BACKGROUND PAPER

Agricultural Mechanization

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Executive summary

Mechanization has the potential to expand production; improve timeliness of operations; widen the application of power to crop processing, irrigation and infrastructure improvement; compensate for labour shortages; and alleviate drudgery – particularly important when the greying, feminizing workforce continues to rely on the hand-hoe for primary cultivation.

The challenges to achieving expanded use of mechanized practices in the smallholder context are many:

- Smallholders often lead precarious lives and so incomes are erratic and low.
- Affordability of mechanization (and other) inputs is often beyond the reach of the smallholder family.
- Low output means low savings leading to low demand for mechanization and increasingly low productivity.
- Lack of enhanced skills needed to adopt and profitably exploit agricultural machinery.
- State operated machinery contract services have practically disappeared as they were uneconomic
- The local machinery manufacturing industry has not developed sufficiently to be able to supply sophisticated machinery – let alone tractors.
- Generally repair services are satisfactory for simple (hand and animal powered) technologies; but for motorized equipment the supply of replacement parts may be slow and lead to long down-times, usually at critical times of the year.

However many challenges there may be to agricultural mechanization there are also a host of opportunities:

- Farmers' incomes can be raised, and natural resources conserved by scaling out the practices of sustainable crop production intensification. This can create the virtuous cycle of higher incomes leading to more savings, higher demand for mechanization services and lead to greater productivity.
- The new climate of optimism (and increased investment) provides opportunities for increased agricultural wages (because of labour shortages); novel agricultural machinery better suited to smallholder farmers' needs; energy efficient sustainable mechanization concepts (including precision agriculture); climate-smart conservation agriculture; new, more appropriate, business models; and public-private partnerships.
- Investment opportunities in the agricultural mechanization sector encompass national agricultural mechanization committees; the creation of enabling environments (particularly in terms of encouraging mechanization service provision and an expanded use of agricultural machines beyond the farm gate); increasing investment in mechanization; capacity building; creation of codes of practice for machinery input suppliers; and the support of regional networks of agricultural mechanization.

Suggested actions for the way forward include:

- The integration of facilitating policies for the development of agricultural mechanization within the pan-African New Partnership for Africa's Development (NEPAD) and in particular with Africa's policy framework for agricultural transformation, wealth creation, food security & nutrition, economic growth **and** prosperity for all (Comprehensive Africa Agriculture Development Programme – CAADP)
- The formulation of sustainable agricultural mechanization strategies for individual countries.
- The adoption of sustainable agricultural practices for smallholders in terms of greening production: "Save and Grow", and conservation agriculture.
- Empowering smallholders via specific and enhanced business models to enable further access and integration into agri-food value chains.
- The further development of agricultural mechanization via organizational and institutional elements common to smallholders, such as producer organizations.
- The further expansion of agricultural mechanization into value addition and the development of agri-food value chains via adoption in post-harvest, processing and marketing activities.
- More emphasis on private sector development as well as public private partnerships in terms of increased pan-African manufacturing of agricultural mechanization vehicles, tools and equipment as well as small mechanization enterprise development (hire services) by small-scale farmers for small-scale farmers
- Far more integration of south–south cooperation for the further development of common understanding in terms of technology and know-how transfer.
- Increased field level capacity building and capacity development for smallholders with agricultural mechanization integration into farmer field schools (FFS) and farmer business schools (FBS)
- The establishment of two regional centres of agricultural mechanization excellence based on the model of the Asian Centre for Sustainable Agricultural Mechanization (UN-CSAM).

1. Background

The 17 Sustainable Development Goals (SDGs) successfully came into being when the United Nations General Assembly formally adopted them recently – on 25 September 2015.

FAO with its expertise and resources is well-positioned to support countries especially in Africa in achieving the SDGs. The opportunity to become the Generation Zero Hunger, cannot be missed. FAO's work on sustainable production intensification and agri-food value chains are part of this and agricultural mechanization is key in this process (Figure 1).

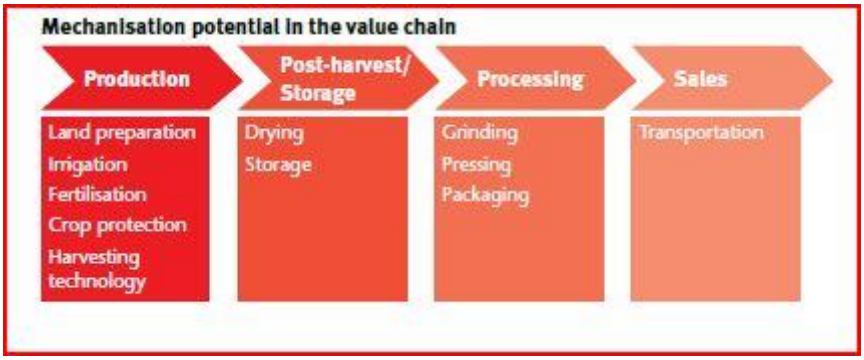

Figure 1. The potential of mechanization in the value chain
Source: Breuer *et al*. 2015

There is no doubt that agricultural mechanization for the multitude of smallholder farmers in sub-Saharan Africa (SSA), has been a neglected issue for too long. Farm power applied to appropriate tools implements and machines – farm mechanization – is an essential agricultural input and has the potential to transform rural families' economies by facilitating increased output of higher value products whilst at the same time eliminating the drudgery associated with human muscle powered agricultural production. Such an improved situation for smallholder farmers can enable access to input supply chains and integration in downstream value chains and thus provide for more income, renewed business opportunities and further value addition. Moreover agricultural mechanization in its broadest sense can contribute significantly to the development of value chains as it has the potential to render postharvest, processing and marketing activities and functions more efficient, effective and environmentally friendly.

Given this situation it is difficult to understand why, internationally, agricultural engineering has been consigned to the back seat. International research centres have been wound down (although there are now positive signs of renewed interest). And the availability of top-class undergraduate university courses is in serious decline. Why this should be the case is not obvious when numerous studies have made it abundantly clear just how crucial an input mechanization is in the pursuit of global sustainable crop production intensification and improved rural livelihoods (see, for example, the deliberations of the FAO Rome forum on how to feed the world in 2050 – FAO, 2009a).

FAO (2014) summarizes the main reasons for replacing the power source for crop production from muscles (human or animal) to tractors: i) the potential to expand the area under cultivation; ii) the ability to perform operations at the right time to maximize production potential; iii) the multi-functional characteristics of mechanization as tractors can be used not only for crop production but also for transport and stationary power applications as well as in

infrastructure improvement (drainage and irrigation canals and road works); iv) mechanization can compensate for seasonal labour shortages (or, indeed, release labour for more productive work; v) mechanization reduces the drudgery associated with the use of human muscle power for arduous tasks such as hand hoeing for primary tillage. This aspect is especially important in tropical areas where high temperatures and humidity (perhaps associated with inadequate nutrition) make manual work extremely arduous.

In spite of these perceived benefits and the fact that animals had been largely replaced by tractors in both the US and western Europe by the 1950s, there were still arguments being put forward to urge caution in the developing world (as highlighted by FAO, 2008). The main preoccupation was the effect of mechanization on rural employment opportunities. However it was not realized at the time that off-farm employment opportunities would actually increase as a result of value addition (post-harvest operations and primary and secondary processing) as well as in services to support agricultural mechanization development. But there were also concerns about high and rising fuel costs. Small and fragmented fields were seen as an obstacle to tractorization and without land consolidation mechanization would not be viable. These considerations led to a reduced focus on mechanization as an essential input throughout the 1980s, whereas the momentum in Asia and Latin America continued unabated.

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

- In Asia the tractor numbers increased fivefold between 1961 and 1970, from 120 000 to 600 000 units. Thereafter the number increased by 10 times to 6 million units by 2000. Since then numbers have continued to increase, especially in India, which had 2.6 million tractors in 2010 – FAO (2013a), and China which reached over 2 million units by 2008 – FAO (2013b).
- In the Latin America and Caribbean region tractor numbers increased 1.7 times between 1961 and 1970, from 383 000 to 637 000 units and thereafter tripled to 1.8 million units by 2000.
- In the Near East region the picture is similar to Latin America, tractor numbers doubled from 126 000 to 260 000 between 1961 and 1970 and then increased 6.5 times to 1.7 million units by 2000.
- In SSA the trend has been rather different. In 1961 the number of tractors in use was more than in both Asia and the Near East (at 172 000). After that the number increased slowly to peak at 275 000 by 1990 before declining to 221 000 by 2000.

The global population (currently 7.31 billion) is on track to reach 9 billion by 2050 and exceed 11 billion by the end of the century. The world's 500 million smallholder farms currently produce around 80% of our food and it is they who will have to bear the brunt of the need to increase food production by over 60% by 2050 compared to 2007 levels (FAO, 2011). Currently many of these smallholder farms have limited access to production inputs, especially mechanization, and so achieve low levels of productivity. They also have fewer opportunities to access markets to take advantage of the numerous value adding activities that more developed food systems can provide. At the same time the rural population is expected to decline as people, especially the young and fit, migrate to urban centres in search of a life of less drudgery than can be offered by agriculture; there is also an increasing feminization of

smallholder agriculture, especially in SSA, as women increasingly are left in control of the farm. Opportunities that agricultural mechanization can offer to women in rural areas, and to the development of local economies, is often under estimated. Currently 50% of the population in developing countries lives in the rural sector and this is projected to fall to 30% by 2050. Given the current importance of human muscles in smallholder agriculture, the power limitation implications are grave (Sims & Kienzle, 2015).

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

Table 1. Sources of power for land preparation (% of total)

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

Source: FAO 2006

Generally engine power is on the increase whilst draught animals are tending to decline in numbers although locally they can still be very important. The move away from muscle power towards tractors and engines for pumping and post-harvest operations is much more rapid in Asia and Latin America. Draught animal numbers in India and China are falling dramatically (from a peak of over 100 million in both countries) and are being replaced with 4-wheel tractor power; whereas in Bangladesh draught animals have been replaced by 2-wheel tractors and now 80% of land preparation is carried out with them.

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

However, there have been serious negative consequences. It is now recognized that those enormous gains in agricultural production and productivity were often accompanied by deleterious impacts on the rural natural resource base and ecosystem functions. They have jeopardized the productive potential of agriculture and subsequently also impacted on the connected agri-food value chains. Land degradation (through erosion and compaction), salinization of irrigated areas, over-extraction of groundwater, the build-up of pest resistance and the decline of biodiversity are some of the easily observable effects at production level. As a consequence of the uncertainty and variability of yields, the reduction in product quality,

coupled with degraded lands and depleted water resources, smallholder-level processing and value addition has become a far more risky business.

In Africa the Green Revolution has not had the same impact as it has in Asia. Mechanization and intensification levels, fertilizer use and use of other modern technologies have remained low throughout most of the continent to date. However, degraded lands are common all over the continent and there are many reasons for this. One of them is the continuous use of the plough (or hand hoe) that leads to soil degradation, the creation of plough- or hoe-pans in the soil profile, and loss of fertile top soil (Kienzle & Sims, 2015). It is astonishing to see how far the reality of soil erosion has progressed in many regions of Africa considering the currently low level of mechanization. However, looking to the future, if Africa should intensify and mechanize its agriculture on a large scale it must be done with care and in line with the principles of sustainable production intensification that FAO has summarized in its 'Save and Grow' guidelines and that has environmentally friendly and natural resource conserving conservation agriculture (CA) mechanization at its heart (FAO, 2011). Farming systems for sustainable production intensification will offer a range of productivity, socio-economic and environmental benefits to producers, and to other value chain actors and to society at large, including greater and more stable production, food distribution and profitability; adaptation and reduced vulnerability to climate change; enhanced ecosystem functioning and services; and reductions in agricultural greenhouse gas (GHG) emissions and 'carbon footprint'. In a nutshell, agricultural mechanization in the twenty first century should be simultaneously: environmentally compatible, economically viable, affordable, adapted to local conditions and, in view of current developments in weather patterns, also climate-smart.

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

- Simultaneous achievement of increased agricultural productivity and enhancement of natural capital and ecosystems services.
- Higher rates of efficiency in use of key inputs, including water, nutrients, pesticides, energy (including farm power), land and labour.
- Use of managed and natural biodiversity to build system resilience to abiotic, biotic and economic stresses.
- A more effective, efficient and environmentally-friendly food system as a result of increased agricultural mechanization.

The farming practices required to implement the first three principles will differ according to local conditions and needs. However, in all cases they will need to:

- Minimize soil disturbance by minimizing mechanical tillage in order to maintain soil organic matter, soil structure and overall soil health.
- Enhance and maintain a protective organic cover on the soil surface, using crops, cover crops or crop residues, in order to protect the soil surface, conserve water and nutrients, promote soil biological activity and contribute to integrated weed and pest management.

- Cultivate a wider range of species – both annuals and perennials – in associations, sequences and rotations that can include trees, shrubs, pastures and crops, in order to enhance crop nutrition and improve system resilience.

In practice this means applying CA practices on a wide scale (FAO, 2015a).

This paper is specifically about agricultural mechanization, the opportunities provided by mechanization for intensifying production in a sustainable manner, in value addition and value chain development as well as the inherent opportunities implied for improved local economies and livelihoods (FAO, 2007). The establishment of viable business enterprises agro-processors, transport services, etc. as a result of increased agricultural mechanization in rural areas, is crucial to creating employment and income opportunities and, thereby, enhancing the demand for farm produce. Mechanization plays a key role in enabling the growth of commercial agri-food systems and the efficiency of post-harvest handling, processing and marketing operations, and as such can be a major determinant in the availability and accessibility of food, the food prices paid by urban and rural poor, as well as contributing to increased household food security.

2. Challenges

Agricultural mechanization, and in fact mechanization throughout the agricultural produce value chain, is affected by a series of constraints in SSA. In a given location (i.e. country) they will have to be identified and strategies conceived to alleviate them to allow the development of mechanization services that can benefit all farmers, especially smallholder producers and other actors along the agri-food value chain. Some of the most likely challenges that will be met are discussed below.

2.1. Affordability

Smallholder farmers are, almost by definition, resource poor and so often have difficulty in investing in agricultural machinery. In many countries, agricultural machinery suppliers are only found in the larger towns and cities and it is often the case that smallholders are isolated by distance and poor infrastructure (especially roads). Access to sources of financial credit are also limited by the same reasons and also because commercial financial institutions (i.e. banks) are reluctant to extend credit to poor farmers with little collateral. There is also a lack of specific financial products that can meet the demands of smallholders investing in agricultural mechanization. Experience from other parts of the world has taught us that extending credit to farmers to invest in agricultural machinery, not only allows them to raise their productivity and participate more fully in the market economy, but can also incentivize the local machinery manufacturing industry to supply their needs (Casão-Junior, *et al*., 2012).

The restricted purchasing power of smallholder farmers is due to a series of factors impinging on the farm family's economy. Firstly there are low yields caused by many factors, but including the lack of adequate inputs (especially seed and fertilizer) at the right price and the right time. More lengthy drought periods and more frequent storms are also reported and predicted as a result of the increasing impact of the effects of climate change and these will also have a deleterious impact on farm yields which, in the case of basic grain crops may struggle to exceed 1 ton/ha. And the backdrop to this situation is the degraded condition of

many agricultural soils as previously mentioned. Poor marketing facilities coupled with inadequate rural, farm-to-market, infrastructure conspire to produce poor returns to smallholder crop production; market prices are low and transport costs can be high.

Farm-gate price issues can be a major disincentive for smallholder farmers. Private sector led input and output markets have not developed as quickly as expected and farmers are constrained by a lack of free competition in these markets, resulting in high prices for agricultural inputs as well as lower farm gate prices for produce than in other regions of the world. The consequent reduction in farm incomes has led to an overall decline in the level of investment in agriculture. At the same time farmer organizations have not generally been effective in assisting smallholders to improve their access to markets and public services.

Land tenure is one of the most important issues in agriculture and in many countries a lack of security of tenure severely hinders investment in the agricultural sector. For a successful transition from semi-subsistence farming to profitable, productive agriculture, land tenure must be secure and guaranteed by the state as well as by local laws and traditions. This will give farmers the security and confidence to invest in mechanization and other production enhancing inputs. Several countries have attempted to organize land tenure by the establishment of regulations and laws but these have often not always met with success. For example, customary common land ownership by clans and extended families makes it difficult to commercialize farming. It is also very difficult to change these traditional patterns of land ownership. In many countries despite the introduction of national legislation, no 'secure' land transaction can take place without the participation of the traditional chiefs. Any investor always has to provide 'gifts' at the beginning of the change of title procedure as well as later when farming commences. Other issues such as 'land-grabbing' are becoming more widespread and serious as world population grows and climate change adds uncertainty to agricultural production (Pearce, 2012).

Smallholders operating just above subsistence level are characteristically extremely risk-averse. For the rural family, a reliable source of food throughout the year, even if this is well below the level of potential yields for the region, is preferable to a situation where they might be very good in favourable seasons, and very bad in adverse years. A steady, even if low yield, resistant to the vagaries of the weather will be preferable but will not result, necessarily, in a marketable surplus in most years. For all these reasons, without financial assistance, it is unlikely that smallholders will be able to invest in the kind of mechanization technologies that would be able to lift them out of their precarious condition.

2.2. Availability

Tractors and agricultural machinery can be imported or locally made. Both sources may have a series of problems associated with them. Generally speaking locally made agricultural machinery is of fairly poor quality and high in price. This is due to the underdeveloped nature of the machinery manufacturing industry which in turn is largely due to poor demand. In addition, supply chains to support tractors and agricultural machinery with spare parts, advice and other services (especially clean fuel) are often underdeveloped and have difficulties in extending to remote rural areas.

Analysis of the low levels and lack of growth in the use of mechanization, and of the relationships between the different determinants clearly indicates that conditions exist in SSA

which have led to the creation of a restrictive environment, which has held back the development of mechanization (Figure 2).

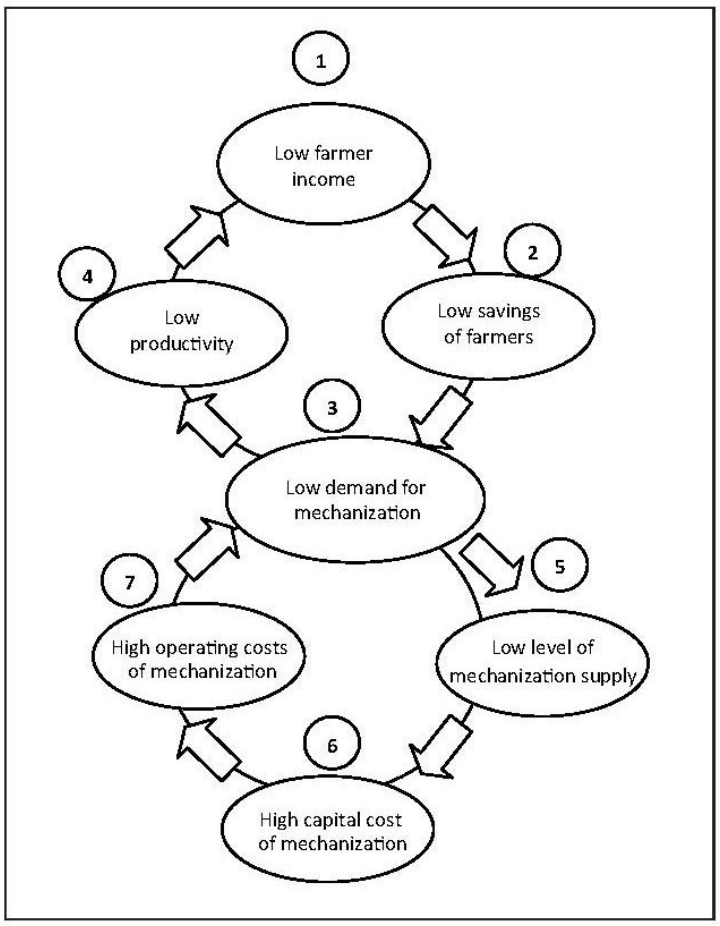

Figure 2. Factors weakening the demand and supply of agricultural mechanization
Source: FAO, 2013d

In Figure 2 it can be seen that the low farmer income (1) discussed in 2.1, results in a very low potential to invest in inputs (2). Inputs, apart from seed and fertilizer, also include agricultural machinery and therefore demand for tools and machinery remains low (3). This lack of investment in production enhancing technologies has resulted in very low levels of productivity (4) which again leads to a continuing situation of low farm incomes (1).

The lack of demand for mechanization drives another debilitating element: the supply side. This is represented by the bottom half of Figure 2. The low supply of tools, equipment and power sources (limited choice and low sales volumes) (5) tends to lead to higher costs of agricultural mechanization (6) which in turn leads to higher ownership and running costs (7). Finally, this high cost of farm machinery use leads back to the low demand in a vicious circle.

These inter-related factors illustrate the structural constraints to the increased use of mechanized methods of farming faced by most African countries. They also demonstrate the inter-dependent relationship between the demand and supply sides of agricultural mechanization inputs. However, they also give some indication as to how debilitating factors might be converted to enabling ones.

2.3. Lack of farmer skills

Although African farmers have a great deal of traditional knowledge and experience accumulated over generations, access to new knowledge remains largely limited. Mostly the level of training for farmers is relatively low and the opportunities for further training are limited. Public and private extension and training services have limitations in outreach, especially in rural and remote areas, as distances are large and transport can be scarce. Demand for extension and training can also be low and so it is often difficult to economically justify such activities. Another problem is that a large proportion of rural farming populations are illiterate. This situation stands in the way of improving agricultural production and productivity as well as general levels of farm management. For example, in many SSA countries only land preparation and transportation are carried out by tractors (FAO, 2009c). Other operations such as seeding and harvesting are still mostly carried out manually. This is due to a lack of knowledge by farmers about suitable equipment and a lack of skills in operating such equipment (FAO, 2011c). Where machines *are* used, the lack of both farmer knowledge and skills leads to misuse and mismanagement of machinery; especially of more sophisticated machines.

2.4. Constraints within the private sector

The whole of the farm machinery sub-sector, which encompasses manufacturers, importers, distributors, retailers and hire services business enterprises, faces several constraints which hinder its development. Like many other sectors in an economy, it also suffers from the same issues confronted by the private sector when trying to develop. For example: lack of enabling laws for facilitating business start-ups and enterprise operation, complex fiscal systems, punitive importation regulations and rigid labour laws. In the private sector agricultural machinery manufacturing is at an early stage in many countries across SSA and is thus hampered by international competition and imports. Markets for mechanization services across SSA are also in their infancy as in most cases demand is latent as a consequence of the lack of awareness by many smallholders of the need for mechanized services. Although low demand is mostly caused by lack of development, other constraints should be taken into account.

2.4.1. Agricultural machinery importation and distribution

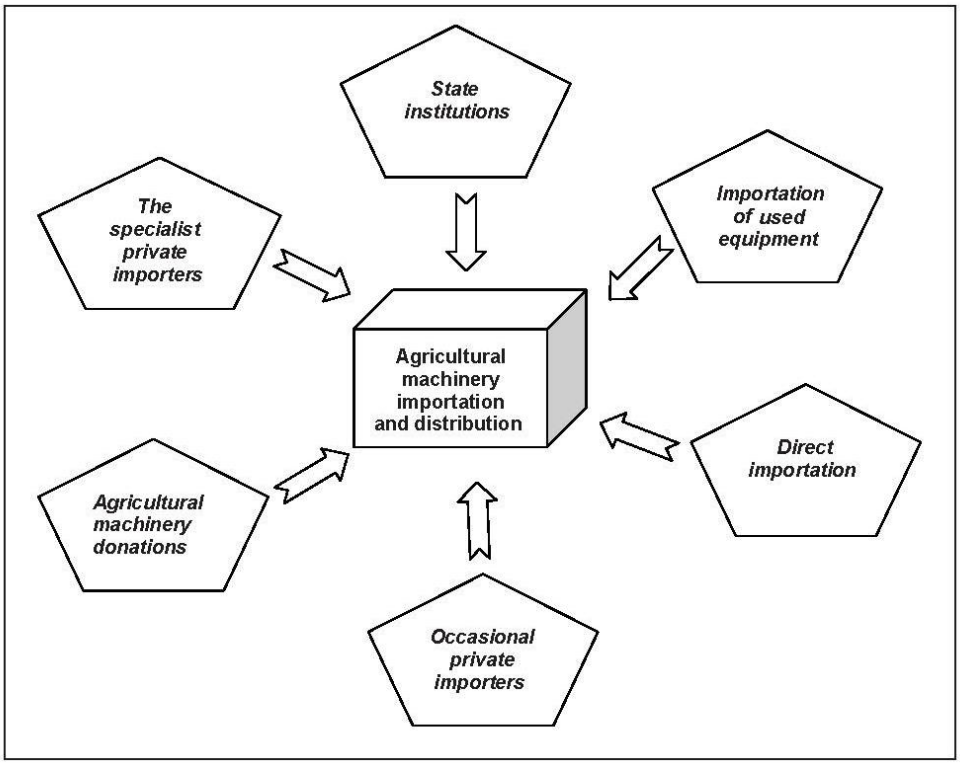

Figure 3. Agricultural machinery importation and distribution
Source: FAO 2013d

There are several ways in which farm machinery is imported and distributed (see Figure 3). Some of these ways are more successful and sustainable than others. The following options are in practice:

Specialist private importers of agricultural machinery. These are usually companies which have a franchise to sell and import a selected and commonly limited number of brands. The franchise is given to them by the company manufacturing the machines. These companies are usually located in the capital city and may sometimes have branches in other major cities and towns. Traditionally they have represented one of the major western agricultural machinery manufacturers but more recently, Asian and Latin American manufacturers have moved into these markets. Unfortunately in almost all markets in SSA, sales of major items of equipment (tractors and combine harvesters) are still very low. This has led these franchise companies to diversify their activities into other types and makes of equipment.

Occasional private importers. These tend to be general traders with no specialist knowledge or experience of farm machinery. It is usual for these companies to import a batch of machines and once they are sold there is no further obligation to provide either spare parts or service for them. The next batch of machines to be sold might well come from a different manufacturer. The farmers who purchase from these companies are mostly inexperienced and often do not realize that there may be later problems with spare parts and repair services.

State institutions. In some countries state institutions as well as aid agencies become involved in the importation of farm machinery. Also, several African countries have created local tractor assembly plants in a mistaken effort to promote agricultural mechanization or with the objective of providing lower cost machinery. The batch importation of farm machinery (in a similar manner to the occasional importation by private traders) also occurs when governments and aid agencies issue tenders for purchasing large quantities of farm machinery. In such a situation the imported machinery generally bypasses the local distributor who subsequently has no obligation to provide spare parts or service for the machines. These tenders are almost always evaluated on the basis of price and the winning bidder may well have no representation in the country nor have any possibilities or interest in supporting the machines. Machines purchased in such a manner tend to end up as 'orphans' with no spare parts or backup services and, as a result, tend to have a very short operating life. They may be cheap initially but end up being very expensive.

Donations of agricultural machinery. Many African countries have over the years received donations of tractors and implements from many different countries. Unfortunately almost all of these, no doubt well intentioned, programmes have failed to produce the desired results. This is due to a number of reasons, the main ones being a lack of compatibility between products manufactured in donor countries and machines that are already on the market. Very often there has been no dealer or spare parts available to support the operation of the equipment. The machines that have been donated quickly become 'orphans' with no support and once the first breakdowns occur the machines cannot be repaired. In many countries 'graveyards' of such machinery are still to be found.

Direct importation. Large farmers and agro-industrial companies often import machinery directly from abroad. This is the case when large orders attract high discounts or when the company or farm has sufficient resources to stock their own spare parts as well as to carry out their own maintenance and repairs. It also occurs when particular specialized machinery is required e.g. sugar cane harvesters.

Importation of used equipment. In some countries the importation of used machinery, particularly tractors, combine harvesters and other specialized machinery offers farmers an alternative source of cheaper machinery and offers an additional way to meet demand. However, whether farmers can benefit from this cheap source of machinery depends upon whether the importer is serious in offering a service to farmers including the provision of spare parts and repair services. Importation and sale of used machinery occurs mainly in countries where there are technicians who have a relatively high level of skills and knowledge but where the costs of labour are low. As is the case with new machinery, it is often tempting for the public sector to become involved in the importation of used machinery, however, without specialized knowledge of agricultural machinery these schemes usually end up with disastrous consequences.

2.4.2. Manufacturing of farm tools and machinery

The manufacturing industries in SSA countries produce a wide range of hand tools, farm implements, and processing equipment. However, there is a wide variation in the facilities to be found in different countries. In some countries only the simplest of hand tools are made mostly in the artisan (blacksmith) sector; in other countries sophisticated manufacturing

facilities exist. At various times farm tool and machinery manufacturing has also been supported through bilateral and multilateral cooperation. Unfortunately the sustainability of the manufacturing industry has often been problematic, because of erratic raw material supplies, fluctuating demand, and issues of quality as well as problems caused by bulk ordering from projects. These being maladies commonly encountered in private sector development. Currently three different kinds of manufacturer are found: state owned and operated companies; private industrial companies; and the informal artisan level.

2.4.3. Maintenance and repair services

In general the maintenance and repair of hand tools and animal traction implements is not a problem as it is mostly carried out at a local level by small workshops and mostly in the informal sector. However such micro enterprises are confronted with the same problems that other private sector actors have to face, paramount being the access to training and updates on new knowledge required for improved services. In terms of spare parts, the situation has been improved in some countries by standardization, facilitating inter-changeability between tools sourced from different manufacturers. However, for motorized farm machinery and equipment many problems still remain, particularly for tractors. This is mostly caused by poor maintenance facilities and a critical lack of spare parts. This situation leads to long down times, and a consequent under-utilization of equipment and eventually to premature write off. A few decades back, emphasis was given to public sector programmes and projects which developed agricultural mechanization maintenance and repair centres. However, these were not very successful and most have since fallen into disuse.

2.4.4. Hire services

Mechanization hire services can be found in many countries, but these suffer from a lack of market access, low demand for such services, lack of financing, know-how in operating an enterprise as a business and maximizing profits (Hilmi, 2013). A wide range of operations can be covered by machinery hire services; in addition to crop operations such as soil tillage, planting, and spraying, other hire services such as threshing, shelling, processing and transport are also offered. Similarly, it is important to note that hire services are not only limited to motorized operations but also to operations where the source of power is animal draught.

During the 1960s several countries established public sector operated farm machinery hire services in an attempt to include small farmers into growing markets for high-value commodities. Most of these schemes, which were mainly for the provision of tractor hire services, did not produce the benefits and outcomes initially envisioned. There are some remaining vestiges of them which only continue to exist through the provision of government subsidies, but the remainder have disappeared. There were many reasons for the demise of these schemes but the main ones were small fields with long travel distances, unaffordable hire charges, problems of non-payment, inflexible and inefficient public sector administration, lack of operator and mechanic incentives, breakdowns, and the non-sustainability of the subsidies that were required to keep the service running. These experiences demonstrated that public sector tractor hire services are generally not sustainable, if not combined with an entrepreneurial spirit and private sector partnerships.

In many countries, the private sector has mainly been involved in the provision of hire services; mostly on a very small scale and mostly in situations where tractor owners have spare capacity and hire out their machines to generate income and to assist in covering costs. In most cases their clientele are neighbouring farmers, known to the owner who can be confident that he will receive payment for the work carried out. In some cases payment is in kind. In fewer cases, but increasingly, local entrepreneurs are investing in two or three machines and running small scale contractor businesses. This again occurs mainly in communities where the contractor knows his clientele. One way to improve the profitability of private sector tractor hire services is to diversify the number of operations offered and thus ensure that the services can be marketed continually throughout the year.

2.5. Gender issues in smallholder mechanization

In SSA, women contribute between 60 and 80% of the labour for food production. Moreover, agriculture is becoming predominantly feminized as a consequence of increasing male out-migration to urban centres. Women now constitute the majority of smallholder farmers and provide most of the labour and manage a large part of the farming activities on a daily basis. On the other hand, however, it is often the men who control the resources required to invest in mechanization (especially capital). Studies show that increasing women's access to productive resources to be at par with those of men would increase farm yields by 20-30% (FAO, 2011b), it would be sensible to consider how women can access or have control of resources invested in mechanization for out-scaling CA (Figure 4).

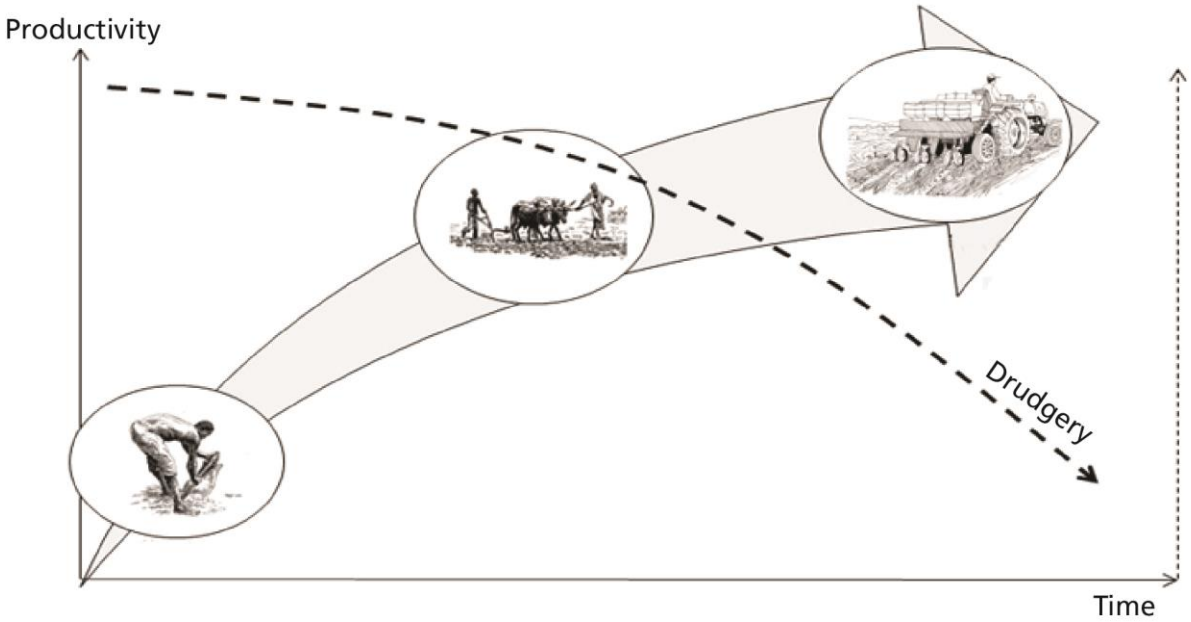

Figure 4. Agricultural mechanization has the potential to reduce the drudgery of hand-powered mechanization drudgery and increase labour and agricultural productivity.
Source: FAO, 2013d

3. Opportunities

3.1. Raising farmers' incomes through sustainable crop production intensification

The greatest opportunity presented by the current state of agricultural mechanization in SSA is to convert the vicious cycles depicted in Figure 2 into *virtuous* cycles as shown in Figure 5.

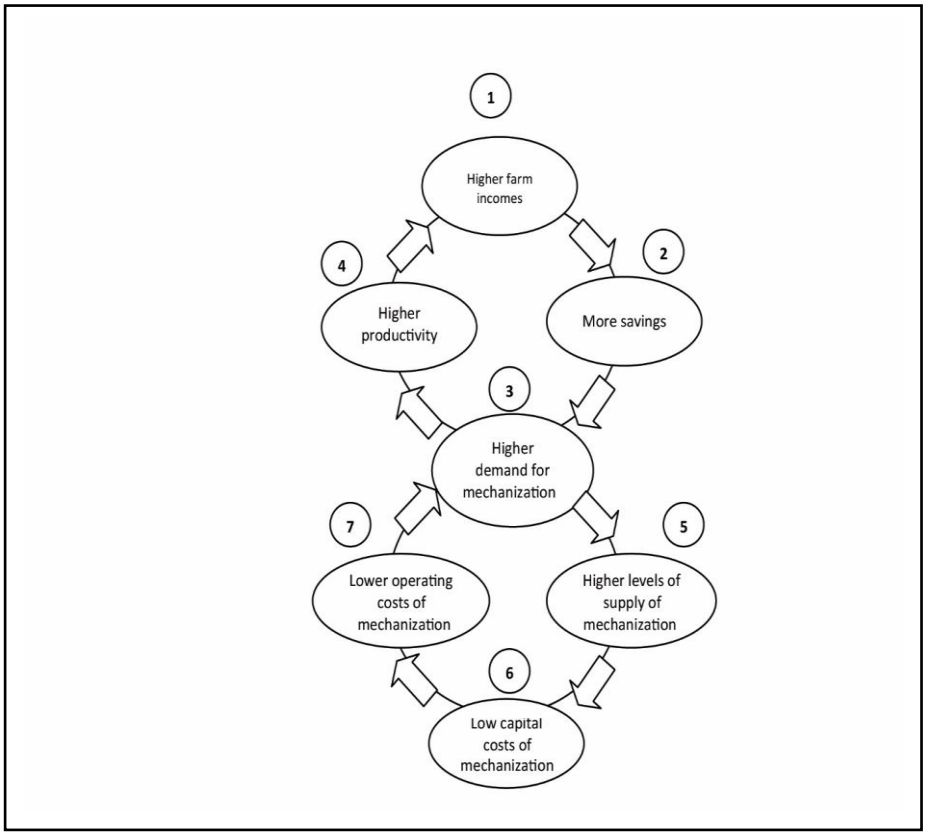

Figure 5. Virtuous cycles resulting from sustainable crop production intensification
Source: FAO, 2013d

In Figure 5 it can be seen that sustainably raising farm family incomes (1) can have a positive knock-on impact on the supply of the essential farm power and mechanization supply. Firstly raised incomes allow greater savings and so demand for agricultural mechanization services (2), or the acquisition of farm machinery (and other inputs) becomes more feasible for the farmer (3). This in turn will raise productivity (4) leading to even further improvements in farmers' incomes. At the same time, in the lower circle of Figure 5, it can be seen how increased demand for agricultural mechanization will lead to a concomitant improvement in supply as a market response (5). An expanding market will mean that operating costs per unit are reduced (6) and so prices can be lowered without jeopardizing profitability (7). The result of lower costs will be a catalyst to increased demand (3) and so the virtuous cycle is completed.

Ending poverty is the UN SDG 1 and is a global priority. FAO (2015) points out that 80% of the world's extreme poor live in rural areas where most are dependent on agriculture. In addition they point out that agricultural growth in low-income and agrarian economies is at least twice as effective as growth in other sectors in reducing hunger and poverty. The

incomes of farm families can be improved through investment in rural development, establishing social protection systems, building on rural-urban linkages and focussing on boosting the incomes of the critical agents of change, which include smallholder farmers.

Raising the productivity of smallholder farmers must be achieved in a sustainable way as the history of the Green Revolution (GR) model teaches. Beginning in the 1950s and expanding through the 1960s, the GR produced changes in crop varieties, and agricultural practices worldwide (Royal Society, 2009). The production model, which focused initially on the introduction of genetically improved, higher-yielding varieties of wheat, rice and maize in high potential areas (Hazell, 2008; Gollin *et al*., 2005) relied upon and promoted homogeneity using genetically uniform varieties grown with high levels of complementary inputs, such as irrigation, fertilizers and pesticides, which often replaced more environmentally friendly practices. Fertilizers replaced organic soil quality management, while herbicides and pesticides provided an alternative to crop rotations as a means of controlling weeds, pests and diseases (Tilmann, 1998).

However, as was detailed in the Background section, there have been serious negative consequences and what is now imperative is to introduce sustainability into the future productivity increases that are required, especially in SSA. These will follow the 'Save and Grow' paradigm (FAO, 2011a) which demands stewardship of fragile natural resources, while at the same time achieving crop production intensification through greatly enhanced land husbandry methods, including conservation agriculture.

3.2. New opportunities for agricultural mechanization development

In many African countries, despite the challenges discussed in Section 2, the situation for the foreseeable future presents numerous opportunities. After decades of decline in per capita food production, a new climate of optimism exists as well as a modified international investment landscape. In the future, the agriculture sector is projected to be economically sustainable because of the rapid expansion of urban centres and the associated demand for agricultural products and also the increases in international food commodity prices. There are many reasons why the new situation will provide opportunities for the adoption and expansion of agricultural mechanization. The main ones are:

3.2.1. Increasing agricultural wages

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

3.2.2. New sources of farm machinery more suitable for African conditions

Western technology, which was a very important source of farm machinery for Africa in the past, has become increasingly more sophisticated and has become less suitable for African smallholder conditions at the same time as becoming less affordable for African farmers. However, the newly emergent industrial economies such as India, China and Brazil have stepped in and have provided new sources of tractors and farm machinery which are continually coming on to local markets. This machinery is often more suitable for African conditions and is considerably cheaper than machinery manufactured in Western Europe or North America. Of special interest are cheaper versions of unsophisticated two-and four-

wheel tractors which can supply the tractive power for smallholder farms, either by being owned directly or cooperatively, or by being used for mechanization service provision in the hands of entrepreneurs.

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

African countries will have to adapt to the world energy crisis and to new energy saving technologies. New ideas on energy efficiency and the use of other energy sources will have to be further developed and adopted. With such a large potential for the utilization of solar energy, the continent has been the subject of particular interest regarding the development and use of solar power. Many technologies have already been developed for drying vegetables and fruits as well as for pumping water and the provision of electrical energy. As discussed above in Section 3.1, the FAO Save and Grow Concept is leading the way for sustainable crop production intensification with leaner and more precise and energy efficient production technologies such as reduced and no-tillage/direct seeding practices.

3.2.4. Climate Smart / Conservation Agriculture – a new need for environmentally sustainable mechanization

The effects of climate change are now with us and we can expect increasing episodes of violent storms, higher temperatures and increased drought (IPCC, 2014). The continuing emissions of GHGs means that these damaging events are bound to occur and are bound to increase in severity. Agricultural innovations are vital if crop production is to continue; and if production is to be intensified then the innovations will need to be very robust indeed. Major international donors and world leaders plead for new agricultural concepts that are more climate-smart (FAO, *et al*., 2014). The use of agricultural machinery has sometimes been criticized for the negative effects it can have on the environment – especially when it is used for fuel-hungry and degradation-inducing soil tillage. At the same time it is clear that developing new machines and techniques which are more precise and protective of the environment is the key to climate-smart agriculture. One powerful concept is conservation agriculture which maintains a permanent cover on the soil and uses direct seeding through the vegetative cover. At no time is the fragile soil exposed directly to solar radiation, high winds or high intensity precipitation. Direct seeding of this sort has only been made possible by the development of specialized equipment. Similar developments or technologies can also be expected in the future in order to tackle other emerging environmental problems.

3.2.5. New need for sustainable business models for mechanization in Africa

The demand for mechanization services in SSA is commonly latent: a need exists but there is a lack of awareness amongst potential customers, mainly smallholder farmers, for such services. The development and expansion of agricultural mechanization (and, indeed, the agricultural and machinery sectors as a whole) can take place with the sensitization and awareness creation of customers for such services, coupled with the appraisals and identification of appropriate business models to suit the most varying of local conditions found within countries in SSA. Such business models may vary increasingly within countries and may also vary over time, as there may be one type of business model to start a machinery service business, and other business models to enable it to grow and prosper. Even though regions of SSA may still seem somewhat underdeveloped in terms of economic activities, there are great possibilities for the development and adoption of new ideas for business models adapted to the prevailing conditions. The potential of such markets should not be overlooked as they offer abundant opportunities for innovative business enterprises (FAO,

2012).

3.2.6. Public Private Partnerships

There are new initiatives in mechanization where public and private sector are working very closely together. One such example is the Potato Initiative Africa (PIA) that is implemented within the German Food Partnership and private sector agricultural machinery suppliers – in this case with focus on potatoes, operating in Nigeria and Kenya. Potatoes as well as other root and tuber crops are very labour intensive and are a staple crop for many smallholders who normally depend on hand labour. Hence the potential for mechanization here is very great but also challenging. This initiative was launched in 2012 and first results are currently being evaluated (Breuer *et al*., 2015).

In this context it should also be noted that FAO and the European Agricultural Machinery Industries Association (CEMA) have just recently agreed on a new partnership that aims to promote wider use of sustainable agricultural mechanization in developing countries. The collaboration will focus on managing and disseminating knowledge on sustainable approaches to agricultural mechanization that could lead to technical programmes to support innovation in mechanization and facilitate the implementation of sustainable mechanization initiatives at the field level (FAO, 2015b).

There are also new purely private initiatives such as the new Model Farm Project in Zambia where the international Agriculture Machinery Company, AGCO has launched a model training farm on 150 ha. It is intended that farmers will get hands-on experience by working with the latest machinery. This Model Farm is divided into a wide range of demonstration crop areas to be planted, cultivated and harvested using a diverse range of equipment. The training facility intends to address the full range of farmers from small scale producers up to larger commercial-scale farmers (AGCO, 2015).

3.3. Investing in agricultural mechanization for SSA

In 2009 FAO and UNIDO (UN Industrial Development Organization) joined forces to debate the opportunities and needs for investment in agricultural mechanization in SSA (FAO, 2011c). The recommendations that emerged were to facilitate support for both private and public sector investment flows into the development of agricultural mechanization in Africa. One of the main objectives was to reduce primary land preparation carried out by hand-tool technology from 80% then to 40% by 2030 and 20% by 2050. Crop establishment practices should be increasingly done by a combination of draught animal power and tractors. The principal recommendations were as follows:

3.3.1. Establish national committees on agricultural mechanization (NCAM)

The NCAMs would comprise representatives of all major stakeholders such as ministries of agriculture, finance, industry and trade; farmers' organizations; financial institutions, manufacturers; dealers, and R&D institutions. The NCAMs would assist the government to review national policy on mechanization, review the need for a national mechanization strategy, ensure the compatibility of machinery entering in aid packages and prepare action plans for capacity building.

3.3.2. Create an enabling environment

An enabling environment of policies, institutions and regulations, would be to facilitate the increased use of tractors and associated agricultural machinery through a series of mechanisms:

- Promotion and support of local entrepreneurial machinery contracting businesses.
- Rationalization of regulations for the use of tractors for off-farm applications (especially rural road infrastructure contracting).
- Increasing the area under irrigation where feasible.

3.3.3. Increase investment in agricultural mechanization

This would principally be to encourage the financial sector, including banks and other lending institutions, to focus attention on facilitating credit lines to farmers and others wishing to invest in tractors and agricultural machinery.

3.3.4. Capacity building

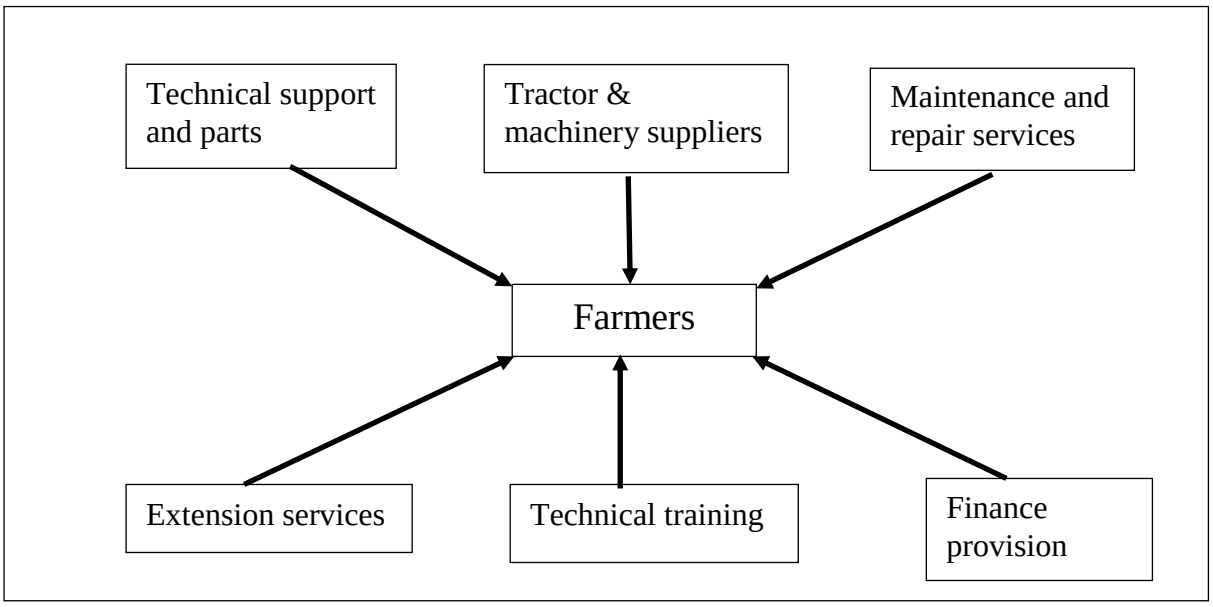

Figure 6. Stakeholders in the farm machinery support network for smallholder farmers

This would require a thorough analysis of the existing situation and the measures needed to ensure that adequate training facilities exist to promote safe and environmentally friendly mechanization. Training programmes would be developed to cover the needs of farmers, operators, mechanics and other relevant stakeholders involved in the provision of agricultural machinery services (Figure 6). Ideally such training centres would be attached to an already existing university or college and should specifically attempt to integrate the various knowledge blocks required in mechanization and agri-food value chains in order to get the highly qualified mechanization business managers that are required.

3.3.5. Code of practice for agricultural machinery suppliers

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

3.3.6. Create regional networks of agricultural mechanization

Membership should be encouraged from R&D institutions, professional organizations, farmers' organizations, manufactures and distributors. Links would be forged with existing networks related to mechanization, conservation agriculture and draught animal power. Again FAO and UNIDO have expertise in this field which they would be pleased to share.

Clearly not all these opportunities will be relevant in all cases, but the fruits of the deliberations of this high level international group of experts show the value of studying the complex issue of getting mechanization services to smallholder farms and can provide guidance when considering the next steps to take.

4. The way forward: suggested actions

As we have seen in earlier sections of this paper, there has been some highly focused analysis of the agricultural mechanization scenario in developing countries over the years (FAO, 2008; FAO & UNIDO, 2008; FAO, 2011; FAO, 2014). Throughout, there have been five recurring themes: i) that farm power and mechanization are essential inputs if agricultural productivity and production are to rise to feed the world's burgeoning population; ii) that the intensification of crop production must be sustainable in the sense that its environmental footprint must be as low as possible and anyway less that the rate of natural renewal; iii) that top-down solutions are rarely successful, all stakeholders need to be considered from the outset and the private sector must lead the development process on the ground; and iv) the role of the public sector is that of providing an enabling environment for the private sector to perform without unnecessary obstacles; and v) a more holistic value chain approach needs to be taken for agricultural mechanization that goes beyond production into post-harvesting, processing and marketing activities. An illustrative quote (from FAO & UNIDO, 2008) helpfully summarizes the way forward: 'If agricultural mechanization efforts are to succeed in Africa, there is an urgent need for all concerned, be they farmers, supporters, planners or policy makers, to understand and contribute to agricultural mechanization efforts across the entire farming system and with a value chain perspective'.

The following main actions can be recommended at this stage:

4.1. Integration of agricultural mechanization in pan-African policy frameworks

There is a need, at a pan-African level, to sensitize and further raise awareness of the potential of agricultural mechanization for the development of Africa and develop the important policies, that are supranational in nature and re-focused at the reginal level, that are required. The NEPAD – CAADP framework can provide a feasible and viable platform for

such an objective as it involves policy-makers from the African Union and thus can play a crucial role in the further integration of agricultural mechanization polices and strategies at country national level.

4.2. Sustainable agricultural mechanization strategies

Mechanization inputs should not be confined only to on-farm uses as economies of use can be enhanced by including off-farm uses. Additionally agricultural mechanization is successful when there is an effective demand for the outputs of farming (including on- and off-farm value addition). For sustainability, the entire agri-food chain, including financing of the capital investments required, must be considered (FAO, 2014). Further, mechanization technologies for agri-food chains can contribute to waste avoidance as well as for maintaining rural infrastructure and providing employment opportunities.

A key feature of sustainable mechanization is the requirement to increase production whilst conserving the natural resource endowment (especially soil and water). It cannot be over-emphasized that future mechanization models must conform to FAO's 'Save and Grow' paradigm. This recognizes that agriculture must be both productive and profitable for the farmer, and at the same time can contribute to the conservation of resources and the delivery of ecosystem services. As the negative effects of climate change become more apparent, the large scale adoption of conservation agriculture practices, which protect the soil, conserve water, use less energy and apply inputs more precisely and efficiently, will be essential to maintain food production. At the same time as reducing the emission of GHGs during agricultural production, carbon is sequestered in untilled soil and in preserved forest areas.

Agricultural mechanization strategy formulation has been a key FAO activity for several decades (FAO, 2013c & d). For change in the use of agricultural mechanization to take place consistently and coherently requires a plan to be formulated and implemented. And, as we have seen, the changes required for agricultural mechanization to be sustainable are dramatic indeed. The process can be guided by referring to FAO's guidelines (FAO, 1988). Essentially two important processes should be adopted during the formulation process. Firstly a fully participatory approach is recommended in order for he views of the multiple stakeholders to be heard. This is best achieved via a series of participatory workshops involving the whole spectrum of interested actors from all along the value chain. Secondly a systematic approach is recommended given the complexity of agricultural mechanization. The methodology for the formulation process comprises four major steps as shown in Figure 7.

Figure 7. The progressive steps in the formulation of an agricultural mechanization strategy
Source: FAO, 2013c

Once the exercise has been launched at the inaugural workshop, the first phase is undertaken by the formulation team who, each within their particular specialization, perform a thorough analysis of the situation. A second participatory workshop is the held to gather views on the current situation. The third step s strategy and action plan formulation which must be aligned with national development goals and policies. These will be refined during a third workshop. The plan can be further defined during the fourth step of the process when a portfolio of project profiles can be prepared. This step is completed with the presentation of the results at a final participatory workshop.

Throughout this process the concept of sustainability must be at the forefront and be an over-riding priority. As FAO (2014) points out, although the FAO guidelines have been used in several countries in Asia and Africa, and were adopted by the Regional Network for Agricultural Machinery (RNAM) in Asia, it is difficult to know how useful the strategies developed have been as there has been no specific evaluation of the programme. There is a need to revise the original guidelines and adapt them to the specific requirements of current mechanization needs, and especially that for sustainability, in order to produce sustainable agricultural mechanization strategies (SAMS) applicable to the requirements of individual countries.

4.3. Adoption of sustainable agricultural practices for smallholders

The necessity of better using natural resources and the overall greening of agricultural practices can find a valid ally and contribution from agricultural mechanization, especially at the smallholder level. The increased availability of mechanization technologies not only enhances yields for smallholders, via intensification, conservation agriculture, more climate-resilient, labour and energy-efficient and hence more gender friendly practices, but enables a more rational and efficient approach to farming in the long term and thus increases the prospect of sustained profitability over time. It can also lead to increased ecosystem resilience and long-term sustainability of smallholder systems. FAO's Farmer Field School (FFS) approach has been successfully implemented in many African countries with regard to

Integrated Pest Management. There will be room to further expand the FFS concept and include themes such as sustainable intensification and small mechanization support at field level (FAO, 2015c). This could include specifically the introduction of tools and mechanization technology that help to adapt better to climate change threats at local level. At the same time the FFS, if organized well, could become the nucleus for innovative finance schemes such as 'matching grants' or 'village saving and loan groups' to facilitate the change of mindset that agricultural mechanization technology cannot be considered as free donations, but should be part of FFS or farmer group based investment decisions.

4.4. Smallholder up-scaling with the adoption of more specific business models

Smallholders are commonly relegated to the margins of agri-food value chains and find it difficult to access and integrate into such modern food systems. The identification and specification of appropriate business models for smallholder mechanization can provide numerous opportunities for improved access and integration in agri-food value chains with more reliable supplies of produce, increased volumes, more timely deliveries and value addition.

4.5. Institutional and organizational arrangements for increased smallholder mechanization

Smallholders that are organized and provided with institutional settings, such as producer organizations, will be able to access more opportunities for agricultural mechanization. The ability to access more sources and varied types of financing, the sharing of knowledge, better bargaining power, increased value addition and the opportunities to better use agricultural mechanization to realize its full potential will raise the level of improved commercial farming and thus enable further integration into more modern agri-food systems.

4.6. Increased integration into agri-food value chains with smallholder mechanization

Agricultural mechanization is a corner stone for smallholder integration in more modern food systems. However such mechanization is not only applicable at the farm level, but also and importantly to value addition operations such as improved post-harvest operations, processing and marketing activities. Agricultural mechanization, enables time savings, between harvesting and consumption and thus enables more time for marketing.

4.7. Increased agricultural mechanization with private sector development

Fostering the further development of the private sector within the context of agricultural mechanization has the potential not only to increase the manufacturing base for agricultural mechanization in Africa, but also to provide the opportunities for more south-south collaboration among manufacturers, dealers and institutions. Private sector development can also support smallholder enterprises at field level where farmers provide mechanization services (hire services) to other famers. This can expand not only farm yields, but also the demand for vehicles, equipment and tools at national level, creating a mutually reinforcing virtuous circle.

4.8. Fostering further south-south collaboration in agricultural mechanization: knowledge sharing platform

Common lessons learnt on development pathways and the sharing of such experiences among and within the context of south-south cooperation can provide a common knowledge sharing platform for improved agricultural mechanization in Africa. This could provide technology transfer and know-how transfer in terms of machinery, tools and equipment, but also and importantly on application models that work or do not work at national and local level. The sharing of policies and strategies for agricultural mechanization that work or do not work can further enhance this collaboration and foster more specific and targeted policies and strategies.

4.9. Field–based capacity building and capacity development for agricultural mechanization

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

4.10. Regional centres of agricultural mechanization

Several African countries have good centres of expertise in agricultural mechanization and these should always be encouraged and supported. These centres can be agricultural engineering institutes, university faculties, or research and testing centres. However there is a need for regional centres of excellence that can guide national policy directions towards sustainable agricultural mechanization. Closely collaborating with farmers, other value chain actors, manufacturers, other relevant private sector stakeholders as well as national government organizations, the centres of excellence would also engage in R&D, machinery testing and training, where those activities were deemed appropriate and useful for the private sector. The centres must be closely attuned to the interests of these crucial stakeholders to avoid the trap of researching concepts (farming methods and machinery) that do not move beyond the prototype stage; and testing machinery with no clear-cut clientele in mind.

An interesting model to study is the Asian Centre for Sustainable Agricultural Mechanization – UN-CSAM[1]. The agricultural machinery manufacturing sector is already large in Asia and it needs to be incentivized to manufacture equipment for sustainable mechanized agricultural practices. National and regional standards and testing centres are already being motivated and directed by the Asian Network for Testing Agricultural Machinery (ANTAM) under the auspices of the Beijing-based Centre for Sustainable Agricultural Mechanization (UN-CSAM) of the UN Economic and Social Commission for Asia Pacific (UNESCAP). Capacity building for SAMS implementation is an important undertaking as agricultural

[1] http://un-csam.org/index.asp

engineering training and education programmes are in decline world-wide. Capacity building focuses on the youth and integrates considerations of, *inter alia*, natural resource protection and gender issues.

CSAM was established as the Asian and Pacific Centre for Agricultural Engineering and Machinery in 2002. The CSAM members are identical with the UNESCAP as it is a subsidiary body of it. In total these are 53 countries in the Asia-Pacific Region.

The CSAM objectives are to enhance technical cooperation among the members and associate members of ESCAP as well as other interested member states of the UN, through extensive exchange of information and sharing of knowledge and promotion of R&D and agro-enterprise development in the areas of sustainable agricultural mechanization and technology for the attainment of the internationally agreed development goals, including the SDGs, in the region.

The Centre will achieve the above objectives through undertaking such functions as:

1. Assistance in the improvement of agricultural engineering and sustainable agricultural mechanization.
2. Enhancement of farm mechanization technologies in addressing issues related to subsistence farming.
3. Increased food security and poverty reduction through the promotion of agro-based small and medium-sized enterprise development and commercial farming to seize opportunities for increased market access and agro-food trade.
4. A focus on an agro-based enterprise cluster concept and enterprise development activities to enhance the capabilities of members in identifying potential agricultural commodities in their respective countries on a clustering basis.
5. Regional cooperation in green agro-technology transfer, including through networking of focal point national institutes in CSAM member countries and other relevant institutions.
6. Setting up an interactive Internet website to allow members full access to information and technology databases, including the sharing of expert systems and decision support systems in financial management of small and medium-sized enterprises.
7. The strengthening of outreach services at field level in countries across SSA, in particular extension, training and demonstration services
8. Promotion of the technology transfer process from research and development institutes to the agricultural and farm machinery extension systems in member countries for poverty reduction.
9. Assistance in the dissemination and exchange of sustainable and commercially successful machinery and related drawings of appropriate tools, machines and equipment.

10. Technical assistance projects, capacity-building programmes, training workshops and seminars and advisory services on sustainable agricultural mechanization and related food safety standards.

11. Tapping the resources of developed countries in building the capacity of member countries.

12. Capacity building and development in economics, business, finance, marketing and entrepreneurship as related to agricultural mechanization

The UN-CSAM model can be used to establish similar centres in Africa with a focus on appropriate sustainable mechanization and encompassing the whole agri-food value chain in their remit. It is proposed that the feasibility of establishing two centres – one in Francophone Africa and the other in Anglophone Africa – be studied as a matter of urgency.

5. Estimated costs

The envisioned way forward is a multi-task and multi-faceted approach to the further development and integration of agricultural mechanization for the agricultural transformation of Africa. The design, development and implementation of the activities described in Section 4 vary from policy sensitization to the development of centres of excellence for sustainable agricultural mechanization. Such activities need to be considered in the medium term of three to five years not only in terms of planning, but importantly in implementation. Thus an estimated budget for the full range of activities is positioned around US$45 million.

6. References

AGCO, 2015. AGCO Launches Model Farm Project in Zambia, Available at: http://investors.agcocorp.com/phoenix.zhtml?c=108419&p=irol-newsArticle&ID=1702132; accessed on 10 October 2015.

Breuer, T., Brenneis, K. & Fortenbacher, D, 2015. Mechanisation – a catalyst for rural development in sub-Saharan Africa. *Rural 21* **49** (2): 16-19.

Casão-Junior, R., J., Guilherme de Araújo, A., Fuentes-Llanillo, R. (2012) *No-Till Agriculture in Southern Brazil*. Food and Agriculture Organization of the United Nations, Rome, Italy. 77 pp.

FAO, 1988. *Agricultural mechanization in development: guidelines for strategy formulation*. Gifford, RC. Food and Agriculture Organization of the United Nations. Rome, Italy. Agricultural Services Bulletin 45. 77 pp.

FAO, 2006. *Farm power and mechanization in sub-Saharan Africa*. Sims, BG & Kienzle, J. Food and Agriculture Organization of the United Nations. Rome, Italy. Agricultural and Food Engineering Technical Report 3. 65 pp.

FAO, 2007. *Addressing the challenges facing agricultural mechanization input supply and farm product processing.* Sims, BG., Kienzle, J. Cuevas, R. & Wall, G (eds). Food and Agriculture Organization of the United Nations. Rome, Italy. Agricultural and Food Engineering Technical Report 5. 71 pp.

FAO, 2008a. *Agricultural mechanization in sub-Saharan Africa: time for a new look*. Mrema, G., Baker, D. & Kahan, D. Food and Agriculture Organization of the United Nations. Rome, Italy. Agricultural Management, Marketing and Finance Occasional Paper 22. 54 pp.

FAO, 2009a. *How to feed the world in 2050*. Food and Agriculture Organization of the United Nations. Rome, Italy. 35 pp. Available at: http://www.fao.org/fileadmin/templates/wsfs/docs/expert_paper/How_to_Feed_the_World_in_2050.pdf

FAO, 2009b. *The State of Food Insecurity in the World: Economic crisis – impacts and lessons learned.* Food and Agriculture Organization of the United Nations. Rome, Italy. Available at: http://www.fao.org/docrep/012/i0876e/i0876e00.htmFAO,2009c.

FAO.2009c. *Rural transport and traction enterprises for improved livelihoods*. Crossley, P., Chamen, T & Kienzle, J. Diversification Booklet 10. Rural Infrastructure and Agro-Industries Division, Food and Agriculture Organization of the United Nations. Rome, Italy. 94 pp.

FAO, 2011a. *Save and Grow. A Policymaker's Guide to the Sustainable Intensification of Smallholder Crop Production.* Food and Agriculture Organization of the United Nations: Rome, Italy. 102 pp. Available at: http://www.fao.org/docrep/014/i2215e/i2215e.pdf

FAO, 2011b. *The State of Food and Agriculture 2010-2011: Women in Agriculture – Closing the Gender Gap for Development*. Food and Agriculture Organization of the United Nations. Rome, Italy. Available at: http://www.fao.org/docrep/013/i2050e/i2050e.pdf

FAO, 2011c. Investment in agricultural mechanization in Africa: Conclusions and recommendations of a Round Table Meeting of Experts. Ashburner, J.E. & Kienzle, J., eds. Food and Agriculture Organization of the United Nations. Rome, Italy. Agricultural and Food Engineering Technical Report 8. 76 pp. ISBN: 978-92-5-1068208-5.

FAO, 2012. *Hire services by farmers for farmers*. Sims, BG., Röttger, A. & Mkomwa, S. Diversification Booklet 19. Rural Infrastructure and Agro-Industries Division, Food and Agriculture Organization of the United Nations. Rome, Italy. 82 pp.

FAO, 2013a. Agricultural mechanization in India. Singh, G. **In**: Kienzle, J., Ashburner, J. & Sims, B.G. (eds) Mechanization for rural development: a review of patterns and progress from around the world. Food and Agriculture Organization of the United Nations. Rome, Italy. *Integrated crop management* **20**: 99-119.

FAO, 2013b. China: development of farm mechanization and the agricultural machinery industry. Wang, M. **In**: Kienzle, J., Ashburner, J. & Sims, B.G. (eds) Mechanization for rural development: a review of patterns and progress from around the world. Food and Agriculture Organization of the United Nations. Rome, Italy. *Integrated crop management* **20**: 121-139.

FAO, 2013c. Agricultural mechanization strategies. Ashburner, J, & Lantin, R. **In**: Kienzle, J., Ashburner, J. & Sims, B.G. (eds) Mechanization for rural development: a review of patterns and progress from around the world. Food and Agriculture Organization of the United Nations. Rome, Italy. *Integrated crop management* **20**: 205-228.

FAO, 2013d. Agricultural mechanization in sub-Saharan Africa: Guidelines for preparing a strategy. Houmy, K., Clarke L.J., Ashburner, JE. & Kienzle, J. Food and Agriculture Organization of the United Nations. Rome, Italy. *Integrated crop management* **22.** ISBN 978-92-5-107762-7.

FAO, 2014. *A regional strategy for sustainable agricultural mechanization: sustainable mechanization across agri-food chains in Asia and the Pacific region*. Mrema, G, Soni, P. & Rolle, R. Food and Agriculture Organization of the United Nations. Regional office for Asia and the Pacific. RAP Publication 2014/24. 74 pp.

FAO, 2015a. Conservation Agriculture; http://www.fao.org/ag/ca/1a.html (accessed on 09 October, 2015).

FAO, 2015b. New partnership to promote sustainable mechanization of agriculture; at http://www.fao.org/news/story/en/item/334988/icode/ (accessed on 10 October, 2015)

FAO, 2015c. Building resilient agricultural systems through farmer field schools. Food and Agriculture Organization of the United Nations. Rome, Italy. 14pp.

FAO, CGIAR, CCAFS & CIMMYT. 2014. *Practice Brief: Climate Smart Agriculture / Conservation Agriculture: Implementation guidance for policy makers and investors*. FAO, CIMMYT, CCAFS. Available at: http://www.fao.org/3/a-i4066e.pdf

FAO & UNIDO, 2008. Agricultural mechanization in Africa: time for action. Food and Agriculture Organization of the United Nations. Rome, Italy & UN Industrial Development Organization, Vienna, Austria. 26 pp.

Gollin, D., Morris, M. & Byerlee, D., 2005. Technology adoption in intensive post-green revolution systems. *Amer. J. Agr. Econ*., **87** (5): 1310-1316.

Hazell, P.B.R., 2008. *An assessment of the impact of agricultural research in South Asia since the green revolution*. Rome. Science Council Secretariat.

Hilmi, M. 2013. Hire services as a business, *Agriculture for Development*, **19**: 21-25.

IPCC, 2014. *Intergovernmental Panel on Climate Change. Fifth Assessment Report* (AR5). www.ipcc.ch.

Kienzle, J & Sims, BG., 2015. *Strategies for a sustainable intensification of agricultural production in Africa*. Open meeting of the Club of Bologna. Milan (Italy) Expo 21 September, 2015. 14 pp.

Pearce, F., 2012. *The landgrabbers: the new fight over who owns the planet*. Eden Project Books. London, UK.

Royal Society, 2009. *Reaping the benefits: Science and the sustainable intensification of global agriculture*. RS Policy document 11/09. London

Sims, B.G. & Kienzle, J. 2015. Rural mechanisation: where are we now and where should we be going? *Rural 21* **49** (2): 6-9.

Tilmann, D., 1998. The greening of the green revolution. *Nature*, **396**:211-212. DOI10.1038/24254