that could also provide mechanization services to small-scale farmers** (FAO, 2008).

3.7. Types of crops

In Asia and Latin America, the dominant crops are cereals. In Africa, substantial areas are dedicated to other crops, such as roots and tubers. In 2000, in the Central Africa region, cereals accounted for 67 percent of the total cultivated area, while roots and tubers occupied 33 percent; this compares with 70 percent and 30 percent in West Africa, 83 percent and 17 percent in Eastern Africa, and 98 percent and a mere 2 percent in Southern Africa (**Figure 13**). The figures for Southern Africa are comparable to those for North Africa (98% cereals and 2% roots and tubers), Asia (96% and 4%) and Latin America (93% and 7%). It is no wonder that Southern Africa and Eastern Africa (both dominated by cereal-based systems, albeit to a lesser extent in Eastern Africa) have much higher intensities of tractor use than either West Africa or Central Africa. Further, the total land under cereals in sub-Saharan Africa increased from 47 million ha in 1961 to 95 million ha in 2010 (**Figure 12**). These statistics demonstrate the challenges of mechanizing agriculture in the region, especially where smallholders dominate.

Figure 12. Land under cereal production in sub-Saharan Africa (million ha)

Source: FAOSTAT/IFPRI (adapted).

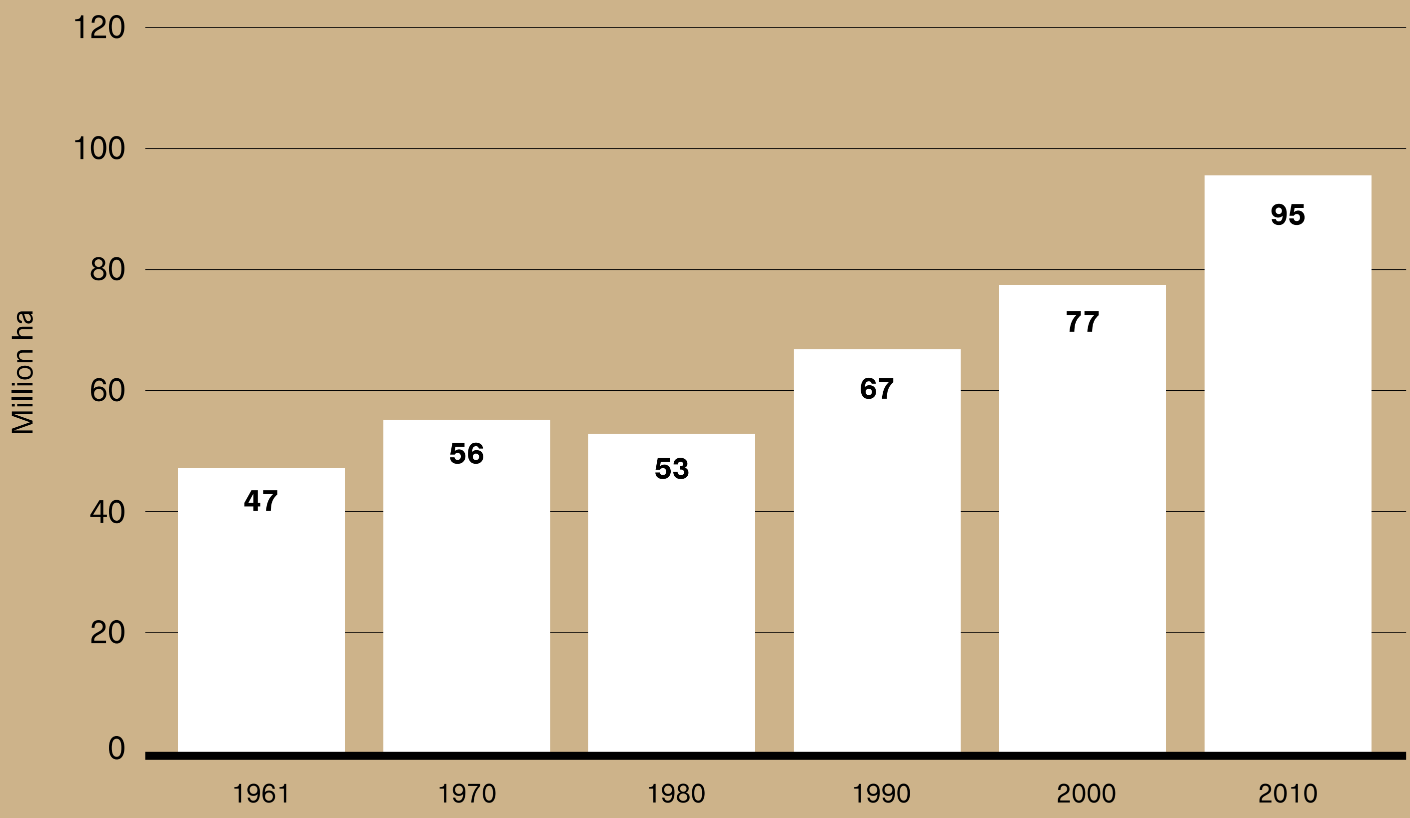
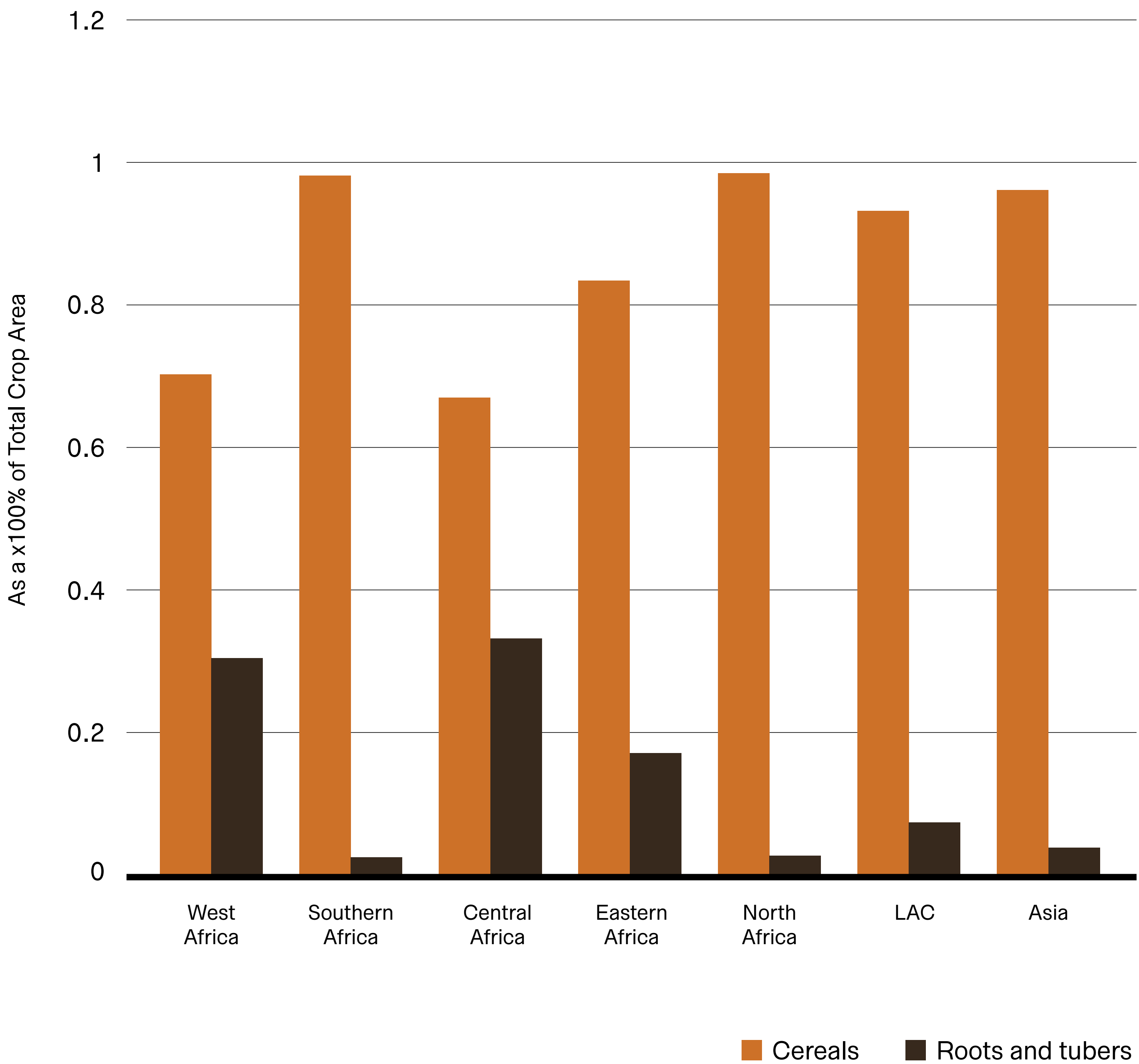


Figure 13. Main annual crops cultivated for food in Africa, Asia and Latin America and the Caribbean (2000)

Source: FAOSTAT/IFPRI.



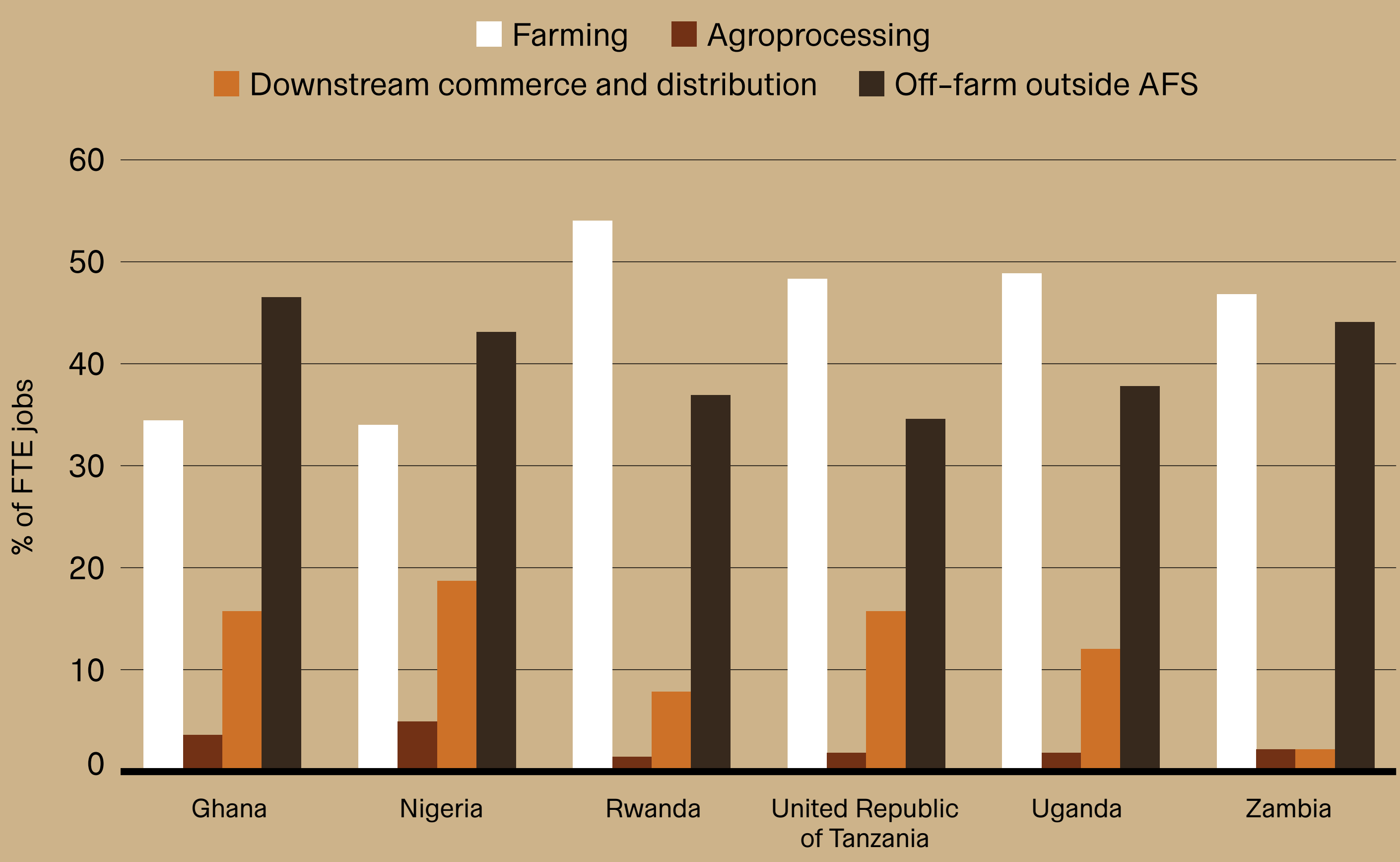
3.8. Mechanization across the value chain

In the past, analysis of agricultural mechanization in Africa and Asia tended to be limited to on-farm production issues and failed to capture the off-farm uses of machinery and implements. Farmers who had invested in machinery and implements were realizing economies of utilization of their mechanization investments by combining on- and off-farm use. It is, therefore, vital to **widen the debate on mechanization and cover the entire agrifood chain** – from the supply of inputs to on-farm production, post-harvest handling and processing, including consumer-protection issues, i.e. food safety.

Experience worldwide shows that success in agricultural mechanization depends on: the effective demand for the outputs of farming (including on- and off-farm value addition); and the mechanization system factors in the entire agrifood chain. Indeed, losses along the value chain – especially post-harvest losses – are considerable (as high as 50 percent in some

Figure 14. Employment patterns: Changes in the share of total jobs among the working age population (15–64 years) (AASR, 2016)

Source: Yeboah and Jayne (2016), computed from Ghana Living Standard Survey 5 and 6; Zambia Labour Force Surveys 2005 and 2012; Rwanda Integrated Household Living Survey; Tanzania National Panel Survey; Uganda National Panel Survey; Nigeria General Household Surveys. Kenya, Malawi and Mali results are from the population and housing census data in Integrated Public Use Microdata Series (IPUMS): https://www.ipums.org/.



SAMA must go beyond on-farm productivity to include post-harvest systems and the entire food chain.

crops in Africa), and agricultural mechanization technologies can make a significant contribution to programmes for loss reduction. Given current demographic trends, **SAMA must go beyond on-farm productivity to include post-harvest systems and the entire food chain.**

Addressing the entire food value chain, from farm inputs to the outputs of farming reaching the table of the (increasingly urbanized) consumer, is a key development issue in Africa in the coming decades. **Figure 14** shows the changes in employment patterns in farming, comparing off-farm jobs within agrifood systems (AFS) and non-farm jobs (non-AFS). It shows that, for a number of countries in the region, the percentage of full-time equivalent (FTE) in farming has fallen to below 50 percent (compared with over 80 percent in the 1970s); an increasing number of jobs are now outside farming, as agroprocessing, trade and off-farm employment become more important (AGRF, 2016; Yeboah and Jayne, 2016). The **entire value chain must be considered when determining the investments required** and identifying their source to ensure sustainability of the agricultural sector.

Another important consideration is the **environmental impact of mechanization technologies** – on-farm, off-farm and in processing operations. It is necessary to take into account emerging global issues, such as climate change and carbon dioxide emissions, and how they are related to overall farm production and mechanization technologies, specifically with regard to techniques for the application of herbicides and pesticides, as well as precision farming (Mrema and Rolle, 2003).

3.9. Machinery utilization rates and timeliness of field operations

Field studies consistently point to the relatively high costs associated with using tractors and full packages of equipment. This raises questions about the profitability of mechanization at the individual farm level and is one of the main arguments against investment in bulky and expensive technologies, namely tractors or comprehensive technology packages (FAO, 2008). However, it is possible to greatly **reduce the costs by increasing annual utilization rates** (Culpin, 1988; Hunt, 1983; Mpanduji, 2000). Another restriction to agricultural mechanization in the developing world is the size and fragmentation of landholdings. **Mechanisms to optimize utilization rates of machinery and implements include:**

1. creation of hiring services;
2. implementation of asset sharing;
3. careful planning of machinery and equipment use; and
4. incorporation of seasonality of demand.

Small-scale farmers cannot usually afford to procure their own machinery and equipment, and hire services offer a viable alternative. In contrast to the negative image of government-operated tractor hire services, there are thousands of individuals across Africa who own tractors and provide tractor hire services to farmers. Hire services, particularly for tractors, can be successfully provided through private or cooperative ownership; nevertheless, **policies and other support systems need to be in place to support hiring or leasing services**. Timeliness is critical in land preparation and planting in rainfed agriculture in Africa. Delays can lead to yield losses of up to 100 kg/ha for each day planting is delayed beyond the optimum time (Kosura-Oluoch, 1983). In addition, the period available for field operations in the rainfed systems common in sub-Saharan Africa (SSA) is only about 30 days (Simalenga, 1989; Simalenga and Have, 1992).

The role of hiring and rental markets for privately owned and operated agricultural machinery and implements is likely to increase in the future. It is, therefore, important to understand the factors affecting the development and sustainability of rental markets for machinery. Lessons need to be learned from cases in Eastern and Southern Africa involving privatized minibus passenger transport services (e.g. matatus and dala dalas), boda boda motorcycle transport service operators and small-scale grain-milling operators (e.g. hammer mills). However, there has been no research to date to find out how these enterprises are able to survive in a very competitive environment often hostile to business.

Asset-sharing arrangements can lead to higher utilization rates for capital machinery. Africa has a strong tradition of asset sharing on which to build (FAO, 2008). Machine sharing is easier for less time-bound operations, such as milling and threshing, because there are fewer time restrictions. Indeed, the success of hiring and asset-sharing strategies designed to increase utilization of field machinery and equipment is limited by the very short time window available to undertake key cultivation operations on different farms simultaneously. This is particularly true for land preparation in semi-arid environments under rainfed agriculture. Weeding operations also must be well timed and are often undertaken at the same time on different farms. On the other hand, the innovative developments in telecommunications infrastructure currently underway throughout Africa will undoubtedly lead to lower transaction costs for machinery hiring (e.g. “Hello Tractor” in Nigeria and Kenya).

In areas with a short time frame for land preparation, utilization rates remain limited, even when there is efficient combination of own use, hire services and asset sharing. This constraint could be overcome by taking advantage of rainfall isohyets by latitude (mainly in West Africa) or altitude (common in Eastern Africa): **farmers can move tractors according to peak land preparation seasons**. Tractors used to move across borders in Eastern Africa during the 1960s and early 1970s, but this activity ceased with the collapse of the first East African Community (EAC) in 1977. However, it still occurs in countries in the Southern Africa Customs Union (SACU) and is quite common across states in Asia, especially for harvesting equipment (FAO, 2008, 2015; FAO-RAP, 2014).

Whether through own use, hire services or asset-sharing arrangements, the most common and practical approach for increasing utilization rates is to **use tractors for transport and other non-agricultural tasks**, such as improvement of rural road infrastructure and building works. This requires close coordination with the organizations responsible for rural infrastructure, as well as policies that encourage the use of tractors for such activities.

Finally, a more **organizational and institutional approach to hiring and sharing** is required to address persistent problems of inefficiency and inadequate use of machinery and equipment. It is not necessary or desirable for all farmers to become experts in equipment and machinery use and maintenance. On the contrary, over time, mechanization services could increasingly be supplied by specialized commercial service providers, with the support of well-trained and professional machinery and equipment operators (FAO, 2008, 2015; FAO-RAP, 2014).

Two-wheel tractor with a direct seeder implement for Conservation Agriculture.

PHOTOGRAPHY: © CIMMYT/F. BAUDRON

3.10. Franchises and supply chains for agricultural machinery and implements

Availability of machinery, equipment, spare parts and other supplies is essential for successful and sustainable agricultural mechanization. Agricultural mechanization includes the development of local industries that produce machinery and implements. Where production is not feasible, local franchise holders must be established and developed to import these goods. Even more important is the need to establish efficient and effective distribution channels for equipment, spare parts and repair services and supplies, such as fuel and lubricants. The **development of supply chains and services should be an integral part of the agricultural mechanization process** to ensure a better choice of equipment for particular types of users and uses and to guarantee the availability of spare parts and technical services.

During much of the second half of the twentieth century, the manufacture and supply of agricultural machinery was dominated by suppliers from the west (Kurdle, 1975; Burch, 1987). Since the beginning of the twenty-first century, however, new suppliers of agricultural machinery and implements have emerged from Asia. The People's Republic of China and India, in particular, have become important global suppliers of low-cost equipment (Singh, 2013; Wang, 2013; Renpu, 2014). Moreover, most of the machinery available from high-income industrial countries is too expensive and too complicated; it often has a high power rating and is adapted for extremely large-scale farms. Brazil, India, the People's Republic of China, Pakistan and other developing countries, on the other hand, produce and export agricultural machinery and implements at lower prices. With the exception of those countries that have a realistic plan to develop local production capacity, the **elimination of import duties on agricultural machinery and equipment could significantly increase access to agricultural mechanization inputs**.

Opportunities exist – in rural settlements and in urban centres and towns – to harness Africa's entrepreneurial potential by promoting the development of input supply chains and agribusinesses focused on the provision of services to producers and processors. The impact could be considerable, including the indirect creation of many jobs through manufacturing and dealer operations (**Figure 14**).

3.11. Manufacturing of agricultural machinery and associated services

In some countries, it may be feasible to develop local industries for the manufacture of machinery, implements and equipment. **Local manufacture has advantages** as it:

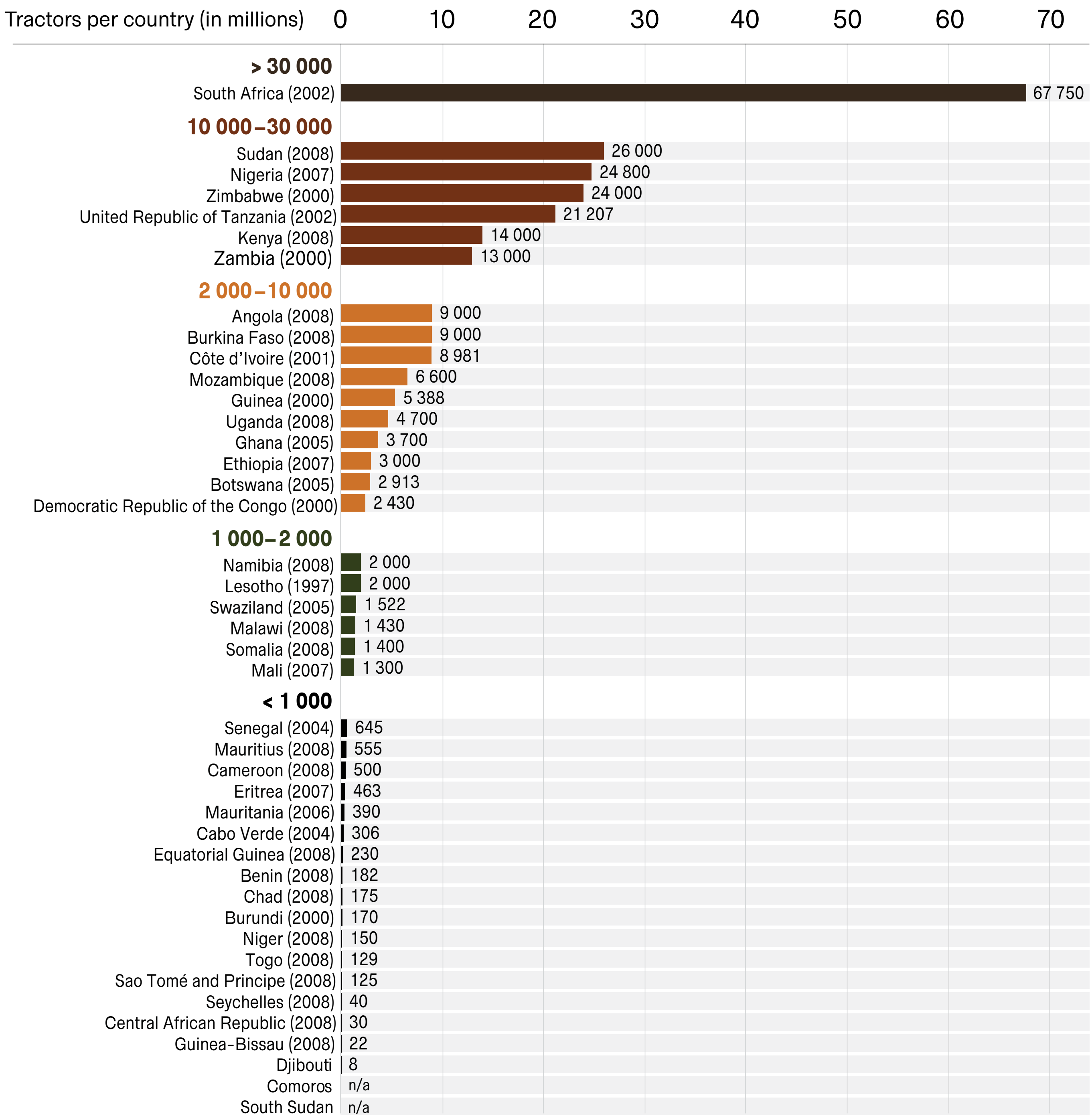
1. generates alternative employment;
2. reduces dependence on imports;
3. saves foreign exchange; and
4. facilitates the supply of parts and services.

Many countries in the region could manufacture and service some of the necessary machinery and equipment (small diesel engines, fodder choppers, threshing machines and numerous implements), whether powered by human/animal muscles or by engines and motors. It is preferable for implements specific to the local circumstances (agricultural conditions, soil type etc.) to be made by small-scale industries; this would also reduce manufacturing and transportation costs and generate employment. As far as possible, **most hand tools and animal drawn implements should be manufactured in the country where they are to be used**.

Although it is unlikely that the agricultural **machinery for medium and large-scale commercial farmers** could be manufactured locally in many countries, it is conceivable that some countries can start by assembling them from Semi Knocked-Down [SKD] parts and Completely Knocked-Down [CKD] parts. Such arrangements should be facilitated through the Regional Economic Communities (RECs), as demand in most countries is small and a subregional market should be considered. Also, testing and certification of agricultural machinery and implements, to the extent possible, should be considered at the regional/REC level. **Most countries in Africa cannot establish and finance adequately equipped and resourced testing centres at the national level**. The RECs should consider facilitating the establishment of regional centres of excellence and networks for standard setting and testing of agricultural machinery and implements.

Figure 15. Number of tractors per country – Sustainability and viability of agricultural machinery franchises

Source: FAOSTAT and World Bank STAT, 2010.



3.12. Sustainability issues: environmental, commercial and socio-economic

ENVIRONMENTAL ISSUES

There has always been concern about the **environmental consequences of using modern agricultural inputs** in African agriculture, and this includes mechanization. Colin Maher, soil conservation expert in Kenya and regarded as the father of soil conservation in East Africa noted:

The grave erosion which occurs on ploughed land from time to time has often induced an "old timer" to say ruefully that we should never have put a plough into Africa. (Maher, 1950)

Maher made this observation at the beginning of a period of ubiquitous introduction of agricultural machinery and implements in the then East African Highlands. Concerns regarding the negative consequences of modern agricultural practices and technologies on natural resources in Africa have been expressed by many experts over the past 70 years (Rowland, 1974, 1994; Anderson and Grove, eds, 1987; Tiffen, Mortimore and Gichuki, 1994; Kayombo and Mrema, 1998; FAO, 2013a, 2013b, 2016).

While the farm power situation undergoes gradual change, the development debate about on-farm mechanization has turned to current land preparation and crop husbandry techniques and their contribution to the sustainability of the entire agricultural system. The environmental, socio-economic and demographic trends predicted in Africa over the next three to four decades will increase the need for more sustainable agricultural strategies.

The paradigm of "sustainable production intensification" as described in the FAO publication, Save and Grow, recognizes the need for productive and remunerative agriculture that conserves and enhances the natural resource base and supports the delivery of environmental services. Sustainable intensification of crop, forestry and livestock production must reduce the impact of climate change on agricultural and forestry production and mitigate the factors causing climate change by reducing emissions and contributing to carbon sequestration in soils (FAO, 2011).

Adoption of **inappropriate agricultural machinery, equipment and implements**, and/or their improper use, can place increased pressure on fragile natural resources by:

1. accelerating soil erosion and compaction;
2. promoting the overuse of chemical inputs; and
3. opening up lands that currently serve as valuable forest reserves and rangelands.

In the quest for environmental sustainability, the **conservation agriculture (CA)** movement has emerged across the globe, promoting minimum or zero tillage and innovative planting techniques. Zero tillage in cereal systems in parts of Southern Africa has contributed to reducing soil erosion and to improving system productivity and soil health.

At the farm level, agricultural mechanization strategies must adopt sustainable land preparation and crop husbandry techniques, drawing on lessons learned from successful programmes worldwide (FAO, 2016). **Different countries, agro-ecologies and farming systems require different strategies**. One method for reducing the environmental effects of modern agricultural production is the adoption of CA practices (Box 6). Although its strongest proponents acknowledge that CA requires cultural change and has a steep learning curve, it can have an increasingly important role in the agricultural systems in the region. In addition, the benefits of CA may not be immediately apparent; incentives and subsidies are therefore required to encourage farmers to adopt the recommended equipment (Friedrich, 2013).

COMMERCIAL ISSUES

African agriculture is dominated by smallholders and other value chain stakeholders who may be disadvantaged by increased agricultural mechanization. It is important to **facilitate access by small-scale farmers to larger items of agricultural machinery**, such as tractors, harvesters, threshers and milling equipment – at affordable prices. To this end, **strategies must be identified**:

1. Set up systems that provide custom hiring services on a commercially sustainable basis.

2. Develop business models that facilitate the competitive provision of mechanization services.

3. Develop financial models that enable small farmers to access agricultural machinery for their own use and for rental to other farmers through the operation of commercially viable hire services.

4. Design equipment on a scale that is best suited to the needs of small farmers.

5. Empower farmer organizations in order to facilitate their access to mechanization inputs through cooperative mechanisms.

In the 2000s, the increasing cost of energy is a potential drawback to mechanization, as it was in the 1970s. Global energy shortages underscore the need to **introduce energy as a criterion of efficiency**, together with land, labour and capital. It should be noted that energy used in manufacturing and the operation of agricultural machinery and implements at the peak of the energy crisis of the 1970s and early 1980s – even in the most mechanized parts of the world – accounted for just 8 percent of the commercial energy used in agricultural production (FAO, 2008, 2015). Chemical fertilizers and pesticides, on the other hand, still account for about 84 percent (Fluck and Baird, 1979; Rijk, 1983; Stanhill, 1984; Fluck, 1984, 1992).

It is important to consider the issue of energy in the right context. While the price and availability of fuel have a direct impact on the profitability of using mechanical power sources in agriculture and must be accounted for at the appraisal stage, infrastructure must also be considered. In the 1960s–1980s, a lack of services in rural areas of Africa meant that even a simple puncture repair required considerable effort and time. However, developments in other sectors (e.g. transport and communication) have led to the establishment of a physical and institutional infrastructure for the supply of fuel and repair services throughout the region. This can certainly be used to provide effective services to the agricultural mechanization subsector.

SOCIO-ECONOMIC ISSUES

In addition to environmental and commercial sustainability, the agricultural mechanization strategy must consider other relevant socio-economic issues, such as the importance of helping **youth** and **women** contribute effectively and efficiently in agricultural production. The **ageing rural population** is another issue of concern to agricultural development in Africa: mechanization could encourage educated younger farmers to consider farming as a full-time career. The Malabo Declaration and Agenda 2063 highlighted these specific issues and they **must be included as core activities under SAMA**.

3.13. Institutions and policy

Policies formulated and implemented in the 1990s were prompted by, among other issues, the recognition of the negative consequences of direct state involvement in agricultural production and other economic activities. There is evidence in many African countries of progress made in establishing more stable macro-economic environments, liberalized markets, tighter fiscal regimes and stronger institutional frameworks. However, as public interventions and investments decline, the private sector does not always step in to provide farmers and other entrepreneurs with essential market, business and financial services. Due to poorly developed markets and low levels of economic activity in many countries in the region, mechanization may depend on public-sector initiatives and actions.

There is an urgent need for continued **public-sector action to strengthen enabling environments for private-sector economic activity and investments**. It is important to identify how to enhance utilization of mechanical innovations in agriculture. Governments in Africa could foster the development of sustainable agricultural mechanization through the following **high priority actions**:

1. Improve rural infrastructure and strengthen agricultural support services to reduce costs and increase profitability, expanding the supply and effective demand for machinery and mechanization services and other input supply and output marketing services.

2. Provide direct support to companies involved in machinery supply and hire services through technical assistance and business advisory services.

3. Reduce or absorb transaction and information costs for the provision of mechanization services to smaller-scale farmers.

4. Remove legal and regulatory constraints against leasing, ensuring that effective procedures are in place for supply and, where necessary, for repossessing assets.

5. Promote cross-border, subregional and regional collaboration for the movement of equipment and provision of mechanization services to increase annual utilization rates of machinery and equipment.

6. Remove or reduce import and sales taxes on agricultural machinery and equipment.

7. Make risk management tools, such as insurance, widely available.

From the standpoint of public poverty-reduction policies, it also would be desirable to "kick start" mechanization through risk-sharing schemes and interventions that directly reduce transaction costs and enhance effective demand. Innovative approaches need to be explored to achieve this, including exit strategies that will result, in the medium to long term, in creating a sustainable and profitable farming sector. This is consistent with the agribusiness priorities identified under Agenda 2063.

3.14. Cross-cutting issues

FINANCING OF AGRICULTURAL MECHANIZATION INPUTS AND SERVICES

Credit and finance are critical for agricultural mechanization investments in Africa. In some countries, government-owned agricultural banks channel subsidized loans to farmers for the purchase of machinery and other capital investments. The best way to finance investments in sustainable agricultural mechanization is for main-line banks to provide loans as part of their regular service to the agricultural sector. Embedding the financing mechanism in the systems of regular financial institutions like any other loan makes it sustainable. In addition, innovative financing mechanisms must be provided to finance investments in sustainable agricultural mechanization (SAM); in particular, credit needs to be made available to farmers wishing to expand their enterprise. Eventual **subsidies need to be based on clear, well-defined and easily understood objectives and requirements.**

The **public sector** has a crucial role:

1. Financing services of a public goods nature, for example, training, licensing of machine operators, research and development, and rural infrastructure (including last-mile rural road and electricity supply systems).
2. Creating an enabling environment for the private sector to finance mechanization investments by enacting appropriate laws for banking, contracts and leasing regulations.
3. Providing subsidies for the adoption of particular technologies (e.g. CA technologies) – with a clear exit strategy.

It is important to learn **lessons from schemes** already in place, such as the recent initiatives of Alliance for a Green Revolution in Africa (AGRA) on lease financing or the innovative financing mechanisms implemented in several countries; their implementation needs to be documented and shared across the region.

There is an urgent need for continued public-sector action to strengthen enabling environments for private-sector economic activity and investments.

POLICY ISSUES

Policy support is critical to mechanization, particularly with regard to "sustainability" issues. Policies must support the sustainable agricultural mechanization process; for example, a change in tillage practices may require additional investments in agricultural machinery and equipment. Likewise, to satisfy demand for agricultural machinery and implements, interventions may be necessary in industrial licensing and trade policies. Local and regional manufacture of implements could require a change in fiscal policies (e.g. subsidies and credit lines), and decisions will have to be made whether to impose or waive duty on imported equipment. Policy formulation necessitates **close coordination within governments**, involving the ministries of agriculture, trade and industry, finance and planning, environment and energy. It is also essential to undertake a study on the impact of the agricultural mechanization strategies (AMS) during 1980–2010, developed by several countries and supported by agencies, including FAO, UNIDO and the African Development Bank (AfDB).

At the subregional and regional levels, there must be close **coordination and collaboration between countries**. With the liberalization of trade policies for goods and services, entrepreneurs can offer cross-border mechanization services (e.g. land preparation, crop husbandry and paddy harvesting) in different countries and in different seasons according to peak demand. As shown in Figure 15, the national market in most countries is currently quite small. Regional cooperation is critical for the establishment of sustainable systems offering such services.

International **development agencies**, such as FAO and UNIDO, have a leading role in promoting the sharing of experiences among member countries on successful in-country policies and strategies. It is important that they keep an open mind and recognize their part in past failed strategies. They must objectively guide the advancement of new enabling policies and regulations to facilitate cross-border trade of mechanization inputs and services as well as support systems. This must take place within an Africa-wide framework and in the context of South–South collaboration. The RECs could play a leading role in facilitating the development of agricultural mechanization in Africa.

RESEARCH AND DEVELOPMENT

In most countries, **public-sector** research and development activities on agricultural machinery and implements, including sustainable mechanization, are the responsibility of numerous

At the subregional and regional levels, there must be close coordination and collaboration between countries.

government departments, but they tend to lack coordination. **Departments undertaking R&D:**

1. Agriculture – mechanization research, soils, post-harvest, irrigation.
2. Trade and Industry – industrial research, manufacturing, patenting, standards, trade licensing.
3. Energy – energy generation and distribution, alternative fuels.
4. Higher Education – research and education on all aspects of mechanization in schools of agriculture and engineering.

At the regional and international levels, the International Agricultural Research Centers (IARCs) – under the Consultative Group on International Agricultural Research (CGIAR) – were actively engaged in the 1960s through to the early 1980s in agricultural mechanization research. Some researchers focused on hardware (e.g. design and development of implements and equipment, such as paddy threshers and animal drawn implements), others on software (e.g. economics of the introduction and utilization of different types of agricultural machinery and implements) (Khan, 1972; Binswanger, 1978, 1994; Farrington, Abeyratne and Gill, eds, 1982; IRRI, 1983; Starkey, 1986, 1988a; Byerlee and Husain, 1993).

At times, opposing views emerged between the software group and the hardware group: economists and engineers were "talking past each other" on the mechanization issue (Gemmill and Eicher, 1973). This was counterproductive and contributed to the decline in the 1980s of the agricultural engineering and mechanization research units in most CGIAR centres. By the 1990s, most work in this area by CGIAR-IARCs had been abolished. As a result, the CGIAR system today has little capacity in this area – in particular in engineering – despite some support for IARC initiatives (Brader, 1994; FAO, 2015; Gummert, ed., 2014).

At the global level, the **private sector** has played an important role in various fields, including:

1. research and development;
2. technology transfer (agricultural machinery and implements) in developing countries; and
3. manufacture and distribution of agricultural machinery, implements and equipment to farmers.

Some private-sector entities are branches of multinational corporations; others are local companies established in the past 10–20 years. Coordinating and regulating the activities of all these public and private entities is an issue of concern for most countries in the developing world, at both the national and regional levels. In order for SAMA to be successful, Africa must explore the possibility of establishing some regional capacity for coordination in order to reduce duplication of efforts and increase efficiency (de Wilde, 1967; ComSec, 1991, 1992; FAO, 2008, 2015; FAO-RAP, 2014).

In the majority of African countries, the strongest in-country capacity resides in the universities, specifically in the agricultural engineering departments, which are responsible for undergraduate and postgraduate training and research and for training human resources in three critical areas:

1. Agricultural engineering and mechanization
2. Irrigation and water resources engineering
3. Post-harvest process engineering.

The engineering and agricultural departments, together with the departments of agribusiness and farm management, are crucial for effective action within a country, provided they are properly enabled. Centres for research in agricultural mechanization and rural technologies (in countries where they exist) would constitute an important country node for any regional network for SAMA. The primary role of a regional mechanism for SAMA should be to facilitate the coordination of efforts of national centres to work together in a structured regional network to achieve economies of scale and scope.

ADVOCACY

SAMA represents a new way of looking at agricultural mechanization and development in Africa. Political, economic and social systems and institutions must be sensitized to the need for and importance of SAMA. Key stakeholders in the public and private sectors must be made aware of the critical role of SAMA in agricultural development in the region, especially given the socio-economic, demographic, technological and environmental trends and projections up to 2063. Public policymakers and resource-allocation decision makers must be made aware of the importance of SAMA.

Advocacy for sustainable agricultural mechanization requires extensive support through media campaigns, public speaking, commissioning and publishing of research findings at both the regional and country levels.

Potential support activities include:

1. promoting a strategic vision for the sustainable mechanization of agrifood chains and systems, linking SAMA directly to national development objectives on economic growth, sustainable development and poverty reduction, with increased investment in environmental services and employment of youth and women in agriculture;
2. facilitating information sharing and lesson learning about good practices; and
3. ensuring the effective participation of all stakeholders (including non-state actors and the private sector) in its processes.

CAPACITY BUILDING

Building the capacity of countries in Africa is vital if SAMA is to succeed. In this regard, it is necessary to strengthen and **rejuvenate the capacity of institutions created in the 1970s and 1980s** to prepare the human resources responsible for training the first mechanization experts in the region. Economic priorities changed during the 1990s and the capacity of some institutions was reduced. To handle the concepts involved in SAMA, these institutions will require additional investments in human resources and physical facilities. Capacity building must focus on three groups:

1. Farmers (especially young farmers and women), extension and research staff and local government officials on SAM technologies and business models.
2. Manufacturers and distributors of inputs (new tools, equipment implements, machines).
3. Franchise holders of agricultural mechanization supply chains.

Knowledge sharing through formal and informal regional mechanisms is crucial in the implementation of sustainable agricultural mechanization in Africa.

It is necessary to **enhance communications** regarding sustainable agrifood mechanization technologies, in order to increase awareness of their profitability and environmental and socio-economic impact, as well as of innovations in agrifood systems. It is essential to develop a knowledgeable, well-trained and disciplined labour force that can serve sustainable agrifood value chains and drive and sustain private-sector-led growth.

KNOWLEDGE SHARING

Knowledge sharing through **formal and informal regional mechanisms** is crucial in the implementation of SAMA. Africa has tried several regional networks, but most of them were donor driven and pursued narrow interests (e.g. ATNs for DAP, ACT for CA). **SAMA requires a holistic approach**. The experience of the 1970s and 1980s in Asia is invaluable, as countries in that region collaborated through the Regional Network for Agricultural Mechanization (RNAM). The network enabled the exchange of information and experiences at a critical stage in the development of agricultural mechanization, when countries in Asia were embarking on the process of transforming farm power sources from animate to mechanical. During its five phases from 1977 to 2002, RNAM received the support of international agencies (FAO, UNDP, UNESCAP and UNIDO) and bilateral donor agencies (Netherlands and Germany) (Lantin, 2013; FAO, 2015; FAO-RAP, 2014). RNAM focused on communicating agricultural mechanization policies and strategies, exchanging technologies and sharing information on best practices.

SAMA requires a similar initiative with **information exchange and knowledge sharing** (FARA, 2014), taking advantage of active national institutions. Organization will be easier than in the 1980s, given the advances in ICT and the established institutional framework for regional cooperation and coordination in agricultural research, trade and information exchange in Africa under RECS, CAADP/NEPAD and AUC. At the national level, better coordination of SAM activities is required; at the subregional and continental levels, networking is necessary to generate knowledge pools and create a critical mass of the required multidisciplinary expertise .

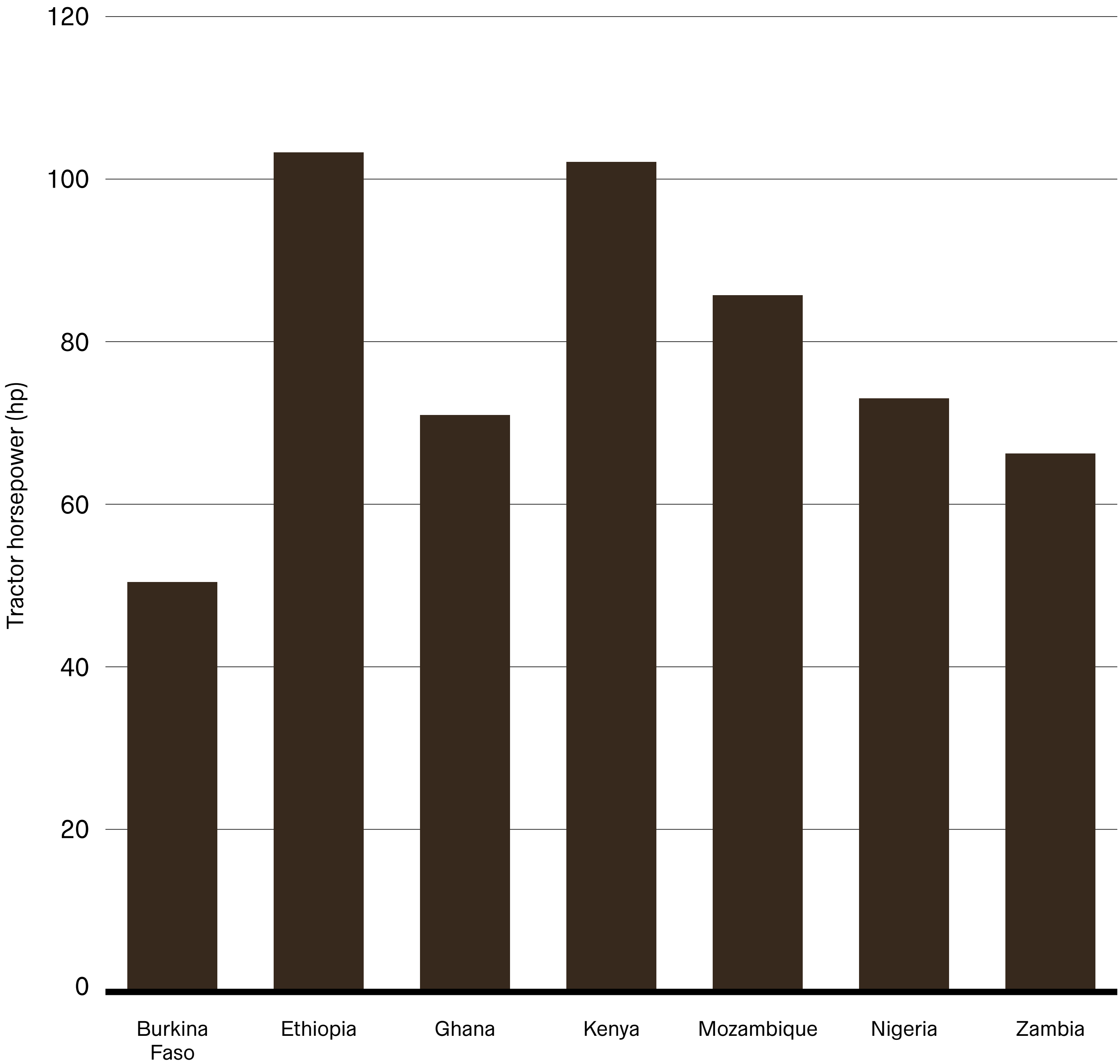
3.15. Concluding remarks

The AUC initiated the development of a framework for SAMA and is steering the process through consultations involving key stakeholders. Continental reviews of the agricultural mechanization situation in the region have been published over the years, create: the Michigan State University/USAID-sponsored 1967–69 study (Kline et al., 1969) and the World Bank-sponsored rapid 1987 study (Pingali, Bigot and Binswanger, 1987). However, recommendations in these reports were quite prescriptive and there was no response from African experts or countries. Other reports, such as those by FAO (2008) and FAO and UNIDO (2010) were "limited" reviews of published works. Rather than offering solutions, they aimed to create awareness of the lack of progress in agricultural mechanization in Africa during the last two decades of the twentieth century and to explain the underlying reasons.

As noted earlier, the success in agricultural mechanization in other regions and countries in the world has been characterized by long-term commitment, a clear vision and specific goals. Success depends on the selection of priorities and on the sequencing of actions; to this end, the AUC has certainly set the agenda. **Now is the time to develop and agree on the main elements to be included in a framework for sustainable agricultural mechanization strategies for countries in Africa.**

Figure 16. Estimated average tractor horsepower per country

Source: IFPRI.



4. Elements of a framework for SAMA

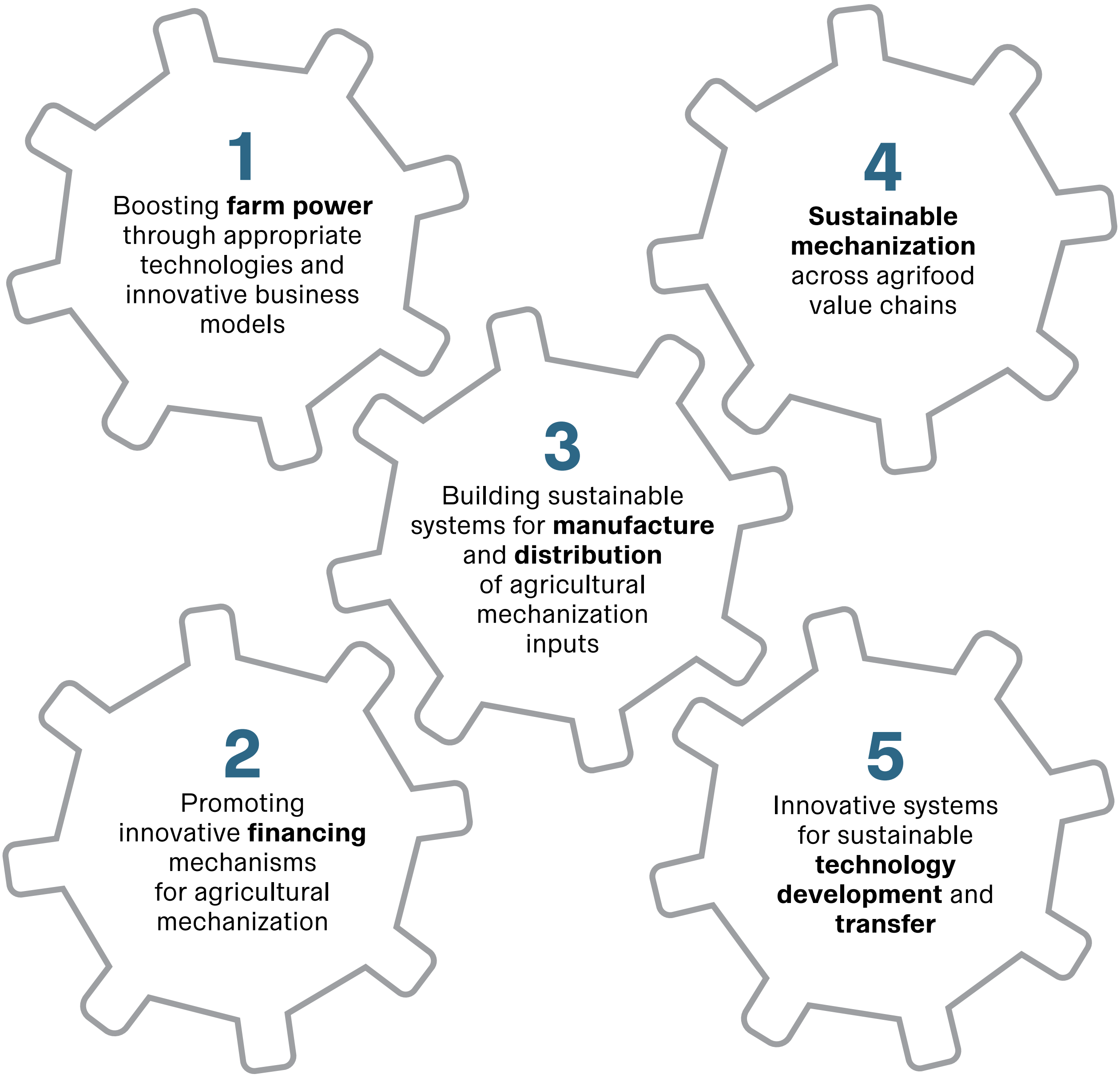
PHOTOGRAPHY: ©B. SIMS

Practical training on the basic technical components of agricultural machinery in Zambia.

Mechanization is essential to agricultural development and it links agriculture to industrialization. It is therefore **fundamental that mechanization be a part of a country's agricultural transformation agenda** rather than a stand-alone activity (FAO and UNIDO, 2010; FARA, 2014). The potential role of agriculture in Africa is similar to the role it played in the economic transformation and industrialization of economies in Asia (FAO, 2008, 2015). For agriculture-based economies in Africa, its role becomes even more important. Furthermore, if

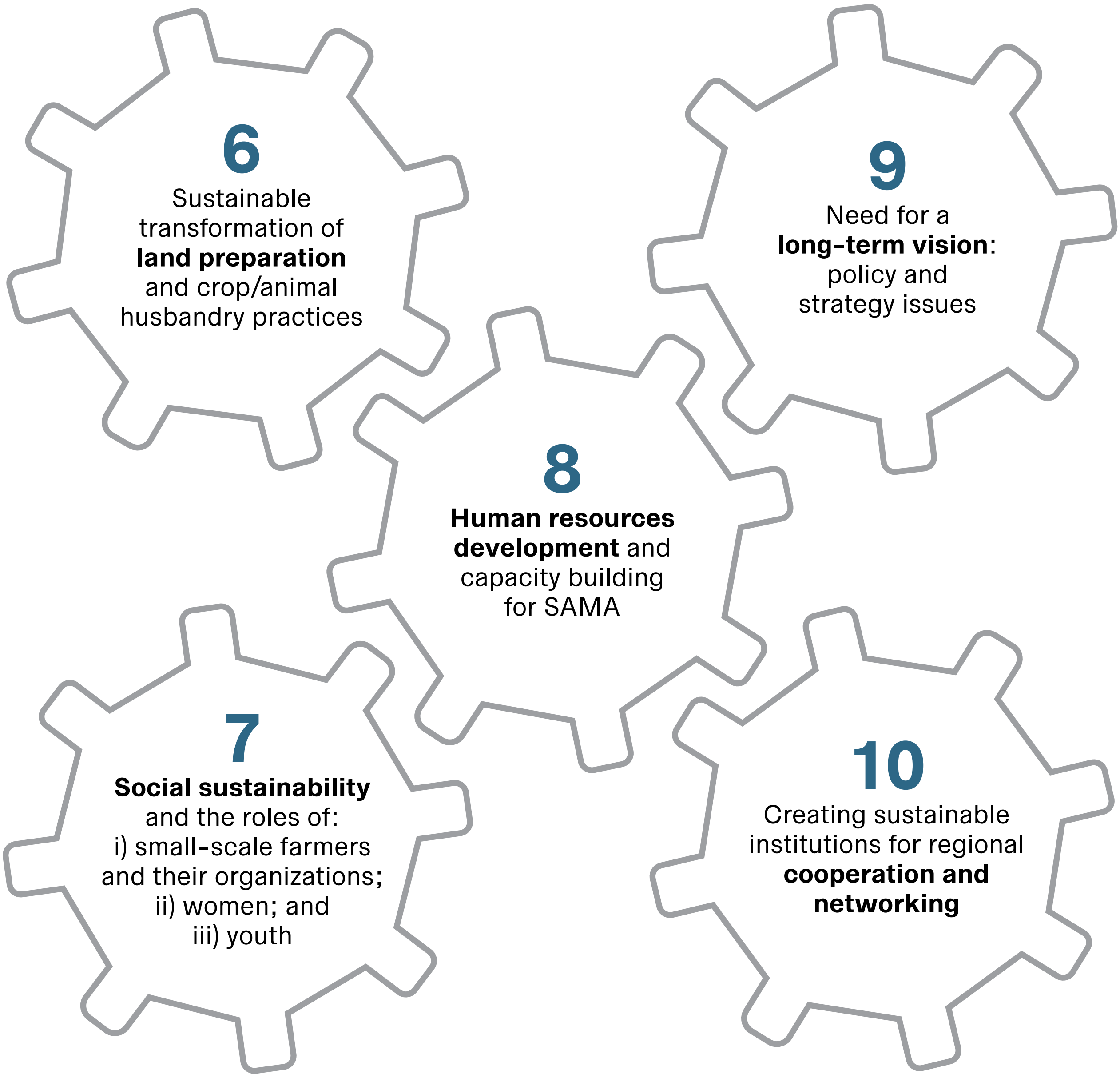
Figure 17. The ten elements of SAMA

Source: FAO, 2018.



agriculture is linked to manufacturing through mechanization across the value chain, it can lead to the economic transformation of many countries in Africa (AfDB, 2016; ACET, 2017).

This chapter presents the **key elements required for the development of Sustainable Agricultural Mechanization in Africa (SAMA)**. The ten elements are based on the principles of sustainability – commercial, environmental and socio-economic. Each element promotes at least one principle and together they ensure that SAMA contributes to structural transformation in Africa (**Figure 17**).



4.1. Ten elements of Sustainable Agricultural Mechanization in Africa (SAMA)

The analysis presented in Chapters 2 and 3 calls for a particular approach. Based on the experience over three to four decades in other parts of the world where significant transformation of the agricultural mechanization sector has occurred, lessons can be learned to enable the development of policies and programmes to contribute to Africa's aspirations of Zero Hunger by 2025. It is necessary to **identify and prioritize relevant and interrelated elements to help countries develop strategies and practical development plans**. This in turn will create synergies in line with their agricultural transformation plans, culminating in the realization of Sustainable Agricultural Mechanization in Africa. However, given the unique needs of each country, the ecological heterogeneity of the region and the different scales of farmers, the framework is not prescriptive; instead, it provides ten interrelated elements to guide agricultural mechanization efforts. This chapter discusses these **ten elements, taking into consideration their commercial, socio-economic and environmental sustainability.**

It is necessary to identify and prioritize relevant and interrelated elements to help countries develop strategies and practical development plans.

4.2. Making SAMA commercially sustainable

Element 1: Boosting farm power through appropriate technologies and innovative business models

Countries in Africa are at different stages of development with regard to use of farm power and sustainable mechanization of the agrifood system. In some countries (or parts of a country), progress is rapid. It is conceivable that, in the near future, the most arduous and back-breaking tasks (e.g. primary land preparation) will cease to be undertaken with total reliance on human muscle power on a significant proportion of the cultivated land. However, for this to happen, supplementary farm power resources must be made available to most farmers at affordable prices and on a timely basis. To this end, the **key objective of SAMA is to increase the farm power available to all farmers** through farmer owned machinery and/or through enterprises offering efficient machinery hire services

It is apparent from the evolution of the agricultural, industrial and economic sectors in the past five decades that the **five main types of power sources used by farmers in Africa** are as follows:

1. Small, two-wheel single-axle tractors (power tillers) (2WT).
2. Medium horsepower four-wheel and two-axle tractors (4WT). In some parts of Eastern and Southern Africa, large-scale farmers are increasingly moving towards higher horsepower tractors.
3. Electric pumps or diesel pump sets – for irrigation where gravity systems are not available.
4. Motorized/powered equipment – for harvesting, threshing and other post-harvest processing operations.
5. Electric power and diesel generators – for driving grain-milling equipment. Significant progress has already been made in many parts of Africa.

While DAP remains important in areas where it has a foothold, it is increasingly challenged by mechanical technologies. Even in Ethiopia – where DAP has been used for more than three millennia – there are plans to transform the farm power situation and significantly reduce the use of DAP over the next two to three decades (EATA, 2015).

Given the impending changes in the wider economy and the demographic trends, **the farm power situation in Africa will need to undergo significant change** – a reality that forms the basis of SAMA's key strategic and policy imperative. The primary objective is the replacement of human muscle power as the main source of farm power for primary land preparation in the region within the coming two decades. This would achieve the AU goal of sending the hand hoe to the museum, liberating the African farmer from the unpopular, arduous and back-breaking chore of primary tillage of the land using hand tools: Africa would no longer depend almost entirely on human muscle power (Stanhill, 1984; Fluck, 1992).

Element 1 aims to significantly reduce the use of hand tools in land preparation and other field activities by creating a supporting environment and facilitating viable and sustainable businesses that can offer timely, efficient and affordable mechanization inputs and services for land preparation and other agricultural operations to farmers. As in other regions of the world, this entails helping farmers acquire and efficiently operate their own machinery and/or obtain mechanization hire services provided by commercially operated small and medium enterprises (SMEs).

The government's role is to create an enabling environment.

Element 1 contributes to the commercial sustainability of SAMA and the attainment of important milestones as stipulated in the Malabo Declaration and Agenda 2063 commitments made by the African Heads of State and Government in 2014 and 2015 respectively.

Options to be considered:

1. National assessments of current and futur short-, medium- and long-term farm power requirements for different agro-ecologies and farmer groups within the country. Assessments need to consider demographic trends (including urbanization and the ageing agricultural population), gender and youth issues, the need for transformation and improvement, and any technical support requirements.

2. Establishment and operation of different business models to provide mechanization services: farmer-operated mechanisms and systems; and machinery hire services offered by SMEs or larger companies, including suppliers of agricultural machinery.

3. Financing of mechanisms for the acquisition of machinery for own use or hire services.

4. Undertaking of studies to establish mechanization requirements of all farmer groups, including consideration of the roles of SSFs and MSFs in the production of basic foodstuffs (e.g. cereals, roots, tubers) and higher value crops (e.g. fruits and vegetables). This should factor in the logistics of produce handling and processing up to the consumer.

5. Introduction of mechanisms to attain higher utilization rates for agricultural machinery and lower unit costs of tractor hire services, including multi-farm use, across different agro-ecologies and districts/regions (**Box 6** and **Box 7**).

6. Implementation of studies of the impact of transformation of farm power sources across the region through the replacement of hand-tool technology and draught animals with mechanical power sources. Assessments should consider the socio-economic and environmental impacts as well as evaluation of the different models/ approaches used in the region and the lessons learned. Considerations include: the consequences for the draft animals; the implications for the livestock sector of their replacement including the availability of feed resources and grazing land; and the effect of mechanization on employment.

7. Attention to the manufacturing capacity; servicing, repair and maintenance, and trade of farm power equipment (tractors, power tillers, pumps, threshers, hammer mills, motors etc.) and implements (ploughs, seeders, CA equipment etc.) in the context of regional trade, import tariffs, testing and standards, given the current low demand in many countries in Africa.

8. Consideration for cross-country use of machinery and equipment (free movement of tractors and combine harvesters) in pursuit of machinery hire business.

9. Enhancement of extension services and farmers' capacity to operate and maintain efficiently the new equipment in order to make sustainable use of it, meeting crop and soil demands, towards a more efficient and sustainable production.

10. Development of specialized programmes for capacity building of potential mechanization hire service providers, strengthening South–South and triangular cooperation, as well as North–South collaboration, through partnerships and mutual support.

Box 7. Annual utilization rates and profitability of agricultural machinery use

The basic knowledge on use of agricultural machinery and implements stems from North America, where the tractor was invented and first used in the middle of the twentieth century (Promsberger, 1976; Esmay and Faidley, 1972; Culpin, 1988; ASAE, 1988; White, 2000). A tractor is designed for 10 000–12 000 hours of use at an annual utilization rate of 1 000 hours, and this is considered the optimum utilization rate in the tropics (Clayton, 1973; Esmay and Faidley, 1973; Kolawole, 1974; Culpin, 1988; Mpanduji, 2000). However, for most tropical areas under rainfed conditions, the period available for tillage rarely exceeds 30 days, especially in drier areas (Morris, 1986; Simalenga, 1989; Simalenga and Have, 1992). Furthermore, most farms in Africa are poorly de-stumped; this hinders ploughing at night at the peak of the land preparation season.

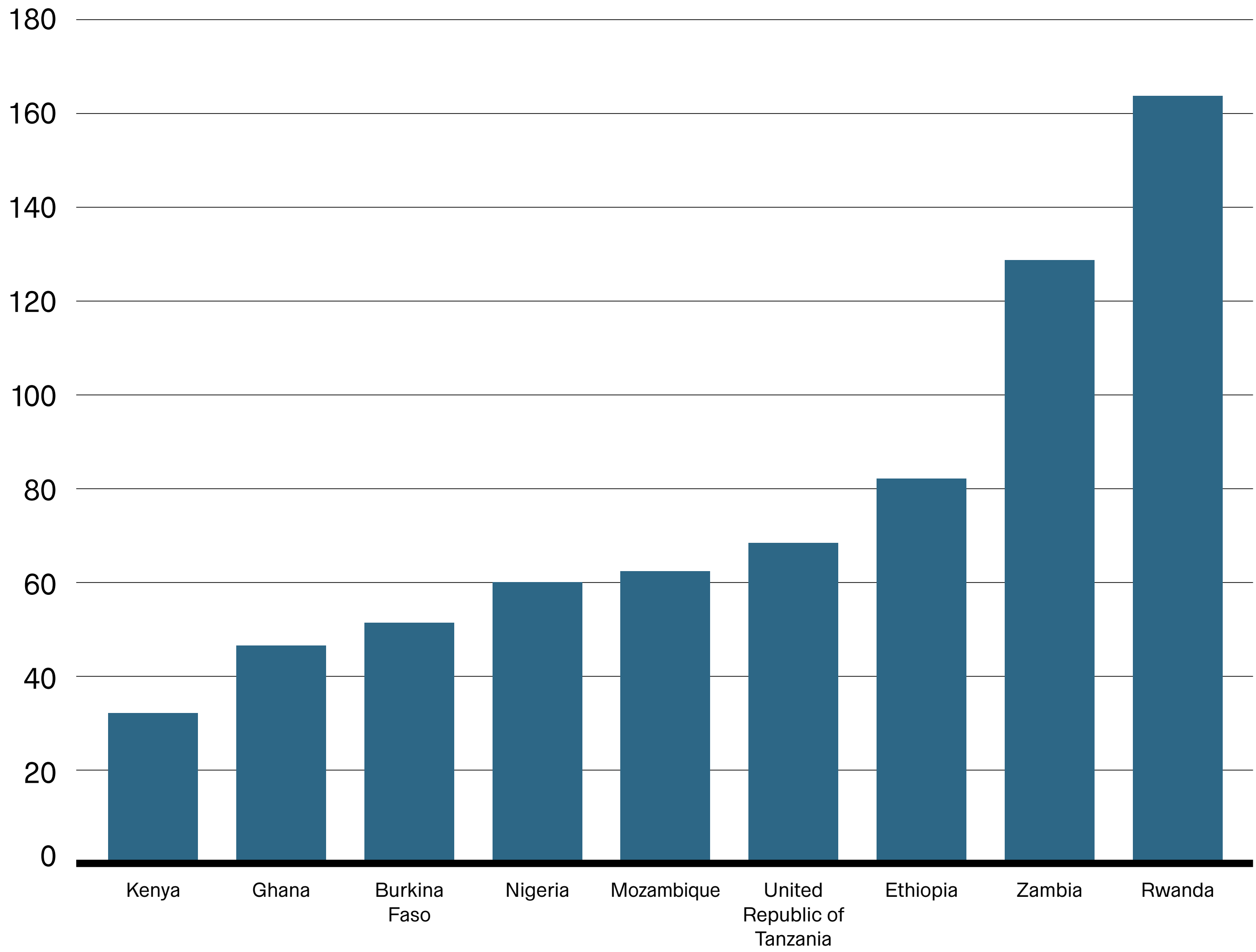
For these reasons, on-farm tractor utilization rates in much of Africa rarely exceed 300–400 hours per year in unimodal rainfall areas. Even in bimodal areas, the figure is rarely over 500 hours. To increase the utilization rate, tractors must move into new areas in pursuit of ploughing work, taking advantage of rainfall isohyets by latitude in West Africa and by height in Eastern Africa (FAO, 2008). The on-farm utilization rates of 1 000–1 500 hours per year suggested by Singh (2013) and Pingali, Bigot and Binswanger (1987) are unlikely to be achieved in the region and are therefore unrealistic. Rates of > 500 hours are feasible if tractors work off farm or are moved across districts and regions in pursuit of land preparation work (ComSec, 1991; Seager and Fieldson, 1984; FAO, 2008, 2015).

This is consistent with data from elsewhere. Misra (1991), Byerlee and Husain (1993) and Singh (2013), for example, report that medium-scale farmers in India and Pakistan hire out their tractors for about 700 tractor-hours per year, i.e. > 50 percent of the accepted economical rates for tractors in developing countries. Singh (2013) and Verma (2006) report average farm-utilization rates for India of 200–250 hours for rainfed areas and 300–400 hours for irrigated areas (assuming the tractors are located in the same district throughout the year). Therefore, **off-farm utilization is the hallmark of the profitability of tractor mechanization in Asia** (FAO, 2015; FAO-RAP, 2014). For Africa, the cost of ploughing is quite high in most countries (**Figure 18**) – equivalent to the price of 200–500 kg of maize in the local market.

Implementation of the recommended options requires concerted action at both the national and regional levels by different stakeholders, including: government departments involved in agriculture, finance, industry and trade; manufacturers and distributors of agricultural machinery, implements and equipment; and research, development and technology transfer agencies in both the public and private sectors at the national and subregional levels. Institutions, such as FAO, UNIDO, AGRA and AfDB, could play a central role in facilitating cross-country collaboration and studies to document lessons on successes, as well as failures, and in reaching a consensus on best practices.

Figure 18. Cost of ploughing 1 ha (2014, USD)

Source: IFPRI, 2016.



Element 2: Promoting innovative financing mechanisms for agricultural mechanization

Biochemical inputs, such as seeds and fertilizer, call for short-term investments; in contrast, **mechanization requires a long-term commitment**. In many countries where mechanization has occurred, financial support has been provided to farmers through credit or direct grants to procure machinery and equipment from public institutions. Nevertheless, the main investment effort must be made by the agricultural private sector, including small- and medium-scale farmers, who constitute the largest group (Alexandratos and Bruinsma, 2012; Collier and Dercon, 2009).

Element 2 aims to get the financial sector to provide funding through loans, credits and other instruments to the farming community to invest in mechanization inputs. It entails financing of investments in SAM interventions, including credit, subsidies and funding costs related to supporting infrastructure.

The government's role is to create an enabling environment whereby these financial organizations are able to commercially lend to the farmers and where the farmers are able to borrow and profitably invest in mechanization inputs and pay back their loans.

Options to be considered:

1. Development of financial mechanisms to facilitate the procurement of machinery and equipment by smallholders, within the context of sustainability of these interventions. Tailored and sustainable subsidies should be considered especially where they can catalyze the initial procurement of mechanization inputs with the provision that viable and sustainable farming enterprises ultimately emerge.

2. Improvement of access to economical resources for entrepreneurs, established artisans and technichians specialized in the repair and maintenance of agricultural equipment, in order to facilitate the development and upgrading of their business.

3. Consideration of collaterals for credit for financing the procurement of agricultural mechanization inputs. Land tenure, for example, plays an inordinate role in this regard.

4. Objective studies on the financing modalities and credit mechanisms (including subsidies) used by different countries for financing through both the private and public sectors. An inventory of best practices and lessons learned from past successful and failed mechanization projects is important for countries in the region developing their own Sustainable Agricultural Mechanization Strategy (SAMS).

5. Development of cross-country financing mechanisms – especially if machinery is going to be used across national boundaries.

6. Provision of incentives for innovative equipment complying with the sustainable intensification paradigm. On the other hand, equipment known to be harmful to soils may be restricted.

Element 3: Building sustainable systems for manufacture and distribution of agricultural mechanization inputs

As indicated in Chapter 3, the agricultural machinery and implements sector is quite small in many countries: 24 countries have < 1 000 tractors in use, six have 1 000–2 000 and 11 have 2 000–10 000. A further six countries have 10 000–30 000 tractors in use, while just one – South Africa – has > 67 000 (Figure 15). This indicates that the volume of trade in agricultural mechanization inputs is small in most countries. Agricultural engineering standard agencies recommend replacing 10 percent of the tractor fleet every year (Culpin, 1988; Kepner, Bainer and Barger, 1978; ASABE, 2012), which means that in the 24 countries with < 1 000 units, fewer than 100 tractors per year can be imported. Assuming that at least four to five brands are represented in each country, the number imported per brand is < 20 units. Furthermore, each brand produces a range of tractors with power ratings varying from 30 kW to > 200 kW. A franchise holder may actually deal with only 5–10 tractor units per year.

For a viable business, a dealer needs to import at least 50 tractors per year in addition to supplying spare parts and servicing about 300–400 units imported previously (Mrema, 2016). Therefore, a business must also deal in other equipment or vehicles, and the agricultural machinery business naturally becomes seasonal and accounts for a minor part of the enterprise. The situation is further aggravated by the fact that African entrepreneurs and farmers tend to maintain their tractors for many years. A nationwide survey in

The key issue is how to enhance the efficiency and effectiveness of the current systems using the regional economic community and other cross-border trading mechanisms.

the United Republic of Tanzania in 2005 revealed that 73 percent of the tractor fleet was > 15 years old and only 15 percent < 10 years old (Figure 20). This implies that the annual rate of replacement is much lower than 10 percent – more like 5 percent – and the commercial sustainability of the franchise holders and supply chains is in most countries is questionable.

Therefore, many countries in Africa (with small tractor fleets) have traditionally opted to use the government system to directly import agricultural machinery and implements – given the absence of private-sector importers. However, government systems cannot sustain the steady flow of spare parts and other services, and after a few years, imported machinery ends up in junkyards of broken machinery and implements (see Chapters 1 and 2). The resolution of the problems of commercial sustainability of the enterprises involved in the distribution and maintenance of agricultural machinery and implements is critical for the success of SAMA.

For a franchise to be commercially viable, greater numbers of machinery must be imported each year on a per country basis; if the internal demand is low, importation could be handled on a subregional basis. It is vital to create an enabling business environment that facilitates subregional importation. In addition, it is necessary to harmonize the standards and the testing of agricultural machinery and implements at the subregional level. At present, each country can demand testing before new equipment is allowed in, and this increases the cost of the imported machinery.

Another key issue to be addressed is the role of manufacturers of agricultural mechanization inputs, in particular in countries where current demand justifies local manufacturing or where regional trading agreements allow manufacturers to set up plants to cater for the subregion. It is important to consider incentives to encourage manufacturers to develop and manufacture agricultural machinery, implements and equipment to contribute to the sustainable mechanization strategy (e.g. CA equipment). In a few countries (e.g. South Africa and Nigeria), manufacture can be handled at the national level, but in most countries, regional collaboration is essential.

The importation sector for agricultural machinery and implements in Africa is dominated by a multitude of small-scale private-sector actors who manage the mechanization supply chains and distribution franchises. Due to their small size, the services they provide to farmers tend to be expensive. The public sector should not be involved in the direct operation and management of mechanization supply chains and franchises. The key issue is how to enhance the efficiency and effectiveness of the current systems using the RECs and other cross-border trading mechanisms.

Element 3 aims to establish and operate viable entities to manufacture agricultural machinery and implements, set standards and carry out testing, and support franchises for distribution, repair and maintenance services at the national and subregional levels.

The government's role should remain at the broad policy level, facilitating the common understanding and the implementation of regulations for the import, trade and manufacturing of equipment.

Element 3 contributes to the commercial sustainability of SAMA.

Options to be considered:

1. Establishment of mechanization supply chains and dealer franchise networks across the subregions. A key issue is how to assist manufacturers to establish supply chains and dealer franchise networks and to cater for areas where profit margins may initially be small or non-existent. Supply chains must be established not only for power sources, but also for other implements and post-harvest equipment, especially in countries where the current demand for machinery and implements is low.

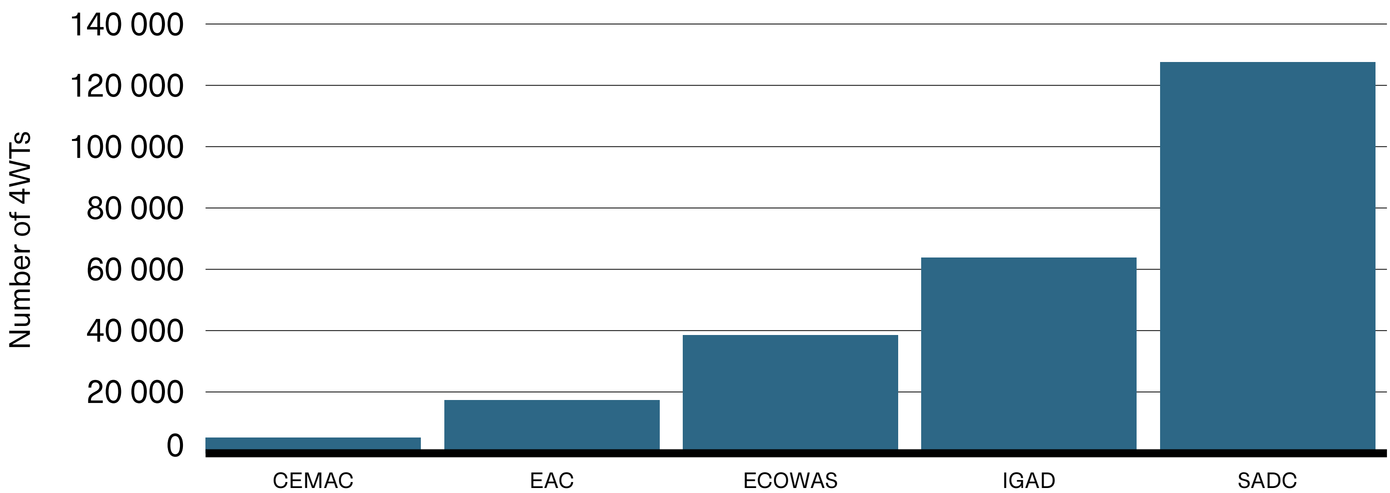
2. Creation of regulatory frameworks by governments, to facilitate the operation and management of mechanization supply chains and franchises through the coordination of chambers of commerce and business associations, which may also operate across national boundaries and offer services at the subregional level. It will be necessary for the RECs to play a leading role in catalyzing action in this regard.

3. Establishment and sustainable financing of testing centres for the certification and development of technical standards on a subregional basis. It is important that such centres command the respect of member countries and instil confidence in key stakeholders. In the light of current trends – urbanization and emerging concerns regarding increased food trade as well as quality and safety – government intervention is important at the individual country level and/or subregionally. Countries with low levels of machinery use require assistance identifying equipment of good quality and having manufactured machinery and implements regionally validated.

4. Development and implementation of mechanisms to harmonize testing protocols across the subregions/regions and create centres recognized by all countries. This is important to facilitate regional and global trade in agricultural machinery and implements and to reach a manufacturing capacity that meets the demands of a (sub)regional market.

Figure 19. Number of 4WTs imported during 2000–2007 in different RECs

Source: UN FAO Resource Statistics, 2010



Element 4: Sustainable mechanization across agrifood value chains

Past analysis of agricultural mechanization in Africa and elsewhere tended to be confined to on-farm production issues and failed to capture the off-farm uses of machinery and implements where, in many cases, farmers were realizing economies of utilization of their mechanization investments. This is particularly the case of tractor hire services operated by private entrepreneurs. It is, therefore of critical importance to widen the debate on mechanization to cover the entire agrifood chain from inputs through to on-farm production to post-harvest handling and processing issues as well as consumer protection, i.e. food safety. This is consistent with Agenda 2063 and the Malabo Declaration both of which emphasize the need to reduce post-harvest losses and increase value addition in the agricultural sector.

Worldwide experience shows that agricultural mechanization has been successful when there is an effective demand for the outputs of farming (including for on- and off-farm value addition) and sustainability of mechanization systems has to factor in the entire agrifood chain (FAO, 2008, 2015). Also sustainable agricultural mechanization technologies can contribute significantly in programmes for reducing losses along the entire agrifood chain. Given current demographic trends, SAMA will have to go beyond on-farm productivity issues to include post-harvest systems and the entire value chain. In essence, this contributes to the commercial sustainability of the agricultural mechanization strategy.

Element 4 aims to adopt a holistic view of agricultural mechanization and examine it across the value chain from on-farm production through harvesting and post-harvest handling to processing issues, with particular attention to the reduction of post-harvest losses. It is important to promote value addition to the outputs of farming, to incorporate food safety measures and to link the producer/farmer to markets.

This element contributes to the commercial sustainability of SAMA.

Options to be considered:

1. Consideration of the entire agrifood value chain – from farm inputs through to farming outputs reaching the consumer. By addressing the entire value chain, it is possible to properly factor in the investments required and appreciate who should pay to ensure sustainability of the agricultural sector. Reduction of post-harvest losses, strengthening of logistics and transportation, improving access to markets, value addition and product safety are all important issues and need to be accorded high priority in the development process; adequate agricultural mechanization can play a critical role in tackling some of these problems.

2. Factoring in the environmental impacts of mechanization technologies both on farm and off farm and in processing operations. It is necessary to consider emerging environmental global issues (e.g. climate change and greenhouse gas emissions and how they are related to overall farm production) and food safety, in particular mechanization technologies for the application of herbicides and pesticides.

Countries should not attempt to develop mechanization for all commodities at the same time. It is important to focus on a few priority commodities that can be easily mechanized. Experience around the world has shown that cereals (maize, wheat, rice etc.) can easily be mechanized with massive increases in total factor productivity. Thus, the focus of SAMA and choice of crops to mechanize depends on the level of total factor productivity to be achieved.

In order for it to work, mechanization must be profitable. Therefore, governments should prioritize profitable value chains. Mechanization needs to be linked to market-oriented enterprises to generate the cash flow needed to cover capital costs and facilitate loan repayments. Effective demand for farming outputs translates into effective demand for equipment and machinery services – but only if farming is profitable. Farm profitability is crucial, because the farm value of crops in many countries in Africa might be too low to support high production costs per unit of area (FAO, 2008). While mechanization can make the difference in farm profitability, its costs are elevated because of the high foreign exchange needs, expensive maintenance and repairs, and the requirement for thorough land clearance. If farms are not profitable before mechanization, there is little likelihood of them becoming profitable as a result of mechanization alone. In most circumstances, farm profitability is a condition of mechanization, not an outcome of mechanization (FAO, 2008).

Farmers use maize sheller provided to reduce post-harvest loss, Aafar region, Ethiopia.

PHOTOGRAPHY: ©FAO/TAMIRU LEGESSE

Element 5: Innovative systems for sustainable technology development and transfer

It is vital to consider research and development especially in the context of the roles of the private and public sectors. The hardware aspects of mechanization inputs and services are offered efficiently almost exclusively by the private sector. Linkages between public and private in research and development (R&D) need to be strengthened to ensure that the many prototypes emerging from large public-sector R&D establishments actually move beyond the laboratory/workshop. These prototypes must be licensed and transferred for development in the private sector, where manufacturers have a comparative advantage in producing and transferring technologies to farmers through their distribution, marketing and financing franchises for agricultural machinery and implements.

Moreover, the extension of agricultural mechanization technologies is achieved through a combination of public- and private-sector organizations with the private sector more involved in the hardware aspects and the public sector dominating the software side. Private-sector enterprises dominate the distribution and servicing of agricultural mechanization inputs, while the public sector is traditionally involved in the extension of know-how, such as cultivation and crop husbandry practices, and soil and water conservation methods. Unless new approaches are adopted, this division is likely to continue.

In addition, it is important to strengthen the capacity of public research and extension services, given their reduced capacity in the past few decades (FARA, 2014; IFPRI, 2014).

Element 5 aims to improve technology development, transfer and innovation systems. Prototypes must not remain on the shelf. However, the national R&D systems for agricultural mechanization are quite small in most countries and lack the critical mass necessary for innovation; they are not sustainably funded.

Options to be considered:

1. Research and development at the national and regional levels. The focus must be on common agricultural practices and needs, determining what works best under prevailing conditions in the countries and subregions.

2. Development of futuristic technology development scenarios. It is essential to consider how the private and public sectors can better work together to develop technologies for small-scale farmers, youth and women, with attention to areas, crops and other factors that have been neglected.

3. Enhancement of technology development, testing, transfer and extension systems. They have an invaluable role as SAMA requires new technologies all along the value chain: from systems and sustainable and efficient use of farm power resources, through new sustainable land preparation and crop husbandry techniques, to harvesting, post-harvest handling and processing.

4. Subregional collaboration for the development and transfer of technologies in order to avoid duplication of efforts and, where necessary, to achieve economies of scale and scope.

5. Provision of support for public- and private sector collaboration, including developing and enforcing systems for regional patenting and licensing of technologies and innovations. It could be effective to begin by establishing an open inventory of "who, where and what" technologies and expertise are available in the subregions.

6. Linking of national and regional research efforts with what is being done elsewhere in the world to determine technologies that have worked well and which could be adapted for use in agrifood chains in the Africa region.

Element 6: Sustainable transformation of land preparation and crop/animal husbandry practices

In most of Africa, land preparation is traditionally done either by adopting the outdated slash-and-burn system, or by using the hand hoe, draught animals or tractors and their implements. The focus is increasingly on the implements used for land preparation, with some experts advocating for the ubiquitous adoption of sustainable land preparation and crop husbandry techniques, such as reduced and zero tillage or CA, in the quest for environmental sustainability (ACT, 2014, 2015). Conventional tillage (CT) implements and practices – used for many years – are not considered environmentally sustainable.

With the exception of small areas in southern and eastern Africa, where initial steps have been taken towards adoption of CA and sustainable mechanization practices (Table 1), in most countries in the region, the attention has focused on harnessing mechanical farm power. It is noteworthy that in the United States of America, after over 70 years of concerted action and massive investment by the public and private sectors, only 25 percent of cultivated land had been converted to CA techniques by 2010 (Friedrich, 2013). In North and South America, Australia, New Zealand and South Africa, CA practices have been adopted on large farms using high horsepower tractors (Baker and Saxton, 2007). The adopted CA systems include no-tillage techniques combined with crop rotation and fallowing of land – techniques and practices that might be difficult to adopt in areas dominated by smallholder farmers, mainly due to limited availability of no-tillage seeding implements and land scarcity (Box 6).

As has happened in other regions of the world, Africa will increasingly need to turn to reduced tillage practices as it overcomes the farm power constraint without compromising either soil resources or land productivity.

Element 6 aims to transform crop production techniques from current CT methods to sustainable agricultural practices, such as CA and reduced and zero tillage adapted to local conditions.

This entails increased R&D effort to determine the best land preparation practices for each region in Africa – it is important to not simply copy what has worked elsewhere in very different farming systems. Local innovation and adaptation are necessary to develop appropriate practices that are sustainable and also adapted to, for example, the transforming local farming systems, farmers' knowledge, agronomical factors, soil conditions and availability of technology.

This element contributes to the environmental sustainability of SAMA and requires a revolution in land preparation techniques.

Options to be considered:

1. Assessment and analysis of current land preparation and crop husbandry practices in the region, in particular with regard to the types of implements used. It is important to consider their long-term environmental impact and sustainability, including transformation required to make them more environment friendly.

2. Short-, medium- and long-term planning. If Africa is to succeed in converting conventional tillage techniques to more sustainable land preparation and crop husbandry practices on most of its cultivated land, planning is essential. The switch to such sustainable agricultural practices requires a national and regional commitment to change from the conventional methods. It is vital to understand the implications of the change, including the costs involved in the short, medium and long term, and the impact on food production and productivity. Requirements include additional manufacturing capacity and investments for agricultural machinery and implements, and a massive research, development and extension effort at all levels. Given the influence of tillage techniques on the environmental impact of agricultural production, this issue concerns policymakers, environmental activists, farmers and the entire agricultural sector.

3. Adoption of sustainable land preparation techniques. The transformation of CT practices to the reduced land preparation techniques advocated under the sustainable crop production intensification paradigm requires a major change of mindset – greater than for the transformation of the farm power situation. Indeed, most stakeholders in the agricultural sector are used to conventional practices and technologies that have been adopted for decades or even centuries. Farmers must be convinced that such practices are no longer sustainable and that there is a need to go through a learning process and invest in new and expensive minimum or no-till implements and develop and learn new land preparation and crop husbandry practices. In essence, there needs to be a land preparation revolution.

The sustainable transformation of land preparation and crop/animal husbandry practices requires a revolution in land preparation techniques.

4.4. Making SAMA socio-economically sustainable

Element 7: Socio-economic sustainability and the roles of: i) small-scale farmers and their organizations; ii) women; and iii) youth

There are a number of socio-economic issues related to the roles of smallholder farmers, women and youth in agriculture. Element 7 puts into perspective how they are linked to sustainable agricultural mechanization strategies and contribute to the socio-economic sustainability of SAMA.

i) Smallholder farmers and their organizations

Smallholder farmers – whether producing purely for subsistence or for subsistence and the market – dominate the agricultural sector in Africa in terms of numbers. In the 1960s and 1970s, the impact of mechanization on small-scale farmers was cause for concern. Since then, experience from different parts of the world has shown that such fears were misplaced (ILO, 1973; FAO, 1975, 2008, 2013a, 2015; FAO-RAP, 2014). Smallholder farmers need not be an obstacle to mechanization, provided the right policy framework is in place, taking into account credit, land tenure, and technology development and transfer. Moreover, smallholder farmers can reap the benefits of scale of production and marketing by organizing themselves in institutions to reduce transaction costs and increase overall efficiency. Such institutions include group farming, farmer hire services, contract farming, community organizations, farm machinery rings and farmer cooperatives. Africa already has considerable experience in the operation and management of such farmer organizations, and the RECs can promote experience sharing. These issues are highlighted in the Malabo Declaration and the Agenda 2063 Aspirations.

However, experience from other parts of the world where mechanization has occurred indicates that it is the more enterprising and medium- and large-scale farmers who have pioneered the mechanization process. They have the resources for capital investment and have traditionally been in a position to establish rural enterprises and provide mechanization and other services to their compatriots, the small-scale farmers. Furthermore, the medium- and large-scale farmers are more likely to provide the volumes required to create viable post-harvest produce-handling, marketing and processing enterprises. However, there are examples in Asia of small-scale farmers who have widely adopted mechanization, thanks to the availability of custom hire services of scale-appropriate equipment meeting their needs. In planning for SAMA, it is important to consider the role and contribution of all farmers, whether from small-, medium- or large-scale farms.

Element 7, part i, involves institutional issues related to small-scale farmers, including land tenure, business licensing, farmer organizations and cooperatives, marketing of agricultural produce, and coordination at the national and regional levels. Strategies for SAMA must factor in all these issues.

Options to be considered:

1. Promotion of custom hiring services for sustainable mechanization of farming operations in agrifood value chains. Custom hiring is an important mechanism through which most smallholders are able to access agricultural mechanization services. Many services can be availed to smallholders on a custom hiring basis, from crop establishment to harvesting, crop processing and irrigation. Such services are efficiently provided by the private sector – hence the need for a suitable regulatory framework and support policies to encourage investment by the private sector and rural entrepreneurs. The cost of hiring machinery in Africa is high in several countries (Figure 18) – equivalent to the market price of 100–500 kg of maize at the peak of the season. Costs need to be lowered by fomenting competition and access to custom hire services.

2. Learning from business models involving interaction. Business linkages may be between medium-scale farmers who own farm machinery and can provide mechanization services to neighbouring small-scale farmers, or with entrepreneurs who can be incentivized to establish enterprises to provide mechanization services to, among others, small-scale farmers.

3. Development of policies (e.g. for credit, land tenure and technology) to support small-scale farmers to access mechanization inputs and services. Schemes include government-supported programmes, such as the "Accelerated Rainfed Arable Programme" (ARAP), through which the Government of Botswana helps smallholders procure mechanization services from private entrepreneurs. Others involve the production of cash crops (e.g. tea, coffee, cocoa and cotton in Eastern, Central and West Africa) or livestock production (beef in Southern Africa, dairy in Eastern Africa). Invaluable lessons about mechanization can be drawn from these programmes.

4. Promotion of different models of farmer groups, organizations and cooperatives which could be empowered to access mechanization services through local development and community-driven approaches. In addition, it is important to provide support for capacity building and preferential access to institutional credit to procure mechanization inputs.

5. Consideration of welfare and industrial policies to facilitate the mechanization adoption process. Experience from Asia shows that this is possible. In China, for example, the introduction of large tractors had a positive impact on the employment situation. Labour shifted from working on the farm to working in the agricultural machinery and mechanization services industry, with a considerable impact on rural industrialization (Wang, 2013; Renpu, 2014). In India, farm labourers have been employed in massive government-funded rural infrastructure programmes, resulting in a dramatic reduction in poverty (Singh, 2013). Similar welfare programmes exist in Africa to transfer resources to the poor and they can be used to facilitate mechanization.

The development of SAMA must take into account the mainstreaming of gender dimensions.

ii) Women and agricultural mechanization

Agriculture in Africa has certainly seen a shift from traditional labour-intensive production and post-harvest operations to labour-saving technologies and mechanization. The change comes in response to increasing labour scarcity and costs, as well as to the increasing feminization of farming due to the fact that more men than women migrate to urban areas. Compared with men, women have less access, control and ownership of land and other productive resources. In addition, mechanization technologies are often designed to fit the physical build of male workers while female workers lack appropriate technologies suited to their build. The development of SAMA must, therefore, take into account the mainstreaming of gender dimensions, as stipulated in both the Malabo Declaration and the Agenda 2063 Aspirations.

Element 7, part ii, involves institutional issues related to women farmers, their role in agriculture and how they can be assisted under SAMA.

Options to be considered:

1. Collection, compilation and analysis of gender-disaggregated data (labour, income, decision-making, access to assets and control of resources) to increase awareness among bank managers, research and extension leaders, and policymakers in order to reduce gender inequalities in access to resources and economic opportunities related to mechanization services.

2. Implementation of legislative changes to assure property rights of women to farm machinery and other related assets. Legal entitlement to land would also facilitate women's access to institutional credit.

3. Ensuring that mechanization positively contributes to the empowerment of women by increasing their labour productivity and reducing the drudgery associated with on-farm and post-harvest operations. Specific attention should be paid to ensuring that women are not displaced and do not lose their sources of income and employment in more traditional systems due to the introduction of mechanization technologies.

4. Design and development of gender-friendly mechanization technologies, capacity-building programmes and support systems for the provision of mechanization services.

iii) Youth and agricultural mechanization

Rural youth represent a huge potential resource for rural development, but they are increasingly migrating to urban areas due to a lack of profitable economic opportunities in rural areas. Indeed, rural areas are associated with subsistence farming, which utilizes low levels of mechanization inputs and is identified with back-breaking and arduous hand-tool technologies. The migration of young people results in "ageing" of the agricultural workforce, and potentially results in increased urban unemployment and greater numbers of regional and international refugees.

Young people have the potential for innovation and risk-taking, and thus represent a major pillar of smallholder commercial agriculture. However, in terms of access to land, credit and new technologies, they face more constraints than their older peers do. It is important therefore that youth are empowered to continue in or embrace farming, and the promotion of sustainable agricultural mechanization is one avenue. SAMA must factor in these issues related to the empowerment of rural youth. The involvement of youth in agriculture and other economic activities is an important component of the Malabo Declaration and Agenda 2063.

Element 7, part iii, involves issues related to youth in agriculture and their role in sustainable agricultural mechanization strategies in Africa.

Employees working inside a fish factory of a former small-scale fishing community in Zarzis, Tunisia.

PHOTOGRAPHY: ©NIKOS ECONOMOPOULOS.MAGNUM PHOTOS

Options to be considered:

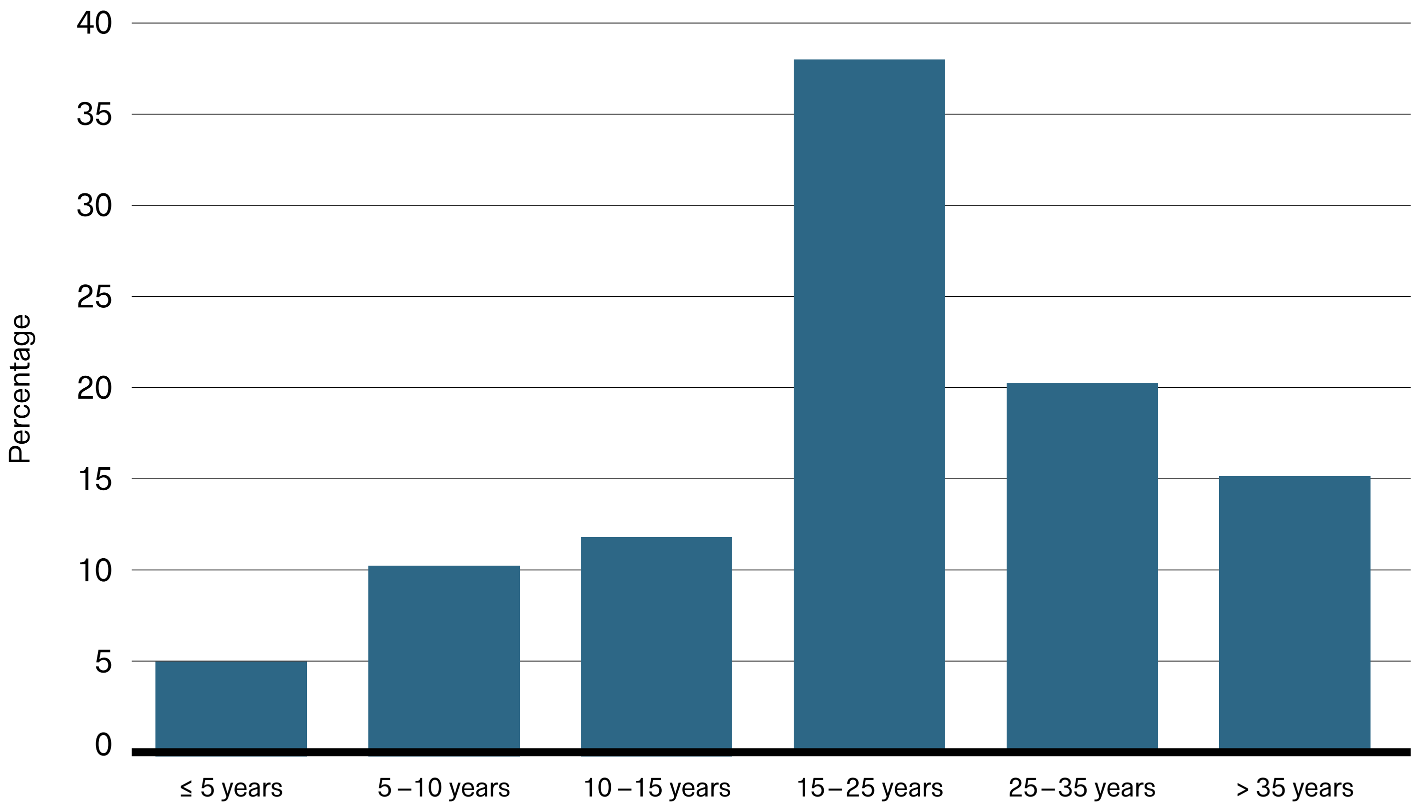
1. Provision of targeted training programmes designed to build the capacity of young people to gain access to mechanization technologies and to effectively and profitably operate and maintain equipment.

2. Introduction of vocational education. Given the shift to more knowledge-intensive farming and post-harvest handling operations in the region, vocational education is imperative in order to train youth to take on critical roles in the emerging commercially competitive agriculture and value-adding activities. Increasing the capacity to offer such training is critical to SAMA.

3. Encouragement and development of a cadre of pioneering young farmers and entrepreneurs. It is necessary to provide appropriate capacity and assistance through programmes such as those offered by several universities and local banks in the region to encourage young university and college graduates to get started in farming. International development agencies should be called on to facilitate such programmes.

Figure 20. Sample data of tractor age – United Republic of Tanzania

Source: TAMS, 2005.



Element 8: Human resources development and capacity building for SAMA

Countries in SSA have – with the support of many development agencies – invested in developing the human resources who have been instrumental in the implementation of mechanization programmes over the last five decades. Many specialists have or are about to retire from the system, and a second (and in some countries, a third) generation of experts is emerging. Furthermore, many of the university training and education programmes established in the 1970s and 1980s are in decline due to competition with other sectors (ICT etc.) and because of reduced public funding and a fall in employment opportunities in the public sector. Sustainable agrifood technologies and practices are relatively new in many parts of SSA; in contrast, the curricula of higher education and training institutions tend to be quite static. New areas of knowledge, such as precision farming and conservation agriculture are emerging and need to be mainstreamed. Finally, capacity development is essential at all levels, from farmers through to artisans, technicians and professional managers, in addition to policy and planning experts.

Element 8 relates to issues of capacity building of the human resources required at the artisan, technician and professional levels, relative to both hardware and software.

Options to be considered:

1. Capacity development – in terms of both human resources and institutional set-up for SAMA – throughout the region of Africa. A major challenge is strengthening the capacity of private- and public-sector technology development and transfer organizations, as they play a key role in the process of developing and transferring SAM technologies. Capacity building must involve ministries (of agriculture, education and science and technology), trade and industry, farmer organizations, and private- and public-sector agrifood supply chain stakeholders, in addition to those working in the agricultural machinery and implement supply chains.

2. Establishment of subregional and regional training programmes where economies of scale and scope command. Training programmes must be planned and made available, especially at the subregional level.

3. Revision of curricula of programmes offered by higher education and training institutions and organization of refresher courses for lecturers and instructors on innovative SAM technologies. Machinery manufacturers could be encouraged to attend courses and to bring their new equipment to be used in training.

4. Implementation of targeted training programmes, including vocational training, short courses and evening courses designed to build the capacity of stakeholders involved in mechanization supply chains (sales, repair, maintenance etc.).

5. Establishment of centres of excellence – endorsed by the public and private sectors – at the regional and subregional levels to carry out capacity development, research and technology transfer.

4.5 Overarching elements for SAMA

Element 9: Need for a long-term vision: policy and strategy issues

An overarching element of SAMA is the need for a long-term vision combined with commitment by a wide range of stakeholders. Policymakers in particular must take a long-term view and remain committed to it in order to mobilize the support of the other multistakeholders and convince them to commit themselves and their resources to the strategy for SAMA. This applies to programmes at all levels: local, national, subregional and regional. Vacillation and a lack of a vision in priorities and policies are the Achilles heel of past agricultural mechanization programmes and strategies Africa. The AU Heads of State and Government, through their decisions as stipulated in the Malabo Declaration and Agenda 2063, have now provided the long-term vision with regard to the mechanization of tillage operations.

Further, agricultural mechanization policy and strategy formulation requires inputs from a wide range of government ministries: agriculture; trade and industry; finance and economic planning; research and development; environment; and education. Each ministry has a role to play in the formulation and implementation of a Sustainable Agricultural Mechanization Strategy (SAMS). Decision makers at the policy level need to fully appreciate the complexities of the political environment and the trade-offs between short-term goals and long-term development objectives; in addition, they must understand the importance of environmental, socio-economic and commercial sustainability at both the national and regional levels. These issues are critical for the formulation of strategies for sustainable mechanization of agrifood chains and their implementation.

Element 9 involves issues of long-term commitment by all key stakeholders involved in the process of policy and strategy formulation and implementation of SAMA. The Heads of State and Government, through the Malabo Declaration and Agenda 2063, have provided the long-term vision with regard to the mechanization of tillage operations.

An overarching element of sustainable agricultural mechanization in Africa is the need for a long-term vision combined with commitment by a wide range of stakeholders.

Options to be considered:

1. Coordination of the inputs and actions of various stakeholders towards the successful formulation and implementation of SAMA at the national, the subregional and regional levels. Coordination is fundamental within the public and private sectors, which encompass a wide range of stakeholders, including farmers, managers of agrifood supply chains and their organizations.

2. Translation of the element into actionable programmes at the country level. Action may be coordinated by international organizations, such as FAO, UNECA, AfDB and AUC, as well as member countries and their RECs.

3. Definition of the priorities of SAMA, within countries and for different farming systems. Efforts should be directed to ensuring that SAMA is focused and consistent with the purpose of agricultural mechanization that countries have identified for their long-term agricultural and economic development plans. Priority areas for different agro-ecologies and farming systems need to be identified in order to ensure focused intervention on mechanization at the country level.

4. Development of industrial and trade policies for agricultural machinery and implements, the manufacturing of equipment locally and regionally, and the transfer of know-how etc. Policies require close coordination within governments, with the involvement of ministries of agriculture, trade and industry, finance and planning, environment and energy.

5. Documentation of past lessons and case studies to assist countries in the planning process and in scaling up their SAM activities. It is necessary to set up adequate and reliable databases of agricultural machinery and implements in use, including those locally manufactured and imported.

Priority areas for different agroecologies and farming systems need to be identified in order to ensure focused intervention on mechanization at the country level.

Element 10: Creating sustainable institutions for regional cooperation and networking

The current market for agricultural machinery and implements in each individual country in Africa is relatively small; furthermore, there is limited capacity for tackling major constraints, including lack of critical mass of experts on a per country basis. In the light of this situation, regional cooperation offers a mechanism to bring countries together to tackle common problems and learn from each other. It also avails mechanisms for achieving economies of scale and scope. During the colonial period and early independence years, regional organizations for agricultural research, such as the East African Agricultural and Forestry Research Organisation (EAAFRO), were quite effective and had relatively strong units dealing with agricultural mechanization problems (Boshoff and Minto, 1974). Funding and political problems, however, led to their collapse in the 1970s.

There have been calls in the past to establish a regional centre for agricultural mechanization in Africa (de Wilde, 1967; ComSec, 1991, 1992; CEMA/FAO, 2015). After the 1948 Goma Conference convened by the imperial powers then ruling Africa, a number of regional organizations were set up in the 1950s to deal with land-use planning and soil conservation issues (e.g. for Southern Africa, the Southern African Regional Commission for the Conservation and Utilisation of the Soil [SARCCUS], operative from 1952 to 1994). The dealings also involved a heavy dose of mechanization research (Rowland, 1974, 1994; Kayombo and Mrema, 1998).

Later, in the 1980s, the AUC (known as OAU at the time) established a number of regional technology development centres, for example: African Regional Centre for Technology (ARCT), Dakar, Senegal; and African Regional Centre for Engineering Design and Manufacturing (ARCEDEM), Ibadan, Nigeria. During the same period, several networks were established in SSA to deal with specific issues in various thematic areas: Animal Traction Network for Eastern and Southern Africa (ATNESA); West Africa Animal Traction Network (WAATN); South and East African Society of Agricultural Engineering (SEASAE); and Network for Agricultural Mechanization in Africa (NAMA) (ComSec, 1990, 1992).

During the 1980s and 1990s, subregional research organizations were established: Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA); West and Central African Council for Agricultural Research and Development (CORAF); and Southern African Centre for Cooperation in Agricultural Research (SACCAR). The various organizations fared differently, and much can be learned from their histories about institution building in Africa during 1960–2010 (FARA, 2014).

In Asia, the Regional Network for Agricultural Mechanization (RNAM) operated from 1977 to 1997 with a rotating secretariat. RNAM successfully developed a number of joint programmes that had a considerable impact on the agricultural mechanization scenario in the region (Lantin, 2013; FAO, 2015; FAO-RAP, 2014). In 2001, RNAM evolved into the Asian and Pacific Centre for Agricultural Engineering and Machinery (APCAEM), and later that year became the Centre for Sustainable Agricultural Mechanization (CSAM) in Beijing and affiliated with the Economic and Social Commission for Asia and the Pacific (UNESCAP).

Element 10 involves issues of regional cooperation and networking, including establishment and financing of a centre/network for SAMA. New institutions/organizations and/or programmes under CAADP and the RECs may be required.

Options to be considered:

1. Implementation of a study on the capacity and resources of current institutions and organizations dealing with agricultural mechanization in Africa.

2. Review of existing and past models for regional collaboration between the above-mentioned institutions and of modalities of financing joint programmes.

3. Implementation of a feasibility study on the establishment of a regional coordinating mechanism (e.g. centre or network) on Sustainable Agricultural Mechanization in Africa.

4. Development of projects and programmes for the involvement of RECs in spearheading SAM initiatives across subregions, including fostering more intercountry programmes.

5. Strengthening of the capacity of regional actors to provide support to member countries in planning and implementation of programmes under SAMA (regional and subregional units of FAO, UNIDO and UNECA as well as AGRA and AfDB).

6. Fostering of South–South collaboration, in particular to create and support a CSAM for Africa based on the successful Centre for Asia and the Pacific established in Beijing.

4.6. Formulation of strategies for SAMA at the country and regional levels

During the debates on mechanization in the 1960s and 1970s, FAO and OECD convened a global expert consultation on agricultural mechanization and employment in Rome in 1975 (FAO, 1975). It was recommended that each country formulate its own agricultural mechanization strategy (AMS) and FAO was requested to develop guidelines to assist member countries in this process. FAO developed the guidelines, which were first considered by its Committee on Agriculture (COAG) in 1979. The Asian Development Bank (ADB) and the Asian Productivity Organization (APO) also developed similar guidelines for use by their member countries (Rijk, 1983, 1989; APO, 1996).

The FAO guidelines detailing the process to be followed at the country level have been used to help member countries in Africa and Asia, in particular to develop their agricultural mechanization strategies (FAO, 1981). They were also adopted by RNAM for Asia. They were used to develop the AMS for a number of countries in Africa (Benin, Burkina Faso, Cameroon, Democratic Republic of Congo, Guinea, Malawi, Mali, Niger, Sudan, United Republic of Tanzania and Zimbabwe) (FAO, 2013b). It is hard to say how useful and applicable these AMS were, as there was no formal evaluation of the programme. It is notable, however, that while AMS was a core priority activity of RNAM during its first phase (1977–1981), it was not a priority activity in subsequent phases (Lantin, 2013).

FAO recently produced an updated version of the earlier guidelines geared specifically for sub-Saharan Africa (FAO, 2013b); however, the principles and conceptual framework basically remain those of FAO (1980). As noted during a review of SAM in Asia (FAO, 2015; FAO-RAP, 2014), the AMS guidelines developed by FAO in 1981 need to be reviewed for their relevance today. This is important, especially given the fact that the emerging scenario during the twenty-first century in agricultural mechanization is quite different from what pertained during the 1970s. New guidelines and processes are required to assist member countries in SSA, in particular with regard to policy formulation and development of strategies for SAM. They must take into account prevailing and future mechanization scenarios, as well as the experience gained in Africa and Asia over the last seven decades. As far as possible, guidelines and processes should avoid blanket prescriptions and should include significant contributions from experts in the member countries. The development of region-specific guidelines for SAM is possible through a regional consultative process (FAO, 2016).

4.7. Conclusion

This framework provides ten main elements and options for reconsidering the priority to be given to agricultural mechanization by African countries and developmental agencies in the process of developing long-term agricultural mechanization strategies for the continent during the first half of the twenty-first century. While there could have been more development in mechanization of on-farm operations during the last 50 years, progress was made in mechanization of off-farm post-harvest operations, such as grain milling.

Agricultural mechanization can help improve rural livelihoods by breaking labour bottlenecks that constrain productivity and growth of rural incomes while reducing the drudgery associated with using hand tools for land preparation and other farming and household tasks. More generally, mechanization can be viewed as a necessary dimension of development strategies that promote the commercialization and modernization of small-, medium- and large-scale farms and firms in order to accelerate agricultural development and initiate sustained poverty-reducing economic growth in both rural and urban areas.

While the benefits of mechanization generally depend on the availability of complementary, improved biochemical inputs as well as water availability and control, the intensification of agriculture requires an adequate supply of power during peak periods, for which a high degree of mechanization is essential. The ten elements for SAMA elucidated in this chapter demonstrate that mechanization is a complex and dynamic process that cannot be appraised only from the standpoint of factor substitution or farm-level profitability. Policy decision makers need to realize the complexities of the political environment and the trade-offs between competing short-run goals and longer-term development dimensions when drawing up mechanization strategies and policies.

In the most general terms, history suggests that mechanization should be viewed and supported within the context of a transformational approach to agricultural development; this is in contrast to the incremental approach adopted in Africa over the last five decades. In part, transformation focuses on larger enterprises with lower unit costs and more effective management, viewed within the supply chain. Thus, the focus of attention for mechanization would initially be placed on medium-scale farmers and agribusinesses. These farmers and firms can provide mechanization services to small-scale farmers and processors. They are also critical to sustainability of the institutions and organizations which service the agricultural sector, including smallholder farmers. They are the ones who have spearheaded the mechanization revolution in Asia over the past 60 years.

There is an immediate need to develop the technical, managerial and entrepreneurial capacity of such farmers and firm managers in Africa, and to provide planning and logistical support. While mechanization strategies might initially focus on medium- to large-scale farms and firms, there is clearly not one single pattern or pace of mechanization. There are mechanization options and opportunities suitable for smaller-scale farmers, although realistic consideration needs to be given to the key success factors identified in Chapter 3, namely, effective demand, adequate infrastructure, economic use rates, *It is important to develop the technical, managerial and entrepreneurial capacity of farmers and managers in Africa.*

efficient machinery and equipment supply chains and services.

History indicates that successful and sustainable mechanization cannot be established by direct public-sector provision of mechanical technologies and services. There are signs that this lesson has not yet been learned and there is therefore a risk that earlier failures will be repeated. The public sector can nevertheless effectively promote mechanization processes by:

1. establishing enabling environments;
2. enhancing capacity building;
3. supporting research and development;
4. strengthening national and subregional organizations and mechanisms which facilitate maximum spill-in and spillover of mechanization technologies and services; and
5. creating incentives by providing public goods and services to ensure that large areas and segments of the population are not left behind as agricultural sectors become more modern, commercial and mechanized.

Efforts to accelerate mechanization in SSA no doubt require substantial long-term political and financial commitments while grappling with new problems. Unless commitments are made to address these problems, the prospects for African agriculture and African farmers and consumers remain bleak. The process may at times be turbulent, but governments and leaders in Africa must remain steadfast and committed to long-term goals like sending the hand hoe to the museum within an agreed time frame. Otherwise, African agriculture will still be using basic tools and implements (like the hand hoe and ox plough) in the mid-twenty-first century, to the detriment not only of food security, but of overall economic growth on the continent. The pronouncements made by the African Heads of State and Government through the Malabo Declaration and the Agenda 2063 Aspirations do provide very clear marching orders on the priorities which need to be tackled first. The transformation occurring in the agricultural sector as well as in the wider economy in most countries suggests that now is the time for new initiatives on sustainable agricultural mechanization in Africa.

5. SAMA implementation mechanism: Agenda for action

PHOTOGRAPHY: UN PHOTO/GILL FICKLING

Baling in a mechanized system in the Enkangala grasslands of KwaZulu Natal (South Africa).

Each country in Africa is unique and the **needs of Africa are diverse** due to the ecological heterogeneity, wide range of farm sizes and the diverse commodities prioritized by each country. Hence, the framework suggests a programme-based approach to sustainable agricultural mechanization in Africa with each country developing its own strategy, based on its own needs and using the ten elements discussed earlier as a guide. These programme actions would then be embedded in national or subregional strategies. Moreover, these strategies would be developed while taking into consideration the global developments in each chosen commodity. **Four programme actions are proposed:**

1. Develop national Sustainable Agricultural Mechanization Strategies (SAMS)

The formulation of a strategy is part of an overall plan for the development of the agricultural sector and an essential step in the implementation of government policy. There is often confusion about the meaning of "policy" and "strategy":

- **Policy** is a general statement setting out what is to be achieved. Policy also states the general overall principle governing the accomplishment of policy objectives.
- **Strategy** is the next step down and is an overall plan stating how to achieve the policy goal. Plans, programmes and projects are the individual components of the strategy (FAO, 2013a).

The purpose of an agricultural mechanization strategy is to create an enabling policy framework, as well as an institutional and market environment in which farmers and other end users have as wide a choice as possible of farm power and equipment suited to their needs within a sustainable delivery and support system (Bishop-Sambrook, 2005).

The framework needs to be aligned with the specific needs and context of each country. Therefore, each country should develop their SAMS with due attention and consideration to their own needs, priority value chains, unique agro-ecology, environmental constraints, agricultural context, existing policy frameworks and market size. Countries with a strategy already in place should consider revising it to incorporate the key elements of SAMA and the sustainability considerations. The national SAMS must have a clear plan of implementation associated with long-term commitment from stakeholders, from both the public and the private sectors. This plan must articulate the implementation mechanisms, including the institutional, organizational and governance structures to be employed in implementing the SAMS.

Indicative projects and actions

- Carry out preliminary analysis on the current status of agriculture and mechanization in the country taking into consideration the needs of the various categories of farmers in the country.
- Identify priority value chains and their mechanization needs while ensuring that natural resources and the environment are conserved.
- Develop and implement appropriate business models for sustainable mechanization.
- Establish a national public–private forum as well as private–private partnerships on agricultural mechanization (monitor the profitability and sustainability of the SAMS)

2. Develop public–private partnerships

It is crucial that any efforts carried out by countries to develop their SAMS pay attention to public–private partnerships. The role of the public and private sectors is important for the development of SAM. While the public sector needs to create an enabling environment for the private sector to develop SAM in the country, the private sector has a key role to play in developing and steering SAM. Partnerships create synergies and understanding, and work together to address any challenges that might be encountered.

Indicative projects and actions

- Carry out appraisal of existing capacities.
- Establish an agrotechnology development public–private partnership to set up a challenge programme for the development of prototypes and to facilitate local manufacturing.
- Hold expositions, share fairs and forums.
- Develop models for capacity building, technology development and transfer.
- Support innovative start-ups that enhance access to mechanization services.

3. Increase national and regional cooperation and partnerships among faculties of agriculture and of engineering

Training, research and development need to be embedded in the development of SAMA. Unfortunately, although there are several faculties (Agriculture, Business and Engineering) working on different elements of SAMA, they fail to collaborate, not only in the region but also within institutions and countries. Efforts must be made to increase cooperation among staff and students of faculties at the national (between and within institutions) and subregional levels.

Indicative projects and actions

- Develop a database of available sustainable mechanization technologies and dealers in Africa.
- Develop joint concept notes for a business partnership forum that involves the major players and manufacturers in Africa.
- Put in place a task force to follow up actions and recommendations.
- Set up common agricultural mechanization curricula at the regional and subregional levels among institutions for the education and formalized training of farmers, engineers and agronomists, with increased collaboration among institutions.
- Undertake training activities aligned with regional needs covering all aspects of production and the value chain in order to strengthen local capacities.

4. Advocate for SAM

Advocacy for SAM is vital for Africa and should be promoted at all levels of production from small- to large-scale farmers, within the private sector and among policymakers. There is an urgent need to ensure that policymakers and extension workers understand and acknowledge SAM as a means to achieve agricultural production transformation in Africa. Further, the key elements of SAMA need to be promoted and understood by those who promote and implement SAM.

Indicative projects and actions

- Evaluate countries annually on status and progress of mechanization initiatives.
- Gather data and statistics.

5.1. Decisions by AU governance bodies on the draft framework for SAMA

The document on the framework for SAMA was presented by DREA and discussed at the Second Meeting of the Specialized Technical Committee (STC) on Agriculture, Rural Development, Water and the Environment, held in Addis Ababa, Ethiopia on 3 October 2017. In its presentation at the meeting, DREA noted that the framework for SAMA provides a menu of priority elements for consideration by countries in Africa in the process of developing their national strategies for sustainable agricultural mechanization.

The SAMA Framework is based on experiences over the last six decades on the issue of mechanization of on-farm and off-farm operations. The framework notes that mechanization strategies and policies may be country specific, but national strategies are best formulated when guided by insights and parameters identified within a framework that factors in outlooks with regional and global perspectives. Therefore, the framework for SAMA is an important element of Africa's agricultural transformation agenda and builds on the strategies and priorities already identified under the Malabo Declaration and Agenda 2063 Aspirations.

Farmers use a tractor-driven, direct seeder with a fertilizer attachment near Nyahururu, Laikipia County.

PHOTOGRAPHY: ©FAO/LUIS TATO

The framework for sustainable mechanization in Africa is an important element of Africa's agricultural transformation agenda and builds on the strategies and priorities already identified under the Malabo Declaration and Agenda 2063 Aspirations.

The Second AU STC endorsed:

1. the framework for SAMA as an integral part of Africa's rural and agricultural transformation programme; and
2. the call by the AU Commission to African governments to prioritize agricultural mechanization and be guided by the menu of the priority elements identified in the process of developing and implementing their national strategies for sustainable agricultural mechanization.

Key issues identified during the meeting:

1. Need to renew the attractiveness of the agricultural sector – especially among rural youth – and to generate employment.
2. Importance of smallholder farmers, constituting the bulk of agricultural producers in Africa, and the potential of creating "mechanization clusters" to address the lack of contiguity.
3. Potential of high-tech technologies, including those for precision agriculture, and the need for technology transfer to enable the productivity of local machinery manufacturing.
4. Need for investments that enable increased agricultural production and productivity, through aspects such as landownership and soil health.
5. Increase in resource-use requirements (e.g. water), especially in the context of climate change.
6. Need for funding mechanisms and regulatory frameworks.
7. Importance of capacity building and training, in both use and maintenance of agricultural machinery.
8. Need for a holistic approach, addressing both on-farm and off-farm segments in the value chain, with a broader framework of rural transformation.
9. Importance of collaboration among all stakeholders and partners.

5.2. Way forward

This framework for SAMA is a follow-up action on implementing aspects of the decisions made by the AU Heads of State and Government at their 23rd, 24th and 25th Summits held in Malabo, Addis Ababa and Durban in 2014, 2015 and 2016 respectively. The approval by the STC and ministers of agriculture is an important aspect of its implementation. The SAMA Framework should, therefore, be widely circulated to correct past misconceptions on agricultural mechanization and to allow a fresh start in the twenty-first century.

The SAMA Framework should be widely circulated to correct past misconceptions on agricultural mechanization and to allow a fresh start in the twenty-first century.

A. Implementation at the national level:

1. Formulate and evaluate **agricultural mechanization strategies**. Develop new guidelines and processes to assist member countries, in SSA in particular, in policy formulation and the development of strategies for SAM. Guidelines must consider prevailing and future mechanization scenarios as well as the experience of the last seven decades in Asia, Africa and LAC. The development of region-specific guidelines for SAM could be done through a regional consultative process (FAO, 2016).

2. Prepare new guidelines or update existing guidelines for the **collection of statistics** on SAM resources available at the country level.

3. Assist member countries in preparation of project proposals for **innovative financing investments** in SAM inputs.

4. Focus on **capacity building** by assisting member countries in strengthening institutions involved in agricultural mechanization, such as institutions for research and development, technology transfer and innovation testing and standards.

B. Implementation at the subregional and regional levels:

1. Prepare a concept note on establishment of a **Regional Network on Agricultural Mechanization** in Africa following the model of the very successful RNAM established in the Asia and the Pacific Region under UNESCAP in the 1970s–1980s and which has now evolved into a Centre for Sustainable Agricultural Mechanization (CSAM). This is in line with the consensus reached at the Nairobi Meeting in December 2016.

2.. Follow up with the World Bank on the **establishment of centres of excellence** on agricultural mechanization in both the Eastern and Southern Africa subregion and the West and Central Africa subregion. As announced at the Nairobi Meeting, the World Bank is already working on this.

3. Prepare a concept note on the **modalities of increasing financial flows** for investments in agricultural mechanization for small- and medium-scale farmers in SSA. AGRA is already working on some aspects of this, as is AfDB with subregional and local banks.

4. Explore the possibility of collaboration in the **testing of agricultural machinery and implements** at the regional and subregional levels. Explore the model adopted by the Asian and Pacific Network for Testing of Agricultural Machinery (ANTAM). Involve representatives of manufacturers from Asia, Europe and Africa, together with UNIDO and FAO, under the coordination of AUC.

5. Facilitate meetings of agricultural mechanization engineering departments offering **higher education and training** for capacity building; facilitate increased regional collaboration and learning from the experience of the last three decades in **human resources development**.

6. Mainstream and **promote SAMA** at the regional,subregional and national levels including the selection and appointment of champions for SAMA.

C. Development of a results framework for implementation of A and B for SAMA over five years:

1. Develop an **implementation plan for SAMA**, as directed by the STC at its meeting on 3 October 2017. The plan will be developed by AUC, FAO and other agencies, and will include a detailed results framework as soon as possible.

5.3. Conclusions

Lessons from the experience in agricultural mechanization during the second half of the twentieth century clearly show the need for transformation or adjustment of the farming system, in order that the main indivisible mechanical technologies available may be utilized efficiently and effectively. While divisible biochemical technologies (e.g. HYVs, fertilizers and plant protection chemicals) can be adjusted to fit prevailing farming systems, this is not the case for indivisible and lumpy technologies (e.g. tractors and combine harvesters). Even more important is the fact that the manufacture, distribution and on-farm utilization of such technologies is normally dominated by the private sector, which means that farmers can only access them through commercially viable enterprises. Efforts to design and manufacture special tractors and implements or to set up government-operated tractor hire schemes proved unsustainable and were abandoned after a few years of trials (Holtkamp, 1988; Starkey, 1988; FAO, 2008).

Leaders in SSA understand the importance of agricultural mechanization in the future vision of agricultural development and food security for the region, as pronounced in the Malabo Declaration and Agenda 2063 Aspirations. Nevertheless, efforts to accelerate mechanization require substantial long-term political and financial commitments in the face of great challenges. Without a commitment to address the problems, the prospect for African agriculture and farmers is likely to remain bleak. For this reason, African leaders have prioritized the banishment of the hand hoe in farming. Both the Malabo Declaration and Agenda 2063 make this a high priority item in agricultural mechanization – to be achieved by 2025. Liberation of the African farmer from the drudgery associated with using the hand hoe as a basic tool in agriculture is strongly supported by African leaders and politicians (AUC, 2016). This is consistent with the strategies of a number of countries to significantly reduce by 2035 the area tilled by the hand hoe.

Fortunately, there are also signs that in some countries, a new cadre of farmers is emerging capable of spearheading and catalyzing the sustainable mechanization effort. They need to be supported and encouraged to provide services to other small-scale farmers. Governments and leaders in the agricultural sector in Africa must remain firmly committed and take a longer-term perspective of mechanization, just as Asian governments and leaders did in the 1960s and 1970s. Other developing regions have mechanized primary agricultural activities, such as land preparation, over three to four decades and they are now moving on to even higher technological levels. Now is the time for transformative action on sustainable agricultural mechanization in this region. This framework for SAMA provides some ideas on what needs to be done while taking note of the experience of the past.

It is also recognized that although many successful mechanization programmes and projects are location specific, national strategies are best formulated when guided by insights and parameters identified within a framework factoring in outlooks with national, regional and global perspectives. The African region is so large and diverse that a single agricultural mechanization strategy would be too prescriptive. However, several aspects related to policy formulation and strategy development could benefit from a common approach and the aim of this framework is to provide the critical elements that need to be considered and included in the strategies for SAMA at the country, subregional and regional levels.

Agricultural transformation is already underway in several African countries, following the adoption and implementation of the Comprehensive Africa Agriculture Development Programme (Africa's main policy framework for agricultural development). However, much remains to be done to transform both on- and off-farm mechanization and liberate the African farmer from the ergonomically debilitating hard labour associated with farming dominated by hand-tool technology. The role of agricultural mechanization goes further, for example: increasing productivity by breaking labour bottlenecks that constrain on-farm production and growth of rural incomes; and making agribusiness attractive to the youth and educated. On a larger scale, mechanization should be viewed as a necessary component of a transformational development process that promotes the sustainable commercialization and modernization of small-, medium- and large-scale farms in order to accelerate agricultural development and initiate sustained poverty-reducing economic growth in both rural and urban areas.

Areas of immediate action include the development of detailed guidelines to help member countries in the design and formulation of policies and strategies for SAMA covering all three pillars of sustainability of agricultural mechanization interventions – commercial, environmental and socio-economic. Most of the existing guidelines were developed in the 1970s and 1980s, when development paradigms emphasized public-sector dominance and subsistence food security. There is an urgent need to develop mechanisms to increase the flow of financial resources for agricultural mechanization investments from commercial banks and other financial institutions, as emerging small- and medium-scale commercial farmers and entrepreneurs require access to loans. Mechanization can only be regarded as sustainable when local financial institutions are actively involved in lending for agricultural machinery and implements to African farmers and entrepreneurs.

Strengthening of the national, subregional and regional institutional infrastructure supporting the development of agricultural mechanization is essential in many areas, including: research and innovation; standards and testing; manufacture and trade in agricultural machinery and implements; technology transfer and extension; and capacity building in all fields. This may involve the institution or strengthening of centres of excellence, and the establishment of coordinating mechanisms at the national, subregional and regional levels. Given the current small size of many national markets for agricultural machinery and implements, the implementation of many activities envisaged under the SAMA Framework requires regional cooperation in order to attain economies of scale and scope, and to create sustainable organizations and institutions with the requisite critical mass of expertise and facilities. The experience in other regions of the world shows that the success of agricultural mechanization in Africa depends on the involvement of national, regional and international organizations and institutions, including national governments, farmers organizations, AUC, RECs, AfDB, AGRA, and development organizations, such as FAO, UNECA, UNIDO and the World Bank.

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This framework presents ten interrelated principles/elements to guide Sustainable Agricultural Mechanization in Africa (SAMA). Further, it presents the technical issues to be considered under SAMA and the options to be analysed at the country and sub regional levels. The analysis in the framework calls for a specific approach, involving learning from other parts of the world where significant transformation of the agricultural mechanization sector has already occurred within a three-to-four decade time frame, and developing policies and programmes to realize Africa's aspirations of Zero Hunger by 2025. This approach entails the identification and prioritization of relevant and interrelated elements to help countries develop strategies and practical development plans that create synergies in line with their agricultural transformation plans. Given the unique characteristics of each country and the diverse needs of Africa due to the ecological heterogeneity and the wide range of farm sizes, the framework avoids being prescriptive.

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