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**Status of Smallholders Agricultural Mechanization
in Sub-Saharan Africa**

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Summary

The mechanization of Africa agricultural system is the next major milestone to ensure improved productivity, of the ailing sector that holds the economic future for the continent. Because agriculture provides livelihood for majority in Africa, the sector holds the fulcrum for its economic development, job provision for growing youth population and overall social wellbeing. Low productivity of agriculture in Africa is largely due to poor use of technologies as well as the use of manual equipment's that are characterized with drudgery. Thus, Africa agriculture is unattractive and needs to maximize mechanical advantage to enhance productivity, quality and benefit from economy of scale. This review study examines the mechanization of the smallholder's systems in Africa. It builds on the history of its mechanization and identified the constraints that require action to ensure the growth of the sector. Efforts to use external tools for agriculture dates to antiquity and this has grown over years till recent decades where motorized machines were developed to aid production, processing, packaging and storage activities for crop and livestock. The inflow and use of these machineries in Africa agriculture is low and largely due to institutional factors that are overlooked by the policy systems. Apparently, Africa will have to devise its own unique mechanization strategy to suit its unique smallholders' system that is defined by the land inheritance pattern and the national land tenure system. The land tenure system in most Africa countries prevents large scale agriculture as well as the use of large tractors and other earth moving equipment's that are suitable for such. Governmental efforts in the past did import tractors and other implements to encourage mechanization, these intervention in most countries did experienced failure across board for reasons which include; lack of knowledgeable personnel to manage the equipment, cost of the equipment, underutilization, lack of spare parts and largely, the running of the program by the government civil service system. Recent development efforts have seen the importation and use of smaller tractors from some Asian countries. The two-wheeler motorized equipment's are gaining ground slowly especially in the regions where animal traction is not effective due to livestock failure. Even at this notable change, considerable actions are still required to ensure that adaptable machineries are made available and affordable by the smallholders. Such action needs to effectively give attention to building systemic capacity to manufacture and maintain the equipment's. A partnership between the public and private sector actors will also be vital to ensure sustainability. In the short run, the establishment of private sector led hiring facilities could be encouraged and moderated by policies.

Key Words:

Mechanization, Tractors, public-private-partnerships, equipment hiring

Introduction

Background on land, population and climate in SSA

The aim of this report is to review the status of Agricultural Mechanization in Sub-Saharan Africa. The report is intended to inform the development of action for effective handling of the mechanization challenges to contribute to sustainable economic growth and poverty reduction in Africa. It aims to develop pathways through which African farmers and rural communities can achieve higher intensities in agricultural production through investments in appropriate mechanization. This has become necessary given the growing consensus that only through appropriate mechanization will Africa be able to feed its rapidly growing urban population. Food production in Sub-Saharan Africa (SSA) must increase by 70% in order to cope with the expected population increase, while at the same time addressing pertinent global challenges such as environmental degradation and climate change.

Sub-Saharan Africa (SSA), according to Geoffrey et al., (2011), is a region with the largest land area compared to other developing regions in the world. It has a land surface area of 24,241,910 km² compared to 20,421,620 km² for Latin America and the Caribbean (LAC); to 16,298,850 km² for East Asia and the Pacific (EAP); to 8,777,910 km² for the Middle East and North Africa, and to 5,131,070 km² for South Asia. Sub-Saharan Africa also has the fastest growth in agriculture with the greatest level of agricultural imports, highest proportion of rural poor and the greatest potential for smallholder-agriculture-led poverty reduction. The region, according to Bationo et al. (2006), is also home to a large diversity of agro-ecological climates, ranging from the arid drylands of northern Mali, to the humid tropics of the Congo. SSA is divided into six agro-ecological zones, differentiated by the length of the potential growing period for rain-fed agriculture, with rainfall ranging from over 2,000 mm/year in central Africa, to less than 400mm/year in arid areas. The current SSA-population of 800 million makes it one of the most sparsely populated regions, but also the fastest growing. As in other developing regions world-wide, population in SSA has steadily increased over the last 50 years and is projected to reach around 1.7 billion by 2050 (Geoffrey et al., 2011).

Agriculture in SSA

Sub-Saharan Africa's rural economy remains strongly based on agriculture relative to other regions. Agriculture in SSA (excluding South Africa) employs 62% of the population and generates 32% of gross domestic products (GDP) and employs 65% of the labour force. In some of the SSA African countries, agriculture contributes 80% of trade in value and more than 50% of raw materials to industries (Staatz and Dembele 2007; Anon, 2015). Despite being a crucial sector in many economies, agricultural productivity on the continent is still very low, with agricultural activities largely based on smallholder farms. Such farms are of two hectares

or less, representing 80% of all farmlands in SSA and contributing up to 90% of the production in some SSA countries, (Wiggins 2009) using various levels of mechanization. A sizable percentage of these smallholders are women, responsible for key components of household production such as weeding, harvesting and processing. No less than 45% of the agricultural labor force in developing countries is occupied by women, with that figure rising to 60% in some part of Africa (FAO 2016). Further, women often independently grow non-cereal crops for income and are increasingly heading rural households due to male urban migration, (Oxfam 2008).

Despite the above challenges, the growth in agricultural GDP in SSA has been relatively strong in recent decades and was the highest of the developing regions in 2009. Overall, increases in agricultural production have kept pace with population growth (FAOStat 2010, IFAD 2010). However, in contrast to other developing regions of the world, this has occurred largely through expansion of the cultivated area onto the region's relatively abundant land, rather than increases in land productivity. Similarly, the agricultural sector faces growing global and regional demand for agricultural products for food, feed, industry and fuel, which factors are aggravated by continued population growth combined with urbanization.

Agricultural experience in some of the growing regions in the world

Experiences in other continents, especially in the developing economies of Asia and Latin America, show that agriculture has been transformed in recent years into a progressive and more productive industry. Investments in irrigation, fertilizer and high-yielding varieties went hand in hand with increasing power inputs, mainly in the form of tractors for land preparation and diesel engines for irrigation. This has enabled farmers to intensify production and improve their quality of life as well as contribute to national and local prosperity. Meanwhile, in most of Sub-Saharan Africa, where farming systems were more complex across variable agro-ecological zones, quality seed and fertilizer were not backed by sufficient irrigation support and mechanization inputs. Sub-Saharan Africa was therefore largely bypassed by the "Green Revolution" that has helped transform agriculture and reduce poverty in Asia and Latin America. Although the use of agrochemical as one of the pillars of the Asian green revolution has been criticized widely, mainly for its potentials to lead to environmental degradation beyond the farms into water bodies and its consequence on human health. Thus, the focus of research and development expert has shifted to sustainable agricultural production techniques with concurrent consideration for social, environmental and economic issues.

In SSA, the use of mechanization is substantially lower than in other regions. Only 15 tractors are in use per 100 km², in contrast to around 170 in South Asia Region(SAR), and 100 in Latin America and the Caribbean. The scarcity of machineries leads many farmers in SSA to suffer significant post-harvest losses from grain shattering, spillage during transport and from bio-deterioration during each step of the chain, including storage. Losses in the East and Southern

Africa region, for example, have ranged from 14%-17% each year from 2003-2009 (weighted average of all cereals), (PHL Network, 2010). However, relatively low-cost storage, transport facilities and protocol are increasingly available in forms and at prices accessible to smallholders based on innovations from Southeast and South Asia (World Bank/FAO 2010).

Agricultural Mechanization

Agricultural Mechanization as defined by many authoritative authors (Clerk, 2008, Mrema et al, 2008, Rijk, 1990), refers to the use of agricultural tools, implements and machines for land preparation, crop production and management, irrigation and drainage, crop harvesting and handling in preparation for storage, and for on-farm processing and value addition.

Mechanization operations also extend to a range of activities involving livestock management sub-activities which include livestock food/feed preparation, mechanized livestock feeding, watering, milking and cleaning of livestock residential shades. Besides the major crop and livestock “use” activities above, other activities associated with mechanization involve design, development, testing, manufacture, distribution, marketing, maintenance and repair of any type of the agricultural tools, equipment (implements) and machinery with a view to enhancing the effectiveness and productivity of human labor, bearing in mind prevailing economic, human and social constraints, as well as environmental and gender issues.

Mechanization is a major catalyst of agricultural production input and for rural development. It increases the power inputs to farming activities, hence putting more land into production; it reduces drudgery in farming activities, thereby enhancing lifestyles; it improves the timeliness and efficiency of farm operations leading to rapid accomplishments of tasks that are difficult to perform without mechanical aids. Mechanization also improves the quality and value of work, produce and processed products, and provides employment and sustainable rural livelihood. Finally, mechanization provides agriculture-led industrialization and markets for rural economic growth.

Fonteh (2010) specifically argues that mechanization strives to reduce drudgery in agriculture, increase land and labor productivity through timeliness of operations and efficient use of inputs. The goal is to increase the income, safety and comfort of crop and livestock farmers, create jobs and improve farmers’ living standards. **The saved labor due to mechanization can be utilized for** marketing of fresh and processed products, manufacturing and sale of improved agricultural tools and implements, and for other allied farm and non-farm activities.

Applying the above broad definition, it is obvious that agricultural mechanization, in one form or another, exists in every country and on every farm. Agricultural mechanization involves three main power sources:

Hand tool technology, the simplest and most basic level of agricultural mechanization based on use of tools and simple implements using human muscle as the main source of power

- Draught animal power technology that refers to implements and machines utilizing animal muscle as the main source of power.
- Mechanical power technology, the highest technology level in agricultural mechanization that varies widely and embraces all agricultural machinery that obtains its main power from other sources other than muscular power. Under this category fall machines like tractors, motorized crop processing and value adding equipment, as well as machines and equipment for water pumping and conveyance for household, crops and animal use.

Hand tool technology

Historically, agriculture in sub-Saharan Africa depended on and still heavily depends on primitive, labor intensive, low productive and time-consuming hand tools mainly for land preparation and for all the activities along the commodity value chains. Agricultural hand tools/technologies were initially made of shaped pieces of hard woods or of stones. Later the soil engagement components of the above tools were made of various grades of cast iron and steel and have mostly been improved. Good examples of the human muscle power technologies in current use are the hand hoe, panga, slasher, sickle and spade. Any of such technologies (see Fig 1 below), have implicit limitations in terms of energy and operational outputs especially in a tropical environment as they are extremely strenuous labor intensive to use. The associated farming communities are therefore locked into poverty, food insecurity and reliance on food import, making farming strenuous livelihood. The use of hand tool technology also places severe limitations on the amount of land that can be cultivated per family. It also reduces the timeliness of farm operations and limits the efficacy of essential operations such as cultivation and weeding, thereby reducing crop yields.



Fig. 1: Typical use of hand tools for land tillage, rice harvesting and threshing (Arusha, Tanzania)

Based on the above challenges, the communities stay in farming because they have no choice. The high labor intensity of the rudimentary technologies above has clearly scared off the bulk of SSA youths from farming, causing most of them to move to urban areas in search of jobs, which in turn are not easily accessible, (Mrema *et al.*, 2008). The frustrations that emerge due to these contradictions have given birth to rising social vices and insecurity especially in urban areas.

In response to the above challenges, most of the agricultural mechanization-related training and research institutions in sub-Saharan African countries (agricultural technical colleges, universities and research institutions hosting agricultural engineering programs, as well as agricultural engineering related private manufacturing firms) have for over two decades now embarked on developing and promotion of a wide range of improved manually operated tools and technologies targeting key cereals, legumes, oil, horticultural and fruit crops value-chains. These technologies are usually documented in small technical brochures and leaflets but have unfortunately not been widely spread. Examples of the improved hand technologies are:

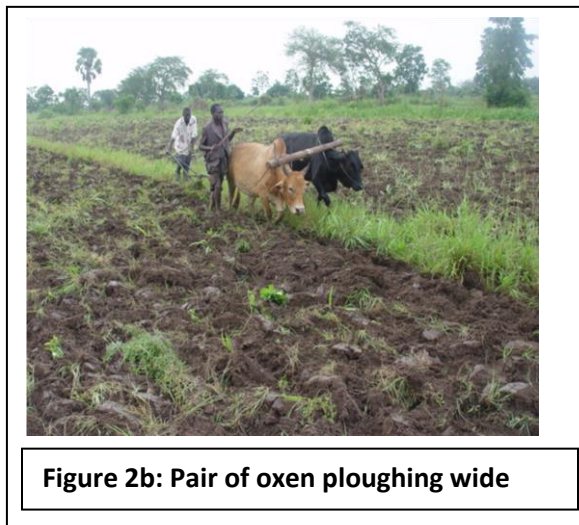
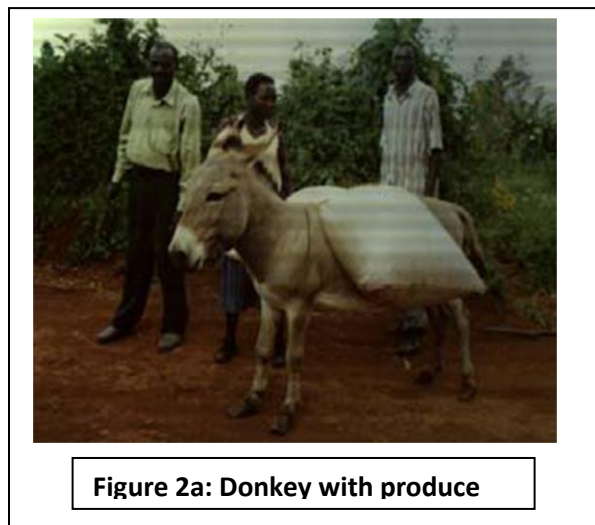
- Hand pushed, and hand pulled row-planters for key cereals, legumes and oil crops;
- Hand-pushed weeders for row planted crops above. Manual weeders for both upland and low-land rice are now available in the markets;
- A wide range of designs of hand operated knapsack sprayers (mainly imported) for crop pests and disease management and for weed control;
- Hand-pulled sprayers for use majorly for a wide range of row-planted crops (cereals, legumes, oil-crops, horticultural and fruit crops, etc.);
- A variety of designs of manually operated treadle pumps for water pumping and delivery for household use, livestock watering, and for smallholder irrigation systems;
- A range of manually operated postharvest handling and value addition technologies: groundnuts and maize shellers, pulverizers and grinders; groundnuts-sesame-cotton seeds oil expellers;
- Cassava and sweet potato harvesting, peeling, slicing and grating tools;
- A wide range of improved hand-pushed and pulled technologies for transportation of farm produce within and outside farms.

Each of the above manually operated technologies bears positive improvements in terms of reducing human drudgery, improving productivity and in most cases improving output quality.

Investment is therefore needed for rigorous promotion of such technologies to effectively aid smallholder farming communities that constitute the majority of farmers in sub-Saharan African countries. Because of affordability of such technologies to a good proportion of farmers, the technologies would increase farming outputs and qualities, save the smallholder farming communities from the extremely strenuous energy currently used in farming and improve their wealth and livelihoods. The technologies would contribute to reduction of massive movements especially of youths to urban areas in search of “better” livelihoods.

Draught animal power technology

In the early 1940s most countries in SSA witnessed the introduction of draught animal power technology into farming and mainly for land opening (ploughing) operations (Stanley 1999). Indeed, the ministries and institutions responsible for agriculture in SSA have since made rigorous efforts in promoting animal traction technologies among smallholder farming communities as part of their agricultural extension services. Between 1980 to 1990 the number of work animals in SSA grew from 10 million to 12.95 million, representing 4.5% of the total cattle population in SSA then estimated as 289,966,000 (FAO, 2016). Of the work animal population, about 53% were in Ethiopia, 25% in parts of four other countries (Zimbabwe, Kenya, Tanzania and Uganda), and the remaining 22% scattered in the semi-arid parts of West Africa, Sudan and Madagascar, (Mrema et al., 2008). Formal trainings and workshops were regularly organized to expose farming communities to the technology. Interaction visits, district and national shows were also organized as a way of popularizing the technology. In some of the SSA countries formal training centres/schools for animal power technology trainings were established. Uganda, Kenya and Tanzania in East Africa, each established a formal factory for the manufacture of several types of animal traction equipment but with emphasis on animal drawn ploughs. The work animals involved were mainly oxen, donkeys, and in some areas horses, etc. This scenario is still widely used in SSA Region as illustrated in Fig.2 below.



One of the important animal technology promotional arrangements in many countries in SSA, prior to the 1980s, was the implementation of favorable policies on provision of loans, subsidies and other incentives to facilitate purchase of draft animal power (DAP) equipment and related inputs to boost agricultural production. As a result, about one million animal drawn implements including ploughs, weeders, seeders and carts were bought by farmers. Around 1980s however, most of the countries in SSA initiated structural adjustments on the above, removing incentives that facilitated easy acquisition of DAP technologies. According to Pearson (1998), by 1984/85 for example, such “modified policy” reduced farmers’ capacities to renew their farm implements or buy new spare parts. As a result, most farmers had to resort to local blacksmiths for required spares so as to maintain their equipment. The blacksmiths-made parts were however of much lower quality compared to the original parts.

Despite some of the above challenges, these findings do indicate that work animal technology, has since its initiation resulted in positive changes in SSA farming as it has significantly contributed to the reduction in human drudgery and led to saving of labor and expansions in farmed lands due to its higher productivity compared to manual labor. Another challenge has been the inadequate adoption of draft animal power technologies beyond land ploughing and to some extent, for transports within and outside farms. Future investments in draft animal technologies must therefore include such vital farm operations as row-cropping and weeding, fertilizer applications, pests and disease managements, water pumping for irrigation, crop harvesting with primary processing, transporting agricultural inputs and products into farms, and within and outside the farm.

Specifically, in Uganda and in most countries in SSA, (Sims *et al.*, 2010, Odogola *et al.*, 2012) a number of challenges were noted related to the adoption of draft animal power technologies. These included:

- Inadequate awareness by some of the farming communities of the wide-range benefits that can be derived from use of work animals;
- Severe cultural prejudices hindering integration of livestock into farming systems in some locations in SSA countries including most areas in Rwanda and Burundi, central and western parts of Uganda;
- In some locations the use of work animals is hindered by the presence of tsetse flies and tick-borne diseases such as east-cost fever;
- Another challenge is occurrence of severe and prolonged droughts due to climate change;
- Access restrictions in agricultural areas on very steep hills and undulating topography, heavy and rocky soil conditions, and areas occupied by tall elephant grass with tough root system, all posing extremely high and unsustainable traction demands to work animals.

As regards future prospects of work animals in SSA, Pearson (1998) strongly argues that small scale farms will not rely on tractor power as on large commercial farms. The power source that will meet smallholder farm energy requirement will rather be a combination of hand tool technologies, work animals, and two-wheel tractors (2WT), with draught animal power being a very significant component. Pearson (1998) further points out that in developing countries, the move to motorize source of power for cultivation and transport is likely to occur only where certain conditions exist, and these are: a) presence of large farms; b) easy access to spare parts and maintenance services located near urban areas; c) tractor hire schemes working efficiently and d) profitable market systems for cash or cereal crops funding properly.

On the other hand, work-animals will continue to be profitable source of power with comparative advantage over tractors under the following conditions: a) on small farms not more than three hectares, b) where timeliness to cropping is crucial as a large number of farmers cannot then depend on the still limited hired tractor services, c) in areas unsuitable for tractor use such as steep hill sides, d) wherever price structure for industrial inputs and equipment is prohibitive on account of low prices for agricultural products and f) under situations where air pollution, soil and water contamination with chemical products is a serious concern.

The future use of work animals should also embrace water and soil conservation techniques i.e. conservation agriculture (CA), which approach was introduced by FAO in the East African countries, including Uganda, Kenya, Tanzania, Zambia and Zimbabwe and also extended to some of the West Africa countries and to parts of South Africa. There will also be great need to diversify use of work animals extending it to using female cows, single oxen on light works, etc. It is also vital that work animals are provided with special feeding and health care as they are often still engaged at work as the herd is already taken for grazing. Most importantly, DAP technology should not only rely on ploughing of lands as subsequent activities will remain farming bottle-necks if left to be handled by hand tool technologies.

Two-wheel tractor (2WT) designs for various farm operations

Whereas most countries in SSA are currently used to using animal traction in farming, with some larger growers using four-wheel (4WT), there are no sustainable 'stepping stones' for animal traction farmers discussed above making progress to affordable 4WT-mechanized production. A 2WT with associated farming implements is currently the next logical step for these small area farmers to get relieved from strenuous hand tools. Clear example as illustrated in Fig. 3a/b show that a 2WT can sustainably be used to open up vast lands (both wet and uplands) at very low cost. The models currently being popularized in East Africa are of 7 – 14 horse power rates.

Following a large workshop launched by CIMMYT in Addis Ababa, Ethiopia in 2014, the Australian Government launched a four-year project at a sum of \$3 million for the development of small-scale mechanized conservation farming systems for East Africa, targeting Ethiopia, Kenya, Tanzania, Mozambique, Malawi, and Zimbabwe. The project is officially called *'Mechanization Entrepreneurship to Leverage sustainable Intensification in Eastern and Southern Africa'* (MELISA). Some of the samples being tested are shown in Fig. 3c/d below.



CIMMYT, through its East African professional network, the NGO is responsible for carrying the work. This was in cooperation with various other NGOs, Government Departments, agribusiness, and farmer groups. During very severe drought, many cattle usually died in SSA, and many farmers who previously use animal traction for crop production are then back to using hand hoes. Therefore 2WT numbers are increasing at a higher rate in some parts of the East Africa sub-region than 4WT. The four-wheel tractor system is not suitable for small field sizes, is too expensive and difficult for the smallholder farmers.

As part of the project, quite a few Chinese 2WT with ARC Gongli seed drills was imported and also small 2WT rotary tillage seed drills, which was converted to strip tillage. It was evaluated in both rice and upland crop work. A pair of disc openers was fitted on to this drill equipment. Israil Hossain and colleagues have built a 2WT driven potato harvester at the Regional Wheat Research Centre, BARI Rajshahi recently (see right-hand Fig 2c/d above). It is a semi-automatic digger, which digs the potato beds and lifts the potatoes via a rotating flat conveyer. This lifts the loose soil and potatoes and the high-speed rotation separates the potato tubers from the soil. The exposed tubers on the surface are then picked up by hand.

In Bangladesh, 80% of the arable land is currently farmed using 2WTs, with different models and power ratings. The country experiences huge labour shortage in potato growing areas during peak harvest. Manual potato harvesting is a slow, time consuming and costly operation. Using the conventional system, a country plough opens potato beds and then the exposed potatoes are picked up by hand. Up to 8 persons are needed and around 0.5 ha per day can be harvested with a loss of 3-4% of the crop. Manual harvest cost is about \$US250 per ha. Using the 2WT potato harvester the process is greatly facilitated. Only three persons are required and up to 1.5 –2.0 ha per day can be harvested at a cost of \$US80 per ha. Harvest losses are negligible.

Conservation agricultural technology

For sustainable development of agricultural production, issues and concerns about the environment are important. In this regard, mechanization has been criticized for the negative impacts that the operations of these machineries have on the environment. In particular, the degradation of natural resources through intensive tillage has been a point of criticism, the breakdown of soil structure and exposure to erosion has been an issue, same way as soil compaction by heavy equipment and harrow pan formation by disc harrow. It should however, also be pointed out that mechanization opens new possibilities for the conservation of natural resources and the environment. Conservation agriculture, for example, is one of those very important concepts that have been developed in the late 1980s and have significantly been promoted in many SSA countries. It is “a concept for cost reduction in crop production that strives to achieve acceptable profits together with high and sustained production levels while concurrently conserving the environment” (FAO, 2007;). The key parts of the “tillage” concept are:

It is a form of agricultural mechanization (see Fig. 4 below) that focuses on three basic farming principles; a) minimum soil disturbance (Fig. 4b) during farming, b) leaves more than 30% of vegetation and crop residues on the soil surface (Fig 4a) to serve as natural manure and effectively prevent soil erosions on farms and, c) strictly adheres to crop rotation practices and crop associations in order to avoid plant disease and pest outbreaks and to allow the soil to re-balance its nutrient availability and to sustain fertility.. This type of tillage has been found to

improve soil productivity due to mulching effects that reduce runoffs and erosion, reduce soil evaporation and hence soil desiccation, and increases soil organic matter content.



Fig. 4a: Newly planted soybeans in maize residue



Fig. 4b: No-till soybeans grown in harvested

Energy and environmental benefits through Conservation Tillage

- Conserves energy due to fewer mechanization equipment trips across the field
- Reduces soil erosion by as much as 60%-90% depending on the conservation tillage method; pieces of crop residue shield soil particles from rain and wind until new plants produce a protective canopy over the soil
- Improves soil and water quality by adding organic matter as crop residue decomposes; this creates an open soil structure that lets water in more easily, reducing runoffs
- Conserves water by reducing evaporation at the soil surface
- Reduces potential air pollution from dust emissions
- Crop residue provides food and cover for domestic and wildlife

Mechanical power technology

Mechanical power technology, the highest level of mechanization as opposed to the use of hand tools and draft animal power technologies, was introduced into farming in sub-Saharan African countries during the early 1950s. Tractor use was received with excitement and support by most governments as tractors were mostly supplied to developing countries either as gifts from some of the European and Asian countries and donors, or on very advantageous loan terms (Mrema *et al.*, 2008). Ministries responsible for agriculture established agricultural

mechanization extension service delivery systems that rigorously promoted the use of tractors which were at that time mostly owned by governments. When hiring the tractors to farmers, most of the SSA government systems also used to charge subsidized rates including rates for the purchase of tractors, their implements and spare parts. The rates of fuels and oils for the tractors as well as rates for tractor maintenance and repairs were also subsidized, (Odogola *et al.*, 2012).

In some of the SSA countries such as Uganda, “heavy agricultural machinery and equipment” were introduced to clear parts of the then heavily forested lands making them available for mechanized agricultural production. Many individuals also procured tractor packages for their private use and for hiring out to other farmers but without adequate commercial insight. In countries such as Kenya, Zimbabwe, Mozambique and South Africa where colonialists settled on large size farm lands, the degree of tractor ownership for high level mechanization significantly increased. Similarly, private institutions practicing large scale agriculture such as sugarcane estates, rice schemes, sisal estates, coffee estates, also benefited from the above conditions.

However, between 1970 and late 1980s, most of the SSA governments witnessed very rapid declines in mechanized land areas as well as irreversible decline in tractor numbers. Most of the mechanization initiatives offered very little benefits and profits to both farmers and government systems owning and managing tractors and their equipment. A number of authoritative experts Mrema *et al.*, (2008) and Rijk (1999) have reported of serious criticisms made on mechanization because it often failed to be effective and was blamed for exacerbating rural unemployment and causing other adverse social effects. As already discussed above, this was largely the result of tractors supplied to developing countries either as “gifts” from donors, or on very advantageous loan terms. The subsidized projects proved not sustainable because of the intrinsic inefficiencies of government-run businesses.

An overvalued foreign exchange rate and low real interest rates made agricultural machinery “artificially cheap” as compared with labor and draft animals. The system also made farmers look at free services other than those they could invest on or pay for. These experiences often combined with a very narrow perception and lack of knowledge about mechanization, namely the one-sided promotion of tractors and other capital-intensive mechanical power technology, has caused the donor community to largely turn its back on mechanization. These challenges resulted in rapid and irreversibly decline of mechanization aspects from the 1970s to-date.

In contrast, Latin America had reached a level where it was unstoppable by such changes: consequently, the number of tractors in the region kept on rapidly rising and positively impacting on the level of agricultural mechanization as illustrated by the Mrema *et al.*, (2008) comprehensive study results summarized in Box 1

The study also indicates that, the tractors in use in SSA in 2000 were only concentrated in few countries, 70% being in South Africa and Nigeria. Similarly, the estimates on primary land preparation in SSA in 2000 relied completely on human muscle-power, which was about 80% of the cultivated land, with draught animals and tractors being used on only 15% and 5%, respectively (compared to Asia where land preparation on over 60% of the cultivated land is done by tractors). Stagnation in some SSA countries and decline of agricultural mechanization occurred during the 1980s and 1990s. In some of the SSA countries, the focus on tractor hire schemes of the 1960s and 1970s was replaced in the 1980s with increased emphasis on draught animal technology.

Box 1: Continental comparison on the status of agricultural mechanization

- a) In Asia, the number of tractors in use increased phenomenally – by five times between 1961 and 1970 – from 120,000 to 600,000 units, and thereafter increased by 10 times to 6 million units by 2000.
- b) In the Latin American Countries (LAC), the number of tractors in use increased by 1.7 times between 1961 and 1970 – from 383,000 to 637,000 units, and thereafter almost tripled to 1.8 million units by 2000.
- c) In the Near East region, the number of tractors in use increase was almost like that in LAC – doubling between 1961 and 1970 – from 126,000 to 260,000, and thereafter increasing by 6.5 times to 1.7 million units by 2000.
- d) In SSA the trend has been quite different. While the number of tractors in use in 1961 was more than in both Asia and in the Near East regions (172,000 versus 120,000 and 126,000 units, respectively), it increased very slowly thereafter, peaking at only 275,000 by 1990 before declining to 221,000 units by 2000 (i.e. about 3.3%, 11% and 12% of numbers of tractors in use in 2000 in Asia, LAC and Near East regions, respectively).
- e) Comparing agricultural mechanization changes in SSA with those in Asia and Latin American countries, it is noted that:
Africa in 1980 had 2 tractors per 1000 ha, by 2003 it only had 1.3 tractor/1000 ha
Asia and LACs had 7.8 tractors per 1000 ha, yet by 2003s it had 14.9 tractors/1000ha
- f) Another comparison is with India: In 1960, each of the East African countries (Kenya, Tanzania and Uganda) had had more tractors in use than India. However, by 2005, India had 100 times more tractors in use than the three East African countries combined. Today, India is one of the top producers of tractors in the world.

Ref: Based on Study by Mrema et al., 2008

In connection to the mechanization frustrations above, a four-day “Round Table Consultative Workshop on Investment in Agricultural Mechanization” was in 2009, held in Arusha, Tanzania.

The workshop handled very important policy issues on mechanization and ended up with very relevant and useful recommendations aimed at facilitating support for both public and private-sector investment flows into the development of agricultural mechanization in SSA. If effectively implemented, the Ashburner and Josef (2010) report-recommendations summarized below will result in reduced use of primary hand-tools from the current 80% to 40% by the year 2030, and to 20% by 2050. Increasingly, land preparation will be done using an optimal combination of appropriate draught animal power and tractor technologies. The said workshop made recommendations summarized as below:

- Establishing national committees on agricultural mechanization with representatives of major stakeholders, such as agriculture, finance, industry, trade and other ministries, farmer organizations, together with financial, private sector and research and development institutions;
- Creating an enabling environment to increase the utilization of tractors and other farm equipment;
- Increasing both private and public-sector investment in agricultural mechanization, drawing experience of India and other developing countries with recorded successes.
- Capacity building in education, research and extension services focusing on farm mechanization in Africa;
- Implementing the 'code of practice' for agricultural machinery suppliers which code will strengthen the role of the private agricultural machinery sector in supplying genuine machinery, providing after-sales services and building capacity and role of machinery;
- Creation of agricultural mechanization networks in SSA with membership from R & D institutions, professional organizations, manufacturers and distributors.

Stationery motorized equipment for agro-processing and value addition

Stationery motorized equipment are those powered by either electric energy, by petroleum or by solar energy, and are some of the pivotal components of agricultural mechanization. Since over 90% of agro-processing and value addition operations are traditionally handled by females, the use of these equipment is vital as they drastically reduce the drudgery input by women, saving their time for other household operations. Compared to manually processed crop products (for example millet ground using stones; rice, maize or cassava milled by pounding using hand pestle, etc.) machine operations result in high quality products with high market demand. Ownership at smallholder levels, of mechanization equipment for agro-processing, such as maize mills, rice mills, cassava graters, also serve as investments that can create wealth and reduce household poverty.

Irrigation, catalyst to agricultural mechanization

Apart from low power inputs above, African agriculture suffers from a lack of investment in irrigation compared with other regions of the world. The irrigated area in SSA, extending over six million hectares, makes up just 5% of the total cultivated area, compared to 37% in Asia, 27% in the Caribbean and 14% in Latin America (Liang Zhi You, 2008, FAO, 2005). Two thirds of the irrigated area in SSA is currently in three countries: Madagascar, South Africa and Sudan, while in India the figure is 40%. In SSA areas where droughts are prevalent, crops are often destroyed resulting in exacerbating food insecurity. Irrigation must therefore be seen as key factor in enhancing food security, as it increases yields of most crops by between 100 and 400%, and it has been projected that in the next three decades, 70% of global gains in cereal production would be from irrigated land. This suggests that increasing the irrigated area in Africa by a factor of about ten would not be excessive, and it would make a major contribution to agricultural productivity.

Investment in large irrigation schemes would be a long-term process but much might be achieved in small schemes for small groups of farms. In mechanization terms, this suggests a substantial opportunity for sales of pumps, diesel engines and related equipment. It also represents a parallel mechanization opportunity, a challenge for local African manufacturing industry to take on. For most rice growing countries in SSA, irrigation is currently being rapidly adopted, resulting in high rice productivity. Irrigation must therefore be intensified especially for high value crops such as fruit trees, vegetable and other horticultural crops.

In view of the strong links between irrigation and agricultural development, proposal to expand mechanized irrigation to increase agricultural productivity and reduce poverty in SSA have received considerable attention, especially when targeting high value crops. Rightly so, but attention is yet to be translated into reality. Many agricultural and agro-engineering universities in East and parts of West Africa currently sponsor a vast number to study in Israel, mostly being attracted by the sophisticated level of irrigation in that country. As a follow up to this initiative, SSA countries must strongly strengthen promotion of small-scale mechanized irrigation systems involving soil water management, supplementary irrigation, rainwater harvesting or small reservoirs. The potential for small-scale irrigation is vital not only based on agro-ecological conditions, but also in terms of market access, since irrigation is

Lessons from the Challenges and Benefits of Agricultural Mechanization in SSA

In most parts of Africa, the youth do not currently actively take to farming because of difficulties and “dirty” working environments characterized using hand tools. The use of hoes and machetes for farm work demands a lot of energy with negative effects on human health. Mada et al., (2013), has stressed that with introduction of improved farm technologies, both manual, animal drawn or motorized, drudgery suffering is transferred to the machines such that anybody, young or old, male or female can productively and profitably work in the farm.

When small-scale farms are mechanized, production levels increase from subsistence to commercial levels to improve the socio-economic status of rural communities and the nation in general. This must however be complemented with creation of the right market conditions. According to the Malawi's Agricultural Strategy (2008), agricultural mechanization is crucial in the fight against hunger and poverty, and at the same time to address environmental and health concerns. Food security is a pre-requisite for economic growth and wealth creation.

Connectivity of this reviewed mechanization status to needed intervention

Way forward

Based on the various challenges discussed above, three key areas have been identified as a way forward calling for redress through a 'Continental Initiative on Agricultural Mechanization for Smallholders in Africa'. The key areas are:

- Formulation of and, (where already in existence) strengthening Agricultural Mechanization Strategy and Policy in each of the countries;
- Development and promotion of approved model with approaches for Public Private Partnerships for the promotion of agricultural mechanization in the above countries;
- Strengthening capacities of institutions directly responsible for implementing innovative agricultural mechanization in partner countries.

Formulation of Agricultural Mechanization Strategy and Policy

The development of Guidelines for successful introduction and promotion of Agricultural Mechanization in a country was originated by the Agricultural Engineering Service (AGSE) of FAO from the early 1990s when interests were expressed by a number of countries in Asia, Eastern Europe and Africa, following lots of complexities and challenges noted in introduction and promotion of mechanization. The guidelines were to create "policy, institutional and market environment" in which farmers have the choice of farm power and equipment suited to their needs within a sustainable delivery and support system. The Agricultural Mechanization Strategy (AMS) strives to create an institutional framework that brings together all key stakeholders in a bid to increase the adoption of agricultural mechanization technologies. Experiences on the AMS formulation guidelines have since grown and been continuously fine-tuned and perfected. The most recent version has been applied in a few SSA countries, including Benin, Burkina Faso, Cameroon, Democratic Republic of the Congo, Guinea, Malawi, Mali, Niger, Sudan, and Tanzania, (Karim H. et al., 2013). In these countries, teams of local experts under the supervision and guidance of a senior consultant, collect data and prepare detailed reports on strategies to be followed for the adoption and wider expansion of mechanization.

One of the key initiatives goes under the proposal project on Continental Initiative on Agricultural Mechanization for Smallholders in Africa, its formulation or (where already existing) fine-tuning of Agricultural Mechanization Strategy and Policy in the SSA countries. AMS deals with manual, draft animal and mechanical power, utilization of tools, implements and machinery, their supply and maintenance. The strategy also covers importation and domestic manufacture of various mechanization technologies, their maintenance and repairs, relevant training and extension programs, improvements of draft animal health services and breeding programs, and promotion of financing systems for the acquisition of the above-area technologies and services. Other issues may include land tenure access rights and management; financing agricultural mechanization and access to credits; taxation and “duties” in accessing mechanization technologies; agricultural mechanization and innovation service delivery, climate change and related food security challenges, etc. The latest key reference materials on procedures and procedures for AMS formulation procedures and processes is found in Karim Houmy (2013). Other references include: Rijk, (1999), Ashburner et al., (2009), Mrema, (2011). Because mechanization strategy implementation will involve many different players, it is strongly recommended that emphasis be placed on using a participatory formulation approach. All stakeholders should be involved at all stages of the process. This will include creating opportunities for them to participate in, and to profit from, the outcome of the strategy. Other reasons for using a participatory approach are:

- To be able to reach a national consensus on the outputs, resulting from the implementation of a mechanization strategy;
- To strengthen the national debate on mechanization, thus giving stakeholders, including civil society and private sector, the means to take a more active role in addressing issues;
- To develop more comprehensive objectives through the participation of all stakeholders;
- To enhance the sense of ownership, responsibility and transparency of the strategy.
- Three main groups of stakeholders to be involved will be:
 1. Farmers who use the technology (the demand side)
 2. Private sector equipment and service providers to the farmers (the supply side)
 3. The public sector (the institutional support)

The process for the elaboration on AMS is shown in a summarized Table 1.

Table 1: Typical five distinct stages for AMS and Policy formulation

Summary of main activities in the process of AMS formulation	
1. Analysis of the present situation <ul style="list-style-type: none"> ▪ economy and policy environment ▪ agricultural sector ▪ farming systems and use of farm power ▪ agricultural tools and machinery supply 	2. Analysis of future scenarios <ul style="list-style-type: none"> ▪ developments in national economy ▪ implications for the agricultural sector ▪ developments in farming systems ▪ farm power and equipment requirements

<ul style="list-style-type: none"> ▪ relevant institutions 	<ul style="list-style-type: none"> ▪ development of agro-machinery industry
<p>3. AMS and Policy formulation</p> <ul style="list-style-type: none"> ▪ roles of government and private sector ▪ policy and institutional recommendations ▪ programs and projects ▪ strategy advocacy and proposals for legislative action 	<p>4. AMS and Policy implementation</p> <ul style="list-style-type: none"> ▪ strategy advocacy ▪ formulation of proposals for administrative and legislative actions ▪ approval of these proposed actions <p>5. AMS and Policy adoption and use</p>

Development and promotion of mechanization approaches based on “Public Private Partnerships” to revitalize agricultural mechanization in partner countries

During the late 1960s and early 1970s, many governments in SSA adopted policies of direct public sector involvement in development; policies in which the governments played a central role not only as facilitators and regulators, but also took over the roles of producers, manufacturers, traders, and bankers. Regarding agricultural mechanization, most SSA governments started to become fully involved in the direct importation of tractors and other agricultural machinery, and in other activities against which private sector importers could not compete. Governments received some of the technologies under high subsidies or free of charge. Governments then also provided significant subsidies on tractors and other agriculture equipment costs including costs on fuels, lubricants and tractor servicing. These “favourable conditions” extremely excited most end-users.

Initially, in response to these government interventions, the growth rate of gross domestic product (GDP) and employment increased. But in the mid-1970’s, these strategies led to increasingly higher budget and trade deficits. Inflation accelerated, and levels of internal and external debts became unsustainable, leading to instability at the macroeconomic level. These structural imbalances were the primary reasons that led to many African countries having to agree to externally impose fundamental structural adjustment programs (SAPs) which focused on macroeconomic stabilization, based on trade liberalization, floating exchange rates and economic deregulation, Karim *et al.*, (2013).

By the time of structural reform in the 1980’s, the distortions present in the markets in most SSA countries had reached extreme levels. One of the pillars of structural reform programmes was the “freeing” of exchange rates where FX was sold to the highest bidder. This had the immediate effect of drastically increasing the local prices of imported goods, including farm inputs, and lowering the purchase prices of exported goods. Unfortunately, the expectation by economists that the private sector, including those handling mechanization, would re-emerge and take up their previous positions did not happen. The private sector had been so destroyed by the distortions of the fixed exchange rates that it simply did not have the

resources to recover to their previous position. Also, some of the commercial and entrepreneurial expertise which had survived were only interested in enterprises that made quick returns and high profits. Mechanization did not belong to that category of enterprise.

Ever since, the market for farm tools and machinery has not recovered and as a result, the agricultural mechanization sector has significantly not expanded or developed. Most countries in SSA took this sad trend!

Based on this challenging scenario, the study therefore proposes the development and promotion a mechanization model based on Public Private Partnerships.

Strengthening institutional capacities for innovative agricultural mechanization in partner countries

Having put in place an operational Agricultural Mechanization Strategy (AMS) and Policy in a country and an operational Public Private Partnership (PPP) that includes organizational issues, tax policy on imports of agricultural equipment and raw materials, the involvement of the state in certain activities which should be done by the private sector, etc, the remaining issues to be simultaneously be addressed include:

Strengthening the state structures in charge of agricultural mechanization

This program aims to strengthen the institutional capacity of state structures in the management of agricultural mechanization. The proposed actions aim at capacity building to conduct and manage the various activities related to the development of agricultural mechanization. It covers the following actions:

- Strengthen institutional engineering infrastructure/workshops to effectively house assorted mechanization equipment and accessories;
- Development and strengthening national training and skills in agricultural machinery management, use, repairs and maintenance;
- Strengthening capacities for agricultural mechanization extension service provision. A number of countries in SSA have strong extension frameworks handling agriculture in general but rather weak in handling agricultural mechanization issues;
- Strengthening Research and Development capacities in agricultural mechanization to enhance local production of machinery, equipment and their parts ,
- Development and dissemination of national standards for agricultural machinery.

Supporting increased use of farm power and land use in agricultural production regions

This component aims at facilitating access to agricultural machinery services, considering the ecological and socio-economic environment and the development of lands in agricultural production regions in partner countries. It covers the following actions:

- Develop agricultural lands for the benefit of farmers;
- Develop partnerships between the actors involved in agricultural mechanization and strengthen their capacities;
- Design and implement an adequate financing system which benefits both the public and private sector;
- Promote some of the new and innovative agricultural mechanization systems such as conservation and irrigation agriculture

Strengthening the capacity of the private sector to supply farm power and agricultural mechanization services

This component aims at stimulating the private sector so that it is able, in partnerships with the public sector, to offer farmers the necessary farm power and adequate related services in a sustainable manner. The component covers:

- Facilitate the importation of farm power and agricultural machinery contract hire and promotion
- Structure and strengthen the local production of agricultural machinery and tools; promote the supply of agricultural mechanization services;
- Integrated education, training and extension geared towards both public and private sectors
- Creating an enabling business environment

Conclusion and Recommendations

This report reviewed agricultural mechanization in SSA dating from the early 1950s to-date. The review systematically captures aspects of hand-tool technologies pointing out associated challenges that include labour intensity and time consuming. It then goes on to discuss the use of animal traction technologies for various agricultural operations, and of tractor utilization both two-wheeled, and four-wheeled. The report also touched on mechanization as applied to irrigation and conservation tillage agriculture, and to postharvest and value addition operations. In each of the above mechanization types, challenges faced as well as advantages and benefits in the technology use are highlighted.

Efforts at developing and promoting Agricultural Mechanization in SSA and associated challenges faced are also discussed. Three key areas are discussed in-depth; namely:

- I. The regulations, laws and policies various governments in SSA used in the acquisition, promotion and development of various levels of mechanization technologies and of agricultural mechanization in general, progress made and the challenges faced. It was established that the various SSA government mechanization regulations, laws and policies of the 1960/80s were rather weak, and were solely established by respective governments with little involvement of end-users, NGOs and the private sector of that time.
- II. The second issue covered was the partnership between government and the private sector in mechanization equipment and machinery acquisition, marketing, distribution and management. As noted above there was hardly any linkage and partnerships between SSA governments with agricultural mechanization private sector in their respective countries at that time. To-date, this area is still also weak.
- III. In most SSA countries physical infrastructures (engineering mechanization workshops) as well as human capacities for proper use, management, maintenance and repairs of mechanization equipment and machinery were also weak. Similarly, research capacities to enhance innovations and development of basics agricultural mechanization tools, equipment and machinery are to-date still weak in most SSA countries. Therefore, hardly any mechanization equipment and machinery needed by farmers get designed, successfully fabricated and mass produced locally.

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