Club of Bologna

STUDY GROUP REPORT

SG 1 - "Sustainable Agricultural Mechanization in Africa"

AGRICULTURAL MECHANIZATION OPPORTUNITIES IN SUB-SAHARA AFRICA

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Summary

AGRICULTURAL MECHANIZATION OPPORTUNITIES IN SUB-SAHARA AFRICA[1]

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Executive summary

This preliminary report on prospects for agricultural mechanization in Africa is structured as follows:

1 - Introduction

Farm mechanization is an essential input with the potential to transform lives and expand economies. But it must be sustainable in the sense that it must be environmentally friendly and climate smart.

Mechanization encompasses all three major power sources; muscles, both human and animal; and engines, both internal combustion and electrical.

2 - Machinery ownership and use

Different forms of machinery ownership and their potentials are discussed, including: individual and collective ownership models and service delivery enterprises.

3 - Changes in agriculture and food supply

This section examines issues of land tenure, farm size, the increasing availability of information and communications technology (ICT), gender issues, crop plant breeding, crop production practices, solar-powered irrigation, agriculture sector employment issues, marketing and post-harvest technology.

4 - Entrepreneurs in agricultural production

The focus is on the profound potential of ICT and ICT entrepreneurs and the uptake from research centres including: weeding and precision spraying, precision agriculture and drones, and scaling up innovation adoption.

5 - The 'uberization' of agricultural equipment use

The term 'uberization' refers to the evolution of machinery usage models such as Hello Tractor, and other service provision enterprises that include the use of ICT and global positioning systems (GPS).

6 - Suggestions for future developments

The areas where the Club of Bologna could be looking to help to improve the availability of mechanization inputs to smallholder farmers include:

- Upgrading the available farm machinery.
- Stimulate entrepreneurs to apply disruptive technologies.
- Upgrading engineer and technician training.
- Scaling up novel technologies such as solar-powered irrigation.
- Reducing the drudgery of hand-weeding.

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- The use of drones for crop monitoring, coupled with micro- dosing of herbicides or other weed elimination methods.
- Complementary action is required from the implementation of a conducive national policy framework to local-level interventions from the private sector.
- Small-scale agriculture can have high land productivity, we need to improve overall productivity by making essential mechanization inputs available along the value chain from production to marketing.

1 - Introduction

There have been a number of recent reviews on the current status of mechanization in Africa as well as on future potential and prospects [1]–[3]. According to Ren Wang (Assistant Director-General Agriculture and Consumer Protection Department, Food and Agriculture Organization of the United Nations – FAO) in [4], *there is no doubt that the application of farm power to appropriate tools, implements and machines – "farm mechanization" – is an essential agricultural input in sub-Saharan Africa (SSA) with the potential to transform the lives and economies of millions of rural families…. Agricultural mechanization in its broadest sense can contribute significantly to the sustainable development and has the potential to render post-harvest, processing and marketing activities and functions more efficient, effective and environmentally friendly.*

In a special edition of Agricultural Mechanization in Asia, Africa and Latin America (AMA)[5], the status of agricultural mechanization in a number of African counties and in some specific crops (e.g. rice and cassava) is discussed. There is a limited review of government policies as well as of activities within African institutions related to agricultural machinery design, development and testing. In the same publication the prospects are discussed of advancing the introduction of Indian or Chinese agricultural machinery into the African market. African governments and international organizations have made recommendations with a number of steps or actions that need to be given high priority to enhance the rate of mechanization of agriculture in Africa as part of the large effort to improve land and labour productivity and production of food in Africa while also looking to maintain employment in rural areas, either related to food production or as a result of technology development. For example, the Malabo Montpellier Panel, a group of 17 African and international agricultural experts, issued a report with seven recommendations including a need to elevate national agricultural mechanization investment strategies within national agricultural plans, design mechanization pathways that are socially and politically sustainable and prioritize the entire agricultural value chain mechanization [6]. These recommendations are given in **Annex 2**.

The African Union Commission (AUC) has posited [7] that agricultural mechanization needs to be developed along the value chain, and should be private-sector driven, environmentally compatible and climate smart, affordable, friendly to smallholder farmers, and inclusive of the interests of women and youth. Subsequently, *The framework for Sustainable Agricultural Mechanization in Africa* (SAMA) was developed through a collaboration between the FAO and the Department of Rural Economy and Agriculture (DREA) of the AUC [7].

In general mechanization level and prospects are characterized by the size or type of the farms: small-scale subsistence farmers, small-scale commercial farmers, medium-scale farmers and large-scale farmers. In sub-Saharan Africa (SSA), large-scale farms (>100 ha) and the emerging medium-scale farms (20–100 ha) do not generally have a problem with access to farm power; but peasant subsistence or smallholder farms (typically <2 ha) experience extreme difficulty [4]. Even if the larger farms may have difficulties in maintaining or improving the mechanization level, then their problems are in general of a different organizational or infrastructure nature than those experienced by smallholder farms.

Zhou [8] estimates that the value retained in three categories of agricultural machinery in SSA is given on the basis of imports and exports, not including local production. The annual investment in these categories is:

- Machinery for soil preparation and cultivation ≈ 1 USD/ha
- Harvesting, produce cleaning and grading < 1 USD/ha
- Tractors: between 5 and 20 USD/ha (these are also used in soil preparation and transport of harvested products).

In SSA there are basically three technology levels of mechanization depending on the power source used:

- **Hand tools** at the most basic level employ only human muscle as the power source. In most cases applications include manual planting, weeding and harvesting and also some post-harvest operations. These are not included in the review on machinery ownership (below), but they will get special attention for change since they involve much drudgery and are often allocated to female labour.
- **Animal draught implements** employ animal muscles as the main power source as, for example, in traditional ploughing. Some of the use or ownership aspects discussed below also apply to this equipment.
- **Mechanical power equipment** has an internal combustion or electrical main power source as in 2- or 4-wheel tractors for ploughing or planting, or a thresher for grain.

Subsequently this paper discusses some of the changes in agriculture and the food value chain that may affect the rate and form of mechanization in SSA agriculture. It will also look at innovations and entrepreneurship that are underway or that maybe encouraged through cooperation from research centers and industry from other parts of the world. Effective development of mechanization in Africa needs to rely on a productive partnership between government institutions, research centres, private companies and initiatives by individual farmers and risk-taking young entrepreneurs who want to bring technology to the field. The examples given will hopefully inspire or stimulate such initiatives and cooperations.

2 - Machinery ownership and use

The types of machinery in a given region or on a given farm depend on the major crops grown. Soil tillage and cultivation equipment powered by 2- or 4-wheel tractors or by animals are the most frequently encountered. A brief description of different forms of ownership and availability of agricultural machinery, mostly tractors and harvesting and threshing machinery, is given in [8]:

- **Individual ownership**

  Individual ownership and use of machinery depends on farm size and also on the type of equipment. Small-scale (subsistence) farms that have their own animals will in most cases also have appropriate soil cultivation implements. Owners of draft animals may share animals in case more power is needed, for example for soil tillage in high-draft conditions.

  Individual ownership of tractors and machinery is also the most likely choice for large-scale farms and even for some of the medium-scale farms. The access to technical support and maintenance as well as the availability of trained operators is then a serious concern. Dealership quality and the availability and price of spare parts can make a difference to smooth operation and operational costs

- **Collective ownership**

Farmers' organizations or structured cooperatives, when they have access to credit or other funds to purchase equipment can make machinery available for their members through shared ownership. This is especially the case for soil tillage and cultivation and also for harvesting equipment. The CUMAs in Benin, modelled after the French *Coopérative d'utilisation de matérial agricole*, is one example. Each member contributes financially to the CUMA proportional to the land area that he/she cultivates, this makes machinery access also available to small scale farms. If land is available then this machinery allows the farmer to cultivate more land while also improve the timeliness of planting and harvesting. This generates a better income for further investments. A CUMA is a collective investment, managed by farmers in independent groups in the same territory. In Benin there are 115 CUMAs serving 1250 farmers with 57 tractors and

associated equipment. The result has been an increase in the cultivated area (by 350%) and better cultivation to produce:

- Increased income.
- Better standard of living.
- Social transformation (entrepreneurship and the involvement of youth).
- CUMAs promote strong relationships within themselves and they react positively with other unions and cooperatives in the national and international institutional environment. The CUMA process is participatory, not passive.

- **Service delivery enterprises**

  Ownership of equipment can be with private companies who then deliver services such as soil tillage, planting, and harvesting as well as threshing and processing of the harvested produce. Such paid-for services can be available to small farms in the neighborhood of large farms ho may have some spare capacity of the machines that they own. A service delivery is also possible between small farms, each owning a machine for a specific operation, thereby spreading the cost of ownership over several farms.

  "Hello Tractor" is an enterprise that provides machinery access to small farmers in Nigeria[9]. Tractor owners or contractors can hire out their tractors and equipment using a mobile phone booking and payment scheme. The platform tracks each piece of equipment as it is used. It links available tractors and their location to the job request so that the contractor's equipment is used in the most effective way. The scheme started with low cost and easy to maintain 2-wheel tractors equipped with the necessary ICT. Recently, it was announced that John Deere will deploy 10 000 tractors and related equipment in Nigeria whereby the owners-contractors will use the Hello Tractor scheme. The company partnered with the Nigerian government, which is providing a subsidy that will keep interest rates low, and was also able to secure low cost bank loans for contractors to buy the equipment [10].

  Investment in smart tractors allows owners to pay off the necessary credit with income earnt from service provision. The enterprise has been well thought through as demand is particularly high ensuring that payback periods are short. It is claimed [11] that the enterprise is especially beneficial to women entrepreneurs (clearly women customers are immediate beneficiaries as the service gives them access to much needed mechanization inputs). Male farmers may be reluctant to hire women to provide mechanization services, but with Hello Tractor's anonymous booking system, women who own tractors can be contracted to undertake work on male-owned farms.

  In Ghana, 'TroTro Tractor' provides a platform that connects farmers and tractor operators for the provision of mechanization services. This platform allows tractor owners to monitor movement and work progress of their equipment. The farmer is able to request, schedule and prepay for tractor services [12].

  Another example of sustainable service delivery model is the Center for Mechanized Services (CEMA) developed and tested by the Syngenta Foundation for Sustainable Agriculture in northern Senegal and Mali [8]. The tractors, combine harvesters and storage facilities are owned by a farmer cooperative but are managed by a private entity (CEMA) which is responsible for operations, maintenance and financial management. The farmers' cooperative in Mali is providing mechanization services and training for more than 1200 rice producers through the CEMA in order to increase production and productivity, as well as the quality of rice [13].

FAO and CIMMYT recently published *'Hire Services as a Business Enterprise'***,** a training manual for small-scale mechanization service providers [14]. The manual is specifically designed to create viable business

opportunities by training actual and potential farm mechanization service providers, in order to increase access to sustainable farm power to raise the productivity of smallholder farmers.

3 - Changes in agriculture and food supply

Mechanization is not a process that occurs in a static agricultural environment. Agricultural practices evolve as better knowledge about crop and animal production becomes available. Also, agricultural machinery and other inputs contribute to these changes and may even accelerate them. Next we look at a number of changes that have had such an affect following the introduction and use of machinery in agriculture, including post-harvest interventions in the value chain.

- **Land and farm ownership**

  Land tenure is one of the most important issues in agriculture; in many countries, a lack of security of tenure severely hinders investment in the agricultural sector. For a successful transition from semi-subsistence farming to profitable, productive agriculture, land tenure must be secure and guaranteed by the state as well as by local laws and traditions. [15]. The use of mobile phones, GPS and blockchain technology (an incorruptible digital ledger of transactions) can help to assure the titling of land to farmers such that they can use this as collateral for bank loans to purchase farm inputs like seeds, fertilizers and equipment (or equipment services). In Ghana, for instance, the nonprofit Bitland runs a blockchain-based land registry system with a written description of each parcel of land as well as GPS coordinates of boundary points and satellite photos of the area[16].

- **The changing farm size**

  Agricultural mechanization itself has been generally scale biased, often complementary to farm size; that is, adoption of mechanical technologies is often higher among larger farms than among smaller farms[17]. A study of the farm size distribution and land holdings in Africa indicates that much of SSA is experiencing major changes in farm land ownership patterns [18]. Among all farms below 100 hectares in size, the share of land on small-scale holdings under five hectares has declined, except in Kenya. Medium-scale farms (defined here as holdings between 5 and 100 hectares) account for a rising share of total farmland, especially in the 10–100 hectare range where the number of these farms is growing especially rapidly. Medium-scale farms control roughly 20% of total farmland in Kenya, 32% in Ghana, 39% in Tanzania, and over 50% in Zambia. The numbers of such farms are also growing very rapidly, except in Kenya. Detailed history surveys of medium-scale farmers in each of these four countries showed that the rapid rise of medium-scale holdings in most cases reflects increased interest in land by urban-based professionals or influential rural people. About half of these farmers obtained their land later in life, financed by nonfarm income. The rise of medium-scale farms is affecting the region in diverse ways that are difficult to generalize. Many such farms are a source of dynamism, technical change, and commercialization of African agriculture. However, medium-scale land acquisitions may exacerbate land scarcity in rural areas and constrain the rate of growth in the number of small-scale farm holdings. It is likely that these medium scale farmers are more likely to invest in inputs like machinery to raise the productivity of their land [19].

- **The emerging ICT**

  The introduction of smart phones has accelerated communication, information dissemination as well as business transactions in which many people in cities and in small-scale farming communities participate. Information on price of agricultural products and on the cost of resource inputs in agricultural production seems to be readily available. Even regional information on crop cultivar selection or crop protection can

be readily accessed. The ability is there to continue to improve ICTs applications and to accelerate growth in agricultural productivity. C cloud-based ICT applications can also be brought to within the reach of smaller-scale farmers.

What made the rapid spread of smart phones possible and what are the lessons we can learn for a speedy introduction of farm mechanization? Hand held phones are, relatively, very low cost and they are connected to a network operated by phone companies. One-third of Kenyans share their mobile phones with friends or relatives, supporting qualitative evidence of free riding and the use of mobile phones as a common property resource in SSA [20]. At the same time, such patterns could also reflect cost-sharing, especially among poorer rural households for whom the cost of handsets and services is still prohibitively expensive. While only 47% of individuals owned a phone, 80% reported having access to a mobile phone through direct ownership or sharing.

Note that machinery service delivery enterprises already make use of the opportunities offered by this ICT and telecoms service.

- **Gender issues**

Mechanized technologies that have been adopted have often addressed challenges related to men's tasks – often with negative consequences for women. For example, tractors and animal-drawn ploughs have been used by men to increase the acreage under cultivation however it has resulted in an increase in weeding and harvesting operations, jobs often performed by women. Moreover, of all women's tasks on the land, weeding with short-handled hoes is the most laborious and time-consuming. Additionally, trainings on mechanized devices are most often organized by extension services, a resource that is highly inaccessible by women[21]. In a study on the uptake of mechanization in the wheat growing regions of Ethiopia, an increasing uptake of mechanization by smallholders was observed with many making use of growing numbers of commercial agricultural mechanization service providers for ploughing, harrowing, and harvesting[22]. It was also stated that tilling and harvesting activities (animal drawn soil tillage or even two-wheel tractor driving) are more frequently undertaken by men than by women, while women have a relatively larger role in weeding. More mechanization would therefore seem to imply that women would become relatively more important in the agricultural production process. Also more active land rental markets would give better access to mechanization in the country, as it would allow more area to be cultivated by single owners[21].

The male bias is not surprising given the muscle force and power needed for guiding and handling some of this equipment (especially two-wheel tractors). Soil cultivation is also a job with higher standing than manual weeding. There are efforts and developments to mechanize the hitherto backbreaking jobs that are carried out by women [22]. Row-planting – as opposed to broadcasting can bring immediate benefits in this regard. However, the incorporation of new, but low cost ICT and battery powered tools can make weed management equipment more versatile and more productive as well as more adapted or attractive for use by women.

- **Breeding adapted crops**

Agricultural R&D centered on plant breeding has often raised total factor productivity (TFP) so that it has also often raised the returns on farm power inputs, complementing rather than substituting for the use of mechanical technologies. Such mechanisms may partly explain why agricultural mechanization has grown rapidly in developing countries in Asia despite land scarcity and persistent smallholder dominance there, primarily through the spread of small-scale machinery (Biggs and Justice 2015 – cited in [17]). The outcome of a study in Nigeria also suggests that not only the spatial variations in agro-climatic conditions but also the spatial variations in public-sector R&D activities are important factors in explaining the spatial variations in demand for mechanization [17].

- **Changing crop production practices**

  Row cultivation seems to be the road to go for the mechanization of crop planting, weeding and harvesting since there is world-wide a lot of experience with the implements associated with this type of agriculture. However, it may necessary to look at other associated effects when changing to row cultivation. For example, the results of a productivity comparison in Ethiopia of broadcast planting versus row planting of teff (*Eragrostis tef*)suggest that both demand and supply issues in technology adoption contribute to lower treatment effects of row planting at the farm level. On the one hand, heterogeneity in farmers' skills and access to information about new technologies explains why some farmers (those with higher levels of literacy and more closely located to agricultural cooperatives) obtain higher (and significant) teff yield benefits. On the other hand, receiving inputs (as part of the government intervention) too late and lower quality of extension given to farmers about the row planting technology can also result in treatment heterogeneity and poor yields [23].

  Row planted crops may, at early growth stages have less foliage to cover the soil to limit the emergence of weeds. Also, the row structure at the start may increase the effect of rain and wind on erosion. Conservation tillage or no tillage may limit the erosion effect but sometimes requires chemical weed control, adding to the production cost.

  To overcome the timeliness problems in crop establishment and weed control, and improve the efficiency of operations in rice production, more energy and appropriate equipment must be added to the production system. The key areas are in land preparation, harvesting and rice milling. When introducing mechanization, changes to current farming practices are often required. For example[24]:

  Fields may need to be ploughed in different ways and at different times. It is always best to plough the soil when residual soil moisture contents are higher which can often be immediately after the harvest.

  Where mechanical weeders are used, crops must be planted in rows. This will require more care and in some instances more labour at planting.

  Mechanical threshing requires short straw. The use of long straw has already caused mechanical problems with some imported threshers and also reduces the machine's threshing capacity. When crops are threshed at higher moisture contents either solar or hot air drying will be required.

- **Irrigation: solar water pumping**

  Diesel engines or human muscles have been the main power sources for irrigation systems in many developing countries. The time for solar pumps has now come. The need is here, the technology is here, and the cost of that technology is making it viable and attractive. Photovoltaic- (or solar-) powered drip irrigation (PVDI) systems combine the efficiency of drip irrigation with the reliability of a solar-powered water pump. They can be implemented in an easily maintained, directly coupled (battery-free) configuration [25]. Although PV systems are often dismissed out of hand due to their high up-front costs, they have long lifetimes, and in the medium-term, cost less than liquid-fuel-based pumping systems. A study in northern Benin [26] compared users of the PVDI systems to control households (without them) and they fared relatively well. Their standard of living increased relative to non-beneficiaries (by 80% of the baseline), their consumption of vegetables increased to the Recommended Daily Allowance, and the income generated by production of market vegetables enabled them to purchase staples and protein during the dry season. This indicates that solar-powered drip irrigation could provide substantial economic, nutritional, and environmental benefits to a large part of the population in SSA.

  Meanwhile, in an emerging agritech hub in Kenya, SunCulture sells solar-powered pumps for affordable irrigation. Nairobi-based SolarFreeze has designed solar-powered cold storage units for farmers and traders[27].

In order for this technology to find more applications and to stay in operation it is required to have trained technicians and engineers. This is also the case for other applications of solar energy and PV systems.

Large scale installation of these small irrigation systems will need support from extension services as well as from suppliers and trained maintenance organizations. Note that the price of PV panels has rapidly decreased in recent years.

- **Evolving agricultural and related employment in Africa**

Since small farmers (1-2 ha) are often part-time wage earners working for large farms, stores or with employment outside the agricultural sector, then looking at agricultural employment in absolute numbers may not be appropriate.

Using nationally representative data from nine countries, demographic and employment trends in Africa's workforce were documented based on full-time labour equivalents (FTEs)[28]. The main conclusions are that, since 2000, Africa has experienced a sharp decline in the share of its labour force in farming. Also, the share of the labour force in farming ranges across the nine countries from 35% in Ghana to 54% in Rwanda. Employment in off-farm segments of agro-food systems is expanding rapidly, but in terms of absolute numbers, non-farm activities are by far the major source of employment outside of farming. Contrary to widespread perceptions, the mean age of adults engaged primarily in farming is not rising. The pace at which the labour force is shifting out of agriculture is strongly and positively tied to the rate of lagged farm productivity growth.

The implications are that there is an influx of young farmers that may be very open to innovation in agriculture and technology. This can lead to a rise in productivity and increased returns to labour which in turn increases spending power (for example on equipment and other inputs as well as marketing) that will foster or stimulate non-farm rural activities. The latter can be post-harvest processing and also manufacturing, repair and maintenance of equipment. There is a need to introduce innovative and state-of-the-art equipment that is challenging and attractive for the rural youth. They should then get appropriate training in basic and new technologies, and in business management

- **Small and large scale trading**

Grain marketing policies and development interventions in SSA have long been dominated by small, poorly capitalized, and often geographically isolated market actors[29]. Data provide compelling evidence that the rise of (large scale traders LSTs), and the structural changes that this creates in grain markets, is likely to be co-evolving with rapid growth in relatively larger-scale producers. The likelihood of farms of five or more hectares selling to LSTs is considerably higher than farms of less than two hectares. Farmers selling to LSTs receive prices that are higher than those offered by small-scale traders, and they are more likely to be able to access input credit, private extension services, and price information[29]. This means that middle-sized farms have better access to markets, and finance to invest in machines and soil fertility as well as in other quality inputs such as hybrid seeds. A main barrier for mechanization is cost. Hence access to finance (through savings, credit or loans) is a necessity.

- **Post-harvest processing**

A recent FAO report highlights the dualistic nature of the agro-processing sector, which is largely comprised of large industrial processors and small-scale informal processors [30]. In a comment on the report [28], it is noted that growth among the more dynamic large-scale industrial processors is usually impeded by a general lack of a reliable supply of local raw materials of consistent quality and they often rely on imported food inputs. A large part of processing of domestically produced food products (especially those based on domestic staples) is still in the hands of the relatively less efficient, small-scale and largely informal-sector operators, characterized by low capacity utilization rates and low productivity

levels. Their activities are also seasonal, and often generate outputs of variable quality, limiting their entry into emerging urban food distribution systems. Addressing the capacity and productivity constraints to growth in the agro-processing sector is necessary and it implies food grade equipment operated according to high hygienic standards. A cooperation between local equipment manufacturers, international companies and research institutes can enhance this activity. This also requires training and education. Also, greater local farm production is required to ensure an adequate supply of quality raw material for local processors, and, more importantly, to generate greater job growth at all stages of the agri-food system.

4 - Entrepreneurs in agricultural mechanization

- **ICT entrepreneurs**
  - Mobile phones as enabling technology

    This has been discussed in Section 2 under 'The emerging ICT' [19].
  - e-agriculture entrepreneurship

    Pitch AgriHack [31] is part of the AgriHack Talent initiative of the Technical Centre for Agricultural and Rural Cooperation (CTA) and aims to accelerate e-agriculture entrepreneurship for improved livelihoods in the African, Caribbean and Pacific (ACP) countries. Co-designed with young innovators and partners from ACP countries, it has included:

    a) competitions to develop ICT applications for agriculture (hackathons) when there is a need;

    b) a start-up competition (called Pitch AgriHack) targeting young companies already offering e-agriculture;

    c) capacity building, mentorship and incubation opportunities;

    d) promotional and networking opportunities;

    e) facilitation of access to grants and investments to scale-up services offered.
  - Weather forecasting for better managed agricultural operations.

    Ignitia is an ICT startup that has developed a disruptive technology that allows smallholder farmers in West Africa to access accurate weather predictions[32]. It expects a willingness by farmers to select higher quality inputs and more fertilizers, because they are more confident about when rain is coming by using the ICT tool, which then may in turn lead to higher yields. The Ignitia entrepreneurs have also been subject of questioning and outright suspicion from international meteorology institutions, due to their claims of achieving higher accuracy than other, more established organizations. Part of the controversy is not about the science and what the company has managed to develop, but comes down to the start-up being a private company, which is selling its services in low-income markets. A start-up that is disrupting a traditional sector, is not welcomed by all with open arms.
- **Spin-out of research centres**

  The Resilient Africa Network (RAN) funded by USAID is a partnership of 20 African universities in 13 countries. RAN strengthens the resilience of communities by nurturing and scaling innovations from the participating universities. RAN will apply science and technology to strengthen and engage a wide

network of students and faculty members in improving livelihood through generating local innovative solutions to specific development challenges in African communities[33].

The Regional Universities Forum for Capacity Building in Agriculture [34](RUFORUM, www.ruforum.org) is a Network of 66 Universities in 26 African countries. RUFORUM was created by African Vice Chancellors with the vision for a vibrant agricultural sector linked to African universities that can produce high performing graduates and high-quality research, responsive to the demands of Africa's farmers for innovations, and able to generate sustainable livelihoods and national economic development. RUFORUM launched the African Young Entrepreneurs Competition Series and a few examples of the 2016 awardees are given below:

- New processing

  MUWOGO Uganda is a social enterprise that seeks to innovatively extend the shelf life of fresh cassava roots, in order to gain access to long distance markets, reduce post-harvest losses and overcome losses associated with poor delivery systems [33]. They can extend the shelf life of fresh cassava from two days to about 40 days with Ugandan cassava varieties. MUWOGO Uganda Ltd seeks to address this challenge through a raft of interventions: (i) pre-harvest planting in ridges, (ii) pre-harvest pruning, (iii) high relative humidity storage, and (iv) waxing. These interventions do not undermine the consumer preferences and desired quality traits at all. It is hoped that in turn these interventions will inspire other young people to come up with new mechanization forms for efficient production and distribution.

- New distribution opportunities

  Fruiti-Cycle is an electric motorized tricycle that uses solar power and manual peddling energy to generate electricity[33]. This innovation is being championed by a team of innovative youth. The Fruiti-Cycle delivers its benefits to the famers by allowing them to carry five times more produce (up to 300kg carrying capacity) every time unlike the current normal bicycles with 60kg carrying capacity. The energy also allows a farmer to reach more distant markets in a radius of 100km without getting exhausted unlike with the normal bicycles. Unlike other motor tricycles in the market, Fruiti-Cycle has a refrigerated storage unit which uses an evaporative cooling system.

- Enhance mobility.

  Taking the above Fruiti-Cycle as a starting point, then one could consider that mobility of farmers and the opportunities to timely delivery of their products to markets is a major challenge. This requires and adequate public infrastructure of roads. It also requires vehicles that are fuel efficient (partial e-mobility ?) and can travel on gravel or better roads for a reasonable distance. Initiatives in this should be explored.

- **Weeding and precision spraying**

These can rely on a new low cost design of sprayers for hand-held micro dosing or as battery assisted mechanical weeding. It can also lead to a new service center of solar powered charging stations for batteries. They also have the potential to be developed as a service (by women?) using batteries charged by solar energy and can greatly reduce drudgery for woman who are the main work force for these activities.

Of course robots could be a technology jump in weeding and other crop applications if supported by well financed entrepreneurs. The Digital Farmhand is a robot with two electrically-powered wheel modules connected by a telescopic frame, with a smartphone on the top to collect data. The robot can be dismantled and reassembled on site in 10 minutes. The objective is to develop a low-cost robotic and

digital technology for row crop applications. In 2016, trials took place in Indonesia to investigate how robotics can be used for farming in a developing country and these trials have continued across Australia [35].

What does the future hold as successful smallholders move into the exacting realms of the commercial sector? Looking well ahead, one possible scenario may involve new developments employing robots that can detect weeds using computer vision. Commercial robotic machines, using RTK GPS (Real Time Kinematic Geographical Positioning System) will be coming available for spot weed control with herbicide, laser; and non-soil inversion mechanical weed control systems for no-till crops may also become a possibility. Being light and cheap, robotic weeding machines have the potential to practically eliminate damaging soil compaction caused by the passage of heavy spray rigs during the weed management operation (**Figure 1**). The use of small robot units operating in swarms and a cloud solution to plan, monitor and document all activities is underway in a collaborative project. The current effort is concentrated on seeding but future use of big data sets will relate to soil compaction, plant diseases and weed management. Weed management options include mechanical cutting or spot application of herbicides in association with weed-mapping drones. As no blanket application is under consideration, this would be a useful step forward in reducing herbicide volumes in weed management [36].

- **Precision agriculture and drones**

The adoption of new techniques in less developed areas should start with a basic, affordable, and effective mix of technologies and practices. In a multiple-variables scenario, where all means are important, close examination invariably teaches that they are not all equally important[38]. The concept of precision agriculture does not depend on the technology level used in farming. However, the expertise of a farmer and his skills are the most important components. Adaptation of local or imported equipment to exploit the benefits of precision farming in terms of efficient use of inputs is therefore often required. Adaptations may be required in order for imported machinery to function well under the local or regional soil conditions or agricultural practices and this requires local manufacturing capabilities. The emergence of mechanization service providers should stimulate local manufacturers to adapt machinery such that it can be used in the framework of service providers. Simplified but functional GPS and telemetry systems can perhaps be also made available and installed at low cost as has been the case for mobile phone handsets in SSA countries

Satellite images have been available for a long time offering insights in the state and health of vegetation and its attributes across the world [39]. The use of drones is evolving rapidly in agriculture and their implementation in Africa offers new opportunities for agricultural productivity. The drones can provide near real time information on crop vigor, crop stress (lack of water or imminent diseases), such that timely action can be taken. These tools have become reasonably low cost, but good operation of the camera and data processing for accurate information and good decision making requires a considerable expertise [40] [41]. This expertise can be made available again from service providers in cooperation with extension services.

Here we should be aware that the average annual investment of equipment (apart from tractors) in SSA is less than 1USD/ha and it needs to be demonstrated that the cost of drone services is less than the generated additional income derived from their use.

The novelty of drones can offer exciting prospects for young people in rural Africa and entrepreneurs can move the use of drones forward to benefit agriculture while creating new employment opportunities. Opportunities also exist for linking this new information source with available equipment and with mobile phone services.

In Mozambique, an intervention is showing that advice provided by extension workers who have been using low-cost drones, has helped farmers make informed decisions for improving crop water use

efficiency and yields[40] [42]. Data gathered during project implementation indicates that crop production had increased by 41%, while total water use was reduced by 9%, resulting in a 55% water productivity increase. The use of drones for weed mapping also has the potential to dramatically reduce drudgery and/or herbicide use in weed management.

- **Scaling up of innovations**

Agricultural research and innovation centers, international cooperation as well as entrepreneurs have developed novel technologies and demonstrated their potential productive use in agriculture, including, importantly, post-harvest. What is lacking in a number of cases is the capability for scaling up these technologies in terms of the size (larger units) and also in terms of widespread use across the continent. In both cases additional investment is required. Donors, venture capital suppliers and government could join forces to make innovation really happen.

5 - The 'uberization' of agricultural equipment use

The evolution in machinery use and ownership described above is sometimes called the 'uberization' of agricultural mechanization. The enabling technology of mobile phones, the adoption of GPS and the entrepreneurship of local IT and machinery service providers has jump-started agricultural mechanization service enterprises. These developments illustrate that private farmers and entrepreneurs are willing to invest in agricultural mechanization and that they can create a vibrant market for services that benefit small-scale farmers and also contribute to the creation of attractive jobs.

The success of these new approaches will also require a rapid deployment of machinery service centres staffed by skilled technical and logistic specialists. They offers new and challenging employment opportunities for young people in rural areas. A public-private partnership in technical training of operators and machinery technical staff should be considered.

It is also necessary to consider how donations of agricultural machinery by donor countries can enhance such disruptive developments rather than create a government supported or financed unfair competitor.

In a number of cases there are adaptations required in order for imported machinery to function well under the local or regional soil conditions or agricultural practices and to operate the equipment in the context of 'uberization'. This requires local manufacture capabilities

It can be expected that improved agricultural productivity will lead to a better financial return for farmers which then will stimulate them to look at agricultural mechanization resources to further improve their production and productivity, as long they can find a lucrative market for their produce. The design of land administration must consider carefully the needs of smallholder farmers, traders and entrepreneurs. New technologies bring new services to agriculture and at the same time require training and industrial or manufacturing activities related to the agricultural and food value chain.

In an effort to accelerate this positive momentum, the African Development Bank is rolling out efforts to rapidly expand access for small-holder farmers—many of whom are women—to 21st century agricultural technologies. Ultimately, the goal is a paradigm shift from "agriculture as a way of life" to "agriculture as a business" that will foster the positive feedback loop of increased gainful employment, rising incomes, and better nutrition and quality of life throughout the continent. Technologies hold the key to making this happen [43].

6. Suggestions for future developments

Agricultural mechanization in Africa can raise productivity and make rural employment more attractive, thus helping to ensure the continent's future growth. Agricultural mechanization includes and even extends the rural post-harvest and processing activities and so provides jobs in processing, packaging, marketing and transport. Mechanizing agriculture can make it more lucrative and also more attractive to young people both from technology use and a technology development focus. Some technology costs may currently be prohibitive for agricultural use, but creative entrepreneurs may soon find ways to reduce costs to end users and service recipients and make their use in the agri-food chain very productive, here is some 'food for thought':

- The available farm machinery sometimes looks old or at least it has been available for a long time. There has not been a disruptive moment or disruptive technology that makes young people attracted to the technology and its ease of use, the low cost, low maintenance and effectiveness. It should above all be very attractive to those people who are now doing the drudgery work. Portable weeding machinery using backpack batteries? Look at electric pruning shears, electric trimmers or 'weed eaters'.
- Stimulate the entrepreneurs and help them to explore disruptive technologies.
- Do a technology scan and look at entrepreneurs that can make a very attractive and productive combination of the new technologies like ICT in conjunction with reliable and well established machinery.
- Improve the mobility of farmers to bring their products to a market place using reliable means of transportation at a low cost
- It has been suggested that high-tech machinery companies should make drawings and construction guidelines of their older equipment available for starting blacksmiths or manufacturing companies in Africa. Perhaps these designs should be changed such that is equipment can be made better adapted. Their value for productivity (and increased profits for farmers) should be demonstrated.
- Upgrade the training of engineers and technicians in Africa. High-tech agricultural machinery companies have very advanced design and assembly methodologies like computer-aided design (CAD) but also augmented reality and virtual reality. Why not use these in training centres in Africa?
- Scaling up of proven novel technologies like, for example, solar driven drip irrigation or small scale processing equipment. The latter should also raise the hygienic standards for processing encompassing hazard control and critical control points (HACCP) guidelines.
- Weeding is drudgery work mainly done by women. Explore the concept of service providers managed by women, using new types of equipment.
- Private extension service (service providers) using drones for crop monitoring in combination with planting, fertilizer application, crop protection. Use small (carried) adapted sprayers with micro-dosing and user friendly health protection. However, payload limitations may make the use of autonomous robots a more attractive possibility.
- In Europe, USA, Asia and a number of other countries (also in Africa) research and development of novel technologies for agricultural production are underway in part based on engineering developments in industry. One can hope that such developments also will start in Africa addressing specific conditions for the diverse agriculture in the continent. Therefore , it would be appropriate to establish a center that has as initial main assignment the training of engineers and technicians to adapt, operate, and maintain novel technologies developed abroad. The next and second assignment will be the pioneering development of new technologies that are based on agronomic science and

engineering concepts adapted to Africa with the purpose of development of an efficient food supply in the continent that can be considered as state of the art in terms of sustainability, quality and safety. The public-private partnership has to play an important role in this. Findings [44]suggest that instead of focusing on the supply of subsidized machinery, the government could be more effective by investing in institutional development to strengthen the agricultural innovation system for mechanization and to support emerging private sector initiatives.

For sustainable mechanization initiatives to work, complementary action on two levels is needed: national (/regional) and local are important (Figure 2):

- a) At the macro-level, the objective is to enhance national food security, in terms of food availability levels, i.e. volume, but also in terms of differentiation, infrastructure or support needed to enable national food security policies in the countries involved;
- b) On the other hand, at the micro or local levels of intervention, the national policies should meet the potential (both agricultural and human) and the needs of communities at local level.

Such components will define an overall framework in which macro, meso and micro levels of intervention can be designed, converging to the following Operational Objectives (OOs).

Local institution and associations are essential if we want to have an impact on social society.

It can be expected that improved agricultural productivity will lead to a better financial return for farmers which then will stimulate them to look at agricultural mechanization resources to further improve their production and productivity, as long they can find a lucrative market for the product. Or will it reinforce one of the rather unfriendly statements on the future of farming in Africa frequently heard in the discussions that: 'Small scale farms should either scale up or get out, or they are trapped in poverty'. This, of course, fails to recognize that small-scale farming is often characterized by high land productivity. Improving labour productivity – through sustainable mechanization – will further enhance the performance of small-scale farms.

FIGURES

Figure 1 A commercially available autonomous robotic solar-powered weeder. Its light-weight (130 kg) minimizes soil compaction (ecoRobotix, Yverdon-les-Bains, Switzerland) [37].

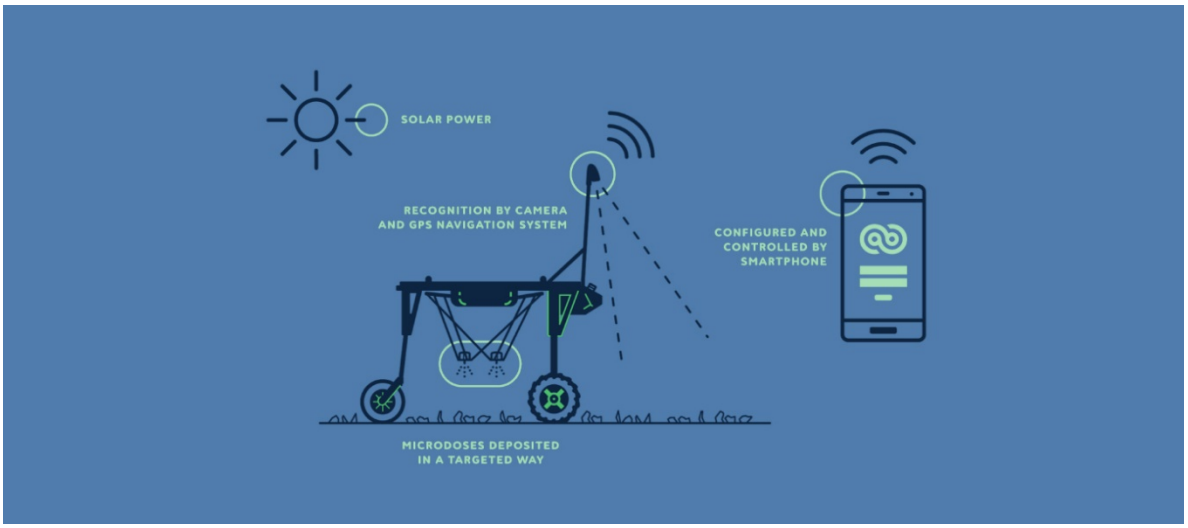
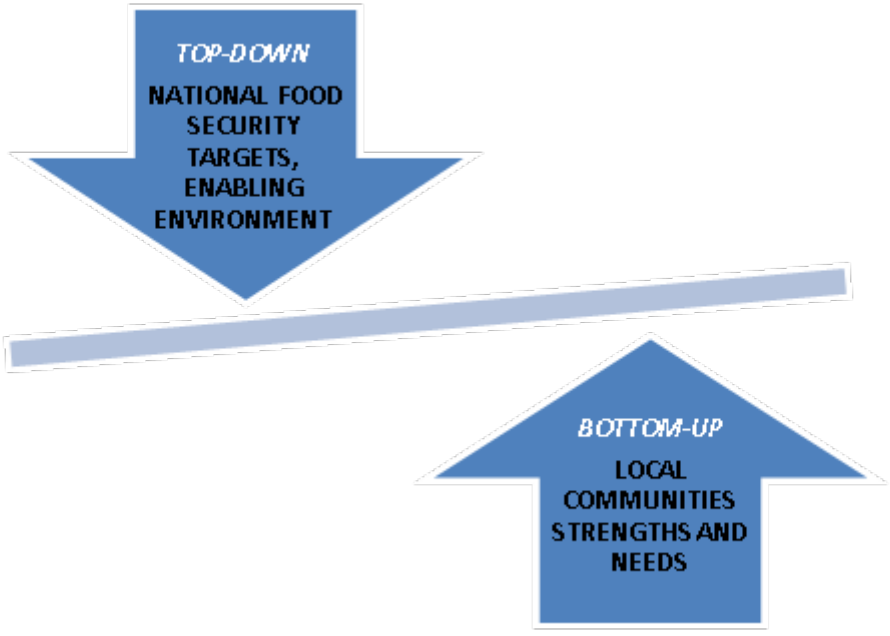


Figure 2 – The mutually supportive interaction of local communities and national policy environment[45].



ANNEXES

Annex 1 - Recommendations of the Consultative Meeting on a Mechanization Strategy, Nairobi (2016)[46].

List of concrete actions to enable SAM systems to function correctly:

• Development of the social sector (food security, improved nutrition, and assured livelihoods).

• Conservation of natural resources and the environment.

• Identification, delivery and application of new models for public-private and private-private partnerships at regional and global levels.

• Establishment of a SAM network with centres of excellence for Africa. For this a well-developed Concept Note is an urgent priority.

• Establishment of a knowledge platform for technology exchange at a pan-African level. This will also require, urgently, a well-developed Concept Note.

• Production of a concise SAM advocacy brief for policymakers and donors. This has been produced as a separate draft advocacy document.

• Elements to take into consideration, which came up during that discussion on the way forward: From the commercial farmer's perspective, the equipment is not so much an issue as its operation (for sustainability). The private sector (e.g. AGCO) wants to be part of the SAM and SAM strategy development process.

• Service providers have potential for job creation in the rural private sector. *Hello tractor* [47] is a good example of how job opportunities for women and youth can be created.

Annex 2 - Malabo Montpellier Panel recommendations [6]

The **Malabo Montpellier Panel recommendations** [6] to African governments, the private sector, research institutions, and development partners to substantially increase their policy attention to and investment in advancing mechanization of agricultural value chains:

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

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

2. **Design socially and politically sustainable mechanization pathways**

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

3. **Prioritize mechanization along the entire agriculture value chain**

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

4. **Investments in supportive infrastructure and vocational training at scale**

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

5. **Create a conducive business and services environment**

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

6. **Develop an African agricultural machinery industry**

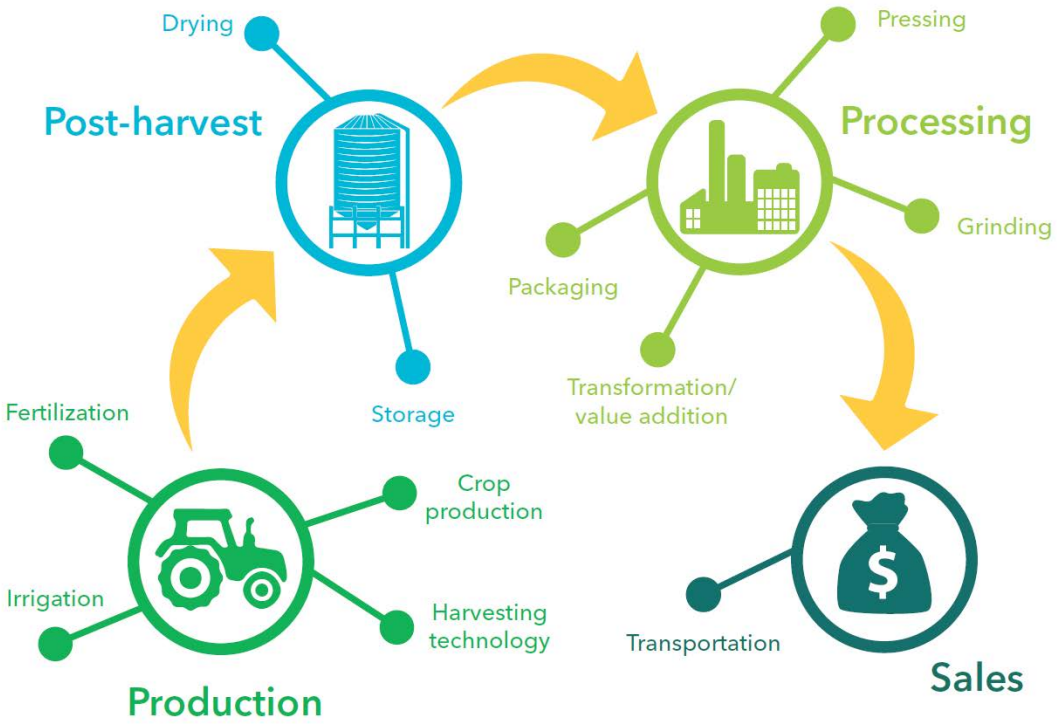
Africa needs to further develop its own agricultural machinery industries, based on the region's inventiveness and by taking its specific context into account. The private sector can play a crucial role bringing to scale the design, development, and provision of technologies that have proven impactful. Increased cooperation between the private sector and research institutions is needed to strengthen domestic mechanization efforts by developing locally appropriate and affordable machines and technologies. Substantial investments in public-private partnerships must therefore be made to foster research and development, vocational training,

and skills development programs and to stimulate innovation along the value chain. This needs to include the design and manufacturing of equipment and the servicing of machinery and tools, for example through mechanization service centers and technical extension services, including the collective action of farmer organizations.

7. Empowering smallholder farmers' and women's groups

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

Annex 3 - Mechanization potential in the food value chain [6].



Annex 4 - Enabling the Business of Agriculture [48] and [49].

Box 1. Enabling the Business of Agriculture

The World Bank Group's Enabling the Business of Agriculture (EBA) project measures and monitors regulations that affect the functioning of agriculture and agribusinesses. The 2017 EBA report covers eight topics: seed, fertilizer, machinery, finance, markets, transport, information and communication technology (ICT), and water. Two overarching themes—gender and environmental sustainability—are also included in the EBA analysis, with a view to promoting inclusive and sustainable practices. Two additional topics—land and livestock—are being developed, and initial results are presented in the 2017 report.

The EBA aims to foster a more conducive environment for agribusiness. By providing key data on regulatory frameworks that are globally comparable and actionable, the EBA strengthens the information base that can be used for policy dialogue and reform. Such efforts can stimulate private sector activity and lead to more efficient and effective agriculture value chains.

Source: World Bank (2017).

Annex 5 - Different considerations when looking at mechanization of agriculture in Africa (SSA)

- Country: Geography, land ownership, climate
- Size of farms
    - Land ownership evolution
    - Size distribution
- Type of crop
    - Rice, wheat, corn, teff
    - Vegetables
    - Cassava, potato…
    - Animal production?
- Major operations – and who is involved
    - Soil cultivation
    - irrigation
    - Planting
    - Weeding
    - Disease control
    - Harvest and threshing
    - Drying and storage
    - Transportation
- Power source
    - Human labour (man/woman/children/ hired…)
    - Animal draught
    - Combustion engines
        - 2- wheel tractors
        - 4- wheel tractors
    - Electric power
        - Grid
        - Battery
- Machinery supplier
    - Local manufacture
    - Assembly using mixture local/import
    - Import
    - Available maintenance and training

    - Machinery ownership and use: Rental services/ machinery hire (hello tractor, trotro tractor…)
- Financing sources
    - Government subsidy or credit
    - Local banks
    - Cooperatives and cooperative ownership
    - Micro-financing
    - Donations
- Product markets and sales
    - Local
    - Cities & distance (and infrastructure)
- Extension and advisory services
- Research and development
    - Machinery R&D
    - Crop productivity research
        - Varieties
        - Fertilizer
        - Crop protection
- Education and training
    - Of farmers
    - Dealers and maintenance staff
    - Manufacturers
- Entrepreneurs
    - with products to improve management or operations of machine use
    - with products (equipment, know-how) that can be applied in agriculture

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